Description of the model

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ARTICLE HISTORY
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1. Purpose

The model aims to evaluate different scenarios of the evacuation of the city of Rouen (France, Normandy). One scenario is detailed in this paper, others can be found in (**?**). Rouen is a city of 110 000 inhabitants built on both sides of the Seine River. There are six bridges allowing people to cross it.

These bridges are particularly critical for traffic in Rouen. For instance, a fuel tanker truck accident in October 2012 led the authorities to close the Mathilde bridge for almost two years. This bridge was, at that time, the most popular for crossing the Seine with 80 000 vehicles per day. This accident had a significant impact on the traffic situation and led to an increase in traffic jams.

Another specificity of Rouen is the presence of several at-risk chemical plants classified SEVESO near the city center, and the absence of an overall evacuation plan in case of a serious accident in one of these plants. In this work, we therefore plan to simulate Rouen evacuation based on a very simple scenario in order to estimate the average time for a mass evacuation.

2. Entities, state variables, and scales

In order to simulate the city evacuation, we need to take into account six types of agents in the model:

- *road*: based on the Road skill.
- *node*: based on the RoadNode skill.
- *traffic signal*: a specific node that manages traffic signals.
- *driver*: based on the Advanced Driving skill.
- *evacuation place*: destinations indicated to the drivers for leaving the danger zone as soon as possible, i.e. places to reach for the drivers.
- *traffic jam*:a traffic jam is an ephemeral agent dynamically created (and destroyed) during simulation by a *road* agent when two conditions are met: there must be (i) a minimum number of drivers present on the road; (ii) the aver-

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age speed of these driver agents is below a certain threshold (depending on the *max_speed* of the road). In addition, to be considered as a real traffic jam by the drivers, the two conditions have to be met for at least a given duration (defined by *time_threshold*, a parameter of the model). Using an agent to explicitly represent a traffic jam facilitates its manipulation and decreases memory usage: rather than having all the attributes linked to traffic jam in all road agents when they actually concern only a few roads, here all the attributes are linked to traffic jam agents that will only exist when necessary. This also allows us to take advantage of the optimization provided by GAMA with respect to spatial queries on agent populations.

The traffic signal agents have all the attributes provided by the RoadNode skill, and three additional attributes:

- *is_red*: a boolean, specifying if the traffic signal is red or green
- *state_duration*: a float, representing the duration of a state
- *counter_state*: a float, corresponding to the time from the last change of state (red and green)

The evacuation place agents have only one attribute:

- *location*: a coordinate, giving the location of the evacuation place which is on the boundary of the simulation zone.

The variables of the traffic jam agent are as follows:

- *shape*: a geometry (polygon), which is the extended spatial shape of the traffic jam.
- *road_concerned*: a road, the road concerned by the traffic jam.
- *blocked_drivers*: a list of drivers blocked in the traffic jam.
- *time_counter*: a float, cumulated time for which the traffic jam exists.
- *is_real*: a boolean, which specifies whether the traffic jam should be considered by the drivers.

The road agents have all the attributes given by the Road skill, and two additional attributes:

- *current_traffic_jam*: traffic jam; the traffic jam on the road (if it exits).
- *traffic_jam_speed*: float; the maximum speed that a driver can have on the road to be considered as stuck in a traffic jam:
  $traffic\_jam\_speed = max\_speed * traffic\_jam\_coeff\_speed$
  with *traffic_jam_coeff_speed* a parameter of the model.
- *min_drivers*: integer; the minimum number of drivers stuck to create a traffic jam agent:
  $min\_drivers = lanes * perimeter/vehicle\_length * traffic\_jam\_coeff\_number$
  with *traffic_jam_coeff_number* a parameter of the model
- *blocked_drivers*: list of drivers blocked in the traffic jam.

The driver agents have all the attributes provided by the advanced driving skill and some additional attributes:

- *known_traffic_jams*: a list of traffic jams that the agent knows.
- *perception_distance*: a float, representing the perceived distance of the traffic jams.

- *proba_avoid_event*: a float, probability of the agent trying to avoid an event (traffic jam, blocked road) by following another path.
- *proba_know_map*: a float, probability that the agent knows the path, i.e. knows an alternative path that helps to avoid the traffic jams that it is aware of.

3. Process overview and scheduling

One step of the simulation represents 1 second. The dynamics of the model are based on 5 consecutive steps:

(1) The road agents compute the potential traffic jams
(2) The traffic signal agents compute their new state.
(3) The driver agents perceive the traffic jam.
(4) The driver agents, which do not have a path to reach their destination or which have to re-compute it due to a change in their context, compute it.
(5) The driver agents drive towards their target. This driving step is asynchronous. Agents move one after the other. The order of activation of the driver agents depends on their distance to the end of their current road: the drivers closer to the road end are activated first.

Traffic jam management
Each road has the capability of computing traffic jams on it. A traffic jam is defined as the presence of at least *min_drivers* drivers on the road with a speed that is lower than *traffic_jam_speed*. A traffic jam becomes real for drivers if it exists for at least the duration of *traffic_jam_time_threshold*.

Traffic signal update
Each traffic signal (only traffic lights in our model) updates its counter state: if the *counter_state* variable is equal to or higher than *state_duration*, the state of the traffic light changes (red to green, or green to red) and the the *counter_state* variable is set to 0.

Traffic jam perception
Each driver agent perceives the traffic jam at their *perception_distance* distance: these traffic jams are added to their list of known traffic jams.

Computation of the path
When the evacuation order is given, each agent receives some coordinates, which may correspond to a shelter or a gathering area. These coordinates are a node number registered in the *final_Target* attribute. Since the *final_target* has changed, the agent will call the *compute_path* function to define its new route. To compute the new path, the agent first tests the probability *proba_know_map*: the idea is that if the agent knows the map, it will be able to compute an alternative optimal path that enables it to avoid the traffic jams that it knows. In the other case, the driver agent will just locally choose roads without traffic jams, which will allow it to move closer to its final target.

Driving step

Each driver agent uses the driving action of the advanced driving skill to move towards its target. If the agent reaches an evacuation place, it is removed from the simulation.

When a driver perceives that its path will cross at least one known uncommon event (traffic jam, blocked roads), it tests the *proba_avoid_event* probability to determine if it will try to avoid it or not. If it tries to avoid, it will update its path by applying the computation of path behavior at the next step.

4. Input and initialization

The model proposed is generic and allows us to test various scenarios, in particular, through the various parameters that can be defined:

- road and node shapefiles: definition of the network infrastructure and more particularly, of the traffic lights;
- evacuation place shapefiles: location of the evacuation places;
- parameters linked to drivers: properties of the drivers (vehicles, tendency to follow the norms...), initial localization, and *final_target*;
- parameters linked to traffic jams: *traffic_jam_time_threshold*, *traffic_jam_coeff_speed*, and *traffic_jam_coeff_number*.