A Simulation Tool to Assess the Impact of Deviation Plans on Disruptive Events of Urban Traffic

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Abstract: Urban traffic management faces growing challenges in evaluating and mitigating the impact of disruptive events, such as road closures, on vehicular traffic flow. This paper presents the design and development of an interactive tool to define and assess the impact of road deviation plans on vehicular traffic. The proposed tool targets traffic management experts and is expected to support them in defining and comparing alternative solutions to mitigate disruptive events (e.g. road/tunnel closures for maintenance). The proposed tool, called *TrafficTwin*, can be adapted to different areas of the town, make use of different traffic models (either synthetic or calibrated) and visualize several quantitative statistics to assess and compare alternative deviation plans. We evaluate the proposed tool using a synthetic traffic model and assess the pertinence of the simulation tool to support the decision-making process in transportation infrastructure management.

1 INTRODUCTION

A challenge in the traffic domain is to provide management experts and decision-makers with methods to assess policies to optimize traffic and avoid congestion, a major responsible of CO_2 emission (Hussain et al., 2023). On the one hand, the impact of the control strategies on road infrastructures is not apparent until they are deployed in real-world motorway applications (Kušić et al., 2023a). On the other hand, testing in real-life settings is costly, risky, and often unfeasible (Argota Sánchez-Vaquerizo, 2021). In this context, urban traffic simulation models have become an indispensable asset: these tools provide a lens through which it is possible to analyze control strategies *in silico*. They rely on computational models to test these strategies before deploying them in the real world. One key requirement for traffic models is realism. If the dynamics of simulated traffic are close to reality, then traffic management experts can assess the traffic resulting from the deployment of some control strategy in the real world (Siebke et al., 2023).

Research on *what-if* scenario modeling is generating increasing interest within the scientific community. The growing complexity of decision-making tasks requires the implementation of strategies that enable the evaluation of the impact of various choices. This is particularly crucial in traffic management, where congestion can be significantly affected by a single decision, especially in the case of disruptive events. Therefore, it is essential to have efficient computational methods that help predict and mitigate congestion issues.

Kušić et al. (Kušić et al., 2023b) propose a digital twin of the Geneva motorway, integrating real-time traffic data from motorway traffic counters. These data include vehicle counts, speeds, and categories, updated every minute. The data are provided as input to the SUMO simulator to provide accurate simulation of traffic conditions. The authors use SUMO's calibrator objects, which adjust traffic demand in the simulation in real time according to the input traffic data. The proposed model allows for evaluating traffic control strategies, such as variable speed limits, in a cost-effective, real-time environment. The authors

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measure the GEH statistics (below 5) and compare the real and simulated traffic flow to evaluate the accuracy of the digital twin.

Naing et al. (Naing et al., 2021) propose a dynamic framework for short-term microscopic traffic forecasting using Long Short-Term Memory (LSTM) neural networks. By integrating real-time data into a traffic simulation, the system dynamically updates the LSTM parameters, enabling more accurate predictions of vehicle behavior, especially in “Just-in-Time” decision-making contexts. To perform what-if analysis, multiple simulations are branched from the base simulation, each one exploring different scenarios based on varying traffic conditions or decisions. The authors evaluate the proposed framework on real-world traffic data from US Highway 101, demonstrating that the dynamic LSTM-based model outperforms traditional models such as the Krauss car-following model, in terms of accuracy and efficiency.

However, interactive simulation tools specifically designed for what-if analysis of disruptive events are limited. Adreani et al. (Adreani et al., 2022) introduce a novel scenario model and editor, integrated into the open-source Snap4City.org platform, to define general processes and what-if scenarios for analysis across different domains. The authors present a case study on traffic flow reconstruction in the city of Florence, Italy, using the scenario editor and data-driven tools to analyze and reconstruct traffic patterns in the area of interest. This enables the performance of what-if analysis, aiding in informed decision-making. The traffic flow reconstruction relies on solving a fluid dynamic problem formulated using partial differential equations (PDEs). PDE models often assume homogeneity in traffic flow, neglecting real-world variations such as driver behavior, heterogeneity in vehicle dynamics, or localized phenomena (e.g., sudden lane changes or road closures). Moreover, authors assume the availability of data of traffic flow entering/exiting in the area of interest, which is not always possible.

Additionally, a major limitation of the current state-of-the-art is the lack of tools to quantitatively and visually assess the impact of mitigation strategies. An example is the evaluation of *road deviation plans*, whose effects of deployment are often unknown. We define a deviation plan as a set of rules that dictate how traffic is redirected to avoid congestion. In a real-world environment, this corresponds to strategic road closures or the placement of road signals.

In this paper, we present a novel tool (called *TrafficTwin*) for assessing the impact of alternative road deviation plans on vehicular traffic. The main contributions of this work are: (*i*) an interactive tool to model disrupting events, such as road closures, and the related deviation plans to divert traffic and avoid closed roads, (*ii*) a simulation-based method to evaluate deviation plans with different traffic demands, synthetic or calibrated, (*iii*) an interactive dashboard to visualize the differences between scenarios. We use the SUMO package to simulate realistic traffic patterns. The proposed tool targets experts in traffic management to define easily simulation models and perform what-if analysis in case of disrupting events that cause road closures. We introduce the features of the proposed tool by showcasing a realistic case study in the city of Brussels.

