SASBE 2025 aims to encourage the international exchange of innovative ideas between researchers from academia and industry. In addition to knowledge dissemination, the conference offers a valuable platform for professional networking, particularly benefiting university professors, graduate students, and postdoctoral researchers.

Research Article. Nr. 2776

Global comparative study of cities through CHOAMS, a nonlinear urban design framework that can support better urban investment schemes while avoiding urban fragmentation

Dan C. Baciu[1], Professorship Baciu[2]

1 Western Kentucky University
2 Münster University of Applied Sciences
Correspondence: dan.baciu@wku.edu

Abstract

At SASBE 2024, we presented a nonlinear framework to study urban environments and help practitioners reliably generate synergistic value through their urban design projects. Our work was based on a model trained for Wellington, NZ, using a dataset of ~200,000 entries. Here we expand our study to compare 10 cities in New Zealand, Europe, and the U.S.A. with models trained on a dataset of several million entries. This new comparative research demonstrates general rules that hold across continents, as well as idiosyncrasies in the functioning of individual urban environments. For example, access to a diverse supply of urban activities generates urban value in all cities. At the same time, synergies and antagonism between activities vary from city to city, creating urban characters and modes of life that may be unique. These insights help architects and planners conceptualize cities and, with modelling support, make decisions for their planned urban designs. Our nonlinear models, which we refer to as **ch**ains **o**f **a**ctivity **m**odels (CHOAMs), not only support decision-making, but they can be trained within hours and are easily shared and expanded. This suggests that they could spearhead an evolution of new, nonlinear urban modelling frameworks. Such frameworks will likely spread worldwide owing to global applicability and relevance. In all cities that we studied across three continents, we found that our approach and the decision-making systems that we build with it can be used to fight urban fragmentation, reducing significant losses in all countries.

Keywords: nonlinear modelling; city life; chains of activities models (CHOAMs)

Highlights

- Nonlinear urban modelling can accurately predict urban value around the world.
- Nonlinear urban modelling can fight urban fragmentation around the world.
- Access to diverse urban activities is valuable as a rule of thumb, around the world.
- Parameters that quantify synergies and antagonism between different activities are inferred with the same learning algorithm around the world, but vary greatly from city to city, reflecting local urban realities.

1 Introduction

At the International Conference of Smart and Sustainable Built Environment (SASBE 2024), held at the Auckland University of Technology in November 2024, we presented a study of Wellington, New Zealand, that called for a paradigm shift from linear to nonlinear, data-driven models in urbanism (Baciu, 2024). This shift in paradigm was motivated through the observation that nonlinear models can reveal the hidden synergies that drive the creation of urban value (Baciu et al., 2022; Baciu, 2023). Wellington, perched on New Zealand's North Island and celebrated for its compact downtown, diverse cultural venues, and robust public transport (Kernohan, 1994), provided an ideal living laboratory. For this city, we collected data and trained a nonlinear model, which we refer to as a **ch**ains **o**f **a**ctivities **m**odel (CHOAM). In this model, the nonlinear effects that arise when different urban activities interact (e.g. synergies between education and shopping or dwelling and sports) are inferred based on an AI learning algorithm (Baciu, 2024; Baciu 2025). Utilizing this algorithm, our Wellington CHOAM was trained on a dataset of roughly two hundred thousand geolocated venues that house diverse urban activities, a thousand rental prices, and a million mobility-based isochrones. The results were that we could empirically prove that diversity is generally beneficial, as a rule of thumb (Baciu, 2024; Baciu et al., 2022; Raszka & Baciu, 2022), and that there are different modes of life that overlap to create the city's urban characters. Furthermore, we demonstrated how our model can be utilized to support investors and planners in making meaningful design decisions while avoiding urban ills such as gentrification, segregation, separation, or sprawl (Harvey, 2012; Schelling, 1978).

Recognizing that insights from a single city may or may not generalize well, we set out to include more cities in our study. To that end, we expanded our data to encompass ten cities across New Zealand, Europe, and the United States of America. In addition to Wellington, our study includes Frankfurt, Stuttgart, Münster NRW, Bonn, Hamburg, Lausanne, Hannover, Cologne and Boston—cities that range from global financial capitals and automotive hubs to university towns and lakeside cultural centres. This comparative setup enables us to recognize general principles of value generation in urban design, while also discovering local idiosyncrasies.

Scaling our analysis from Wellington's two hundred thousand data points to a combined dataset of several million entries across all ten cities ensures the statistical robustness needed for reliable cross-city comparison. Each entry in this dataset represents a specific urban activity—schools, cafés, theatres, offices, parks, or other infrastructures that house urban activities and are tied to precise geospatial locations (Baciu et al., 2022). We complement these with multi-scale isochrone computation, capturing walking, cycling, and driving catchment areas that trace the flow of urban life (Cervero, 1998; Banister, 2005). Finally, attractiveness for inhabitants—and, with it, urban value—is assessed based on an expanded set of more than ten thousand rental prices across the ten cities (Baciu, 2023).

