

# What Social Patterns of the City Can Machine Learning Reveal?

## Exploring Correlations Between Social and Physical Urban Data

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### Abstract

This study advances the Social Urban Digital Twin (SUDT) framework by introducing a new analytical phase: Critical Algorithmic Correlation—a method that uses interpretable machine learning to detect latent associations between physical urban form and social vulnerability. While digital tools are widely used to optimize infrastructure and simulate growth, their critical potential to diagnose structural exclusion remains underutilized.

Using the rule-based WizWhy algorithm, we analyzed a dataset of over 640 physical and social indicators at the block level in the Hatikva neighborhood of Tel Aviv—a historically marginalized area shaped by fragmented tenure systems and long-standing planning neglect. In each iteration, one independent variable—either physical or social—was tested against the full dataset to expose non-obvious, yet robust, correlations. This approach revealed consistent links between specific urban morphologies—such as micro-apartment concentration or infrastructure malfunction—and indicators of poverty, civic disengagement, and demographic instability.

Rather than predicting future trends, this method surfaces patterns of socio-spatial inequality embedded in the present. Framed within the lens of degrowth urbanism and critical spatial theory, the findings offer a novel diagnostic layer to urban digital models—one that renders visible the mechanisms of systemic neglect.

Methodologically, the study demonstrates how interpretable AI can serve as a diagnostic tool for detecting urban inequalities. Theoretically, it contributes to critical urban discourse by bridging digital urbanism and social theory. Practically, it informs equity-oriented planning by offering a data-driven approach to recognize and address spatial injustice—providing planners and policymakers with actionable insight grounded in both technical analysis and social critique.

Keywords:

Social Urban Digital Twin; Degrowth Urbanism; Critical Algorithmic Correlation; Urban Data Analysis; Socio-spatial Segregation; Marginalized Neighborhoods

## 1. Introduction

In contemporary urban planning, digital and algorithmic tools have become central to the optimization of physical infrastructure—analyzing traffic flows, predicting building performance, and simulating environmental impacts. These tools are increasingly embedded within the frameworks of smart cities and digital twin systems (Batty, 2021; Nochta et al., 2021). However, despite their growing sophistication, such technologies remain largely disconnected from the lived social realities of the city. While physical infrastructures are modeled and monitored in real time, social conditions—such as inequality, segregation, or civic marginalization—often remain invisible to algorithmic scrutiny.

This paper seeks to address this critical gap. We propose a methodological and conceptual enhancement of the Social Urban Digital Twin (SUDT)—a model we previously developed to integrate social and spatial data for critical urban analysis (Yossef Ravid & Aharon-Gutman, 2023). Building upon the model's original correlation phase, we refine and extend it through the development of a focused analytical process: Critical Algorithmic Correlation. We refer to this phase as *Critical Algorithmic Correlation*—a rule-based statistical correlation analysis framed through a critical urban lens. The term emphasizes interpretability and theoretical reflection rather than computational novelty. This advancement operationalizes the use of the WizWhy association rule algorithm to extract structured, interpretable patterns between built environment features and social indicators. Rather than introducing a wholly new stage, this work deepens an existing phase in the SUDT, embedding machine learning into the framework while maintaining transparency and theoretical coherence.

This methodological innovation is tested in the Hatikva neighborhood of Tel Aviv, a historically marginalized area shaped by decades of planning neglect, fragmented land tenure (*mush'a*), and layered forms of social vulnerability (Shamur, 2020). Using a dataset of over 640 physical and social variables at the urban block level, we

examine correlations between features such as apartment size, building age, and ownership types, and social indicators like marital status, education level, and public order violations.

This study was guided by two core questions. The first is methodological, and the second is rooted in urban sociology. The first question asks: *Can algorithmic analysis of urban data reveal hidden correlations between spatial underdevelopment and social segregation in marginalized neighborhoods?* The second question asks: *What is the relationship between the socio-economic condition of a neighborhood's residents (in terms of welfare and poverty) and the proliferation of small, intra-neighborhood enclaves, which impede urban renewal due to a fragmented ownership structure?*

To address those questions, we not only apply a novel analytical approach but also engage with broader theoretical frameworks—particularly *degrowth urbanism*. Studies clarify that degrowth in urban planning is understood not merely as limiting expansion but as rethinking planning practices. The concept is rooted in a critique of inevitable urban growth and is reformed through strategies that emphasize community resilience and integrated spatial dynamics (Florentin, 2018; Krähmer, 2022).

From this perspective, neighborhoods like Hatikva—characterized by unresolved land tenure and persistent spatial stagnation—exemplify urban conditions often associated with the Global South. Despite being embedded within the territory of Tel Aviv, Hatikva remains spatially and economically marginalized. While most city neighborhoods have undergone accelerated development and infrastructural investment, Hatikva has been effectively left behind, operating as a *de facto* ethnic enclave. Degrowth theory enables us to name and confront this condition not as an anomaly, but as a structural outcome of planning regimes that systematically overlook or exclude vulnerable communities.

