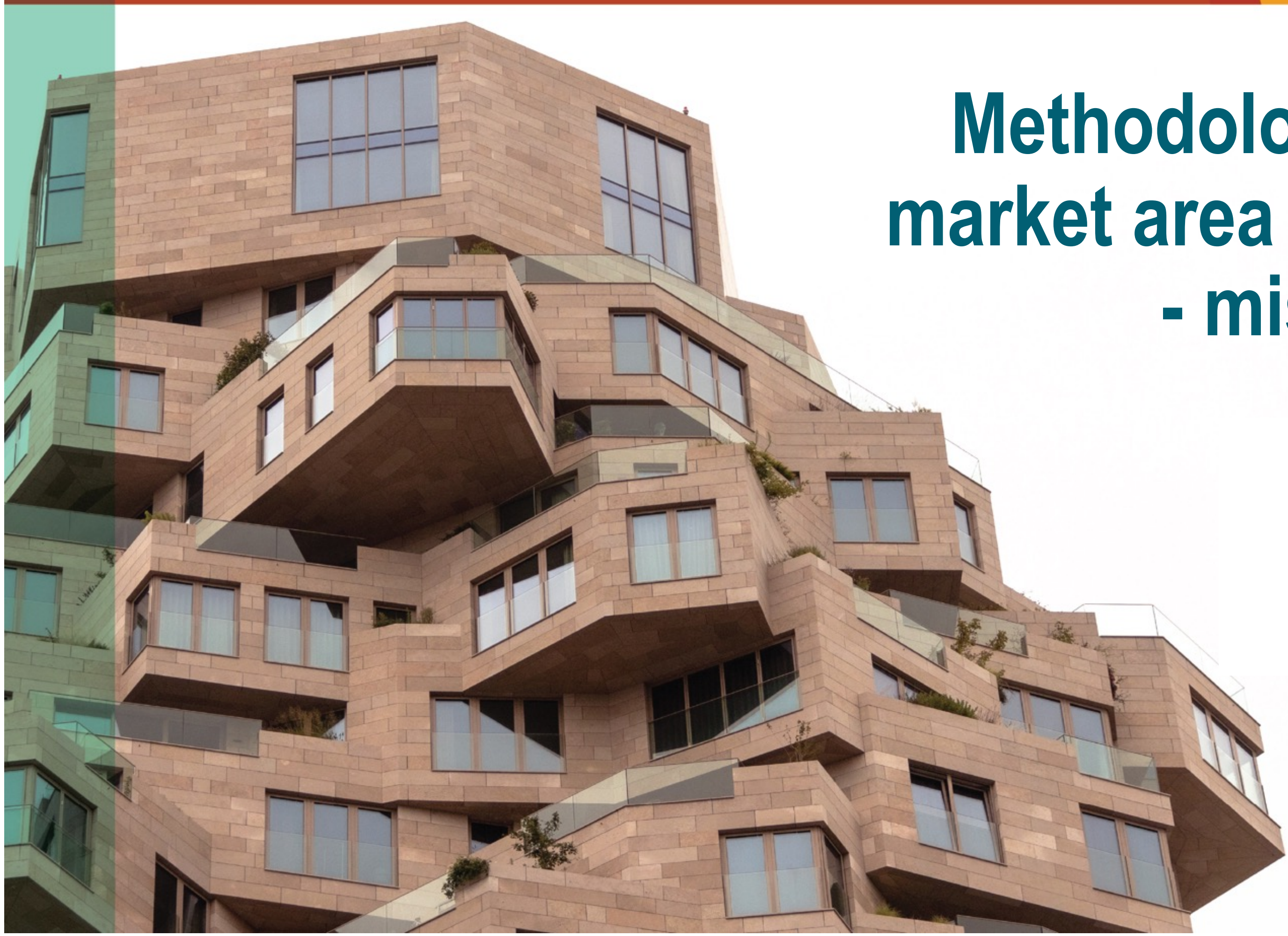
INTERNATIONAL RESEARCH SYMPOSIUM
Amsterdam, The Netherlands · December 4 - 5, 2024

ASSESSMENT INNOVATION & COLLABORATION WITH A FOCUS ON AI

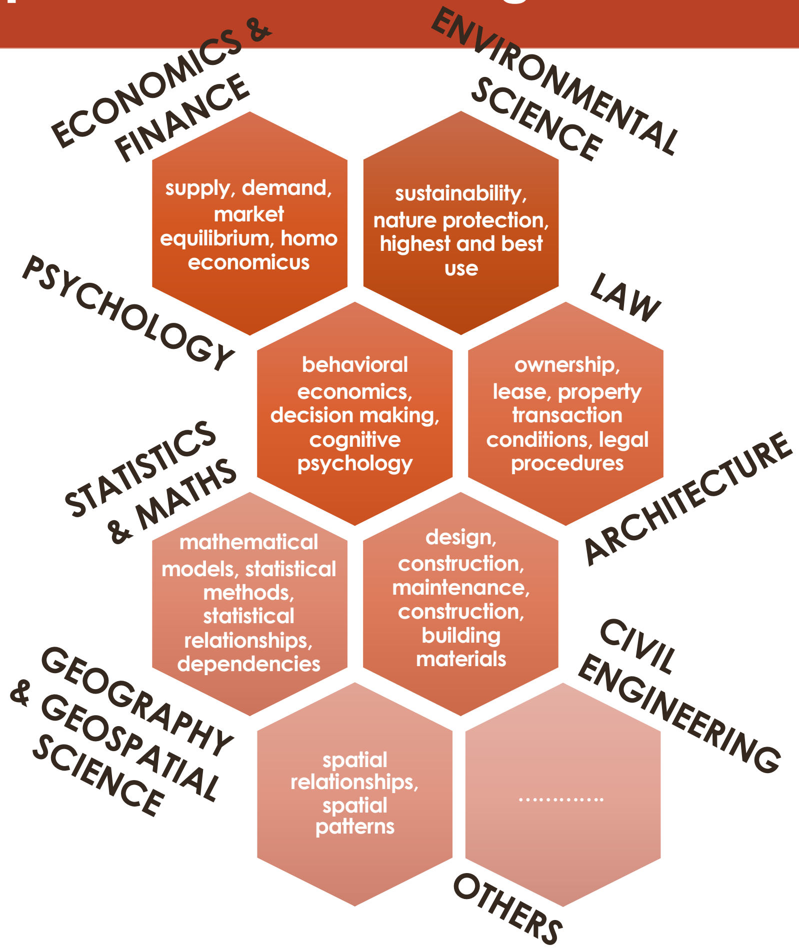


Methodology for homogenous market area determination HAD^2 - mission accomplished

PhD Marek Walacik MRICS, CCIM, REV
PhD Aneta Chmielewska

IAAO | IIFI IPTI International Property Tax Institute

Inspiration to investigate real estate market



"As an art form, property valuation has adopted the status of a mystical skill" (Brown, 1998)

Property valuation involves a combination of a number of **scientific paradigms**, methodologies, and approaches to accurately determine the value of real estate properties.

Understanding them, their assumptions and providing solutions making them comprehensible is a form of **demystification**

When it all begin?

ELSEVIER

Land Use Policy

Volume 78, November 2018, Pages 104-115

Forced sale discount on property market – How to assess it?

Małgorzata Renigier-Biłozor [a], Marek Walacik [a], Sabina Źróbek [a], Maurizio d'Amato [b]

Geoscience Methods in Real Estate Market Analyses Subjectivity Decrease

by Malgorzata Renigier-Bilozor *, Artur Janowski and Marek Walacik

Faculty of Geodesy, Geospatial and Civil Engineering, University of Warmia and Mazury in Olsztyn, 10-7 Poland

Sustainable Development

RESEARCH ARTICLE | Full Access

Property sustainable value versus highest and best use analyzes

Marek Walacik, Małgorzata Renigier-Biłozor, Aneta Chmielewska, Artur Janowski

First published: 02 September 2020 | https://doi.org/10.1002/sd.2122 | Citations: 22

The authors believe that the conducted research and drawn conclusions support the need for further analysis concerning (...):

methodology for determining comparable real estate markets and an accurate selection of sales for the needs of development of property valuation theory.

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Land Use Policy
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Forced sale discount on property market – How to assess it?

geosciences

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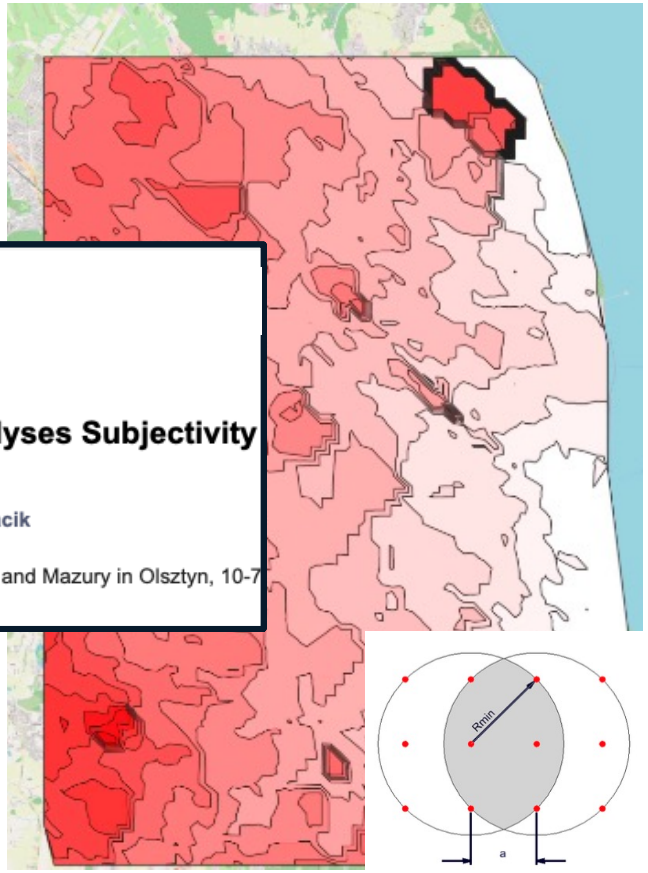

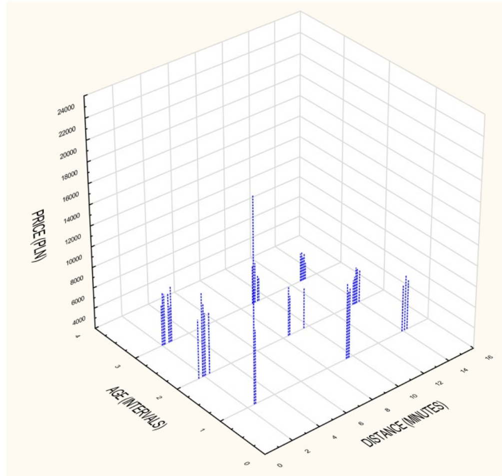

Use of the geoscience method is not new in property analyses; however, specific approaches and solutions are different and can shed new light on the existing solutions. The problem is that the analysed data in the real estate market has a discrete character.

When it all begin?