2 THE TrafficTwin ARCHITECTURE

TrafficTwin is composed of the following components, as shown in Figure 1:

- the *data sources*, currently supporting static files containing the traffic demand definition (when using calibrated traffic), and the definition of deviation plans;
- the *server component*, responsible for the simulation of urban traffic (using SUMO), data aggregation and management;
- the *message broker*, based on RabbitMQ (RabbitMQ, 2024), for handling the data exchange between client and server;
- the *client component*, allowing traffic management expert to define virtual traffic, road closures and deviation plans;
- the *dashboard component*, allowing presenting the result of modification in urban infrastructures through graphical plots.

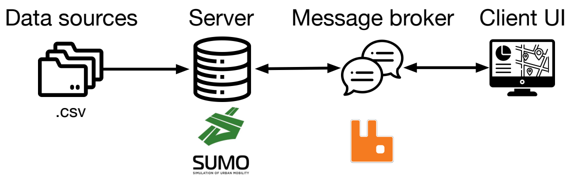


Figure 1: Main components of TrafficTwin. The system consists of four components (from left to right): data sources, a server that simulates urban traffic using SUMO and manages data, a message broker (RabbitMQ) facilitating data exchange and a client interface for traffic experts to define virtual scenarios.

In the following, we describe the core components of the proposed tool.

2.1 Client Component (User Interface)

The graphical user interface allows three main functionalities: (*i*) the definition of deviation plans, each including the closed roads and the specification of how the vehicles must be diverted to avoid closed roads, (*ii*) traffic modeling, where the user can specify the level of congestion in simulated traffic, and (*iii*) dashboard, where it is possible to analyze the impact of roadworks in traffic congestion. In the following, we describe the functionalities of each part of the user interface.

Definition of Deviation Plans

The panel for managing disrupting events (Figure 2) enables the definition of road closures and deviation plans. Herein, a deviation plan consists of a set of roads where vehicles cannot drive, a time interval defining the temporal horizon of the plan, a source road, and a set of destination roads to which vehicles are redirected during road closures.

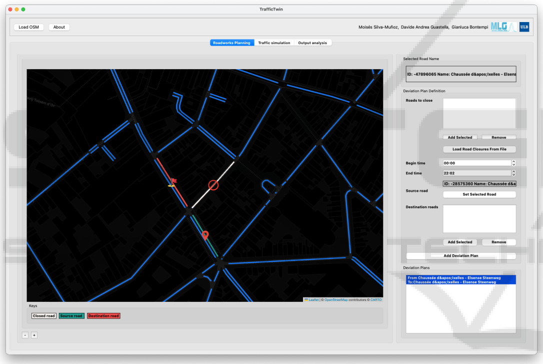


Figure 2: Roadworks planning in the proposed tool. On the left a map is shown, with roads represented as blue lines. Also, yellow lines represent closed roads, green lines the source roads, and red lines represent the destination roads. Simulated vehicles cannot enter the roads highlighted in gray. In the sidebar to the right, a “Deviation Plan Definition” is set, where users can close specific roads, define time intervals for closures, and specify rerouting plans (source and destination roads).

We implement the deviation plans in SUMO by properly configuring rerouters. The rerouters allows vehicles’ routes to be modified as they travel over specific roads (the source roads in the deviation plan), based on the available options and the current traffic conditions (Lopez et al., 2018). When a new destination is selected, the fastest route is calculated from the vehicles’ current position to the new destination (see red line in Figure 2). However, it is not always possible to determine a new alternative route. This is mainly due to the conditions of the road network. In this case, the rerouter has no effect and the vehicle’s original route is maintained. If the edge ahead is closed due to roadwork, the vehicle waits until the edge is reopened, leading to congestion. However, after a predefined time (in SUMO), the vehicle is removed from the simulation.

The following XML code shows the definition of a rerouter for use with SUMO.

```
<rerouter id="example" edges="-19 -17 -25
    9">
   <interval begin="0" end="3600">
      <closingReroute id="-9" disallow="
         all"/>
   </interval>
</rerouter>
```

Using the previously defined rerouter, vehicular traffic is prohibited on the edge with ID -9 and redirected to the adjacent edges with IDs -17, -25, and 9, respectively. The closure of edge -9 occurs between time instants 0 and 3600 seconds. The TrafficTwin software allows to define deviation plans through an easy-to-use interface. In this way, it is not necessary for non-expert users to have specific knowledge on how to encode rerouters for simulating deviation plans.

The TrafficTwin user interface (Figure 3) allows configuring the traffic demand used by SUMO to replicate the realistic dynamics of traffic.

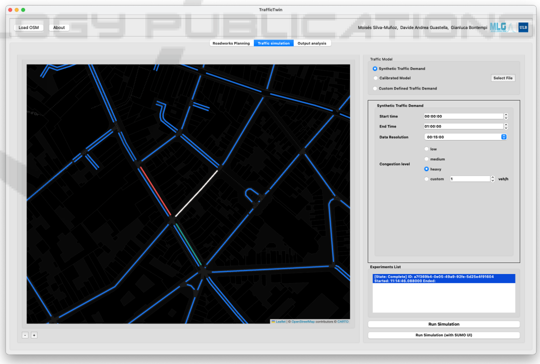


Figure 3: Traffic simulation modeling interface in the proposed tool. The tool displays on the right the road network (blue lines), the closed roads (in yellow), the source roads (in green), the destination roads (in red). The sidebar on the right contains settings for configuring the traffic model, including options for synthetic traffic demand, calibrated models, or custom traffic demand inputs. Users can specify a time range for the simulation, set the data resolution, and adjust the congestion level (low, medium, heavy, or custom).

Currently, the proposed tool supports the definition of the synthetic traffic demand (specifying the number of vehicles per hour), and the use of traffic models generated from external calibration tools.