In neighborhoods like Hatikva, where formal development has been frozen and legal property registration remains unresolved, residents have adopted informal, off-the-books strategies to reshape their spatial and economic futures. These everyday practices illustrate the idea of spatial non-development not as failure, but

as a call to rethink planning paradigms. Degrowth, in this context, is not a call for stasis, but for new institutional and methodological tools to address social and spatial inequality.

This study contributes to three intersecting debates. Methodologically, it demonstrates how interpretable algorithms can be employed not for optimization, but for diagnostic insight. Empirically, it uncovers how specific combinations of physical attributes—such as micro-apartment density and informal ownership—correlate with indicators of poverty, civic disengagement, and demographic isolation. Theoretically, it positions digital tools within critical urbanism and degrowth frameworks, reframing planning not as a growth-centered endeavor but as a means of identifying and addressing embedded inequalities (Hatuka & Zur, 2020; Xue, 2022).

Ultimately, this research demonstrates that algorithms—commonly used for forecasting demand or optimizing efficiency—can serve as powerful tools for urban social inquiry. When applied to social data through a critical lens, they offer a new kind of urban intelligence: one that is not only predictive, but reflective—capable of exposing how the city’s physical form and social fabric are co-constructed through patterns of systemic neglect.

## 2. Research case study- The Hatikva Neighborhood, Tel Aviv

The Hatikva neighborhood, located in the southeastern periphery of Tel Aviv, serves as a compelling case study of a historically marginalized urban area. Its trajectory has been profoundly shaped by systemic planning neglect, spatial segregation, and entrenched social vulnerability. Established in the 1930s beyond the formal jurisdiction of the Tel Aviv Municipality, Hatikva developed in an unregulated manner, receiving minimal state or municipal investment. This foundational exclusion from formal planning frameworks continues to significantly impact its development (Shamur, 2019). As Shamur and Marom (2021) demonstrate in their research on local environmental concerns and urban marginality, such historically neglected areas often become sites where formal planning mechanisms not only fail to address but can actively perpetuate existing inequalities.

Initially founded by Mizrahi Jewish immigrants, Hatikva’s early characteristics included limited infrastructure and the complete absence of an official planning

framework, cementing its status as a "no man's land" (Shamur, 2019; Yiftachel & Cohen, 2022).

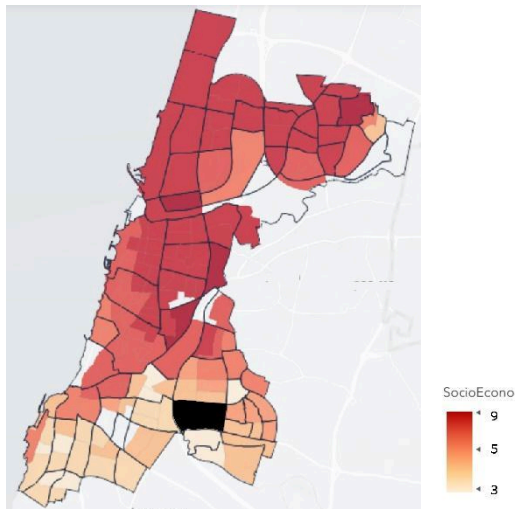


Figure 1 - Map of Tel Aviv with HaTikva neighborhood highlighted in black. The background shows the city's socio-economic index by statistical areas (CBS 2021), illustrating HaTikva's position within one of the lowest socio-economic tiers in Tel Aviv's urban fabric.

Despite its geopolitical significance as a strategic buffer zone, the area consistently suffered from chronic infrastructural neglect. Recurring floods from the Musrara River (now the Ayalon River), inadequate sewage systems, and its proximity to poorly developed transit routes underscored the municipality's marginal commitment to the neighborhood. This persistent infrastructural deficiency can be understood as a manifestation of planning as social control (Yiftachel, 1998). In Hatikva, this control has not been exercised through overt exclusion, but through enduring administrative ambiguity and selective implementation. The neighborhood has experienced fragmented planning efforts, uneven infrastructural investment, and limited regulatory continuity. The unresolved status of land registration under the mush'a tenure system has further restricted both private development and public renewal, sustaining conditions of spatial stagnation and peripheralization within Tel Aviv's urban fabric.

These institutional dynamics mirror patterns observed in several Global South contexts, where planning often operates through omission as much as through intervention. Administrative inertia, infrastructural neglect, and ambiguous property

regimes reproduce marginality—not as intentional policy but as the cumulative outcome of uneven governance and selective recognition.

Hatikva's spatial structure vividly reflects this enduring logic of marginalization, characterized by fragmented parcels and dense, low-rise buildings. Covering approximately 1,000 dunams and home to around 13,000 residents, Hatikva is defined by a unique land tenure system known as *mush'a*. This system involves undivided collective ownership, where multiple stakeholders hold common, undifferentiated shares in a parcel of land without specific individual plot demarcation. As Ansenberg (2025) explains, *mush'a* creates a complex web of fractional ownership, rendering it exceptionally difficult to partition, register, or develop individual properties. This absence of legal clarity over land ownership directly leads to spatial stagnation and severely limits the municipality's capacity to implement urban renewal.