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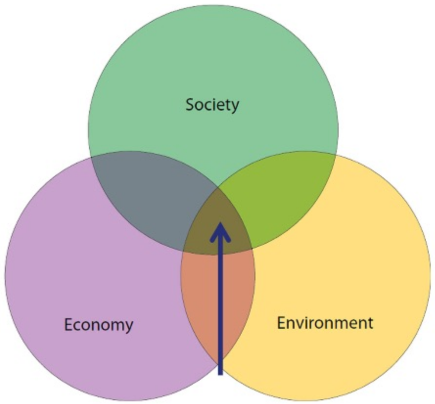

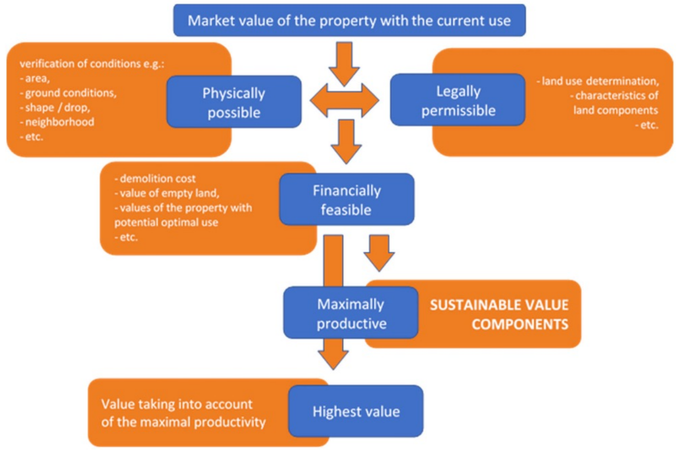

When it all begin?

ELSEVIER

Land Use Policy

Volume 119, August 2022, 106209

Modern challenges of property market analysis- homogeneous areas determination

Małgorzata Renigier-Biłozor [1], Artur Janowski [2], Marek Walacik [3], Aneta Chmielewska [4]

IAAO Research Grant Program

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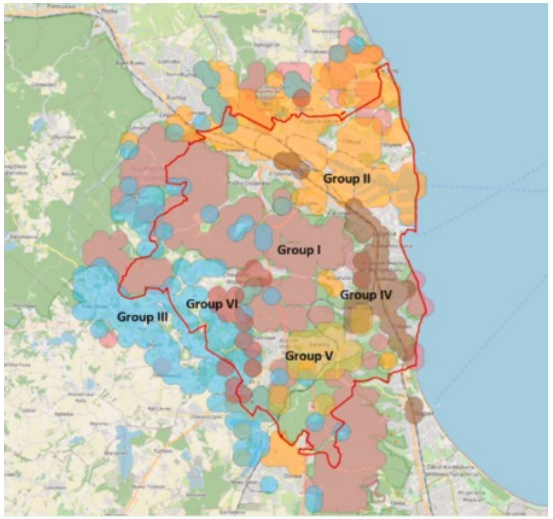
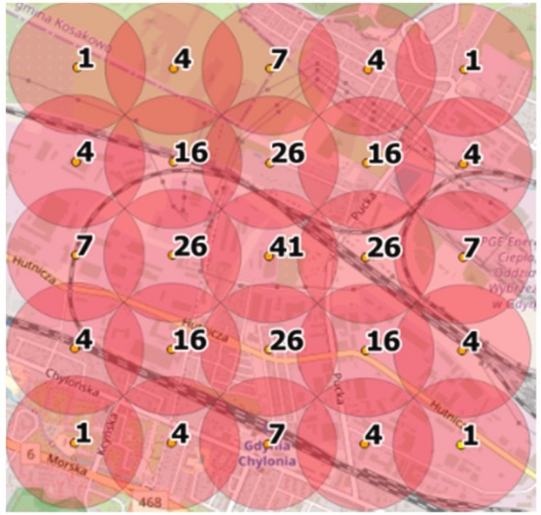
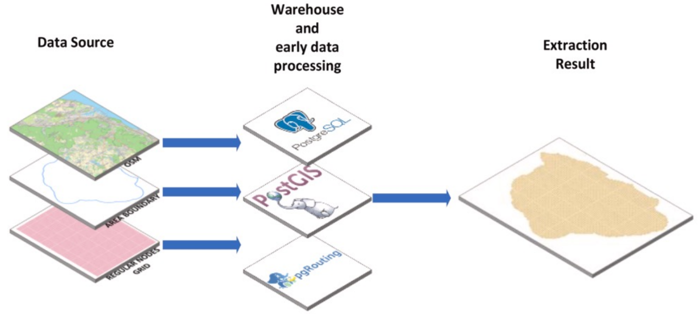
PROPERTY APPRAISAL VIA LENS OF PROPERTY REGISTRATION ABUNDANCE REAL ESTATE MARKET ASYMMETRY ASSESSMENT

Marek WALACIK *

Department of Real Estate and Urban Studies, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland







Extraction process and components diagram.

Effective comprehension of highly complex and spatially heterogenous property market requires its' appropriate recognition. One of the most critical steps in property analyses and valuation procedures is the identification of the sub-markets as the fundamental comparable units.

The Necessity of Sub-Markets delineation

- Every comprehensive real estate market analysis for property valuation purposes begins with understanding its sub-markets,
- These sub-markets, often referred to as **market unit areas**, are critical components of the broader property market,
- **Without a clear delineation of these sub-markets, analysts and valuers risk oversimplifying complex market behaviors,**
- Their identification plays a pivotal role in understanding price dynamics and valuation factors reflecting property **price formation components**,
- A thorough identification process ensures that analyses are based on **accurate, representative data – comparable properties**.

Homogeneity in Real Estate Markets

- Homogeneity in the context of real estate refers to areas or sub-markets with consistent **unit** characteristics,
- This **uniformity** is vital for ensuring objective and accurate property analyses,
- The concept is deeply intertwined with the goals of property market **analyses for valuation purposes**,
- A homogeneous area ensures that external factors affecting property value are **consistent across the unit**,
- This consistency **eliminates** potential **discrepancies** that could arise from analyzing properties in dissimilar areas,
- **Defining homogeneity is challenging** due to the numerous of factors influencing property value

Challenges in Submarkets Delineation

- The real estate market's inherent complexity makes defining submarkets a challenging endeavor,
- Factors such as location, property type, age, and facilities can all influence a property's value,
- Ensuring that these factors are consistent across selected units is a thorough and **time-consuming process**,
- Additionally, the **ever-evolving nature** of the real estate market means that definitions of submarkets may need regular updates,
- External factors, like **economic trends** or regulatory changes, can also influence the delineation of submarkets,
- Despite these challenges, defining submarkets remains a **critical step** in ensuring accurate property valuations

Current State-of-the-Art Solutions

- The real estate society has witnessed a number of innovative solutions aimed at addressing the challenges of homogeneous market area determination,
- **Geospatial analyses**, for instance, use advanced mapping techniques to delineate property markets,
- **Machine learning algorithms** are being harnessed to predict property values based on vast datasets,
- The integration of **big data** in real estate analysis has also revolutionized the way submarkets are identified,

Ceteris paribus based method

$$wg_{il} = \left(C_{jl_s} - C_{jl_k}\right) \cdot \left(\max_j C_{ij} - \min_j C_{ij}\right)^{-1}$$

$$wg_j = \left(\sum_{l=1}^{l=z} wg_{il}\right) \cdot z^{-1}$$

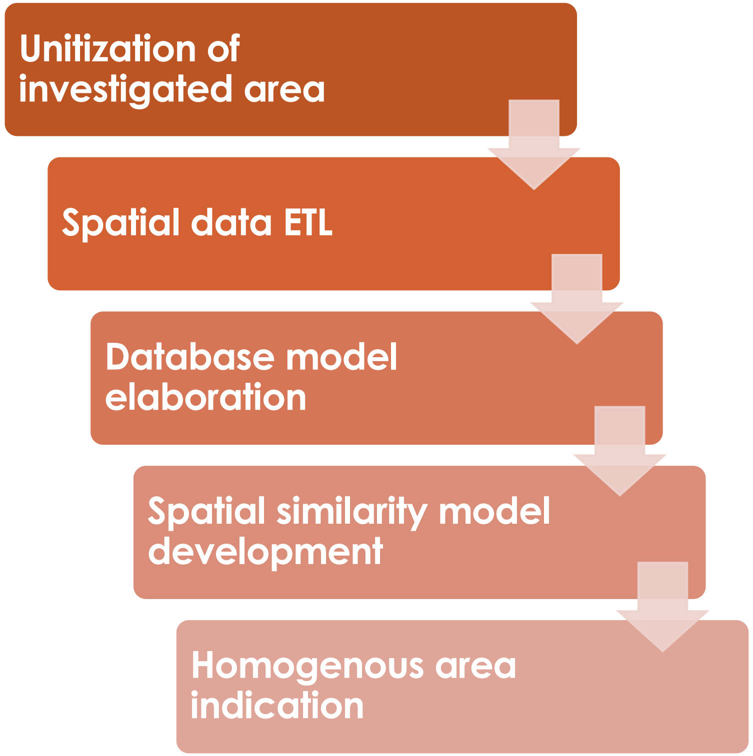
Correlation matrix-based solution

$$wg_j = \left(\sum_{i=1}^{n} x_{ij}\right) \cdot \left(n \cdot \sigma_j\right)^{-1}$$

Scientific aim and it’s assumptions

The project's main aim was to propose a solution enabling the increase of equity and fairness in property taxation procedures with particular respect to market analyses and, consequently, property valuation/ assessment.

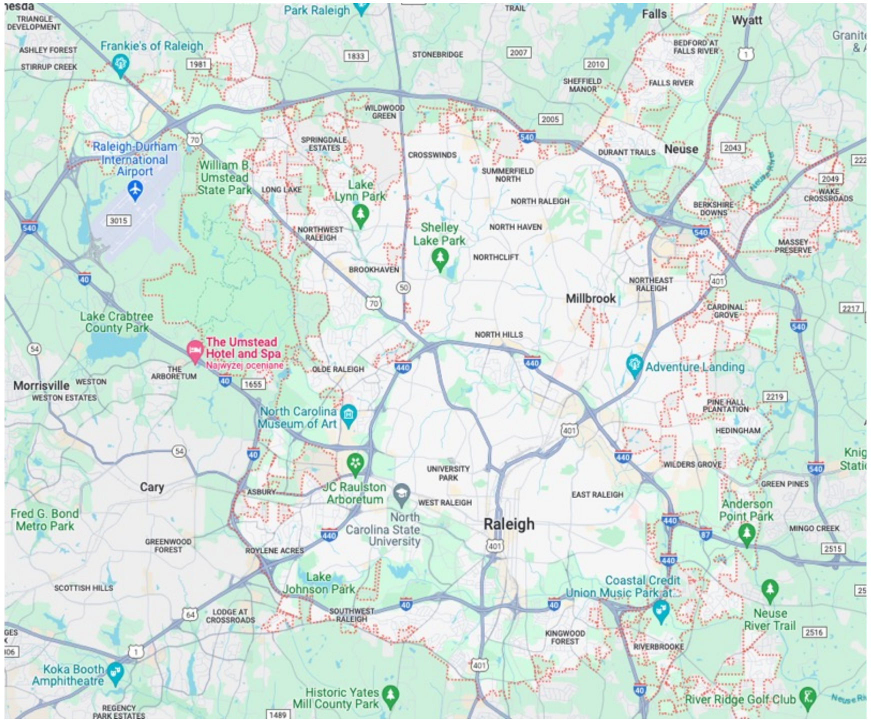
From that perspective, the project's main objective was to establish appropriate decision-making stages of a methodology for homogenous area determination that involved 5 particular stages:



