Traffic Flow Simulation

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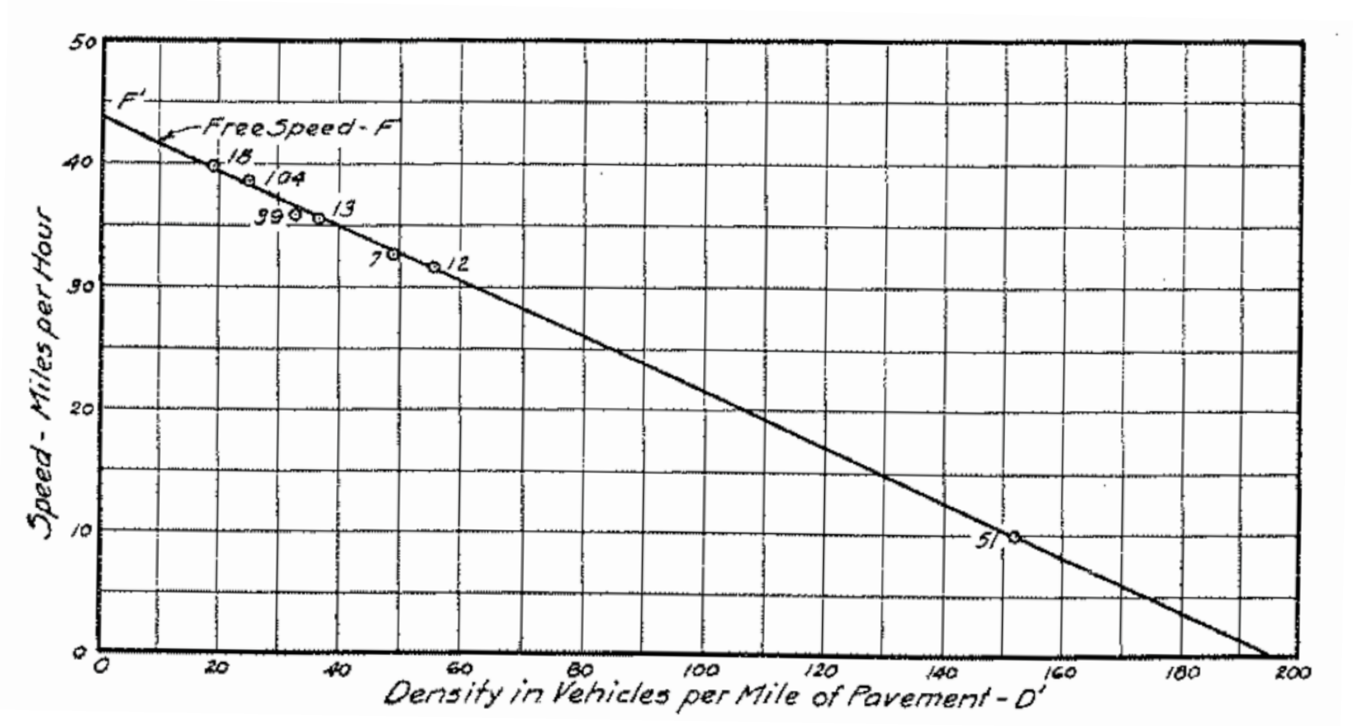
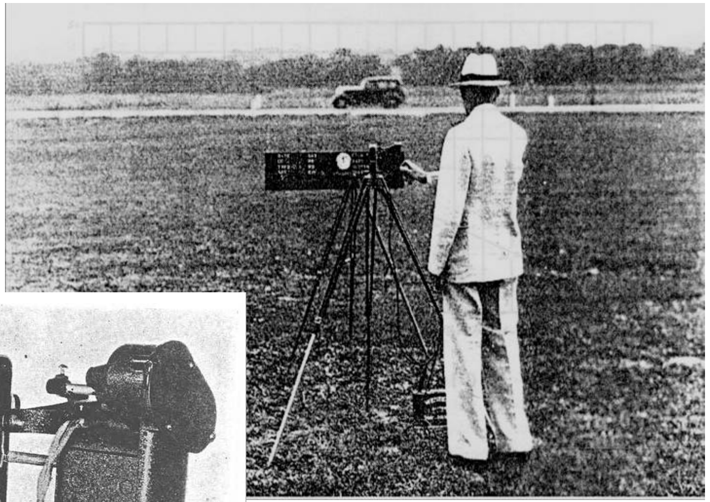
exo

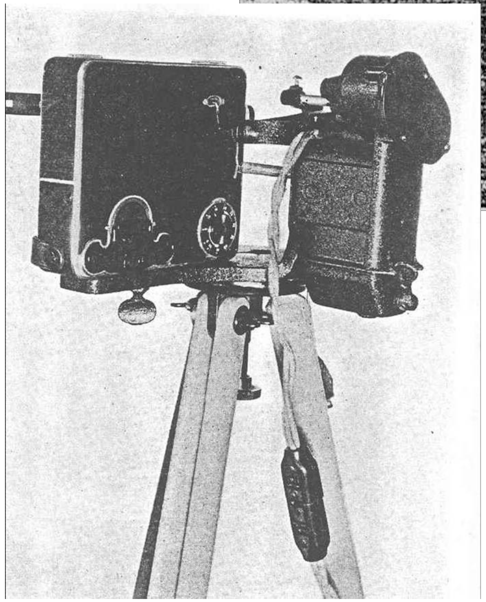
Introduction

- Do you recognize this plot?



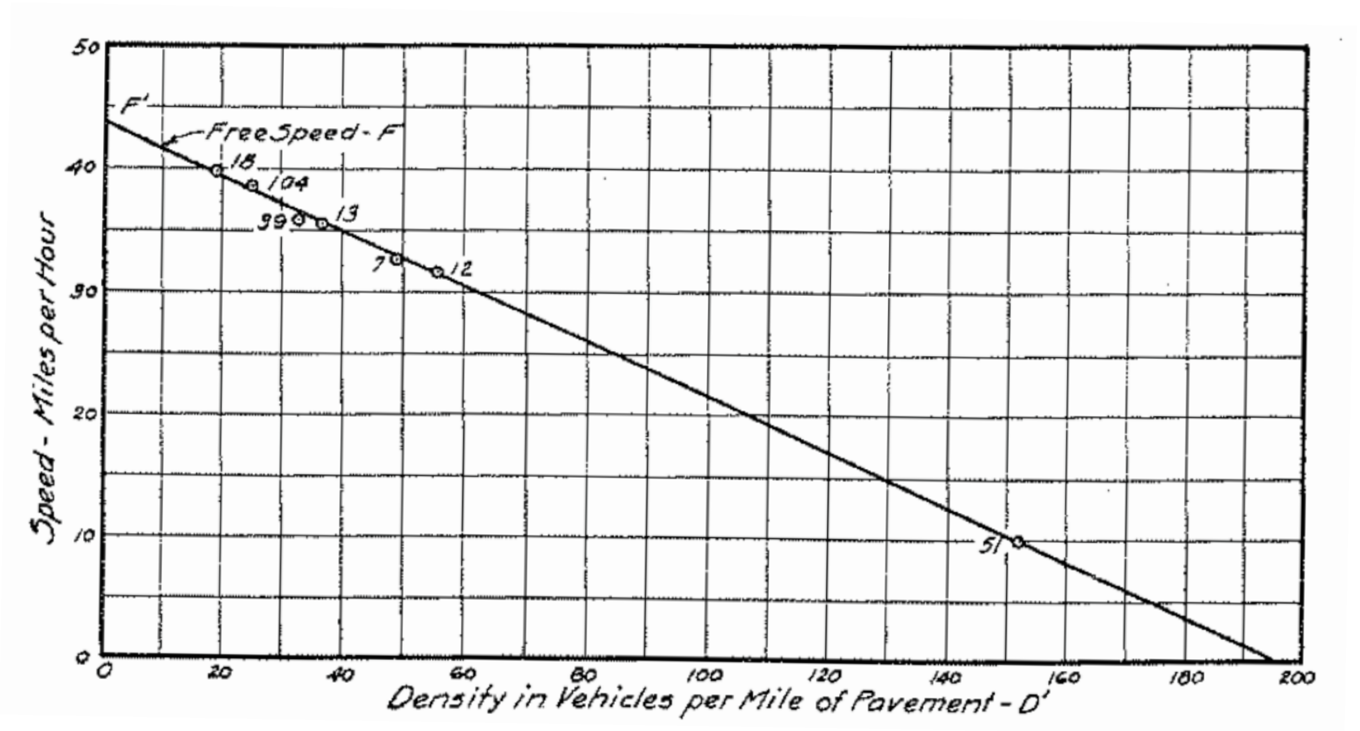
Introduction





Camera with motor attachment used by Greenshields (1930s)

Greenshields measurement set up (1930s)

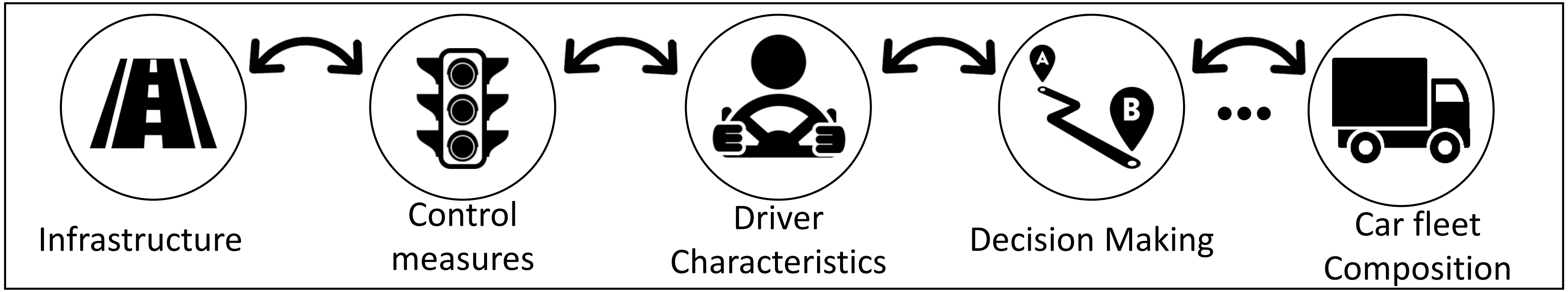


Greenshields' fundamental diagram (1935), showing a linear relation between density and speed

Traffic Flow System

Traffic flow System / Model?

