Title

Concentric and polycentric models of the city through the lens of linear and nonlinear modeling

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Publication Date

2024-04-01

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Sociology has brought forth two antithetical models of the city: the concentric "Chicago" model and the polycentric "Los Angeles" model. In this presentation I revisit these models through the lens of linear and nonlinear mathematical modeling. I show that the concentric model can be described with linear mathematics while the polycentric model requires nonlinearity. My presentation also traces the distinction between linear and nonlinear modeling across a broad array of sciences and summarizes what type of observations can be described with linear and nonlinear modeling respectively. Linear models are best at describing predictable change, evolution, and progress. Nonlinear models are required when it comes to interplay between multiple diverse parties and chaotic behavior that is hard to predict. For architects, these insights may be particularly intuitive to understand. A straight line looks straightforward, while curves are more frequently associated with playfulness. The presentation will fit the present conference topic, as it is a discussion about urban models and about order and linearity versus disorder, playfulness, and nonlinearity.

The field of sociology has historically presented two fundamentally contrasting frameworks for understanding urban development: the centralized, concentric structure epitomized by the "Chicago" model, and the decentralized, dispersed form represented by the "Los Angeles" model. This presentation delves into these divergent paradigms through the analytical lens of mathematical modeling, employing both linear and nonlinear approaches to elucidate the underlying dynamics of each model.

The concentric "Chicago" model, emerging from the early 20th-century sociological studies, posits a city expanding outward in rings from a central core, each ring representing different urban functions and social groups. This model, with its inherent simplicity and predictability, lends itself to linear mathematical descriptions. Linear models, characterized by proportionality and additive relationships, effectively capture the gradual, predictable processes of urban growth and zoning characteristic of the Chicago model.

In contrast, the "Los Angeles" model, reflective of late 20th-century urban development patterns, presents a city with multiple centers or nodes, each acting as a focal point for different economic, cultural, and residential activities. This polycentric arrangement, with its complex interactions and dependencies between nodes, necessitates a nonlinear approach to modeling. Nonlinear models, which include feedback loops, threshold effects, and emergent properties, are adept at capturing the dynamic, often unpredictable interplay between diverse urban elements intrinsic to the Los Angeles model.

This presentation extends the discussion of linear and nonlinear modeling beyond urban studies, exploring their application across a variety of scientific disciplines. From physics and biology to economics and psychology, the distinction between linear and nonlinear models offers profound insights into the nature of systems and phenomena within each field. Linear models are invaluable for their ability to describe systems undergoing steady, incremental changes, making them suitable for analyzing phenomena where cause and effect are directly proportional. Conversely, nonlinear models are essential for understanding complex systems characterized by sudden shifts, emergent behavior, and chaotic dynamics, where the relationship between variables cannot be simplified to direct proportionality.

For architects and urban planners, the distinction between linear and nonlinear modeling resonates on both a practical and intuitive level. The simplicity and directness of a straight line can be seen as analogous to linear models, which are straightforward and predictable. Meanwhile, the curvature and flexibility of nonlinear forms mirror the complexity and adaptability of nonlinear models, capturing the essence of dynamic, multifaceted urban systems.

In conclusion, this presentation not only revisits the foundational urban models of Chicago and Los Angeles through the sophisticated perspectives of mathematical modeling but also bridges these urban theories with broader scientific concepts of linearity and nonlinearity. By doing so, it contributes to a deeper understanding of urban dynamics and offers valuable insights into the modeling of complex systems. This discussion is particularly pertinent to the theme of the current conference, as it engages with core concepts of order and predictability versus disorder and flexibility, providing a comprehensive framework for examining urban models and their broader implications in the architectural and planning domains.

Key articles

Dan C. Baciu (2015). Systemic Analysis of Cooperation: Architects, Urban Space and Tourism. *JETK* 4 (2015), p.27-30. https://escholarship.org/uc/item/81h50276

Dan C. Baciu (2020). Cultural Life: Theory and Empirical Testing. BioSystems. https://doi.org/10.1016/j.biosystems.2020.104208

Dan C. Baciu (2023). Causal Models, Creativity, and Diversity. Humanities and Social Science Communications. https://doi.org/10.1057/s41599-023-01540-1

Dan C. Baciu et al. (2022). Mapping Diversity: From Biology and Human Geography to Urbanism and Culture. Springer Nature Social Sciences. https://doi.org/10.1007/s43545-022-00399-4

Linear and nonlinear modeling

AMS Conference 2024 — Blueprints for Messy Cities.

Baciu, Bentvelsen, Bianco

This 2024 AMS conference goes under the subtitle “Blueprints for messy cities”

Our presentation is about linear and nonlinear modeling and urban diversity,

We use nonlinear modeling as blueprint for messy cities

Let us make the connection between messy cities and nonlinear modeling and diversity with an anecdote…

Here is an image of a messy cooperation, inspired from French romanticism, from the “Raft of the Medusa”. We’ve created this image with ChatGPT…