Case study area selection – City of Raleigh

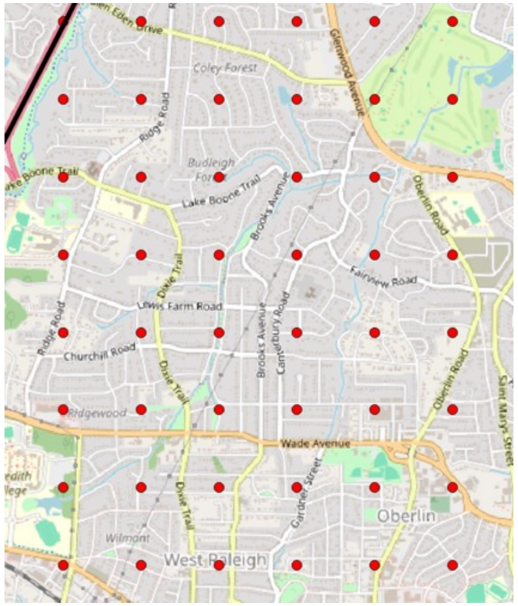
The project execution required additionally case study area selection. For that purpose, the authors decided to pick the City of Raleigh. The selection was based on:

- geographical diversity,
- population dynamics,
- economic viability,
- representativeness of municipal structure,
- **data availability,**
- **willingness to collaboration from the administrative bodies (Tax Office in Wake County Government).**

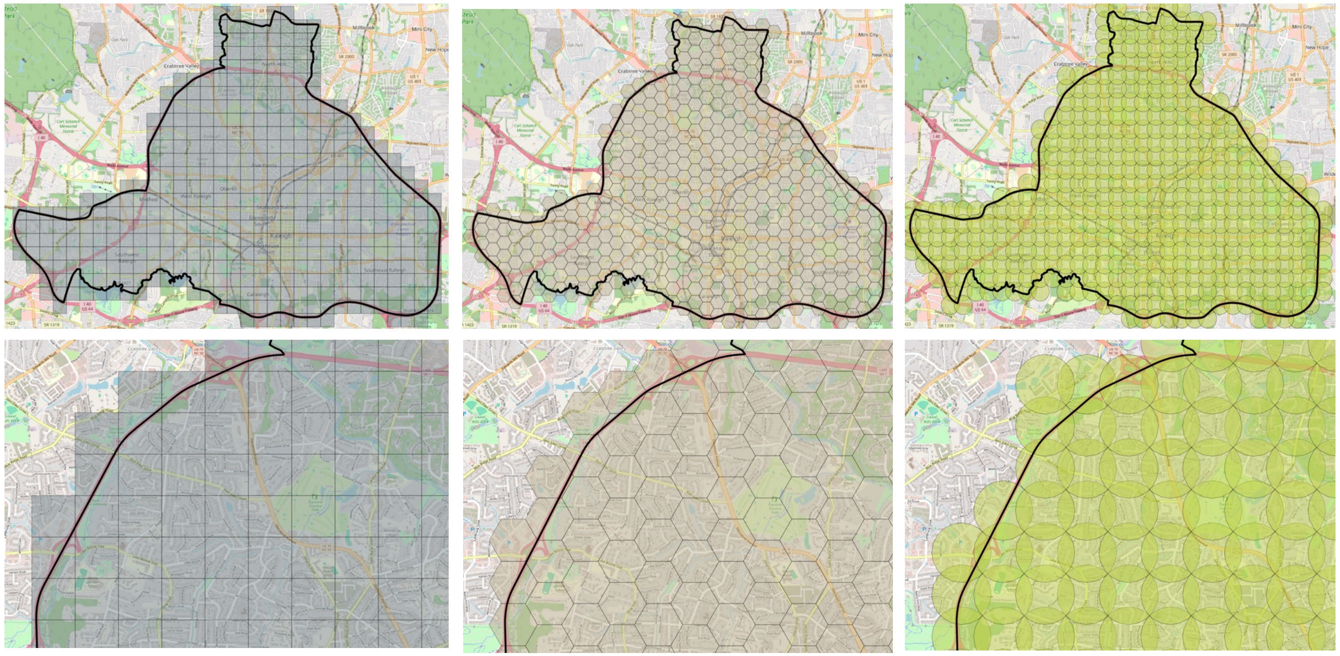


STAGE 1 – Unitization of investigated area

The objective of this stage was to establish a structured framework for spatial analysis within a defined area, utilizing a regular grid of nodes with assumed parameters.



grid nodes



squares hexagon circles

STAGE 1 – Unitization of investigated area

The parameter that will be a subject of optimization include:

- the **A** distance between the grid nodes,
- the **B** edge length in case of **hexagon** and **squares** and **C** the radius length in case of **circles**,
- the computing time **H** with highest amount of 3 hours (measured for ordinary computing device).

$$\boldsymbol{E}(\boldsymbol{A},\boldsymbol{B},\boldsymbol{C},\boldsymbol{H}) = \boldsymbol{f}_1(\boldsymbol{A},\boldsymbol{B},\boldsymbol{C},\boldsymbol{H}) + \boldsymbol{f}_2(\boldsymbol{A},\boldsymbol{B},\boldsymbol{C},\boldsymbol{H}) + \boldsymbol{f}_3(\boldsymbol{A},\boldsymbol{B},\boldsymbol{C},\boldsymbol{H}) + \boldsymbol{f}_4(\boldsymbol{A},\boldsymbol{B},\boldsymbol{C},\boldsymbol{H})$$

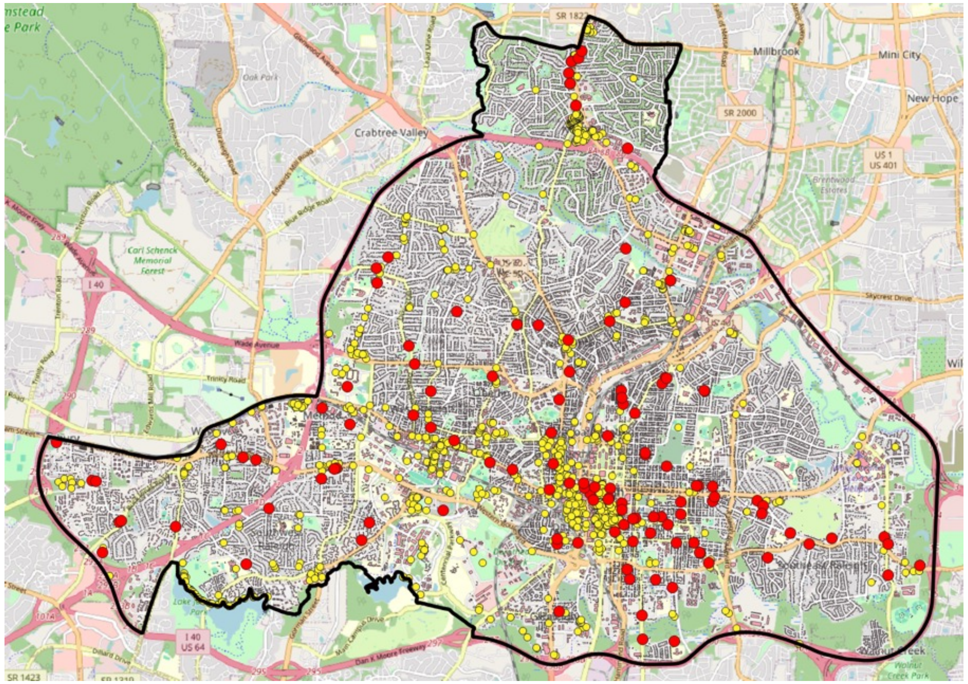
STAGE 2 - Spatial data ETL

Spatial (**extrinsic**) data extraction refers to the process of retrieving information from external sources to enhance or supplement existing data.

Factors	Layer name (number of objects)	Kind	Object classes	Extraction
Environmental conditions	Waterways (568)	lines	stream, drain	Distance (Euclidean & PGRouting)
	Water (109)	polygons	reservoir, riverbank, water, wetland	Distance (Euclidean & PGRouting)
Communication	Transport (829)	points	bus stops, helipad, railway halt, railway station, taxi	Euclidean & PGRouting / number in units
	Railways (197)	lines	railway	Euclidean & PGRouting / length in units
	Traffic (2680)	polygons	parking, parking multistorey, parking underground	Euclidean & PGRouting / area in zone
	Roads (30683)	lines	bridleway, cycleway, footway, motorway, path, pedestrian, primary, residential, secondary, service, tertiary, track, trunk, unclassified	Euclidean & PGRouting / length in units
Facilities/services	Sacred objects (70+51)	Points /polygons	Christian, Catholic, Lutheran, Methodist, Anglican, Muslim	Euclidean & PGRouting / number in units
	Points of interest (108)	points	Arts center, bakery, bank, bar, beauty shop, bookshop, café, chemist, cinema, clinic, community center, dentist	Euclidean & PGRouting / number in units
	Buildings (44984)	polygons	Apartments, boathouse, college, commercial, dormitory, fire station, garage, government, hospital, hotel, house, industrial, museum, office, prison, public, residential, retail, school, theatre, train station, university, warehouse (...)	number in units / area in units
Aesthetics	-	-	-	-
Social and economic background	-	-	-	-