Interconnected, complex, and functionally related components



Traffic Flow System

A complex unity formed of diverse parts, joined in regular interaction or interdependence, subject to a common plan or serving a common purpose.

Traffic Flow Model

A mathematical representation of the traffic flow system, which is used to study the effect of various components on traffic flow dynamics.

Traffic Flow Simulation

What is traffic flow Simulation?

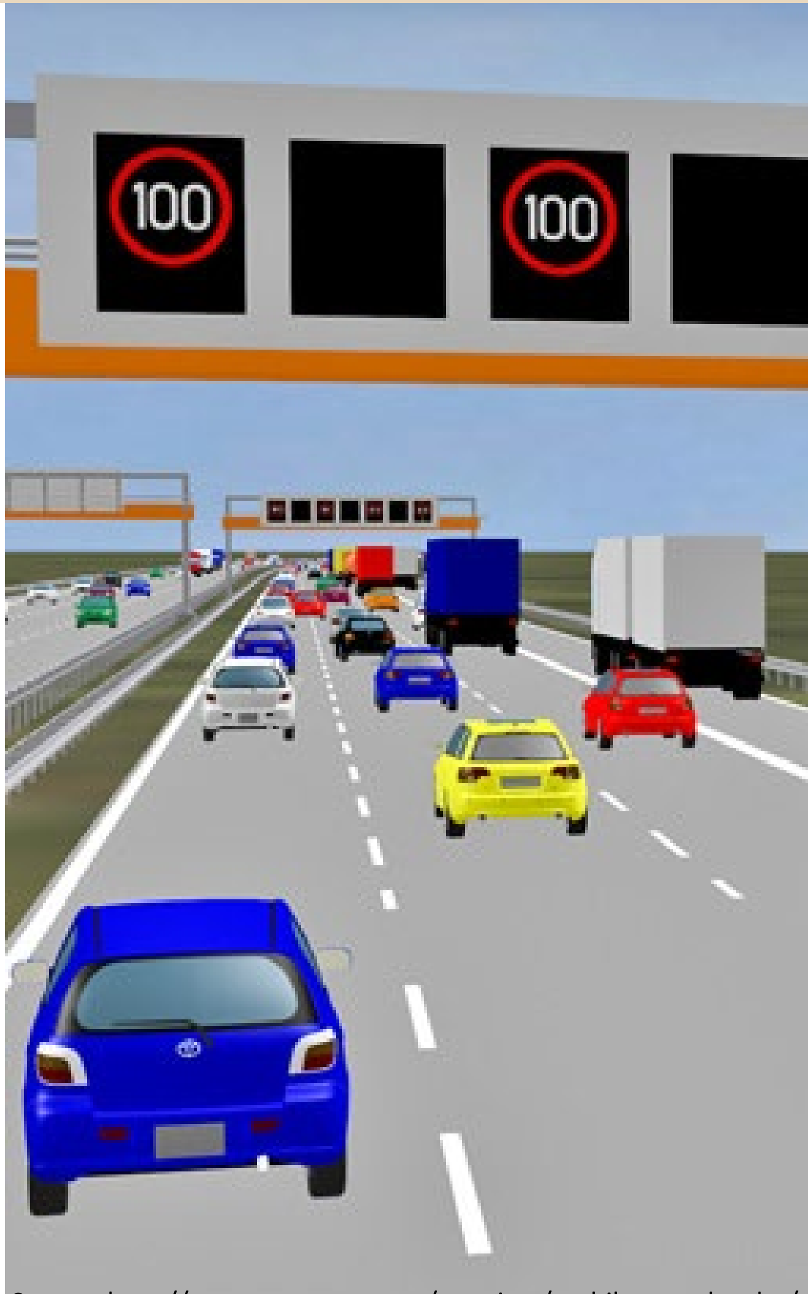
The implementation of traffic flow models to create a device for describing and understanding how a traffic flow system works, behaves, and evolves over time is called traffic flow simulation.

What is the purpose of traffic flow Simulation?

This device is used for predicting the output from a real system, under various conditions that are specified by the input data, without actually using the real system to make this prediction.

What are the applications traffic flow Simulation?

In general simulation models are used as tools to solve problems in complex systems, when system components interact.
Traffic flow simulation models are principally used to assess the impact of a new infrastructure, a new road design or a new traffic management measure on traffic flow dynamics.



Source: http://www.tatweer-co.ae/t-project/mobile-speed-radar/

Travel Demand Modelling

Four-Step Travel Demand Modelling

- First step – Trip Generation: How many trips are generated?
  - The goal of trip generation step is to estimate the number of trips that are produced or originate in each Traffic Analysis Zone (TAZ)
- Second step – Trip Distribution : Where do the generated trips go?
  - In this step matches between origins and destinations are developed. Trip ends are linked to create complete trips.
- Third step – Mode Choice: What travel mode is used for each trip?
  - Mode choice predicts the choices that individuals or groups make in selecting their transportation modes. For instance, an important objective is to predict the share of trips attracted to public transportation.
- Fourth step – Trip Assignment: What is the route of each trip?
  - The final step is to determine the routes travelers choose to reach their destinations.

Mathematical Models

Different Approaches

General mathematical models aimed at describing observed phenomena in traffic flow include the following approaches:

- *Purely deductive approaches,* where widely accepted and accurate physical laws are applied to describe the phenomena (ex: conservation law).
- *Purely inductive approaches,* where available data from real systems (i.e., real-world observations) are used to fit generic mathematical structures (ex. ARIMA models, neural networks).
- *Intermediate approaches*, where basic mathematical model-structures are developed in the first step, then calibrated using real-world observations in the second step.

Hoogendoorn and Bovy, 2001
Papageorgiou (1998)

Mathematical Models

Desired Characteristics

1. Tractable

Roughly speaking, a tractable model uses simple and robust methods.

2. Parsimonious

Simple models with great explanatory power with as few predictor variables as possible.
We should mostly compromise between the model's ability to explain and its complexity.

3. Predicting

A good model leads to useful forecasts.
The most useful forecasts are not always produced by the most accurate model

Buisson, C. (2010).
Comprendre, quantifier et réduire la congestion autoroutière. Technical report, ENTPE.

Traffic Flow Models

Unique model of a system

It should be pointed out that in traffic flow simulation there exists no such thing as “the model of a system”, i.e. a unique model of the traffic flow system.

A model depends to:

- the objectives of the study,
- the problem that the model builder tries to solve, and
- the understanding that he has of the modeled system.

A

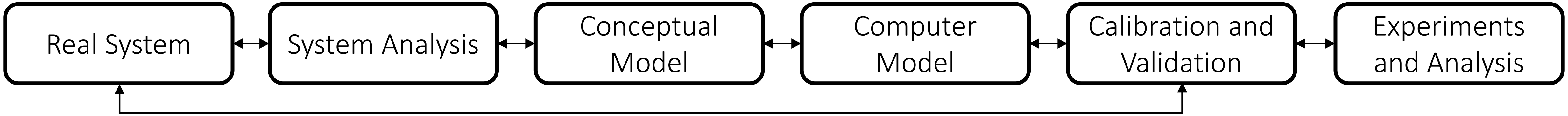
An isolated intersection

B

Trips originating from Laval with a destination in Montreal

Model Building Process
Methodological Framework

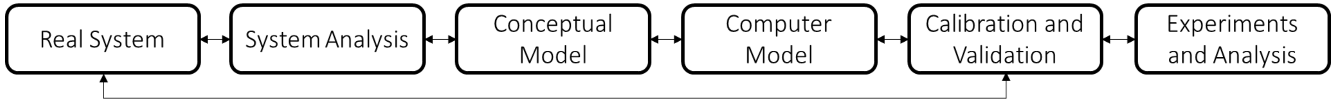
- Methodological steps of the model-building process



Inspired from
Barceló, Jaume (2010)
Fundamentals of Traffic Simulation

Model Building Process

Methodological Framework



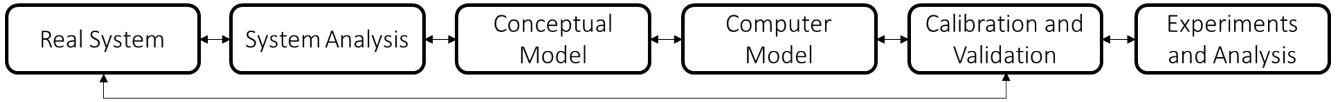
<u>System Analysis</u>

- The model-building process usually begins by systems analysis, a process of knowledge acquisition that can also be interpreted in terms of an abstraction of reality, consisting of the conceptualization of the situation.
- This step has three major components :
  1. *<u>Elements of structure</u>*: Aspects of the situation that are stable or change only very slowly in the time frame implied in the situation: physical structures, buildings, equipment, etc.
  2. *<u>Elements of process</u>*: Aspects of the situation that undergo change, such as ongoing activities within the structure, flow, information processing, and ongoing decision making.
  3. *<u>Relationships between structure and process and between processes</u>*: How does the structure affect or condition the processes? What things or aspects are direct or indirect results of such relationships?

