

## 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.

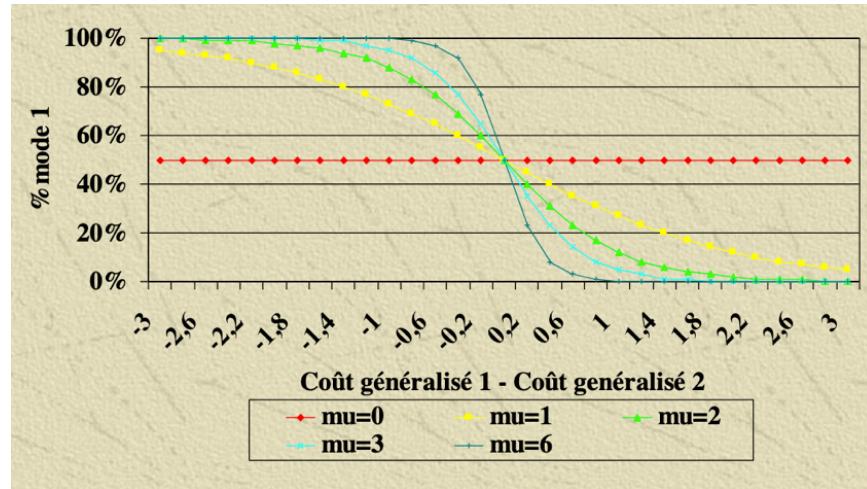
These two parameters makes possible to reproduce the sensitivity of the driver (or a set of drivers) to make an appropriate route choice. The route choice will be accurater if the driver dispose of information about the traffic states and if this information is regularly updated with time. It means that 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  $\tau$  this indicator, where  $\tau$  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  $\mu$  and the refreshment period  $\tau$  of the Travel Times (TT).

As illustrated by the figure below, the  $\mu$  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.

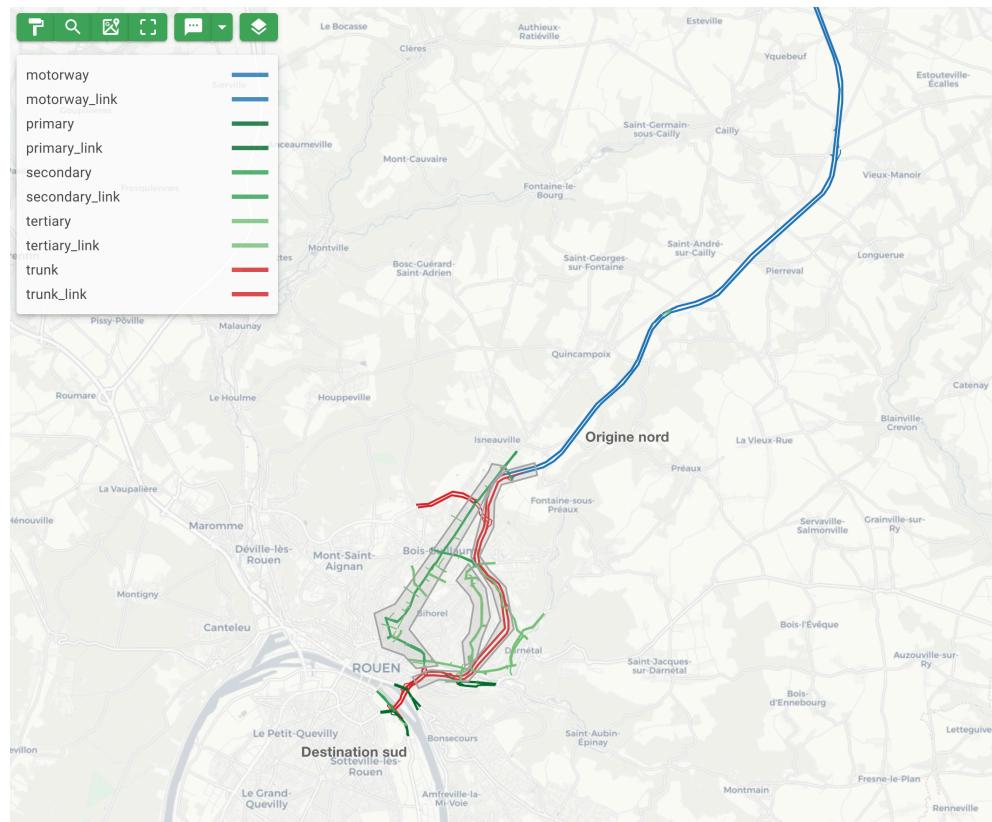
### Scenarios under consideration

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.