The neighborhood's housing stock is predominantly old, with most residential units built in the 1940s and 1950s. Since the 1970s, new development has been virtually non-existent, in stark contrast to significant planning and infrastructural investment in surrounding areas. This physical inertia perpetuates Hatikva's peripheral status, further isolating it from Tel Aviv's broader urban fabric (Tel Aviv Municipality, 2020).

Concurrently, Hatikva has undergone substantial demographic shifts. Once primarily a working-class enclave for Mizrahi Jews, it has increasingly become home to diverse marginalized populations, including migrant workers, asylum seekers, and low-income households. These overlapping forms of exclusion—ethnic, economic, and legal—collectively produce what Wacquant (2008) terms territorial stigmatization, reinforcing the structural inequalities embedded in the urban periphery. Shamur (2019) further elaborates on the ethno-class marginalization in Hatikva, revealing how its socio-spatial trajectory is deeply intertwined with broader processes of exclusion in Tel Aviv. The influx of new, vulnerable populations into an already neglected area exacerbates existing fragilities, creating a complex, multi-layered dynamic of disadvantage.

This convergence of fragmented land ownership, socio-economic vulnerability, and long-term planning inertia positions Hatikva as a critical site for examining the

correlation between social segregation and spatial underdevelopment. The layered nature of exclusion in Hatikva—evident in both data and lived experience—makes it an ideal case for algorithmic analysis seeking to identify hidden patterns of urban inequality, offering insights into how planning can inadvertently contribute to displacement and marginalization (Shamur & Marom, 2021).



Figure- 2 The photos show typical streetscapes of the neighborhood, characterized by a dense, low-rise urban fabric and a strong local identity.

### 3. Methodology

This study adopts a three-stage methodological framework to investigate the correlations between the social and physical dimensions of the urban environment in Tel Aviv's Hatikva neighborhood. These stages include: (1) constructing a unified spatial database and developing the Social Digital Twin; (2) categorizing urban data into social and physical indicators; (3) applying a machine learning algorithm (WizWhy) to uncover associative patterns.

Building upon the foundational concept of the Social Digital Twin, this research introduces and applies a "critical algorithm" designed to move beyond mere data visualization. This approach extends the capabilities of the Social Digital Twin by actively seeking to uncover hidden dimensions of urban inequality and systemic planning failures, thereby informing more equitable and sustainable urban planning practices (Yossef Ravid & Aharon-Gutman, 2023).

### 3.1 Database Construction

Data were collected from multiple municipal and governmental sources, each with differing spatial resolutions, formats, and content. The datasets were standardized into a structured SQL database, allowing for integration across sources. Geospatial data were unified under a common coordinate system to maintain locational accuracy.

The first stage of the research involved the creation of a digital twin through the construction of a data-driven three-dimensional city model. This methodology is adapted from the architectural modeling process, in which the physical environment is translated into a computerized 3D model using design technologies such as CAD (Computer-Aided Design) or VRML (Virtual Reality Modeling Language). In the digital era, the urban model assumes a new, virtual form—its physical materiality replaced by photogrammetric and multi-scalar representations that allow for dynamic and integrative analysis (Shirowzhan et al., 2020). Accordingly, the foundation of the Social Digital Twin lies in generating a three-dimensional mirror of the built environment within a virtual space.

Given the variety of spatial scales and the sensitivity of the social data—ranging from city-wide metrics to household-level indicators—a key methodological decision was the selection of an optimal unit of analysis. In this study, the urban block was defined as the core spatial unit. All data were therefore translated and aligned at the block level. This definition was established during the research and validated by all participating stakeholders, following a protocol that meets EU harmonization standards.

Normalization techniques were applied to facilitate comparisons across blocks. For instance, absolute values (such as the number of households reporting community engagement) were converted into relative indicators (e.g., the percentage of participating households within a given block). This methodological step enabled the analysis to highlight disparities and patterns rather than raw quantities. The resulting database includes detailed metadata documenting the source, transformation process, and normalization procedures used for each variable.

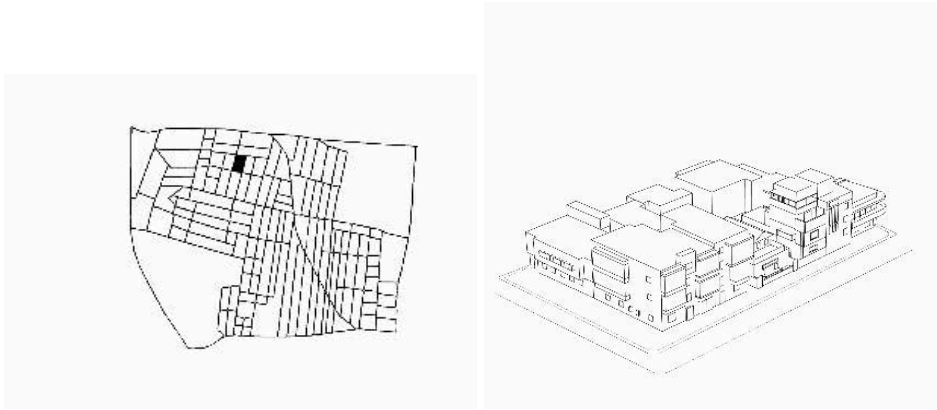


Figure 3: Block division in the Hatikva neighborhood and 3D model of a representative block. The left image shows the neighborhood's division into urban blocks. The right image presents a three-dimensional model of one of the blocks, illustrating its built morphology and volumetric characteristics as part of the normalization analysis.