Barceló, Jaume (2010)
Fundamentals of Traffic Simulation

Model Building Process

Methodological Framework



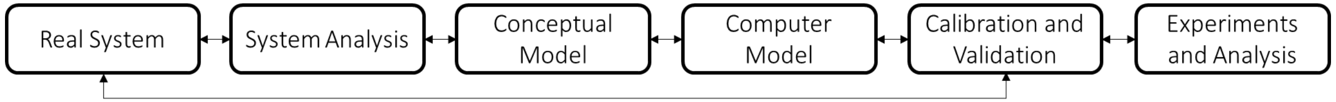
- In short, system analysis provides the elements for system description:
  - ✓ Identifies the system components or entities,
  - ✓ Characterizes them in terms of their attributes,
  - ✓ Identifies the interactions and relationships between entities,
  - ✓ Characterizes the entities' interactions in terms of attributes,
  - ✓ Specifies the system objectives,
  - ✓ Formulates hypotheses on how the system works.

<u>Conceptual Model</u>

- The systems analysis provides a primary representation of the system, which serves as a basis for the conceptual model
- In other words the conceptual model is the representation of the system that the analyst has in his head.

Model Building Process

Methodological Framework



Computer Model

- The conceptual model, which is often a mathematical model, is then translated into a numerical algorithm to build a suitable computer model.

Model Calibration and Validation

- Calibration: Parameters of the computer model are adjusted in order to optimize the agreement between observed data and the model's estimations and predictions.
- Validation: Measurement of the adequacy of the calibrated model to the reality with a set of observations different from that used in calibration.

Experiment and Analysis

- Experiments can be conducted, and various scenarios can be studied.

Model Classification

Criteria

- Scale of independent variables
  - ✓ Continuous
  - ✓ Discrete
- Process representation
  - ✓ Deterministic
  - ✓ Stochastic
- Operationalization
  - ✓ Analytic
  - ✓ Simulation
- Level of detail
  - ✓ Sub-microscopic
  - ✓ Microscopic
  - ✓ Mesoscopic
  - ✓ Macroscopic
- Scale of the application
  - ✓ Large city
  - ✓ Small network
  - ✓ Link
  - ✓ Intersection

Model Classification

Scale of independent variables

- Since almost all traffic models describe dynamic systems, a natural classification can be based on the time-scale.
  Two time-scales are distinguished in traffic flow models:
  - ✓ Continuous: A continuous model describes how the traffic system's state changes continuously over time in response to continuous stimuli.
  - ✓ Discrete: Discrete models assume that state changes occur discontinuously over time at discrete time instants.
- Besides time, other independent variables can also be described by either continuous or discrete variables (e.g. position, velocity, desired velocity).
- Mixed models have also been proposed in the literature.

Hoogendoorn and Bovy, 2001

Model Classification

Process representation

- Two different representations can be distinguished:
  - Deterministic models
    - ✓ Relationships between dependent and independent variables are defined by exact equations with no random variables.
    - ✓ The output of the model is fully determined by the parameter values and the initial conditions.
  - Stochastic models
    - ✓ Stochastic models possess some inherent randomness.
    - ✓ Incorporate processes and equations that include random variates to describe relationships.
    - ✓ The same set of parameter values and initial conditions will lead to an ensemble of different outputs.
- For instance, a car-following model can be formulated as either deterministic or stochastic by defining the driver's reaction time as a constant or as a random variable respectively.

Hoogendoorn and Bovy, 2001

Model Classification

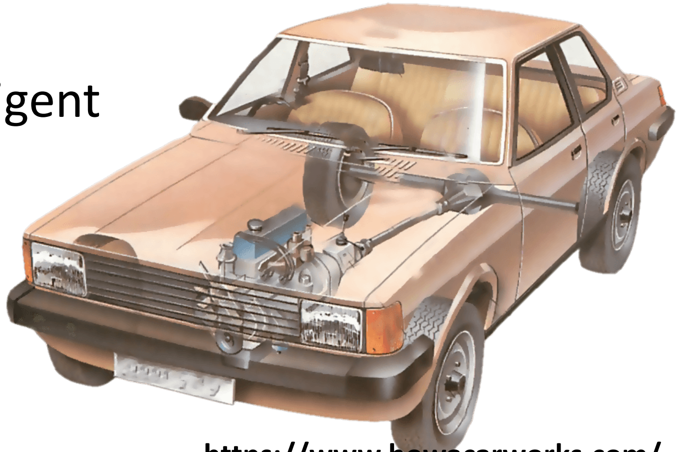
Operationalization

- Analytic model:
  - ✓ A mathematical abstraction of a phenomena.
  - ✓ Provides a generic way to get performance results in various conditions through a mathematical formulation.
  - ✓ The accuracy of the model is related to the validity of the assumptions used to derive the mathematical formulation.
  - ✓ Some uncertainties can be handled by introducing stochasticity in the model.
- Simulation model:
  - ✓ Mostly used when an analytical formulation cannot be derived (for example when the size of the model is too large, or the system is too complex).
  - ✓ Simulation models should be run many times to counterbalance the effect of simulation biases.
  - ✓ The simulation should be run over again for every different set of parameters.
  - ✓ A simulation model can be accepted when results are validated under different working conditions and various input assumptions.

Model Classification

Level of detail

- Sub-microscopic models
  - ✓ Like microscopic models, they regard single vehicles as models’ entities, but further extend them by describing specific parts and processes of vehicles and driving tasks (such as gearbox operation, acceleration process, etc.).
  - ✓ For instance, they describe how a driver brakes: its reaction time, the time for pressing the brake pedal, the operation of the gearbox, etc.
  - ✓ Sub-microscopic models allow more detailed computations compared to microscopic simulations. However, they require longer computation times, which restrains the size of the networks to be simulated.
  - ✓ Suitable for modeling the impact of driver assistance systems and intelligent systems such as Automatic Cruise Control (ACC).
  - ✓ The Model of Motorways with Next Generation Vehicles (SIMONE) (Michiel M. Minderhoud, 1999)



https://www.howacarworks.com/

Model Classification

Level of detail

- Microscopic models
  - ✓ A microscopic simulation model describes both the space-time behaviour of the systems' entities (i.e. individual vehicles-drivers units), as well as their interactions, at a high level of detail.
  - ✓ For instance, for each vehicle in the stream a lane-change is described as a detailed chain of drivers' decisions.
  - ✓ Examples?

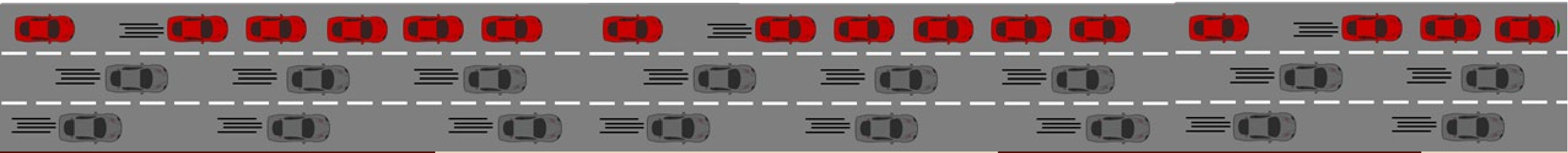
    Safe-distance models, car following models, stimulus-response models, psycho-spacing models, lane changing model, etc.

http://www.motoraty.com

Model Classification

Level of detail

- Mesoscopic models
  - ✓ The traffic flow is represented by (small) groups of entities whose activities and interactions are described without details, within which elements are considered homogeneous. A typical example is vehicle platoons.
  - ✓ They describe the behaviour of individuals in probabilistic or aggregated terms.
  - ✓ For instance, lane change maneuver can be represented for an individual vehicle as a decision based on the relative densities of the lanes and the speed differentials.
  - ✓ Some mesoscopic models are derived in analogy to gas-kinetic theory. These so-called gas-kinetic models describe the dynamics of velocity distributions.
  - ✓ Ex: Headway distr. Models, Reduced / Improved / Multilane / Multiclass gas-kinetic models, etc.



Model Classification

Level of detail

- Macroscopic models
  - ✓ Macroscopic flow models describe traffic at a high level of aggregation as a flow without distinguishing its constituent parts.
  - ✓ The traffic stream is represented in an aggregate manner using characteristics as flow-rate, density, and velocity. Individual vehicle manoeuvres, such as a lane change, are usually not explicitly represented.
  - ✓ Macroscopic flow models can be classified according to the number of partial differential equations that frequently underlie the model on the one hand, and their order on the other hand.
  - ✓ Examples?

    LWR model, Payne-type models

Model Classification

Scale of the application

- The application scale indicates the area of application of the model.
  - ✓ Entire road network of a city or several cities,
  - ✓ An entire traffic corridor,
  - ✓ A section of a single roadway,
  - ✓ An isolated intersection,
  - ✓ Etc.