**WARNING:** Please pay attention to the fact the modelling process of this use case is performed with 2 different tools:

- Refined simulation based on macroscopic model for the A28 road (in blue and red);
- Simple Demand propagation on Cumulative Flow Curves for the secondary roads (in green on the map).

As a consequence, some artefacts might happen since the loop linking Travel Time and Demand is not effective on the secundary roads. We make sure to not consider such cases within the GUIDED SECTION of this lab. Please, if you identify or find such artefacts while designing your experiments, do not hesitate to report it in your final deliverable.

## 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:

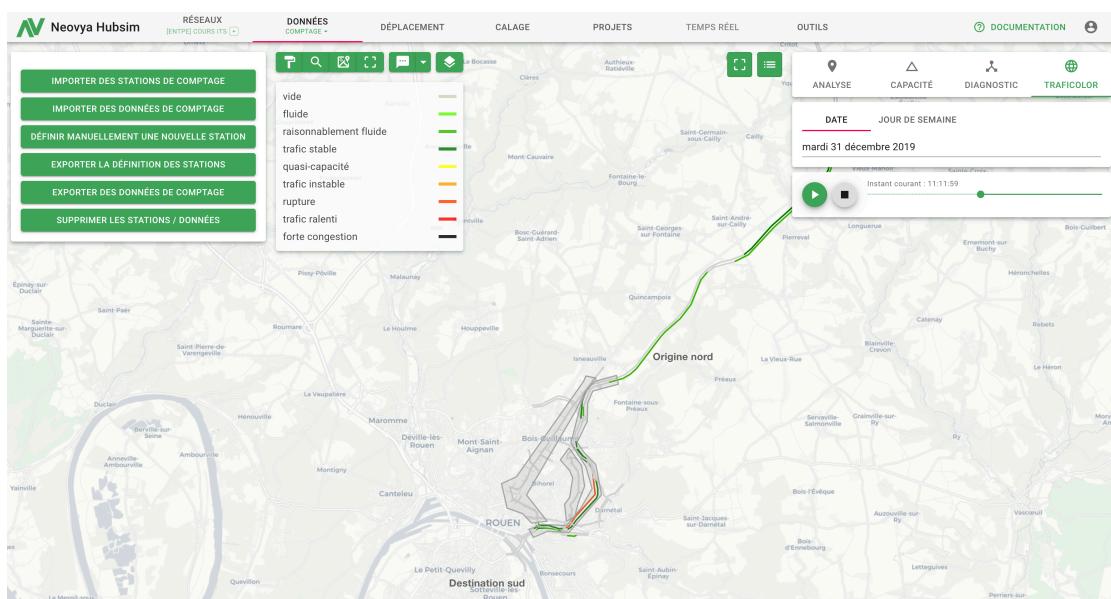
- the panel données,
- the panel calage,
- the panel projets.

## 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 aggregation 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.