### 3.2 Data Categorization

The dataset was then categorized into two main groups:

- **Social Data:** Including variables such as demographics, marital status, education levels, and public order violations.
- **Physical Data:** Including indicators such as apartment size, ownership structures, and spatial configurations.

Each category and sub-category was transformed into an individual variable to enable fine-grained pattern detection. For example, apartment-size ranges (30–60 m<sup>2</sup>, 60–90 m<sup>2</sup>, etc.) and building-age intervals (1940s, 1950s, 1960s) were encoded separately. This structuring process substantially increased the number of variables but allowed the algorithm to identify subtle, localized relationships between the physical and social dimensions of the city.

In the context of this study, urban data is more than just raw numbers. It represents the underlying social and physical structures that shape the urban environment. As Zins (2007) articulates, "Data are the basic individual items of numeric or other information, garnered through observation; but in themselves, without context, they are devoid of information. Information is that which is conveyed, and possibly amenable to analysis and interpretation, through data and the context in which the data are assembled." Therefore, in this research, urban data not only refers to the physical measurements of infrastructure but also encompasses the relationships and interactions between the social dynamics and the built environment. This dual

perspective allows for a comprehensive understanding of how the physical city and its social components influence one another.

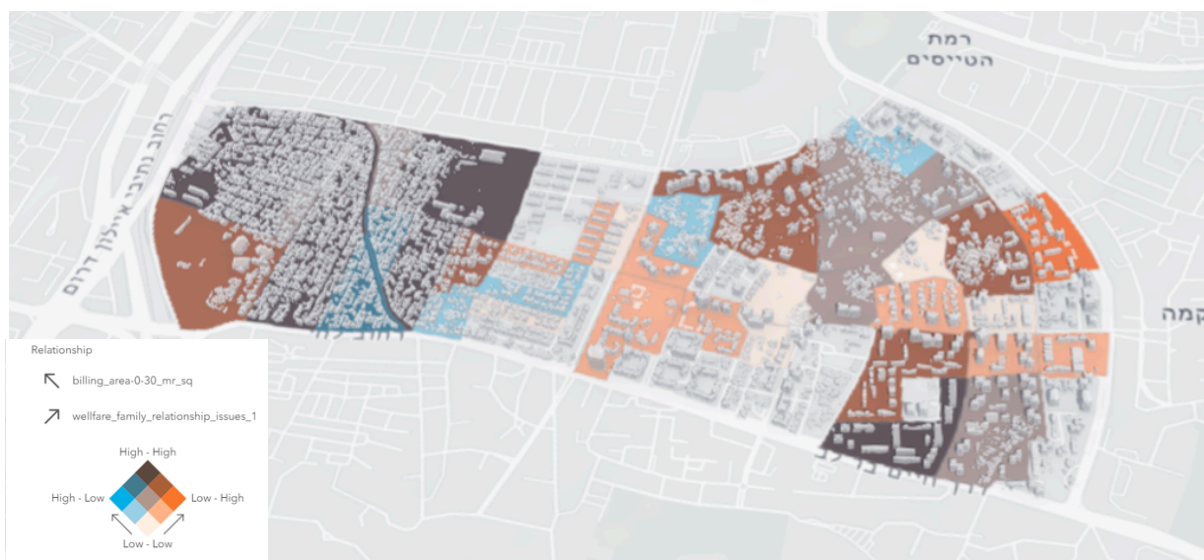


Figure 4: Apartment size 0-30 in relation to welfare patients due to family problems. Correlation between physical and social data in social digital Twin.

### 3.3 Association Rule Algorithm – WizWhy

in order to identify statistically significant relationships between variables within the dataset, this study applies the WizWhy<sup>1</sup> algorithm, a rule-based machine learning tool. While numerous algorithms exist for data mining—such as decision trees, random forests, and neural networks—WizWhy was chosen for its unique ability to generate clear, interpretable rules and to effectively analyze imbalanced social datasets, which are common in urban studies. A central innovation of this research lies in applying the same analytical framework to both physical and social datasets. While earlier studies have combined social and spatial indicators, this study distinguishes itself through its block-level granularity, its interpretability, and the use of a rule-based association approach to expose latent socio-spatial inequalities.

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<sup>1</sup> A working demo of WizWhy (limited to 1,000 records) is available at: <https://www.wizsoft.com>.

Documentation: [https://www.wizsoft.com/wizwhy\\_description.pdf](https://www.wizsoft.com/wizwhy_description.pdf)

WizWhy is a commercially available rule-based statistical tool developed by WizSoft Inc. It identifies if–then and if–and–only–if associations that meet user-defined thresholds of support and confidence. In contrast to regression or decision-tree models, WizWhy can detect patterns specific to subpopulations and explicitly lists the logical rules on which its classifications are based, thereby enhancing interpretability.

Although referred to here as an “algorithm,” WizWhy functions as a transparent rule-based correlation analysis rather than a black-box predictive model. Its analytical parameters and procedures are documented in the program’s Help files, allowing replication by other researchers.

