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A Participatory Simulation Tool in Virtual Reality for Managing Stormwater Nature-Based Solutions

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Keywords

Nature-based solution, Stormwater management, Virtual Reality, Participatory simulation, SIMPLE

Abstract

Nature-based solutions for stormwater management (NBSSM), such as swales, rain gardens, and infiltration basins, aim to reduce flood risk while preserving the environment and water resources. However, these solutions need to be properly managed throughout their life cycle in order to minimize operation and maintenance costs, maintain the required level of service, and maximize their expected co-benefits, including biodiversity and quality of life. Several studies have shown that involving local residents in the operation and maintenance of NBS may contribute to their long-term performance (Khaniya et al., 2026; Thomas, 2020). Nevertheless, the management of NBS remains a highly technical topic that often attracts limited interest from the general public. The INTERFACES project addresses this challenge by developing an awareness-raising tool focused on NBS and their operation and maintenance. The project combines participatory simulation and virtual reality (VR) to engage citizens and encourage them to reflect on the practical management of NBS. It is based on an agent-based model (ABM) developed using the GAMA modelling and simulation platform. The simulations are presented through an interactive virtual reality environment as part of workshops designed as a collaborative game; The agent-based model used in INTERFACES is adapted from the NBS-SM simulation model developed by Girot et al. (2026), which simulates the behavior of NBS under different climatic conditions and accounts for potential deterioration over time. This model was transformed into a collaborative game focusing on the maintenance of four swales exposed to different failure situations. The game is organized around a series of scenarios, each corresponding to a specific failure situation that players must investigate. Players have to analyze the situation, identify the potential causes of the failure, and propose corrective actions. They then implement these actions directly within the simulation, leading to different possible outcomes depending on the relevance and effectiveness of the actions selected. Virtual reality is used to facilitate the players' understanding of the simulated situation and to enhance immersion. The virtual environment represents the neighborhood in which the game takes place, including the different swales. Using a VR headset and controllers, players can move around the virtual environment and interact with the NBS, for example by accessing information about their condition or carrying out operation and maintenance actions. The 3D environment and player interactions are developed using the Unity game engine. The SIMPLE plugin for GAMA (Drogoul et al., 2025) provides the interface between the agent-based model developed in GAMA and the virtual environment implemented in Unity, allowing the simulation and the VR environment to interact dynamically.





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A Pedestrian Mobility Simulation Tool for Evaluating Transit Expansion and Densification in Freetown, Sierra Leone

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Figure 1: Simulation dashboards comparing the baseline (left) and transit expansion (right) scenarios for Freetown's Central Business District.

Keywords

agent-based modelling; pedestrian mobility; transit planning; urban simulation; Global South

Abstract

Advances in geospatial and computational modelling have opened new possibilities for evidence-based urban governance, yet these tools remain concentrated in cities with the fiscal and institutional capacity to deploy them. In lower-resource urban contexts, decisions about transit investment, densification, and infrastructure sequencing are too often made without instruments capable of anticipating their effects on everyday urban life. This raises a broader question for urban technology research: how can computational tools remain accountable in the Global South, where pedestrian activity, alternative transit modes, and informal economic practice are mutually constitutive rather than separable planning variables?

Freetown, Sierra Leone, offers a productive site for examining this question empirically. The city is pursuing a development agenda centred on its Central Business District (CBD), aimed at strengthening the commercial core while advancing municipal goals around low-emission transit. A proposed cable car system is central to this agenda, intended to expand transit access into the CBD and draw new commuters into the area. Its scale of impact makes a strong case for data-based planning to evaluate the additional pedestrian foot traffic this ridership will generate. This opportunity sits alongside two further, concurrent pressures on the CBD: housing densification and commuter growth projected through 2028. Freetown's steep hillside terrain, which has historically limited road-based connectivity, further motivates the cable car proposal.

Freetown's cultural and spatial context carries particular weight, where pedestrian congestion routinely overlaps with informal street vending on vehicle-oriented roads, producing mobility constraints and safety risks that transport models rarely capture. This project develops a pilot pedestrian mobility simulation for Freetown's CBD using GIS and General Transit Feed Specification (GTFS) data and the GAMA agent-based modelling platform (Taillandier et al., 2019), building a decision-support tool for municipal planners. The model simulates daily pedestrian flows across times of day, identifies streets likely to experience increased pressure, and supports scenario testing within typical data and budget constraints. The pilot focuses on professional workers' mobility, both those living and working in the CBD and those commuting along designated origin–destination pairs, allowing planners to compare current and future congestion and identify streets suitable for pedestrianization or traffic calming.

The model draws on GIS data covering the CBD's road network, building uses, and public transport routes, together with the proposed cable car station location, treating transit inputs as capturing both formal, city-operated services and the privately operated minibus and shared-taxi operations that carry most daily commuters. Time-of-day transit speed data derived from GTFS analysis links observed mobility conditions to simulated pedestrian congestion, generating footfall estimates without costly field surveys. This presentation situates the model as a case study in data-frugal, culturally grounded agent-based modelling for cities where such rigor has long been treated as unaffordable.

Additional material

Code repository: `https://github.com/georinep/Freetown-mobility-gama`

A livestock feed allocation model for agri-food scenarios at the territorial scale

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Keywords

Linear Optimization; Animal Feed; Organic Farming; Livestock Farming; Agro-ecological Transition Pathways

Abstract

Feeding a growing global population without exceeding planetary boundaries remains a central challenge for agri-food systems, calling for exploratory and prospective modeling of agro-ecological transitions (*1*). Organic farming (OF) has been extensively studied and modeled as a candidate pathway. In scenarios projecting large-scale expansion of OF, livestock occupies an ambivalent position. On the one hand, it converts otherwise unusable biomass into food and manure. On the other hand, it competes with human food production and remains a major source of greenhouse gas emissions (*2*). Despite this key role, most global and territorial models rely on simplified livestock rations based solely on the aggregated availability of nitrogen or energy per broad feed category (*3*), overlooking physiological constraints such as intake capacity, amino acids, and digestible proteins. To overcome these limitations, we developed a linear optimization model of livestock diets and herd size designed to be coupled with MAELIA, a multi-agent platform for the integrated assessment and modeling of agricultural and bioeconomy systems at the territorial level (*4*). MAELIA simulates biomass production, transformation, and recycling activities, together with the ecological processes governing biogeochemical cycles and crop growth, at a daily time step. This coupling captures the spatio-temporal interactions between changes in agricultural practices, the availability of feed resources, the livestock carrying capacity, and the availability of organic fertilizers. First, OF relies heavily on manure, whose availability depends on livestock populations. Second, OF affects feed resource availability through two main mechanisms: (i) lower crop yields, which may reduce feed availability, and (ii) changes in crop rotations, particularly the integration of legumes and temporary grasslands, which may provide additional feed resources for livestock. Our model explicitly represents this dynamic feedback loop that single-year diet formulations cannot. The optimization model was implemented in GAMA 2026-06 using the *Constraint and Linear Solvers* plugin (*5*) with the HiGHS solver, dedicated to linear problems (*6*). The decision variables of the model are the herd size and the quantities of each feedstuff consumed by each livestock category, whether sourced locally (*i.e.*, within the study territory) or purchased on the market. The model includes two alternative objective functions, depending on the scenario considered: (i) minimizing total feed costs, subject to constraints on herd size, or (ii) maximizing animal-source protein production, subject to constraints on market dependence and feed-food competition. Nutritional requirements (*i.e.*, energy, amino acids, and proteins), feed intake capacity, and feed inclusion constraints were estimated for eight livestock categories (laying hens, broilers, pigs, dairy cows, beef cattle, dairy goats, dairy ewes, and meat sheep) under both organic and conventional farming systems. The composition and market prices of 83 organic and conventional feedstuffs were also incorporated into the model. By combining constraint-based diet optimization with territorial biomass simulation, this model offers a flexible tool for exploring how livestock systems could adapt to, and support, the expansion of OF while respecting physiological constraints.

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A model to quantify the effect of diversity within the herd on the resilience of dairy sheep farming systems in the face of climate change

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Keywords

Agent-based model, Adaptation to Climate Change, Feed shortage, Milk production, Reproduction

Abstract

Climate change has significant impacts on livestock farming systems. Droughts and heatwaves have a direct impact on animals through heat stress, affecting their health and performance. Climatic hazards also affect the availability and quality of forage resources to feed the herd (resources from fodder crops, grasslands and rangelands, that could be harvested or grazed), leading to possible feed shortages. This risk of feed shortages will be particularly important for grass-based systems. In this context, the diversity of animals within the herd – particularly the diversity in production and reproduction performance, as well as in biological responses to feed shortage – could strengthen the resilience of livestock farming systems (Dumont et al., 2020). Few studies have quantified these effects, especially in dairy ewes.

We developed a mechanistic and dynamic agent-based model of a dairy sheep farming system to quantify these effects. Each ewe was an agent modelled as an energy converter. A ewe's profile was defined by a set of input parameters. For each ewe, its profile, its physiological status as well as the environment – climatic conditions and available forage resources – defined its energy intake and priorities between the different biological functions (milk production, reproduction etc.). Its productive life within the herd was determined by the feeding, reproduction and culling practices of the farmer agent, who managed the ewes in batches. Forage resources were produced by several area entities, on which different types of resources grew and senesced over seasons. Forage resources were harvested to produce stock or grazed in each season.

We calibrated the model to simulate a case study of a dairy sheep farm located in the mountainous region of the Causses (Occitanie, France). We used meteorological data to estimate the ewes' daily heat stress levels and the ISOP database (INRAE, n. d.) to estimate the effect of climate change on the seasonal productivity of forage resources. We defined three dairy ewe profiles with different production potential and responses to feed shortage. We simulated different herd compositions in terms of the number and proportion of each profile, over a ten-year simulation with the climate observed between 2015 and 2024.

The performance of each tested herd composition varied from year to year, with a coefficient of variation ranging from 10% to 13.5% for total quantity of milk collected (TQMC) and from 0.8% to 3.3% for pregnancy rate (PR). Comparison between herds comprising a single ewe profile demonstrated that each ewe profile exhibited different levels of TQMC (from 195 to 220 kL/year) and PR (from 90.8% to 94.0%). Herds composed of several profiles showed a higher average level and greater stability of performance than herds composed of a single profile, particularly in years with a severe annual resource deficit as in 2022. Depending on the proportions of each profile, the balance between the level and stability of TQMC and PR varied, demonstrating the different roles played by each profile in shaping herd performance. These results highlighted diversity within the herd as a lever for adaptation to climate change.

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A reusable Gale-Shapley matching module for GAMA

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Keywords

Stable matching, Gale-Shapley, resource allocation, agent-based modelling

Abstract

Many agent-based models need matching techniques to pair suppliers and consumers, allocate resources or assign services based on preferences. In some of these problems, no two agents should both benefit from leaving their current partners for each other. The Gale-Shapley algorithm (1) solves this through successive proposals and rejections, and it is widely used, from medical residency matching (2) to industrial symbioses (3). To the best of our knowledge, no reusable implementation exists in GAML. We address this gap with a ready-to-use module that modellers can integrate without reimplementing the algorithm for each model.

We built a module that covers several variants of the algorithm: one-to-one, one-to-many, many-to-many, and many-to-many with divisible capacities. The first three follow the classical algorithm. The last one is inspired by the work of Kleinpeter et al. (3) but preserves the classical proposer-optimal asymmetry: each agent holds a capacity (a volume, a time-budget, or any divisible resource), and the matching decides both who pairs with whom and how much they exchange. Proposers push as much as they can towards their preferred partner; acceptors keep the best offers and free up space by displacing lower-ranked ones. The result favours the proposing side. Swapping which side proposes yields a different, equally valid solution.

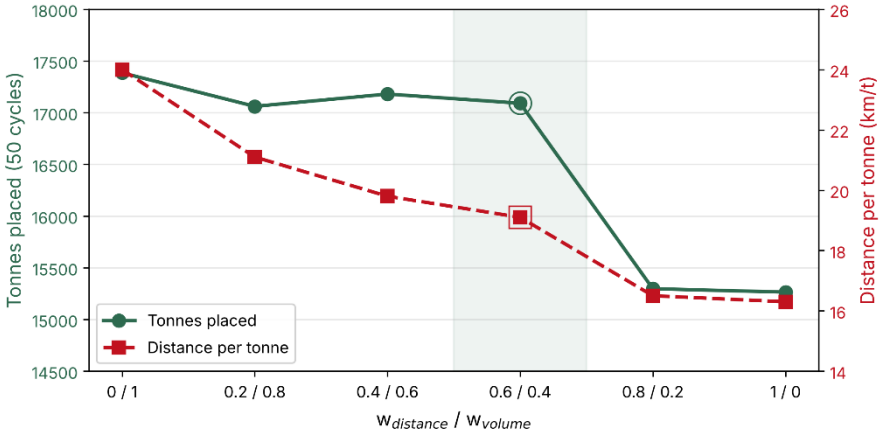
Using the module is straightforward: pass two ranked preference lists and, optionally, a capacity per agent. The module returns each pairing with its assigned quantity. Absent pairs are treated as forbidden, so upstream constraints are respected automatically.

We developed the module as a standalone GAML species and tested it inside MAELIA (4), an agroecological platform built on GAMA (5) at INRAE. There, it matches production and consumption units that exchange organic residues. Preferences can be set by distance, volume, material type, or past exchanges, and a producer can supply several consumers (and vice versa).

We tested the module with 25 farms and 6 plants over 50 cycles, where each farm could only reach nearby plants. Under distance-based preferences, farms filled the closest plants and peripheral farms were left out: 86 % of production was placed. Under volume-based preferences, where plants favour large suppliers, placement rose to 98 %, but at 47 % more distance per tonne. A weighted combination (0.6 distance, 0.4 volume) recovered nearly all the volume gain at much lower transport cost. A sweep over the weights showed that placement holds steady until distance dominates above 0.8, then drops sharply (see Figure 1). Across four seeds, volume always placed 17–21 % more tonnes at 50–70 % more distance per tonne.

These trade-offs are controlled entirely through the preference lists. The module and test suite are available at https://gitlab.cirad.fr/recyclageetrisque/stable-matching-in-gama. We tested the asymmetry on 522 random instances of varying size. In small cases, swapping which side proposes rarely changed the outcome (0.6 % of instances). As size grew, differences appeared in 19 % of cases, and whenever they did, the proposing side always obtained a better deal, as theory predicts. Next step is validation on real farm data.

Figure 1. Weight sweep: distance vs volume trade-off
(25 farms, 6 plants, 50 cycles)



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A server-client architecture for model coupling: the case of MAELIA and STICS

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Keywords

Model coupling, GAMA, MAELIA, STICS

Abstract

Coupling simulation models developed by different teams, in different languages and on independent release cycles is as much a maintenance problem as a technical one. A tight integration binds the evolution of each model to the other, so that a change in one code base can break the coupling or force changes in the other. In this work, we propose a coupling approach that preserves the independence of the coupled platforms, allowing each to keep evolving with minimal impact on the other.
We illustrate this approach through the coupling of MAELIA(*1*), an integrated, spatially explicit platform implemented in GAMA(*2*), with STICS(*3*), a mechanistic soil-crop model implemented in Fortran. The two models are complementary. MAELIA represents agricultural territories and their dynamics. Its strength lies in expressing general decision rules for farmers, so that management practices emerge dynamically during the simulation rather than being fixed in advance at given dates. Its underlying plot model, however, is deliberately simple: it only accounts for water and nitrogen stresses and takes potential yield as an input parameter. STICS, conversely, simulates a single, non-spatially explicit plot, but with a detailed mechanistic representation of soil-crop interactions. It accounts for water, nitrogen, phosphorus, temperature and anoxia stresses and computes potential yield itself. Its management operations must all be specified before the simulation starts and cannot be decided at runtime. Coupling the two benefits both sides: MAELIA gains a more realistic and explainable representation of each plot, while STICS can be driven by dynamic management decisions.
The coupling relies on a client-server architecture built around a high-level API. A lightweight Fortran server layer exposes the state of individual STICS simulations through JSON-RPC 2.0 and allows management operations to be submitted during a simulation. This API is the only contract between the platforms: MAELIA has no knowledge of how STICS implements a simulation, and STICS has no knowledge of who calls it. Errors are therefore part of the contract. STICS reports them without deciding how they should be handled, leaving the caller, which holds the simulation context, free to recover, retry or stop. On the GAMA side, the coupling is isolated in a dedicated agent, so the external model can be added, removed or replaced without affecting the rest of the simulation.
This architecture keeps both platforms independent. As the API is the sole interface between them, internal changes to either STICS or MAELIA do not require changes to the other, and the implementation behind the server can be replaced without modifying the coupling logic. Moreover the API is expressed in terms of STICS's core concepts rather than implementation details, it is expected to remain stable as STICS evolves and generic enough to support future coupling needs. Performance measurements show that an individual request-response exchange costs orders of magnitude less than the cost of a MAELIA simulation step. However, with a naive implementation, each of the STICS plots requires its own exchanges at every simulation step, making communication overhead significant when thousands of them are represented. The introduction of batched operations into the API reduces this to three or four exchanges per step, making the communication cost negligible overall. These results suggest that the approach provides a good balance between independence, flexibility and performance for loosely coupled simulations.

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Activity-Based Model in GAMA: Application to Hanoi's Mobility Transition

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Keywords

Agent-based simulation, Grid-based congestion, Mode choice, Transportation planning

Abstract

Hanoi, the capital of Vietnam, is a rapidly expanding metropolis where mobility is dominated by two-wheelers, which account for roughly 70% of daily trips [6]. This overwhelming reliance on private motorized vehicles within a dense urban environment leads to chronic road congestion and significant greenhouse gas emissions [5]. To address these issues, the city aims to encourage a modal shift toward sustainable transport through a massive expansion of its public transit system, scaling from two to twelve metro lines by 2050 [8].

In this context, Activity-Based Models (AcBMs) offer valuable decision support by simulating how inhabitants adapt their daily activity chains and travel choices to new infrastructure [9]. However, applying these models to Global South metropolises reveals a methodological gap. A vast majority of frameworks, designed for Global North cities, struggle to integrate complex transit networks with explicit transfer delays, to replicate the fluid congestion generated by massive motorcycle fleets, and to model how individuals adapt their mode choices in response to dynamic traffic. To bridge this gap and evaluate future scenarios in Hanoi, we introduce an AcBM developed on the GAMA platform [10].

This work presents three main contributions. First, to achieve unified multimodal graph integration, we developed a method to seamlessly fuse OpenStreetMap road networks with General Transit Feed Specification bus and metro schedules. By generating virtual "waiting" and "exit" transfer connectors, GAMA agents can compute optimal multimodal itineraries (combining walking, bus, and metro stages with transfer delays) in a single shortest-path search using the New Bidirectional A* (NBA*) algorithm [7]. Second, we introduced a grid-based Passenger Car Units (PCU) [1] congestion model to simulate Hanoi's mixed, fluid traffic without the computational cost and rigid constraints of microscopic car-following models. We implemented a continuous-space spatial grid overlay where each cell acts as a local traffic accumulator, dynamically updating its density based on the PCU of agents currently traversing it, coupled with a temporal decay factor. Agents moving on the road network dynamically adjust their effective speed according to the ambient density of their current cell. Third, we integrated a Multinomial Logit mode choice model [4] in the agents' decision process. At their scheduled departure time, agents evaluate the utility of available modes (motorized, active, or public transit) based on monetary costs, socio-demographic preferences, and expected travel times affected by the dynamic grid congestion.

The model is applied to a synthetic population of 10,000 agents [3] across Hanoi's urban area (Figure 1). A comprehensive description of the model and its application is detailed in [2]. We demonstrate how the GAMA simulation successfully reproduces the observed baseline travel behaviors from a 2024 mobility survey. Furthermore, we showcase the evaluation of the 2050 scenario, showing that adding new metro lines and optimizing bus itineraries could more than double the modal share of public transport, increasing it from 3.11% to 6.99%, yielding a 6.18% reduction in total CO_2 emissions from transportation.

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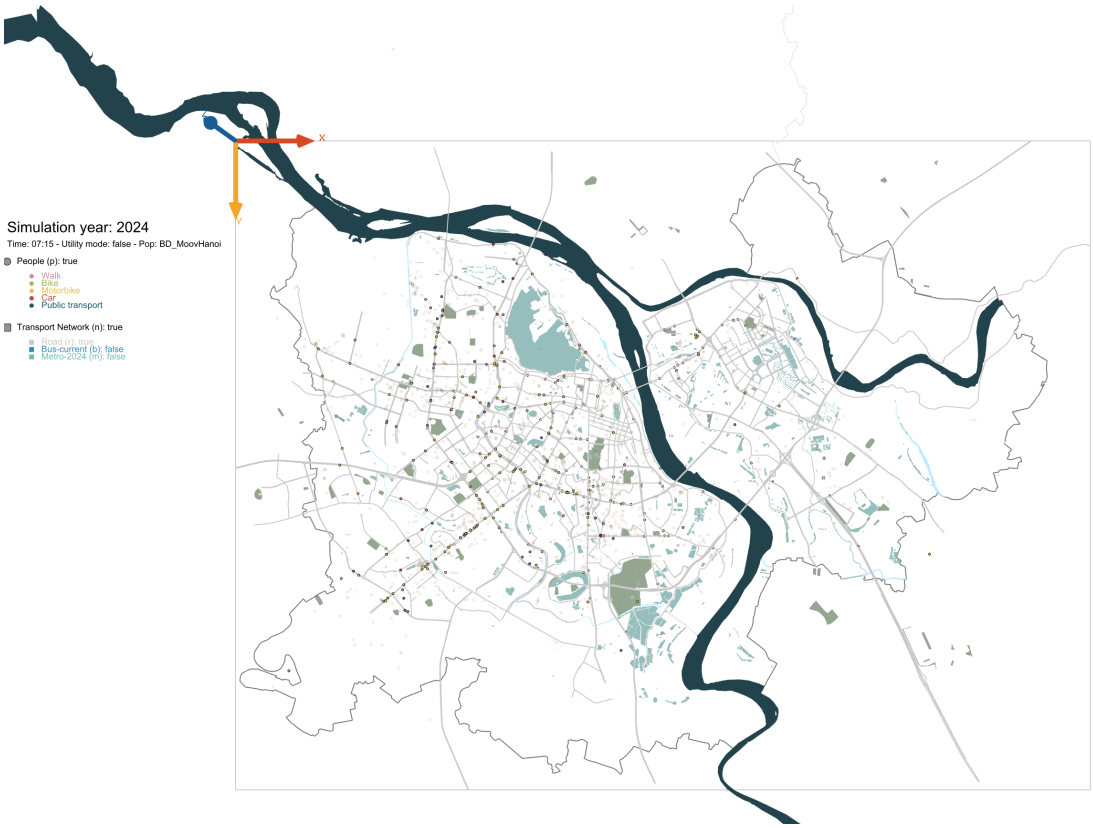

Figure 1: Screenshot of the simulation model in GAMA

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Agent-Based Modeling of Urban Flooding and Storm Drainage Performance Under Rainfall and Waste Conditions

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Keywords

Agent-based modeling; urban flooding; storm drainage; GAMA; geographic information systems

Abstract

Urban flooding is a recurring challenge in cities where rainfall intensity, terrain characteristics, drainage infrastructure, and waste accumulation interact in complex ways. This project presents an agent-based model developed using the GAMA Platform to simulate urban drainage systems under different rainfall and waste conditions. The model focuses on Guadalajara, Mexico, using geographic information to represent terrain elevation and urban infrastructure, while incorporating streets as the spatial environment in which drainage elements operate. The model represents storm drains as dynamic agents with individual attributes, including size, water collection capacity, unclogging rate, and operational availability. These agents interact with rainfall and surface water, while their effective capacity changes according to the amount of waste present in the water. At each simulation cycle, rainfall is introduced into the environment, water distribution is updated according to terrain characteristics, and each drain evaluates its ability to collect incoming water. System-level behavior is evaluated through metrics such as total water collected, average water level in critical areas, and the number of operational drains remaining after a rainfall event.

The experimental design considers three scenarios: a reference rainfall condition, an intense rainfall condition, and a condition with increased waste accumulation. These scenarios allow the model to explore how changes in environmental conditions affect drainage performance and urban water accumulation. The main objective is to minimize average water levels across the simulated area while maintaining high water collection and drainage system availability.

Beyond demonstrating an application of agent-based modeling to an urban environmental problem, the project highlights the capabilities of GAMA for integrating geographic data, representing spatially distributed agents, dynamically updating agent states, and evaluating alternative infrastructure configurations. The model can therefore serve as a practical demonstration of how GAMA can be used to study complex urban systems and experiment with different drainage configurations and environmental conditions.

Additional Material

The following figures provide examples of the urban flooding model and its simulation environment.

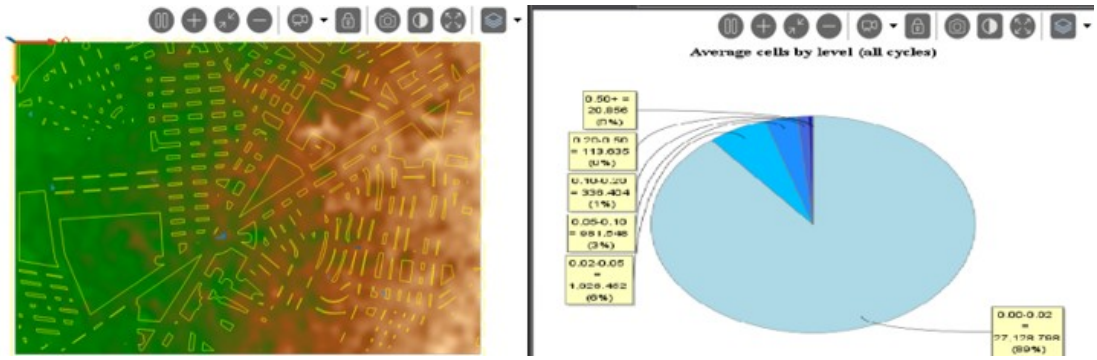

Figure 1: Water level and filtration results. Under moderate rain (max filtration).

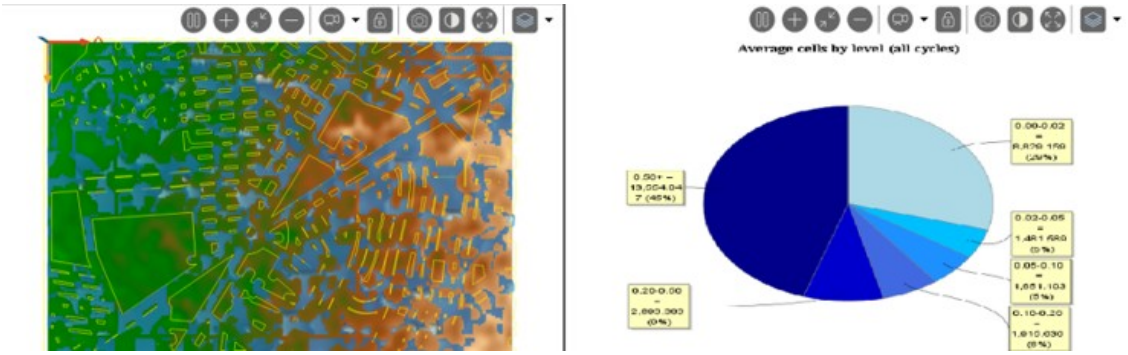

Figure 2: Water level and filtration results. Under heavy rain and half filtration capacity.

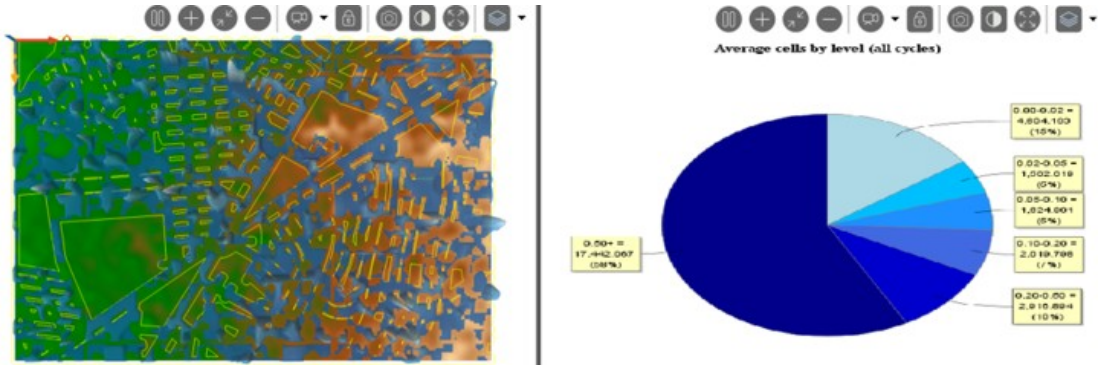

Figure 3: Water level and filtration results. Under very heavy rain and minimum filtration.

The source code is available in the project repository: `https://github.com/Carlosedochb/inundaciones/tree/correcta`

Agent-Based Simulation of Insecurity Perception and Pedestrian Route Choice in Student Mobility in Central Guadalajara

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Keywords

Agent-based modeling, Insecurity perception, Pedestrian mobility, Subjective risk-weighted routing, CPTED, GAMA platform.