Macroscopic Simulation

Introduction

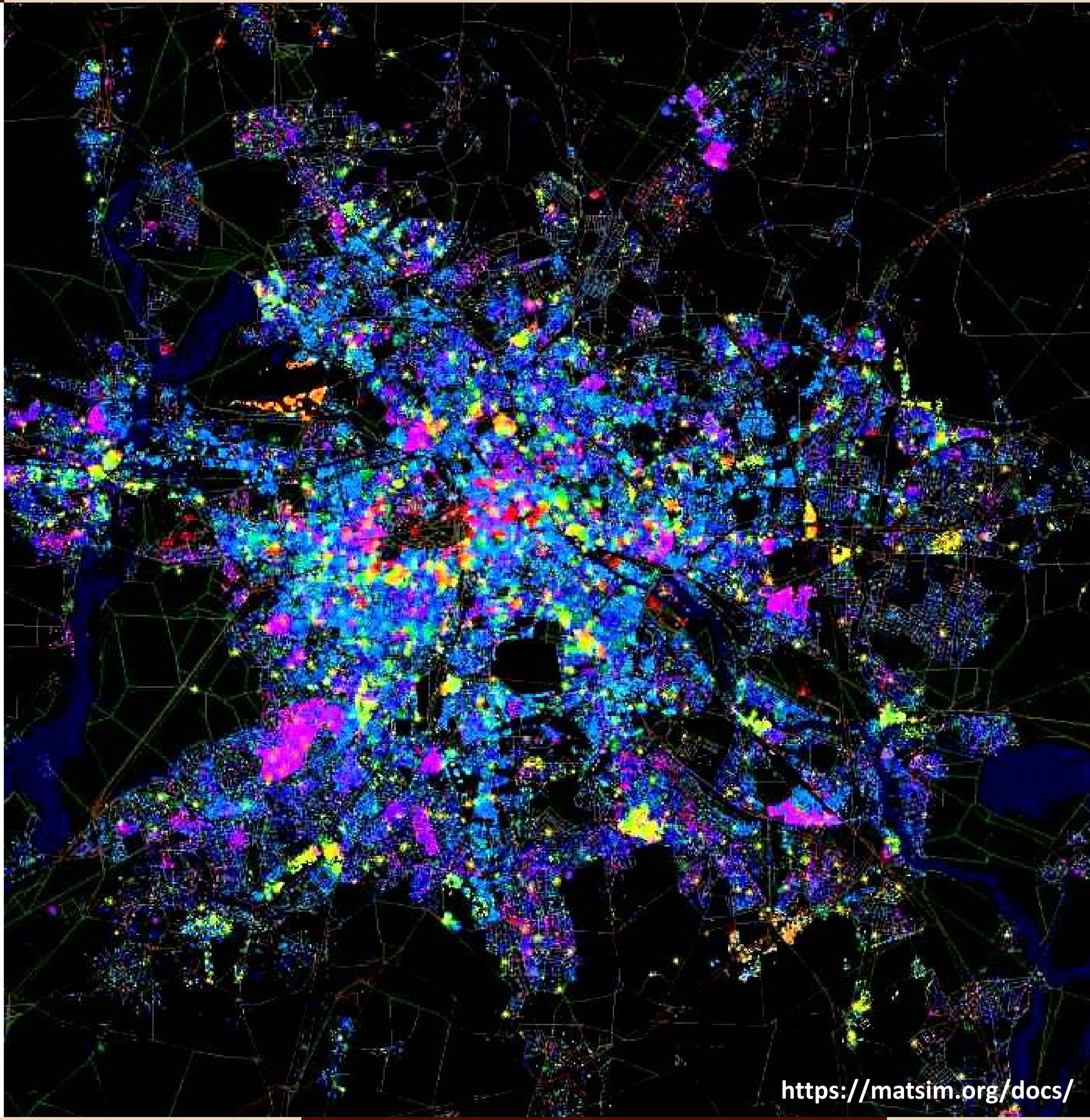
- Macroscopic models deal with traffic flow in terms of aggregate variables. Usually, the models are derived from the analogy between vehicular flow and flow of continuous media (e.g. fluids), yielding flow models with a limited number of equations that are relatively easy to handle.
- The independent variables are location x and time instant t.
- Consider a small segment $[x,x+dx]$ of a roadway referred to as *'cell x'*. Most macroscopic traffic flow models describe the dynamics of the density $k = k(x,t)$, the velocity $v = v(x,t)$, and the flow $q = q(x,t)$ in the *cells*.
- The density $k(x,t)$ describes the number of vehicles on the roadway segment $[x,x+dx]$ per unit length at instant t.
- The flow $q(x,t)$ equals the number of vehicles flowing past x during $[t,t+dt]$ per time unit.
- The velocity $v(x,t)$ equals the expected velocity of vehicle defined by $q(x,t)/k(x,t)$.
- Ex: Lighthill-Whitham-Richards (LWR) models, Payne-type models

Macroscopic Simulation

Software Packages

- EMME (INRO, Montréal)
- VISUM (PTV, Germany)
- MATSim (Open source projet - ETH Zurich)

- Why do we use traffic macroscopic simulation for?



https://matsim.org/docs/

Microscopic Simulation

Introduction

- The management of a road network often requires the forecasting of the impacts of implementing various traffic management measures. The impact usually involves the road itself, the whole corridor and its neighboring areas
  - ✓ These measures include:
    - Signal coordination
    - High-occupancy vehicle (HOV) lanes
    - One-way systems
    - Different types of intersection control (priority sign, signal or roundabout)
    - Signal priority
    - Driver information systems
    - Incident management
    - Public transit, such as trams, light rails, BRT
    - Pedestrians and cyclists movements
    - Queue management
    - Toll booths
    - Road works

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Microscopic Simulation

Software Packages

- VISSIM (PTV, Germany)
- AIMSUN - Polytechnic University of Catalonia (UPC) (Capable of hybrid simulations)
- CORSIM (FHWA)
- Simple tool for simple configurations: http://www.traffic-simulation.de/
- Cellular automata (YouTube video)

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Microscopic Simulation

VISSIM - Introduction

- VISSIM is a microscopic, discrete traffic simulation system, modeling motorway traffic as well as urban traffic operations.
- Widely used by consultancies and industries, public agencies, as well as academic institutions.
- Considering the microscopic nature of the software, it is primarily suited for traffic engineers.
- Based on several mathematical models, the position of each vehicle is recalculated every 0.1–1 s.
- VISSIM can be used to investigate private and public transport as well as pedestrian movements.
- Similar to any other traffic simulator a mathematical model is used to represent the transportation supply system, simulating the technical and organizational aspects of the physical transportation supply.
- A demand model has to be generated to model the demand of persons and vehicles traveling on the supply system.
- Unlike macroscopic transport models, traffic control has to be modeled in detail.

Barceló, Jaume (2010)
Fundamentals of Traffic Simulation

Microscopic Simulation

VISSIM – System Architecture

- Major building blocks of the simulator

1

Physical and stationary network elements:

- Road and railway infrastructure
- Public transit stops
- Parking lots

2

Traffic flow

- Technical features of a vehicles
- Traffic flow from OD matrices or link entries
- Traffic assignment and route choice model
- Public transport supply

3

Elements required to control the traffic flow

- Intersection priority rules
- Gap acceptance
- Traffic signals

4

Output

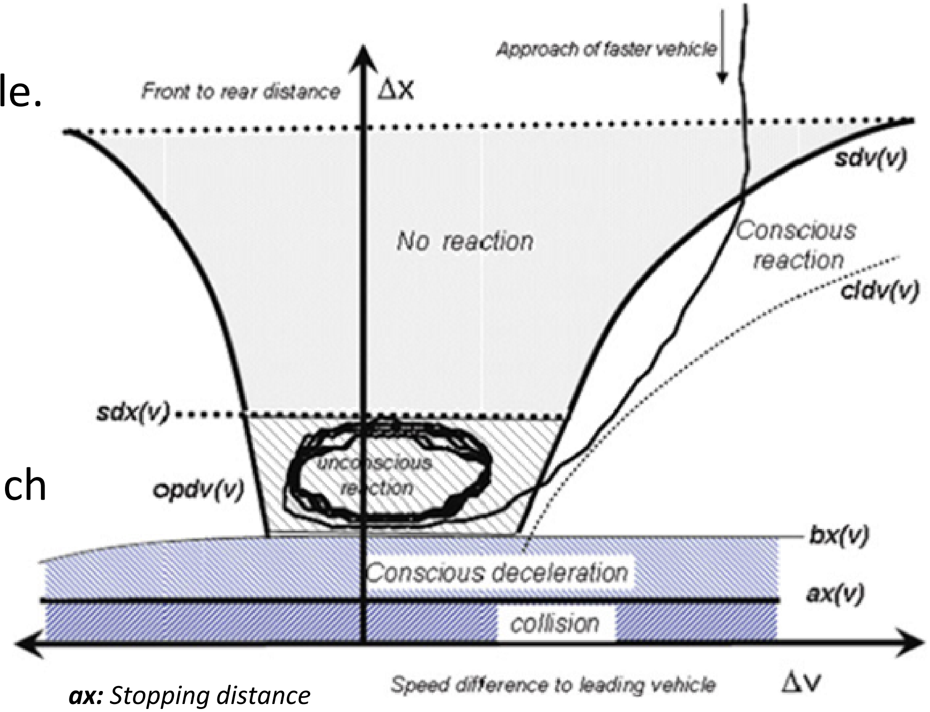
- Animated vehicles
- Measures of performance
- States of traffic control devices

Barceló, Jaume (2010)
Fundamentals of Traffic Simulation

Microscopic Simulation

VISSIM – Fundamental Core Models

- Car following
  - Psycho-physical car-following models (also referred to as action point models) are implemented in VISSIM.
  - Speed differences are perceived through changes on the visual angle.
  - A driver will recognize changes in the apparent size of a leading vehicle as he approaches this vehicle of lower speed.
  - The action point of conscious reaction depends on the speed difference, relative distance to the leading vehicle, and driver-depended behavior.
  - Driver-specific abilities are modeled by adding random values to each of the parameters.
  - The minimum acceleration and deceleration rates are fixed for different vehicle types.



ax: *Stopping distance*
bx: *Minimum following distance*
sdv: *Action point where a driver approaches a slower leading car*
opdv: *Action point where the following driver starts to accelerate again*
sdx: *Perception threshold to model the maximum following distance*

Barceló, Jaume (2010)
Fundamentals of Traffic Simulation

Microscopic Simulation

VISSIM – Fundamental Core Models

- Lateral Movements
  - Discretionary lane change:
    - ✓ If the driving condition is not free ➔ He checks the neighboring lanes if there is a better interaction situation ➔ If a lane change is possible considering the gap between vehicles
  - Mandatory lane change
    - ✓ For a necessary lane change, the driving behavior parameters contain the maximum acceptable deceleration for a vehicle and its trailing vehicle on the new lane. The deceleration depends on the distance to the emergency stop position of the next route connector (aggressiveness increases).
    - ✓ The stop distance is the distance to the connector where a driver will stop when he was not able to reach the necessary lanes to change to the connector.
  - Cooperative merging
    - ✓ Cooperation is implemented by giving drivers information about vehicles in a mandatory lane change situation aiming to the lane they are currently using. If a driver sees a merging vehicle on the neighbor lane that could possibly change into his lane in front of him, he applies a user-defined deceleration to keep the gap open or even widen it.