The new results from our comparative study corroborate that access to a supply of diverse urban activities generally benefits the generation of urban value, as a rule of thumb. At the same time, synergies and antagonism between activities reflect the idiosyncrasies of individual cities, giving rise to different urban characters and modes of life across the settings we studied.

In the sections that follow, we outline our results. The methods that we have employed in Wellington have not changed in the least and may be found it our earlier articles.

2 Results

Before we come to the main results from our comparative study, it may be useful to quickly recall how **ch**ains **o**f **a**ctivity **m**odels (CHOAMs) work. Rather than assigning value to separate urban activities, 'shopping', 'education', 'work', 'leisure', etc., CHOAMs are trained to evaluate chains of activities, which are composed of pairwise connections between activities—in this way, individual activities are connected to each other. This setup lets CHOAMs detect synergies and antagonism between activities that are chained together, which, in turn, serves as a blueprint for understanding nonlinear urban realities.

Based on this setup, a value is assigned to every pairwise connection between activities. For example, the connection 'shopping, education' receives a value that gauges how relevant it is towards generating urban value. These assigned values between pairwise activities can be studied individually, and they can also be grouped. In this way, we can summarily study different types of connections between activities. In following three subsections, we will focus on three types of grouping connections:

1. Grouping pairwise connections into same-type and different-type connections.
   In this approach, same-type-connections such as 'shopping-shopping' are compared with diverse-type-connections, such as 'shopping, sports'.

2. Grouping pairwise connections into larger groups of mutually synergistic connections.
   Here, different groups are created such that each group contains mutually synergistic connections. Mathematiclly, the groups are obtained through eigendecomposition of the matrix containing all pairwise connection values.

3. Grouping pairwise connections by the type of urban mobility required to establish the connection.
   Here, the groups are created by averaging the values of all pairwise connections that are established through urban mobility at the same speed. In this way, connections established at small speed can be compared with connections established at higher speeds.

In the following three subsections we discuss each of these three types of grouping, highlighting general insights that are valid across all cities as well as idiosyncrasies that are observed locally.

2.1 Same-type and diverse-type connections

Same-type-connections take place whenever the same type is repeated in an urban connection, e.g. 'work, work'. By contrast, diverse-type-connections refer to the cases when different activities co-occur in a sequence, e.g. 'education, sports'.

In our Wellington studies, we showcased specifically that, as a rule of thumb, same-type-transitions generate less synergies than diverse-type-transitions. This highlighted that urban diversity is beneficial, as a general rule.

At the same time, we showcased that there is high variability across individual connections. Some same-type-connections may be exceptionally beneficial, while some diverse-type-connections can be detrimental. This led us to the conclusion that it is crucial to train CHOAMs and have a clear picture that is locally validated in a city.

Our present study demonstrates that these rules are valid across all cities that we studied. In general, diverse-type-connections generate more value than same-type-connections. At the same time, there is a great amount of variation across parameters. Different connections are valued differently in different cities.

This result is remarkable. It shows that one can use the same mathematical description for diversity and nonlinear interactions across all cities, globally. Furthermore, in all cities, diversity and nonlinear interactions are valuable. At the same time, there is great variation across cities in the exact parameter values that are inferred from the data obtained in each city. Connections between the same activities may generate synergies in one city while creating antagonism in another.

2.2 Mutually synergistic connections

CHOAMs let us study mutually synergistic connections that can be linked into longer chains of activities that can be particularly valuable together. These mutually synergistic connections can be interpreted as 'modes of life' that give a city its blend of local characters.

In our SASBE 2024 contribution, we showed how the modes of life can be extracted from CHOAMs through a simple mathematical analysis: matrix eigendecomposition performed on the matrix containing all pairwise connection values. The question remained whether all cities have modes of life, and whether the modes of life are the same or variable across different cities.

The comparative study we now performed demonstrates that all cities have modes of life that link multiple activities into larger groups of mutually synergistic connections. These groups of connections are not universal, however, but vary across cities. This result is similar to the one obtained in the previous subsection. The overall functioning of cities follows the same principles, even though these principles create a local character that can be interpreted as a unique expression of human life.

2.3 Access to a diverse supply of activities at different speeds

As part of our SASBE 2024 contribution, we demonstrated that slow-speed, middle-speed, and fast-speed mobility are valuable in different ways. Here, we continue this research direction, evaluating six different speed groups, ranging from 0.5 km/h to 45 km/h. This study demonstrates that all speeds generate value, and it would be detrimental to artificially eliminate them. Admittedly, the parameters obtained at 0.5 km/h and 45 km/h are closer to zero than those obtained at intermediary speeds. This result reflects that the outlier speeds are outliers, after all. Nevertheless, even these speeds do not fall much above or below zero on average. They are not more or less beneficial on average than other speeds. In general, we do see that different speeds can be more or less valuable in different cities. Sometimes 6 km/h or 30 km/h may have a slight edge over other speeds. Nevertheless, no speed group (e.g. 'pedestrian') is the universally best in all cases. Therefore, here, as well, it is relevant to have CHOAMs trained to reflect local urban conditions.