These rules are not causal, but they do highlight patterns that are statistically significant and potentially meaningful in planning contexts. For example, instead of providing an abstract correlation coefficient, the algorithm produces a rule like: “If a block has characteristics A and B, then condition C is likely to occur.”

The algorithm identifies two types of logical relationships: if–then rules, which describe sufficient conditions, and if–and–only–if rules, which define both necessary and sufficient conditions for a given outcome. These are generated through an iterative process that minimizes error and seeks the most compact, explanatory combination of input variables.

WizWhy allows users to control the thresholds for rule probability (confidence), the number of supporting cases (support), and the number of conditions (complexity). It then evaluates each rule based on statistical significance and error cost weighting, enabling balanced predictions even in datasets where certain outcomes are rare.

The choice to use WizWhy was motivated by its ability to produce transparent, logic-based outputs that can inform spatial decision-making. Its interpretability allows for the translation of complex data relationships into actionable planning insights—making it especially valuable in interdisciplinary research involving architects, planners, and policymakers.

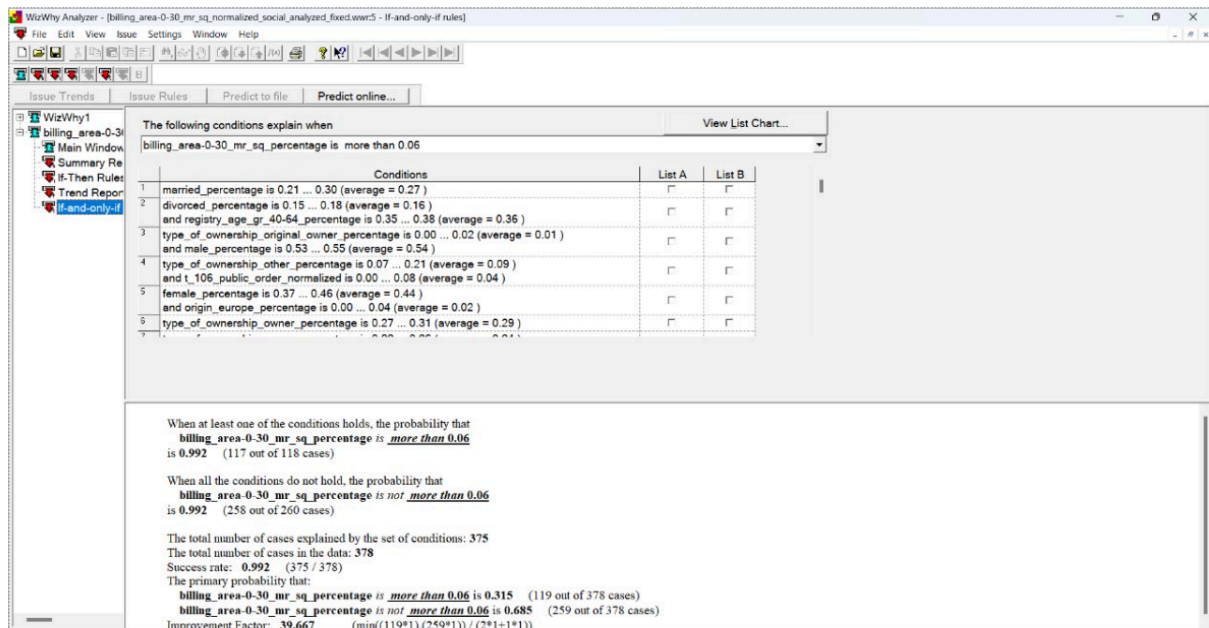


Figure 5: User interface of the WizWhy software, illustrating its rule-based output

## Selection of Variables

The process of selecting variables for each analytical iteration is a central component of the modeling strategy. For each run of the algorithm, one variable is designated as the dependent variable—the outcome to be predicted or explained. This variable may belong to either the social or physical domain, depending on the thematic focus of the analysis.

All other variables in the dataset are treated as independent variables, which the algorithm tests for conditional relationships with the selected outcome. This structure enables the identification of both intra-domain correlations (e.g., between social indicators) and cross-domain correlations (e.g., between physical form and social behavior).

Each analytical run produces a set of rule-based associations between the dependent variable and the relevant independent conditions. By conducting multiple runs with different dependent variables, the study reveals a broader set of patterns embedded in the urban dataset. This iterative approach supports the exploration of how physical characteristics of the built environment relate to social dynamics—and vice versa—at the scale of the urban block.