Barceló, Jaume (2010)
Fundamentals of Traffic Simulation

Microscopic Simulation

Advantages

- Clarity
  - A comprehensive real-time visual display and graphical user interface illustrate traffic operations in a readily understandable manner. The animated outputs of microsimulation modelling are easy to understand and simplify checking that the network is operating as expected, and whether driver behaviour is being modelled sensibly. If a microsimulation model does not look right, then it probably is not right, and vice versa.
- Accuracy
  - By modelling individual vehicles, choices and behaviours, the potential exists for more accurate modelling of traffic operations. Individual drivers make their own decision on speed, lane changing and route choice, which could better represent the real world than other modelling techniques.
- Flexibility
  - A greater range of problems and solutions can be assessed, and multiple measures can be evaluated (see slide 25)

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Microscopic Simulation

Limitations

- Calibration
  - Depending on the scale and nature of the model being developed, there is likely to be a need for more detailed calibration or validation data than is traditionally collected in traffic studies
- Complexity
  - Microscopic models are usually more complex and have a large number of parameters to be understood and adjusted.
  - Lack of guidelines to understand and appropriately choose and calibrate parameters
- Network size
  - When the scale of the problem increases, it becomes more and more difficult to use a microsimulation model, since:
    - ✓ More complex to implement all the network details (ex. Intersection control measures, priority rules, etc)
    - ✓ More difficult to calibrate the model– requires an extensive data collection, calibrating, and validating effort at several points of the network as well as the whole network.

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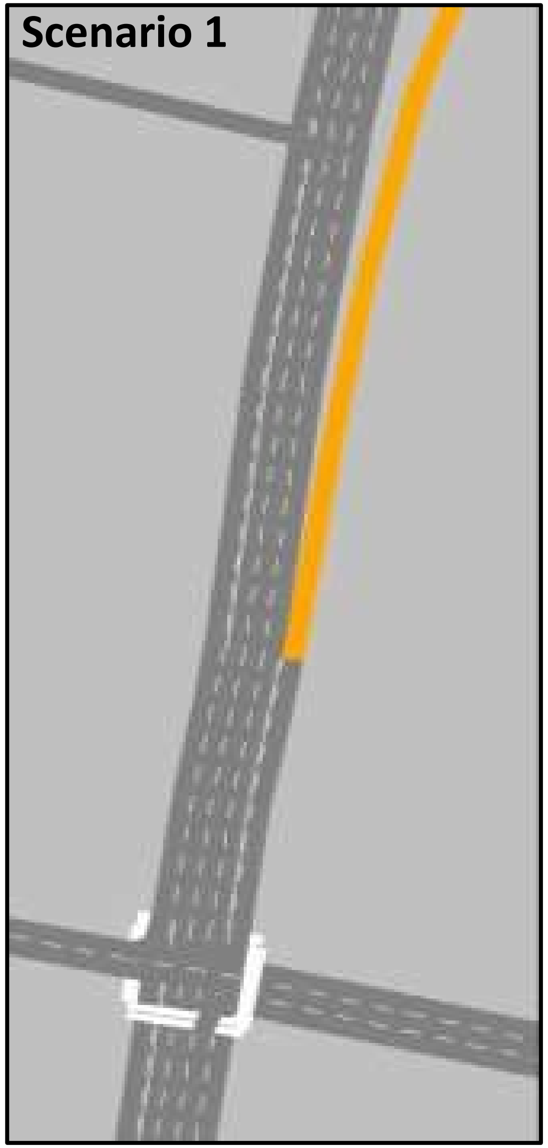
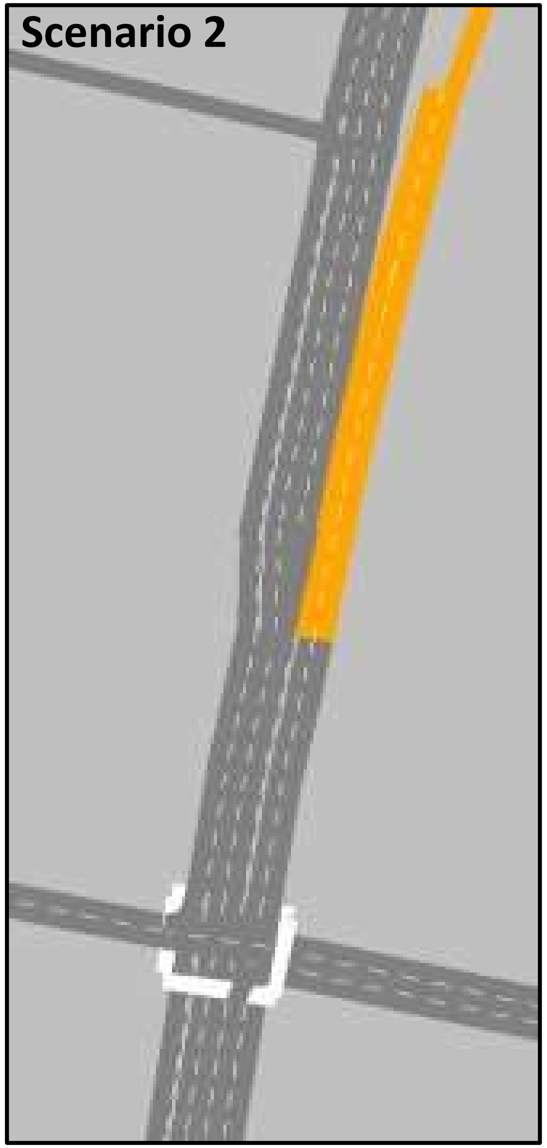
Model Calibration

Importance of Calibration

- Consider the following example:
- Two scenarios are considered for an access route on a multilane highway leading to a signalized intersection. The following two scenarios are proposed. Which one should be selected and built?
- Analyses are performed with two sets of calibration parameters:
  1. Default parameter values of the model.
  2. Small change of two parameters (perception distance and acceleration) to reduce them to more conservative values.