* the factors were not represented by objects

STAGE 2 - Spatial data ETL



The data transformation for the assumed objectives of the study was executed with utilization of **entropy measures.** The transformation based on entropy function was based on the following mathematical apparatus

$$H(X) = -\sum_{i=1}^{n} p(x_i) \cdot \log_2(p(x_i))$$

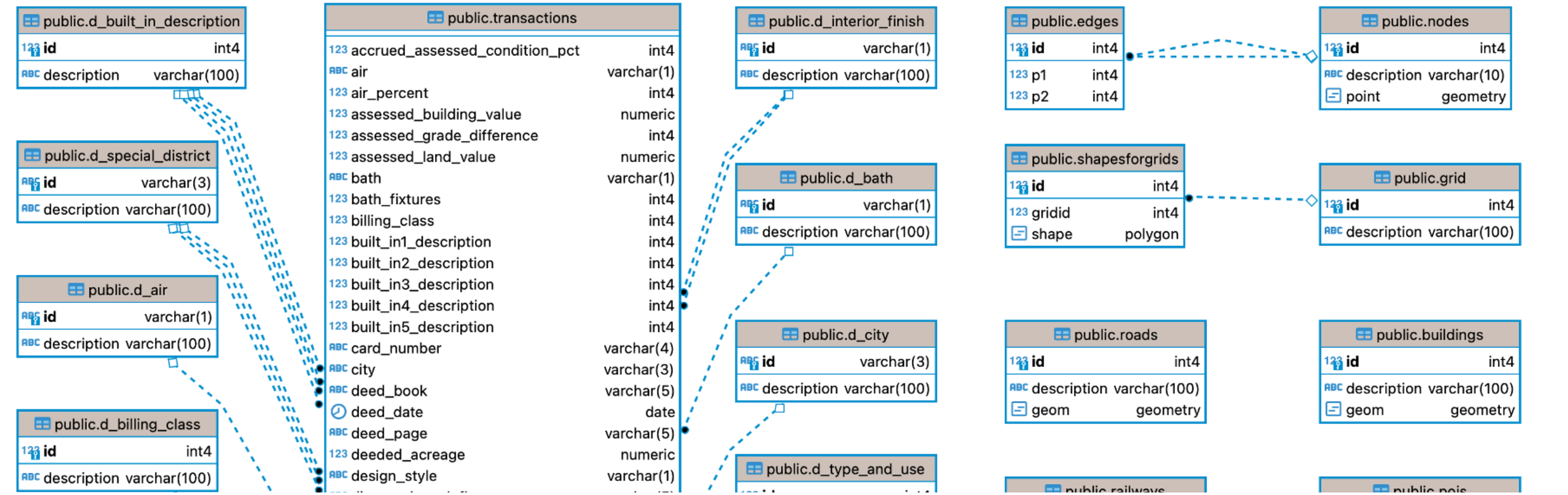
STAGE 2 - Spatial data ETL

Transport_point_POINT_DR	Sacred_point_POINT_DR	Pois_point_POINT_DR	Sacred_POLY_DR	Water_POLY_DR	Waterways_line_LINE_DR	Railway_line_LINE_DR	SERIES_VALUE
10,64	11,37	11,32	11,34	10,96	10,26	11,55	1,00
9,82	10,13	10,12	10,14	9,92	9,49	10,20	2,00
9,03	9,24	9,23	9,23	9,10	8,84	9,24	3,00
8,40	8,52	8,48	8,53	8,42	8,25	8,50	4,00
7,90	7,93	7,93	7,95	7,85	7,63	7,94	5,00
7,41	7,47	7,50	7,51	7,45	7,40	7,47	6,00
7,06	7,04	7,06	7,09	7,04	6,87	7,04	7,00
6,72	6,75	6,74	6,74	6,71	6,49	6,74	8,00
6,50	6,52	6,48	6,52	6,52	6,39	6,50	9,00
6,20	6,20	6,20	6,23	6,20	6,11	6,23	10,00
6,02	6,02	6,02	6,02	5,99	5,93	6,02	11,00
5,75	5,75	5,75	5,75	5,75	5,72	5,75	12,00

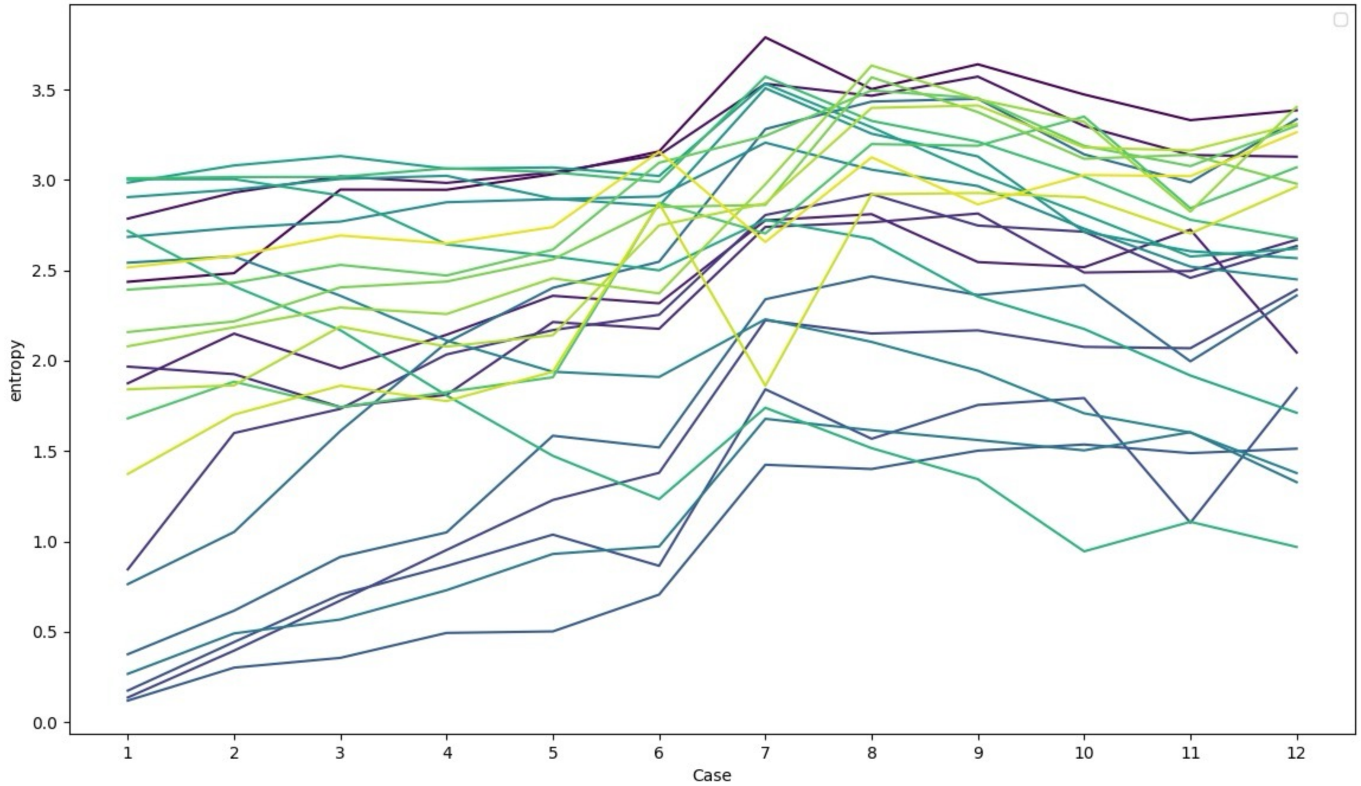
Transport_POINT_DE	Sacred_POINT_DE	_pois_POINT_DE	_sacred_POLY_DE	Water_POLY_DE	Waterways_line_LINE_DE	Railway_line_LINE_DE	SERIES_VALUE
9,87	11,72	11,69	11,63	10,94	9,24	11,64	1,00
7,15	9,85	9,91	9,97	9,00	6,79	9,72	2,00
5,39	8,51	8,60	8,72	7,43	4,83	8,47	3,00
4,42	7,40	7,65	7,73	6,23	3,48	7,61	4,00
3,48	6,43	6,71	6,93	5,42	2,66	6,81	5,00
3,22	5,86	6,18	6,32	4,72	2,01	6,26	6,00
2,67	5,10	5,62	5,75	3,93	1,53	5,72	7,00
2,50	4,85	4,97	5,09	3,74	1,56	5,37	8,00
2,35	4,57	4,71	4,78	3,30	1,28	4,99	9,00
1,99	3,98	4,24	4,18	2,84	0,81	4,73	10,00
2,22	3,76	3,85	3,85	2,75	1,24	4,33	11,00
1,94	3,38	3,49	4,05	2,31	1,18	3,83	12,00

STAGE 3 - Database model elaboration

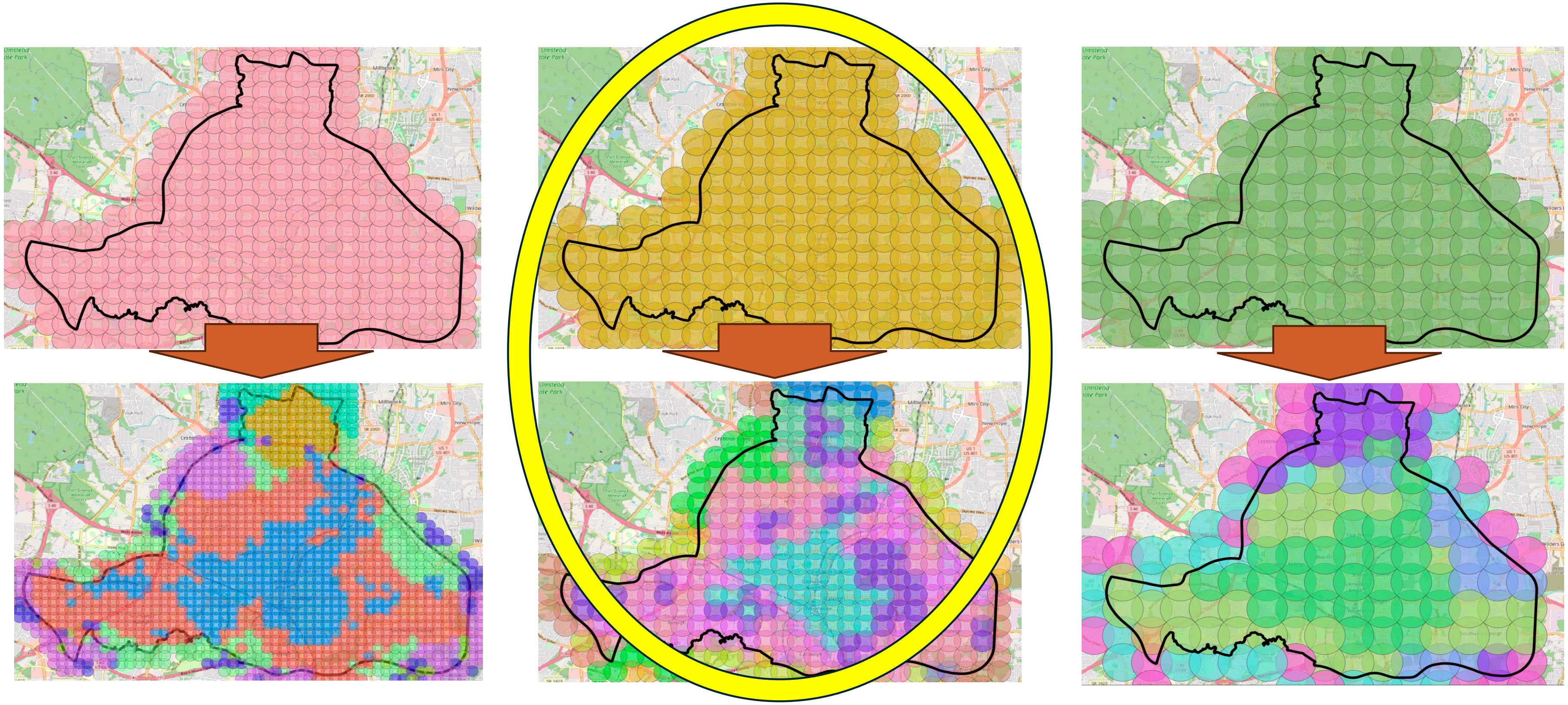
When designing a database model, there were several crucial assumptions that served as the foundation for the overall structure and functionality of the database: data **integrity**, **normalization**, **consistency** .