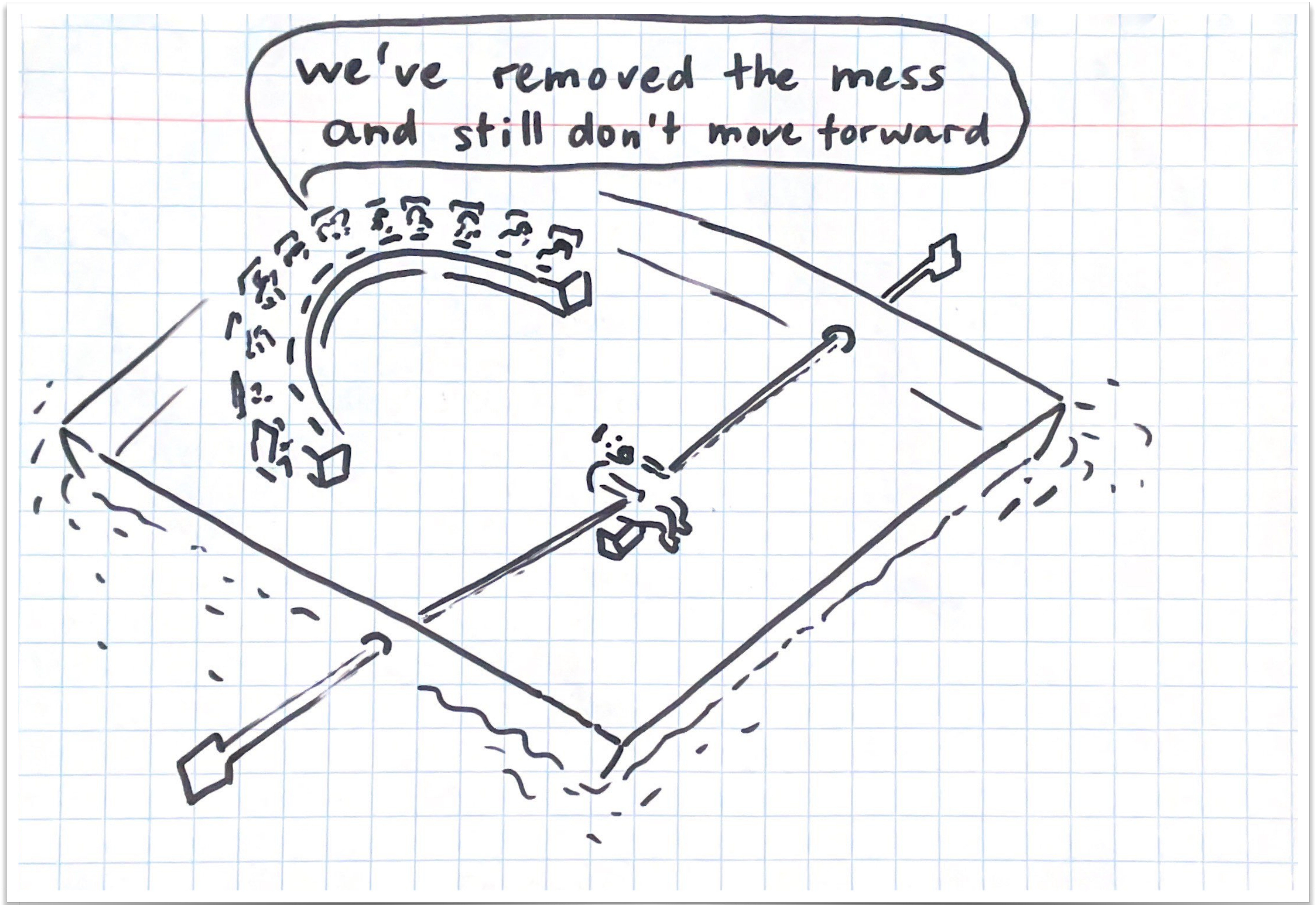
It’s symbolizes a messy city

Baciu, Bentvelsen, Bianco

Everyone is at work, but people are not coordinated, and the sea is stormy

Now, look at this image. We’ve drawn it by hand.

We tried our best to remove the mess…



Baciu, Bentvelsen, Bianco

Removing the mess is not always a solution.

Many cities seem messy.

They seem messy, because we don’t grasp the order.

In messy cities …

Two people are …

Two people are three political parties.

Me, you =

Me, you = three political parties.

Me, you = Party 1 (you AND I)

Me, you = Party 1 (you AND I)

What's the second party then?

Me, you =

Party 1 (you AND I)

Party 2 (I AND you)

Me, you =

Party 1 (you AND I)

Party 2 (I AND you)

What's the third party then?

Party 1 (you AND I)

Me, you = Party 2 (I AND you)

Party 3 (us AND us)

us := you OR I = I OR you

Seriously!
Let's translate this statement into math!

Logic

Math

Me, you = Party 1 (you AND I)

Party 2 (I AND you)

Party 3 (us AND us)

$$f(x_1, x_2) = x_1 \times x_2$$

$$x_2 \times x_1$$

$$(x_1 + x_2) \times (x_1 + x_2)$$

us := you OR I = I OR you

Baciu, Bentvelsen, Bianco

In a binary system with just 0, 1,
the two formulas give the same result

	Party 1 (you AND I)		$x_1 \times x_2$
Me, you =	Party 2 (I AND you)	$f(x_1, x_2) =$	$x_2 \times x_1$
	Party 3 (us AND us)		$(x_1 + x_2) \times (x_1 + x_2)$

us := you OR I = I OR you

Baciu, Bentvelsen, Bianco

Let’s restructure the math a little…

Initial math

$$f(x_1, x_2) = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)(x_1 + x_2)}$$

Rearranged formula

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

Baciu, Bentvelsen, Bianco

Initial math

$$f(x_1, x_2) = \frac{x_1 x_2 \quad x_2 x_1}{(x_1 + x_2)(x_1 + x_2)}$$

Rearranged formula

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

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Initial math

$x_1 x_2$

$f(x_1, x_2) = x_2 x_1$

$(x_1 + x_2)(x_1 + x_2)$

Rearranged formula

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

Initial math

Rearranged formula

$x_1 x_2$

$f(x_1, x_2) = x_2 x_1$

$(x_1 + x_2)(x_1 + x_2)$

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

The rearranged formula is Simpson's Diversity Index

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

The rearranged fromula is Simpson's Diversity Index

The upper term shows the interplay between each of us

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

The rearranged fromula is Simpson's Diversity Index

The upper term shows the interplay between each of us

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

The lower term normalizes, dividing by all possible interplay

The rearranged fromula is Simpson's Diversity Index

The upper term shows the interplay between each of us

$$D = \frac{x_1 x_2 + x_2 x_1}{(x_1 + x_2)^2}$$

The lower term normalizes, dividing by all possible interplay

Each of us is an independent dimension in the system, which makes the system nonlinear

What question does this anecdote lead us to?

Can nonlinearity be a blueprint for messy cities?

Can nonlinearity be a blueprint for messy cities?
… it's still a hypothesis

Can nonlinearity be a blueprint for messy cities?
… it's still a hypothesis
… … at the present conference, we have 3 case studies!

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Case study 1.

Case study 1. Tourism in Amsterdam and Sassi (IT).

Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

Baciu, Bentvelsen, Bianco

Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

We’ve looked at this settlement

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Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

We’ve looked at this settlement
It was once evacuated, planners said it was messy

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Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

We’ve looked at this settlement
It was once evacuated, planners said it was messy
Later, the mess was recognized as a quality

Baciu, Bentvelsen, Bianco

Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

We've looked at this settlement
It was once evacuated, planners said it was messy
Later, the mess was recognized as a quality
It has become UNESCO World Heritage Site

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Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. "Mapping Diversity" (2022)

UNESCO warned of the effects of too much tourism

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Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

we studied the effect of tourism on urban diversity

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Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

we studied the effect of tourism on urban diversity (mathematically applying Simpson's index)