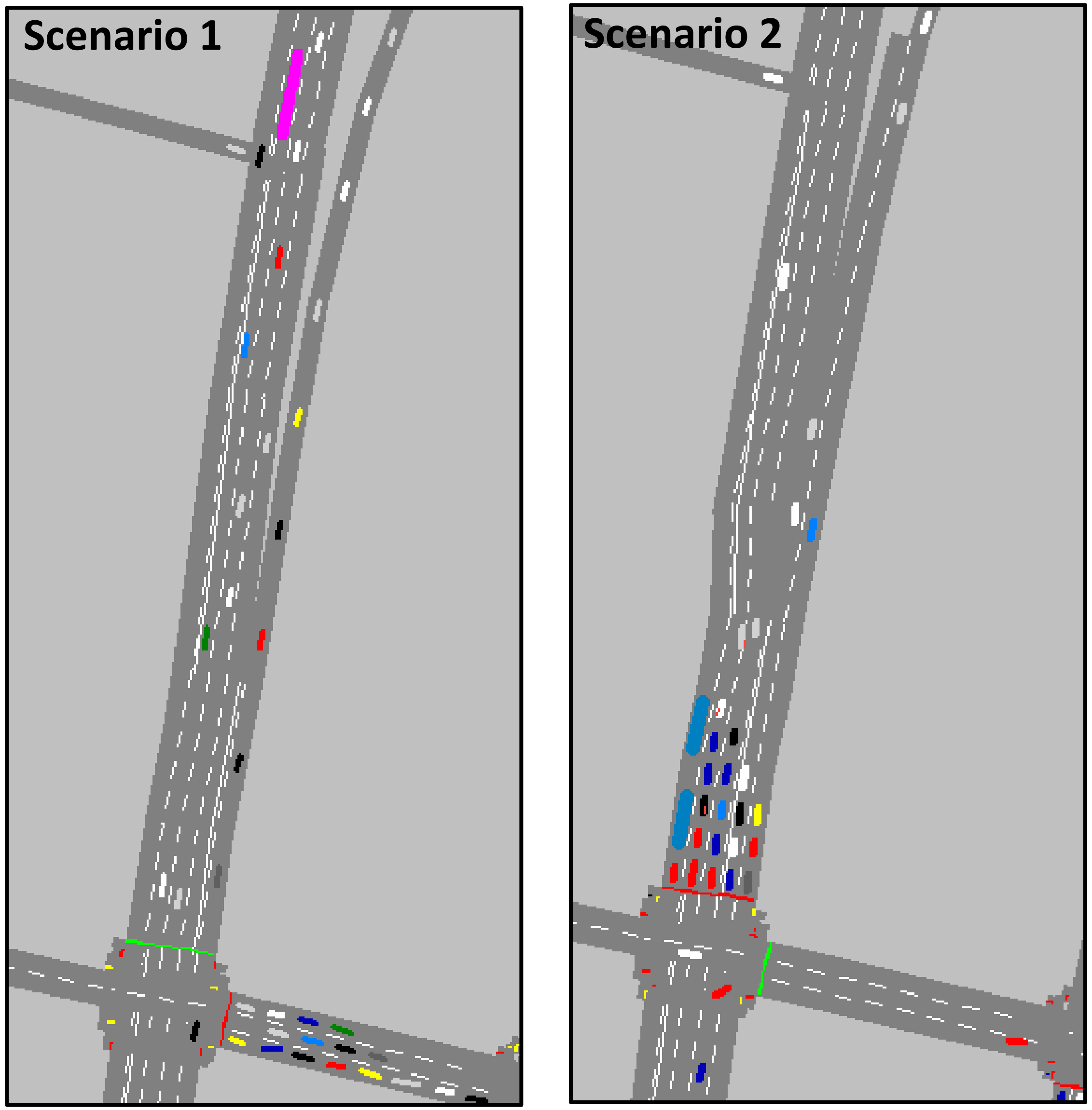




Model Calibration

Importance of Calibration

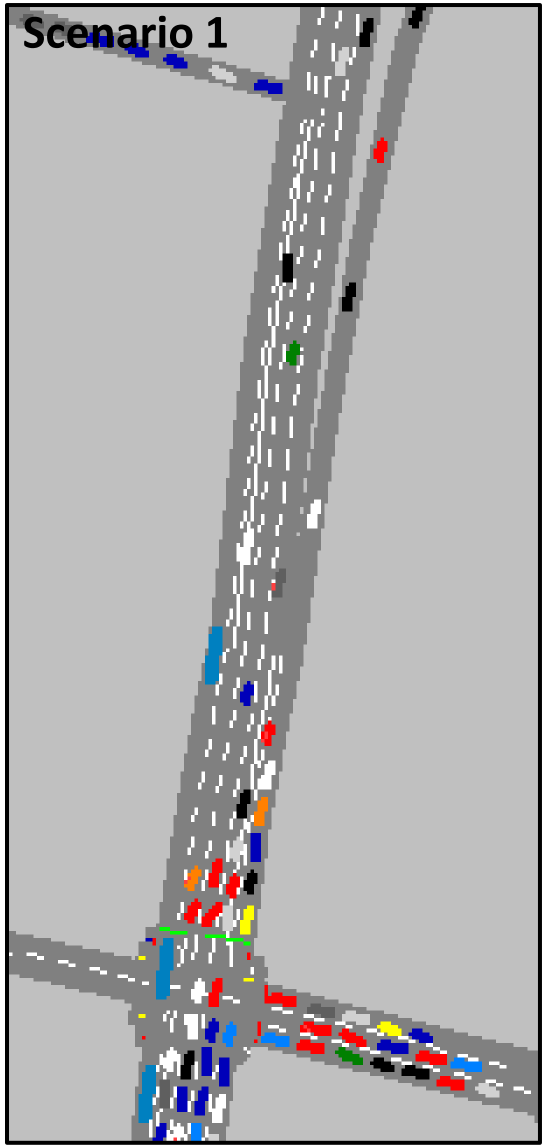
- Scenario 1: Default parameter values
- Using default values, the preferred scenario seems to be the dual path.
- The queues on the dual access path (scenario 2) are smaller.
- There is an accumulation of vehicles on the single access road (scenario 1)
- The local network is not affected by either of the two scenarios.

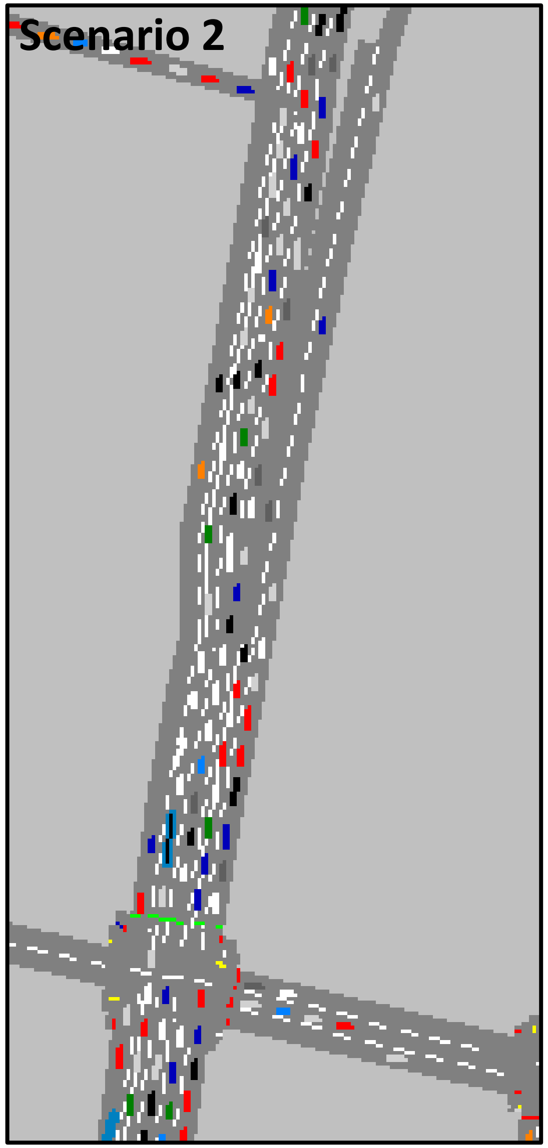


Model Calibration

Importance of Calibration

- ➢ Scenario 2: Using more conservative values
- The preferred scenario seems to be that of a single access way (scenario 1)
- The queues of the two scenarios in the ramp are comparable.
- The local network is very affected by dual access (scenario 2)





Model Calibration

Importance of Calibration

- Which scenario should be recommended?
  - Both scenarios show ***possible*** results of the simulation.
  - However, it is possible that ***none*** of them shows the actual behavior of drivers.
  - Without calibrating the simulation models for the situation under study, it is impossible to predict which of the scenarios should be favored, or even if both should be rejected.
  - A model, even well calibrated and validated for a given situation, does not allow us to study with full confidence a situation whose conditions are different from those used during the initial calibration and validation conditions of the model.
  - Models should be calibrated separately, every time the initial conditions and the case study changes.

Model Calibration

Importance of Calibration

- MULTITUDE (Methods and tools for supporting the Use, caLibration and validaTIon of Traffic simUlation moDEls) project conducted a survey in 2011 regarding how practitioners used traffic simulation models.
- The study revealed that 19% of those polled, conducted no calibration of their models.
- From those that did use, only 55% used guidelines during this process.
- The remaining 45% relied solely on their personal experience.

Model Calibration

Calibration steps of a traffic simulation model

- Step 1 - Properly define the problem statement
  - This step is the cornerstone of the calibration process.
  - The different scenarios studied, or the different sub-problems involved in the study should be identified, since their specific data needs may differ.
  - The simulation method is defined based on the objective needs of the study.

Gauthier, L. (2015). Master's thesis

Model Calibration

Calibration steps of a traffic simulation model

- Step 2 - Determine the most relevant software parameters to solve the problem
  - The calibration cost increases with the number of parameters to be optimized.
  - A smaller number of parameters allows the analyst to better track the impact of each change on the results.
  - Large number of parameters require the assistance of automated algorithms.
  - Some parameters can be quickly discarded since they simply have no chance of having an impact on the indicators used in the analysis of the simulation. This is the case, for example, with all the parameters of a pedestrian behavior model in the case of a simulation that does not include pedestrians.
  - If the analyst is unsure of the effect of a parameter on the results, it should either be retained or subjected to a sensitivity analysis.
  - The range of the parameter space must be determined according to the literature and the user manual of the software used.
  - Upper or lower limits should be specified for some parameters to prevent improbable or erroneous situations.

Gauthier, L. (2015). Master's thesis

Model Calibration

Calibration steps of a traffic simulation model

- Step 3 - Collect and process the required data
  - The type of data used, and their spatial and temporal resolutions and coverage should be defined
  - Their relative importance should be specified based on the objectives and the chosen indicators.
  - Some basic data is essential, such as geometric information about the network to be reproduced: length of links, number of channels, traffic control measures, etc. However, these data are now easily accessible thanks to geospatial data, such as Google Maps or OpenStreetMap.
  - A variety of data representing different traffic conditions should be collected to improve the model calibration and increase the accuracy of the predictions.
  - This diversity of the data is also important to avoid “overfitting” of the model to particular traffic conditions during the calibration.
  - Overfitting reduces the model's ability to adequately predict conditions different from those in the data range for which it is adjusted.

Gauthier, L. (2015). Master’s thesis

Model Calibration

Calibration steps of a traffic simulation model

- Step 4 - Determine the indicators used to describe the system, both in the collected and simulations data
  - Indicators are measurements used to compare model simulations to reality.
  - They can also be used for the initial purpose of developing the model, namely, to compare different simulated scenarios.
  - Different or same indicators can be used for the two above-mentioned purposes.
  - For instance, in microsimulation models, indicators such as delay, travel time, queue length and vehicle emissions are often used.

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Model Calibration

Calibration steps of a traffic simulation model

- Step 5 - Determine the adjustment functions to compare.
  - The adjustment function compares the indicators calculated based on observed data and simulated results to measure the fit or adequacy of the model to reality.
  - This comparison gives an evaluation of the error made by the model in attempting to reproduce a given phenomenon.
  - In most of the cases results are expressed in either i) aggregated sums, such as aggregated values of flow, or ii) distributions, such as the distribution of the speed of all the vehicles having borrowed a link.
  - The nature and quantity of the data partly determine the choice of the adjustment function used to evaluate a given indicator and different indicators can be evaluated using different adjustment functions.
  - Some adjustment functions are more appropriate for processing distributions while others are useful for aggregate indicators such as the average.

