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Research Article

Pathways and Gaps in Literature through Linking Urban Transformation to Public Health

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Abstract

Urban transformation reshapes cities through changes in land use, urban morphology, infrastructure, and environmental conditions. These changes influence environmental exposures, particularly air pollution and thermal stress, and ultimately affect public health. This study investigates the urban transformation–health nexus through bibliometrics and qualitative content analysis. Based on data mining of the Scopus database, this study employed a three-track analytical approach comprising bibliometric analysis of 122 manuscripts published between 2020 and 2026, conceptual synthesis, and content analysis of 89 selected manuscripts. The results identified three pathways of transformations including uncontrolled, controlled, and human-centred transformation. The results indicated that across all pathways, air pollution and thermal stress emerged as the primary mediators of health outcomes. In addition, our investigated materials indicated limited studies were in environmental health risks are rarely integrated into land-use planning as explicit decision-making parameters. The literature was further characterised by health linkages, dominance of single-exposure studies, and limited representation of rapidly urbanising regions, particularly in the Global South specifically the Middle East and Northern Africa (MENA) region. This study presents a novel exposure-based planning framework that integrates dynamic environmental metrics into spatial decisions, thereby positioning urban transformation as an actionable determinant of population health. Serving as a comprehensive conceptual synthesis, this framework provides a novel theoretical blueprint to guide future primary analytical modelling.

Keywords: Urban transformation; Urban dynamics; Environmental exposure; Public health; Health risk

Highlights

- Literature documents the effects of urban transformation on air quality and public health.
- Urban transformation shapes health through air pollution and thermal stress.
- A gap in the literature is the integration of exposure into land-use planning.
- Exposure-based planning offers a pathway to healthier urban development.
- The review proposes an exposure-centred framework for healthier urban planning.

1 Introduction

Rapid urbanisation in cities of the Global South has produced accelerated and uneven patterns of urban transformation (Agyemang et al., 2023; Elshater et al., 2025; Hao et al., 2025; Kumar et al., 2023). Such transformation typically unfolds through two dominant and interrelated pathways. The first is the uncontrolled expansion, including urban sprawl (Carneiro et al., 2021; Sathe & Rahman, 2024), land-use change (Fonseca et al., 2025; Milà et al., 2020), or informal urbanisation (Stuhlmacher et al., 2020; Younis et al., 2025). The second pattern of transformation is the controlled, infrastructure-led development driven by transport networks and road expansion (Amgad et al., 2025; Çelik et al., 2025; Etuman et al., 2024; Najah et al., 2023). In some contexts, particularly in the Global North, a third pathway can also be identified in the form of human-centred development (Abdollahpour et al., 2024; Scheuer et al., 2024), led by institutions and governments aiming to respond more directly to everyday human needs (Khanh et al., 2025; Semeraro et al., 2023; Shoina et al., 2024; Vásquez-Álvarez et al., 2022). Although these pathways are often treated as distinct or even opposing, all generate significant, often unintended consequences for environmental conditions and population well-being (Amaechi et al., 2025; Andriulė et al., 2025; Santika et al., 2023; Shirgholami et al., 2025; Stuhlmacher et al., 2020).

In academic discourse, literature defines urban transformation as both a process and an outcome that reshapes the systemic configuration of urban environments (Lowton, 2026; Wolfram et al., 2016). Within this framework, a transformation is distinguished by its radicality—defined as deep, non-linear, fundamental, and irreversible changes that reshape the urban fabric (Erős et al., 2022; Lowton, 2026). While the process reflects the continuous, evolving dynamics of these radical shifts, the outcome signifies the emergence of a newly configured urban system (Abusaada & Elshater, 2026; Amgad et al., 2025; Lowton, 2026).

Beyond urban transformation, the literature describes Public Health not merely as a medical outcome, but as a dynamic framework inherently intertwined with the spatial and systemic configuration of cities (Fathi et al., 2020; Northridge & Sclar, 2003). It is conceptualised as a multi-dimensional lens that shapes—and is shaped by—planning decisions regarding the built environment (Alam, 2026; Nanayakkara et al., 2023), including land use(Michail et al., 2021; Sun et al., 2025), transport systems (Alabi, 2021), and green infrastructure(Dong et al., 2025; Fathi et al., 2020). Ultimately, the literature identifies a public health–urban planning nexus, in which health serves as both the motivation and the governance tool for steering urban systems toward equity, resilience, and population health (Alam, 2026; Fathi et al., 2020; Zhong et al., 2022).