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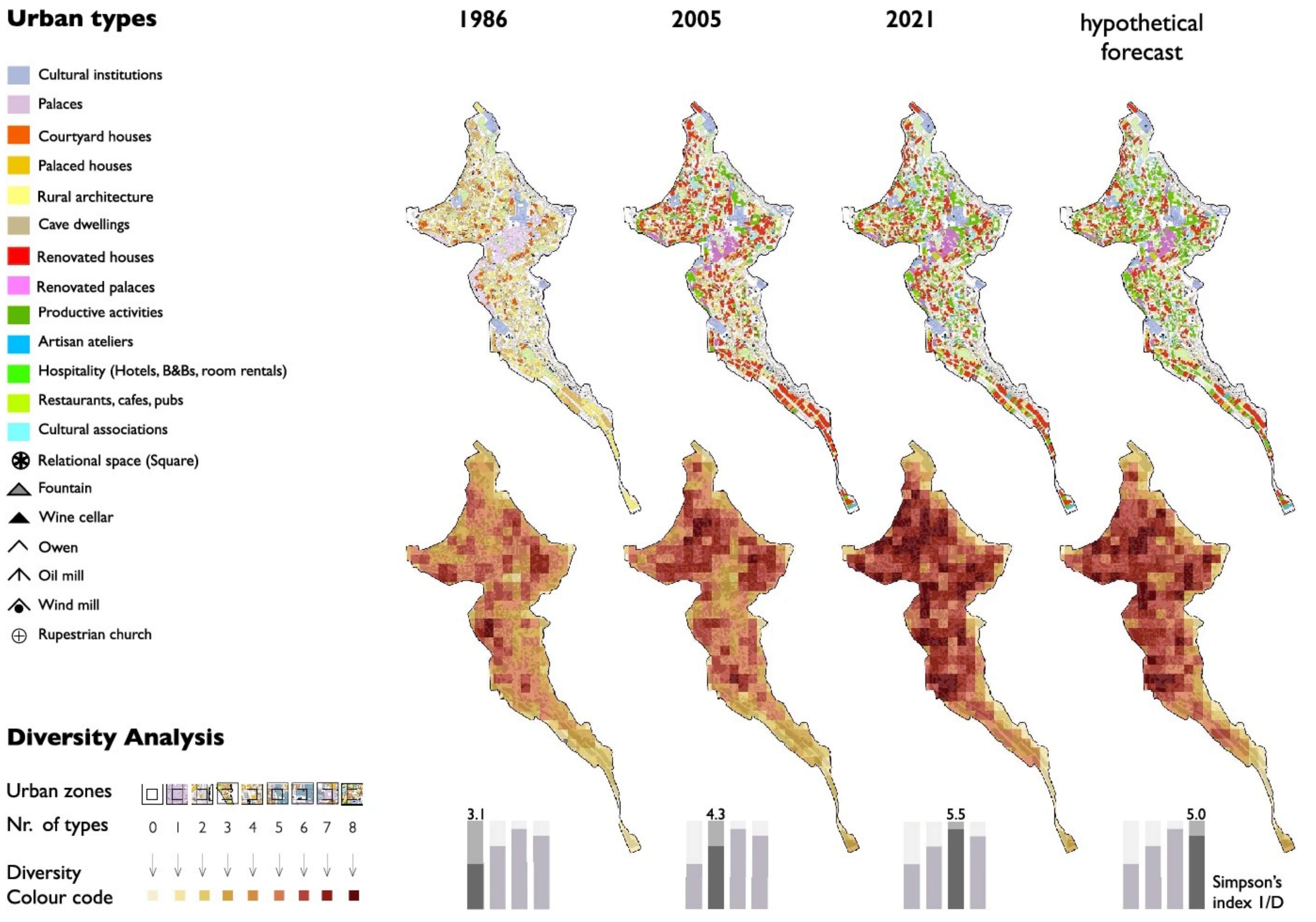
Baciu et. al. "Mapping Diversity" (2022)



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Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. "Mapping Diversity" (2022)

Our conclusion:
Tourism and other urban activities are in an unstable balance

Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

We have also come to this conclusion in Amsterdam, applying the same methods

Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)


Areas where we estimate that additional hotels could bring about a decline in urban diversity
OVERHOEKS
IJPLEIN EN VOGELBUURT
Meidoornweg
SLOTERDIJK
WESTERPARK
WESTELIJKE EILANDEN
HAARLEMMERBUURT
LANDLUST
STAATSLIEDENBUURT
BOS EN LOMMER
CENTRALE MARKT
FREDERIK HENDRIKBUURT
GRACHTENGORDEL-WEST
AMSTERDAM-WEST
JORDAAN
Rozengracht
BINNENSTAD
NIEUWMARKT EN LASTAGE
KATTENBURG
EASTERN DOCKLANDS
BORNEO ISLE
VAN GALENBUURT
DE BAARSJES
DE WALLEN
BURGWALLEN NIEUWE ZIJDE
OOSTENBURG
IJ-tunnel
MERCATORBUURT
DA COSTABUURT
MARKEN
KADIJKEN
OOSTELIJKE EILANDEN EN KADIJKEN
CRUQUIUSEILAND
JODENBUURT
PLANTAGE
HOOFDWEG EN OMGEVING
KINKERBUURT
Kinkerstraat
AMSTERDAM OUD-WEST
GRACHTENGORDEL
Zeeburgerdijk
WEESPERBUURT EN PLANTAGE
Postjesweg
LEIDSEPLEIN
ZEEBURG
OVERTOOMBUURT
ROETERSEILAND
Flevoweg
DAPPERBUURT
WESTINDISCHE BUURT
INDISCHE BUURT OOST
Insulindeweg
CREMERBUURT
VONDELPARKBUURT
DE WETERINGSCHANS
OUD-OOST
OOSTERPARKBUURT
AMSTERDAM-OOST
OVERTOOMSE SLUIS
ANDREAS ENSEMBLE
OOSTPOORT
Carolina MacGillavrylaan
Amstelveenseweg
MUSEUMKWARTIER
OUDE PIJP
DE PIJP
WEESPERZIJDE
WILLEMSPARK
De Lairessestraat
AMSTERDAM OUD-ZUID
NIEUWE PIJP

Conclusion: There is an unstable balance between diverse urban activities.

Della Pietra, Baciu, AMS conference contribution 2024.
Baciu et. al. “Mapping Diversity” (2022)

Urban mobility further influences this balance

This is illustrated in Case study 2.

Case study 2. Tel Aviv's light rail.