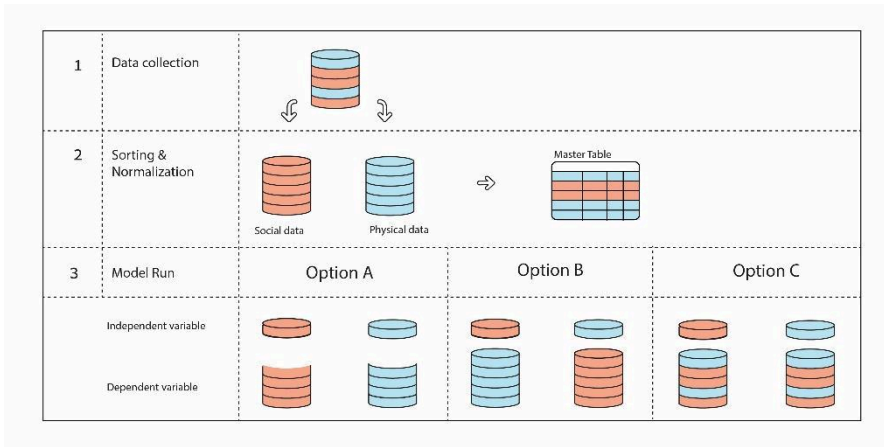


Figure 6: Workflow of urban data analysis. The process includes data collection, categorization into social and physical groups, normalization, and modeling, enabling exploration of correlations between social dynamics and the physical city.

For clarity, several locally specific terms are used in this study—such as *dunam* (1,000 square meters), *key money* (informal tenure arrangements), *municipal code 106* (Tel Aviv’s public service hotline), and *Mizrahi Jews* (Jewish communities of Middle Eastern and North African origin). These are retained in their original form to preserve their contextual meaning.

#### 4. Results: Machine Learning-Based Correlational Analysis of Social and Physical Urban Data

This section presents the main findings from a series of exploratory runs using the WizWhy rule-based machine learning algorithm. In each run, one variable—either physical or social—was selected as the target (dependent variable), and the algorithm was asked to search for correlations across the entire dataset. The analysis does not aim to establish causal relationships but to identify statistically significant associations that reveal underlying socio-spatial patterns. No prior hypotheses were applied to guide the process; instead, the goal was to identify unexpected and non-trivial associations emerging directly from the data.

The analysis did not aim to prove causality or confirm pre-existing assumptions. Rather, it followed an inductive logic: What do the data reveal when allowed to speak for themselves? The answers that emerged were not always intuitive, but they consistently exposed patterns of spatial and social stratification deeply embedded in the urban fabric.

The four examples presented below reflect the diversity of the results. Each focuses on a different dependent variable and highlights key correlations, particularly where social vulnerability aligns with physical characteristics of the built environment.

These cases offer insight into how infrastructure, housing form, and demographic indicators coalesce to shape urban exclusion.

#### 4.1 Micro-apartments as Indicators of Social Exclusion

The built environment, as theorized by Henri Lefebvre (1991), is never neutral—it embodies social relations, power hierarchies, and historical processes of inclusion and exclusion. In the context of capitalist urbanization, spatial form becomes a mechanism for organizing inequality. David Harvey (1973) similarly pointed out that urban space reflects the spatial fix of capital, wherein uneven development is not a flaw but a feature of growth-oriented planning. More recently, scholars such as Madden and Marcuse (2016) have argued that housing typologies themselves can function as tools of social sorting, reinforcing divisions of class, ethnicity, and legal status.

Micro-apartments—residential units up to 30 square meters—serve not only as physical structures but as spatial markers of social abandonment. Far from serving as flexible or affordable housing solutions, their concentration often signals areas of sustained underinvestment, informal tenure, and demographic precarity. In Hatikva, a historically marginalized neighborhood of Tel Aviv, these typologies emerge not randomly, but as products of deliberate planning neglect and fragmented land regimes. They reflect how zoning, regulation, and ownership patterns channel inequality into space.

Independent variable: Share of micro-apartments per block (physical)

Dependent variables: Full set of social indicators

Key finding: When micro-apartments exceed 6% of the housing stock in a block, there is a 99.2% probability that one or more of the following social conditions will be present:

- High proportion of divorced residents
- Low marriage rates
- High share of elderly residents
- Prevalence of non-standard ownership types (e.g., key money, informal tenure)

- Elevated levels of public order complaints
- Lower representation of women overall, and particularly of those of European origin
- Complete absence of long-term private ownership

These correlations reveal how constrained housing environments overlap with demographic instability and limited civic engagement- measured as the share of households not participating in local community programs or civic associations, according to municipal welfare datasets.. Rather than reflecting affordability or flexibility, micro-apartments encode zones of disinvestment—where the built form mirrors and reinforces marginality.

#### 4.2 Family Welfare Issues and Spatial Housing Conditions

This section examines the relationship between family-level distress and spatial housing conditions. The analysis is guided by classical and contemporary scholarship on urban poverty and the spatial reproduction of inequality. David Harvey (1973) argues that the city operates not only as a stage for social processes but as a mechanism that produces and reproduces class-based disparities. Building on this, recent studies (Desmond, 2016; Wacquant, 2008) emphasize how housing insecurity, unstable tenure, and fragmented urban form contribute to cycles of poverty and social fragility—particularly in marginalized neighborhoods.

In this case, family-level distress is not only reflected in the built environment—it is shaped by it. The analysis explores the extent to which indicators of family distress (e.g., welfare dependency, child vulnerability, family dissolution) are spatially patterned and materially reinforced.

Independent variable: Family welfare distress indicator (social)

Dependent variables: Full dataset (social + physical)

Key correlations:

- High concentration of micro-apartments
- High poverty and social exclusion scores
- Absence of original long-term private ownership

These findings indicate that unstable tenure and small housing units are statistically associated with fragile living conditions, suggesting that patterns of housing instability often coincide with social vulnerability. In this context, the erosion of private

ownership and the lack of spatial continuity limit intergenerational mobility, anchoring poverty in place.