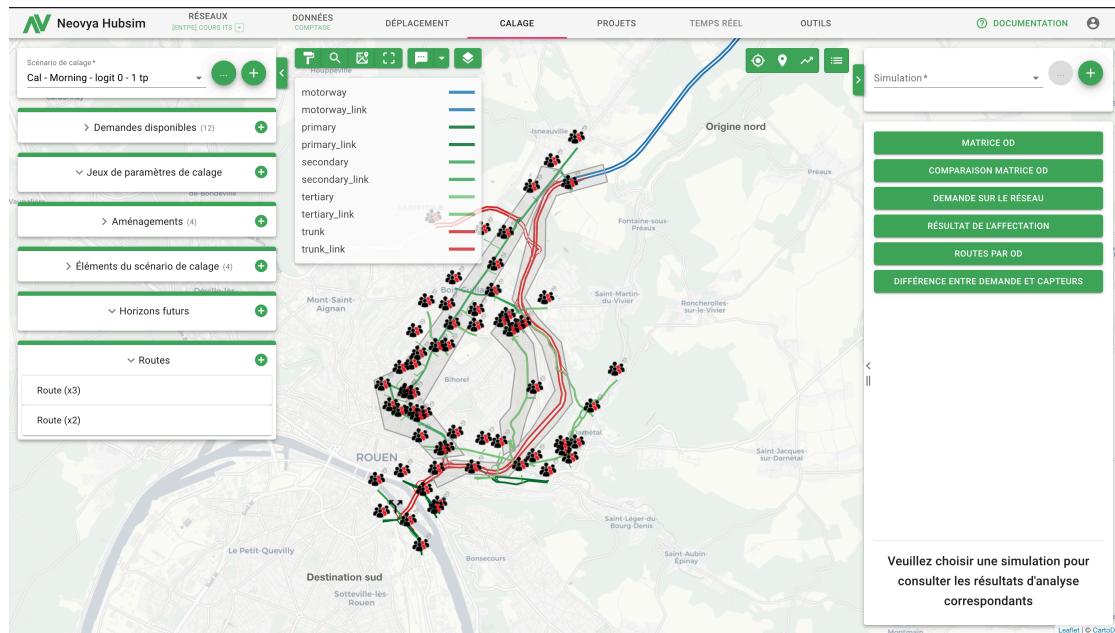
### Panel calage

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.

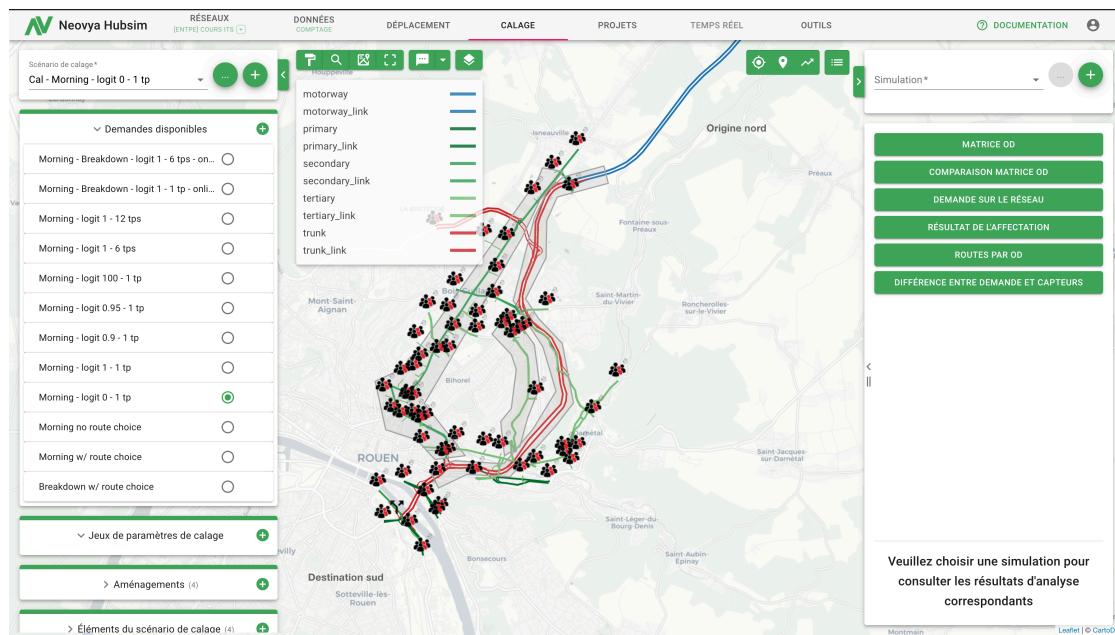


A new **calage** scenario is composed of a new folder called scenario, supporting: a demand profile dispatching the demand per OD over the routes, some supply or demand restrictions and few supplementary parameters.