Abstract

Perception of insecurity significantly alters how students navigate between educational campuses and public transportation nodes. This study presents an agent-based model developed in GAMA (v2025.6.4) to simulate pedestrian mobility within a 15-minute walking shed surrounding three higher education campuses in central Guadalajara, Mexico (CUAAD Artes, CUAAD Música, and Preparatoria de Jalisco), accounting for 5,208 enrolled students (SIGED 2024–2025). The spatial environment integrates 3,095 pedestrian road segments from OpenStreetMap, street lighting per block-face from INEGI's 2020 National Housing Inventory, 606 cadastral blocks, and 51 mass transit access points (Light Rail, Macrobús, and SiTren) (Figure 1).

Two continuous commuting flows of 10 agents per minute were modeled: students traveling from campuses to transit stations, and individuals moving from transit stops to academic venues. Student agents are parameterized with individual personality traits, victimization history, and Crime Prevention Through Environmental Design (CPTED) perception weights—evaluating street lighting, blind walls, and natural surveillance ("eyes on the street")—to continuously compute instantaneous and accumulated perceived risk. Three experimental scenarios were evaluated across three 48-hour simulated runs (excluding a 10-minute warmup): (1) the current baseline environment (70% lighting, 40% physical decay, 30% litter), (2) an urban physical intervention (100% lighting, 10% decay and litter), and (3) dark-avoidance adaptive route selection behavior.

Simulation results demonstrate that under baseline conditions, nocturnal perceived risk was 42% higher than daytime levels (0.43 vs. 0.30), with 24% of total walked distance occurring on unlit streets (Figure 2). While the physical intervention elevated overall route safety scores (from 0.42 to 0.92 at night and 0.53 to 0.91 during the day), perceived risk remained at 0.43 because agent perception in this model version depends on street attributes not directly linked to the intervened layers. Crucially, when agents executed subjective risk-weighted routing to avoid unlit streets, distance walked in darkness dropped by 79% (from 103 km to 21 km), while total travel distance increased by only 2.6%. The model reproduces day-night operational contrasts and proves that risk-avoidance routing significantly mitigates exposure to nocturnal insecurity at a negligible distance penalty. The model underwent internal consistency checks and sensitivity analyses across contrasting urban and behavioral scenarios, establishing a baseline for subsequent calibration with field counts and survey data.

Additional material

Model source code and GAMA simulation repository: https://github.com/CityScienceLab-GDL/perception_mobility.git

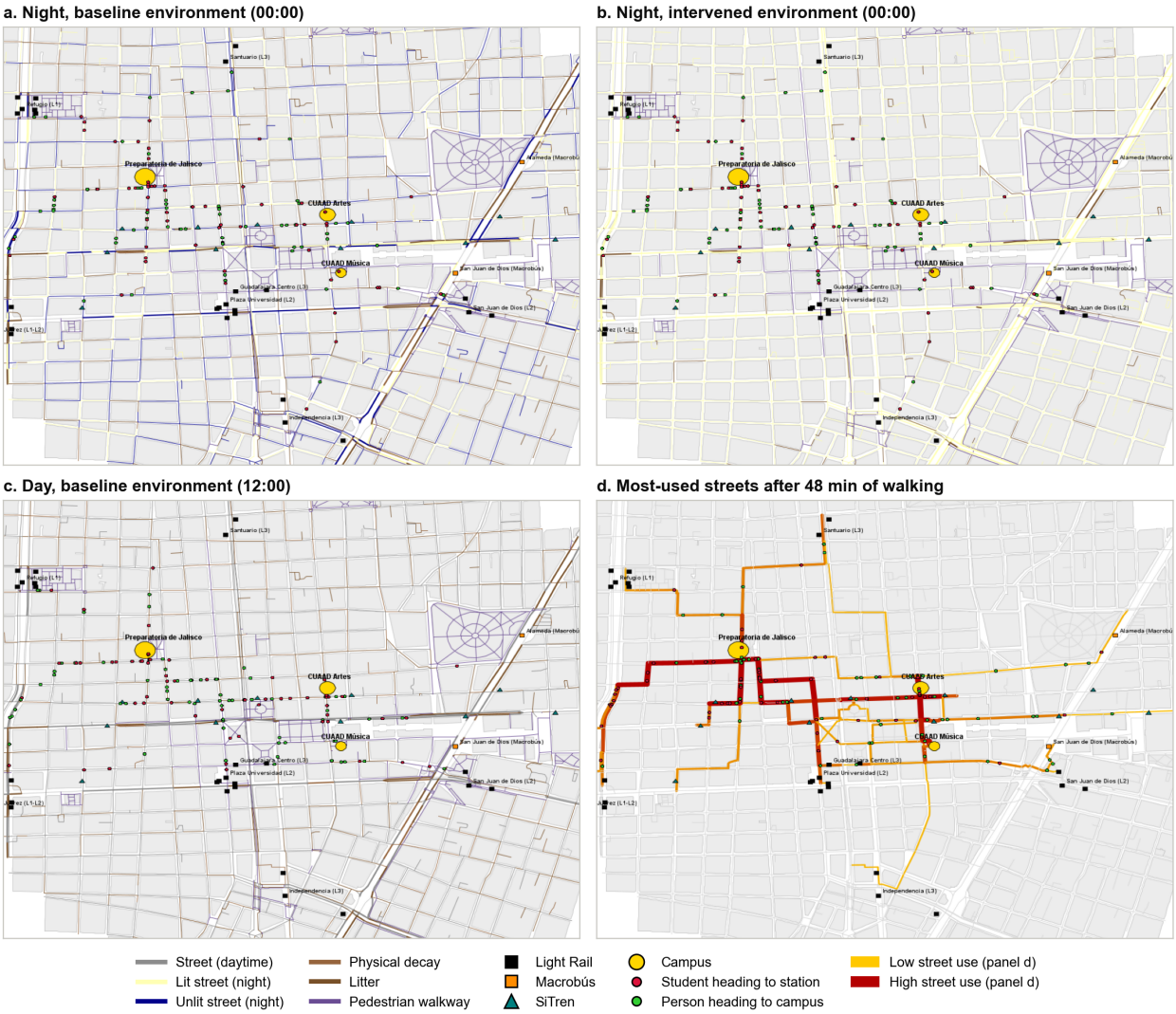

Figure 1: GAMA simulation environment of central Guadalajara pedestrian network. (a) Nighttime baseline environment (00:00) with 70% street lighting. (b) Nighttime intervened environment (00:00) with 100% street lighting. (c) Daytime baseline environment (12:00). (d) Spatial street usage density after 48 minutes of continuous pedestrian flow.

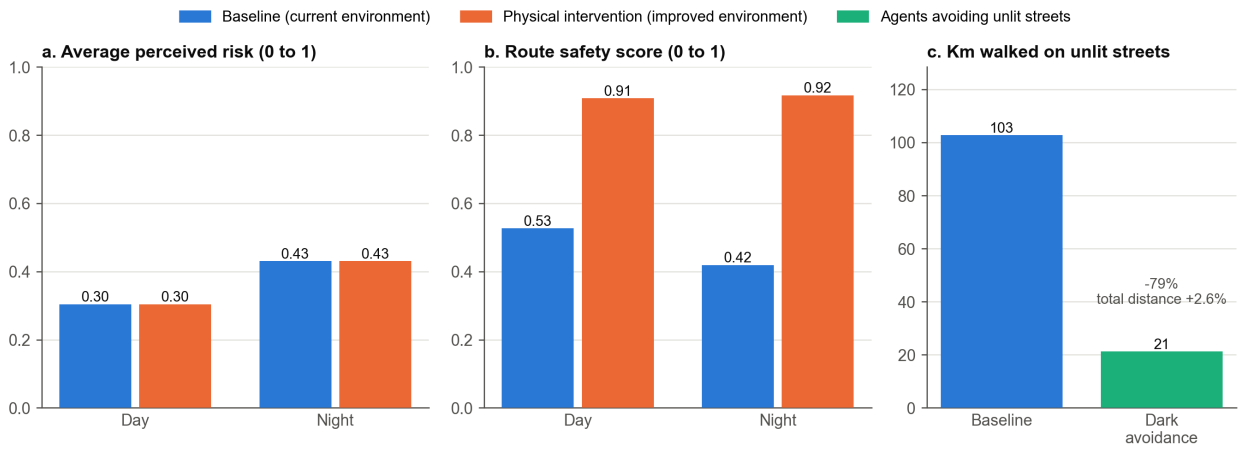

Figure 2: Simulation experiment results comparing baseline, physical intervention, and dark-avoidance routing scenarios. (a) Average perceived risk on a 0 to 1 scale across day and night conditions. (b) Route safety score per walked meter (0 to 1 scale). (c) Total kilometers walked on unlit streets comparing current conditions against subjective risk-weighted routing.

Agent-based modelling of traffic jam emergence at an urban roundabout in Kinshasa

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Keywords

agent-based simulation, traffic congestion, emergence, urban mobility, Kinshasa

Abstract

Kinshasa, the third most populous city in Africa, suffers from chronic road congestion whose formation mechanisms remain poorly documented. This work presents an agent-based model, built with GAMA, of traffic jam emergence at the Victoire Roundabout, a major intersection that operates without any traffic light.

The road network was extracted from OpenStreetMap and processed in QGIS, yielding 48 road segments and 214 intersections; missing junction nodes, common in sub-Saharan OpenStreetMap data, were regenerated by geometric computation. Seven agent species were implemented: cars, motorcycle taxis, buses, trucks, pedestrians, street vendors and traffic officers. The model follows a purely reactive architecture: each vehicle perceives only the local density of its current segment and adapts its speed accordingly, with no global representation and no anticipation. Congestion is therefore never prescribed; it emerges solely from local interactions, which grants the model its explanatory and prospective value. Four context-specific factors were integrated and calibrated from field data: rainfall, road-surface degradation (potholes), informal roadway occupation by vendors, and traffic violations.

The model was calibrated against four field sessions (dry morning peak, off-peak, evening peak, and rain) combining vehicle counts and video-based speed estimation. Keeping the observed vehicle proportions (45% cars, 43% motorcycle taxis, 9% buses, 3% trucks) and adjusting the simultaneous vehicle stock, the simulated reference speed reached 14.8 km/h against 16.8 km/h observed (12% deviation). Validation across three situations gave deviations of 12%, 1% (rain) and 13%, all below the 15% acceptance threshold.

Five scenarios were then compared (Fig. 1); indicators are averaged over the stabilised phase of a 200-cycle run (cycles 105–200). Rainfall proved the most aggravating factor (–33% speed), faithfully reproducing the observed drop and the desertion of motorcycle taxis (from 43% to 18% of traffic). The evening peak degraded speed by 26%. Notably, adding a traffic light degraded flow by 10% rather than improving it, since it interrupts the continuous roundabout flow, while removing street vendors barely changed speed (–2%) but reduced blocked vehicles by 13% and yielded the lowest congestion rate. These counter-intuitive results, grounded in a validated model, illustrate the value of agent-based simulation as a decision-support tool: it helps avoid a costly and counter-productive investment and reprioritises rain management over the more visible informal occupation.

To our knowledge, this is the first GAMA-based simulation of a sub-Saharan African roundabout integrating rainfall, degraded pavement, informal occupation and non-normative behaviour simultaneously, bridging a gap between Congolese studies that analyse congestion without simulating it and GAMA traffic models developed for other contexts.

Additional material

GAML model, Python analysis scripts and field-data sheets are available on request. A live GAMA demonstration of congestion emergence and the rainfall scenario can be presented at the conference.

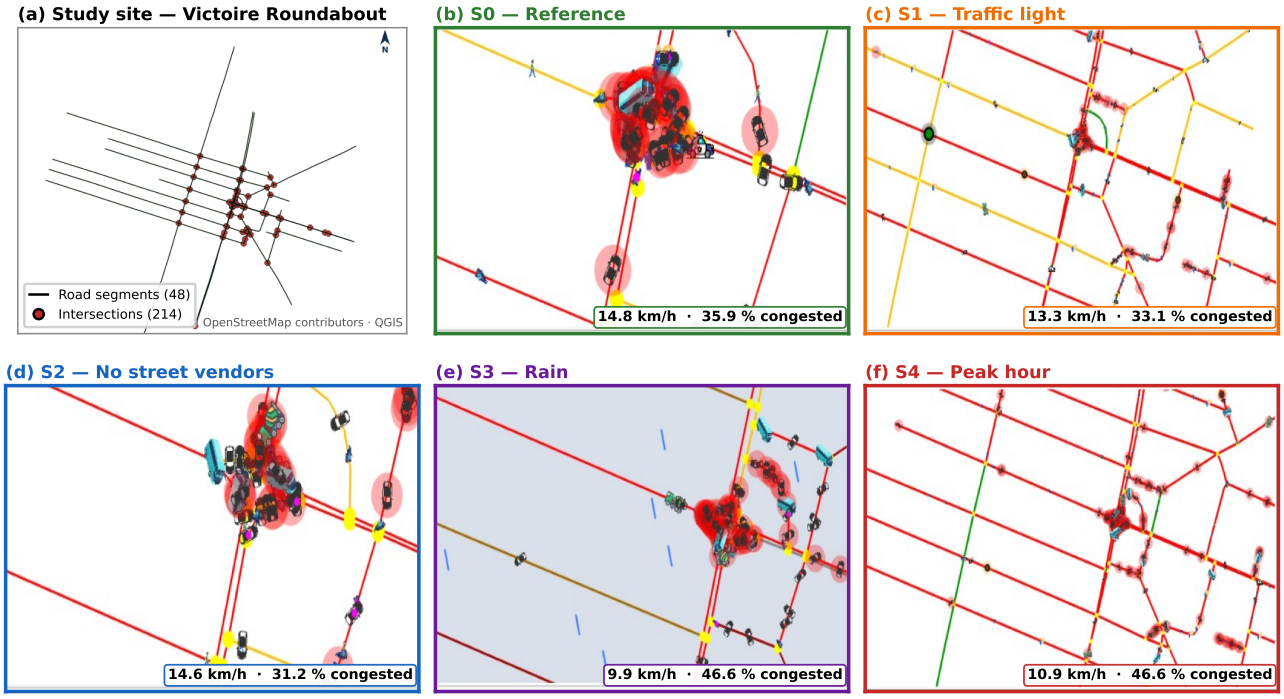

Figure 1: (a) Study site: road network of the Victoire Roundabout, Kinshasa, extracted from OpenStreetMap and processed in QGIS. (b)–(f) GAMA map view of the five scenarios at cycle 200, with the stabilised mean speed and congestion rate (share of blocked vehicles); red halos mark vehicles that are stopped or moving below 3 km/h.

Amenities, Quality of Life, and Displacement: A Cellular Automaton and Agent-Based Model of Gentrification

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Keywords

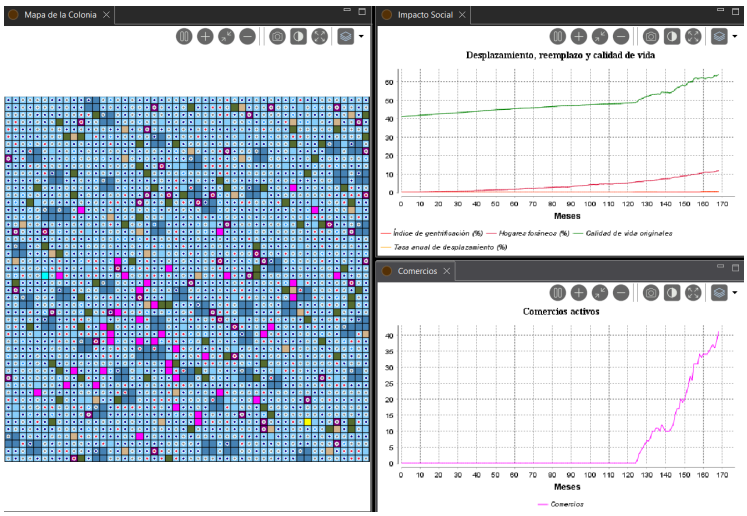
gentrification, residential displacement, urban amenities, agent-based and cellular automata modeling.

Abstract

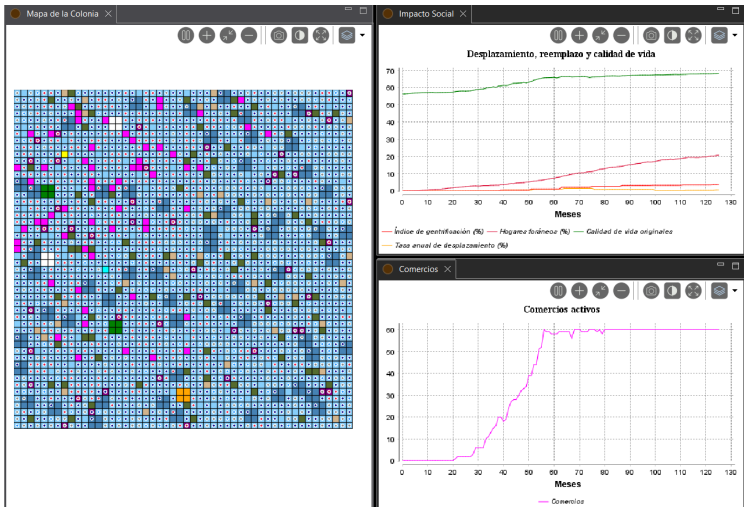
Urban amenities such as parks, clinics, schools, and local commerce improve residents' quality of life, yet they also raise land values and can trigger gentrification that displaces the very households they were meant to serve, a paradox documented for urban greening [1] and visible in Guadalajara's city center, where park renovation and cultural projects have driven an ongoing gentrification process [2]. Planners rarely know how much upgrading a working-class neighborhood can take before this happens. The question is pressing in Guadalajara: comparing the 2000 Census [3] with the 2025 Intercensal Survey [4], we estimate that the municipality lost about 402,000 inhabitants, a decline not attributable to gentrification alone but indicative of how hard it has become for residents to remain in the central city. This study asks: how many amenities can a working-class neighborhood absorb before the displacement of its original households outweighs the gains in quality of life?

We built a hybrid cellular automaton and agent-based model in GAMA in which rents respond to amenity proximity and to the income composition of neighboring lots, and commerce opens and closes endogenously with local high-income demand. Household incomes are calibrated with INEGI's (National Institute of Statistics and Geography) ENIGH (National Household Income and Expenditure Survey) 2024 deciles for Jalisco [5] and rents with listings from the Guadalajara metropolitan area. Renters leave after sustained severe cost burden, and owners may sell under price pressure.

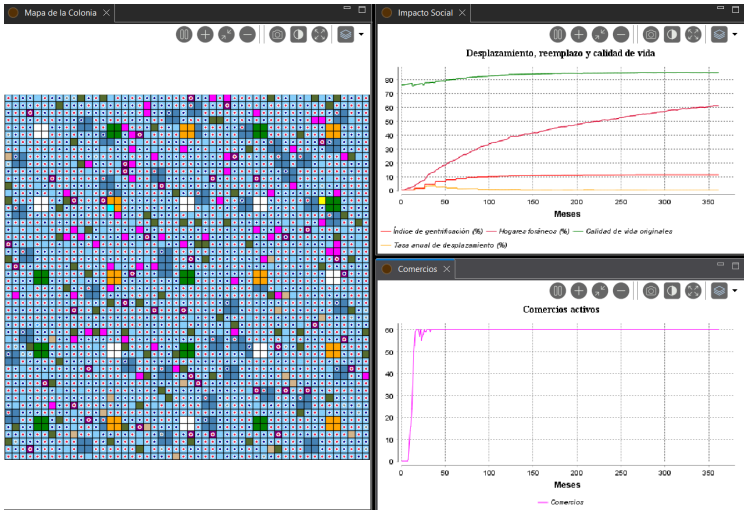
We simulated three scenarios over about 30 years: a baseline with no amenities, a normal scenario with four, and a stress scenario with twenty-five (Fig. 1). After ten years, the gentrification index was below 1% in the baseline, about 6% in the normal scenario, and about 12% in the stress scenario, while newcomer households made up roughly 5%, 32%, and 41% of the neighborhood, respectively. The quality of life of original residents rose with amenities, from about 49 in the baseline to 79 and 84. Endogenous commerce reached a plateau of 60 shops after about one year in the stress scenario and three years in the normal scenario, whereas in the baseline shops only appeared after about eight years. In all three runs the gentrification index eventually stabilized, at about 2%, 7%, and 13%, but replacement continued: newcomers became the majority after about 14 years in the stress scenario and 20 years in the normal scenario, and reached half of the households only at the end of the baseline run. Displacement thus grew with the number of amenities while quality-of-life gains flattened, and even the normal scenario exceeded the 5% displacement tolerance we set as a target. This suggests that amenity-led upgrading should be dosed and paired with anti-displacement policy. Because these are single runs, a replicated sweep across amenity levels is needed to locate the threshold precisely. The model offers a low-cost way to test such thresholds before public investment is committed.



(a) Baseline scenario (0 amenities). Quality of life rose slowly for about eight years with almost no gentrification. Once shops emerged endogenously (from month 100, reaching 60 by month 160), quality of life jumped and newcomer households grew until they made up about half of the neighborhood at 30 years, while the gentrification index stayed near 2%.



(b) Normal scenario (4 amenities). Shops reached the plateau of 60 in about three years. Newcomer households reached about 32% after ten years and about 60% after 30 years, while the gentrification index stabilized near 7%.



(c) Stress scenario (25 amenities). Shops reached 60 in about one year. Quality of life, already high at the start, rose from about 76 to 86. Newcomer households reached about 41% after ten years and about 65% by the end of the run, while the gentrification index stabilized near 13%.

Figure 1: Representative run of each scenario in GAMA: neighborhood map (left), gentrification index, newcomer households, quality of life of original residents and annual displacement rate (top right), and active shops (bottom right).

Additional material

Source code of the model: https://github.com/AlanElPlatano/gama_lab

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An Agent-Based Model of Neighbourhood Security, Housing Prices and Displacement in GAMA

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Keywords

Agent-based modeling, Urban security, Housing affordability, Residential displacement.

Abstract

Neighborhood security is one of the many factors households may consider most when choosing where to live, yet interventions such as street lighting or surveillance are usually evaluated only in terms of their effects on crime. Their indirect effects on housing demand, prices, affordability, and the ability of low-budget households to remain in their neighborhoods are still not well understood. This study presents an agent-based model developed in GAMA to explore how household decisions and neighborhood security interact to shape housing affordability, mobility, and displacement. The city is represented as a hexagonal grid of 7 neighborhoods (colonias), each containing 91 hexagonal dwellings. Security, measured from 0 to 100, changes through random improvement and crime events, with the probability of crime increasing as security falls. This feedback allows neighborhoods to either recover or deteriorate over time. Around 540 households with different levels of savings, security preferences, and price sensitivity update their perceived security over time, pay a periodic housing cost based on dwelling value, and choose among affordable dwellings using a multi-attribute utility. Households move only when the expected gain is large enough, or when insecurity or housing costs become intolerable. Housing prices respond to latent demand, defined as households that would want and could afford to live in a neighborhood, relative to supply, while prices also move back toward fundamental values; transactions conserve money within the system.

Three scenarios were simulated for 240 monthly ticks using common random numbers: a baseline (E1), a security intervention in the least secure third of neighborhoods (E2), and an increase in buyers equal to 25% of the housing stock (E3). Preliminary results show that the security intervention substantially increased security and housing prices in targeted neighborhoods, while reducing household mobility and largely retaining low-budget residents. In contrast, increased demand had a stronger effect on housing prices and displacement, with many low-budget households moving to cheaper or less secure neighborhoods and some left without housing. The model also showed that measuring demand only through houses for sale can underestimate housing scarcity in secure, fully occupied neighborhoods. These results suggest that security improvements raise housing values but, in this setting, tend to retain rather than displace residents, while overall demand pressure is the main driver of displacement. Future work will include more replications, a rental market, and calibration using data from the Guadalajara Metropolitan Area.

Additional material

Model source code: [https://github.com/SergioIsaacSantanaJimenez/Agent-Based-Model-of-Neighbourhood-Security-Housing-Prices-and-Displacement-in-GAMA-]. A live demonstration of the model will accompany the talk.

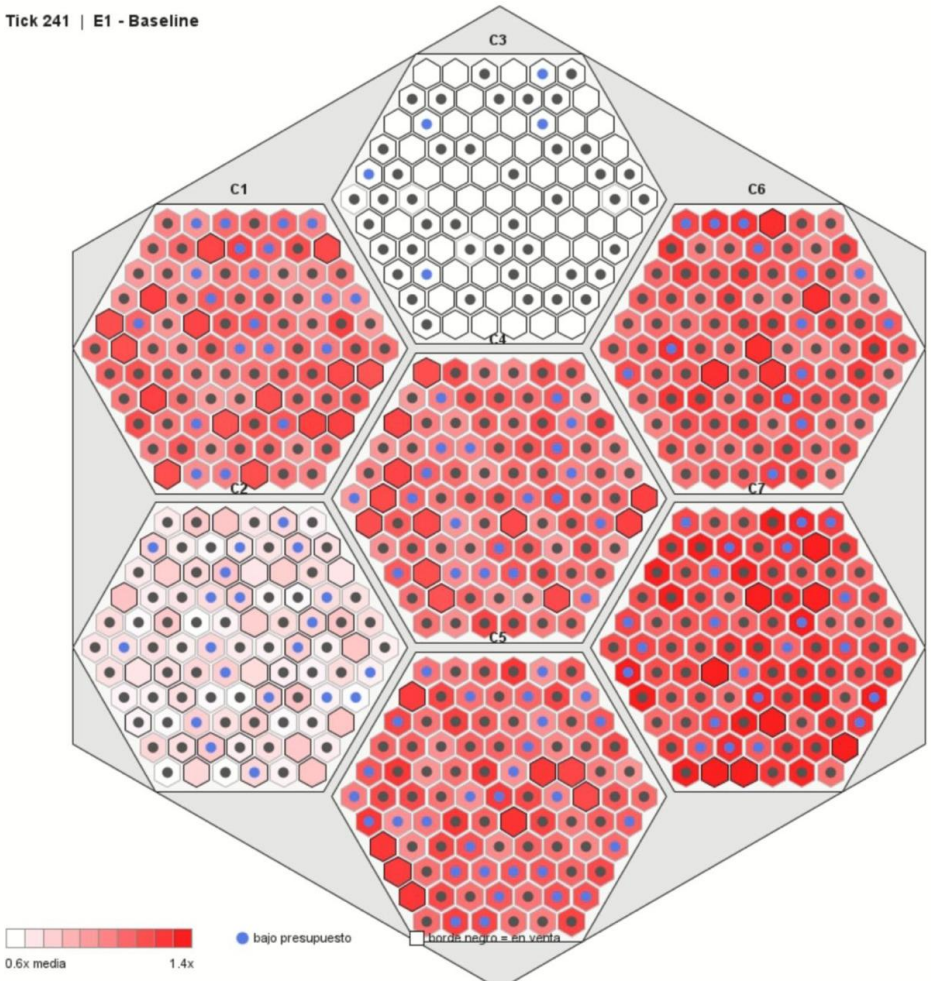

Figure 1: Model interface in GAMA (baseline scenario E1, tick 241). Seven hexagonal neighbourhoods (C1–C7) contain 91 dwellings each. Colour shows dwelling price relative to the city mean (white $\leq 0.6\times$, red $\geq 1.4\times$); dots mark occupied dwellings (blue: low-budget households) and black borders mark dwellings for sale. Prices diverge across neighbourhoods: C7 is fully occupied and among the most expensive, while C3, the cheapest, has the most vacant dwellings.

An Integrated GAMA Framework for Urban Mobility: From Mode Choice Decisions to Network Congestion Dynamics

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Keywords

Agent-based modeling, Urban mobility digital twin, Mode choice decision, Mobility stress dynamics, GAMA platform.

Abstract

Evaluating urban mobility policies in complex metropolitan regions requires computational tools capable of bridging individual traveler decision-making with macroscopic network dynamics. This paper presents an integrated computational framework developed within the GAMA platform for the Guadalajara Metropolitan Area (AMG), Mexico, establishing the empirical and architectural foundations for an urban mobility digital twin. The operational maturity, spatial explicit modeling capabilities, and modularity of this GAMA-based architecture are demonstrated through two complementary simulation models addressing travel demand generation and physical network supply constraints.

The first model investigates transportation mode choice under heterogeneous socioeconomic conditions, territorial vulnerability, and spatial equity across the AMG (Figure 1a). Integrating official census microdata, the Origin-Destination Survey (EOD-2023), Sustainable Urban Mobility Plan (PIMUS) parameters, and GIS layers from IMEPLAN, a synthetic population of agents is categorized into four representative urban profiles: peripheral students, car-owning workers, women without vehicle access, and central multimodal users. Agents evaluate four modal alternatives—walking, cycling, public transit, and private automobiles—via a multi-attribute utility decision process incorporating travel time, monetary cost, spatial accessibility buffers, route connectivity, and perceived safety. Simulation experiments across five policy scenarios show that isolated interventions yield limited modal shifts, whereas an integral scenario combining simultaneous enhancements in public transit service frequency, dedicated cycling infrastructure, spatial connectivity, and public safety produces a systemic shift toward active and collective transportation.