When using a calibrated model, the traffic demand is generated from realistic traffic data. The traffic demand consists of a set of vehicles to be inserted into the simulation, with each vehicle defined by a time instant (when it enters the simulation) and the set of roads it drives on to reach its destination (Guastella et al., 2025).

When defining synthetic traffic demand, TrafficTwin allows the user to specify the number of vehicles per hour to be included in the simulation. In the resulting traffic demand, each vehicle is assigned a random origin and destination, and its route is determined using the Dijkstra algorithm (Utomo et al., 2023).

Dashboard for Simulation Analysis

TrafficTwin includes an interactive dashboard for conducting a comparative analysis of simulation outcomes. The dashboard visualizes different traffic attributes obtained from two simulations: one in which deviation plan configurations are active and another where they are not. By comparing the results of the two simulations, traffic management experts can assess the impact of roadworks on traffic congestion without any technical knowledge about the functioning of the simulation tool. Figure 4 shows the dashboard, developed as a web application using Dash[1]).

Figure 4: Interface for analyzing the simulated traffic with and without roadworks.

Table 1 lists the attributes that can be analyzed with the dashboard.

2.2 Server Component

The server component is responsible for performing traffic simulations by using the open-source simulator SUMO. This tool allows emulating the complex dynamics of traffic, including stop-and-go patterns, traffic lights, and junctions. In SUMO, the road network is modeled as a graph, where the edges represent the roads and the vertices represent the junctions. Vehicles in SUMO are defined by an identifier, departure time, and route through the road network. A vehicle can be described in more detail, including properties such as departure and arrival times, the lane to use, and maximum and minimum speeds. Also, each vehicle can be associated with a class that defines its type (for instance, private vehicles, taxis, coaches, trucks, or bicycles). Each class has different properties that determine how vehicles move within the road network.

Table 1: Traffic attributes that can be analyzed with the dashboard available in TrafficTwin.

Attribute (unit)	Description
Edge Occupancy (%)	Occupancy of the edge/lane in %. A value of 100 would indicate vehicles standing bumper to bumper on the whole edge (minGap=0).
Edge Density (#veh/km)	Vehicle density on the edge
Waiting Time (s)	The total number of seconds vehicles were considered halting (speed <speedThreshold). Summed up over all vehicles
Average Speed (m/s)	The mean speed on the edge/lane within the reported interval.
Time Loss (s)	The total number of seconds vehicles lost due to driving slower than desired (summed up over all vehicles)
Travel Time (s)	Time needed to pass the edge/lane.
Sampled Seconds (s)	The number of vehicles that are present on the edge/lane in each second summed up over the measurement interval (may be subseconds if a vehicle enters/leaves the edge/lane).

We assume that the user can generate synthetic traffic or use a pre-existing (calibrated) traffic model. The former case is useful when no realistic traffic model is available, or when the user wants to determine the impact of different deviation plans under unknown traffic conditions. The latter case is useful for evaluating deviation plans in a realistic traffic condition, that is, in a simulation model where vehicles follow realistic routes (similar to real traffic flow).

We use the `randomTrips` tool provided with SUMO to generate synthetic traffic demand. `randomTrips` generates a set of random routes (random departure and destination points) for a given road network. Each route is associated with at least one vehicle. To generate realistic traffic demand, the `randomTrips` tool allows, through the parameter `--insertion-rate` to specify the number of vehicles per time interval. In this way, it is possible to simulate the variation of traffic during peak hours.

The `randomTrips` tool first generates a set of origins and destinations for the specified number of vehicles, with this number provided as input. The `randomTrips` tool uses the Dijkstra algorithm to find routes connecting the origin and destination for all ve-

[1]https://dash.plotly.com. Last visited: February 6, 2025

hicles. The parameters used to generate random traffic for each simulation are the *insertion rate* and the fringe value: the former refers to the number of vehicles per hour to be introduced into the simulation; the latter determines the probability that an edge at the boundary of the modeled road network is selected as the origin or destination of a vehicle. This allows modeling vehicles whose origin or destination is over the modeled road network.

We input the following parameters to generate random traffic (Guastella et al., 2023):

- *network*: the road network definition;
- *begin*: begin time of the simulation;
- *end*: end time of the simulation;
- *insertion rate*: the expected number of vehicles per hour. By varying this parameter, it is possible to control the amount of traffic in the simulation. This is modeled in the “Traffic Modeling” interface.

The output of `randomTrips` is a list of vehicles, each associated with a route. The set of vehicles is in XML format. The calibrated traffic models supported by TrafficTwin are in the same XML format, containing a list of vehicles associated with the starting time and an edge list that constitutes their route. This can be generated starting from real traffic count data and using standard tool such as RouteSampler (Behrisch and Hartwig, 2022), included with SUMO.

2.3 Communication Between Client and Server

We use RabbitMQ (RabbitMQ, 2024), an open-source message broker that acts as an intermediary between the client (user interface) and the server through a message queuing technique. Message queuing is a method of communication between applications or components. With message queueing, client and server can remain independent while processing their individual tasks. Messages are typically small requests, responses, status updates, or simple pieces of information. A message queue temporarily stores these messages, allowing applications to send and receive them as needed. One advantage of this approach is that systems are loosely coupled-they do not need to know the physical location of other components; a simple name is sufficient to reach them. This enables systems to evolve independently without affecting one another, as the reliable delivery of messages is managed by the broker.

RabbitMQ uses an Erlang-based implementation of the Advanced Message Queuing Protocol (AMQP), an open standard protocol that defines how a system can exchange messages (RabbitMQ, 2024). The protocol defines a set of rules that the communicating system must follow. It also defines the representation of messages and commands exchanged between several systems.