#### 4.3 Public Order Complaints and Social Isolation

This analysis explored the relationship between the spatial distribution of public order complaints (municipal code 106) and patterns of social isolation and exclusion. These complaints, often interpreted as technical reports about disorder, reveal deeper social dynamics when examined at the urban block level.

Independent variable: Normalized rate of public order complaints (social)

Dependent variables: Full set of social indicators

Key correlations identified:

- High percentage of elderly residents with welfare dependency
- Low community participation among children (ages 0–6) and adults (36–65)
- High share of residents aged 40–64 with limited civic engagement
- Elevated presence of foreign-born residents from South America and Africa
- High proportion of divorced individuals
- Spatial concentration in Hatikva neighborhood blocks, measured using a local clustering index that identifies contiguous blocks with above-average complaint densities. Rather than signaling disorder alone, these complaints appear in zones of institutional absence and frayed social ties. They reflect places where minor conflicts are less likely to be mediated informally, and more likely to escalate due to lack of trust, capacity, or social cohesion. In such areas, complaints are not simply reports—they are symptoms of social fragmentation.

These data suggest a spatial paradox: neighborhoods that are neglected in terms of investment and services become hyper-visible through monitoring and surveillance. Public complaints thus serve as indirect indicators of civic disconnection and symbolic exclusion.

#### 4.4 Infrastructure Breakdown and Layers of Social Exclusion

This analysis examined the correlation between physical infrastructure failures—specifically drainage and sewage malfunctions—and indicators of entrenched social exclusion. While typically considered technical issues, such malfunctions serve as proxies for spatial abandonment and reveal patterns of cumulative neglect in the urban fabric.

Independent variable: Rate of drainage/sewage malfunction (physical)

Dependent variables: Full dataset (social + physical)

Key correlations identified:

- High concentration of micro-apartments
- Housing stock from the 1940s
- Absence of registered businesses
- Lack of formal kindergartens
- Low community participation (especially among elderly and widows)
- High share of singles and low marriage rates
- Significant representation of residents of North African origin
- Peripheral blocks in municipal indexing

The spatial overlap of infrastructure breakdown with demographic vulnerability suggests more than just technical failure—it signals chronic institutional withdrawal. These are not temporary disruptions, but enduring indicators of where maintenance stops and marginalization deepens.

The material decay of underground infrastructure serves as an indicator of long-term disinvestment. In these spaces, what lies beneath the surface—cracked pipes and blocked drains— reflects patterns of policy neglect and systemic exclusion.

## Conclusion

In this study, we introduced a critical step forward in digital urbanism by expanding the Social Urban Digital Twin (SUDT) model through the development of a new analytical phase: Critical Algorithmic Correlation. This phase leverages machine learning not to predict urban futures, but to diagnose the present—revealing latent relationships between built form and social vulnerability through interpretable, data-driven insights.

Using the WizWhy association rule algorithm, we analyzed a comprehensive dataset of over 600 variables mapped at the urban block level in the Hatikva neighborhood. This approach, guided by theoretical frameworks from critical urban studies, yielded consistent and interpretable correlations between physical conditions—such as micro-apartment density, infrastructure malfunction, and housing tenure—and

indicators of socio-economic hardship, civic disengagement, and demographic isolation.

Our contribution is threefold:

Methodologically, we demonstrate that machine learning can be integrated into urban social research without sacrificing interpretability or critical depth. The algorithm is not used as a black box, but as a tool for structured, theory-informed exploration.

Empirically, we uncover layered geographies of exclusion in a marginalized urban area, highlighting how physical neglect, demographic vulnerability, and institutional withdrawal converge within specific spatial patterns—many of which are overlooked by traditional planning tools.

Theoretically, we propose reframing the relationship between optimization and diagnosis as complementary rather than opposing processes. Optimization relies on diagnostic insight—there can be no effective improvement without prior understanding. Our approach therefore emphasizes diagnosis as the necessary foundation for any future optimization of urban systems, shifting the focus from predictive modeling of growth to the critical surfacing of inequality.

The findings also resonate with principles of Degrowth Urbanism. By revealing how systemic underdevelopment and infrastructural stagnation can persist as structural features rather than anomalies, the study reframes “non-growth” conditions as opportunities for social resilience and redistribution. Rather than treating stagnation as failure, a degrowth-oriented perspective interprets it as a space for rethinking planning logics—moving from expansion toward equity, recognition, and care in the built environment.

This work has direct implications for planners, policymakers, and urban researchers. It shows that existing data—when interpreted critically—can illuminate hidden dimensions of spatial injustice and support more targeted, just, and accountable interventions. Rather than simulating a smarter future, we argue that digital tools must also be used to expose the uneven present.

Looking ahead, future work should apply this methodology in diverse urban contexts and at multiple spatial scales, while also embedding community participation in the

interpretation of algorithmic findings. Building participatory dashboards, local observatories, and transparent decision-making tools could help translate these insights into practice.

