



## 2.1 Computational Layer

The computational layer includes the abstract elements of the platform: data and computational models to perform data analyses and visualizations. The computational layer is projected onto the CityScope table and uses different data sources as a baseline for simulation. It has been implemented using the GAMA platform [4] and Processing [8]<sup>1</sup>. GAMA is a modeling and simulation-development environment for building spatially explicit agent-based simulations.

## 2.2 Tangible Layer

The tangible layer has three components which enable the user to interact with the platform in different ways: the physical table, a tangible interface and an augmented reality module.

*Physical Table.* CityScope Andorra table is a 3D topographical model of the two main cities of Andorra—Andorra la Vella and Escaldes-Engordany and the rest of the territory is conceptually represented by visual clusters, giving an abstract country-level view.

*Tangible Interface.* CityMatrix [9] is a TUI that allows the user to modify the city's structure by manipulating predefined physical pieces. It gives real-time feedback to users for facilitating rapid, collaborative, informative decision-making. Users can reshape the design of the urban area under study and the ABM then takes into account (via CityI/O server) this modification and updates the agent behavior accordingly.

*Augmented Reality.* CityI/O [7] extends the physical confines of CityScope providing an AR tool for remote participation, data sharing, and high-end realistic visualization. In this case, CityI/O provides the following data layer: (1) telecom data origins, (2) existing built environment, (3) real-time 3D representation of design iterations, and (4) mobility analysis.

## 3 ANDORRA CASE STUDY

### 3.1 Model Description

CityScope Andorra ABM provides a dynamic simulation in which users can instantly identify three main elements: (i) clear representation of the cityscape defined by geography, buildings, amenities, cell towers, and roads, (ii) people's movement defined by dynamic agents, and (iii) amenities' popularity and density.

*Agents. State.* The set of variables is composed of (1) agent's country of residence, (2) origin location—defined using telecom data—, (3) preferred destination—generated by a decision making submodule—, (4) distance traveled, (5) speed of movement, and (6) passable streets. *Behavior.* The agent's trajectory is determined by the Origin-Destination matrix computed from the CDR<sup>2</sup> data and constrained to the local weighted road network. Agent behavior will slightly evolved according to traffic congestion (recomputing path in case of high congestion) and amenities occupancy (choosing another amenity if the current amenity is full).

<sup>1</sup>A release of the ABM model can be downloaded here [github.com/CityScope](https://github.com/CityScope).

<sup>2</sup>Call Detail Records (CDR) are digital records gathered by the mobile network operator containing spatial-temporal information. Andorra Telecom privately (anonymized using SHA-512 Algorithm) released three years of CDR data sets (2014-2016).

## 3.2 Results

Results focus on two major aspects: visitors' attendance at certain events held annually in the country and traffic congestion levels caused by these events. The two events analyzed—(i) *Cirque du Soleil: VISION* and (ii) *Le Tour de France*—occurred in 2016.

*Visitors' Flow and Impact.* People are represented by solid circles and vehicles by stroke circles. Their colors vary according to the country of residence. The number of people present in the city's amenities evolves during the simulation. The amenity size increases (or decreases) according to the number of agents currently in the location.

*Heatmaps.* Aggregated data can be visualized onto the CityScope platform, resulting in graphic heatmaps that summarize global activity in the city and provide geo-located attendance estimates.

### Online Media.

- ABM visualization: [youtu.be/fLikAuFvVyg](https://youtu.be/fLikAuFvVyg).
- Smart City Expo World Congress 2016: [youtu.be/hdL0aundHL4](https://youtu.be/hdL0aundHL4)
- Andorra Deployment [youtu.be/42hfpzJXhhU](https://youtu.be/42hfpzJXhhU)

## 4 CONCLUSION

In this article we presented a version of the CityScope Andorra that, after being developed and tested at the MIT Media Lab City Science group and Barcelona Smart City Expo World Congress (2016 - 2017) was finally deployed in Andorra in Aug. 2017. During this period, dozen of workshops, classes, and more than a hundred public-private demonstrations have been successfully conducted, supporting the performance of the CityScope Andorra as an efficient civic engagement tool. Finally, we hope to have contribute to the spreading of ABM by democratizing the usage of ABM into new fields, using new methods and to the broad non-expert community.

## REFERENCES

- [1] Julián Candia, Marta C González, Pu Wang, Timothy Schoenharl, Greg Madey, and Albert-László Barabási. 2008. Uncovering individual and collective human dynamics from mobile phone records. *Journal of physics A: mathematical and theoretical* 41, 22 (2008), 224015.
- [2] Andrew Crooks, Christian Castle, and Michael Batty. 2008. Key challenges in agent-based modelling for geo-spatial simulation. *Computers, Environment and Urban Systems* 32, 6 (2008), 417–430.
- [3] Arnaud Grignard. 2015. *Modèles de visualisation à base d'agents*. Ph.D. Dissertation. Paris 6.
- [4] Arnaud Grignard, Patrick Taillandier, Benoit Gaudou, Duc An Vo, Nghi Quang Huynh, and Alexis Drogoul. 2013. GAMA 1.6: Advancing the art of complex agent-based modeling and simulation. In *International Conference on Principles and Practice of Multi-Agent Systems*. Springer, 117–131.
- [5] Mohammad Hadhrawi and Kent Larson. 2016. Illuminating LEGOs with Digital Information to Create Urban Data Observatory and Intervention Simulator. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems*. ACM, 105–108.
- [6] Ariel Noyman, Tobias Holtz, Johannes Kröger, Jörg Rainer Noennig, and Kent Larson. 2017. Finding Places: HCI Platform for Public Participation in Refugees Accommodation Process. *Procedia Computer Science* 112 (2017), 2463–2472.
- [7] Ariel Noyman and Yasushi Sakai. 2018. CityScopeAR: Urban Design and Crowd-sourced Engagement Platform. *Proceedings of the 2018 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (2018).
- [8] Casey Reas and Ben Fry. 2007. *Processing: a programming handbook for visual designers and artists*. Number 6812. Mit Press.
- [9] Yan Zhang. 2017. *CityMatrix - An Urban Decision Support System Augmented by Artificial Intelligence*. Master's thesis. Massachusetts Institute of Technology.