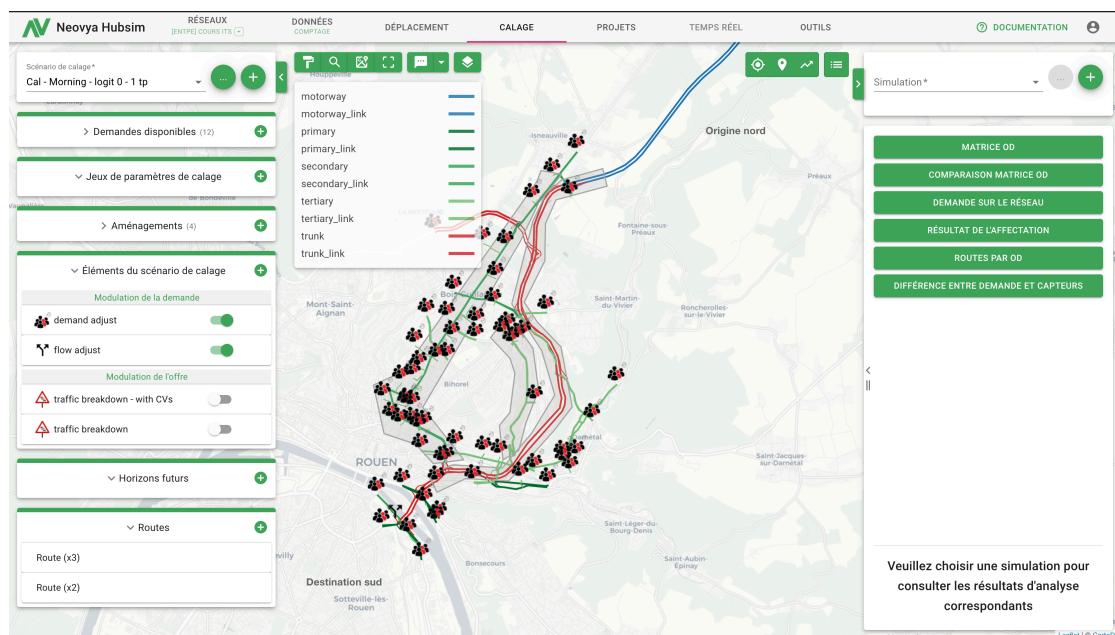
The main process to build a new **calage** scenario is the following one:

- 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 the study, we will consider K=3.
- create a new "Demandes Disponibles". It is recommended 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.

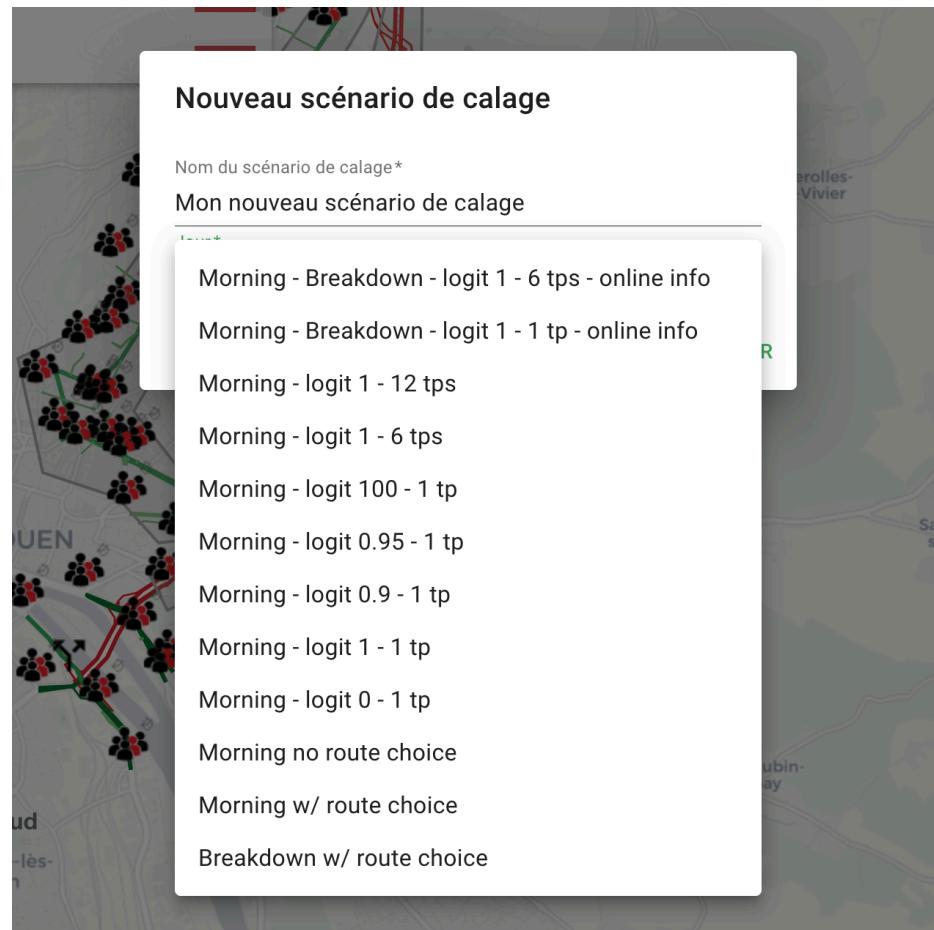
The validation (saving) of a new demand will automatically trigger the computation of the **calage** scenario (generation of O-D matrices per period, etc).