The second model analyzes vehicular traffic dynamics under temporary mobility stress caused by mass public events at the Auditorio Telmex venue in Zapopan (Figure 1b). Coupling spatially explicit GAMA vehicle agents on a GIS road graph with queueing theory, critical intersections and venue access gates are represented as capacity-constrained service nodes governed by arrival (λ) and service (μ) rates. Across four simulated operating regimes—from baseline operation (550 attendees, 143 vehicles) to extreme mobility stress (5000 attendees, 1875 vehicles, 40% capacity multiplier)—results reveal a nonlinear system transition (Figure 2): high travel demand alone does not generate severe congestion when nominal processing capacity is preserved (average waiting time remains 0 minutes with 780 vehicles). However, infrastructure capacity constraints trigger rapid queue propagation (peaking at 575 vehicles) and exponential travel delays (mean travel time rising from 40.92 to 120.81 minutes), proving that congestion is an emergent threshold phenomenon.

Together, these models illustrate GAMA's flexibility in unifying behavioral social simulation with spatial queueing dynamics. Ongoing work co-simulates both modules within a unified GAMA environment, enabling dynamic feedback between individual mode choice decisions, real-time road network load, and bottleneck formation to provide urban planners with a robust decision-support system for transport equity and infrastructure resilience.

Additional material

Model source code and simulation repositories: https://github.com/CityScienceLab-GDL/mobility-stress

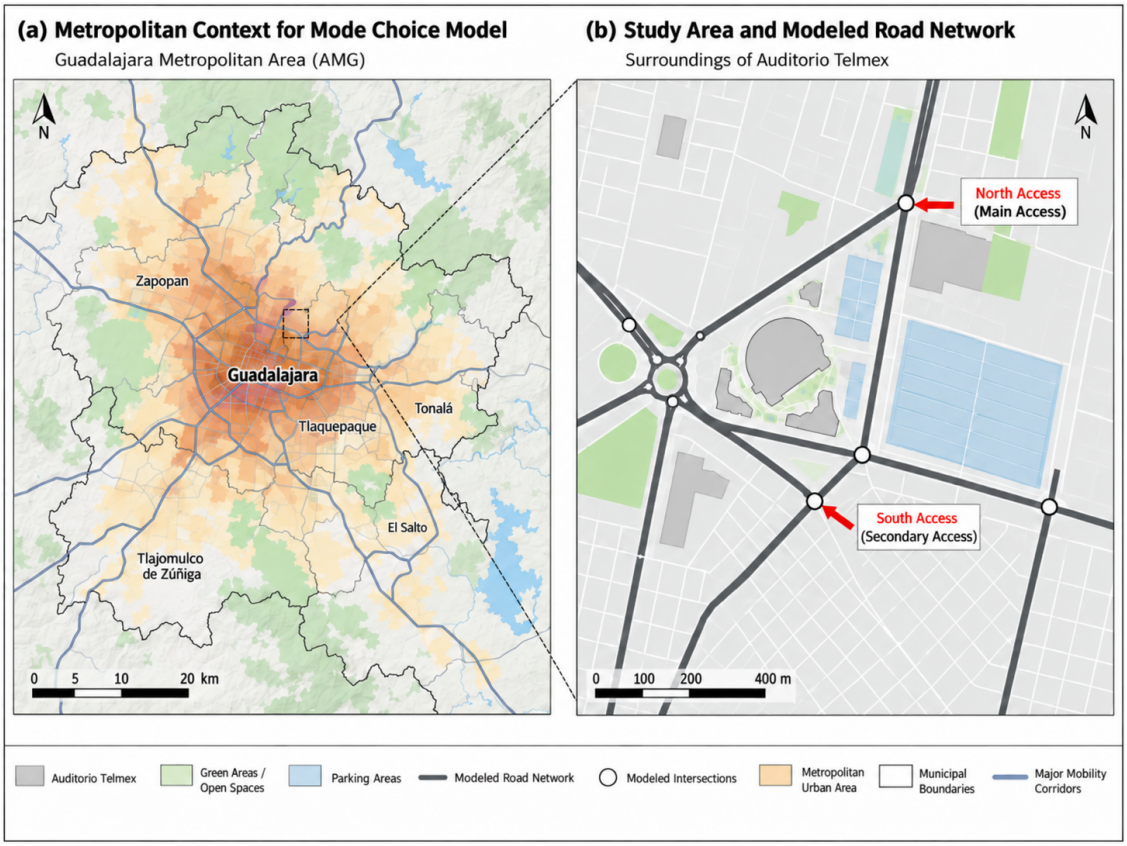
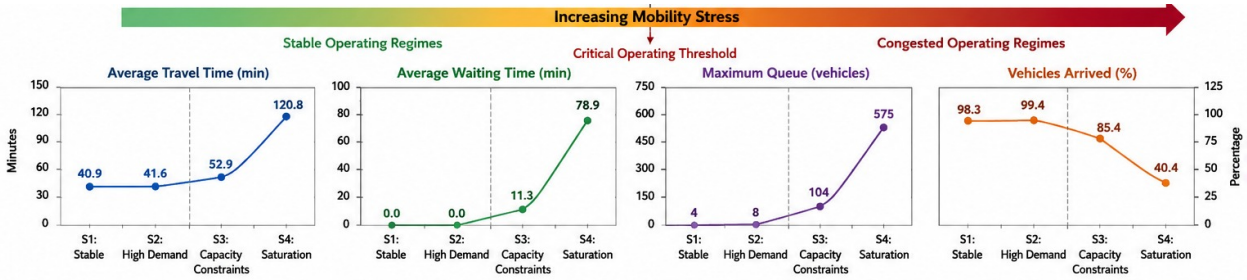


Figure 1: Spatial contexts of the two urban mobility models. (a) Metropolitan context of the Guadalajara Metropolitan Area (AMG), showing the urbanized extent, municipal boundaries, and major mobility corridors considered in the mode choice model. (b) Study area surrounding Auditorio Telmex, showing the modeled road network, access points, and critical intersections represented in the mobility stress model.



Operating Regime	Mobility Stress Level	Demand Level (vehicles)	Infrastructure Capacity (% of nominal)	Mean Travel Time (min)	Mean Waiting Time (min)	Max Queue (vehicles)	Vehicles Arrived (%)
S1: Stable Operation	Low	1,000	100%	40.9	0.0	4	98.3
S2: High Demand	Medium	5,000	100%	41.6	0.0	8	99.4
S3: Capacity Constraints	High	4,800	50%	52.9	11.3	104	85.4
S4: Network Saturation	Very High	7,000	50%	120.8	78.9	575	40.4

Figure 2: Operating regimes and congestion metrics under increasing mobility stress, showing the transition from stable operation to congested conditions as travel demand increases and effective infrastructure capacity decreases.

An agent-based model of insecticide resistance in the brown planthopper: Comparing spray strategies in Mekong Delta rice

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Keywords

Agent-based modeling, GAMA, insecticide resistance, pest management, rice farming, Mekong Delta

Abstract

As the main rice-producing region of Vietnam, the Mekong Delta depends on intensive, continuous cropping that provides pests with a host almost year-round. The brown planthopper (*Nilaparvata lugens*) is one of its most damaging pests. During the 2006–2007 outbreak, the planthopper and the viruses it carries damaged about 485,000 ha and destroyed about 828,000 t of rice (Heong et al., 2015). Farmers often manage it by spraying insecticides on a fixed schedule. However, the planthopper has developed resistance to several insecticides, with higher resistance levels reported in the Mekong Delta than in northern Vietnam (Khoa et al., 2018). Moreover, a survey of more than 5,000 households found that more frequent spraying did not generally increase yield (Heong et al., 2015).

We develop a pest-management agent-based model to analyze how spray frequency and insecticide choice affect rice yield and farm profit as resistance builds up. The model extends STAR-FARM, an agent-based model of the Mekong Delta that couples farmer decision-making with a crop model (Taillandier et al., under review), and supports the analysis of transitions towards more sustainable practices, including those promoted by Vietnam's One Million Hectares program.

In its current form, STAR-FARM represents pest invasion and spraying in a simplified way: spraying completely clears the pest population, and spray frequency has no long-term consequences. We introduce explicit mechanisms of insecticide resistance and farmer management decisions. Each local pest population develops resistance through repeated use of a compound, while resistance declines between seasons as susceptible insects immigrate from outside the field.

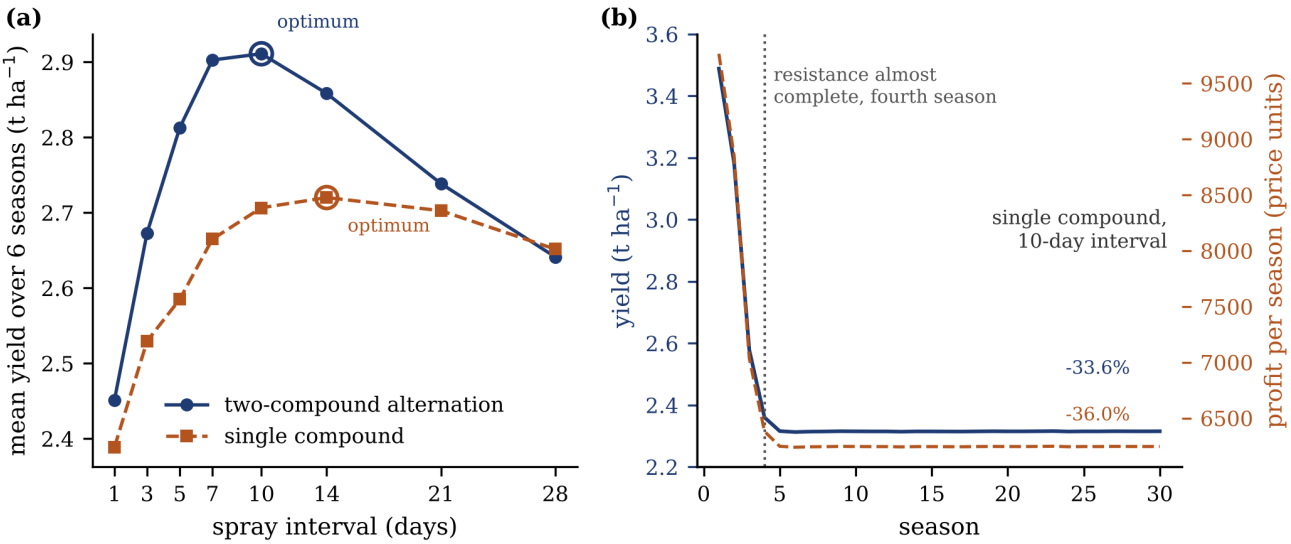

Figure 1: Spray interval, yield and profit in the resistance model. (a) Mean yield over the first six seasons against spray interval, for two-compound alternation and a single compound. The optimum is a 10-day interval under alternation and a 14-day interval with a single compound, and daily application gives the lowest yield. (b) A single compound sprayed every 10 days over 30 seasons. Yield (left) and profit (right) fall by 33.6% and 36.0% as resistance becomes almost complete by the fourth season. Profit uses placeholder values of 3000 per t and 100 per spray.

We compare three strategies (*No spray*, *Calendar*, and *Threshold*) over the long term. *Calendar* spraying applies treatments at fixed intervals, whereas *Threshold* spraying treats a field only when pest pressure exceeds a given level. Farmers may use a single compound or alternate between two insecticides from different chemical classes, etofenprox and a neonicotinoid, across successive seasons. We also consider an adaptive strategy that increases the spray interval as profit declines.

Our results show that short-term yield and long-term profit can point in opposite directions. Over the first six seasons, yield does not increase monotonically with spray frequency: daily application gives the lowest yield, while an optimum appears near a 10-day interval under alternation and a 14-day interval with a single compound. Over 30 seasons, however, this pattern is reversed. With a single compound sprayed every 10 days, resistance becomes almost complete by the fourth season, causing yield to fall by 33.6% and profit by 36.0%.

The relative performance of strategies also depends strongly on pest immigration, as incoming susceptible insects dilute resistance. At low immigration rates, no spraying performs close to the best strategies tested, whereas at higher rates, alternation with a wide calendar interval and adaptive backoff generate higher profits than no spraying. Overall, maximizing short-term pest suppression can accelerate resistance and turn an initially profitable spraying schedule into one of the least profitable strategies over the long term.

Additional material

Standalone model code: https://github.com/jpcabatingan/pest-management

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Khoa et al. (2018). Variation in susceptibility of eight insecticides in the brown planthopper *Nilaparvata lugens* in three regions of Vietnam 2015–2017. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0204962

Taillandier et al. (under review). STARFARM: A hybrid, spatially explicit agent-based framework that couples crop physiology and socio-hydrology for exploring agricultural adaptation pathways in mega-deltas. *Ecological Modelling and Software*. http://dx.doi.org/10.2139/ssrn.7275371

An agent-based model of public Junior High School choice: A case study in San Pablo City, Philippines

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Keywords

school choice, school preference, agent-based modeling

Abstract

The Philippines faces numerous educational crises affecting Filipino students, including, but not limited to, shortage of classrooms, deteriorating buildings, and high student-to-classroom ratios. In light of these conditions, examining how Filipino families decide where their child will enroll in a public Junior High School (JHS) can provide important insights into how households navigate constraints in the educational system and weigh available schooling options. This study developed an agent-based model to simulate family decision-making based on two distinct patterns of school choice (Termes, Edwards Jr, & Verger, 2020): *passive choice*, in which financial and distance constraints restrict the set of schools available to a family; and *well-being choice*, in which favorable school attributes related to comfort and safety are associated with higher overall enrollment. The model operationalizes school choice using four parameters: *proximity*, measured as the road-network distance between a student's residence and a prospective school; *crowdedness*, represented by current school enrollment; *popularity*, captured by the aggregate enrollment of nearby schools; and *classroom capacity*, proxied by the number of available classrooms. Model experiments were conducted using geospatial, residential, and educational data from San Pablo City, Philippines. The model was calibrated and validated against historical school enrollment data from 2013 to 2016 to assess its ability to reproduce empirical enrollment patterns. The initial findings demonstrate the impact of family decision-making heuristics on the student-classroom ratio within the school district, the number of school shifts, and the mean travel distance required for students to reach school.

Additional material

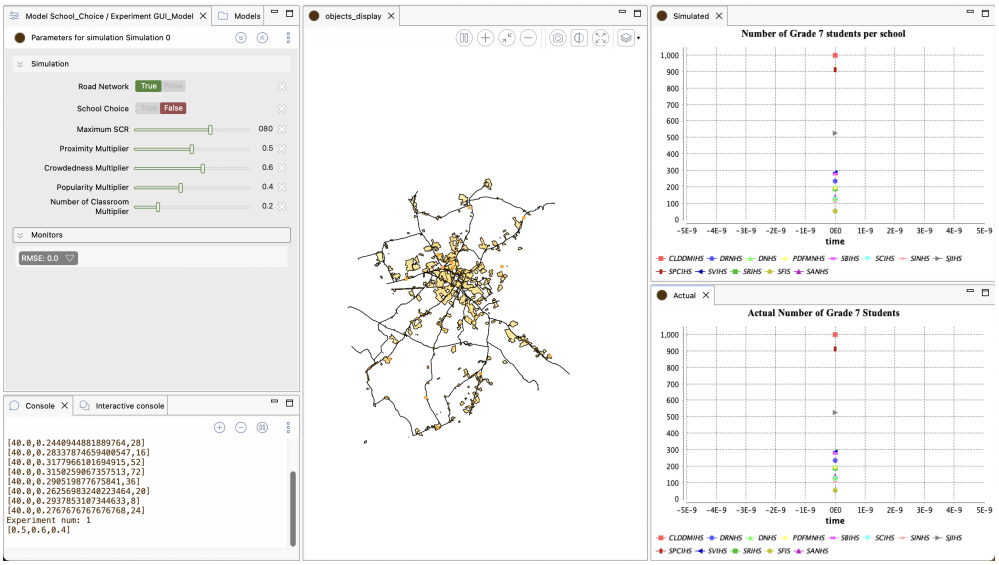

Figure 1: Philippine secondary school choice model

Termes, A., Edwards Jr, D. B., & Verger, A. (2020). The development and dynamics of public–private partnerships in the philippines' education: A counterintuitive case of school choice, competition, and privatization. *Educational Policy*, *34*(1), 91–117.

BioChains; a model for bioprocesses, biomass fluxes and logistics to simulate bioeconomy scenarii

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Keywords

Integration Assessment Modelling, Bioeconomy, Bioprocess, Logistics

Abstract

Public policy aims to mitigate climate change by decarbonizing the economy, and because of growing instabilities in the supply of some resources (fertilizers, fuel…), agriculture ought to and will have to adapt and change through the decades to come. Since the 2000s, the concept of bioeconomy has gained traction among policymakers as a possible way to structure that change, with benefits such as local economic development prospects, a decreased carbon footprint of the economy, and an increased resilience to resources supply instability[1]. At territory scale, fostering bioeconomy implies developing a network of agricultural and industrial producers, transformers and consumers of biomass. Developing such a network raises questions about the comparative viability of various scenarios in this network; their resilience, their environmental impact, their economic output, the dimensioning of bioprocess plants, and last but not least the resource competition that can arise between said plants. Those questionings call for the use of a predictive model encompassing a large spectrum of phenomena and processes at territory scale.

MAELIA[2] is an integrated assessment modelling platform used to simulate the functioning and evolution of agricultural territories under different climate and policy scenarios. While its existing modules already allow it to integrate agricultural and environmental processes, this presentation covers a newly developed module, BioChains, which introduces biomass fluxes and bioprocesses in MAELIA. As opposed to other modules from MAELIA, BioChains is designed to be able to be simulated as a standalone project[3].

BioChains implements a notion of "biomass pool", representing an actual clump of biomass with a specific type, volume, age and physicochemical/engineering variables (dry weight, proportion of volatile matter, carbon and nitrogen proportion etc.), that can be transported, stored, split or mixed with other biomass pools, hence allowing a network of modelled "units" to produce, consume, process and exchange biomass at discrete time step. At each time step, all the biomass needs of the various units are dynamically connected together using a matching algorithm (N-N Gale-Shapley[4]). The feasibility and costs of biomass transportation is thereafter determined accounting for limited vehicle pools.

In addition to arbitrary production, BioChains can also implement bioprocesses, such as a discretized version of the SysMetha model (emulating an anaerobic digester)[3]. Other ongoing projects are going to grant BioChains with composting platforms and bioplastic production units. This possibility makes BioChains able to integrate multiple instances of bioprocess models together in a spatialized territory model.

Another exciting potentiality of this new module is its use alongside MAELIA; indeed, BioChains explicitly represents biomass feedbacks in agriculture (such as with grain processing residues and livestock manures that can become fertilizers through bioprocessing), thus allowing the platform to capture the impact of the seasonal variation of biomass production on its future.

Altogether, BioChains extends MAELIA with the ability to tackle bioeconomy scenarios.

[1]: Bioeconomy report 2022 from the knowledge center for bioeconomy
[2]: Therond, O., Sibertin-Blanc, C., Balestrat, M., Gaudou, B., Hong, Y, Louail, T., Nguyen, V.B., Panzoli, D., Sanchez-Perez, J.M., Sauvage, S., Taillandier, P., Vavasseur, M., Mazzega, P. (2014). Integrated modelling of social-ecological systems: The

MAELIA high-resolution multi-agent platform to deal with water scarcity problems. In Daniel P. Ames, Nigel W.T. Quinn and Andrea E. Rizzoli (Eds.). 7th Int. Congress on Env. Modelling and Software (iEMSs), San Diego, CA, USA

[3]: BioChains, un modèle de simulation des filières biomasse pour accompagner le développement de la bioéconomie (hal-05689004v1)

[4]: Kleinpeter V., Lo Seen D., Degenne P., Lurette A., Wassenaar T., Vayssières J. (2024) A stakeholder decision and road-network-based deterministic model to simulate material flows in regional scale industrial symbioses. Journal of Cleaner Production, 434. DOI: 10.1016/j.jclepro.2023.139778

BiodiVRestorer VU2: A GAMA-Driven Virtual Reality for Biodiversity Restoration, Toward School Curriculum Integration

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Keywords

BiodiVRestorer, SIMPLE, GAMA, virtual reality, biodiversity restoration

Abstract

BiodiVRestorer is a virtual reality (VR) game-based learning tool that raises awareness about biodiversity loss and restoration. This second version (VU2) builds on VU1's success. VU1 focused on seed collection, guiding players to gather seeds according to a designated phenology and framework species approach. VU2 has been elevated into a more engaging and competitive experience, expanding its scope to cover forest monitoring. Players now learn essential forest restoration skills through gameplay, including tree sapling care, wildfire suppression, weed control, and the management of invasive alien species. A key innovation in VU2 is the integration of a GAMA-based forest growth simulation model, which serves as the core indicator of success for forest restoration efforts within the game. By simulating how forests grow and respond to player actions over time, this model transforms complex environmental dynamics into visible, measurable progress, allowing players to see the direct impact of their monitoring and restoration decisions.

The tool draws on the strong technical foundation established by the SIMPLE (Sustainability Issues Metaverse for Building Participatory Learning Environments) project. A key focus of this phase is expanding real-world application through multiple use cases tailored to different learning contexts, including one-day and half-day extra-curricular activities, exhibition booths for public engagement, and training-the-trainer sessions conducted in collaboration with a pedagogy team. This potentially supports educators in integrating the game into formal classroom curricula and ensuring its sustainability and scalability within the education system.

Additional material

https://project-simple.eu/virtual-universe/#thailand

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Figure 1. BiodiVRestorer Showcase. Implementation of the learning tool under the SIMPLE project, featuring the GAMA-based forest growth simulation model (top left), mobile AR visualization (bottom left), and immersive VR gameplay during active educational sessions (center and right)

Comparative Analysis of Evacuation Scenarios using Agent-based Modelling: The 2020 Flood Event in Vietnam

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Keywords

Agent-based modelling; GAMA; Flood evacuation; Evacuation scenarios; Dong Hoi

Abstract

Evacuation simulation and optimization are urgently needed in Vietnam, where floods have become the country's most devastating disaster and residents' evacuation behaviour remains largely subjective, lacking solid evidence to identify safe zones. This research presents an agent-based model (ABM), developed on the GAMA platform, that couples dynamic hydraulic flood progression with urban resident evacuation behaviour during the 2020 flood in Dong Hoi ward, Quang Tri Province. Using empirical flood depth and velocity data from this event, the model integrates a shapefile of approximately 41,000 buildings and the surrounding road network, and implements a non-linear hydraulic mechanism in which local inundation depth and flow velocity at each building scale dynamically with the global water level. Agent decision-making draws on a well-validated pedestrian instability function together with flood indicators, building attributes, and travel distance. Comparative analysis shows that Scenario 2 (Centralized Evacuation to People's Committee offices and schools) significantly outperforms Scenario 1 (Free Evacuation to the nearest available building), achieving a safety rate of 96.4% compared to only 58.5% under free evacuation, in which independent evacuation causes a higher casualty ratio. The model captures the spatial-temporal bottlenecks of urban emergency logistics and demonstrates that structured, public-shelter-led evacuation strategies substantially improve survivability. These findings provide an analytical foundation for further research into evacuation behaviour and support the design of optimized spatial guidance, in particular by identifying and pairing vulnerable residential zones with their nearest designated safe houses (shelters and private residences)

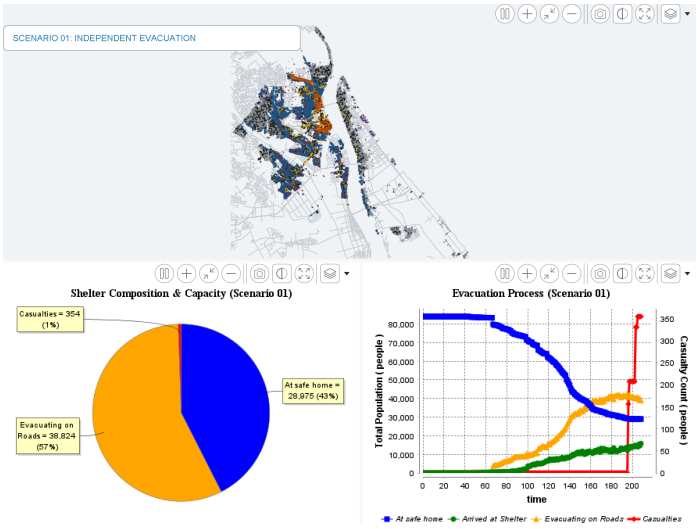

Fig. 1 Scenario: Free evacuation

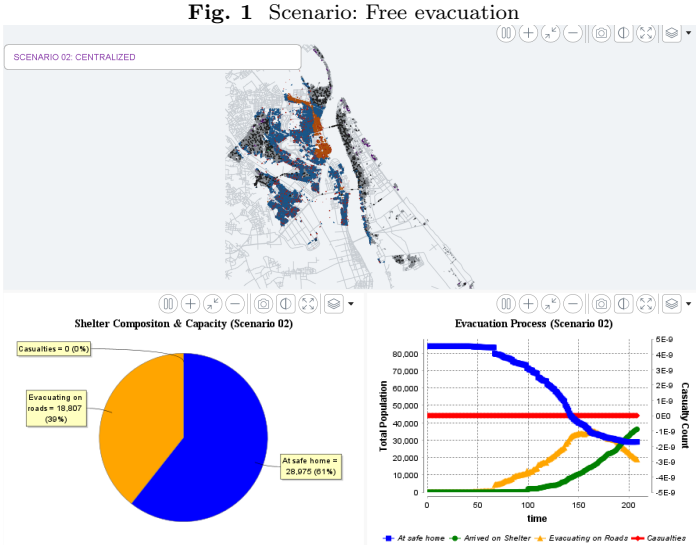

Fig. 2 Scenario: Centralized evacuation

Coupling GAMA with LLMs for Simulating Dialogues Among Agents: An Application to Farmers' Attitudes Toward Smart Water Meters

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Keywords

LLM-driven agent-based modeling, GAMA-LLM coupling, Attitude dynamics, Natural language argumentation

Abstract

Large Language Models (LLMs) offer new opportunities to simulate human-like social behavior and decision-making. A growing body of research now employs LLMs to drive agent-based models, ranging from generative agents that plan and reflect on their routines [1] to LLM-populated simulations of human survey responses [2]. Building on this trend, we present a GAMA-based agent model in which agents' attitudes toward an innovation evolve through LLM-driven peer-to-peer dialogues, where each accepted argument can potentially shift an agent's attitude.

Instead of relying on hard-coded opinion-dynamics rules, every stage of this two-agent dialogue is driven by an LLM and decomposed into three independent calls, allowing each stage to be logged and constrained separately. Within an exchange, the sender first generates an argument and, within the same call, reports whether it wishes to continue. The receiver then determines whether to accept the argument based on its profile and dialogue history, likewise indicating its own willingness to continue. If the argument is accepted, a third call estimates the extent to which it should shift the receiver's attitude score; the resulting delta is subsequently applied and bounded within GAMA.

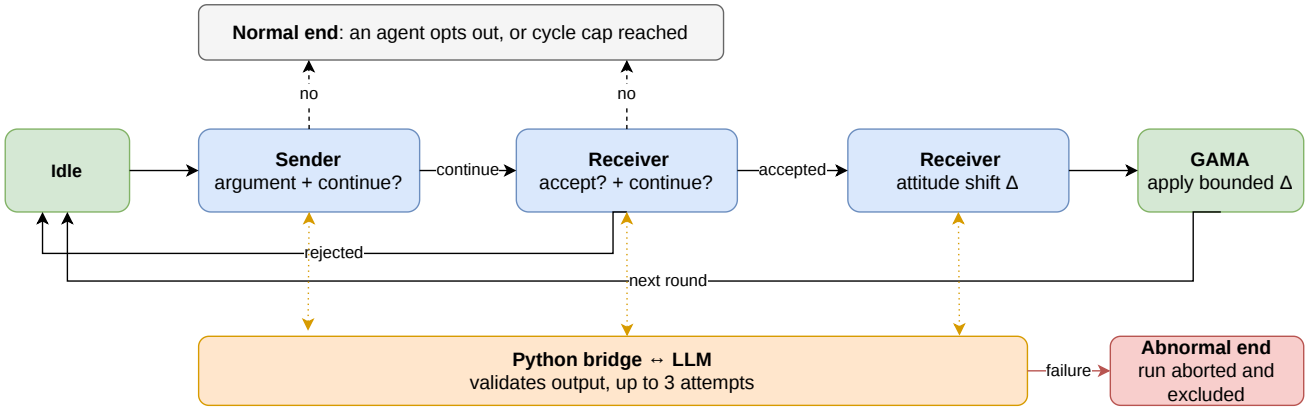

Figure 1: One dialogue round in GAMA. Blue boxes are the three LLM calls. Each call is asynchronous and spans several simulation cycles. A "no" answer ends the dialogue normally. If the bridge still fails after three attempts, the run is aborted.

To implement this in GAMA, we designed a state machine that tracks the current state of an exchange's LLM pipeline, cycling through `idle`, `waiting_generate`, `waiting_accept`, and `waiting_attitude`. This architecture ensures compatibility with GAMA's cycle-based simulation loop, as a single LLM call spans several simulation cycles before returning a response. Each agent communicates with the LLM via a lightweight Python bridge that forwards prompts and returns structured responses parsed in GAML.

Every stage is logged with a stage-specific outcome label, regardless of success. When a response cannot be parsed up to three times, the run is aborted rather than supplemented with a fallback value; a fabricated argument, decision, or attitude shift would propagate and silently corrupt subsequent exchanges—a concrete instance of the micro-to-macro validity risks recently highlighted in LLM-driven social simulations [3]. Aborted runs are flagged and excluded from the analysis.