The research problem addressed in this study is that current understandings of how urban transformation influences public health remain conceptually limited. Urban change is typically examined through isolated perspectives that separately address uncontrolled growth (Dong et al., 2025; Thakrar et al., 2024), planned infrastructure development (Dong et al., 2025; Li et al., 2020), or human-centred approaches, without adequately capturing their interactions or cumulative effects (Niu et al., 2024; Vásquez-Álvarez et al., 2022). This fragmentation obscures the underlying mechanisms through which different transformation trajectories shape wellbeing outcomes. A further research problem is the presence of a ‘planning paradox’ within controlled, infrastructure-led development(Dong et al., 2025).

While such interventions are designed to enhance efficiency, connectivity, and urban order, they can simultaneously generate environmental and health-related consequences that resemble—or even exacerbate—those associated with uncontrolled expansion (Al Mudahka et al., 2025; Etuman et al., 2024; Ferrante et al., 2025). This highlights a gap in the literature, as both controlled and uncontrolled forms of urban transformation are often studied in isolation, with limited attention to how planning processes themselves produce unintended exposure pathways. Consequently, existing research does not sufficiently explain how infrastructure-led development contributes to population-weighted exposure to key environmental risks, including air pollution(Al Mudahka et al., 2025; Bhattarai et al., 2024; Thakrar et al., 2024), urban heat (Alam, 2026; Alkaraki et al., 2024; Carneiro et al., 2021), and reduced opportunities for physical activity (Shoina et al., 2024).

Despite the growing body of literature on urban transformation (Bannan et al., 2022; Ryńska & Solarek, 2018; Thaweepworadej & Evans, 2023; Wolfram et al., 2016), limited attention has been given to systematically linking these processes to public health through clearly defined pathways(Ryńska & Solarek, 2018; Thakrar et al., 2024). Existing research largely adopts static, form-based interpretations of the built environment, overlooking the dynamic, exposure-mediated mechanisms through which urban transformation affects health.

Moreover, the literature remains limited to uncontrolled, infrastructure-led, and human-centred approaches, often relying on single-exposure analyses and considering interactions across pathways. This gap is particularly evident in rapidly urbanising contexts (Schmidt, 2020; Sun et al., 2025), especially in the Middle East and North Africa (MENA) region (Al-Kazwini et al., 2020; Shirgholami et al., 2025; Najah et al., 2023), where transformation processes are intense yet insufficiently examined from an integrated exposure–health perspective. Additionally, the reliance on static representations of urban form limits understanding of how exposure patterns evolve spatially and temporally (Elshater et al., 2025; Lowton, 2026). Hence, the relationship between urban transformation and population-weighted exposure remains under-theorised. To address this gap, this study systematically identifies, maps, and synthesises the pathways linking urban transformation to public health through a scoping review and content analysis, conceptualising urban transformation as a dynamic, multi-scalar process shaping interconnected exposure pathways and health outcomes.

This study aims to identify, map, and analyse the pathways in the literature through which urban transformation influences wellbeing. To achieve this aim, this study conducts a scoping review of the literature to identify pathways through which urban transformation affects wellbeing. The review draws on the Scopus database using Boolean search strategies, followed by content analysis to synthesise and interpret the findings. The content analysis examined urban transformations across uncontrolled, controlled/infrastructure-led, and human-centred development forms.

This study contributes to planning research in three ways. First, it develops a triple-pathway conceptual framework that synthesises the systemic relationships between urban transformation and public health. Second, it advances an exposure-based planning approach that links micro-scale environmental exposure data with macro-scale land-use decision-making. Third, it identifies key limitations in the current literature, particularly the dominance of single-exposure analyses, and proposes a research agenda for rapidly urbanising and data-scarce regions, especially in the Global South and the MENA region.

2 Method

Our bibliometrics study adopts a mixed-methods approach, integrating a quantitative scoping review with qualitative content analysis. Figure 1 illustrates our search strategy for the scoping review. Key components include three analytical tracks: bibliometric analysis, concept mapping, and content analysis. Through the synthesis of bibliometric evidence and thematic analysis, the study develops a more nuanced understanding of how urban transformation, in turn, influences public health outcomes. Our data mining attempted to explore the literature on urban transformation and public health. It addressed two key questions:

- What pathways have been identified in the literature to explain the relationship between urban transformation and public health, and
- What gaps persist in this field of research?