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Model Calibration

Calibration steps of a traffic simulation model

- Step 6 - Formulate the objective function and the optimization algorithm
  - The objective function is a function that combines several adjustment functions and produces only one value, representing the error made by the model to reproduce the conditions observed in reality.
  - This allows the optimization algorithm to compare results produced by various sets of parameters and evaluate whether successive tests improve or degrade the simulation results.
  - This provides the ground rules based on which the next set of parameters to be tested are adjusted.
  - The optimization algorithm should not be too expensive in terms of calculations to allow the analyst to perform the calibration in a reasonable amount of time.
  - The most widely used algorithms are *genetic algorithms*, the *Simplex method* and the *Box's Complex Algorithm.*

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Model Calibration

Calibration steps of a traffic simulation model

- Step 7 - Formulate the calibration constraints
  - Calibration constraints are conditions that the optimization algorithm must respect while evaluating different objective functions.
  - It serves to define which simulation results can be considered in the calculation of the objective function.
  - For example, a constraint could be formulated to verify that simulated vehicles do not have abnormal behavior or that a certain number of vehicles are assigned to use a given path in the network if a route assignment model is used.

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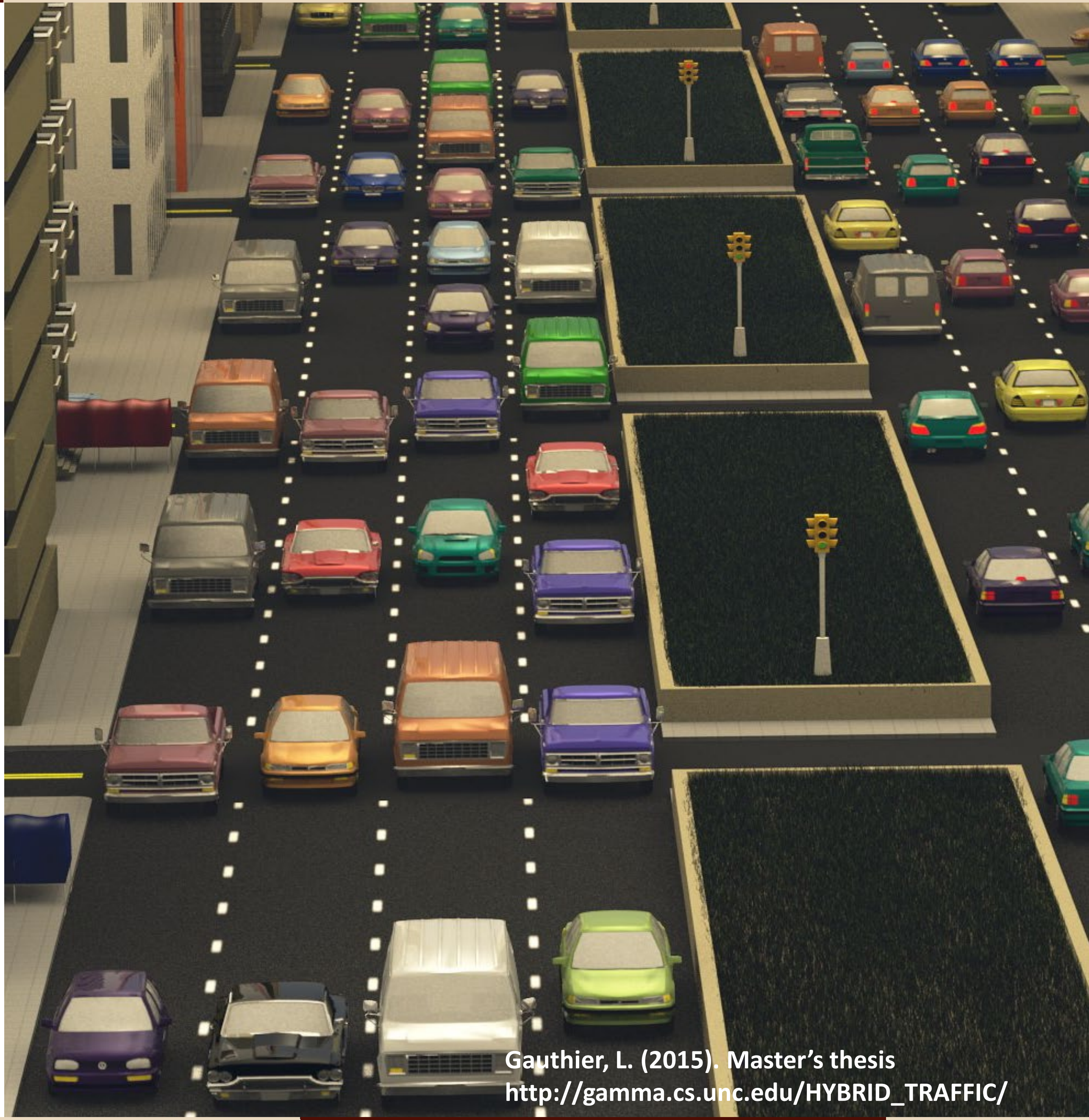
Model Calibration

Calibration steps of a traffic simulation model

- Step 8 - Determine the number of repetitions of the simulation to be performed
  - When simulation models are based on a stochastic representation of the system, it becomes indispensable to know the number of simulations necessary to obtain statistically representative results.
  - Some studies use an arbitrary number of simulations, and some do not even mention it.
  - Methods have been developed for calculating the size of a sample.
  - An alternative method is to define a large number of repetition, to detect after how many repetitions the value of a given indicator converges to a stable value.



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http://gamma.cs.unc.edu/HYBRID_TRAFFIC/

Model Calibration

Calibration steps of a traffic simulation model

- Step 9 - Calculation of the objective function with calibrated parameters on an independent data set
  - The last phase is the validation phase, where the results of the calibration are checked on an independent data set.
  - The dataset may come from a different site or from another time at the same site but must not have been included in the calibration process.
  - The aim is to verify whether the calibrated parameters obtained apply in a multitude of conditions and not only for the specific situation studied during the calibration.
  - It is often considered that a better level of calibration is obtained if, in addition to the indicator used in calibration, for example the flow rate, another complementary indicator, for example speed, also obtains good results in the validation process.

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Model Calibration

Case Study

- Step 1 - Objective of the study
  - Calibrate car following and lane changing models of VISSIM for different sections of a freeway.
- Step 2 - Parameter identification
  - Parameters of Wiedemann 74 et 99 and lane changing models implemented in VISSIM.
  - A sensitivity analysis is performed to identify the most important parameters.
- Step 3 - Data collection
  - Video data from four different sections including
    - ✓ A section without on- and off-ramps
    - ✓ A section with on-ramps and merging lanes
    - ✓ A section with off-ramps and diverging lanes

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Model Calibration

Case Study

- Step 4 - Determining the studied indicators
  - Distribution of time headways
- Step 5 - Adjustment function
  - D statistic of the Kolmogorov–Smirnov test
- Step 6 – Objective function and optimization method
  - Optimization of D statistic to minimize the difference between distributions
  - Mesh Adaptive Direct Search (MADS)
- Step 7 - Defining constraints
  - VISSIM errors and detection of "collisions"
- Step 8 – Number of repetitions
  - Setting a large number of repetitions to determine the maximum number necessary for parameter convergence.
  - 20 repetitions has been set for all the simulation
- Step 9 – Validation

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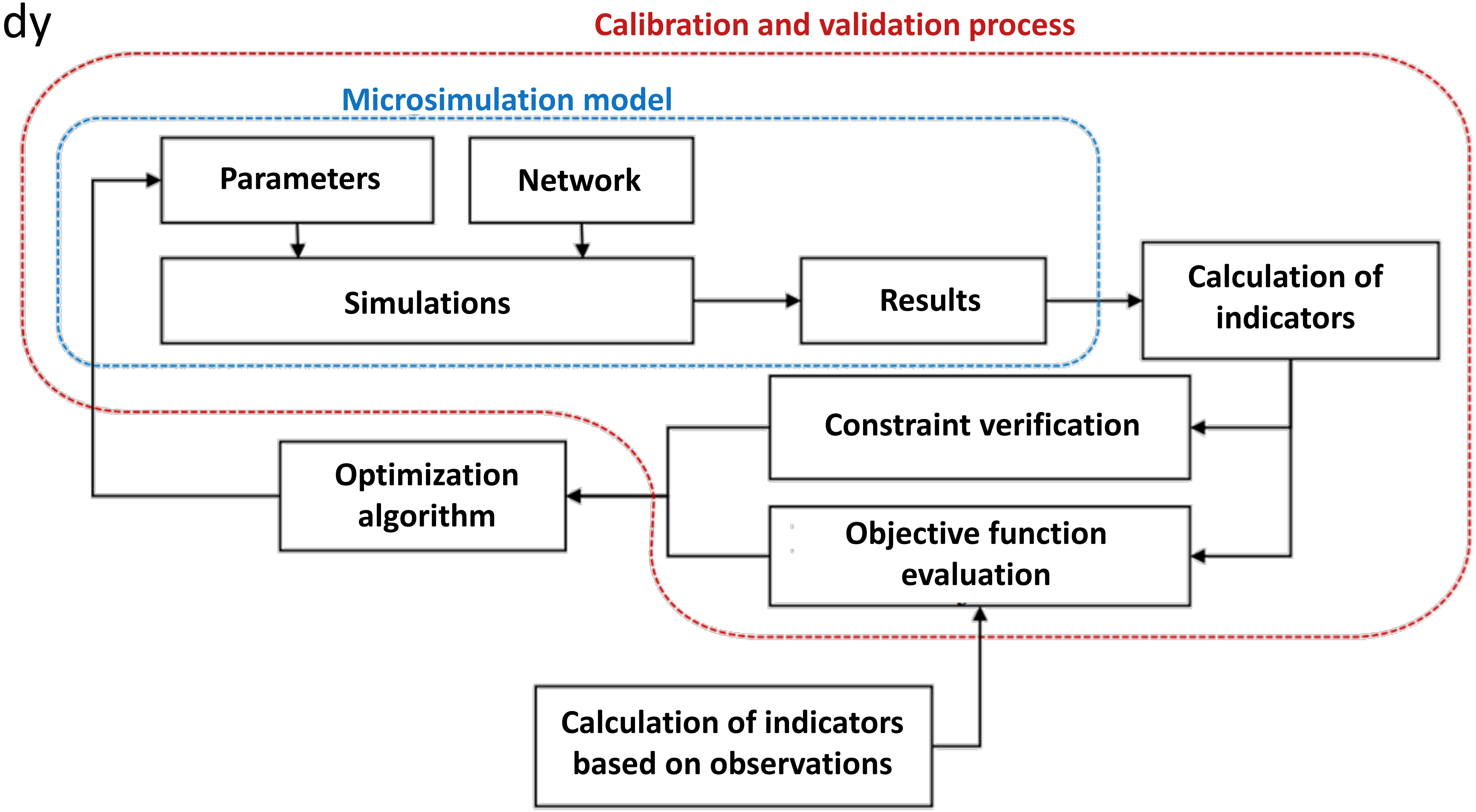
Model Calibration