We apply this model to farmers' attitudes toward smart water meter adoption in France, drawing on a survey of 30 farmers in the Occitanie region to examine how attitudes evolve through conversation among simulated agents.

A simulation concludes in one of two ways. It terminates normally when the cycle cap is reached or when an agent opts out during an argument generation or acceptance call—an emergent, agent-driven outcome that reflects how real conversations

naturally end. Alternatively, it terminates abnormally if any stage fails to parse or if the bridge reports an unrecoverable failure.

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Development of a Participatory Urban Design Environment Based on Stylized Representations of Urban Structure

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[2] College of Information Science and Engineering, Ritsumeikan University, Japan

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Keywords

Participatory Simulation, Urban Design

Abstract

Cities, where diverse people live and interact, are among the most complex artificial systems. Because urban dynamics emerge from accumulated local interactions between individuals and their surrounding environment, it is difficult to predict in advance how a planned environment will be used and what value it will generate.
Multi-agent social simulation (MASS) is an approach to estimating collective behavior in a prospective urban environment and to finding optimal solutions for urban design. Its bottleneck lies in defining suitable objective functions for optimization. Hopes and desires vary widely among people in human societies. As a result, MASS-based optimization rarely yields socially acceptable solutions.
We have tried to tackle this issue by introducing a participatory approach. We expect this approach to elicit diverse desires and preferences from stakeholders and to help them understand how difficult it is to design the structures, policies, and systems of a city. We are developing a space where a range of stakeholders can discuss how to design a city, by harnessing GAMA and CityScope. As part of this effort, we report our ongoing development of a participatory MASS environment. It represents a target city with stylized urban structure data, which may make the environment easier for stakeholders to accept and engage with.



Figure 1: CityScope and MAS Environment

Distributing GAMA Simulations on HPC Clusters with the Distribution Model

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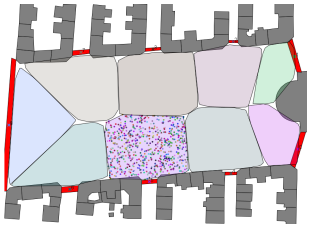
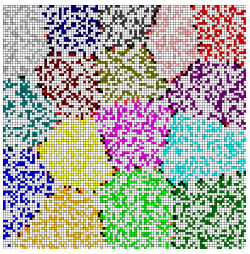
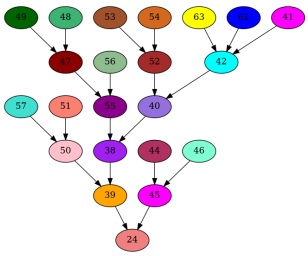
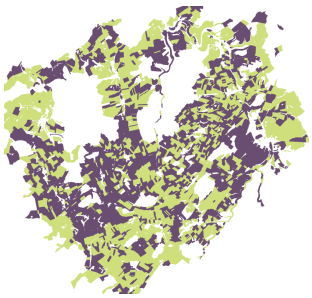
Keywords

Agent-Based Modeling, High-Performance Computing, Distributed Simulation









Abstract

Large-scale agent-based models (ABM) increasingly require distributed execution on high-performance computing (HPC) clusters to explore larger populations, finer spatial resolutions, and wider parameter spaces. Adapting an existing ABM to a distributed architecture usually forces modelers to rewrite simulation code, entangling domain logic with low-level concerns such as partitioning, load balancing, communication, and synchronization, which raises the barrier to HPC use and complicates model maintenance and validation.

We present the concept of **Distribution Model**, built on the principle of Separation of Concerns [1, 2]: a way to distribute the execution of an agent-based model (ABM), called the **Thematic Model**, across compute nodes without modifying its core model code. A dedicated distribution layer, composed of Partitioning, Communication, Load-Balancing and Synchronization agents, takes in charge the distributed execution of the Thematic Model, so that the modeler keeps working with the model as originally written, requiring only limited configuration rather than in-depth parallel-computing expertise.

We apply this concept to the GAMA platform [3], first on toy models, Prey-Predator and Evacuation [2], then on real-world models, CAMMISOLE [2], SWAT [4] and MAELIA [5]. Across these models, originally designed for single-machine execution, the Distribution Model enables execution on HPC clusters with limited overhead [6], improving both scalability and performance.

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Evaluating Green Streetscape Interventions with GAMA: Pedestrian, Vehicle, and Ecological Trade-offs in Gowanus

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Keywords

GAMA, Agent-Based Modeling, Urban Mobility, Pedestrian Behavior, Green Streetscape

Abstract

Urban streetscape interventions can simultaneously affect pedestrian activity, vehicle mobility, and ecological performance. These effects emerge through changes in individual route choice and use of public space, processes that agent-based models can represent through heterogeneous behavioral rules and spatial interactions (Filomena et al., 2022). Prior studies have also shown that environmental features and individual preferences can influence pedestrian route choice and activity patterns (Wozniak 2026). This study develops a spatial agent-based model in GAMA to examine the mobility and environmental effects of tree planting and street-space reallocation in the Gowanus neighborhood of Brooklyn, New York.

The model integrates geospatial data on the street network, buildings, district gateways, the Gowanus Canal, and individual trees with pedestrian and vehicle agents. Pedestrians represent commuters, local travelers, scenic walkers, and active users, with route and dwell decisions responding to trip purpose, network conditions, tree density, and proximity to the canal. Vehicle agents travel between buildings and gateways under scenario-specific roadway constraints. This behavioral structure is informed by prior pedestrian ABM research emphasizing heterogeneous route-choice strategies and responses to environmental attributes.

GAMA provides a common spatial environment for modifying network conditions, generating agents, calculating routes, simulating movement and dwell behavior, and comparing outcomes across scenarios. Our analysis compares three scenarios structure the comparison: S1 represents the existing condition with 842 trees; S2 adds 176 trees while retaining the baseline street configuration; and S3 combines the same 1,018 trees with sidewalk widening and roadway-space adjustments. S2 provides a tree-planting-only comparator, allowing S1–S2 comparisons to examine additional planting and S2–S3 comparisons to examine the added street-space intervention (Figure 1). The simulation is configured to run continuously, and the reported mobility outcomes were averaged over three runs, with outputs recorded after two minutes of elapsed runtime in each run.

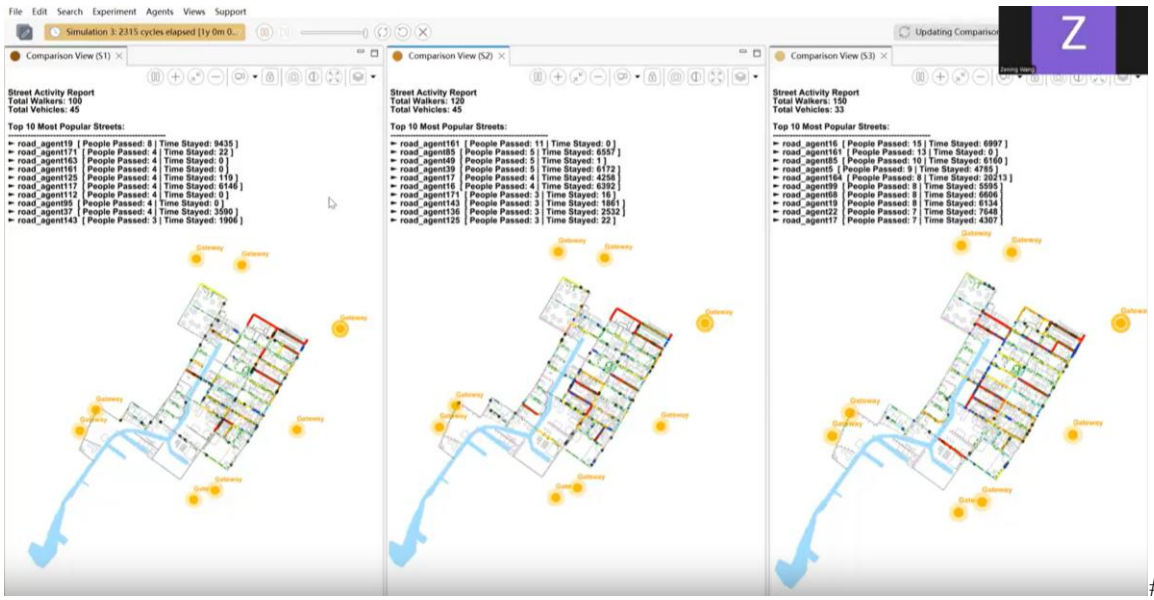

Figure 1

The current scenario outputs indicate substantial cross-domain effects. Compared with S1, the combined S3 intervention increases simulated pedestrian pass-through activity by 41.5% and average pedestrian dwell time by 83.1%. Completed vehicle trips decrease by 10.7%, consistent with additional constraints on roadway movement, while modeled localized emissions decline by 14.9%. The additional and repositioned tree canopy also improves modeled ecological performance. These results quantify the gains and mobility costs that emerge when planting and hardscape changes are assessed as one intervention (Figure 2).

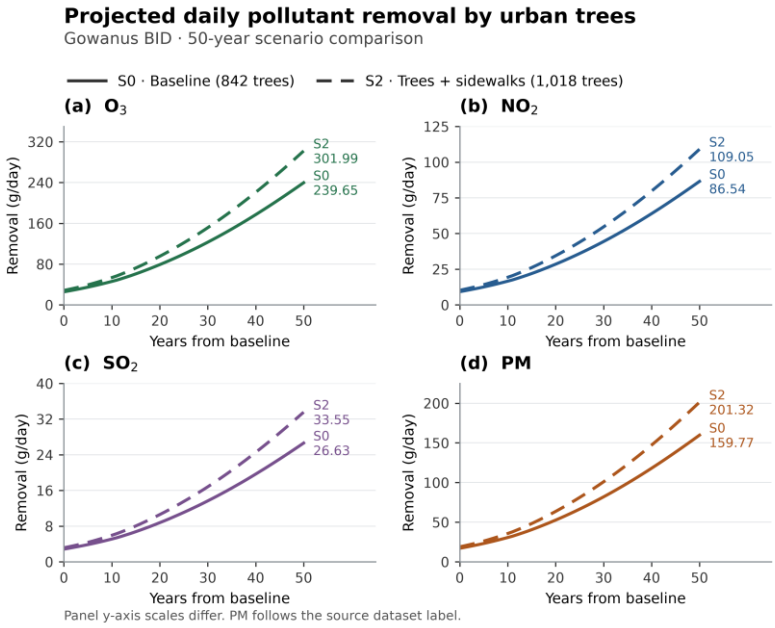

Figure 2

Together, the contribution is an integrated method for illustrating potential trade-offs between pedestrian activity, vehicle trip completion, and tree-based pollutant removal. The framework could also support discussions among community organizations and transportation agencies by making these modeled outcomes explicit before implementation. In this role, GAMA supports both technical evaluation and negotiation over limited street space, linking urban goals with pedestrian mobility, commercial activity, and transportation access.

Additional material

Filomena, G., et al. (2022). *Empirical characterisation of agents' spatial behaviour in pedestrian movement simulation*. Journal of Environmental Psychology, 82, 101807.

Wozniak, M., & Filomena, G. (2026). *Beyond urban form: Introducing dynamic factors in agent-based simulations of pedestrian movement*. Computers, Environment and Urban Systems, 128, 102439.

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https://github.com/Cornell-Tech-Urban-Tech-Hub/uds26_team3/tree/main

Exploring Future Giant-Clam Trade and Conservation Trajectories Using a CITES-Informed Agent-Based Model

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Keywords

Wildlife Trade Modeling; Giant clams; CITES Trade Data; Conservation policy; Agent-based Model

Abstract

Giant clams are ecologically important marine organisms traded internationally and facing increasing conservation concern, with populations reported to have declined by more than 80% over the last century. The CITES Trade Database, established under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), provides the most comprehensive and authoritative record of reported international wildlife trade, including the giant-clam trade with records from 1986 to 2023 (see Fig 1). However, these records alone offer limited insight into how trade, governance, enforcement, and resource conditions interact over time or how these dynamics may respond to future policy interventions. To address this gap, we developed a historically grounded agent-based model that functions as a digital policy laboratory for exploring how alternative policy interventions may shape future trade and conservation trajectories. The model integrates historical transaction replay with synthetic simulations based on exporter–importer, exporter–taxon, and regulatory relationships. Following calibration and validation, we used the model to project trade trajectories from 2024 to 2050 under three policy scenarios: (1) a business-as-usual baseline, (2) strengthened governance and enforcement, and (3) an integrated conservation and demand-reduction strategy. Each scenario was evaluated across 100 stochastic replications, with simulated trade volumes compared at three future benchmark years: 2030, 2040, and 2050. Preliminary results suggest that stronger governance and enforcement improve institutional control but have limited effects on simulated trade volume. In contrast, integrating conservation with demand reduction substantially reduces projected trade and sustains these gains through 2050. This integrated strategy consistently outperformed baseline and governance-only scenarios across replications, although uncertainty remained substantial. Our findings suggest that strengthening governance and enforcement alone may be insufficient when demand and ecological pressures persist, whereas integrated interventions that combine institutional reform, demand reduction, reduced trade pressure, and ecological recovery may produce more sustained conservation benefits. More broadly, the study demonstrates how historically grounded agent-based modeling can complement reported trade data by providing a transparent framework for testing alternative policy pathways and their long-term consequences for wildlife trade and conservation.

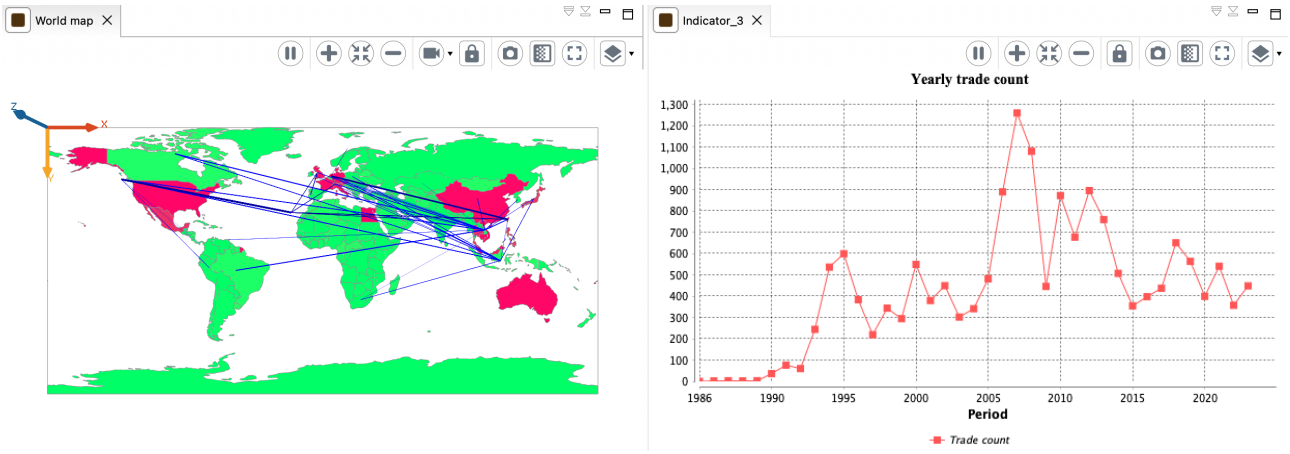

Figure 1: Spatial distribution and temporal dynamics of reported international CITES trade in live giant clams (1986–2023)

Exporting standalone GAMA simulation, from an IDE project to a simplified executable usage

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Keywords

GAMA Platform, Software engineering, Simulation deployment, Packaging

Abstract

The GAMA Platform [1] is an *Integrated Development Editor (IDE)*, an expert software developed and designed for researchers and modelers. Therefore, the use of a GAMA simulation requires some prior knowledge on how to use such a platform before being able to execute a model. This comes as a constraint when the project needs to be shared to people with no background or expertise in computer science or software development (eg. other researchers, stake holders, etc).
Therefore, this contribution proposes a technical solution answering the need of a simple approach for sharing GAMA projects with a functional plugin dedicated to exporting GAMA simulations as independent applications that can be run without needing the GAMA platform, Java or any prerequisite to be installed on the target machine.
The plugin automatically takes care of embedding all the necessary files (i.e., models, assets, and other technical dependencies) in the export, allowing modelers to easily create a GAMA *application* to share. Moreover, the plugin is able to export a project containing multiple models and experiments, and features the possibility of embedding a *Java Development Kit (JDK)* to the export, as well as exporting projects as a single, standalone, native executable file. Overall, the work has been focused on reducing the amount of complexity exposed to the modelers and actions required to build and run simulation exports.
This presentation introduces the features, export configuration, and limitations of the plugin, as well as providing some details on the inner workings of the export plugin and the applications produced.

Additional material

https://github.com/gama-platform/gama/tree/start_on_simulation

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FastBathtub - a fast, interactive, reduced-complexity flood-inundation agent-based model implemented in GAMA

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Keywords

flood, simulation, modelling

Abstract

Flood simulation can provide an important environmental component for agent-based models addressing evacuation, traffic, emergency response, risk communication, and participatory planning. However, detailed hydrodynamic models are often computationally demanding and can be difficult to integrate into interactive simulations. This work presents FastBathtub, a reduced-complexity flood-inundation model implemented in GAMA and designed for fast, interactive, and agent-based simulation. FastBathtub simulates the spatial evolution of flooding using terrain elevation, hydrologic connectivity, flood propagation constraints, and changes in river water level. Rather than solving the complete shallow-water equations, the model relies on a simplified representation of flood accessibility and propagation across the landscape. This approach aims to preserve the main spatial characteristics of inundation while maintaining computational efficiency and allowing the flood state to evolve dynamically during the simulation. The model also represents flood-protection infrastructure such as dykes and supports changes in their state, including breach events. Such modifications alter the accessibility of the floodplain and consequently affect subsequent flood propagation. Because the model is implemented directly in GAMA, water depth, flooded areas, infrastructure, and environmental conditions can be accessed and modified by other agents during simulation. FastBathtub has been applied to flood scenarios in Quang Binh, Hanoi and Phu Tho. These experiments show that the model is able to reproduce the main spatial patterns of flooding while providing substantially faster simulations. The objective is therefore not to replace detailed hydrodynamic models, but to provide a lightweight alternative for applications where interaction, scenario exploration, and coupling with agent behaviour are more important than high-resolution hydraulic accuracy. The demonstration presents the implementation and execution of FastBathtub in GAMA, including flood propagation, evolving water depth, flood-protection infrastructure, and dynamic breach events. The model can serve as an environmental layer for simulations involving residents, vehicles, emergency services, decision-makers, or other agents. It therefore provides a reusable basis for interactive flood-risk simulations, educational applications, participatory modelling, and rapid exploration of flood-management scenarios within the GAMA platform.

From Iterated Prisoner's Dilemma to Design Standards: Which Laws of Cooperation Hold When Combined?

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Keywords

evolutionary game theory, iterated Prisoner's Dilemma, agent-based modelling, psychoergonomics, architectural design

Abstract

Evolved patterns of cooperation and socialisation, formalised in evolutionary game theory (EGT), are increasingly invoked to explain how the built environment shapes social behaviour. Before such patterns can inform design standards, one step of the translational path is rarely taken: checking whether the theories they rest on are compatible with one another.

EGT offers a common language for this test. Many behavioural-biology models of cooperation have been written in game-theoretic form, which translates directly into autonomous agents and GAMA submodels, although spatial and individual-level implementation can change their predictions. Direct reciprocity, a central route to cooperation among non-kin, hinges on memory: individuals must recognise one another, remember past encounters, and track each partner as a separate, ongoing game. Axelrod's iterated Prisoner's Dilemma made this one of the founding problems of agent-based modelling.

Decades of such models, together with empirical work, have produced regularities often cited as general. Under frequency-dependent selection, populations can stabilise with a minority of defectors, a result some authors link to the prevalence of psychopathy. Unconditional altruists persist only under specific conditions, such as drift, mutation or spatial clustering. Hamilton's rule ($rB > C$), in its predictive form, states when selection favours helping relatives. Dunbar's number posits a cognitive limit on stable relationships. These regularities were largely established separately, and several remain contested. Using them jointly to inform design silently assumes their mutual compatibility, the horizontal compatibility problem that arises at every stage of psychoergonomic translation.

We address it with a Spatial Iterated Prisoner's Dilemma (SIPD) model in GAMA/GAML. Agents move through a GIS-based street network and either follow classical strategies, including unconditional cooperators and defectors, or learn through Q-learning with location-reputation states and a decaying character anchor. A disorder field couples behaviour to place. We extend this testbed with two switchable modules: a cap on partner memory operationalising Dunbar's limit, and an evolutionary strategy-update rule that lets the shares of defectors and altruists emerge rather than be seeded. Relatedness-weighted payoffs, needed to test Hamilton's rule, are the next planned module. An ablation design tests the modules in combination.

The question is whether these regularities reinforce one another or whether the combined model breaks down. The model tests internal consistency, not empirical truth: a breakdown may reflect conflicting assumptions or implementation choices, including spatial structure itself, and identifying which is part of the result. Regularities that survive combination are candidates for robust design constants; those that conflict are better treated as context-dependent parameters requiring empirical calibration. Either outcome yields falsifiable hypotheses of the kind a science of architectural design requires, narrowing in silico what must later be tested with people.

We present the model architecture, the design of the compatibility experiment and first results of the extended model, showing how GAMA's species and experiment facilities support modular switching of theoretical assumptions. Dunbar's limit, in particular, opens a route from cooperation dynamics to spatial measures of neighbourhood resilience.

From Relief Camp to Slum or City: in silico testing of how socio-spatial moderators steer migrant co-adaptation between criminalisation and self-revitalisation

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Keywords

Psychoergonomics; slumsification; self-revitalisation; evolutionary game theory; urban social resilience

Abstract

Temporary settlements, from relief camps to corrugated-iron districts, often consolidate into permanent slums, now home to 1.12 billion people, two and a half times the EU population. Reflecting a demographic asymmetry, fertility in low-income countries is nearly fourfold that of high-income ones. After 2029 the EU population will fall from 453 to 399 million by 2100, while admitting over 100 million immigrants, almost one fifth of future residents. Adaptation to local patterns takes time. When inflows exceed a city's resilience threshold, urbanisation turns into criminalisation and slum formation. This wicked problem lacks both an interdisciplinary explanation and a validated resolution procedure. We treat it as a challenge, not a verdict.

We adopt a psychoergonomic perspective: urban social resilience arises from the socio-spatial environment to which migrants co-adapt, and even a minimal, cost-free organisational-architectural intervention may steer this process towards urban culture rather than criminalisation. We test cognitive hypotheses and socio-engineering regeneration doctrines in silico on the GAMA Platform, without risk to humans.

Agent rules derive from evolutionary game theory (EGT): iterated prisoner's dilemma strategies, kin selection (Hamilton) and cognitive limits on social closeness (Dunbar), adapted to human interaction under the science of behavioural change and the neuroscience of habit formation. Digital twins of built environments are widespread but lack bio-behavioural twins of people; we fill this gap, a barrier to a science of architectural design.

The prototype models food-aid distribution in a tent camp, delivered every few days. During secondary distribution, hungry agents may steal, leaving others hungry – often a taboo in humanitarian logistics. Agents rank acquaintances by interaction history into Dunbar circles (5, 15, 50, 150). Closeness and kinship reduce theft and increase helping; theft lowers cooperation towards the perpetrator, while closeness favours forgiveness. Rules evolve with experience: those without food steal from strangers, those with food protect their own.

EGT models reproduce expected transformation trajectories of individuals and populations. Cooperation persists where stable local ties form, reinforced by layouts supporting small trust networks. Yet close groups do not exceed about 50 people: ties that traditional societies matured over isolated generations are here disrupted by competing networks. Such a tribe is an alliance both defensive and conflictual, challenging planning models deriving cooperation from residential proximity. The model is calibrated on Kibera (Kenya) data and validated against long-term outcomes of past regeneration interventions, analogues of socio-spatial experiments.

Next simulations test: (1) moderators of micro-groups of 5–15 people sharing space and a defensible resource, e.g. a sanitation module with clean water; (2) wide, straight avenues supporting small-scale entrepreneurship, whose participants build mutual protection against theft and gang dominance; (3) dividing the slum by avenues into autonomous zones where moderate but broad cooperation may emerge – a nucleus of public order.

The same mechanisms that under scarcity produce organised crime may, when moderated, trigger self-regeneration: not through costly aid but through mutual support among close kin – from family self-sufficiency, through economic activity, to urban culture. In silico experiments frame slum formation in bioscientific rigour, within the science of architectural design.

From Simulation to Situated Experience: Coupling GAMA and Unity for Immersive Tsunami Risk Awareness in Mayotte

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Keywords

Virtual reality, Serious game, Tsunami evacuation, scientific mediation

Abstract

Building on the SIMPLE toolchain, which links a running GAMA simulation to a Unity 3D environment, an immersive perspective on an agent-based evacuation model of Mamoudzou [2] is proposed: the idea was to push the model's impact beyond purely scientific quantitative results, and to bring research outputs to an audience of secondary-school students. This contribution presents the resulting multi-role serious game. The device distributes play across three asymmetric roles, each mirroring one of three dimensions of an abstract alert chain: the *Network*, a set of monitoring teams holding knowledge about various aspect of alert and evacuation through paper reference sheets (bottom-up alert phase); the *Post*, a communal command-centre operator receiving abstract signals of varying sources and reliability on a computer (top-down alert phase); and the *Field*, the VR player embodying a Mamoudzou resident who must observe, document and ultimately evacuate (the last phase of population response). The gameplay unfolds in two phases: a pre-alert phase centred on detecting tsunami precursors (sea withdrawal, tremors, abnormal animal behaviour), whose collective quality sets the initial alert condition (degraded / normal / optimised) of the second phase — the 10–20-minute evacuation itself, driven by the GAMA model.
A central aim of the work is to show how methodological tools from video game design can turn a simulation into more engaging content and increase scientific mediation potential. Rather than exposing information through text or graphics, the design embeds it in rules and consequences [1]: correctly observing and reporting a precursor measurably accelerates the simulated evacuation, missing it slows it down. In doing so, the game pushes forward one specific capability of the SIMPLE toolchain: *asymmetric gameplay*. Each role is tied to a distinct interface and a distinct slice of information. The Field player wears a VR headset and experiences the event from the ground, with direct perception but little context. The Post operates the GAMA user interface — a GIS "god view" of the territory — yet with limited knowledge of what actually happens on the ground. The Network has no digital interface at all: it relies on a rich set of thematic sheets on tsunami precursors and evacuation, and can only contribute by transmitting interpretations and framing others information. Asymmetric cooperation thus becomes the core of the experience, and mimics how several real-world actors must chain their partial clues and actions together to make the best of the whole alert-then-evacuation sequence.
Beyond awareness-raising, the work illustrates how GAMA, through SIMPLE, can act as a live back-end for scientific mediation, exposing what the model computes — reaction delays, alert timing, evacuation dynamics — as perceptible, causally linked consequences. We discuss the technical and design implications of this coupling, the interest of feeding gameplay with quantitative simulation outputs, and current limits; that is, the vertical slice has not yet been evaluated with the target audience, and its pedagogical hypotheses remain to be tested in classroom settings.

Additional material

Github repository of the project

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From Urban Design to Population Health: Agent-Based Modelling as a Translational Medicine Tool

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Keywords

Psychoergonomics; Agent-based modelling; Translational medicine; Urban planning; Physical activity

Abstract

Physical inactivity is a major modifiable risk factor for cardiovascular and other non-communicable diseases, while opportunities for everyday movement are strongly influenced by the built environment. This study proposes that urban planning can be approached through the framework of translational medicine, where established knowledge about health needs and disease prevention is translated into environmental interventions and ultimately into measurable population-health outcomes.

The proposed approach uses GAMA to simulate how different urban design concepts may influence the development of physical-activity habits. The simulation environment is constructed from spatial data describing street and pedestrian networks, buildings, recreational areas and other relevant urban features, combined with demographic data used to create a heterogeneous virtual population. Each agent represents an individual resident and accumulates its own experiences while moving through the environment. Positive and negative experiences modify the probability of undertaking future physical activity, allowing motivation and behavioural habits to develop over time. This individual-level mechanism is a major advantage of ABM: population outcomes emerge from the accumulated experiences and decisions of individual residents rather than from an assumed statistical average.

Alternative residential-neighbourhood designs can therefore be compared by estimating the proportion of agents reaching a predefined physical-activity threshold, operationalized in the model as approximately 30 minutes of daily activity, and by observing how this proportion changes over time. Different street layouts, pedestrian connections, access to recreation or other design interventions can thus be treated as environmental analogues of preventive health interventions. A proposed metric can be used to compare project variants according to their capacity to support health-promoting behavioural change at population level.

This approach can be positioned within the translational continuum. Knowledge linking physical activity with disease prevention provides the mechanistic and clinical foundation (T0–T2). Agent-based simulation translates this knowledge into testable environmental interventions and can support their implementation in planning practice (T3). Aggregated behavioural effects, expected reductions in disease burden and potential economic savings can then be interpreted as T4 population-health outcomes. Observations from implemented projects may subsequently be used to refine behavioural assumptions and simulation rules, providing a pathway for reverse translation.