2.1 Search Strategy

To ensure a comprehensive capture of the nexus between urban dynamics and health, a systematic search was executed in April 2026 using the Scopus database. The data mining started on 26 March 2026. The investigation focused on the intersection of urban transformations and their resulting environmental and health outcomes. The selection of the database was guided by accessibility and coverage considerations, given the institution's subscription. The study relied on Scopus for its broad, interdisciplinary indexing of high-quality, peer-reviewed journals. Databases such as Web of Science, although available through subscription, were excluded to maintain consistency in data extraction and avoid duplication (Martín-Martín et al., 2018).

Free-access databases, including Google Scholar, were also excluded because they do not provide consistent quality filters, which were essential to this study. Additionally, subscription-based databases, such as Lens, as well as domain-specific databases like PubMed, were not included because they either fall outside the primary disciplinary scope of this research (which includes the social sciences, art, and the humanities) or offer more limited coverage than Scopus.

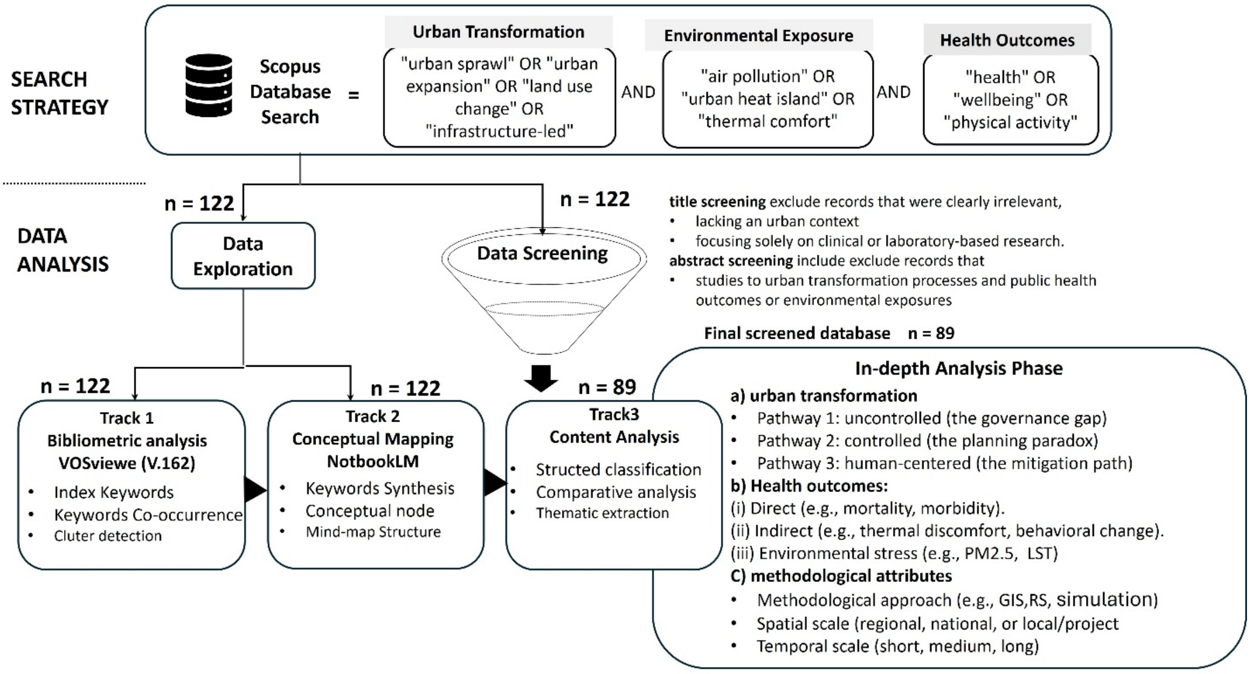

Figure 1. Research design (Source: authors).