STAGE 4 - Spatial similarity model development

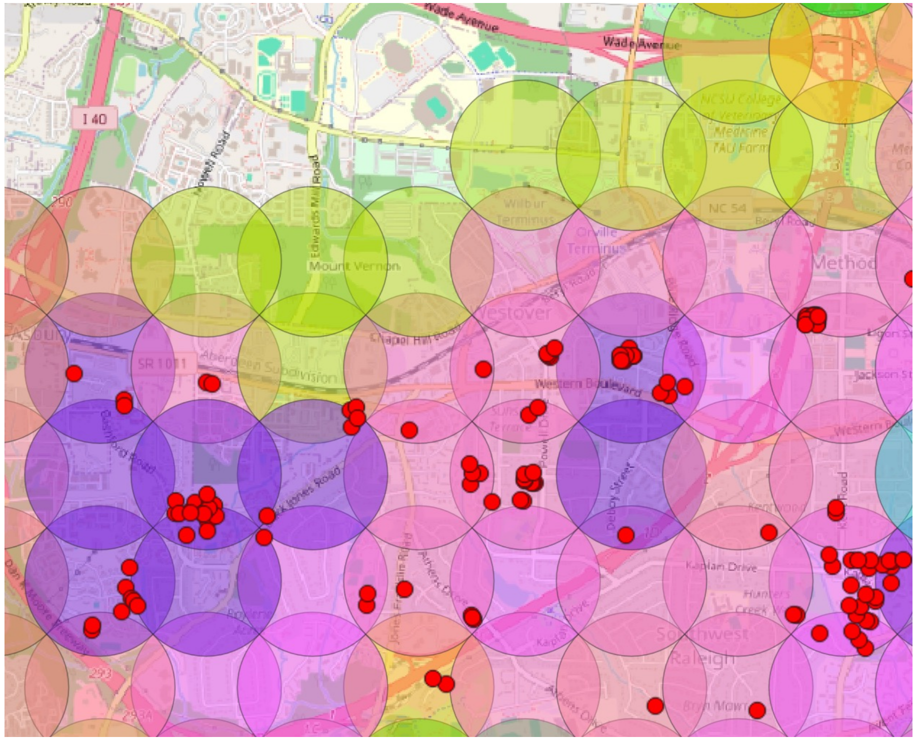


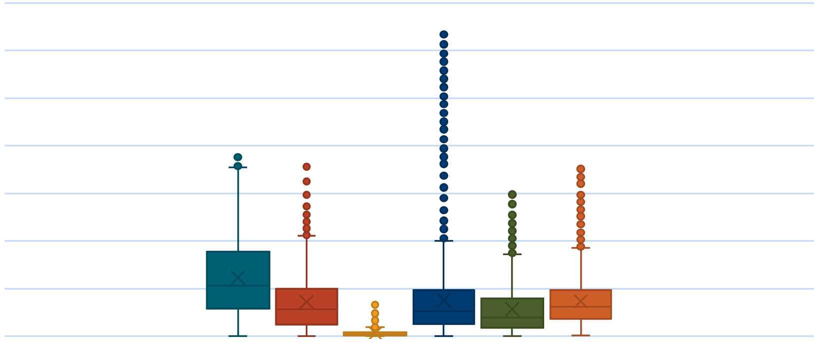
STAGE 4 - Spatial similarity model development



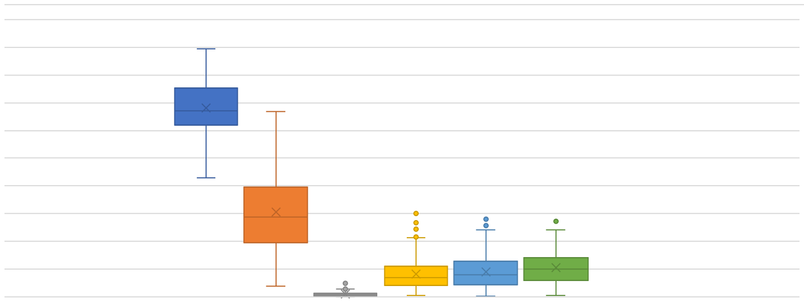
Clusterization with k-mean method

STAGE 5 - Homogenous area indication





73% lower diversity



Conclusions at that time

- The proposed solution can fill in **the gap between** the algorithms provided in the current state of art publications and the solutions implemented in property valuation industry.
- The method **follows all the Doubters** standards so it can be implemented without threat that the method will not be accepted.
- Entities implementing the method should also bear in mind the **limitations** of the methods implementation e.g. Scalability Concerns, Computational Intensiveness.

energies

Article

Energy Performance in Residential Buildings as a Propert Market Efficiency Driver

Marek Walacik * and Aneta Chmielewska

sustainability

Article

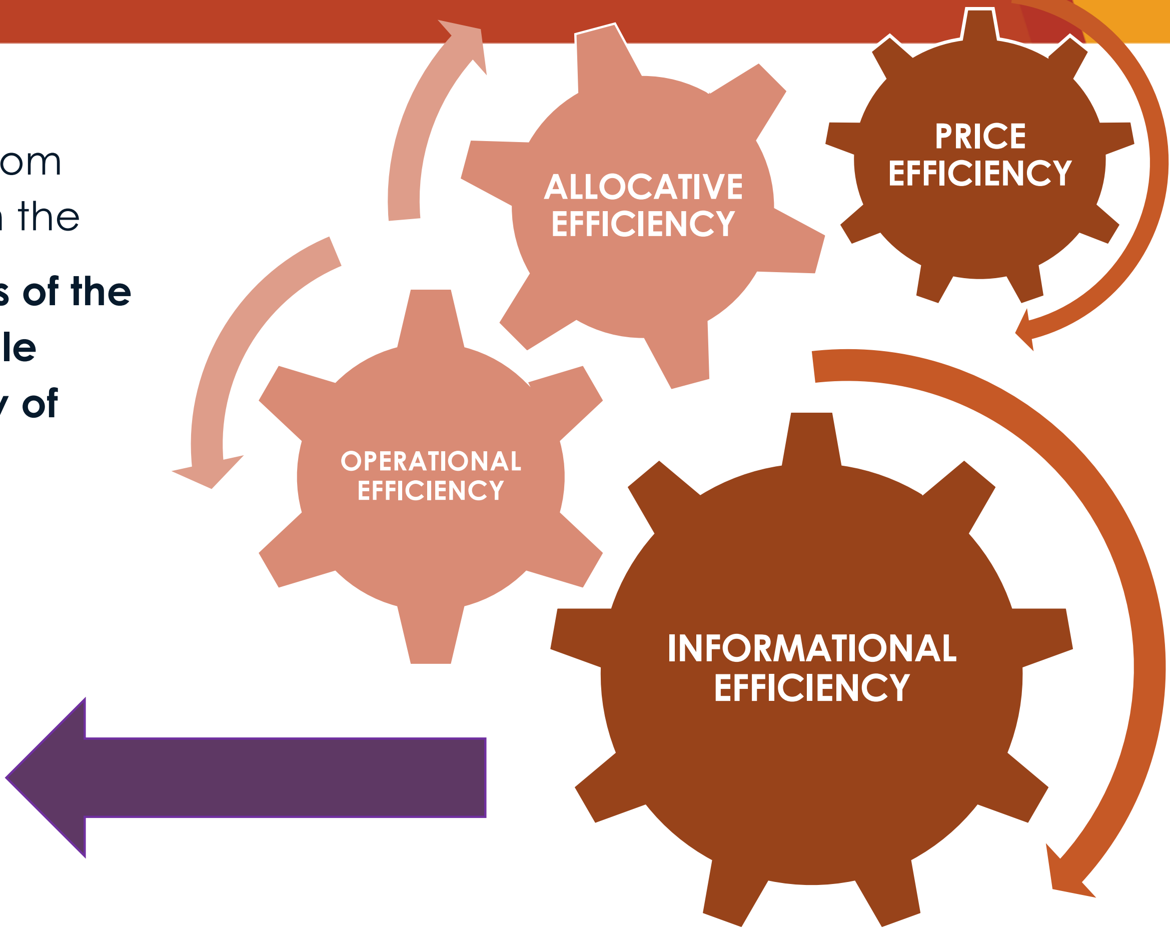
Real Estate Industry Sustainable Solution (Environmental, Social, and Governance) Significance Assessment—AI-Powered Algorithm Implementation

Marek Walacik * and Aneta Chmielewska

What were the areas that required further examination?

The efficiency of the real estate market, from interpretative perspective, is identified with the

ability to achieve specific development goals of the system with the maximum use of available information and maximizing the efficiency of individual participants in this market.



INFORMATION ASYMMETRY

Property transactions registration principles

Information asymmetry and property registration for valuation purposes - SCIENTIFIC GAP

Economics, Econometrics and Finance, Social Sciences

IRT: Abundance in property registration significantly reduces the effects of information asymmetry in mass appraisal processes, leading to more accurate and fair market valuations.

Information asymmetry in real estate valuation refers to the situation of **non-uniform access** to information about the features and conditions of a transaction resulting from the availability of datasets on properties of different abundance.

„the valuer should be aware that any analytical tool is only as reliable **as the data that is fed into** it and the **analytical model it uses** (…)"

Property Market Efficiency

THE REAL ESTATE MARKET IS DEEPLY INFLUENCED BY THE DYNAMICS OF INFORMATION FLOW AND TRANSPARENCY

- In real estate market analysis, the quality and depth of information are essential for increasing **market transparency**, ensuring **accurate property valuation**, and facilitating **efficient market operations**.
- While there is a wealth of literature emphasizing the importance of information in real estate, **what is often underexplored is the specific role that property transaction registration plays in reducing information asymmetry and promoting market transparency!**

Table . Examples of selected studies on information asymmetry in real estate market, with special respect to the context of analysis, implemented methods and sources of asymmetry.