Agent-based modelling may therefore provide a practical bridge between medical knowledge and urban design, allowing investments in pedestrian infrastructure and other activity-supporting environments to be evaluated not only as spatial improvements, but also as investments in prevention and long-term population health.

GAMAX: Compiling GAML Models to JAX for Faster Simulations

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Keywords

Agent-based simulation; GAML; Compilation; JAX; Differential testing; GAMA Platform

Abstract

A modeling study in GAMA rarely relies on a single run: estimating stochastic variability, exploring parameters, or calibrating a model all require many simulations, and their cost quickly becomes a bottleneck [6]. Array-oriented frameworks such as JAX [3] make repeated executions cheap by compiling pure functions, as JaxMARL shows for multi-agent environments [5]. Moving a GAML model to such a backend, however, raises a question that speed alone cannot answer: is the faster program still simulating the same model?

ABM compilers such as OpenABL [1] and GPU frameworks such as FLAME GPU 2 [4] reach high performance, but from their own languages, not from existing GAML models. JAX versions of models are usually rewritten by hand and must be validated again for every model, while interoperability layers such as gama-pettingzoo [2] keep the native engine in the loop.

We present GAMAX (Figure 1), a compiler that automatically translates a supported subset of GAML into standalone Python/JAX simulations. Sources, imports and assets are left unchanged; an external configuration only selects parameters, seeds and capacities. Since GAMA executes agents one after the other, ordered selections, births, deaths and conditional random draws all depend on this sequence. GAMAX therefore lowers each model through a typed intermediate representation that makes the order of effects and random draws explicit, so that agent scheduling and identities follow the native engine. Constructs outside the supported subset are rejected with a diagnostic that points to the offending location, rather than being silently approximated. An optional optimizer then applies generic rewrites only when their premises hold. Premises that depend on the simulation state are checked at run time, and the original computation is used otherwise. The generated module exposes reset and transition functions and runs without GAMA or a Java virtual machine.

The native GAMA engine is used as a differential oracle. Both engines run the same configurations and seeds, and their states, identities and outputs are compared cycle by cycle. We evaluate GAMAX on six complete models from the official GAMA library: spatial SIR, Schelling, Boids, a one-road traffic model, predator–prey and ant foraging. Against GAMA 2025.06.4 on ten seeds and 100 cycles, the generated programs reproduce all discrete states and agent identities exactly, and all 265,947,945 compared floating-point values stay within fixed tolerances. Performance is measured only on these conforming configurations, and the measured time includes compilation and startup costs. Across two CPU campaigns totalling 840 trajectories, once startup is amortized, every model runs faster than GAMA when frames are rendered, by factors between 1.06 and 7.63. Without rendering, Schelling remains slower than GAMA.

These results show that a scoped GAML-to-JAX compiler can speed up existing models while preserving their native trajectories. Because the six models also guided the development of the compiler, generalization to arbitrary GAML programs remains to be established. At GAMA Days, we will present the approach, show a model being compiled and checked against GAMA, and discuss with the community which GAML constructs and models should be supported next.

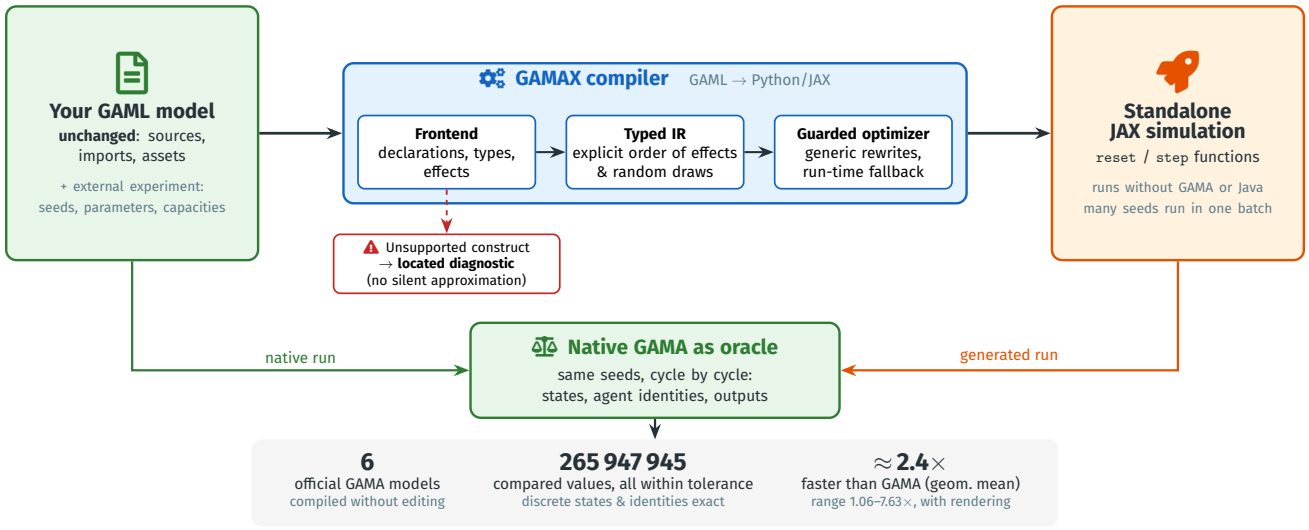

Figure 1: Overview of GAMAX. An unchanged GAML model is compiled into a standalone JAX simulation; constructs outside the supported subset are rejected with a located diagnostic. The native GAMA engine serves as an oracle: both runs are compared cycle by cycle, and only conforming configurations enter performance measurements. The speedup is the geometric mean over the six models of the batch-time ratio with rendering.

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Hoarding or Solidarity? An Agent-Based Simulation for the Self-Regulation of Shared Water Resources

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Keywords

Water Management, Human Right to Water, Water Governance, Self-regulation , Agent-Based Modeling

Abstract

This research develops an agent-based model for the governance and management of community resources. The aim is to design simulation scenarios that demonstrate how collective action regarding a shared resource, through the self-regulation of consumption, can extend its availability. This objective responds to a broader gap in resource governance: the technical feasibility of shared infrastructure is insufficient unless accompanied by social viability and community governance. Formal regulation is not always present or enforceable, so understanding whether awareness alone can sustain collective self-regulation has implications beyond any single resource or setting.

Specifically, this study addresses the following research question: Under what conditions can community awareness and social interaction among households enable the self regulation of water consumption and prevent the depletion of a shared water reserve? To answer this, in the model, a shared cistern is replenished by local precipitation that varies stochastically by season. Households (agents) observe two things: the consumption of their neighbors and the cistern's remaining volume. Based on that visibility, agents shift along a spectrum from hoarding to sharing. The direction of that shift depends not just on scarcity or need, but on each agent's fixed level of social consciousness, which determines how strongly need translates into hoarding: a high consciousness agent facing real scarcity may still act cooperatively, while a low consciousness agent may hoard even when its own need is limited. The governance mechanism under study is awareness itself: regulation, if it emerges, comes entirely from what agents can see of each other and of the shared stock, filtered through this individual disposition, rather than from external allocation rules. This structure is designed to be generalizable beyond water, capturing how visibility of a shared resource and of others' use of it shapes cooperative versus extractive behavior in any common pool setting.

The model is applied to the implementation of community based rainwater harvesting systems in the Guadalajara Metropolitan Area (AMG), Mexico, specifically in La Martinica neighborhood, an informal settlement where the local government cannot provide full public services to its residents. Given the increasing water stress and the need to guarantee the human right to water, stored water in community cisterns becomes a common pool resource outside the direct management of traditional water utilities. In the absence of a formal regulatory authority, a social dilemma associated with the "tragedy of the commons" may emerge, as households may prioritize individual consumption and hoarding, potentially depleting the shared reserve before the next rainfall recharge. The research asks whether visibility of neighbors' consumption and of the cistern's remaining volume is sufficient for households to self regulate and delay that depletion.

Preliminary simulation results, run across three comparative scenarios with a population of 120 households and a per-household consumption target of 100 L (WHO benchmark) under a medium consciousness level, confirm that cooperation responds inversely to resource availability. In a dry year (84% of average precipitation), the full population remained cooperative, and this level of cooperation stayed stable for approximately 150 days. In a wet year (122% of average precipitation), cooperation dropped by 20 households, and the reserve's duration shortened by approximately 20 days relative to the dry-year scenario. The model shows self-regulation to be a response to scarcity, not a stable outcome of resource abundance.

Additional material

Model source code and GAMA simulation repository: `https://github.com/CityScienceLab-GDL/lluviagdl.git`



Figure 1: Visualization of the agent-based model of the Martinica case study, simulating an informal community dependent on a main water supply cistern.

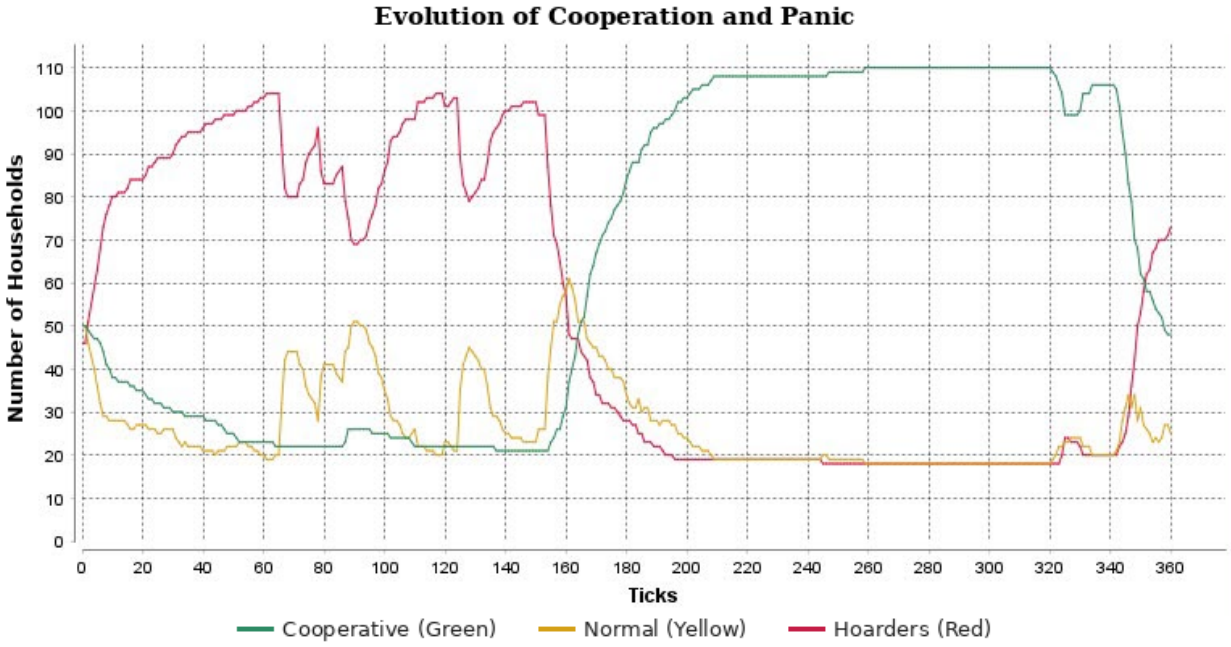

Figure 2: Community cooperation and household water deficit under an optimal consumption scenario in a dry year (84%). An increase in collective action is observed in response to resource scarcity, reducing the number of affected households.

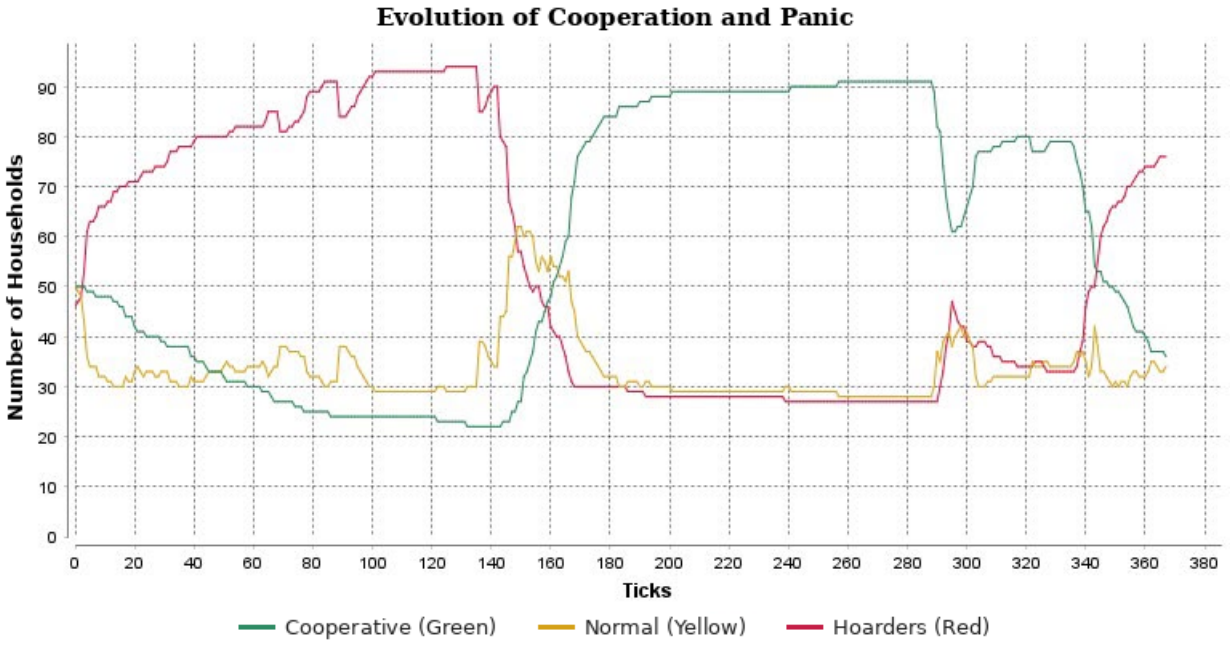

Figure 3: Community cooperation under an optimal consumption scenario in a wet year (122%). A decrease in collective action is observed given the greater availability of the resource.

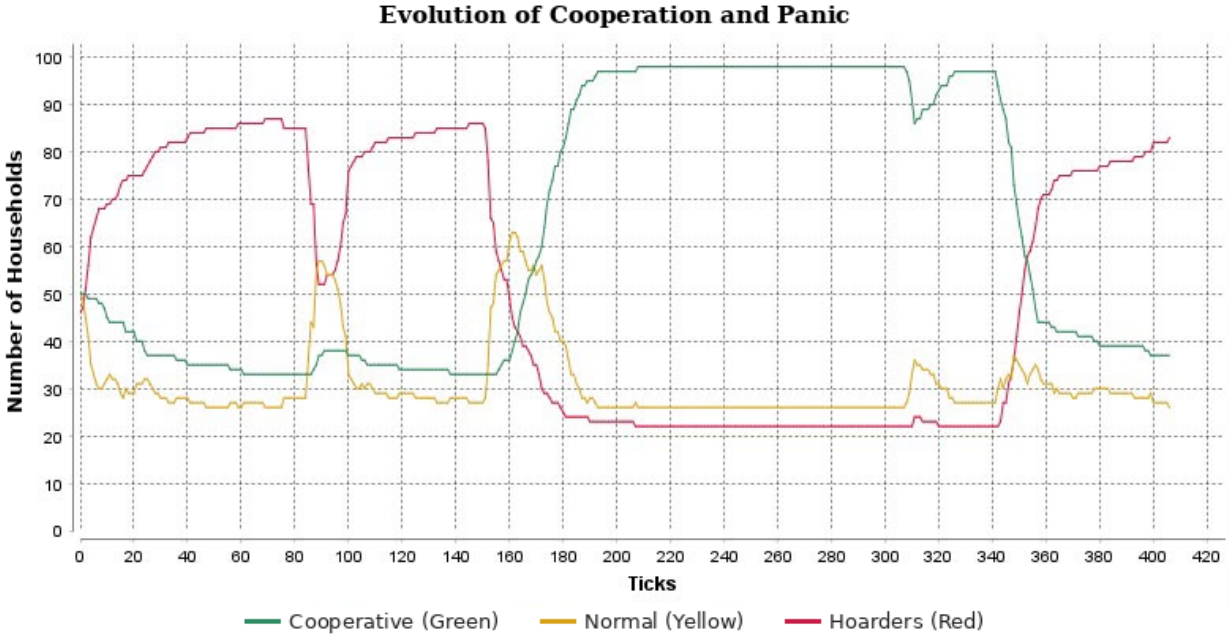

Figure 4: Community cooperation under an optimal consumption scenario in a normal year (99%). The declining trend in collective action as resource availability increases is confirmed, albeit less pronounced than during the rainy season.

Hybridization of conceptual modeling and agent-based simulation in a context of climate change-related crisis management

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Keywords

Disaster risk management, Agent-Base Modeling, Model-Driven Engineering, R-IO Suite, GAMA

Abstract

The increased frequency and complexity of crises due to climate change make crisis management increasingly dependent on the ability to anticipate the consequences of decisions in dynamic and uncertain environments, particularly for threatened populations. Decision-support systems can assist crisis stakeholders by structuring available information into a Common Operational Picture (COP), identifying potential courses of action, and supporting operational planning (Barthe-Delanoë et al. 2025). However, such systems generally rely on conceptual representations of situations and actions, which may not fully capture the emergent and unpredictable behavior of populations during a crisis. Agent-based simulation offers a complementary perspective by explicitly representing individuals and their interactions, making it possible to explore how situations evolve and populations react to interventions (Carles et al. 2025).

Model-Driven Engineering (MDE) and Agent-Based Modeling and Simulation (ABMS) provide complementary approaches to representing complex systems. MDE uses models as primary artifacts to structure domain knowledge at different levels of abstraction and transform it into more concrete representations. ABMS represents systems through autonomous and heterogeneous agents whose interactions can generate emergent behavior. Their hybridization can therefore combine structured and operational knowledge with the ability to explore its dynamic and emergent consequences. In crisis management, conceptual models can represent situations, actors, constraints, and intended actions, while agent-based models can explore how these elements evolve through interactions between individuals and their environment. This creates a feedback process in which situational awareness guides simulation, while simulation results provide information for revising the conceptual representation and subsequent decisions.

To explore and assess this approach, we use two software programs implementing these paradigms: R-IO Suite[1], a decision-support software designed to represent crisis situations and stakeholder actions according to a defined operational framework (Congès et al. 2024), and GAMA, an agent-based simulation platform. Their combination is investigated as a means of improving the preparation and adaptation of crisis management plans.

Several conceptual and technical challenges have been identified. The first concerns the conceptual and semantic alignment between the models used by R-IO Suite and GAMA. The second concerns differing temporalities, including discrete versus continuous time and synchronous versus asynchronous exchanges. The third relates to technical interoperability, while the fourth concerns computational performance and its impact on synchronization between the two systems.

To investigate these challenges, several approaches to constructing the GAMA simulation are being considered. One possibility is to develop a simulation of the crisis environment approaching a digital-analogue paradigm, where new data progressively updates the simulated situation and enables exploration of its evolution under different conditions. Another is to develop reusable simulation models that can be instantiated and parameterized according to the inferences and predictions produced by R-IO Suite. The choice between these approaches remains an open research question and may depend on the crisis type, available data, and requirements of the decision-support process.

Additional material

This proposal is part of a collaborative research project ANR-24-CE39-5449-05 ATEsT aiming to study and enable the participation of citizens in crisis management.

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Learning in and with GAMA: bridging agent-based modelling and machine learning

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September 28, 2026

Keywords

Agent-based Modelling, Machine Learning, Reinforcement Learning, Multi-agent Reinforcement Learning

Abstract

Agent-based models (ABMs) and machine learning are complementary approaches to the study of complex systems. On the one hand, learned models can enrich agent-based models by providing approximations of mechanisms that are difficult to specify explicitly. On the other hand, ABMs can provide rich and controllable environments in which learning algorithms can be trained, evaluated, and explored. Bridging these two approaches is therefore an important challenge for modelling and simulation platforms. Over the past years, the GAMA modelling and simulation platform has progressively developed an ecosystem of tools enabling learning to be integrated with agent-based models at different levels of granularity. Learning can be performed directly within GAMA, using its modelling, data-processing, statistical, and external-data capabilities, while models learned externally can also be incorporated into simulations. This includes, for instance, statistical and regression models exported in standard formats such as PMML, as well as neural networks that can be executed within GAMA through its ONNX-based tooling(*1*). Conversely, GAMA simulations can be exposed as environments for specialised machine-learning frameworks, building upon standard interfaces such as Gymnasium (*2*) and PettingZoo (*3*). More loosely coupled architectures can also be built through GAMA's server capabilities and client libraries, allowing customised interactions with external learning systems. This flexibility enables a continuum of approaches, ranging from fully integrated learning mechanisms expressed within the agent-based model to fully external learning workflows, with intermediate approaches combining the respective strengths of simulation and machine-learning ecosystems. The relevance of this combination has been illustrated, for instance, by using an agent-based simulation in GAMA as an environment for reinforcement learning to explore innovation diffusion policies (*4*). More recently, dedicated bridges such as *gama-gymnasium* (*5*) and *gama-pettingzoo* (*6*) have facilitated the connection between GAMA simulations and established reinforcement-learning ecosystems. This presentation provides an overview of this emerging ecosystem and of the different ways in which learning can be performed *in GAMA and with GAMA*. Rather than focusing on a particular learning technique, it explores the different roles that GAMA can play in a learning workflow and how the level of integration can be adapted to the modelling problem, the learning method, and the desired balance between simulation and external computation. It finally discusses the current limitations and open questions raised by these increasingly integrated simulation learning workflows.

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MIMIcking the COmplexity of agent-based models: the MIMICO Project

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Keywords

Surrogate Modeling, Explainable Artificial Intelligence, Agent-Based Models, Decision Boundaries

Abstract

Agent-based models (ABMs) are powerful tools for studying complex phenomena in which numerous heterogeneous entities interact non-linearly, but their systematic exploration is constrained by the computational cost of each run and by the opaque nature of the mapping between parameters and results. The MIMICO project addresses these two obstacles jointly: (1) surrogate models relax the computational bottleneck by learning a fast approximation of the scenario-to-result relationship [6] while (2) recent advances in Explainable Artificial Intelligence (XAI) make it possible to analyze the behavior of these learned models themselves, beyond the original simulator. This dual perspective leads us to focus on the decision boundaries of the models: the regions of the parameter space where the model's response becomes unstable. Our working hypothesis is that these boundaries carry information about the dynamics of the target system, independently of the predictive accuracy of the model that reveals them: a stance that departs from the usual accuracy-centric evaluation of surrogate models, since even an imperfect surrogate can be informative about the system's dynamics if it correctly locates its instabilities.

To operationalize this idea, MIMICO proposes a two-stage pipeline designed to optimize the use of a fixed simulation budget [5]. A first, inexpensive model-based screening built on naive sampling or expert knowledge consumes a limited share of the budget to build an initial parameter-result space and discard trivial regions. This space is then used to train a surrogate model, whose fast inference identifies the most unstable or informative sub-regions; the remaining budget is reallocated toward the original model to reinforce and statistically confirm these regions rather than sampling the parameter space uniformly.

This approach has already produced concrete results across several case studies. On a stochastic predator-prey ABM, reallocating the simulation budget between an initial screening (3,250 runs) and a refined, focused batch (13,000 runs) reduced the share of trivial outcomes from 60% to 16%, and revealed, through Sobol' indices, that 69% of the output variance stems from higher-order parameter interactions invisible to linear analysis, exposing sharp tipping points and a "metabolic trap" governing ecosystem coexistence [5]. On the real-world MAELIA agro-ecological platform, a dedicated random-forest-supervised HSIC-ANOVA extended this decision-oriented sensitivity analysis to a genuinely hierarchical, mixed-variable parameter space, an obstacle classical global sensitivity analysis cannot handle [4]. On a spatial double-auction market of adaptive, reinforcement-learning agents, the same exploration principles scaled to learning agents, showing how spatial structure and market design jointly govern the emergence of industrial symbiosis [2]. Finally, on the explainability side, a SHAP-based methodology for characterizing model decision behavior illustrates the broader applicability of explanation-driven diagnostics beyond ABMs [1], while a state-of-the-art survey structures the emerging XAI-surrogate field and sets a research agenda for embedding explainability throughout the simulation-exploration workflow [3].

Additional material

Link to the MIMICO Website: https://www.irit.fr/mimico/.
Link to the MIMICO repository: https://github.com/orgs/ANR-MIMICO/.

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Modelling insect interactions in rice crops on the GAMA platform as a basis for educational VR games

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Keywords

Agent-based Modelling, GAMA Platform, Rice Paddies, Insect Interaction, Pesticide Applications

Abstract

Agriculture plays an important role in the economy and daily life. Rice farming plays a key role in the country's economy, approximately 15% of GDP (Census of Agriculture Cambodia, 2023). Rice is the most vital crop in Cambodia, serving as a staple food for almost the entire population. It is critical for national food security and a primary source of income for rural households. Approximately 54% of Cambodian households are engaged in agriculture (Census of Agriculture Cambodia, 2023), significantly bolstering the agricultural economy and playing an integral role in cultural traditions. As both a daily dietary staple and an export commodity, rice is essential for Cambodia's economic stability and rural development. The Cambodian government aims to boost production for increased exports. However, this increase presents several challenges: a decline in soil fertility, heightened chemical inputs, reduced crop diversity, and a subsequent rise in pest populations and damage from certain pests. The increased use of pesticides to manage these pests poses dangers to human health, environmental health, and, more specifically, contributes to biodiversity loss. To make farmers and technicians aware of this issue, our expert in agriculture built a board game in Microsoft Excel as an educational tool on the risks of pesticide use and especially of the preventive use of pesticides. This study targeted only one hectare of rice field in Cambodia. Currently, technology is more modern, so digital technology and agriculture are crucial in helping farmers and students understand insect interactions in rice fields and how to apply treatments effectively. These were utilised with the GAMA platform, a dedicated platform for agent-based modelling. An agent-based framework is appropriate for studying the ordinary population of insects interacting on a rice crop, but it is still difficult to adapt for non-computer scientists in more specific application contexts (e.g., various treatment scenarios, insect reproduction, insect resistance, and crop yields), which require integrating particular behaviours for agents. This paper presents a built-in model integrated into the GAMA open-source modelling and simulation platform, allowing modellers to easily define the interaction of insects with a detailed presentation of rice field, insect population and treatment decision. In particular, it enables modelling the application of insecticide on paddy fields while understanding its effects. This agent-based model serves as a foundation for creating a comprehensive virtual reality (VR) game that presents scenarios involving pesticide application decisions, interactions between insects, and their impact on crop yields.

Additional material

The source code, and video demonstrations for this paper are publicly available at: GitHub Repository and YouTube Demo.

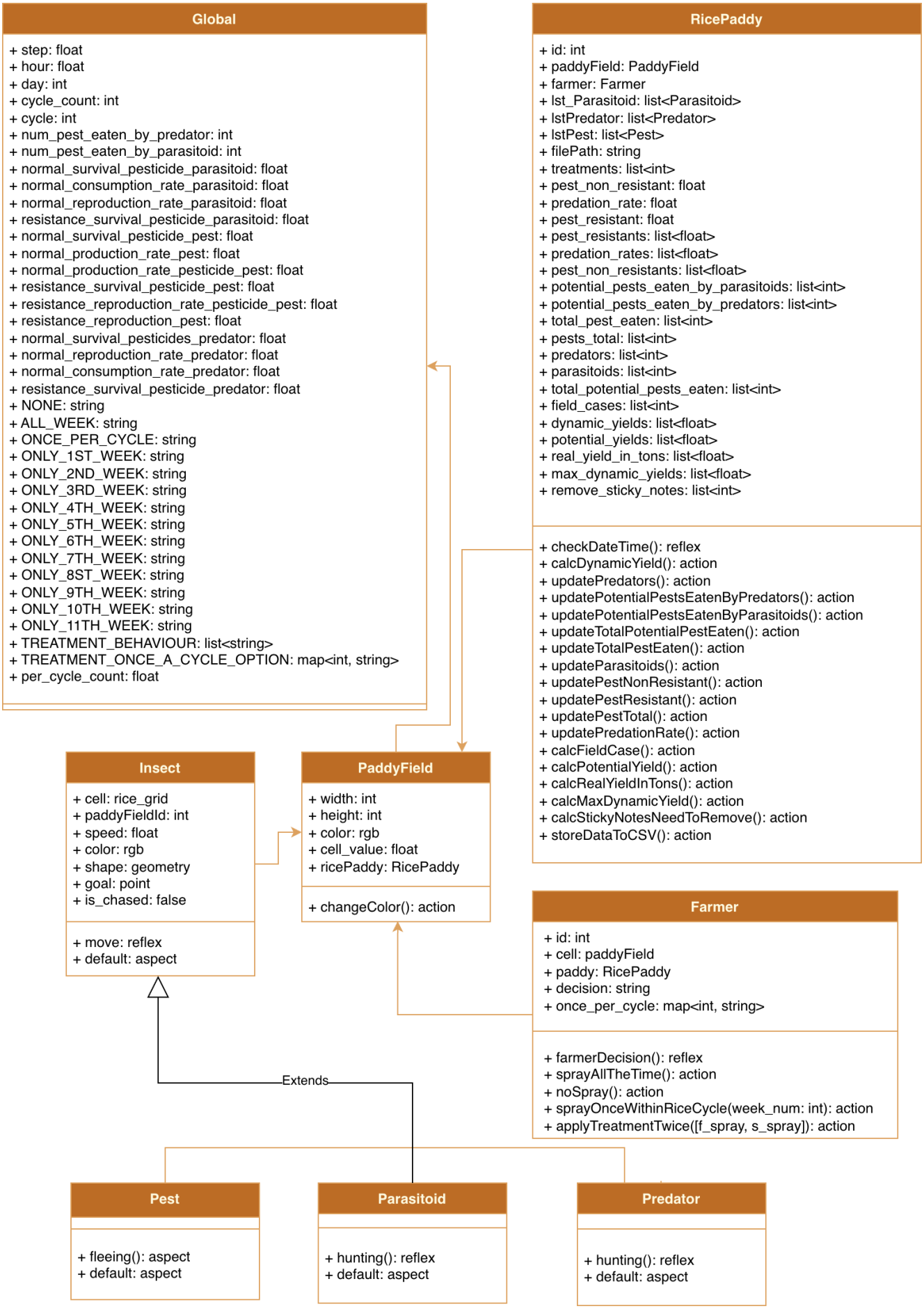

Figure 1: Model class diagram illustrating the core classes, attributes, and associations of the proposed framework.