In the proposed tool, we use two message queues to facilitate communication between the client and the server. One queue is used to transfer requests from the client to the server, mainly involving the execution of simulations and uploading OpenStreetMap (OSM) files. Communications from the server to the client transfer the output of the simulations.

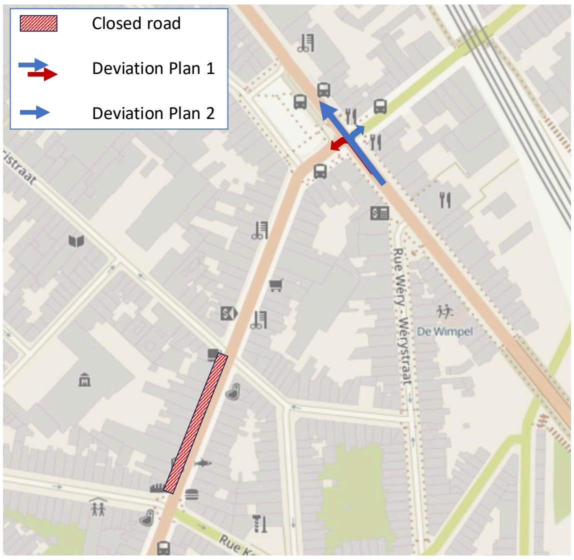
The use of message queues enables the configuration and subsequent execution of numerous simulations on the server.

3 EXPERIMENTAL RESULTS

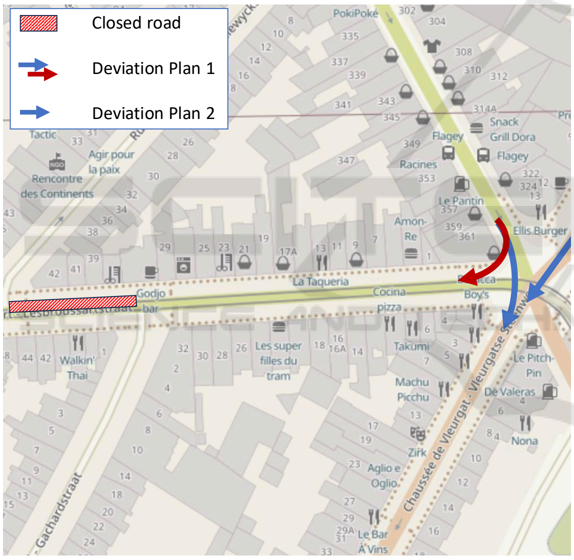
This section presents a case study where TrafficTwin is used to assess alternative deviation plans designed to mitigate congestion when different roads are closed due to roadworks (or other events). The case study focuses on the area of the Ixelles municipality in Brussels, Belgium.

We begin by defining the road network, modeling the roadworks (by closing roads to vehicular traffic), and establishing the deviation plans and traffic demand (Section 3.1). We define two configurations, each containing different deviation plans for the same set of roadworks (closed roads). The configurations of deviation plans differ in the choice of possible edges where vehicles can transit in order to deviate their trajectory to avoid closed edges. Let us consider the two deviation plans in Figure 5. In Figure 5a we define two possible alternatives for diverting traffic. In Deviation Plan 1, vehicles can go left, right, or straight. However, allowing vehicles to turn left could lead to congestion on minor streets near the roadwork site. For this reason, we have defined a second Deviation Plan, where vehicles can only go straight or turn right. Similarly to the previous case, the deviation plan 2 in Figure 5b prevents vehicles from entering a partially closed road. Deviation plans can be set up to model various situations requiring traffic diversion, such as tunnel closures, roadworks, accidents, or strikes.

In Section 3.2, we verify the effectiveness of the first configuration by comparing the traffic statistics with and without roadworks. In Section 3.3, we compare the first configuration to the alternative one to determine if a different deviation plan would be more effective in reducing the impact of roadworks on vehicular traffic (e.g. in terms of congestion).



(a)



(b)

Figure 5: Two alternative deviation plans for the roadworks (indicated as white and red rectangles) in Rue Malibran (Figure 5a) and Rue Lesbroussarts (Figure 5b). In the main deviation plan, vehicles can follow the directions indicated by both red and blue arrows, whereas in the alternative deviation plan vehicles follow only the direction indicated by blue arrows.

3.1 Scenario Modeling

We use OSM to extract the road network in the concerned area and load it in TrafficTwin. Figure 6 shows a roadwork plan provided by the municipality of Ixelles. Figure 7 shows the location of the roads (around Rue Scarron) where we simulate the presence of roadworks.

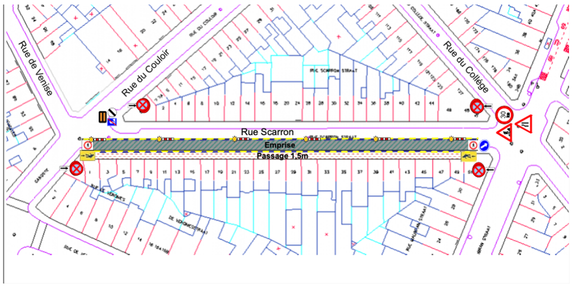


Figure 6: Detailed roadwork plan for Rue Scarron (Ixelles, Brussels, Belgium), outlining the restricted areas during construction activities. This is provided by Brussels Mobility, the government agency responsible for managing and developing transport infrastructure in the Brussels-Capital Region of Belgium.