- 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.



### **WARNING:**

On the right side of the panel *calage*, you can see a tab dedicated to *Simulation*. This tab is shared between panels *calage* and *projets*. The main purpose of this tab is to build a scenario, launch a simulation, then display the outputs through various Key Performance Indicators (e.g. Travel Time comparison, etc). Please refer to section *Launching a simulation* for further details. Please pay attention to the fact that any simulation executed from this tab requires: a *calage* file and a *projet* file, even if there is no modification between the *projet* (i.e. the scenario under consideration) and the calibration (*calage*) file.

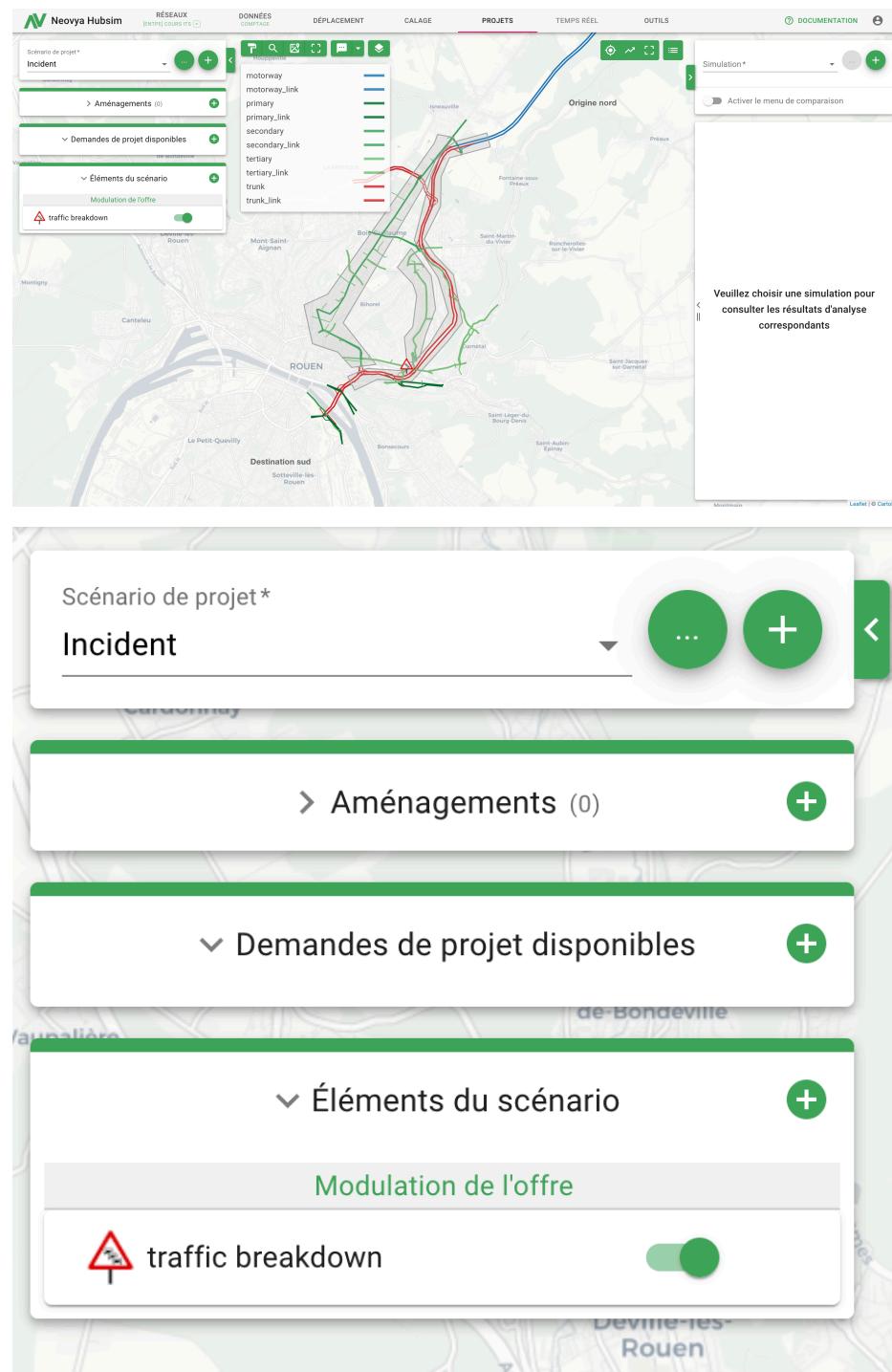
### Panel *projets*

The *projets* panel enables to build some new scenarios including new features or constraints that are not used to calibrate 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.

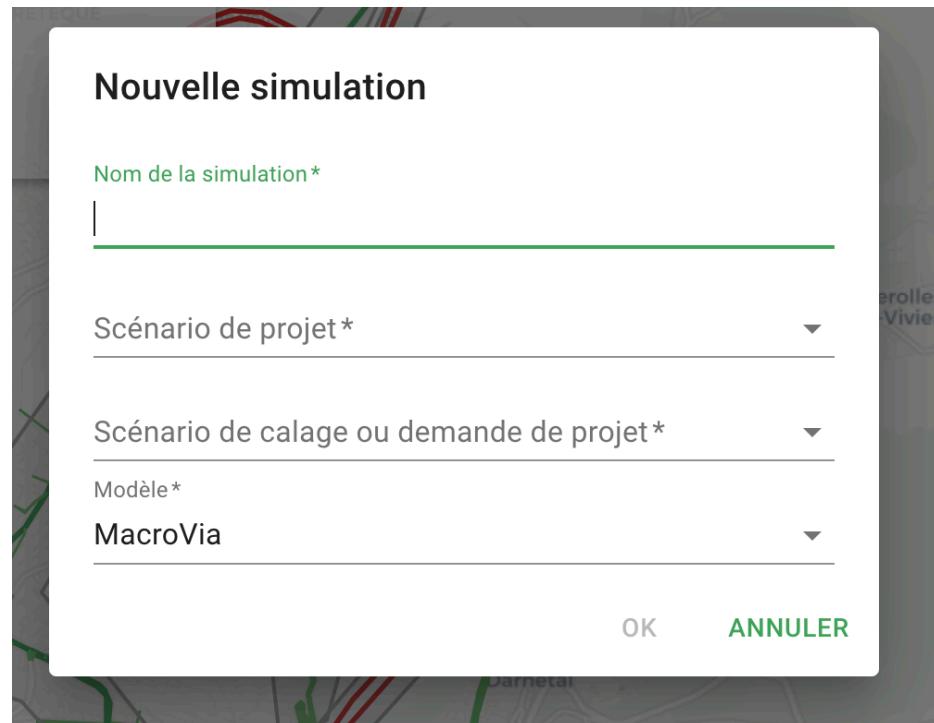
A *projet* scenario requires to:

- 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.