Source of Analysis	Utilized Methodology	Real estate market context	Source of asymmetry
Ambrose & Shen (2023)	Bayesian learning model	Impact of fracking risk on house buyers	Lack of past experience
Ling et al. (2018)	Hedonic model	Impact of anchoring and search costs	Reference to other markets
Chau & Wong (2016)	ECM & SUR*	Decomposition of land and building value	Complex nature of property
Zhou et al. (2014)	Hedonic model	Investments of local / non-local buyers	Real estate market locality
Chinloy et al. (2013)	Hedonic model	Investments of local / non-local buyers	Real estate market locality
Wong et al. (2012)	Panel data analysis	Impact of warranties on house buyers	Perception of building quality
Levitt & Syverson (2008)	Hedonic model	Impact of brokers on property buyers	Data manipulation
Johnson et al. (2005)	Hedonic model	Impact of listings on property buyers	Kind of listing
* Error Correction Model, Seemingly Unrelated Regression			

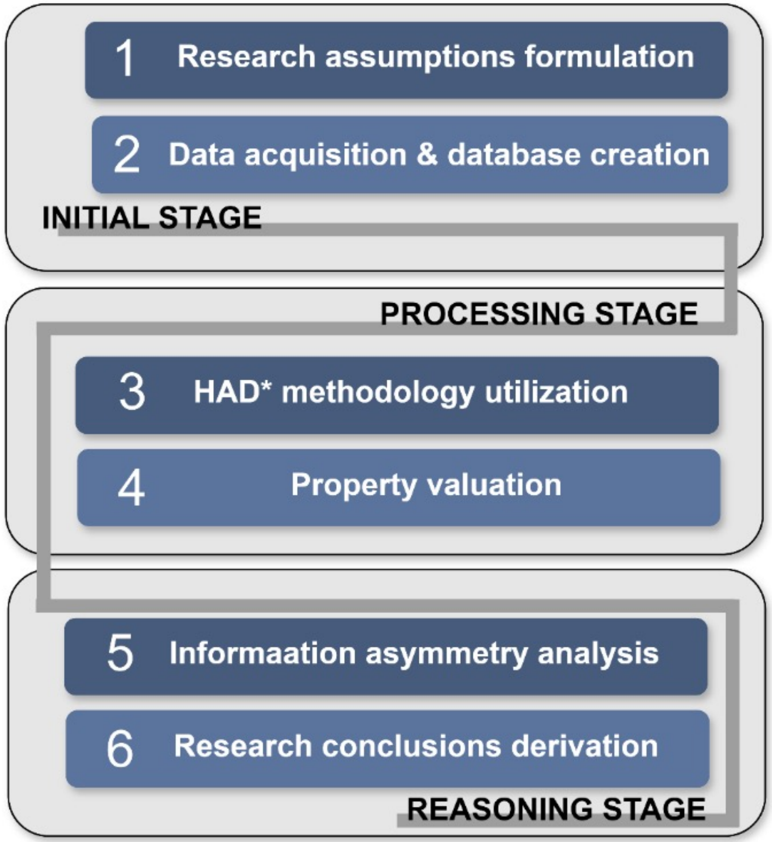
Although existing studies have addressed the broader implications of information asymmetry in market operations, few have directly examined how the formal registration of property transactions can mitigate these asymmetries.

Main research questions

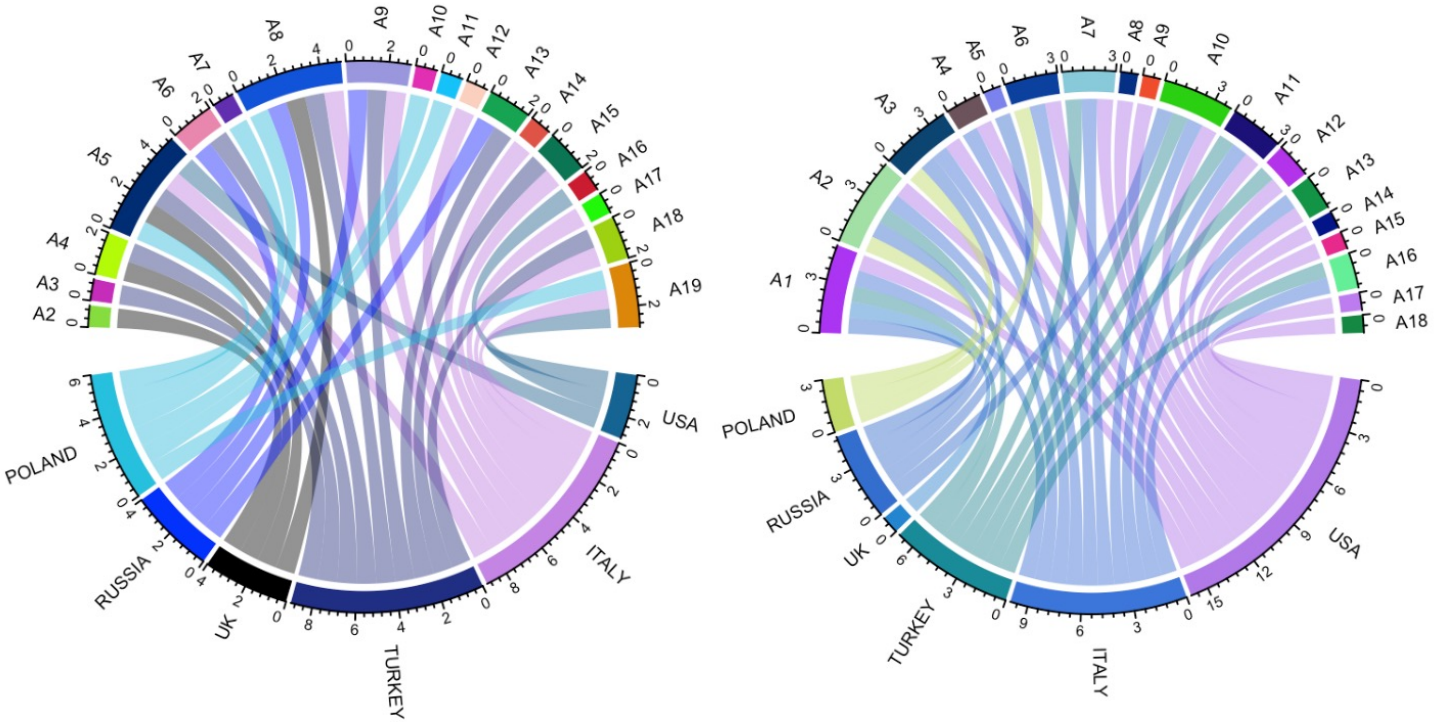
RQ1: How do registered property transaction attributes influence the degree of information asymmetry in real estate markets?

RQ2: To what extent do advance property valuation algorithms, respond to varying levels of information symmetry in the dataset?

RQ3: What are the economic consequences of information asymmetry in property markets, particularly in terms of valuation accuracy and fairness?



Database creation



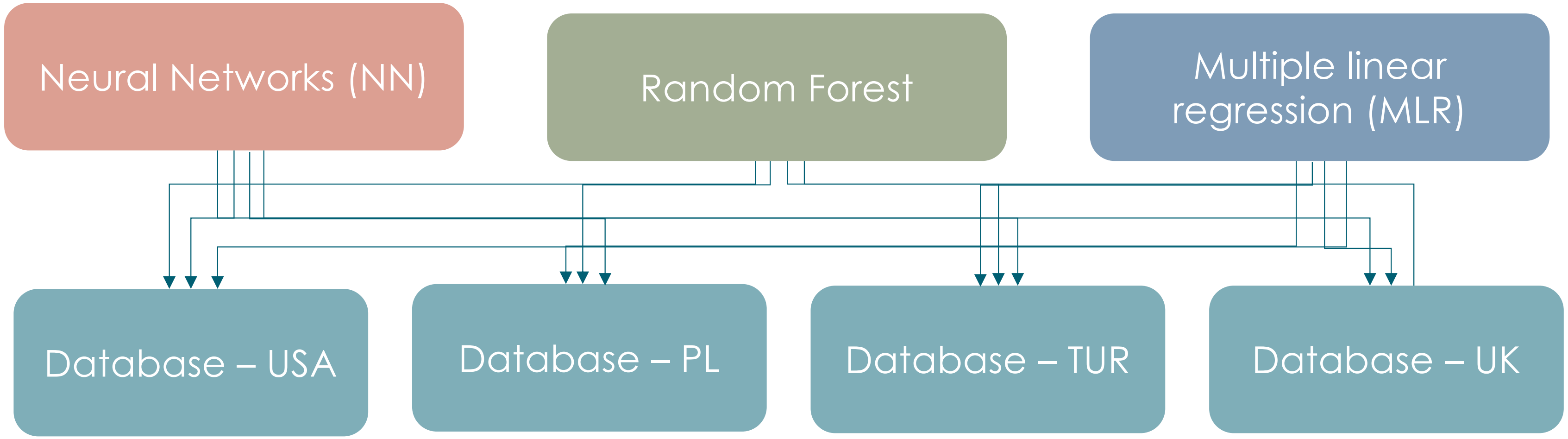
Where:
A1 – Location,
A2 – Parcel,
A3 – Building built-up area,
A4 – Building heated/usable area,
A5 – Street type,
A6 – Date of construction,
A7 – Design style,
A8 – Utilities,
A9 – Effective building year,
A10 – Number of stories,
A11 – Foundation basement,
A12 – Foundation basement [%],
A13 – Exterior wall,
A14 – Air conditioning,
A15 – Bath,
A16 – Floor finish,
A17 – Interior finish,
A18 – Heating,
A19 – Grade factor.

Figure. Scope of data provided in
(A) property transaction registers directly,
(B) other public registers.

Considering the fact that, according to the information acquired in the questionnaire, property transactions registration in US had the most detailed scope data collection (19 attributes), the US database structure formed the basis for further studies in the initial stage – "data acquisition and database creation" in selected case study area.

Property valuation

- Investigating the phenomenon of asymmetry in the property market resulting from unequal access to information required a property valuation to examine the discrepancies in the value of individual properties and their transaction prices.



Models' validation – information asymmetry analysis

To determine the impact of the richness of real estate databases on the asymmetry of the real estate market, several classic criteria for evaluating prediction results were applied.

Mean Error (ME)	$ME = \left(\frac{1}{n}\sum_{i=1}^{n} A_i - P_i\right)$	Root Mean Squared Error (RMSE)	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(A_i - P_i)^2}$
Mean Squared Error (MSE)	$MAE = \left(\frac{1}{n}\sum_{i=1}^{n}\lvert A_i - P_i\rvert\right)$	Root Mean Squared Percentage Error (RMSPE)	$RMSPE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{A_i - P_i}{A_i} * 100\%\right)^2}$
Mean Absolute Percentage Error (MAPE)	$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n}\left\lvert\frac{A_i - P_i}{A_i}\right\rvert\right) \cdot 100\%$	Coefficient of Dispersion (COD)	$COD = \frac{\sum_{i=1}^{n}\left\lvert\frac{A_i}{P_i} - \frac{A_{\left(\frac{n+1}{2}\right)}}{P_{\left(\frac{n+1}{2}\right)}}\right\rvert}{n \times \frac{A_{\left(\frac{n+1}{2}\right)}}{P_{\left(\frac{n+1}{2}\right)}}} \times 100$
Mean Squared Error (MSE)	$MSE = \left(\frac{1}{n}\sum_{i=1}^{n}(A_i - P_i)^2\right)$	Price-Related Differential (PRD)	$PRD = \frac{\frac{1}{n}\sum_{i=1}^{n}\frac{A_i}{P_i}}{\frac{\sum_{i=1}^{n} A_i}{\sum_{i=1}^{n} P_i}}$

Models' validation – information asymmetry analysis

Value determination prediction accuracy metrics for all databases were used to identify and assess discrepancies between property values and their transaction prices. The Table presents the results of the adopted analysis of accuracy metrics four databases based on the results of the processing of the Neural Network method.