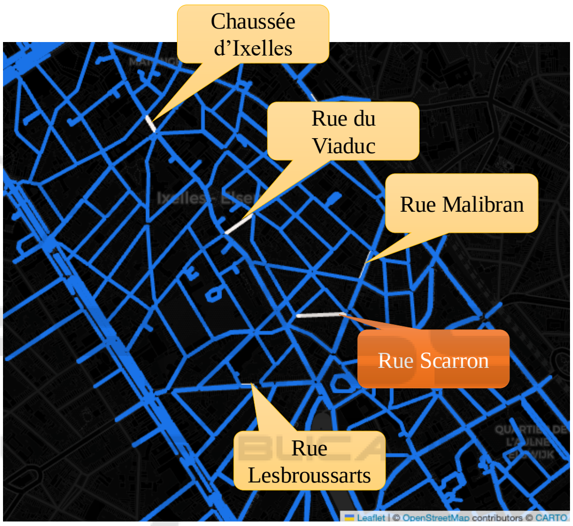


Figure 7: Location of the roadworks in the area of Ixelles (Belgium), implemented using the proposed tool.

To assess the impact of the deviation plan on vehicular traffic, we present the results of two scenarios: one with roadworks, considering a configuration of deviation plans (Figure 7), one without roadworks. Then, we evaluate an alternative configuration of deviation plans to assess if this allows for minimizing the congestion.

We consider a 1-hour traffic simulation and we generate random traffic using the `randomTrips` tool available with SUMO. By considering random traffic, we can evaluate the effects of road closures under different hypothetical traffic congestion levels.

We introduce stochasticity to better replicate reality in simulation scenarios by varying i) the departure times of vehicles (uniform distribution over $[1, 60]$ seconds) and ii) the edge weights so that the Dijkstra algorithm returns different routes for the same origin-destination pair. Weight perturbation allows us to take into account drivers' individual preferences.

This stochastic approach results in different congestion outcomes with each simulation run. To capture this variability, we perform 100 simulation for each traffic congestion level.

Finally, we analyze the simulation output. We begin by edge-wise measurements returned by SUMO, then we analyze aggregated information on individual vehicle trips. The first analysis aims to show that, on average, the congestion level increases when multiple roadworks are present. The second analysis aims to show that, on average, vehicles take longer to reach their destinations when roadworks are in place. This information is expected to support traffic management experts in assessing the impact of deviation plans in a virtual setting before real-world deployment.

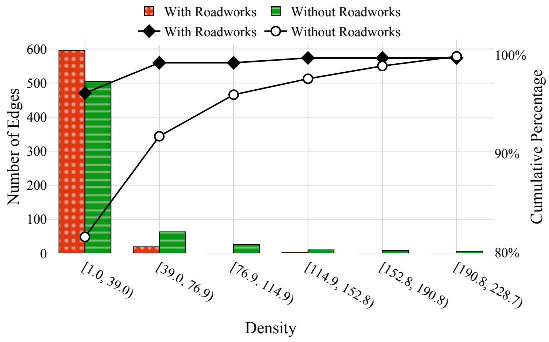
3.2 Deviation Plan Assessment (With/Without Roadworks)

This Section presents the assessment of the first deviation plan. Figure 8 shows the Pareto chart (Wilkinson, 2006) clustering the edges according to the average density (in #veh/km), considering the simulations with and without roadworks. The line represents the cumulative percentage of the average density. The density measures the average spacing of vehicles per km, obtained by dividing the number of vehicles by the road segment length.

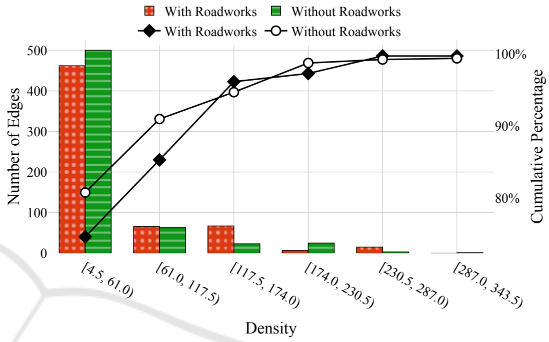
For 500 and 2000 vehicles, there's no remarkable difference in average density after road closures. Contrarily, when 5000 vehicles are present, the average density is lower compared to scenarios without road closures. Although this outcome may seem counterintuitive, it can be explained by the elimination of certain bottlenecks at intersections that typically cause congestion. Additionally, deviation plans may reroute traffic away from areas affected by roadworks. When vehicles are diverted, their destinations may change as a result of the deviation plans, further contributing to a reduction in vehicle density within the road network.

Figure 9 shows the Pareto chart clustering the edges by average speed (in m/s), from simulations with and without roadworks. For scenarios with 500 and 2000 vehicles, the absolute average speed difference obtained by the simulations with and without roadworks is not significant. However, when considering 5000 vehicles per hour, the average speed is higher in the case of roadworks. As for the traffic density measure, this can be caused by the elimination of certain bottlenecks at intersections that typically cause congestion.