3 Methodology

As mentioned in the introduction, we made no methodological changes whatsoever compared to our Wellington CHOAM. The algorithms employed in Wellington have been used without a change in architecture or training parameters. No city-specific calibration had to be introduced. The city-specific parameters for synergies and antagonism are all obtained through the same approach down to same training parameters. Only the training data reflects local realities, collected separately from each city. However, here as well, the data are collected with the same methods and algorithms — and they are all publicly available.

4 Discussion

We have led a comparative study, expanding on our 2024 SASBE contribution. This new study reconfirmed our earlier findings, while also adding substance to them, highlighting which results are general, and where the idiosyncrasies of each city lie. In general, we find that nonlinearity is relevant in studying, describing, and modelling urban phenomena in all cities.

Nonlinearity is relevant because it allows us to study diverse activities and their synergistic or antagonistic interactions. In doing so, our study systematically demonstrates that access to diverse urban activities is valuable as a rule across the globe, even though synergies and antagonism play out differently at different locations.

Our capabilities to detect this synergistic and antagonistic interplay allow us to build decision-making tools that help alleviate fragmentation. In particular, both the analysis and the decision-making tools we presented at our SASBE 2024 contribution work across all cities we studied, supporting the development of diverse cities with a diverse supply of activities and a broad range of mobility options. As such, our decision-making tools can help alleviate urban fragmentation, which is a global ill.

Urban fragmentation is caused by failed investment that does not take into account the nonlinear aspects of urban life. Our approach works exactly against this shortcoming. From the start, we set out to model nonlinear aspects and demonstrate that they are relevant. Today, our results allow us to usher in a shift in paradigm from linear to nonlinear modelling in urbanism.

The results that this present SASBE 2025 contribution is reporting have been obtained from studying 10 cities across three continents. Since we first submitted this article, we have further expanded our comparative study to include additional cities, which has further supported the same conclusions. It is certainly true that urban fragmentation has long been a bottomless pit of failed investment. However, if everyone starts using our tool, we could soon find ourselves forgetting how ubiquitous the problem has once been.

Acknowledgements

Data processing for this article was completed at the Professorship Baciu, Münster University of Applied Sciences, in the class 'Data Driven Design: Urban Diversity'. The contributions of the involved team are recognized as a group authorship of the research group Professorship Baciu.

Funding

Dan C. Baciu would like to acknowledge support he obtained through FH Starter grant of Münster University of Applied Sciences.

Data Availability Statement

The data are available from the corresponding author upon request. The code has been repeatedly publicly shared. Its functioning is explained in our SASBE 2024 contribution here: https://doi.org/10.1108/uss-12-2024-0084

Conflicts of Interest

The authors declare no conflict of interest.

References

Baciu, D. C. (2022). Mapping Urban Diversity: Applications. OSF Preprints. https://doi.org/10.31219/osf.io/buajg

Baciu, D. C., Mi, D., Birchall, C., Della Pietra, D., Loevezijn, L., & Nazou, A. (2022). Mapping diversity: From ecology and human geography to urbanism and culture. Springer Nature Social Sciences. https://doi.org/10.1007/s43545-022-00399-4

Baciu, D. C. (2023). Causal models, creativity, and diversity. Humanities and Social Science Communications. https://doi.org/10.1057/s41599-023-01540-1

Baciu, D. C. (2024). 'How Changes In Urban Mobility Affect Experienced Urban Diversity: Case Study For Scenarios In Wellington.' SASBE conference, Auckland, NZ, November 2024. https://doi.org/10.1007/978-981-96-4051-5

Baciu, D. C. (2025). Nonlinearity Is All You Need! CHOAMs for Better Cities. USS, https://doi.org/10.1108/uss-12-2024-0084

Banister, D. (2005). Unsustainable Transport: City Transport in the New Century. Routledge.

Bianco, C., & Baciu, D. C. (2024). Estimating how changes in mobility affect perceived urban diversity. Reinventing the City, Amsterdam Institute for Advanced Metropolitan Solutions, April 26–28. https://osf.io/fhwr2/

Cervero, R. (1998). The Transit Metropolis: A Global Inquiry. Island Press.

Harvey, D. (2012). Rebel Cities: From the Right to the City to the Urban Revolution. Verso Books.

Jacobs, J. (1961). The Death and Life of Great American Cities. Random House.

Kernohan, D. (1994). Wellington's New Buildings: A Guide to the Architecture of the Capital City. Victoria University Press.

Newman, P., & Kenworthy, J. (1999). Sustainability and Cities: Overcoming Automobile Dependence. Island Press.

Raszka, P., & Baciu, D. C. (2022). Mapping commuter diversity in New York City: Diversification and vertical growth may form positive feedback loop. https://doi.org/10.31219/osf.io/etn32

Schelling, T. C. (1978). Micromotives and Macrobehavior: Fels Lectures on Public Policy Analysis. W. W. Norton & Company.

Vertovec, S., Hiebert, D., Gamlen, A., & Spoonley, P. (2021). Superdiversity: Today's migration has made cities more diverse than ever in multiple ways. Retrieved February 21, 2021, from https://mpg.de