ACCURACY METRICS	NN MLP				MLR				RF			
	PL	USA	TUR	UK	PL	USA	TUR	UK	PL	USA	TUR	UK
ME	-20,63	6,87	-15,74	-3,48	0,00	0,00	0,00	0,00	-5,94	-3,36	1,49	2,48
MAE	62,79	43,63	63,13	59,80	62,56	45,52	47,64	52,33	72,35	52,29	47,98	47,36
RMSE	80,03	60,18	85,54	79,82	84,52	61,60	64,62	68,44	96,41	69,42	64,80	65,32
MAPE	18,09%	10,37%	15,84%	14,71%	17,89%	11,02%	11,58%	12,77%	22,34%	12,90%	11,67%	11,56%
RMSPE	23,39%	14,49%	23,16%	20,90%	24,21%	15,53%	16,34%	17,62%	31,62%	18,20%	16,49%	16,70%
MSE	6405,39	3621,39	7316,52	6372,00	7143,47	3794,06	4175,50	4684,48	9294,63	4819,40	4199,18	4266,22
COD	1,04	1,02	1,03	1,03	1,04	1,02	1,02	1,02	1,08	1,03	1,03	1,03
PRD	15,24%	10,41%	15,11%	14,46%	17,40%	10,99%	11,50%	12,86%	21,17%	12,57%	11,59%	11,54%

Each metric provides a different lens to assess the performance of the regression model. The metrics indicated above are used to monitor prediction accuracy. In order to explore the problem deeply, the author decided to use additional differentiation criteria.

PREDICTION ACCURACY Price – to – Value (PTV)	$PTV = \frac{A_i}{P_i}$	EQUALITY Gini Index	$G = \frac{n + 1 - 2\left(\frac{\sum_{i=1}^{n}(n-i+1)(A_i - P_i)}{\sum_{i=1}^{n}(A_i - P_i)}\right)}{n}$
VARIABILITY Coefficient of Price Variability (CPV)	$CPV = \frac{St.Dev.(A_i - P_i)}{\frac{1}{n}\sum_{i=1}^{n} A_i - P_i} * 100\%$	QUARTILE ANALYSIS Interquartile Range (IQR)	$IQR = Q3 - Q1$

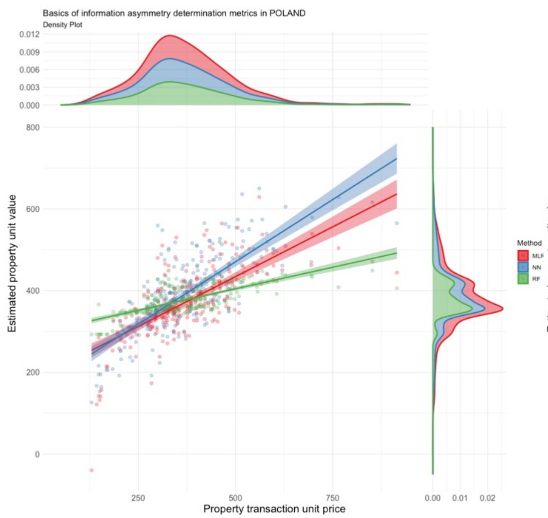
Models' validation – information asymmetry analysis

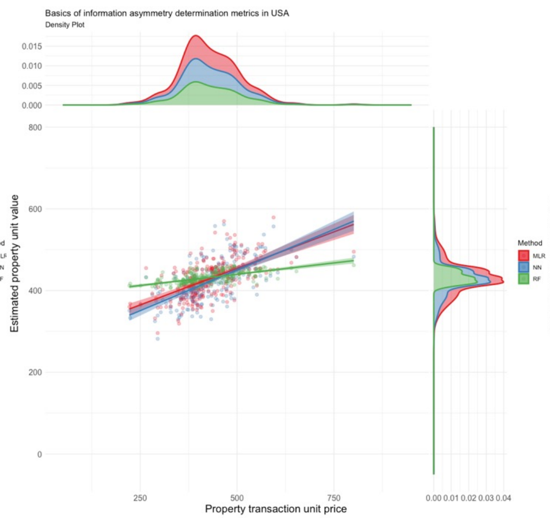
ASSYMETRY METRICS	NN MLP				MLR				RF			
	PL	USA	TUR	UK	PL	USA	TUR	UK	PL	USA	TUR	UK
Mean PTV	0,9484	1,0165	0,9723	0,9978	0,9791	0,9999	0,9999	0,9999	0,9714	0,9898	1,0003	1,0030
CPV	0,1859	0,1409	0,1881	0,1857	0,3466	0,1419	0,1496	0,1585	0,2518	0,1596	0,1502	0,1512
Gini index	0,1089	0,0751	0,1047	0,1011	0,1366	0,0776	0,0814	0,0876	0,1404	0,0877	0,0815	0,0815
Q1	0,8242	0,9444	0,8577	0,8801	0,8550	0,9157	0,9061	0,9044	0,7992	0,8896	0,9078	0,9161
Q2	0,9175	1,0083	0,9719	0,9855	0,9755	0,9976	0,9940	0,9905	0,9610	0,9819	0,9941	0,9987
Q3	1,0507	1,0912	1,0655	1,1028	1,1187	1,0807	1,0814	1,0968	1,1130	1,0842	1,0842	1,0813
IQR	0,2265	0,1468	0,2078	0,2227	0,2637	0,1651	0,1753	0,1924	0,3138	0,1947	0,1763	0,1653

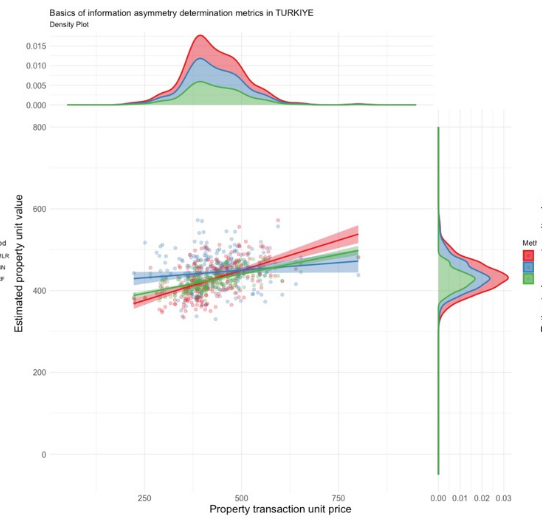
In order to analyze and interpret the relationship between real estate transaction prices and their values obtained using different predictive methods, classic scatter plots were developed for each of the analyzed databases.

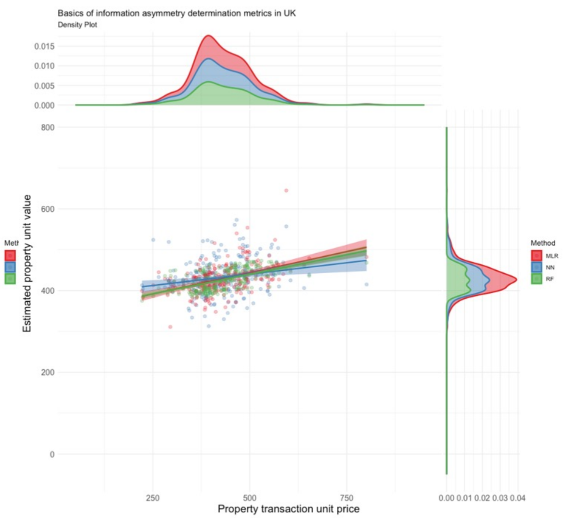
The introduced graphical solutions allow for examining both the relationship between two variables and the distribution of each of these variables. Data visualization can help by delivering data in the most efficient way possible. The analysis of scatter plots and regression functions indicated the predictive capabilities of individual methods in light of the richness of the databases.

Models' validation – information asymmetry analysis









Research substantially contributes in several ways:

- by focusing on property registration systems, the study improves understanding of how information asymmetry affects market fairness and efficiency,
- it effectively integrates various classical theories and paradigms, such as location theory and the sustainable development paradigm, to analyze the complexities of real estate markets,
- it utilizes advanced analytical techniques for property valuation and provides a modern approach to addressing the challenges posed by information asymmetry.

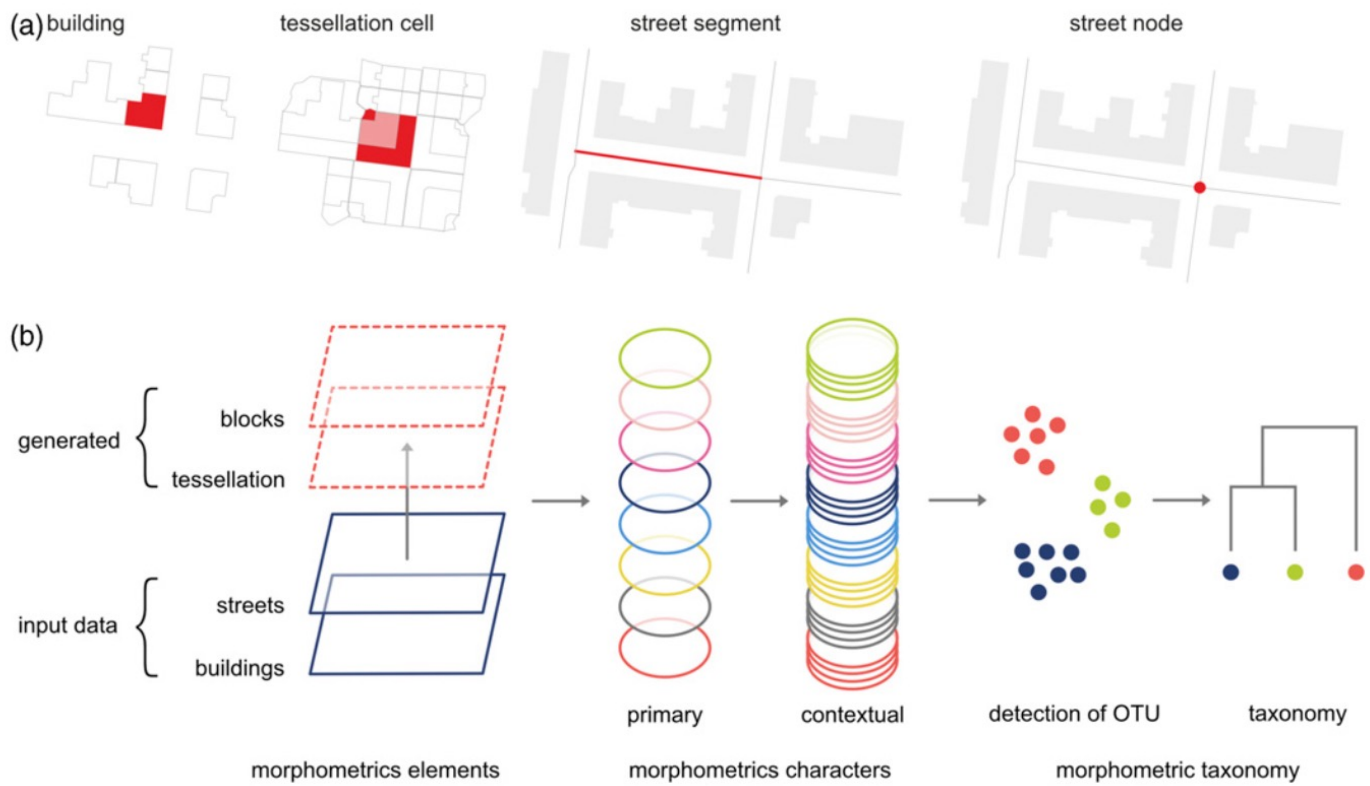
Urban morphology -> Urban morphometrics -> Morphological tessellation

