Simulating the transition of mobility toward smart and sustainable cities

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Abstract. This paper introduces a simulation framework to model and study mobility changes. Novelty comes from the possibility to combine different agent-based models into the GAMA platform, and to interact with the simulation through pre-designed scenarios and a serious game. The objective is to explore the impact of different urban policies on future mobility.

Keywords: Agent-based model · Mobility · Smart Cities

1 Introduction

Transport infrastructures play a large role in defining a smart, sustainable and resilient city. Innovative urban policies might either facilitate mobility and increase citizen well-being, or create negative side effects [7]. Urban planning therefore requires the city to assess the impact of these disruptive innovations based on "what if?" prospective studies [9]. However, cities are complex socio-technical systems: dynamics of transportation are nonlinear, and even wise choices might lead to negative side effects (*e.g.* the improvements in road layout might decrease the number of accidents, but increase car use and therefore pollution). Unfortunately, even if urban planning models and methodologies are available for traditional modalities (car, bus, etc.), no tool, nor methodology, exists today to assess the potential impact of these disruptive innovations, and how they can be progressively integrated into planning infrastructures.

The SwITCh project aims at providing a simulation tool for a participative reflection on the evolution of urban mobility in the next 30 years (horizon 2050). The ambition of the project is not to produce a simulator that can predict what will happen from now until 2050, nor to solve all the problems, but rather to help stakeholders (urban planner, citizen, etc) to enrich their reflection and build a shared project to improve transport infrastructures. The tool is based on an agent-based model (ABM) of citizens' mobility that simulates different evolution scenarios and tests different strategies to face them. The tool will be experimented and calibrated in the real context of two French cities, Bordeaux and Dijon. In this paper, we introduce the project architecture in order to illustrate three scientific challenges: (I) modeling individual mobility choices, (II) multi-level modeling of the city, and (III) design and exploration of different scenarios of mobility evolution.

2 Project Architecture

SwITCh uses ABM as a unifying framework to couple different models and take into account multiple temporal and spatial scales, in order to build a holistic model. The ABM contains different models to simulate individual mobility behaviour (daily activities, transportation choice, etc), transport infrastructures (streets, train tracks, etc) including different types of vehicles (private cars, taxis, bicycles, etc.), and city dynamics (pollution, etc). Those different models are dynamically combined through a dedicated middleware. SwITCh includes: a city model based on real geographic data obtained from publicly available Openstreetmap data; and a realistic representation of the city inhabitants based on a synthetic population, generated from public data records by the Mobisim generator[4]. The ABM is implemented with the GAMA platform [8]. Interactivity with the simulation is performed through either the exploration of different scenarios translated into the model by defining values of contextual parameters, or a serious game that allows users to change the configuration at runtime. The framework will include a scenario generator allowing users to easily implement new scenarios based on elementary bricks.

3 Modelling individuals choices of mobility

SwITCh aims to create a tool to explore and discover scenarios for smart and sustainable cities. So far we have developed a first model of citizens' decisions regarding their mode of transport for their daily home-work commute. This choice is influenced by a variety of factors, both internal (profile of the user, level of fitness, etc) and external (denivellation of the journey, weather, availability of public transport, etc). Based on these factors, we have designed a first multi-criteria decision model. Concretely, each agent (representing one resident of our town) has different priorities (or values) for 6 different evaluation criteria: comfort, price, ecology, simplicity, safety and time. Each transport modality also receives a mark on each of these criteria (for instance cycling has the best mark *w.r.t.* ecology, but a lower mark for comfort depending on the level of fitness of the user). Finally, the agent combines the marks weighed by their priority to choose their preferred transport mode (according to their own attributes and priorities). Different agents with different attributes or with different priorities will make different choices, even in the same situation.

[4] http://thema.univ-fcomte.fr/mobisim/

This choice is further moderated by a logarithmic routine coefficient. Therefore, when an agent is very used to a given transport mode, it will not reconsider it every time, even though the context might have changed (for instance keen cyclists will not be stopped by rain, and keen drivers will bear with increased petrol price and daily traffic jams) [2]. Our first results with this simulator [5] show that better cycling infrastructures result in an increased number of cyclists; and that a simple petrol price rise is not enough to discourage car users. Future work will further focus on the role of routine in the inertia often noted in mobility habits.

4 Multi-scale coupling of agent-based models

In the frame of the SwITCh project, various models will be implemented within the GAMA platform to model individual behaviors (activities, choices of transportation, etc.), transportation infrastructures (public transports, cars, etc.), and city dynamics (pollution, etc.). Each model has its own set of parameters, dynamics, and hypotheses. The approach chosen in the project is to build models dedicated to exploring different scenarios by combining different models. This model combination can be performed either at runtime, because of the user's actions, or before the simulation, through descriptive scenarios.

Multi-level model coupling is a technique used to combine the advantage of complementary representations of the same system (implemented in different models). There are different ways of coupling models: integrated (model as a new model from the combination of two, or more, models), weak (the model as a set of interconnected independent models), and strong (model as a set of parallel models sharing data during the simulation), these techniques have some advantages and drawbacks (in terms of modularity and easiness of maintenance) and not all models can be coupled [6, 3, 1]. The coupling could be static or dynamic, *i.e.* the composition plan could (or not) change during the simulation [4].

The novelty of the SwITCh project is to develop a model composition framework providing a dynamic model coupling service to help the development of coupled models, to increase the expressiveness of such models, and to help to choose the good coupling way. The goal is to: (1) enable the exchange of models at runtime (for example in the serious game) depending on user needs, (2) switch between models, for example, to zoom in/zoom out, and to improve scalability by finding a balance between simulation accuracy and computation time, and (3) reuse existing models in the composition.

5 Modelling scenarios

SwiTCh aims at building a decision support tool that allows a group of users to test different choices related to infrastructures under different scenarios, and to assess them with respect to relevant indicators. This set of indicators (and the model to assess them) was built from the combination of a literature analysis and a set of interviews with various stakeholders. Each indicator can be computed from a set of the ABM variables by rules (equation, algorithm, expert rule...) allowing to evaluate them. It is thus possible for a territory to evaluate its level of performance via these indicators, for each scenario. Scenarios are sets of events, assembled together like bricks, describing a potential evolution of the city/environment (*e.g.* authorization of the autonomous car, world pandemic, increase in petrol price). The bricks can be assembled according to dedicated rules to create scenarios. Each scenario will be decomposed as a set of "snapshots" representative of the main situation that can be simulated by the ABM. This will make it possible to simulate (ABM) and evaluate (indicators) different evolutionary trajectories. Two important challenges are to make the model capable of simulating these future situations (model flexibility) and to make the results understandable by all participants in the context of a participatory simulation. This is essential to make it an effective tool for collaborative thinking.

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