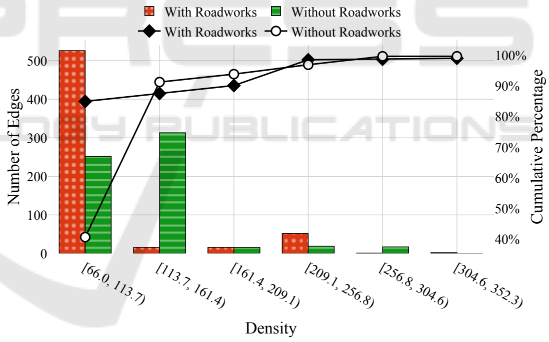
Figure 10 shows the road network, with edges colored based on the absolute difference in average speed



(a) 500 vehicles



(b) 2000 vehicles

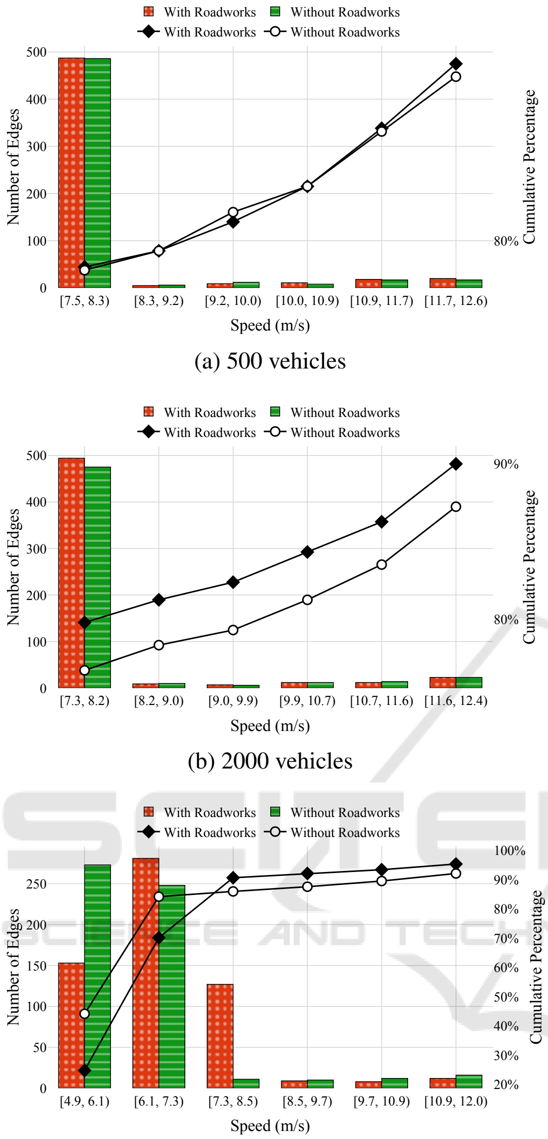


(c) 5000 vehicles

Figure 8: Average density of vehicles per edge, measured in #veh/km, using 500 (Figure 8a), 2000 (Figure 8b), and 5000 vehicles (Figure 8c). Lower values are better.

between simulations with and without roadworks, in the 5000 vehicles scenario.

A positive speed difference indicates that the roadworks have a major impact in congestion, as in this case the average speed is lower. Contrarily, a negative difference indicates a higher speed in the simulation when roadworks are applied. This can be attributed to the configuration of deviation plans, which allow for avoiding congested areas of the environment, reducing average traffic and resulting in higher vehicles speed. We also observe a greater difference in boundary roads, particularly in the northern part of the en-



(a) 500 vehicles

(b) 2000 vehicles

(c) 5000 vehicles

Figure 9: Average speed of vehicles (m/s) in the simulations with and without roadworks, using 500 (Figure 9a), 2000 (Figure 9b), and 5000 vehicles (Figure 9c). Higher values are better.

vironment. Although this area is not directly affected by any roadworks, this highlights how simulation can reveal emerging traffic dynamics that may not be easily identified through analytical methods.

The results presented so far refer to network edges. In what follows, we present individual trip statistics.

Figure 11 compares the average duration of trips (shorter trips are obviously preferable) with and without roadworks. This is the time required by vehicles to go from origin to destination.

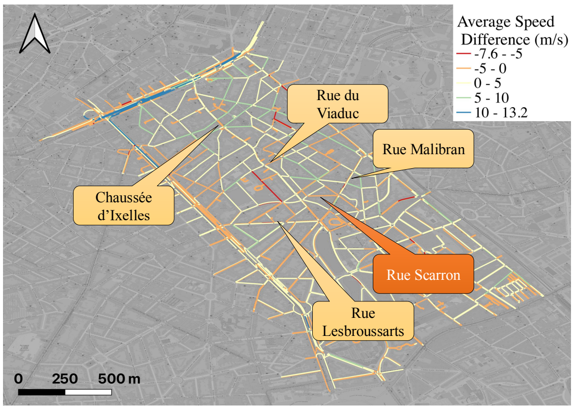


Figure 10: Average absolute speed difference obtained by the simulation with and without the roadworks.

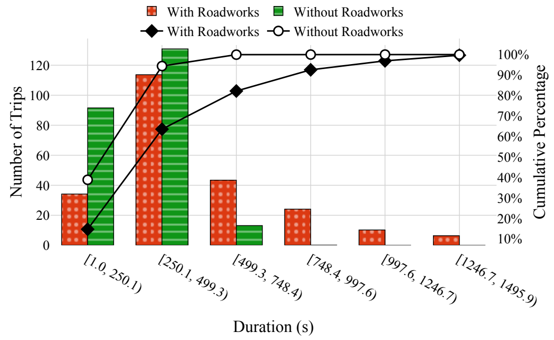
Without roadworks, trip duration is generally shorter. When roadworks are present, trips take more time as vehicles face delays and detours due to road closures. The comparison highlights the significant impact roadworks have on travel time, causing congestion and longer trips.