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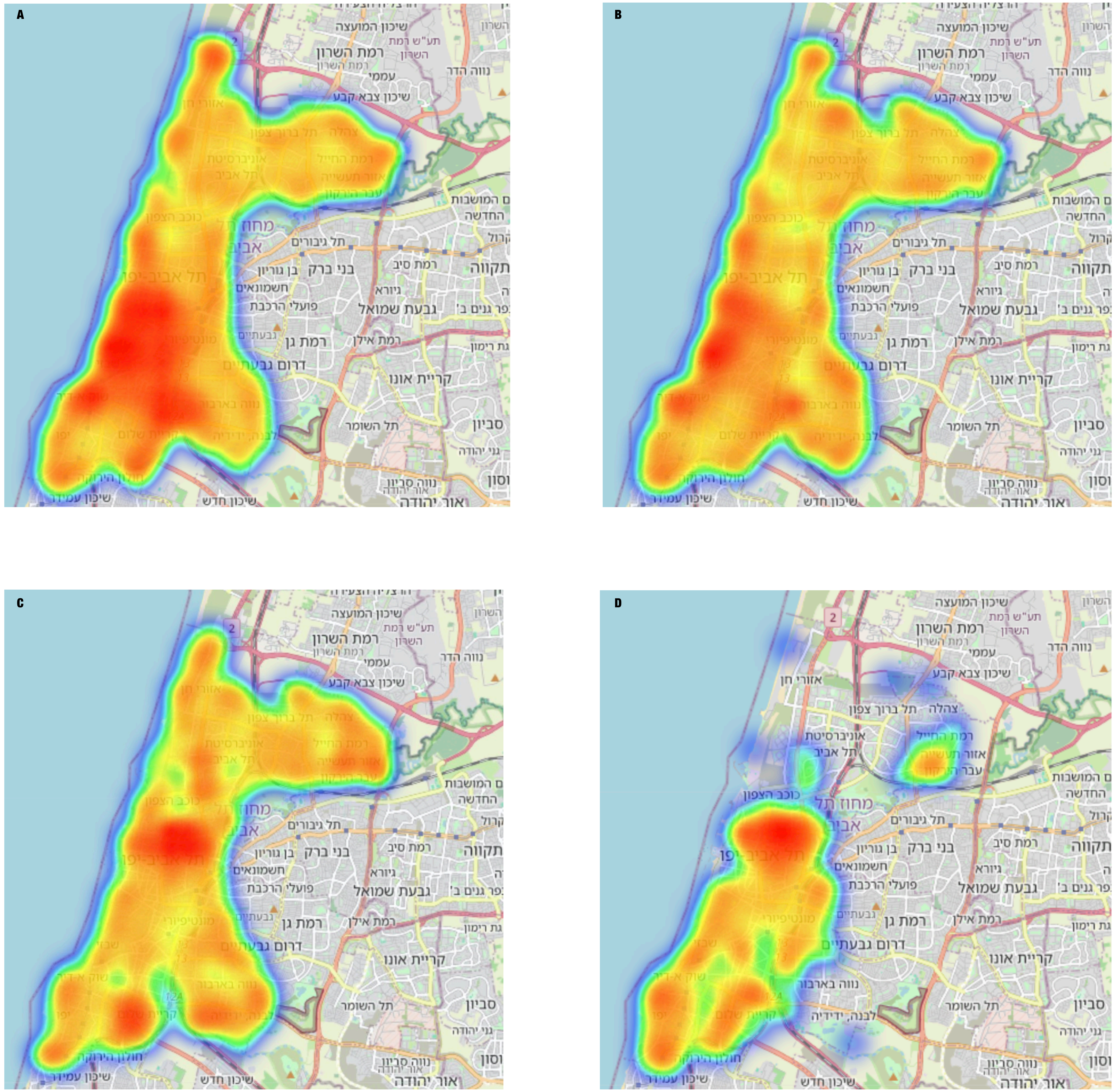
Using isochrones, we represented urban mobility before and after the light rail is built

With an advanced diversity index,
fitted to labeled data,
we simulate changes in diversity



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Conclusion: The maps visualize how the experienced urban diversity is transformed, already in response to changes in urban mobility alone

These ‘unstable balances’ raise a question…

Are Amsterdam, Sassi, and Tel Aviv ‘messy cities’?

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Technically, diversity is nonlinear mathematics.

In the 1960s, nonlinear models receive the name…

In the 1960s, nonlinear models receive the name…

CHAOS THEORY

Can we say more about the distinction between linear and nonlinear modeling?

The distinction between linear and nonlinear modeling permeates all sciences

$$\dot{x}_i = q_1 x_1 + q_2 x_2 + q_3 x_3 + \ldots + q_n x_n \,.$$

+

Linear models can describe growth, movement, evolution, creativity, innovation, progress, and competitive exclusion.

Movement
Creativity
Evolution
Progress
Growth
Survival of the fittest
Competitive exclusion

$$\dot{x}_i = x_i \times \phi(x_1, x_2, x_3, \ldots x_n) \,.$$

×

Freedom
Play
Ecology
Revolution
Surprise
Changing relationships
Diversity

$$\dot{x}_i = q_1 x_1 + q_2 x_2 + q_3 x_3 + \ldots + q_n x_n \,.$$

$$\dot{x}_i = x_i \times \phi(x_1, x_2, x_3, \ldots x_n) \,.$$

$+$

Linear models can describe growth, movement, evolution, creativity, innovation, progress, and competitive exclusion.

Movement
Creativity
Evolution
Progress
Growth
Survival of the fittest
Competitive exclusion