## GUIDED SECTION - 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 points 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 Thursdays?)
- 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 ( $\mu, \tau$ ). In the subsequent configuration, these parameters are assumed as representative of the Market Penetration Rate of Connected Vehicles. It is assumed that Connected Vehicles will dispose of accurate 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.
- In the subsequent parts, we will consider that we work on a 3h-long time-window between 6:30am and 9:30am in the morning peak period. The parameter  $\tau$  is represented by the number of time-periods **tps**: the relationship between  $\tau$  and **tps** is the following one:  $\tau = \frac{3^h}{\text{tps}}$ . For **tps**=3, the value of the refreshment period  $\tau$  is set to 1h.

#### **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? Thereafter, 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 associate 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:**

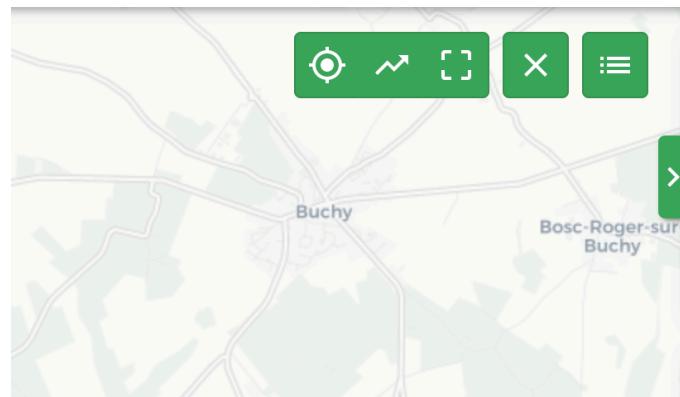
- What is the difference:
  - in terms of Cumulated Queue-Length?
  - in terms of Cumulated Travel Time ?

**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?
- by predefined Zones
  - 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.



**Alternative way to proceed:** To perform the comparison analysis, make use of the button Analyse des indicateurs, then proceed to the analysis according to various Key Performance Indicators.

**Note:** To draw a comparison between the multiple scenarios according to various Key Performance Indicators, please proceed this way:

- if relevant, select the sensor / itinerary or Zone, on which you want to proceed the analysis;
- select multiple scenarios by clicking on + Simulation de Comparaison on Simulation tab;

- click on the buttons Temps Totaux passés and/or Analyse des Indicateurs, to draw comparisons. Some further options are available, do not hesitate to explore.

#### Question 4:

Explore the impact of the refreshment period  $\tau$  parameter on the global performance of the network. What did you observe? Does it change? 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 (calage tab). Such scenarios are performed with a refined  $\tau$  value.

- Compute the duration of the time-window  $\tau$  for any number of time-periods (**tps= 1 / 3 /6**) under consideration
- How can you interpret a larger number of Time-Periods with the perspective of Connected Vehicles? What kind of information the driver dispose of? Why?

Support your findings with relevant indicators and pictures.

#### Analysis of the Breakdown use case

According to the previous findings and to further explore the impact of the  $\tau$  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 propagating 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 **occurrence 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 occurrence of a breakdown when he takes his car);
- one scenario should consider the **occurrence of the breakdown**, while the driver make their route choice based on aggregated **traffic conditions reflecting the occurrence of a breakdown** (i.e. the driver is aware of the occurrence 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 analysis on the itinerary with only the mai road)

Draw a comparative analysis on the 4 alternative itineraries to join the North to the South. (you may use the analysis option) How does evolve the Cumulative Travel Time (Cumulative Delay)? How does evolve the Average Delay?

**Note:**

To draw a comparison between the multiple scenarios according to various Key Performance Indicators, please proceed this way:

- if relevant, select the sensor / itinerary or Zone, on which you want to proceed the analysis;
- select multiple scenarios by clicking on + Simulation de Comparaison on **Simulation** tab;
- click on the buttons Temps Totaux passés and/or Analyse des Indicateurs, to draw comparisons.

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

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

Especially, draw a comparison between the 4 scenarios according to various Key Performance Indicators thanks to the buttons Temps Totaux passés and Analyse des Indicateurs. To draw comparisons, you need to add and select multiple scenarios by clicking on + Simulation de Comparaison on **Simulation** tab.

To proceed, you need to build by yourself one of the 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 ( $\mu, \tau$ ) 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).

## OPENING - 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 happen 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 happen when you consider lower speed restrictions? What happen when you consider different periods of application?

## Credits

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