Open-source
Python toolkit

momepy

PySAL

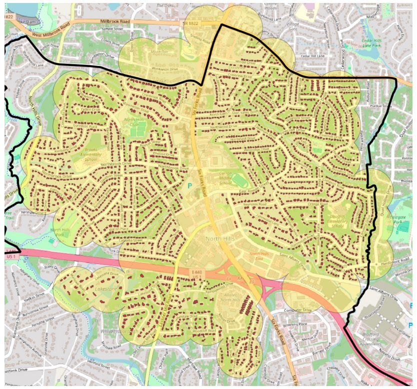
GeoPandas

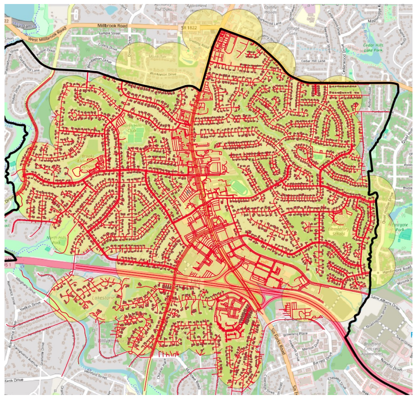


Martin Fleischmann (2022)

HAD2 -> PM-metrics -> PM-tessellation

INPUT DATA





TESSELLATION

momepy

PySAL

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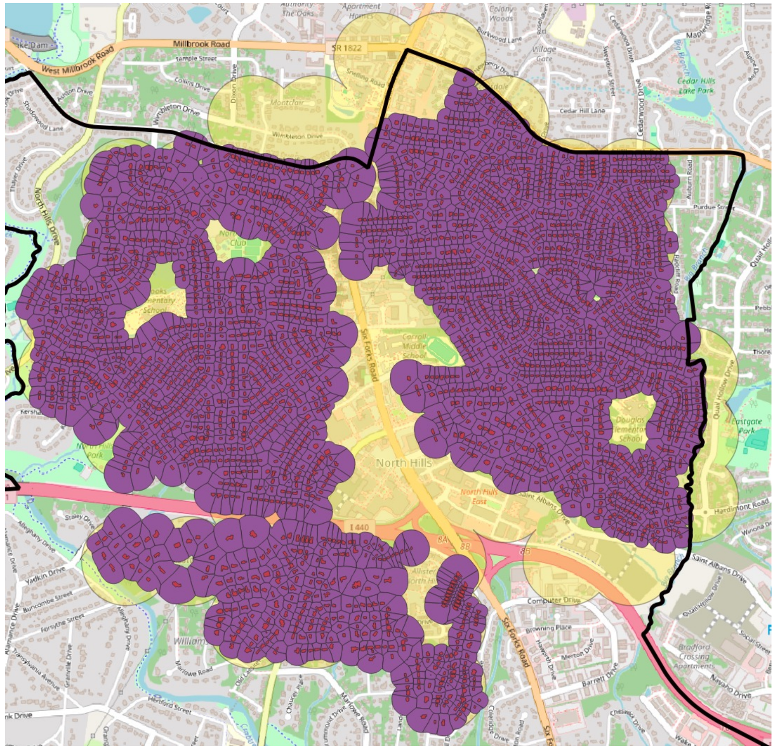
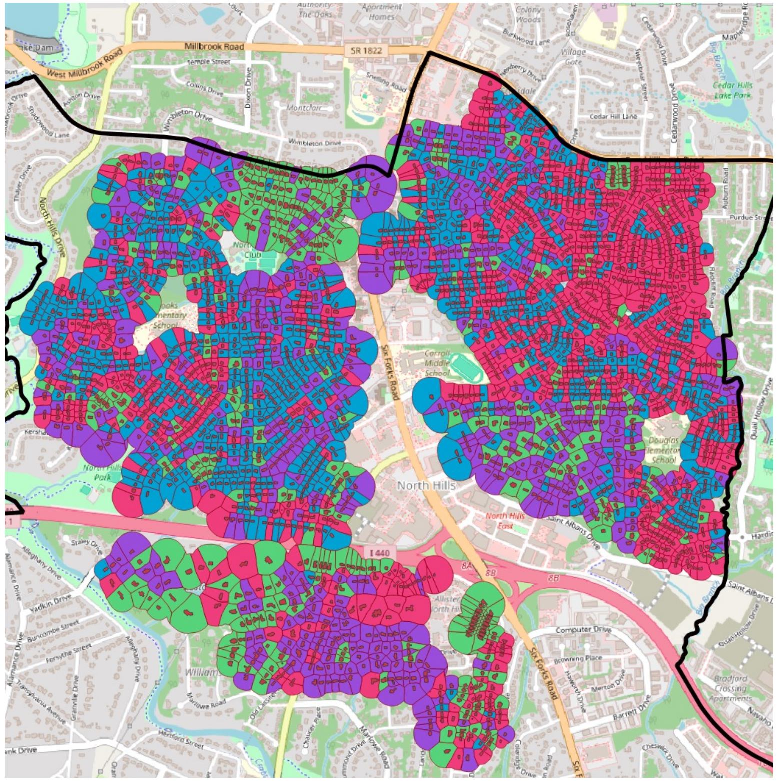
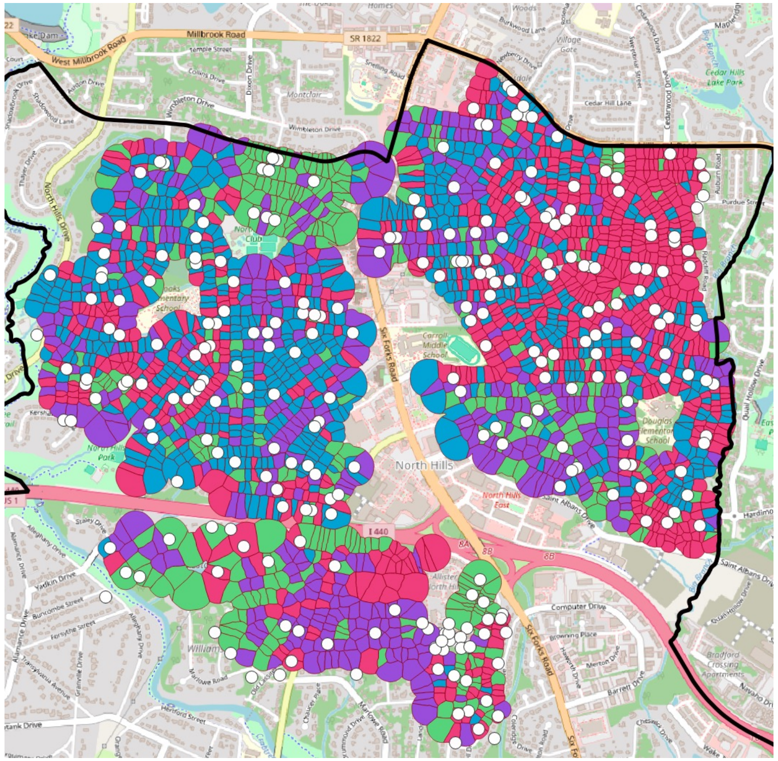


HAD2 -> PM-metrics -> PM-tessellation

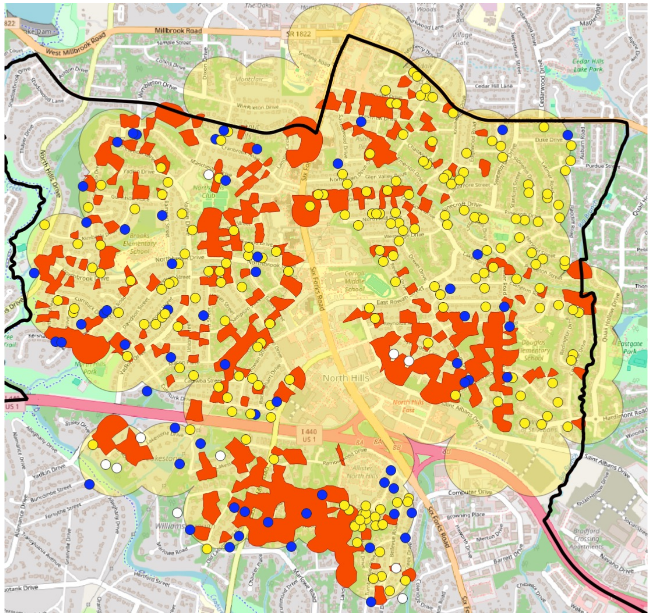
PM-metrics primary/contextual



Detection of OTU

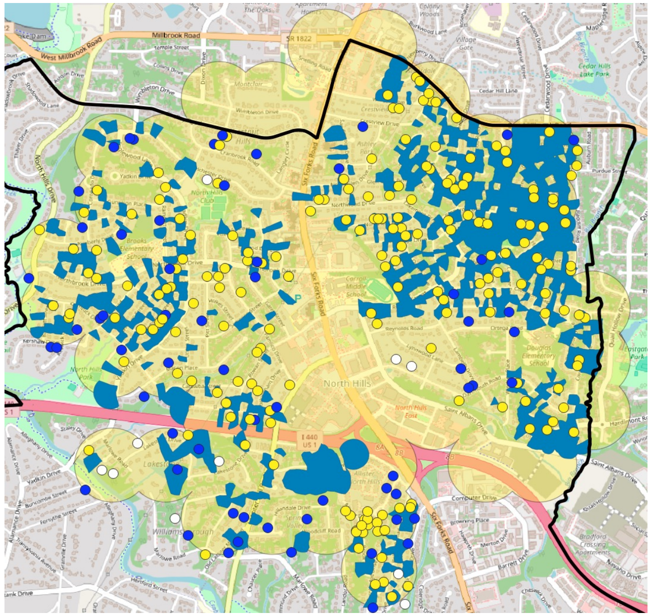


PM-metric taxonomy



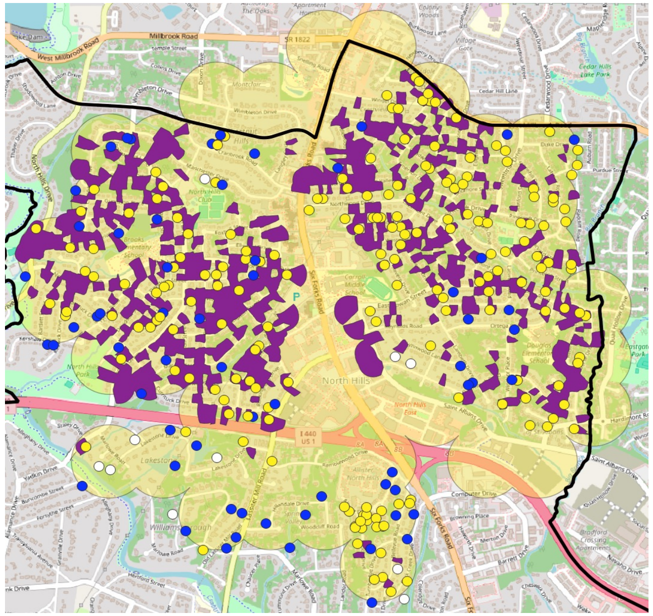
Probability

73%



Probability

88%



Probability

76%

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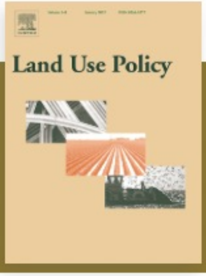

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