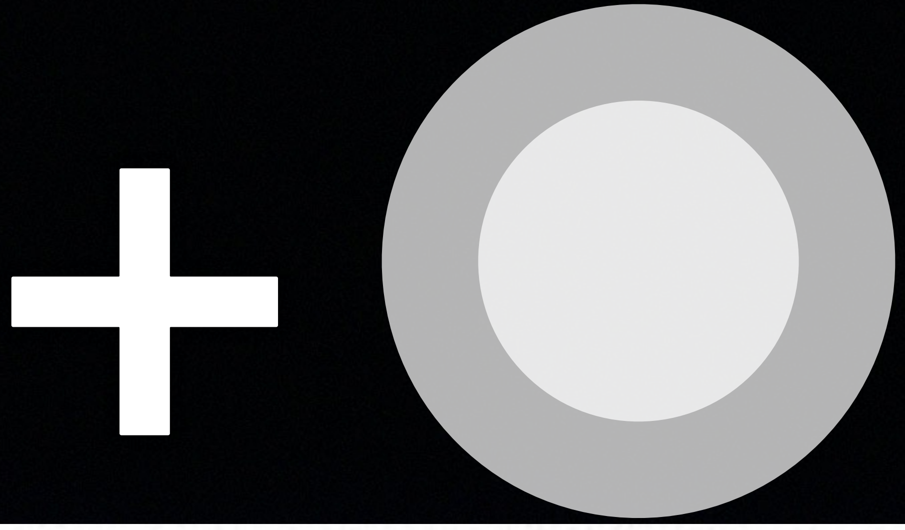
$\times$

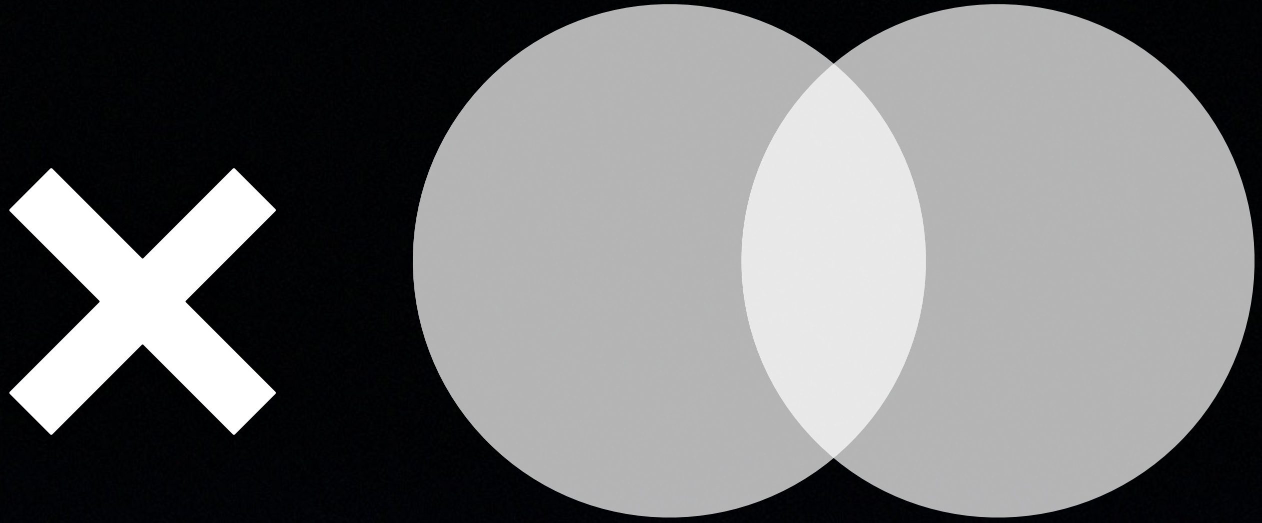
Nonlinear models can describe play, ecology, revolution, surprises, changing relationships, and diversity.

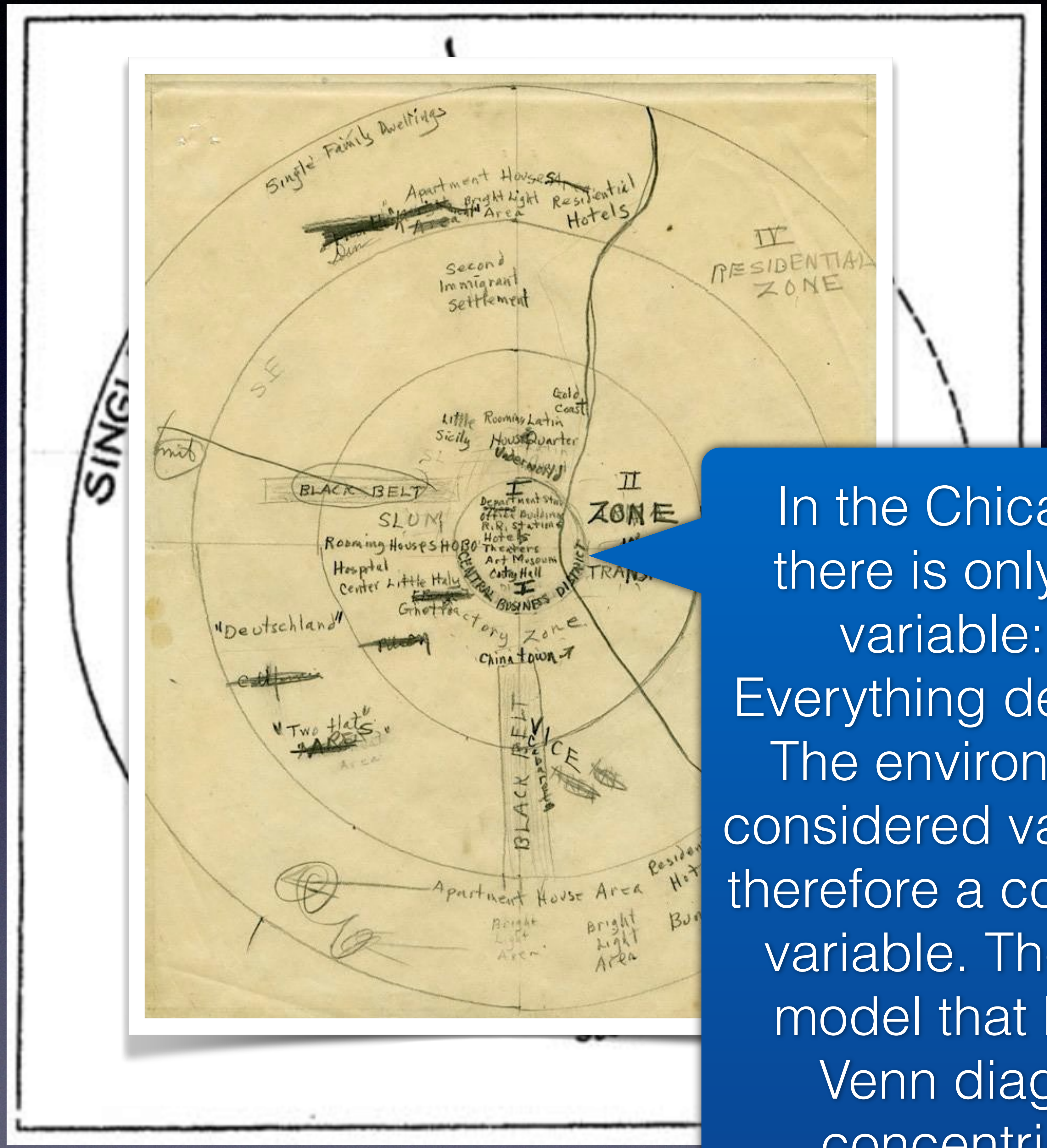
Freedom
Play
Ecology
Revolution
Surprise
Changing relationships
Diversity

In urbanism, the distinction between linear and nonlinear models is also found in the concentric and polycentric models of the city

The social sciences have brought forth two antithetic models: the concentric “Chicago model” and the poly centric “LA model”. The first can be expressed as a linear model. The second requires nonlinear components.