Case Study



General methodology of the calibration and validation process adopted in the case study

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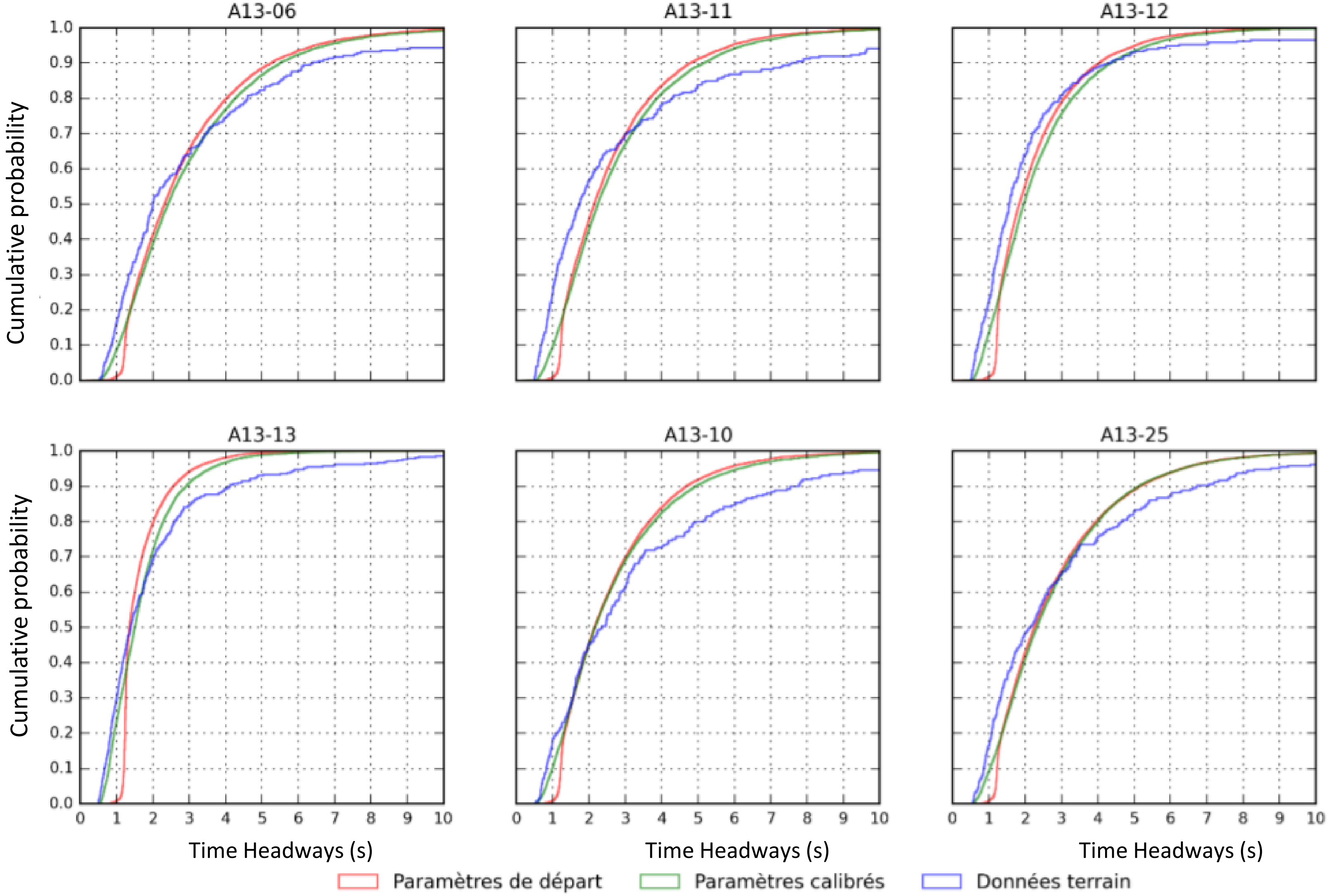
Model Calibration

Case Study



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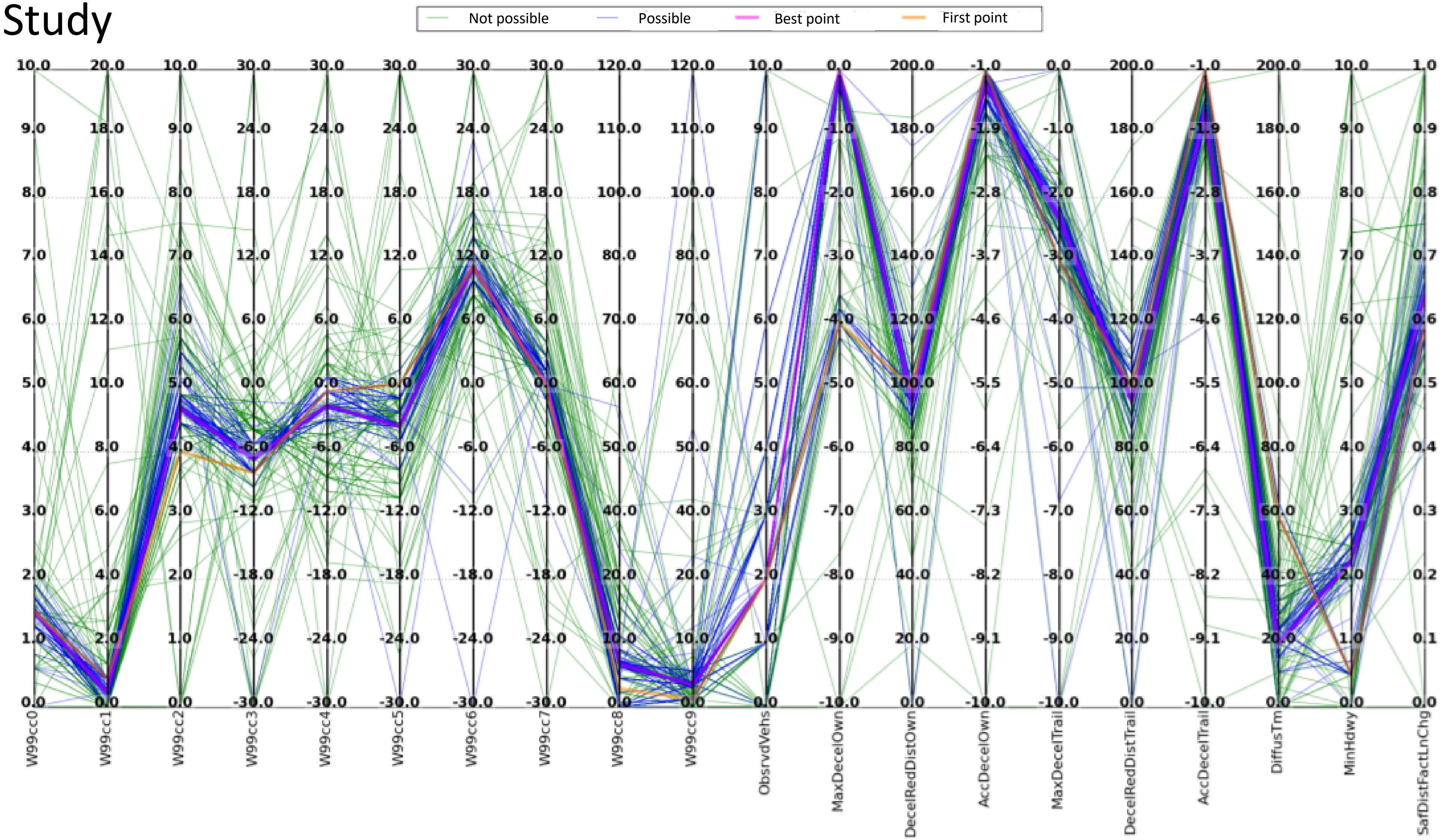
Model Calibration

Case Study



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Traffic Flow Models

Final remarks

- It might seem tempting to break down a complex problem into different sub-problems that are simpler and less demanding in computing power, for example by isolating the different models involved, and then solving them independently and in a chain. However, this approach may not work well if the sub-problems are not perfectly independent. In fact, in most traffic simulation calibration problems, a strategy for overall problem calibration should be used rather than splitting into sub-problems.

Traffic Flow Models

Final remarks

- Model ‘warm-up’ period:
  - The warm-up period in a simulation study is needed, because the initially empty network needs some time to fill with vehicles. Otherwise, when the first vehicles are generated, they encounter no friction with other vehicles and their travel time is greatly reduced. Moreover, the different indicators that one would like to study will be biased by the fact that no other vehicle interacts with these vehicles.
  - Therefore, data from the start of any run have a strong bias toward smaller delays, which does not reflect the real situation.
  - It is therefore necessary to allow time for the model to be in a state of equilibrium before measuring the indicators
  - The time required to reach equilibrium will depend on the length of the network, its complexity, the presence or absence of traffic intersections, the travel speed, the desired flow rate, etc.
  - A good rule of thumb is to wait for the longest travel time of the system under consideration, and then double this (FHWA).

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Thank
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