Moov'Hanoi: Design of a web-based architecture for operationalizing GAMA mobility simulations

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Keywords

GAMA platform; Web-based architecture; Model coupling; Mobility simulation

Abstract

Hanoi's mobility remains dominated by private vehicles, contributing to frequent congestion and traffic-related pollution [2]. To reduce this dependence, the city is expanding its bus and metro infrastructure, with twelve metro lines planned by 2050. However, infrastructure alone cannot guarantee modal shift. Services must also provide coherent connections between buses, metro stations, and travellers' daily activities. Moov'Hanoi project addresses this context with a GAMA spatial agent-based model that combines mobility and geographic data to assess public-transport reorganization, station accessibility, and travel and environmental indicators under different scenarios. However, using the model directly in GAMA platform requires specific knowledge to configure experiments and execute simulations, creating a barrier for stakeholders without GAMA experience. A separate interaction layer could reduce this barrier while preserving GAMA as the simulation engine.

Previous work, including the SIMPLE project, explored coupling GAMA simulations with Unity virtual-reality worlds, enabling exchange between model state and user actions [1]. Whereas SIMPLE relies on a specialized VR environment, we investigate coupling through a standard web browser. The application connects to an already running GAMA server, loads a configured model and experiment, and manages one active runtime instance. Users can then control simulation execution, manage execution mode, and observe spatial outputs. The architecture does not expose editing of the GAML specification, model parameters, GIS geometries, network topology, or agent behaviors.

To realize this objective, we designed a three-component architecture containing a MapLibre GL JS browser client, a NestJS back-end, and GAMA server (figure 1). The browser provides simulation controls and spatial visualization. The back-end coordinates the experiment lifecycle, retrieves model state, and distributes updates, while GAMA server executes the experiment. In terms of communication, the browser sends commands through HTTP, while Socket.IO delivers lifecycle events, cycle information, and dynamic spatial updates from the back-end. Between the back-end and GAMA server, the TypeScript GAMA client library uses WebSocket to load the experiment, issue simulation commands, and retrieve model state. To make this exchange reusable across models, a lightweight model-to-web contract uses GAML metadata to select, order, and classify species. Static species, such as Moov'Hanoi's road and public-transport networks, are transferred during initialization, while dynamic species, such as person agents, are retrieved periodically again during execution. This classification determines which spatial layers are refreshed. The retrieved geometries are rendered through point, line, and polygon layers.

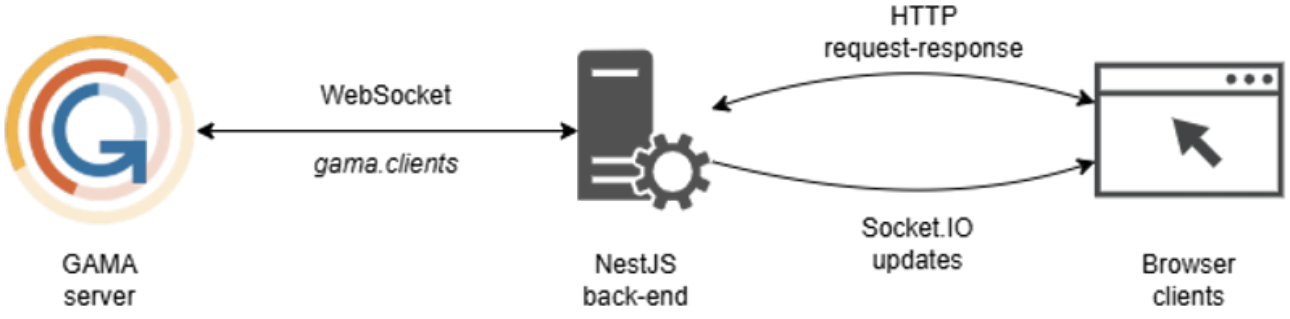

Figure 1: Architecture of the web application.

The evaluation of this architecture confirmed the expected lifecycle transitions: initialization enters STOPPED state, starting enters RUNNING state, and pausing or completing a manual step enters PAUSED state. Stopping returns to UNINITIALIZED state, reloading resets the cycle, and failures enter ERROR state. Spatial updates contain full snapshots of each dynamic species. There were two execution modes implemented: the synchronous mode makes updates follow each completed cycle, while the asynchronous mode periodically samples the independently running simulation. Moreover, the application can be used on other standard GAMA models with only limited model-side declarations. The implementation remains a local prototype. Other aspects like experiment discovery, parameter configuration, secure multi-user support, and remote deployment remain future work.

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Next-Generation Infrastructure for GAMA: IDE Extensions, Containerization, and Mobile Integration

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Keywords

Agent-Based Modeling, GAMA Platform, GAML, Visual Studio Code Extension, ARM64 Containerization, 3D Rendering, Android Native Port, Cross-Platform Simulation

Abstract

Agent-based modeling (ABM) using the GAMA platform traditionally relies on native desktop installations, creating deployment friction across diverse hardware architectures and cloud-hosted desktop environments. This work presents a next-generation infrastructure suite designed to modernize and expand the GAMA ecosystem across three critical domains: developer tooling, containerized execution, and mobile deployment. First, we introduce a Visual Studio Code extension that brings real-time GAML syntax validation, language support, and modern IDE ergonomics to developers outside the native GAMA UI. Second, we present an ARM64-optimized Linux container environment hosting the full-featured GAMA platform—including complete 3D display and rendering capabilities—enabling reproducible, desktop-grade GUI execution on low-power embedded hardware and cloud infrastructure without functional compromise. Third, we demonstrate a native Android port of the GAMA engine, bringing portable, on-device agent-based simulation to mobile platforms without reliance on remote server connections. Together, these tools reduce setup overhead, streamline GAML development, and extend full-featured agent-based modeling across edge, cloud, and mobile environments.

Additional material

https://marketplace.visualstudio.com/items?itemName=hqnghi88.gaml-for-vscode
https://play.google.com/store/apps/details?id=com.simulation.mobile
https://play.google.com/store/apps/details?id=com.gama.nativeapp

PHU CU 2050: an attempt at unveiling hydraulic uncertainties using an interactive simulation

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Keywords

Interactive simulation ; participatory research ; irrigation ; agriculture ; water bureaucracy

Abstract

Since *Đổi mới*, the Red River Delta, an agricultural and hydraulic space dating back hundreds of years (Poisson, 2009; Tessier, 2011), has been going through rapid territorial shifts. This is linked both to rapid economic growth, driving urban sprawl from city centers (notably Hà Nội) and increased industrialization; and environmental change, with increased uncertainty in rainfall, salinization, and riverbed incision (Trinh et al., 2025).

In this context, the hydraulics of the delta is called into question, as agricultural decline is seemingly the cause of a lesser investment in irrigation infrastructure. Following systemic interdisciplinary studies in the area giving a good idea of past (Fontenelle, 2004; Fontenelle et al., 2007) and present situations in terms of water management practices and the challenges they face, this presentation sets out to do several things.

First, we will provide an overview of what appears to be a « problem »: the investments in the maintenance of irrigation infrastructures have been steadily decreasing, at a pace that is faster than agricultural decline. Subsequently, we will unpack one question that stems from it: « How do bureaucrats in charge of local development envision the future of the delta against a backdrop of steady cuts to the budget allocated to the maintenance and renovation of hydraulic infrastructures? ». Second, we will present an agent-based model and its derived interactive simulation, using GAMA, that we used in participatory workshops with bureaucrats from Tiên Tiến and Tống Trân communes (province of Hưng Yên). The goal of said workshops was to discuss desirable futures and explore how the studied territory's trajectories can influence the bureaucrats' choices in terms of what infrastructure they prioritize for maintenance.

The workshops showed an important attachment to the already existing development plan (horizon 2050) that made it hard for the participants to fully engage in the prospective activity introduced by the interactive simulation. However, the workshops drove conversations that went beyond the mere link that the model was suggesting between territory and irrigation infrastructures. They allowed us to observe the various dilemmas (Lipsky, 1980) and intricate uncertainties the bureaucrats have to face day to day.

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Plugging Language Models into GAMA Mobility Simulations: Generative Mode Choice Against a Real Household Travel Survey

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Keywords

Large Language Models; Generative Agents; Urban Mobility; Mode Choice; GAMA Platform

Abstract

Existing multi-agent simulations of multimodal urban mobility either rely on machine learning models on structured data estimated from household travel surveys, or on explicit rules defined by domain experts. In both cases, the space of representable behaviours is fixed *a priori*: a factor encoded as neither variable nor rule cannot influence any decision of the agent. However, in reality, choosing a transport mode is multidimensional: objective factors like travel time, physical effort, speed and comfort intertwine with subjective factors tied to personality and experience. Integrating such decision-making complexity into a city-scale multimodal mobility simulation is a difficult task. Generative agents based on Large Language Models promise to overcome this limitation. Fed on massive textual corpora, they inherently exhibit human-like decision heuristics [5] that surveys do not record, and adapt their decisions without explicit rules.

Published evaluations of generative mobility agents rarely confront them with an observed population: most compare them with rule-based agents, or with patterns their authors produced. Against a certified household travel survey [1], we measure the calibration gap between these agents and the models estimated from it, and test whether the agents adapt to situations no variable encodes. We built using GAMA a simulation of the Toulouse metropolitan area [6, 7], integrating road, rail and three public transport networks. A synthetic population of 1,000 individuals is generated with eqasim [2], and alternative itineraries are computed on the real networks with OpenTripPlanner [4]. The simulation represents a realistic day with realistic constraints unknown to the route planner: a car available only where it was left, the driver needed to move it, forced returns home, and the temporal chaining of activities. Each inhabitant becomes a generative agent: its mode choice rule is no longer written in the simulation model, a language model queried in batches produces it from the agent profile and the itineraries actually offered.

Using a dataset of 3,299 trips, we compare generative agents with classical systems. In known situations (where the space of representable behaviors is defined a priori), our results show that generative agents are very close to traditional models, with a slight deviation. Their true strength emerges in unforeseen circumstances: a news article mentioning bed bugs in the metro influences the agents' decisions. We observe an evolution in their choices over time, as well as their ability to gradually reduce the impact of this information-an adaptability that classical models cannot replicate.

Each decision incurs an inference cost, and on an ordinary day, the representativeness of generative agents does not justify the expense: tabular models perform just as well, if not slightly better at no cost and instantly. The value of the language model lies in describing complex mode choices, especially during unforeseen circumstances, which rule-based models and static household travel surveys cannot capture. This opens the way for a hybrid architecture [3]: the tabular model would handle the nominal regime, while the language model, aligned with the inhabitants' choices, would determine when to take over and make decisions based on each individual's personality.

Additional material

GitHub repository: `https://github.com/Ytlse/llm-urban-mode-choice`.

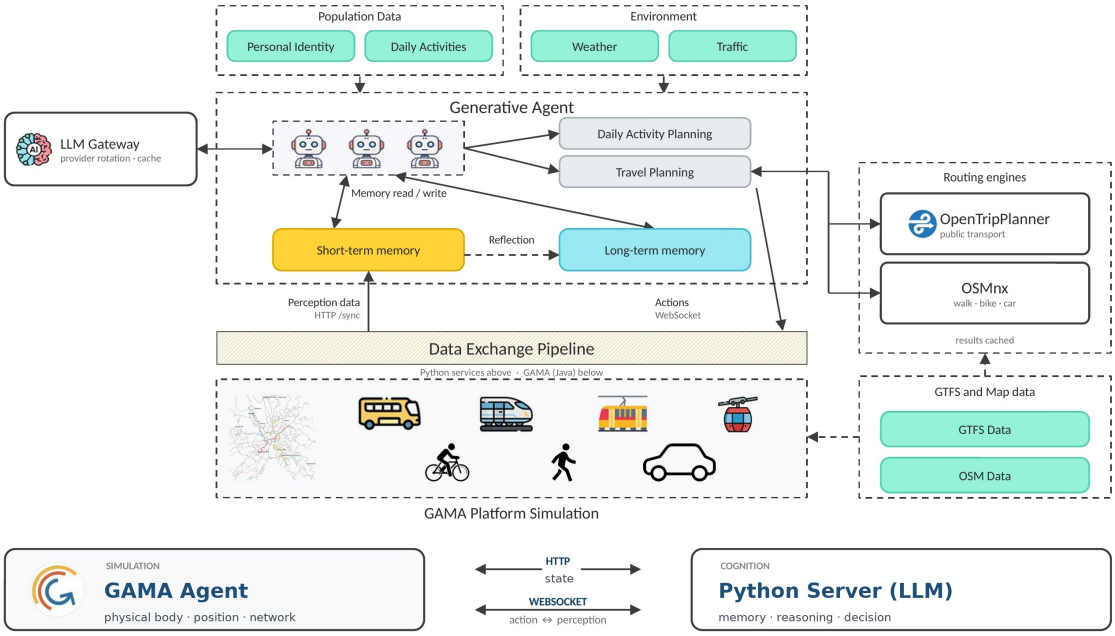

Figure 1: Architecture of the GAMA-generative agents coupling

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Prognostic CPTED: in silico testing of how neighborhood form steers adolescent socialization between cooperation and criminalization

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Keywords

Psychoergonomics; CPTED; Agent-based modelling; Adolescent socialization; Urban planning

Abstract

Safety in residential environments has long been treated as a question of opportunity: sightlines, access control, territorial markers. Across its successive generations, Crime Prevention Through Environmental Design (CPTED) has developed robust tools for diagnosing the condition of a neighborhood at a given moment (Newman 1972; Saville & Cleveland 1997). It offers no means of forecasting where that neighborhood is heading. Yet a layout fixed at the design stage persists for decades, shaping the environment in which successive cohorts pass through adolescence — the period in which patterns of cooperation are acquired rather than merely expressed.

Prognostic CPTED (P-CPTED) reframes the field within psychoergonomics and shifts the dependent variable from recorded crime to adolescent socialization. The built environment is treated as a moderator of encounter probability: it governs who meets whom, how often and in which setting. Encounters are formalized as iterated cooperation games whose outcome differs for each participant, depending on individual history and cognitive-behavioral profile. Repeated outcomes consolidate into habits, habits aggregate into local culture, and culture feeds back into how the same space is read and used.

Three trajectories emerge from this loop. Trajectory A (stabilization) is a balancing loop: the environment supplies just enough cues to reproduce the existing local culture. Its stability is produced, not given — a shared staircase rebuilds mutual recognition only as long as residents keep passing each other on it. Trajectory B (criminalization) is a reinforcing loop directed downward. The trajectory belongs to the environment, while outcomes remain individual: a minority enters defensive alliances, the majority withdraws out of fear — a harm barely visible in police statistics, yet manifest in health and isolation. Trajectory C (development) is its mirror image, accumulating social capital that becomes a resource for the next iteration.

B and C are asymmetric. B may arise from neglect alone; C almost never emerges from B spontaneously, since cooperation requires a minimal history of positive interactions. This hysteresis explains why regeneration often underdelivers and indicates a two-stage strategy: stabilization first, development second. Throughout, form moderates rather than determines: design shifts the probability of each branch without selecting it.

Agent-based simulation in GAMA gives architecture a procedure long considered unavailable to it: prototype testing. Full-scale experiments on neighborhoods are ethically inadmissible, yet estates built one and a half to two generations ago are completed, if uncoordinated, natural experiments. Their design doctrines, together with historical and current GIS and census data, supply input for retrodictive validation: a correctly specified model should reproduce observed outcomes before it is trusted to forecast. Aggregated across a neighborhood, individual trajectories shape the stability of local social networks — the scale at which safety is ultimately decided.

Project SIMPLE: Simplifying the integration of GAMA with Unity 3D

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Keywords

GAMA, Unity, agent-based simulation, virtual reality, scientific visualization

Abstract

Agent-based models (ABMs) and video games, including those taking advantage of virtual reality (VR), have undergone a comparable evolution, achieving impressive levels of complexity and sophistication. The SIMPLE project [1] argues that while ABMs prioritize scientific analysis and understanding and VR aims for immersive entertainment, they both simulate artificial worlds and can benefit from closer integration.

The SIMPLE project renders GAMA [2] simulation in immersive environment in Unity through a middleware which transfers agent geometries, positions, attributes and interactions [1]. Although this software chain was already functional, the Unity integration and the initialization of a new project (GAMA + Unity) required significant knowledge of the underlying architecture and configuration, limiting the use of this software stack by projects and developers unfamiliar with it.

This paper presents the design and development of the *SIMPLE Unity Plugin*, a reusable Unity package intended to simplify the integration and the visualization of GAMA simulations in Unity projects. The package aims at simplifying the current SIMPLE's integration stack for a non-expert public allowing developers to automatically create ready-to-use Unity scene, handle connection between GAMA, Unity and the middleware, and simplify the visualization of GAMA simulation in the Unity Editor.

The ease of use and the stability of the plugin was evaluated through multiple end-to-end tests, involving developers and researchers of various level of expertize with the GAMA Platform, the Unity IDE, the SIMPLE project's complete software architecture or a mixture of all the previous.

The resulting package keeps the project's separation logic with GAMA processing agent-based simulations and Unity ensuring the visualization in 3d environment and VR interaction, while reducing the amount of Unity-specific configuration required for the coupling. It provides a reusable basis to easily build interactive 3D and virtual-reality applications from GAMA models.

Additional material

https://github.com/project-SIMPLE/SIMPLE-Unity-Plugin

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Proof-of-concept BDI modeling of green corridors for wildlife protection

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Keywords

MAS, BDI, wildlife, green corridors, ecology

Abstract

Predictive ecology aims to model and simulate animal behavior to predict its responses to human interventions and improve wildlife safeguard and ecological services. Modelling and simulations are particularly beneficial to assess the impact of large and expensive interventions of ecological engineering, such as the wildlife (or "green") corridors. Now implemented worldwide, wildlife corridors consist on infrastructures realized to connect habitats and natural areas. They spam from small cross-road tunnels to bridges traversing highways. Recently, their traditionally heuristic design has been coupled with different mathematical models to possibly anticipate the corridors perturbative effects on each ecological context.
Here, I will present a proof-of-concept study for the use of MAS modelling to assist the assessment of green corridors' usefulness and impact. Wildlife (specifically, big mammals) are modelled as agents with a Belief-Desire-Intentions (BDI) architecture, with plans and habits that were informed by colleagues from ecology. Agents can forage, interact, cross green corridors and plan to take into account the risk of crossing roads. Agents are placed in a toy environment, focusing on key characteristics of green corridors to aid road crossing. The toy model, which constructs an initial replica of animal behaviors within a given environment, has two main benefits: first, it provides preliminary results about the efficacy of green corridors with given widths to prevent road killing; second, it fosters interdisciplinary research and planning with ecologists and managers of natural parks, as shown with an initial collaboration with an Italian Regional Park (Ticino Lombardo). Future developments can include the use of GIS data, improved modelling of animal behavior, tailoring to specific animals, verification with data, and implementation in real-world settings.

Additional material

GitHub repository with model: https://github.com/daniele-proverbio/GreenCorridorsBDI

Psychoergonomics as Environmental Behavioural Medicine: A Translational Path Built on In Silico Experiments in GAMA for Adolescent Digital Addiction Prevention

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Keywords

psychoergonomics, science of architectural design, in silico experiments in GAMA, behavioural biology, adaptive intra-group diversification

Abstract

Psychoergonomics extends ergonomics from the human body to the cognitive-behavioural dimension of human nature, where testing scientific hypotheses and testing engineering prototypes are, for ethical or practical reasons, rarely possible. Applied through the design of the built environment, it becomes what we propose to call environmental behavioural medicine. We present a model of a complete translational path (T0–T4) for one public-health problem, adolescent digital addiction, and show where GAMA enters it: as an experimental instrument at several stages and, equally, as a school of model structuring that organises the path itself

T0 – biological mechanism. We hypothesise that intra-group diversification of cognitive-behavioural profiles is an adaptive trait of Homo sapiens: through play, children differentiate into complementary competence niches, and the peer group rewards each member for its own strength.

T0→T1 – structuring. Writing this hypothesis in GAML forces explicit agent rules: which attributes an adolescent agent needs for divergent individual trajectories to emerge in one shared environment, including a competing, always-available online reward channel.

T1 – in silico hypothesis test. Agents with identical rules are run in two environments. In an integrated peer group with free group formation, each profile can display its strength. In a traditional school setting, which serves as the control, groups are assigned and competence is ranked on a single scale. The indicator is the occurrence of agents whose profile is distinct but finds too few occasions to display its strength, so that social reward falls below the level sustaining group attachment and the online channel takes over. We expect school-organised peer groups to act as an indirect but significant behavioural activator of digital addiction.

T1→T3 – prototype testing. The same simulator then tests successive schoolyard variants for a specific school and its pupils, until design, funding, equipment and maintenance options are exhausted. Embedded in a standard architectural design procedure, it plays the role a medical device plays in a clinical standard operating procedure; T2 is proposed as a parallel study with real pupils.

T4 – population. Replicated schoolyards act as population-scale prevention. We outline which data would convert simulated reductions in problematic use into population-health and economic indicators, and how such observations feedback to T0.

The modelling discipline typical of the GAMA community (explicit species, rules and experiments) maps directly onto translational logic: horizontally, by making agent rules compatible within a stage, and vertically, by moving a hypothesis from mechanism to design standard. This points to a potential of GAMA beyond simulation: providing experimental foundations for psychoergonomics as science-based architectural design.

Quantifying Building-Related Climate Impacts in Hamburg through a Digital Twin

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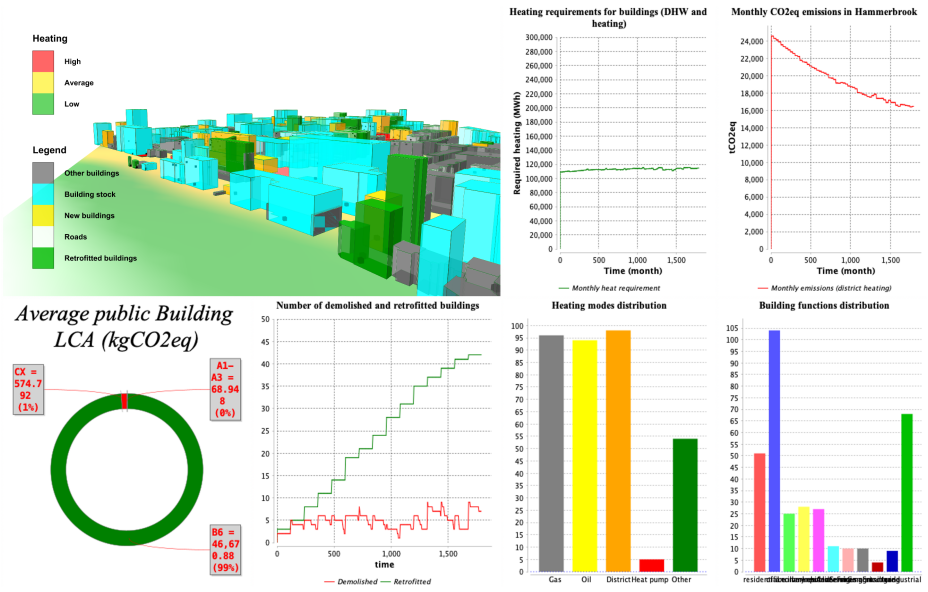

Figure 1: The Energy Twin Model Interface in GAMA, showing the district of Hammerbrook in Hamburg.

Keywords

Energy Twin; Decision-making Aid; Buildings Carbon Footprint; Agent-Based Simulation

Abstract

Urban areas are central to achieving global climate goals, yet cities face a core dilemma: demolishing and rebuilding creates high embodied carbon, while older buildings often perform poorly in operation. Urban Digital Twins (UDTs) can help navigate these trade-offs, but their use in municipal governance is limited. This presentation introduces the Energy Twin, an Agent-Based simulation developed with Hamburg city stakeholders to assess long-term Global Warming Potential (GWP) in district-scale demolition-versus-retrofit scenarios, specifically on non-residential buildings. The model integrates embodied and operational emissions at the building level, enabling comparison of policy pathways towards the city's 2040s carbon-neutrality targets. Scenarios are calibrated against empirical German renovation and demolition rates for non-residential buildings, and were co-designed through an iterative, four-phase consultative process with Hamburg's Authority for Environment, Climate, Energy and Agriculture, translating planning knowledge into model parameters and decision rules.

A demonstration for the Hammerbrook district compares five intervention strategies over a 25-year horizon – All Refit, All Demolition, Worst-first, Old-first, and Random – highlighting the carbon payback period required for new construction to compensate its embodied emissions. Results show that continuous retrofit consistently yields the lowest cumulative GWP, as the embodied-carbon debt of demolition cannot be repaid by operational savings within the available timeframe, even accounting for the greater efficiency of new construction. The targeted renewal of the worst-performing building stock narrows this gap but does not outperform the retrofit scenario. The results also show that rapid intervention – renovation rates above roughly 2% per year, prioritized on the worst-performing buildings – is essential for meeting near-term climate goals.

The Energy Twin provides a problem-driven UDT that links energy modeling to planning needs. It was implemented on the GAMA Platform as an interactive and decision-maker friendly tool, allowing stakeholders to inspect buildings and trigger interventions in simulation. The presentation also outlines the consultative methodology used to co-develop the model with municipal authorities, showing how collaborative, transdisciplinary processes can support more sustainable urban transformation, and discusses current limitations and pathways for enriching agent-level decision logics.

SBDI Architecture: Enabling Spatial Reasoning in Cognitive Agents for Traffic Simulations

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Abstract

The increasing complexity of socio environmental systems requires agent based models that capture human like cognition, particularly spatial reasoning. GAMA already provides architectures such as simple BDI and BEN for representing deliberative agents with beliefs, desires, intentions, emotions, and norms. However, these agents reason about space only implicitly through coordinates and distances, lacking an explicit vocabulary for topological relations such as connection, overlap, or containment. This limits realism of models in spatially explicit domains such as land use change, urban mobility, and crisis management. We introduce SBDI (Spatial BDI), an extension that brings qualitative spatial reasoning, based on the Region Connection Calculus (RCC8), into the belief base and the deliberation cycle. RCC8 defines eight topological relations (DC, EC, PO, EQ, TPP, NTPP, TPPi, NTPPi), which SBDI computes between an agent's geometry and the entities around it. SBDI is a compact GAML skill that extends *simple_bdi* with three primitives: *sbdi_perceive* detects RCC8 relations and stores them as predicates, *sbdi_update* keeps this spatial knowledge up to date, and *sbdi_reason* derives the beliefs that trigger plans. We tested it in a traffic simulation with three populations of 60 drivers on a 110-segment road network: *driver_basic* (no deliberation), *driver_bdi* (BDI without spatial perception), and *driver_sbdi* (BDI with spatial perception and reasoning). SBDI drivers notice congestion through the EC (externally connected) and PO (partially overlapping) relations and re-route before they get stuck, instead of reacting only once they are on a jammed road (Fig. 1). Over $N = 10$ independent 1000-cycle runs, paired t-tests show that SBDI drivers register about 61% fewer jam detections than both other populations ($p < 10^{-15}$), and this gap stayed at 60–62% through successive versions of the avoidance plan. Cumulative detections fall from 51,435 $\pm$ 690 (*driver_basic*) and 51,520 $\pm$ 466 (*driver_bdi*) to 19,830 $\pm$ 590 (*driver_sbdi*), i.e., a rate of $33.7 \pm 1.0\%$ against about 87.5% (Fig. 3, Table 1). Since detection is not sampled identically for all populations, part of this gap may stem from the measure itself (see p. 2). Travel time does not differ significantly between populations ($p \geq 0.53$), so we found no efficiency cost. The degradation slope of travel time is lower for *driver_sbdi*, but not significantly. Sharing knowledge globally backfired: travel time rose by 15.0–16.8% because many drivers chose the same detours. Sharing only with nearby peers that lacked the observation kept travel times on par while widening each agent's sensing horizon, and we adopted this design. The supplementary videos show the three populations side by side with live indicators (Fig. 2). Beyond traffic, SBDI is meant as a reusable component for any spatially explicit agent-based model that must reason about connectivity, overlap, and containment. We expect it to carry over to land-use change, logistics, and crisis response such as building or urban evacuation, where hazard zones would take the place of traffic jams. Next, we plan to learn spatial predicates from data instead of hard-coding them, and to formally verify SBDI's temporal properties.