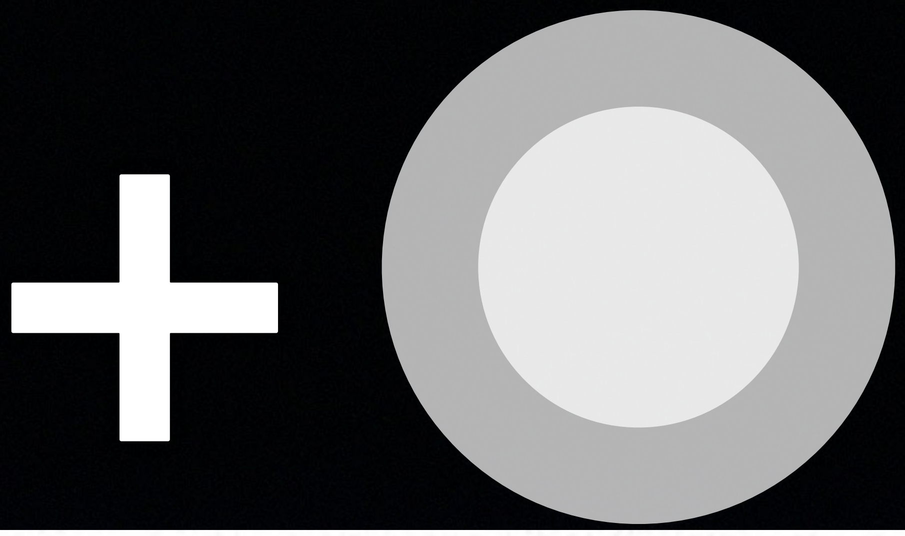


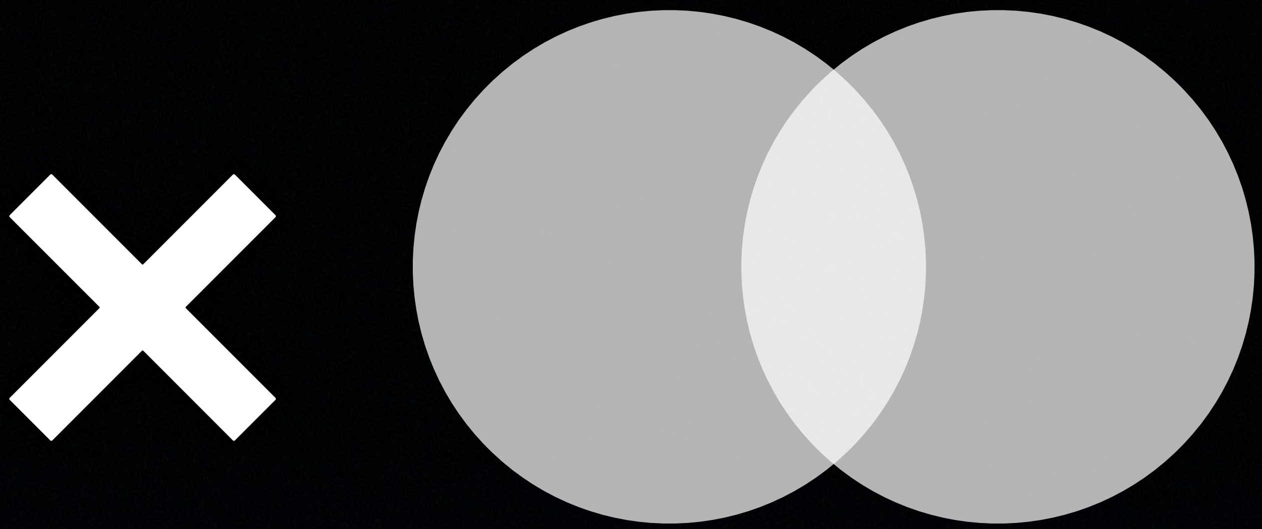


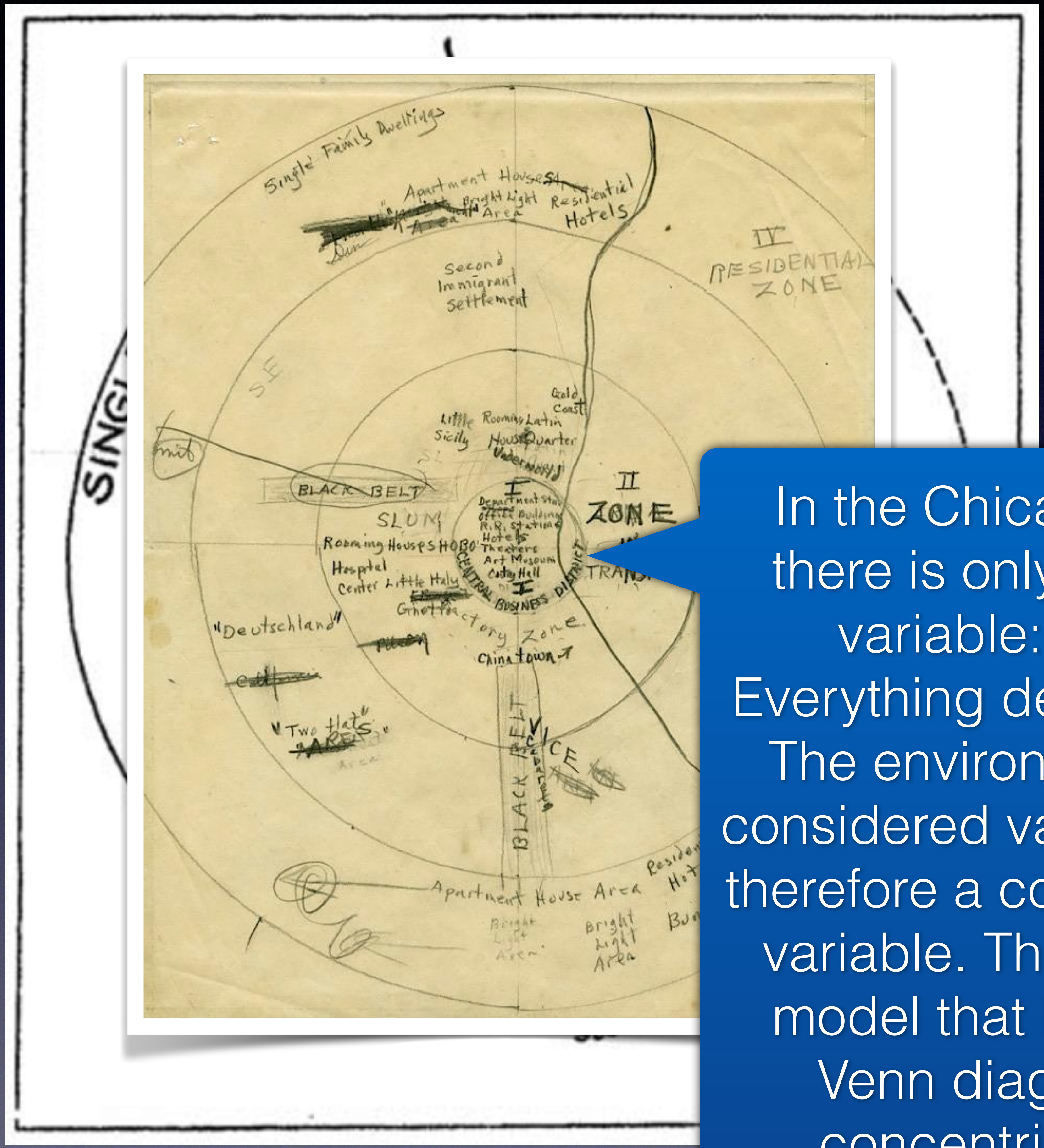
In the Chicago model, there is only really one variable: the city. Everything depends on it. The environment is not considered variable and is therefore a constant, not a variable. The result is a model that looks like a Venn diagram with concentric circles.

The concentric (Chicago) model of the city can be expressed as a linear model.

Polycentric (Los Angeles) models of the city require a description of interplay between multiple centers. This brings in nonlinearity.