Figure 12 compares the average trip lengths with and without roadworks. Vehicles adjust their routes when they encounter rerouters, placed on roads near the closed ones. As expected, this leads to longer paths to bypass the closures and reach the destination. However, not all destinations are reachable due to road closures, primarily because of the limited scope of the considered environment. For this reason, it is possible to include in the simulator a probability for drivers to change the destination (in our experiments this value was set to 0.5). Note that if a vehicle does not change its destination and the deviation plan does not allow finding an alternative route (because both road network configuration and deviation plan), the vehicle remains stationary in front of the closed road until it is reopened. In this case, SUMO teleports vehicles that wait too long to avoid grid-locks.

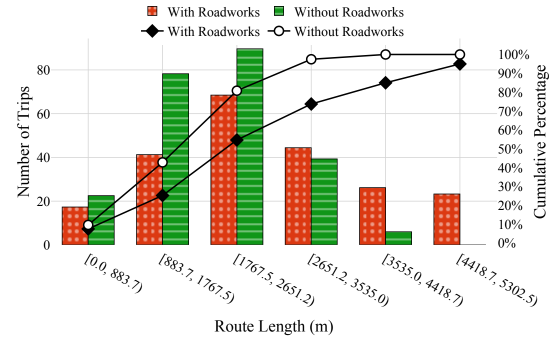
3.3 Alternative Deviation Plans Assessment

This Section focuses on the comparison of two alternative deviation plans. Figure 13 compares the respective average edge density and vehicle speed. This result is obtained as the average of each attribute after 100 simulations, using the same set of routes. For both configurations, we show the results obtained from 1 hour of simulation using 5000 vehicles per hour.

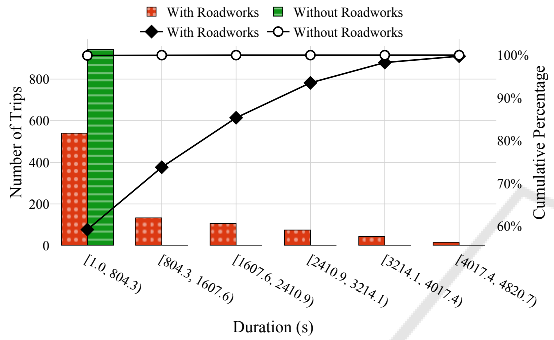
The density plot does not reveal significant differences, while the speed comparison indicates that the average speed is higher when using the first deviation



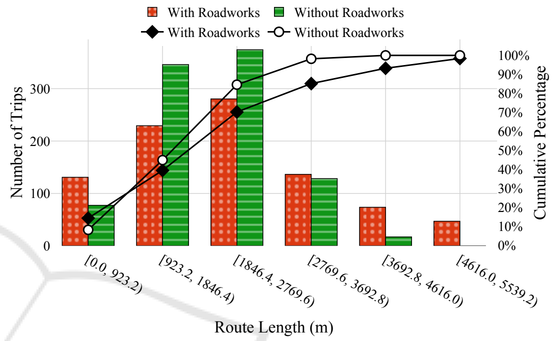
(a) 500 vehicles



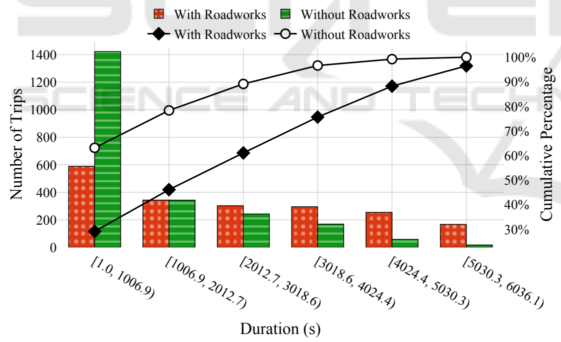
(a) 500 vehicles



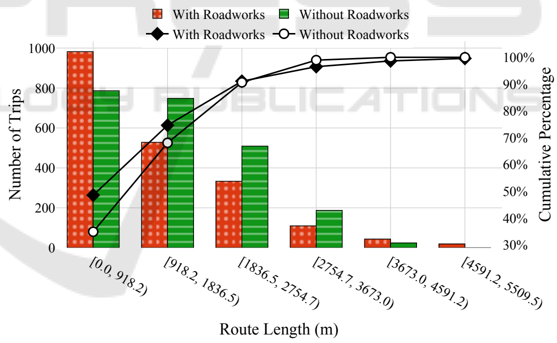
(b) 2000 vehicles



(b) 2000 vehicles



(c) 5000 vehicles



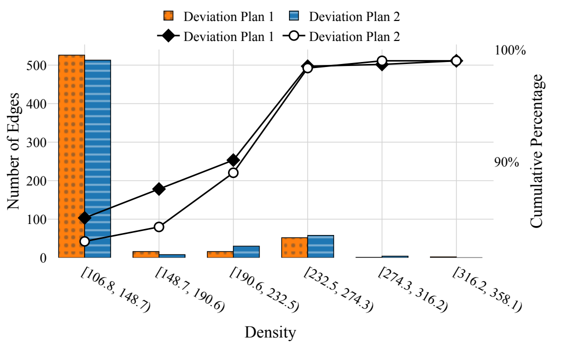
(c) 5000 vehicles

Figure 11: Average duration (in seconds) of the trips, using 500 (Figure 11a), 2000 (Figure 11b), and 5000 vehicles (Figure 11c). Lower values are better.