Keywords

multi-agent systems, BDI Architecture, spatial representation and reasoning, traffic simulation, GAMA

Additional material

- Github repository: *https://github.com/ktsvi/sbdi-gama*

- Videos: *https://drive.google.com/drive/folders/144ozcUKDfihuPhxzIqRLy0_KzTMunsgD?usp=sharing*

Results

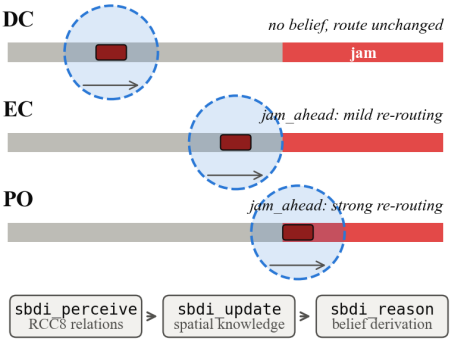

Figure 1: How SBDI anticipates a jam. Each *driver_sbdi* carries a sensing disc (radius 20). When a busy road touches the disc (EC) or cuts through it (PO), a *jam_ahead* belief is raised and *avoid_traffic_jam* re-routes on RCC8-weighted road edges, with PO weighted more than EC, before the driver enters the jam.

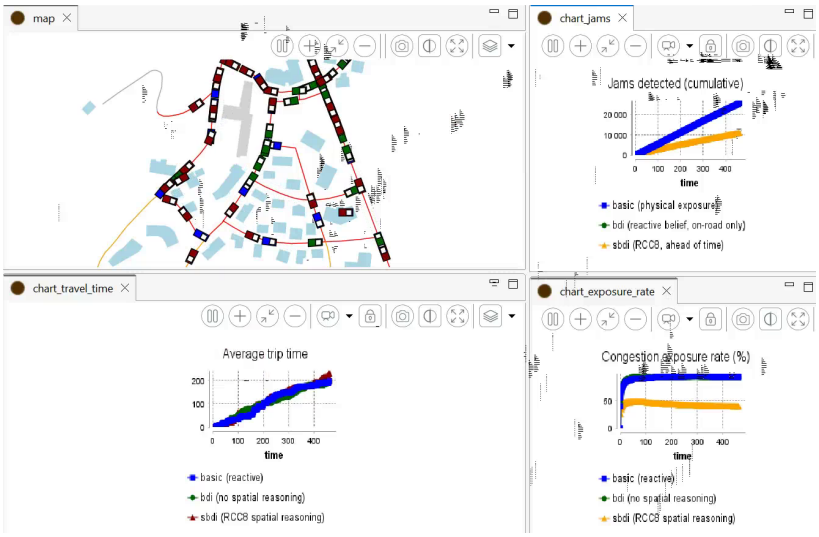

Figure 2: A GAMA run at cycle ≈ 450 with the three populations side by side. On the map, *driver_basic* is blue, *driver_bdi* green, and *driver_sbdi* dark red (orange while avoiding a jam). Roads turn orange above half the congestion threshold and red above it. The live charts track cumulative jams, average trip time, and the jam-detection rate.

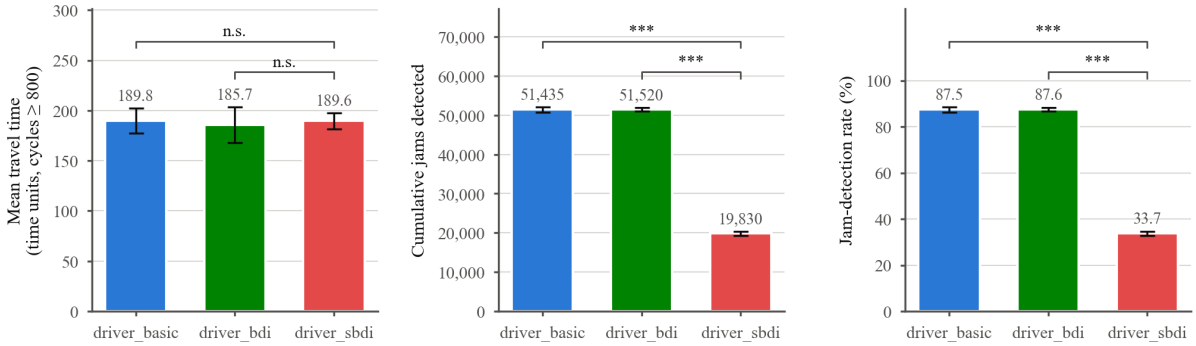

Figure 3: Final design (RCC8-weighted re-routing with local knowledge sharing), $N = 10$ runs of 1000 cycles, mean ± SD. Brackets show paired t-tests of *driver_sbdi* against each baseline (n.s.: not significant; *** $p < 0.001$). Travel time does not differ significantly, whereas jam detections are about 61% lower.

Table 1: Final design: $N = 10$ independent 1000-cycle runs, 60 drivers per population, 110-segment road network (mean ± SD). Δ: relative difference of *driver_sbdi* vs. each baseline; p: two-tailed paired t-test, df = 9.

Metric	*driver_basic*	*driver_bdi*	*driver_sbdi*
Travel time (cycles ≥ 800)	189.8 ± 12.6	185.7 ± 18.0	$\mathbf{189.6 \pm 7.9}$
Δ; p	-0.1%; 0.954 (n.s.)	$+2.1\%$; 0.533 (n.s.)	–
Jams detected (cumulative)	$51{,}435 \pm 690$	$51{,}520 \pm 466$	$\mathbf{19{,}830 \pm 590}$
Jam-detection rate (%)	87.5 ± 1.2	87.6 ± 0.8	$\mathbf{33.7 \pm 1.0}$
Δ; p	-61.4%; $< 10^{-15}$	-61.5%; $< 10^{-15}$	–
Travel-time slope ($\times 10^{-2}$/cycle)	1.99 ± 2.01	1.45 ± 2.41	$\mathbf{1.32 \pm 0.99}$
p	0.350 (n.s.)	0.890 (n.s.)	–

How to read these results. The jam-detection rate is the number of cumulative detections divided by (60 drivers × elapsed cycles), times 100. The two baselines count a cycle whenever a congested road (load ratio > 0.7) lies within 15 units. *driver_sbdi* counts a non-DC relation between its 20-unit disc and a road whose load ratio exceeds 0.35, but checks only every second cycle and pauses during re-routing cooldowns. The two counts are therefore not strictly like-for-like. Travel time is averaged over cycles ≥ 800 and its slope is fitted over cycles ≥ 400. Across all versions of the avoidance plan, the detection gap stayed at 60–62%. A global sharing board, by contrast, increased travel time by 15.0% and 16.8% compared with *driver_basic* and *driver_bdi* ($p = 0.0009$ and 0.016) through herding. Limiting sharing to peers within 150 units (perception radius 500) restored parity.

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STARFARM: An Agent-Based Model for Exploring Agroecological Transitions in the Vietnamese Mekong Delta

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Keywords

Spatial Agent-Based Modeling, Hybrid Architecture, Agronomy, Mekong Delta, GAMA Platform

Abstract

Simulating agroecological transitions in vulnerable delta regions requires representing both the management of individual agricultural plots and the spatial diffusion of hydrological externalities such as salinity and agrochemicals. Existing modelling approaches have complementary limitations. Process-based crop models generally provide limited support for representing explicit spatial interactions between plots and may require extensive parameterization, whereas bio-economic Multi-Agent Systems often rely on simplified representations of crop dynamics. We present STARFARM, an open-source Agent-Based Model developed on the GAMA modelling platform that integrates spatially explicit farm management with daily biophysical processes. The model was also designed to support participatory simulation workshops in the Vietnamese Mekong Delta.

STARFARM couples vector polygons representing agricultural plots with an underlying raster-based cellular automata grid. Solute transport is simulated through a synchronous double-buffering diffusion mechanism based on a Moore neighbourhood and integrated into a five-phase daily execution sequence. Agricultural practices are implemented using the Strategy Design Pattern and organised into interchangeable modules for sowing, irrigation, nutrient management, pest management, fallow, and harvesting. These practices interact with a hydraulic constraint algorithm accounting for salinity conditions, canal water availability, and mechanical capacity. Crop growth is represented by a lightweight ecophysiological model that simulates daily above-ground biomass accumulation, radiation response, soil fertility dynamics, and spikelet sterility associated with salinity exposure during flowering.

The model was calibrated and validated using multi-year empirical data collected between 2016 and 2022 in the Dong Thap province. A two-phase Genetic Algorithm was used to estimate biophysical and socio-economic parameters. STARFARM reproduces seasonal patterns in yield, water use, agricultural inputs, income, labour, and methane emissions, with no statistically significant differences between simulated and observed indicators ($p > 0.05$).

The model was subsequently used to explore 25-year scenarios combining market variability, climate change, and alternative agricultural practices. The results indicate that the combination of Alternate Wetting and Drying, premium cultivars, and mechanised straw collection can reduce methane emissions and input use while improving the economic robustness of smallholder farms under adverse market conditions. A 25-year simulation involving 400 plots over a 5×5 km study area required less than 4 minutes on an Apple M2 processor.

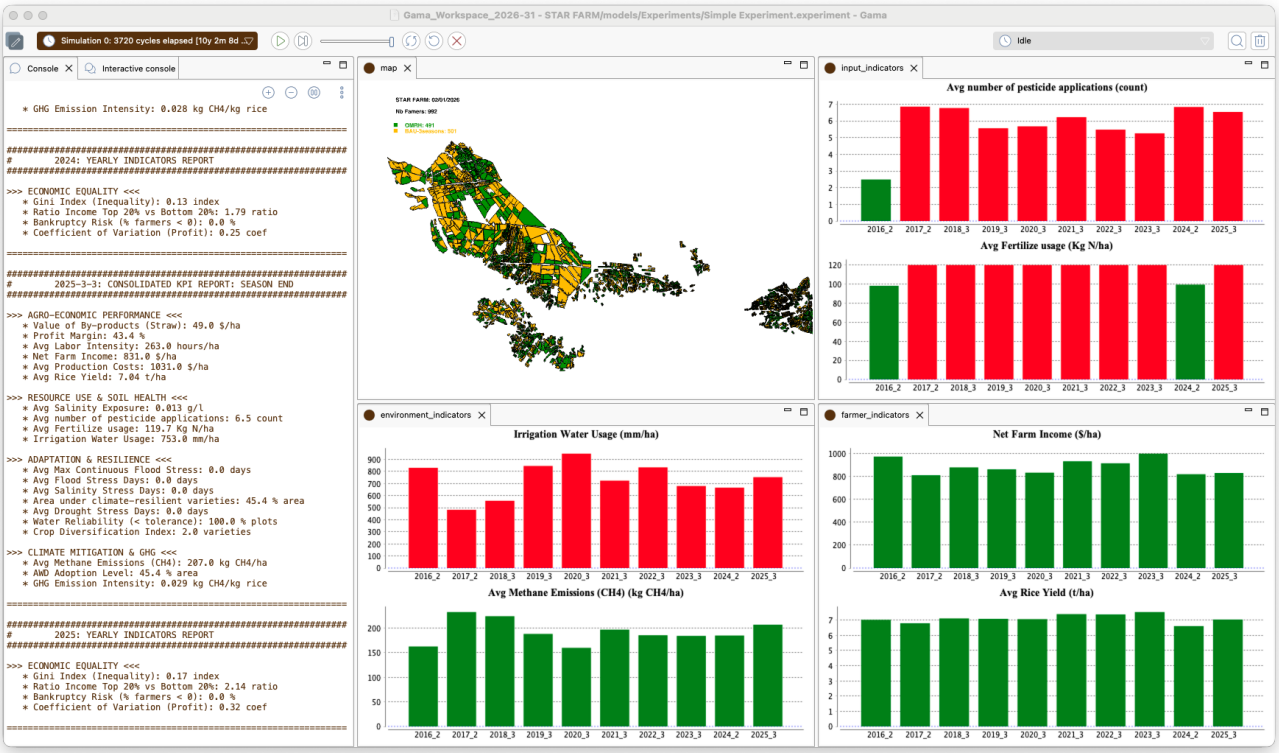

Figure 1: Graphical user interface of the STARFARM model on the GAMA platform, displaying spatial plot maps and dynamic agro-economic indicators.

Sensitivity Analysis in Hierarchical and Mixed Parameter Space. Application to Decision Rules of the MAELIA model

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Keywords

Sensitivity Analysis, Agro-Ecological System, MAELIA platform, Hierarchical and mixed Parameter Space, Kernel-Based Dependence Measures

Abstract

Socio-agro-ecological systems couple human decisions with biophysical processes such as crop growth, water flow, and nutrient cycling. Agent-Based Models (ABMs) have become a reference tool for representing these couplings because they relax the strong analytical assumptions of aggregate models and make space, heterogeneity, stochasticity, and individual decision-making explicit. The MAELIA (Modelling of socio-Agro-Ecological system for Landscape Integrated Assessment) platform is a representative example: built on the GAMA simulation platform, it simulates the interaction between agricultural activities, hydrology and water-resource governance at a daily time step and from the plot to the territory spatial scale, and it produces a broad range of socio-economic and agro-environmental indicators. Still, this descriptive variety makes the model difficult to analyse, since any simulated output emerges from the coupling of its components, computed jointly at each time step, each feeding the others, rather than from a single parameter taken in isolation.

To understand such complex models and quantify how much of the output variability can be assigned to the inputs, practitioners generally perform Global Sensitivity Analysis (GSA). Attributing an output to the inputs is further complicated by the shape of the input space itself. In applications such as the MAELIA model, parameters form a *decision tree* rather than a flat vector: *conditionally active* sub-parameters have meaning only when decreed by a higher-level *meta* variable, so the very existence of a parameter depends on the value taken by another one. Applying a flat sampling strategy to this branched space generates invalid architectural combinations, typically handled by imputing default values to inactive decreed variables. Furthermore, imputed values mask the true influence of the upstream decisions that actually control a branch, breaking the variance decomposition. Therefore, a structured hierarchical treatment of the parameter space is necessary. Classical GSA assumes *independent and identically distributed* inputs, which a hierarchical space violates by construction.

This work addresses this challenge of exploring a hierarchical parameter space. We model the structure of agricultural decisions and analyse MAELIA's sensitivity within it. Our contributions are twofold: (i) **A hierarchical, structured parameter space for SA:** we encode MAELIA's crop-management decision as a design space of meta and decreed variables (soil-preparation and fertilisation switches activating their dependent counts, depths, doses and dates), spanning 14 potential parameters, so that sampling and sensitivity analysis respect the conditional activation of variables; (ii) **A structure-aware analysis pipeline:** we propose a two-stage pipeline over the hierarchical space that couples random-forest supervision with an HSIC-ANOVA decomposition. The random forest identifies the influential variables, and the subsequent decomposition quantifies how strongly the outputs depend on them, handling categorical and numerical inputs alike.

Applied to 5,000 simulated winter-wheat itineraries (hierarchical Latin hypercube sampling, 10 weather years, homogenised plot) and three outputs — nitrogen leaching (Nlixi), soil organic carbon change (ΔCorg), and yield — the method delivers an interpretable, decision-oriented reading. Fertilisation doses dominate all three outputs, but the secondary driver differs by output: fertilisation timing for nitrogen leaching, the sowing/harvest calendar for soil organic carbon, and itinerary structure (number of fertilisations/preparations) for yield.

Additional material

Link to the GitHub repository: https://github.com/BenjaminPianet/Sensitivity_analysis_MAELIA.
Link to the SMT repository: https://github.com/SMTorg/smt-design-space-ext.

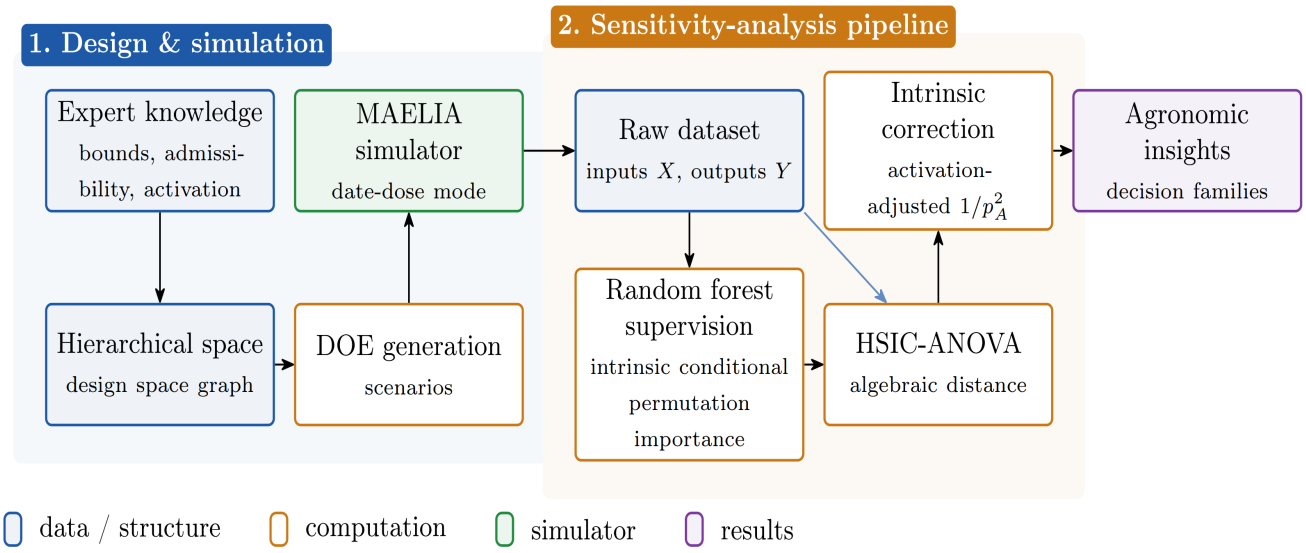

Figure 1: Workflow of the data-driven hierarchical sensitivity-analysis pipeline. Expert knowledge fixes the bounds, admissibility constraints, and conditional activation that define the hierarchical space. Scenarios are simulated in MAELIA's date-dose mode. The resulting dataset feeds a random forest that *supervises* the HSIC-ANOVA decomposition by setting its kernel scales, and a frequency correction yields the intrinsic indices.

Simulating Autistic Spatial Related Experience in Public Offices: A Psychoergonomic in Silico Experiments in GAMA Platform

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Keywords

psychoergonomics, in silico experiment, virtual twin of the autism spectrum, experimental validation of universal design

Abstract

Research gap. Despite growing interest in autism, its medical definitions keep shifting: from Kanner's (1943) narrow category of severe cases, through Asperger's disorder (DSM-IV; APA 1994), to a single spectrum (DSM-5, APA 2013; ICD-11, WHO 2019). Dedicated psychological support for adults remains scarce, while children are supported mainly in education rather than everyday life. Research on spatial needs is limited and averages them across the spectrum, as if autistic people were clones. Yet atypical sensory processing, mostly hypersensitivity (Dunn 1997; Pellicano and Burr 2012), shapes route choice, walking pace, crowd avoidance and responses to noise, light and colour (Mostafa 2014).

Problem and aims. We narrow the problem to emotional, cognitive and behavioural determinants of movement in public office buildings. Rather than prescribing one autism-friendly design, we build an in silico decision-support tool: architects can test proposed adaptations (e.g. quiet zones, alternative routes, lighting) before construction for their effect on the sensory load, stress and wayfinding of autistic users, while checking that they do not become barriers for others. This dual check distinguishes universal design from approaches misclassified as such. The model is grounded in medical and psychological literature, expressed as agent rules within psychoergonomics, and also supports testing cognitive-behavioural hypotheses.

State of the art. Accessibility is typically assessed on floor plans, and pedestrian models derived from the social force model (Helbing and Molnár 1995) treat agents as homogeneous clones. The BDI-based GAMA reconstruction of a nightclub fire evacuation (Valette et al. 2018) differentiates agents by psychological traits. Its psychology is one of many possible models, but it demonstrates that a psychological model and agent rules can be calibrated to empirical data.

Foundations and model. Our foundations combine medical and psychological sources, the self-advocacy movement and detailed consultations with autistic people on the modelled phenomena. The core comprises a cognitive mechanism building a cognitive map from accumulating spatial experience (Tolman 1948) and an emotional mechanism subjectively validating the environment, primarily other people. Following Damasio (1994), behavioural rules are not fixed but moderated by current emotional states, themselves shaped by environmental and internal factors. Environmental triggers are termed behavioural activators rather than affordances (Gibson 1979). The same agent can represent typical and autistic profiles through variable values, and validation reads out each individual's subjective experience.

Working rules and outlook. Four rules already operate in simulation:

(i) A dynamically built graph of perceived space (layout recognition) with individually experienced obstacles.

(ii) A "health points" variable, from sustained comfort to fight-or-flight, homeostatically balancing available resourcesagainst action costs (cf. Barrett 2017).

(iii) Two-dynamics navigation: spatial cognition sets successive subgoals towards a desired destination, while emotionalexperience adjusts movement to anticipated sensory cost.

(iv) Avoidance rules for crowds and visual stimuli, producing route rigidity, stops, direction changes and longer traveltimes.

Preliminary experiments in familiar local buildings show agent state dynamics qualitatively matching expected autistic accounts. Next steps include calibration on empirical data, expert validation, testing typical profiles for barriers and further sensory modalities.

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Additional material

(Optional.) A link to additional material can be added here if necessary: images and videos (for demos), code, repository, website, etc.

Simulating Commuter Mobility in the Gipuzkoa Region: An Agent-Based Approach using GAMA

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Keywords

Agent-based modeling, Urban mobility, GAMA Platform, Traffic simulation, Macro-micro visualization

Abstract

The Gipuzkoa province, with its economic hub in San Sebastián, experiences high volumes of daily commuter traffic, leading to significant congestion. To address these challenges, this presentation introduces agent-based simulation models developed by the City Science Lab Gipuzkoa (MUBIL).

Developed within the open-source GAMA Platform, the primary *GipuzkoaTraffic* model leverages rich geospatial datasets, such as regional mobility surveys, geographic road networks, and origin-destination matrices from MITMA data, to create a spatialized representation of the region's infrastructure. In this environment, commuters are modeled as autonomous agents, color-coded based on their origin city, providing a comprehensive view of regional traffic distribution and peak-hour bottlenecks. Leveraging GAMA's native capabilities, such as 3D navigation and camera tracking, the simulation allows users to dynamically follow specific agents and visually identify the micro-level causes of congestion.

In parallel, the presentation will showcase a second visualization module designed for macro-level flow analysis. This approach abstracts regional traffic by representing specific zones as distinct circular nodes with active percentage indicators. Utilizing GAMA's built-in Box2D physical engine, commuters are simulated as organically moving, non-overlapping particles that navigate. By proportionally distributing these particles based on real-world population datasets, this macroscopic visualization aggregates complex individual trajectories into clear regional flows, facilitating the analysis of large-scale mobility dynamics.

Ultimately, establishing this model serves as the foundational core of the project, providing a robust baseline for future exploration of alternative mobility scenarios and data-driven urban planning. The GamaDays 2026 presentation will detail the data integration methodology and the underlying GAMA architecture, illustrating how these initial visualizations pave the way for complex scenario testing.

Additional material

Simulation resources and full macroscopic visualizations can be accessed at: https://github.com/City-Science-Lab-Gipuzkoa/Simulation-MITMA-data

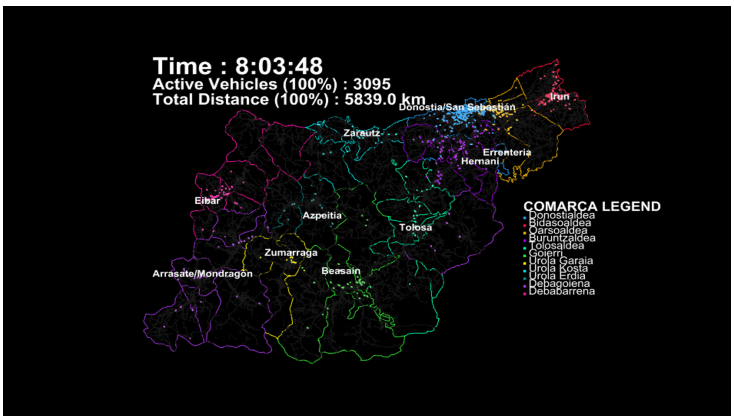

Figure 1: Visualization of the *GipuzkoaTraffic* model, demonstrating regional commuter flows on February 14, 2025.

Simulating Habit Formation in Urban Green Infrastructures: A Spatial Anchor Mechanism in the Strolling Activity Simulator (SAS)

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Keywords: agent-based modelling, GAMA platform, green infrastructure, spatial anchors, habit formation, urban morphology

Cities still plan green space by counting it: square metres per resident, or the distance from home to the nearest park, as in the 300 m element of the 3-30-300 rule (Konijnendijk, 2023). Such counts describe geometry. They do not say whether people will walk.

The Strolling Activity Simulator (SAS; Szurlej, 2025), written in GAML and run in GAMA (Taillandier et al., 2019), tests this with agents. Each agent is a resident with a home, walking a pedestrian network at a one-minute step. A walking habit grows from repeated contact with green or blue space: the more time an agent has walked beside it, the more often it sets out and the longer it stays out. The rules are calibrated to universal data from reviews, not to any city, and the model needs only geometry from OpenStreetMap: buildings, paths, green space and water. SAS is explanatory, not predictive. It is evaluated by pattern-oriented modelling (Grimm et al., 2005): the share of regular walkers rises and then slows, and 18 to 37% of residents meet the WHO guideline, in or just below the 20 to 40% used as a criterion.

SAS 2.0 adds a spatial anchor mechanism. An anchor is a place an agent has reached and keeps returning to. At the start of each walk the agent either explores a new destination, with a probability that falls as it knows more places, or returns to a known one, following the exploration and preferential return model of Song et al. (2010). A distant destination is less likely to be chosen than a near one.

We ran batch experiments in four European cities of different form: Cork, Ghent, Göteborg and Girona (windows of 3 × 3 km, 1000 agents, 180 simulated days, five to seven seeds per layout, 330 runs in all). Each city had five layouts: the existing green and blue space, a corridor along the water, and islands of the same area drawn in three sizes (Figure 1). Every addition raised the share of residents walking 30 minutes a day, by 17 to 81%. No form won everywhere. The corridor led clearly only in Ghent, where housing lines the rivers. Elsewhere the gap between corridor and islands was smaller than the gap between two drawings of the islands. The anchors suggest why: islands brought more residents to green space at all, and the corridor gave those who already walked more places to return to. Reach within 300 m sorted the island layouts in the order of the model, but it placed the corridor last in every city, where the model placed it first in two (Figure 2).

The outcome followed the individual layout of each city, not the idea behind it and not the rule. A model built on a few universal rules can test such layouts before they are built.

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Taillandier, P., Gaudou, B., Grignard, A., et al. (2019). Building, composing and experimenting complex spatial models with the GAMA platform. *GeoInformatica* 23, 299–322.

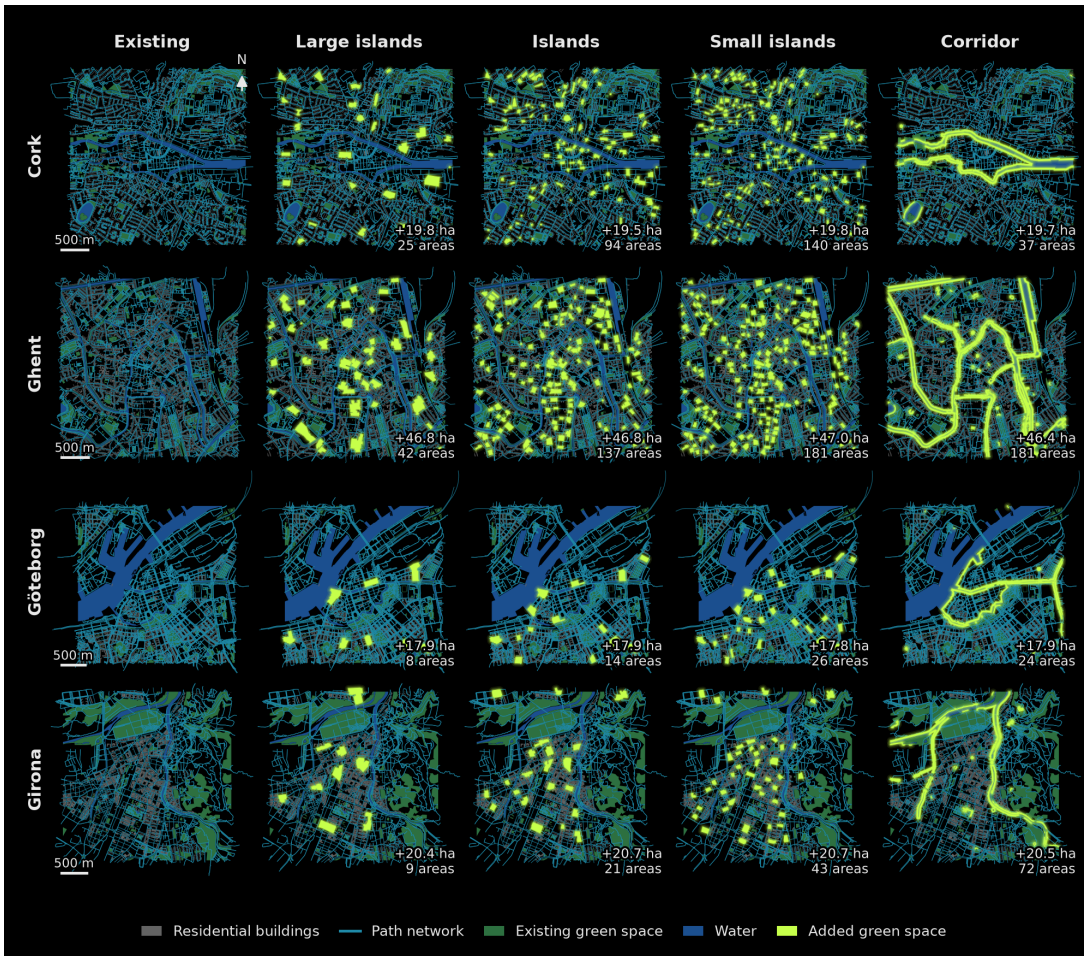

Figure 1: The five layouts (columns) in each city (rows): existing green and blue space, the same area added as large islands, islands and small islands, and a corridor along the water. The added green space is in bright colour, with its net area and the number of separate areas.