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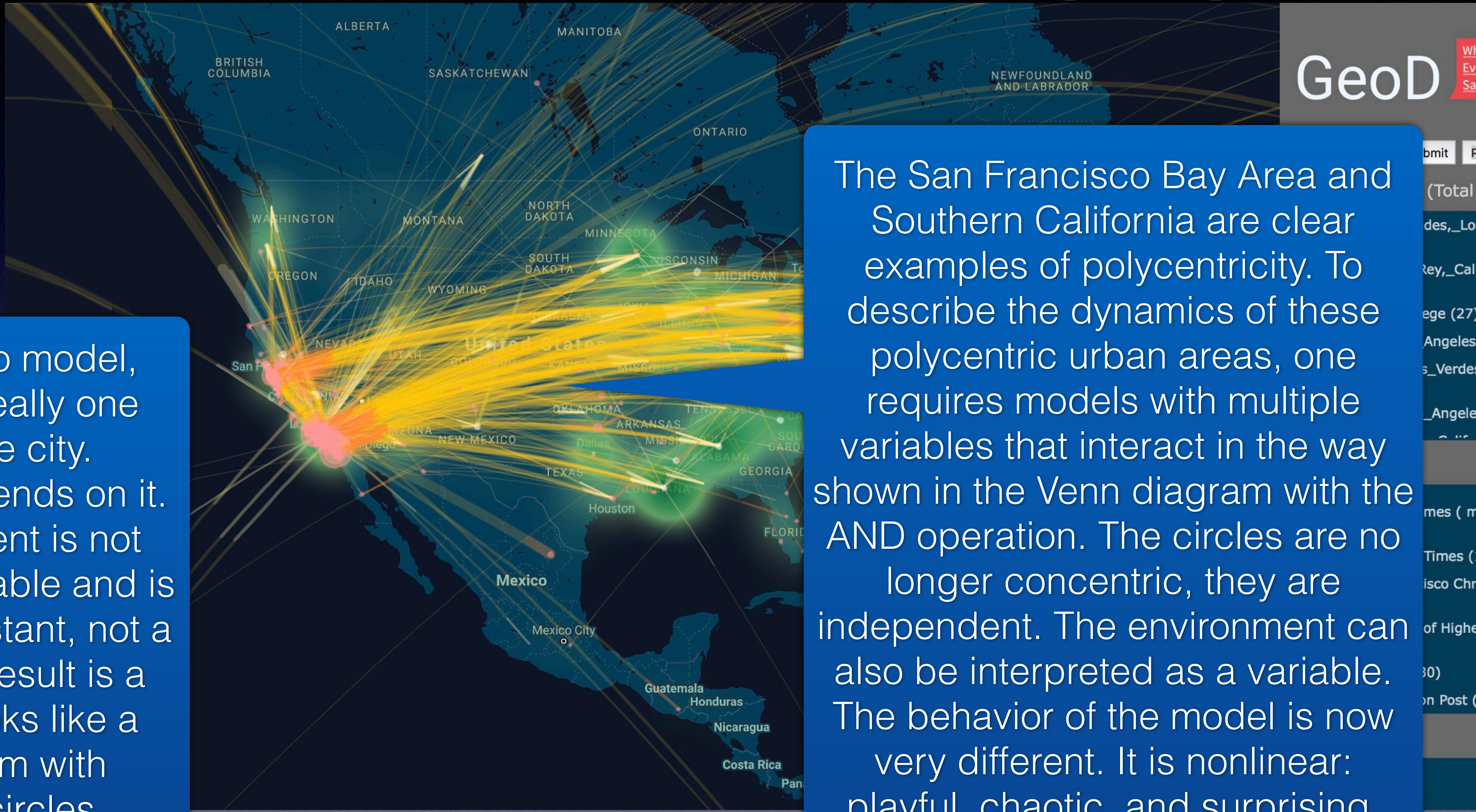

The San Francisco Bay Area and Southern California are clear examples of polycentricity. To describe the dynamics of these polycentric urban areas, one requires models with multiple variables that interact in the way shown in the Venn diagram with the AND operation. The circles are no longer concentric, they are independent. The environment can also be interpreted as a variable. The behavior of the model is now very different. It is nonlinear: playful, chaotic, and surprising.

The concentric (Chicago) model of the city can be expressed as a linear model.

Polycentric (Los Angeles) models of the city require a description of interplay between multiple centers. This brings in nonlinearity.

Explaining nonlinearity is not always easy.

We promised a third case study.

Case study 3.

Case study 3. A chatbot to explain urban diversity.