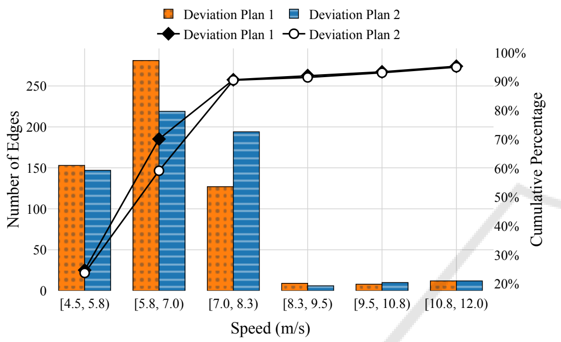
Figure 12: Average length (in meters) of the routes, using 500 (Figure 12a), 2000 (Figure 12b), and 5000 vehicles (Figure 12c). Lower values are better.

plans. This suggests that the first plan is more effective in reducing congestion. The same analysis indicates that, in some cases, the second configuration outperforms the first, notably in the range [7, 8.3]. By examining the locations of the edges where the average vehicle speed falls within this range (Figure 14), it appears that most edges are near the roadwork sites. This suggests that using the second plan would result in higher average speeds on edges in the proximity of the roadworks.

In some cases, congestion is caused by vehicles that cannot reach their destinations due to road closures. Suppose a road is closed, and this road is required for a vehicle to reach its destination. If no alternative route is available, the vehicle will remain stationary in front of the closed edge, waiting for it to reopen. This situation leads to congestion, which the simulator resolves by teleporting the vehicle after a predefined time. A teleported vehicle is removed from the network. It is then moved along its route, but no longer being on the street, and reinserted into the



(a) Average edge density (#veh/km). Lower values are better.



(b) Average speed (m/s). Higher values are better.

Figure 13: Average edge density (Figure 13a), speed (Figure 13b) obtained by the comparison of two alternative deviation plans.

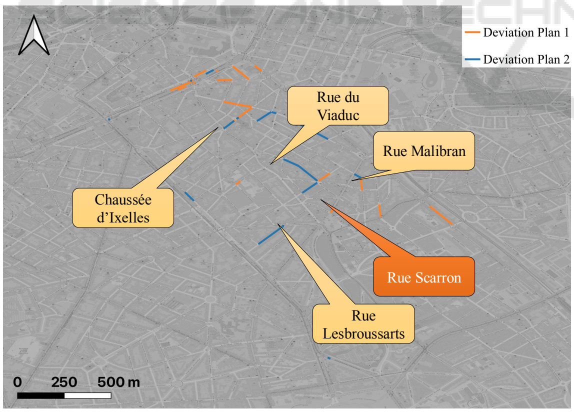


Figure 14: Location of the edges which average speed falls in the range [7, 8.3] using the two deviation plan configurations.

network as soon as this becomes possible[2]. To solve this issue, a rerouted vehicle has a 50% probability of changing its destination if it cannot reach its original destination road.

We evaluate the number of teleported vehicles as a congestion metric to compare the effectiveness of two deviation plan configurations by quantifying (1) the number of vehicles that cannot reach their destination due to a closed road and (2) the number of vehicles teleported due to congestion phenomena arising from the closed road and the deviation plan configuration. Table 2 compares the average number of teleported vehicles using both deviation plan configurations. Each value is calculated as the average number of vehicles teleported in the 100 simulations performed for each configuration.

Table 2: Average number of teleported vehicles using the two deviation plan configurations. The lower the average value, the more vehicles find an alternative route to reach their destination without being teleported.

	Deviation Plan 1		Deviation Plan 2	
	Average	Std Dev	Average	Std Dev
500 Vehicles	0.68	0.004	0.61	0.008
2000 Vehicles	0.74	0.039	0.43	0.063
5000 Vehicles	6.4	0.58	6.13	0.59

From the results shown in Table 2, we can observe that, on average, the number of teleported vehicles in both deviation plan configuration is low. This indicates that the majority of vehicles are able to find an alternative route to reach their destination.

4 CONCLUSION AND FUTURE WORKS

This paper introduces TrafficTwin, a tool to assist traffic management experts in decision-making tasks, by enabling the design and assessment of alternative deviation plans.

The tool is based on a client-server architecture. The server component is responsible for simulating traffic, while the client component enables traffic management experts to define deviation plans and traffic demand through a graphical user interface. We also developed a dashboard to visualize plots that can be used by traffic management experts to evaluate the impact of disruptive events.

The TrafficTwin software is based on the SUMO package. This simulator software typically has a steep learning curve, which poses a barrier to non-expert users. TrafficTwin enables researchers, urban planners, and decision-makers to use SUMO's simulation capabilities without needing extensive technical knowledge. This positions TrafficTwin as a key tool for making SUMO accessible to non-expert users.

TrafficTwin should be intended as an enabler for a more general digital twin solution to assist traffic officers in decision-making. The challenges still to

[2]https://sumo.dlr.de/docs/Simulation/Why_Vehicles_are_teleporting.html. Last visited: February 6, 2025

address are: (*i*) continuously calibrating traffic using real-time count data, and (*ii*) employing machine learning methods to suggest the best deviation plans that minimize the impact of roadworks. For challenge (*i*), the key difficulty lies in balancing off-line and online (simulation-based) methods for traffic calibration using real-world data. Although online methods are typically more accurate due to their reliance on realistic vehicle dynamics, they are computationally intensive, making the development of traffic digital twins more challenging. For the (*ii*), the aim is to use machine learning techniques to extract insights from various traffic models. By analyzing traffic dynamics over time, these methods can provide recommendations on where disruptive events are likely to have the greatest impact, potentially causing significant congestion effects.

Furthermore, we will investigate the integration of our tool with Unity 3D to provide a more realistic view of the urban environment. This will allow traffic management experts to evaluate control policies within a highly realistic digital twin before deploying them in the real world. This virtual environment can also be used by citizens to understand the impact of these policies on traffic, thereby promoting alternative forms of mobility to private vehicles.

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