The analytical results presented here can directly inform municipal planning and policy design. By identifying block-level correlations between social vulnerability and physical neglect, planners can target interventions more precisely. Such diagnostics can guide the allocation of maintenance budgets, prioritize infrastructure repair in under-served blocks, and align social programs with the physical indicators of exclusion revealed by the model. Beyond technical insight, the findings also highlight the need for participatory processes that include residents of marginalized neighborhoods in interpreting and acting upon the data, turning algorithmic diagnosis into collaborative urban practice.

While the analysis provides robust correlations between physical and social indicators, its scope is limited to a single urban case—Hatikva neighborhood in Tel Aviv. As such, the findings should not be generalized to other urban contexts without further comparative research. The use of administrative and welfare datasets may also introduce reporting biases and temporal inconsistencies. Future work should expand the model to additional cities and longitudinal datasets to test the reproducibility and broader applicability of the correlations identified here.

In an era where cities are increasingly mediated by data, this research points toward a different paradigm: not smart cities as systems of optimization and control, but critical digital urbanism as a practice of collective inquiry, transparency, and structural change.

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## Conflict of Interest

One of the co-authors, Abraham Meidan, is the founder and owner of WizWhy Inc., the company that developed and owns the WizWhy software used in this study. The authors confirm that no financial support or influence from WizSoft Inc. affected the design, analysis, or interpretation of the research.

## References

Ansenberg, U. (2025). Mediating urban realities: The role of real-estate appraisers in dismantling the Musha'a system. *City*, 29(1–2), 52–75.

<https://doi.org/10.1080/13604813.2025.2458970>

Batty, M. (2021). Multiple models. *Environment and Planning B: Urban Analytics and City Science*, 48(8), 2129–2132. <https://doi.org/10.1177/23998083211051139>

Desmond, M. (2016). *Evicted: Poverty and Profit in the American City*. Crown Publishing Group.

Florentin, D. (2018). Planning as a Myth: The Politics of Spatial Planning in Peripheral Urban Areas. In Xue, J. (Ed.), *Degrowth and Critical Urbanism*. [Chapter details pending publication info]

Harvey, D. (1973). *Social Justice and the City*. London: Edward Arnold.

Hatuka, T., & Zur, H. (2020). From smart cities to smart social urbanism. *Cities*, 106, 102866. <https://doi.org/10.1016/j.cities.2020.102866>

Krähmer, D. (2022). Urban Shrinkage and Degrowth: Planning without Growth. In *Degrowth Urbanism Reader*. [Full citation details to be completed]

Lefebvre, H. (1991). *The Production of Space* (D. Nicholson-Smith, Trans.). Oxford: Blackwell. (Original work published 1974)

Madden, D. J., & Marcuse, P. (2016). *In Defense of Housing: The Politics of Crisis*. London: Verso.

Nochta, T., Wan, L., Schooling, J. M., & Parlikad, A. K. (2021). A socio-technical perspective on urban analytics: The case of city-scale digital twins. *Journal of Urban Technology*, 28(1–2), 263–287. <https://doi.org/10.1080/10630732.2020.1798177>

Shamur, T. (2019). The construction of multi-layered melancholy in peripheral Tel Aviv. *Emotion, Space and Society*, 32, 100594.

Shamur, T. (2020). Ethno-class marginalization in the heart of the city: Urban planning in the Hatikva neighborhood, Tel Aviv. *Journal of Israeli Sociology*, 31(2), 111–136. [Hebrew]

Shamur, T., & Marom, N. (2021). People as environment: Local environmental concerns and urban marginality in the Tel Aviv Metropolitan region. *Local Environment*, 26(5), 615–631. <https://doi.org/10.1080/13549839.2021.1904858>

Tel Aviv Municipality. (2020). *Urban Renewal in the Southern Neighborhoods: Annual Report*. Tel Aviv–Yafo Planning Department.

Wacquant, L. (2008). *Urban Outcasts: A Comparative Sociology of Advanced Marginality*. Polity Press.

Xue, J. (2022). Critical urban theory and degrowth urbanism: A framework for understanding planning without growth. *Urban Geography*, 43(2), 215–233. <https://doi.org/10.1080/02723638.2021.1878374>

Xue, J. (2022). Degrowing the city: Urban planning and degrowth. In *Rethinking Urbanism* (pp. 33–47). Routledge.

Yiftachel, O. (1998). Planning and social control: Exploring the dark side. *Journal of Planning Literature*, 12(4), 395–406. <https://doi.org/10.1177/088541229801200401>

Yiftachel, O., & Cohen, N. (2022). Defensive urban citizenship: A view from southeastern Tel Aviv. In A. K. M. A. Karim, R. F. C. Da Silva, & S. C. Hamnett (Eds.), *Theorising Urban Development from the Global South*. Routledge.

Yossef Ravid, B., & Aharon-Gutman, M. (2023). The social digital twin: The social turn in the field of smart cities. *Environment and Planning B: Urban Analytics and City Science*, 50(6), 1455–1470. <https://doi.org/10.1177/23998083221137079>

Zins, C. (2007). Conceptual approaches to data, information, and knowledge. *Journal of the American Society for Information Science and Technology*, 58(3), 479–493.