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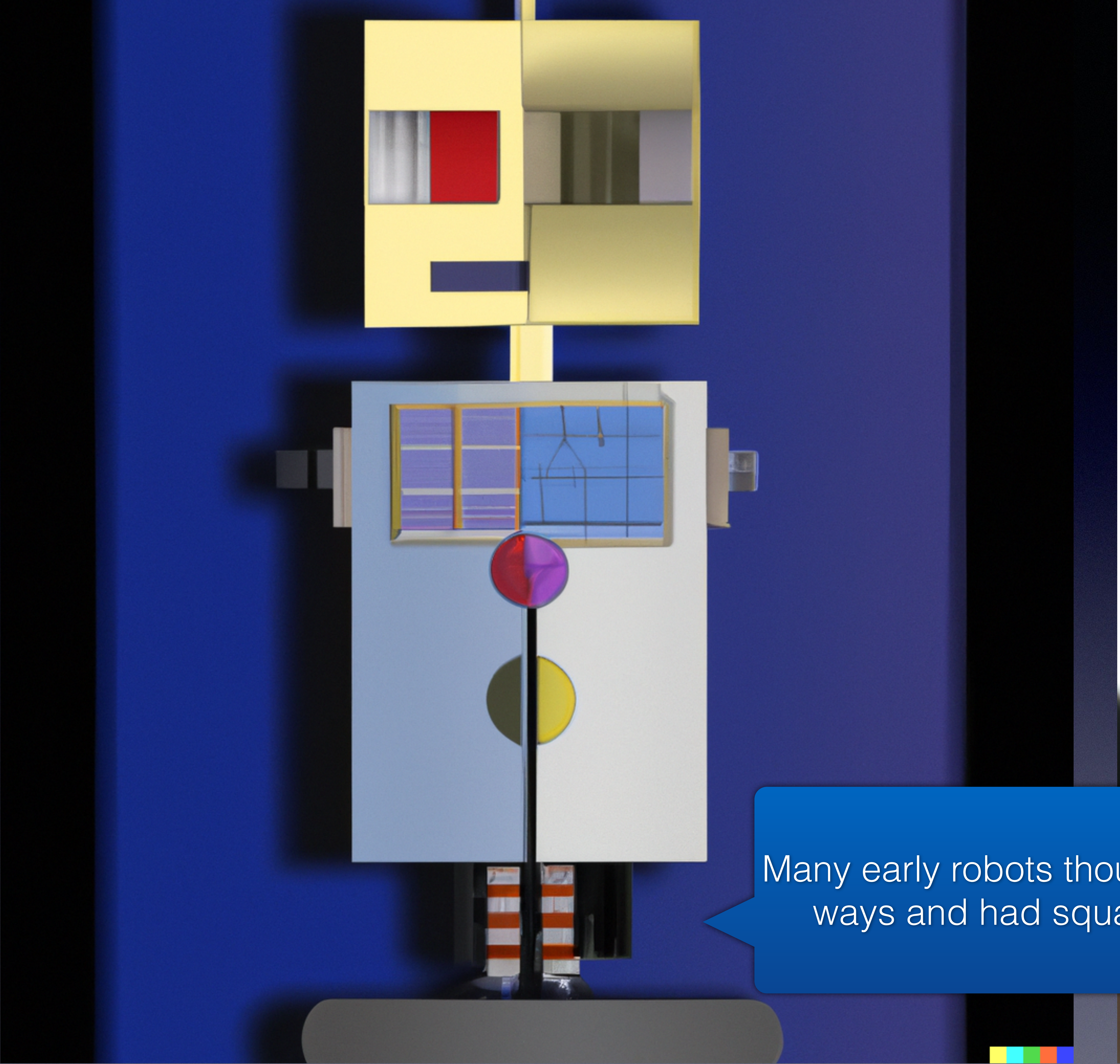
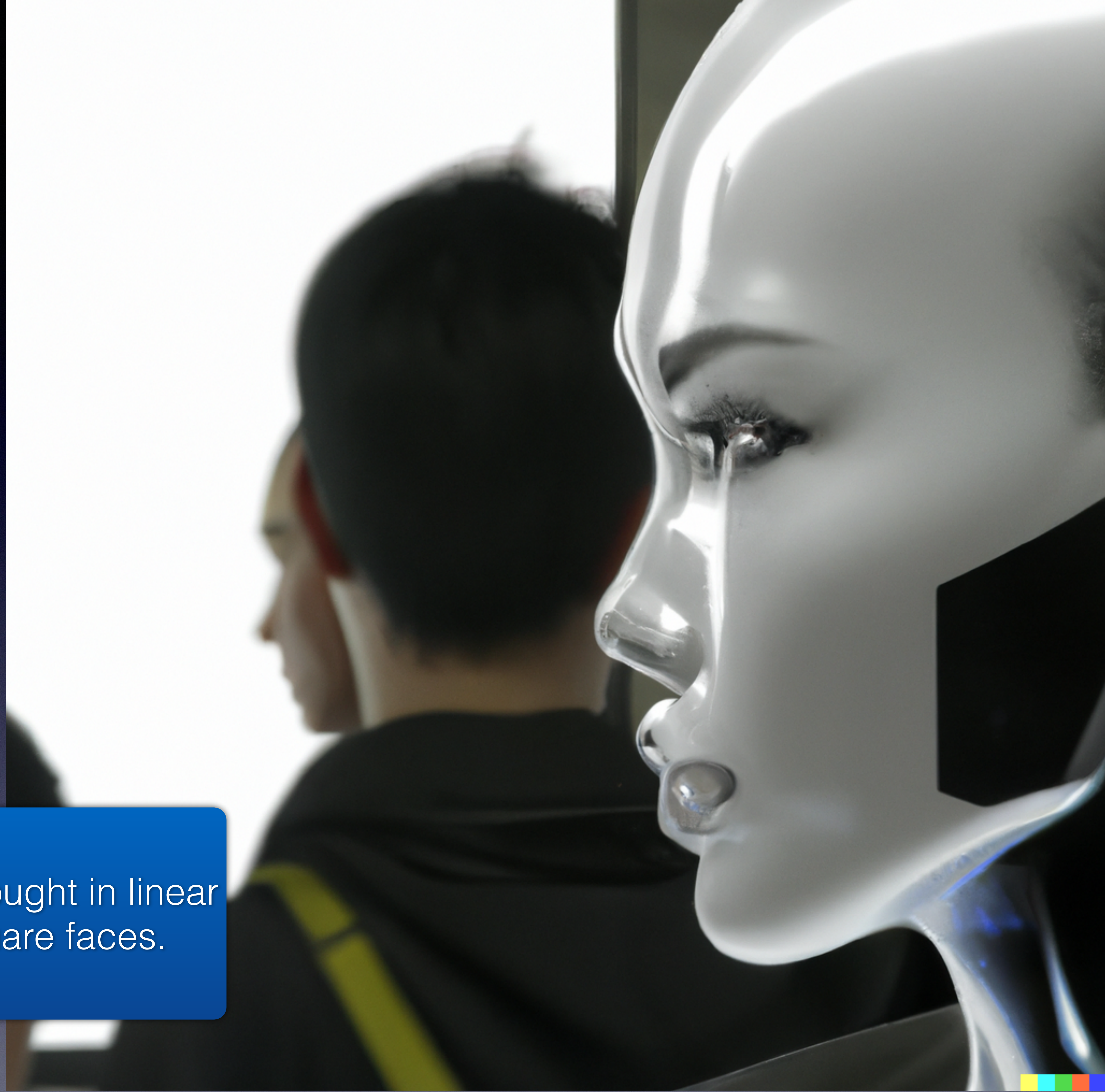
Case study 3. A chatbot to explain urban diversity. The math of the chatbot technology is also linear and nonlinear.

Case study 3. A chatbot to explain urban diversity.
The math of the chatbot technology is also
linear and nonlinear.
It’s a state-of-the-art chatbot!





Many early robots thought in linear ways and had square faces.
Now, nonlinear mathematics helps robots think more organically, and artists imagine them to have more non-linear faces.
Their intuition is correct. Image credit: Dan Baciu, created with Dall-e.

Many early robots thought in linear ways and had square faces.
Now, nonlinear mathematics helps robots think more organically, and artists imagine them to have more non-linear faces.
Their intuition is correct. Image credit: Dan Baciu, created with Dall-e.

Our chatbot's behavior is organic, and messy, too…

Rather than representing our research as clearly as it is rendered in the research articles

Rather than representing our research as clearly as it is rendered in the research articles, the chatbot places the research in a constantly evolving context.

Final conclusion:

Cities can seem messy.

Cities can seem messy.
The mess can be described with nonlinear models.

Cities can seem messy.
The mess can be described with nonlinear models.
We used nonlinear models to make sense of the mess.

Cities can seem messy.
The mess can be described with nonlinear models.
We used nonlinear models to make sense of the mess.
The nonlinear models can still behave chaotically.

Before finishing…

Here comes the real ‘Raft of the Medusa’
an allegory for the mess in French society
after the Revolution
by the romantic painter
Jean-Louis André Théodore Géricault

The final question…

What does it mean when we translate the mess into a nonlinear model?