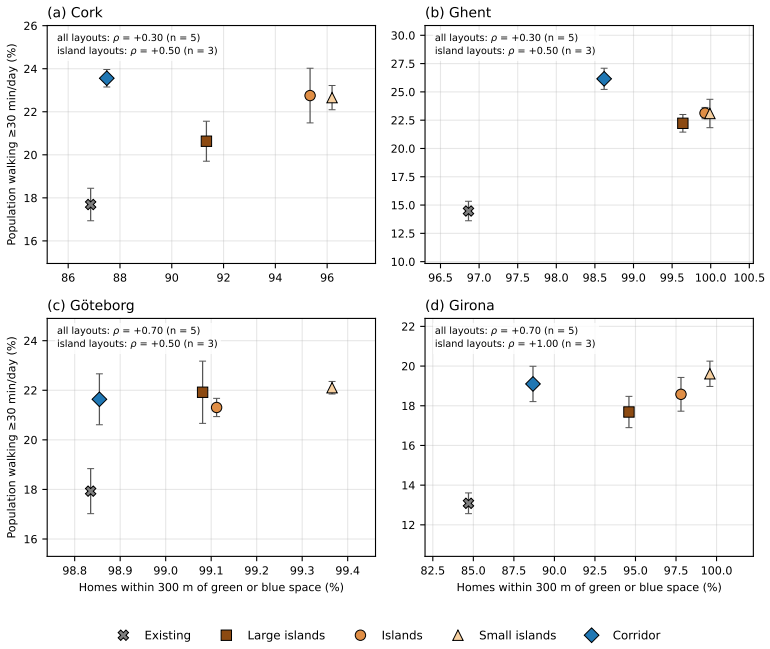

Figure 2: Share of homes within 300 m of green or blue space against the simulated share of residents walking at least 30 minutes a day. Each point is one layout (mean ± SD across seeds).

SImulating online deBAtes (SIMBA)

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Keywords

Agent-Based Simulation, Food Decision-Making, Social Influence

Abstract

The choice of what we eat has profound impacts on our health, the environment and the Greenhouse Gas Emissions. Existing research in this domain has primarily focused on behavioral interventions grounded in social norms and nudges, yielding mixed results. A proposed shift from this is investigating deliberation — a structured process facilitating the exchange of diverse opinions — as a lens through which to understand how individuals' positions on meat consumption evolve through group interaction.

We present SIMBA, an open-source Agent-Based Model developed in GAMA with the goal of better understanding the mechanisms by which individuals influence each other in collective eating settings (e.g., restaurants, university cafeterias). The model was designed to reproduce pre- and post-deliberation attitude shifts observed across 55 online debates (N = 459) from an empirical study on collective eating behavior and red meat consumption reduction (Dheilly et al., unpublished). Debates were homogeneous (composed only of anti-reduction agents) or heterogeneous (combination of pro and anti-reduction agents).

SIMBA draws on three established models of social influence (Flache et al., 2017) — consensus, clustering and bipolarization — to recreate individual opinion trajectories observed in the empirical debate context. In the consensus model, the individual agents' opinions gradually converge toward the mean opinion of all agents in the debate. In clustering, agents only influence those with similar enough views and do not interact with those that are too dissimilar. Bipolarization extends clustering where individuals who are too dissimilar push each others' opinions apart. Simulated agents are initialized solely with pre-deliberation attitudes, ensuring that any predictive improvement stems from the interaction dynamics rather than from additional individual-level covariates.

Model calibration was performed on a subset of the debates, with an explicit held-out set reserved for validation. The two-step calibration process used Latin-Hypercube Sampling (200 samples) to explore the parameter space, followed by a Genetic Algorithm optimizing Mean Absolute Error (MAE) relative to empirical attitude shifts to identify final parameter values applied to the held-out debates.

Results indicate that none of the three social influence variants produced significantly lower MAE than a naive no-change baseline or a multilevel linear regression at the individual, debate or global level ($p > 0.05$). On the global level, simulation predictions differed from the linear model by less than 0.1% of the full attitude scale, with the linear model falling within the confidence interval of all three variants. Agents in homogeneous debates changed their opinion more on average than those in heterogeneous debates ($p < 0.01$), though neither composition outperformed the no-change baseline. The Genetic Algorithm converged toward near-zero predicted attitude change rather than learning genuine debate dynamics, suggesting that simple opinion-averaging and bounded-confidence interaction rules are insufficient to capture the deliberative processes observed empirically.

Additional material

OSF Protocol: SImulating online deBAtes (SIMBA)

Dheilly et al., Can deliberative reasoning induce sustainable dietary change? Effects of different deliberative formats on attitudes and meat consumption. *Communications Sustainability*

Flache, A., Mäs, M., Feliciani, T., Chattoe-Brown, E., Deffuant, G., Huet, S., & Lorenz, J. (2017). Models of social influence: Towards the next frontiers. *Journal of Artificial Societies and Social Simulation*, 20(4), 2.

TANGO: An open-source framework to visualize GAMA simulations through tangible robots

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Keywords

agent-based modeling; tangible simulation; robotics orchestration; GAMA; ROS2.

Abstract

Agent-based models (ABM) are widely used to study complex socio-environmental systems, yet their outputs remain confined to screens, limiting spatial intuition and hindering scientific mediation with non-expert stakeholders. Prior work on tangible interfaces [1, 2] has shown that coupling simulations with physical scale models improves both interpretability and public engagement. However, in these systems the simulated agents themselves remain immaterial, typically projected onto a physical support rather than embodied within it. TANGO (TAngible iNterface through GAMA Orchestration) proposes to close this gap by turning the virtual agents of the GAMA modeling platform into mobile physical entities, allowing a simulation to control a small robot fleet in real time.

This paper presents the first concrete steps toward connecting GAMA to robots, organized around two architectural pillars: (i) an open-source connector implemented as a custom plugin inside GAMA that communicates over ROS (Robot Operating System), allowing simulated agents to command physical units without additional robotic complexity; and (ii) a digital-to-physical synchronization architecture providing a synchronization and error-correction environment that guarantees coherence between the state of the digital model and the measured position of each robot.

The physical layer relies on *off-the-shelf* Waveshare AlphaBot2 mobile robots equipped with Raspberry Pi 3 B+ or Raspberry Pi Zero 2 W low-power single board computers [3]. This choice keeps the experimental focus on the model-to-robot bridge rather than on robot design: each simulated agent is mapped to one physical unit, trajectory commands computed in GAMA are published as ROS messages consumed by the robots, and position feedback returns through ROS topics to keep the model state aligned with reality.

We present a minimal working prototype and its preliminary results demonstrating that a GAMA-driven agent can reliably command a physical robot's trajectory on a controlled surface. These early results validate the technical feasibility of digital-to-physical agent control via GAMA and establish a first, reusable building block toward a fully open framework built on the presented generic GAMA-to-device connector, and a synchronization layer and extended by open-sourced robot hardware; intended to let other researchers couple existing GAMA models to simple physical devices without extended robotics expertise.

Beyond validating this control pipeline, these first steps lay the groundwork for TANGO's broader roadmap. Future work will extend the current setup to a larger, more heterogeneous robot fleet, test the connector against more complex GAMA models, and move from off-the-shelf platforms toward open-sourced, low-cost robot hardware that will let other researchers and projects adopt the framework without deep robotics expertise.

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TsunaWAVE : coupling uncertain landslide-generated tsunami scenarios with agent-based evacuation modelling through an interactive web platform. Application to Mamoudzou (Mayotte, France)

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Keywords: Tsunami evacuation; Agent-based modelling; Early warning; Model coupling; Decision support; Web interface; Mayotte

Abstract

Pedestrian tsunami evacuation depends on wave arrival time, warning dissemination, the spatial configuration of the exposed area and population response. These factors are studied by distinct disciplines and are rarely integrated within a single framework, which limits the use of evacuation models for local planning. We present TsunaWAVE (Web interface for Agent-based modelling and Visualisation of Evacuation), an open web interface that couples tsunami hazard scenarios with a GAMA agent-based model of pedestrian evacuation. Arrival times computed by a surrogate hazard model (Landslide-Tsurrogate v1.0) define the time available to evacuate, against which precomputed evacuation outputs are read. The agent-based model simulates warning dissemination, pre-evacuation delay and movement towards safe areas. The framework is applied to the Mamoudzou waterfront (Mayotte, France), exposed to landslide-generated tsunamis with lead times of 10 to 16 minutes, where 759 exposed individuals were counted in the field and from drone and video imagery. Across 90 scenarios (42 replicates each), warning reliability drives evacuation success, while imitation among neighbours partly compensates for a degraded warning when lead time is sufficient.

Although designed as a planning-support tool for local authorities, TsunaWAVE is not specific to tsunami evacuation. The interface reads and compares GAMA outputs across scenario combinations, and may be extended to support any kind of simulation exploration protocol, for instance global sensitivity analysis or uncertainty analysis, with little adaptation of the current workflow and user interface. Even if the use of the proposed device supporting the valorisation of other models may be limited due to thematic related framing and dedicated script data processing, it may open a generic avenu especially for model spatial outcomes analysis and exploration. The next step toward such a generic proposal includes standardising the GAMA output format and documenting this chain.

Urban Mobility Improvement Methods and Their Acceptance: An Agent-Based Model of Commuter Mode Choice

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Keywords

agent-based modelling (ABM), urban mobility, mode choice, congestion pricing, policy acceptance

Abstract

Urban mobility policies such as vehicle restrictions, congestion pricing, road capacity expansion or public transport upgrades are often assessed only through their technical effect on traffic, yet their success depends on whether commuters actually accept them and change their behaviour. This work presents the conceptual design of an agent-based model, to be implemented in GAMA, that compares mobility improvement strategies while explicitly representing how they are perceived and accepted by individual commuters.

The environment is a road network graph obtained from a map of Tlaquepaque, Jal. México: intersections are nodes, and road segments are edges with capacity, length, number of lanes and toll-zone status. It is complemented by public transport stations with waiting queues that generate demand according to a configurable origin–destination pattern. Global parameters encode the policies under study: a partial vehicle ban (share of cars barred from circulating), a congestion toll in the spirit of Singapore-style road pricing, a lane multiplier, carpooling adoption, public transport frequency and capacity, the perceived quality of public transport (which influences mode choice but not the real service quality), and driving-culture compliance, which controls friction at intersections.

Two species of mobile agents drive the dynamics. Commuters have an origin, a destination, a departure time and a tolerance to public transport. At the start of each trip, a commuter chooses either traveling by car or by public transport through a simple utility rule that compares estimated cost and travel time, adjusted by the toll, the ban and the perceived quality of public transport. Vehicles (cars and public transport units) then move over the network at a speed reduced by the number of vehicles sharing the same segment and by low compliance at intersections. Extraordinary slowing events, such as sports events or roadworks, can be injected to test the robustness of each policy.

The model reports average travel time (globally and by mode), mode share, a network congestion index, toll revenue, public transport occupancy and an acceptance rate, which captures how comfortable individuals feel with the proposal they use and how willing they are to use it again.

The main expected contribution is a common framework in which policies can be compared, alone or combined, not only in terms of efficiency but also of behavioural uptake: whether changes in perception or driving culture really shift mode share. Early simulations show how traffic conditions, public transport characteristics, and commuter preferences affect the decision between the two transportation options.

Additional material

Model repository can be accessed at: https://github.com/KennethC18/Urban-Mobility-ABM
Screenshots of early simulations can be found below:

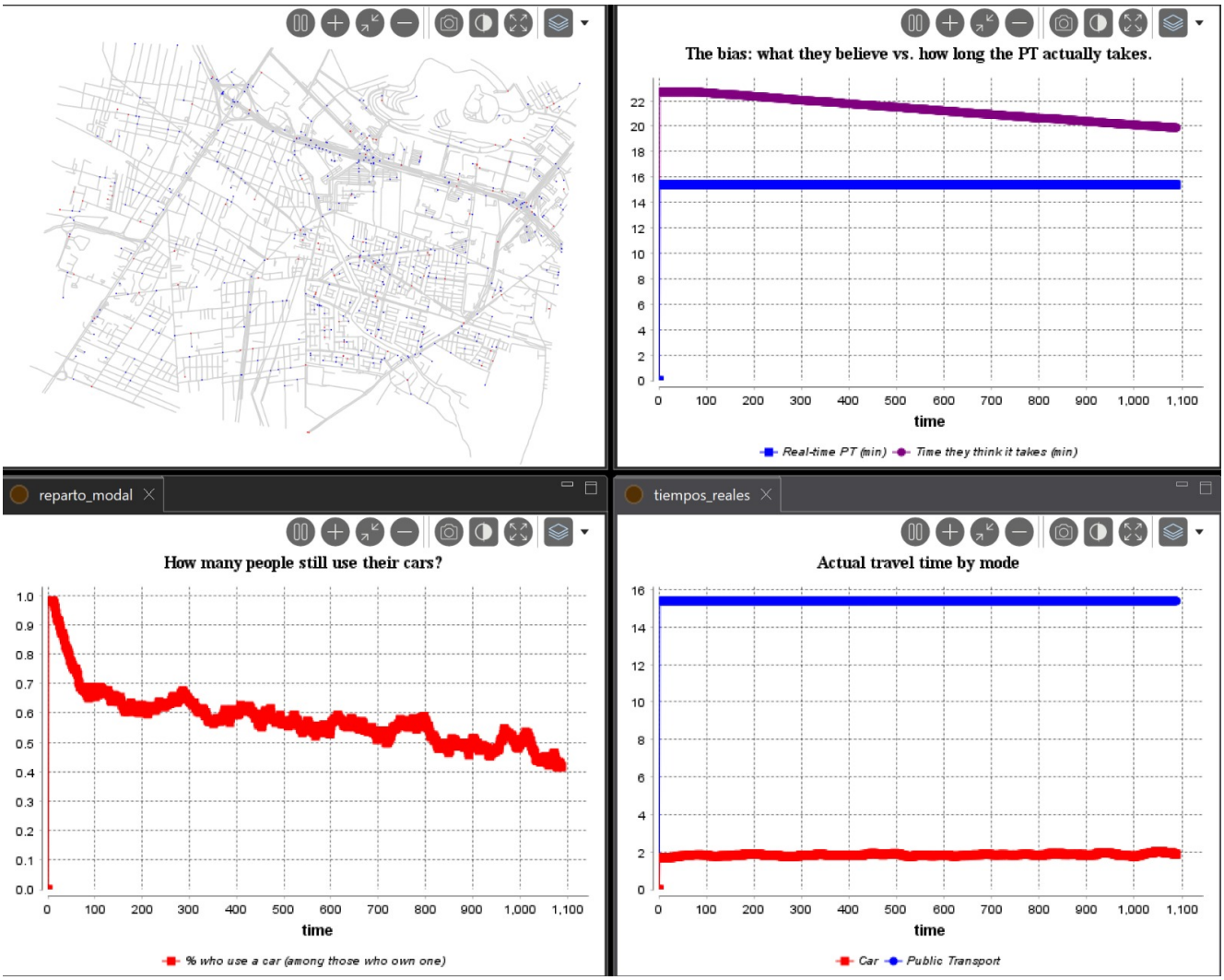

Figure 1: Scenario 1 - Worst case for public transport, where it takes more time to get to each station and has a lower average speed. Results show a slower response to bias to the actual speed of public transport, however a small percentage people are still willing to try to reduce car usage, time travel for cars increases slightly due to traffic congestion.

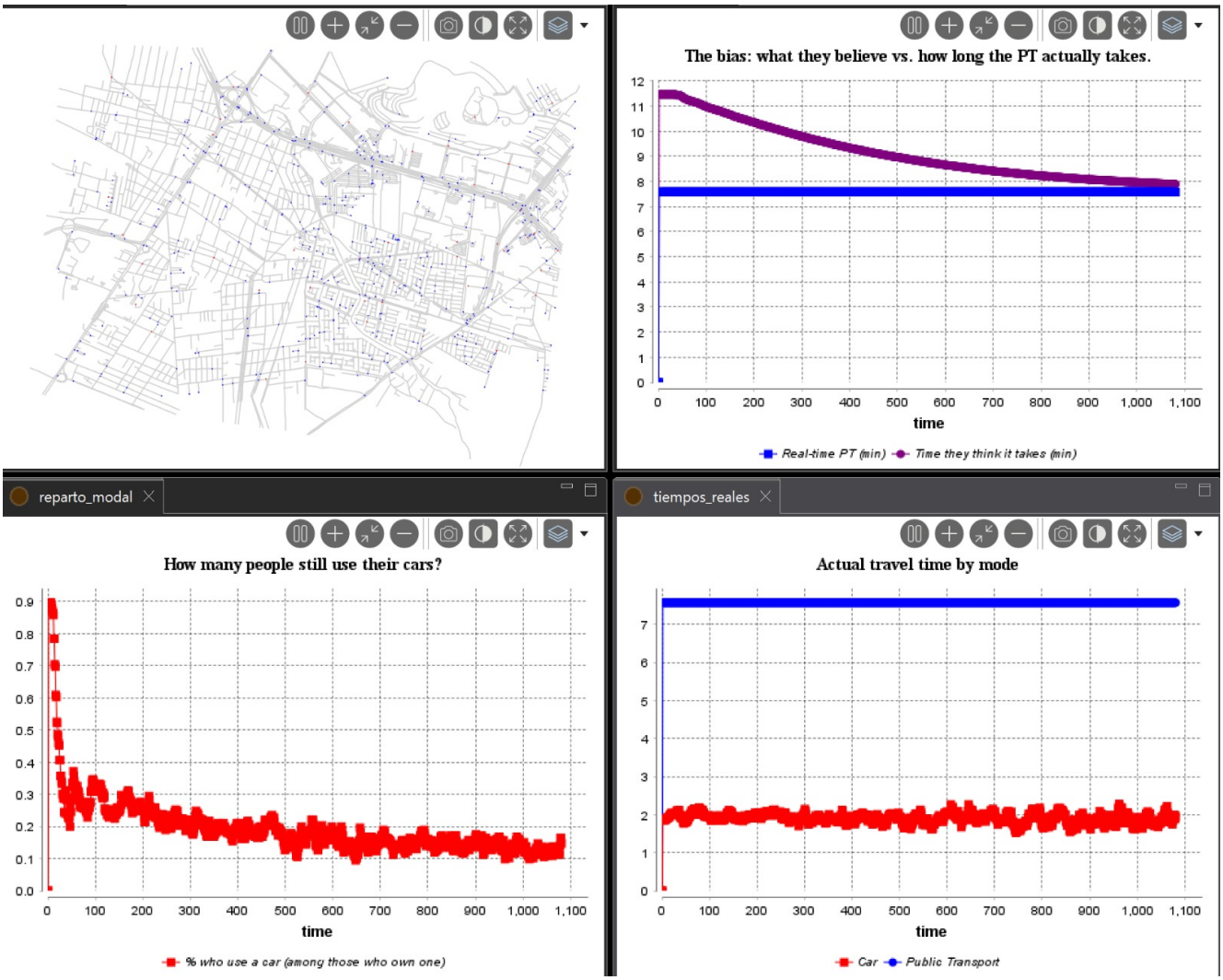

Figure 2: Scenario 2 - Best case for public transport, where it takes less time to get to each station and the average speed is closer to that of a car. Results show a quick reduction in bias towards how much time public transport actually takes, car usage reduces to almost 10 percent, travel time by car oscillates but still averages the same initial travel time

Using Agent-Based modelling to design urban food environments surrounding schools for adolescents
A case study on Strandeiland, Amsterdam

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Keywords

Agent-Based Model; Urban Food Environment; Adolescents; Amsterdam; ArcGIS

Abstract

Adolescents' food choices are influenced by urban food environments, particularly the food environment surrounding schools. However, limited insight exists into how the spatial configuration of food outlets influences adolescents' interaction with these environments. This research addresses this gap by developing an agent-based model (ABM) in GAMA to explore how spatial configurations of the urban food environment surrounding schools affect adolescents' food outlet choices, using the yet-to-be-built neighbourhood of Strandeiland, Amsterdam, as a case study.

While conceptualising the urban food environment as a complex system, the ABM represents spatial, temporal and economic constraints, food outlet attractiveness and exposures to food cues. GIS-based scenario testing created a Baseline Scenario and five alternative spatial configurations, including a 400-metre ban and targeted substitution.

The results suggest that the urban food environment shapes adolescents' food outlet choices through two mechanisms. First, spatial and temporal constraints influence which food outlets can be reached within adolescents' space-time prisms. Second, the spatial configuration of the urban food environment determines adolescents' exposure to food cues, which can influence the probability of visiting food outlets. Furthermore, scenario testing revealed distinct effects on adolescents' food outlet choices across the different spatial configurations. Scenario 1 (400-Metre Ban) reduced the overall unhealthy and healthy food outlet visits, while Scenario 2 (Spatial Banishment) retained the most adolescents on campus. Scenario 4 (Green Food Valley) produced the highest number of healthy food outlet visits. Scenario 5 (Targeted Substitution) retained a relatively high number of adolescents at school while increasing healthy food outlet visits and reducing unhealthy food outlet visits.

This research demonstrates how GIS-based scenario development can be combined with ABM to explore the adolescents' food outlet choices under different spatial configurations of food environments. Although the specific results are context-specific to Strandeiland, the approach can be adapted to other urban contexts.



Spatial scenario experiments

0 Baseline



1 400-metre ban



2 Spatial banishment



3 Close-by hub



4 Green Food Valley



5 Targeted substitution



Using MAELIA platform for participatory climate adaptation of agricultural territories: an integrated assessment and multi-agent modelling approach

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Keywords

Integrated Assesment and Modelling; Participatory approach; Agriculture; Climate change; Landscape

Abstract

Climate change is considered as a major threat to agriculture in the current and upcoming years. Farmers needs to adapt their practices in consequence to maintain the performances of agriculture. However, it is difficult to evaluate the impact of climate change experimentally, as it requires the ability to forecast future events and evaluate situations that have not yet occurred. Furthermore, agricultural systems must meet multiple objectives: agronomic (e.g., production), economic (e.g., profitability), and environmental (e.g., reduction of GHG emissions), and as such, they must be evaluated based on multiple criteria. The use of integrated assessment and modelling approaches (IAM) seems to be a fitting solution.

In the French Region of Bourgogne-Franche-Comté (NUTS 1), with the local policymakers, we conduct a study that aims to inform local farmers about the impact of climate change on their farming systems, assist them in co-designing and evaluating alternative scenarios of adaptation, and support public policies for broader adaptation efforts in the Region. For that, we use the MAELIA platform to assess the impact of climate change in three contrasting territories and simulate adaptation strategies co-designed during workshops with farmers.

MAELIA is an agent-based platform that aims to simulate and evaluate agricultural and bioeconomic systems at the territorial level. MAELIA combines a georeferenced database (e.g., soil, climate, agricultural parcels) with a modelling chain that simulates the various components of an agricultural region (e.g., soil-crop model, hydrology, farmer strategies) at a daily time step. As an output, MAELIA calculates a number of agronomic (e.g., yield), economic (e.g., margins), and environmental (e.g., GHG emissions) indicators that enable a multi-criteria assessment of the performances of sustainability, and insights to the resilience face to climate change. Because MAELIA provides a spatially explicit description of each territory, it allows us to assess how the variability of the territory's various components affects the variability of the indicators.

The study expects a strong participatory approach involving multiple stakeholders including scientists, farmers, policymakers, local experts. The participatory approach is applied at almost every stage of the process: including integrating knowledge about crop management strategies as an input of the model, assessing the current system, co-designing of adaptation scenarios, and analysis of the results. The participatory approach and the use of MAELIA nourish and complement each other in this framework.

This study is a proof-of-concept demonstrating the interest of using an IAM agent-based model (i.e., MAELIA) as a pivotal tool for diagnosis, forecasting, and design within the framework of a participatory, multi-stakeholder approach. By incorporating local constraints and stakeholders' operational perspectives, MAELIA can facilitate the co-production of knowledge and the development of actionable strategies for farmers and policymakers.

Additional material

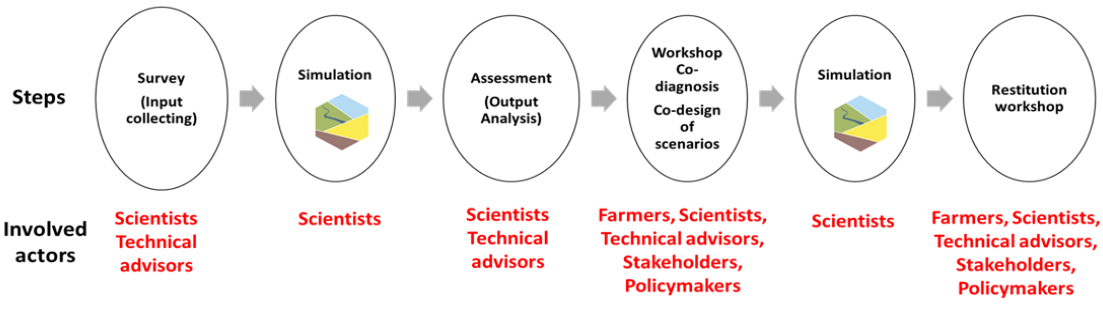

Figure 1. Simplified workflow for each territory, representing the main steps of the project and highlighting involved actors and MAELIA platform use.

What if Networks Could Reason?
Agent Guidance by Decision Models at Spatial Nodes

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Keywords

Agent-based modelling; network reasoning; decision models; accessibility; GAMA

Abstract

We propose network reasoning: decision models (DMs) associated with spatial nodes guide lightweight agents in GAMA [4]. Earlier TravelAgent work coupled agent perception, memory and planning with repeated language-model inference [2]. Here, nodes combine a traveller's destination, accessibility profile and recent actions with local connections and service observations to select an explicit next action.

Two experiments illustrate the approach (Fig. 1). The campus study uses H2O-Lightning-4B [1] at six decision locations for 500 pedestrians across four accessibility profiles. All reached their destinations through 1,724 decisions, averaging 3.45 per traveller, during 5,320 GAMA timesteps. Median client HTTP latency was 159.3 ms. The station study models 300 passengers, with previously collected API decisions replayed for 30 information-desk visitors. Jev 1.13.0 [5] interprets destination and access needs; shared rules translate answers into routing or clarification. Against the GPT-6 Luna comparator [3], median API latencies were 223.6 and 1,510.8 ms respectively, a 6.76-fold ratio in this task.

This work makes two contributions. First, agents follow simple movement heuristics between nodes; semantic inference is triggered only at decision locations or after information inspection. Requests therefore follow decision events rather than every movement timestep. This targets simulation speed through lower inference frequency and shared environmental knowledge, alongside the response time of the decision service itself.

Second, we propose nodes as a common interface for environmental updates. A closure, reduced access or changed service could be represented in node context and communicated as a revised next action, without each traveller maintaining or interpreting a global network update. Our contribution combines explicit contextual decisions, sparse inference and lightweight agent design.

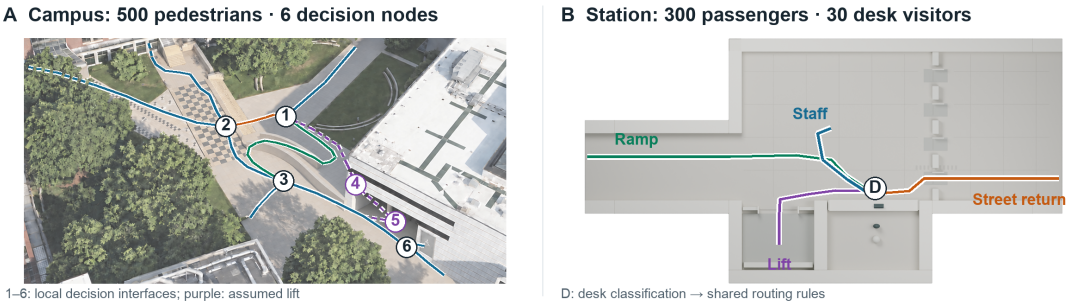

Figure 1: Campus accessibility (A) and station information-desk guidance (B); network overlays are schematic.

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