The search query was structured around three primary clusters using Boolean operators (AND/OR). The final refined query string used in Scopus was as follows: (TITLE-ABS-KEY ("urban sprawl" OR "urban expansion" OR "land use change" OR "infrastructure-led") AND TITLE-ABS-KEY ("air pollution" OR "urban heat island" OR "thermal comfort") AND TITLE-ABS-KEY ("health" OR "wellbeing" OR "physical activity"). The search strategy intentionally integrates multiple transformation pathways (n=327) into a single query to enable comparative analysis, while allowing flexibility to capture studies that address individual exposure mechanisms (Goessens et al., 2024).

To ensure the quality and relevance of the synthesised literature, specific inclusion and exclusion criteria were applied during data mining. The temporal scope was limited to 2020–2026 to capture recent patterns of urban transformation alongside contemporary health data. This specific window reflects a major paradigm shift in urban studies, capturing the post-pandemic surge in literature. Crucially, this contemporary boundary was chosen to map current empirical gaps. Only final-stage research articles published in English were included to maintain a consistent standard of peer-reviewed empirical quality. The search was further restricted to journal sources, excluding book chapters and conference proceedings, to prioritise high-impact scholarly contributions. Finally, the scope was refined to focus on relevant subject areas, including Social Sciences, Environmental Science, Earth Sciences, Medicine, and Engineering, ensuring alignment with the research topic's interdisciplinary nature. The results retrieved using the inclusion and exclusion criteria were 122 manuscripts (Appendix 1 in the supplementary materials).

2.2 Data Analysis

The analytical framework of this study integrated quantitative bibliometric analysis with qualitative thematic content analysis. This approach ensured a rigorous evaluation of literature, transitioning from broad structural trends to nuanced thematic insights. The data analysis was organised into three tracks: VOSviewer, NotebookLM, and content analysis.

2.2.1 VOSviewer–the First Track

In the first track, upon exporting 122 manuscripts from the Scopus database, the initial stage focused on structural mapping using VOSviewer (version 1.6.20). The intention was to visualise the overarching research landscape and terminological clusters and to explore the structural relationships within the dataset, particularly through co-occurrence mapping of keywords across the three rounds of data extraction (Elshater et al., 2025).

To ensure a comprehensive and consistent representation of health-related outcomes and environmental parameters, index keywords were prioritised over 'author keywords.' This approach reduces terminological variability and enhances comparability across studies by standardising index keywords within the database. It also enabled the identification of more specific and systematically classified health-related clusters—such as cardiovascular and epidemiological impacts—that are often underrepresented in author-defined keywords. The technical configuration of the bibliometric mapping process was meticulously defined to ensure the reproducibility and statistical reliability of the network. A summary of the key parameters, including the keyword selection criteria and threshold settings used in VOSviewer, is presented in Table 1. To eliminate noise within the co-occurrence mapping, general and non-content terms (e.g., "article", "review", "human") and geographical identifiers (e.g., "USA", "China") were excluded. This allowed the analysis to focus strictly on the interaction between urban form, environmental variables, and health outcomes (Elshater et al., 2025).

Table 1: Technical parameters and threshold criteria for VOSviewer bibliometric mapping (Source: authors).

Parameter	Setting	Description
Total number of keywords	1379	The initial pool of Index Keywords is extracted from the 122 manuscripts.
Minimum Number of Occurrences	5	The threshold is set to filter out infrequent or peripheral terminology.
Keywords meeting threshold	102	The number of terms that appeared 5 times or more in the dataset.
Number of selected keywords	102	The final count of keywords is used to generate the co-occurrence network.
Unit of analysis	Indexed keywords	Prioritized for standardized terminology and reduction of synonym noise.
Analysis type	Co-occurrence	Used to identify the strength of association between urban and health variables.
Normalization method	Association strength	Standard VOSviewer method to balance keyword frequency variations.

2.2.2 Mind Maps–the Second Track

To complement the bibliometric results, NotebookLM (an AI-powered research assistant based on large language models, Google, 2024 was deployed strictly as an exploratory and synthesis tool to convert raw keyword data into structured conceptual mind maps (Cevik & Abu-Zidan, 2025). This computational synthesis served as a thematic bridge between the high-level cluster data from VOSviewer and the granular content analysis. This computational step transformed dispersed keyword co-occurrence outputs into coherent thematic groupings, enabling a clearer interpretation of the relationships between urban transformation, environmental exposure, and public health. The generated maps facilitated the identification of core research nodes and their interconnections, revealing dominant thematic clusters and latent linkages that are not always apparent in bibliometric visualisations alone (Cevik & Abu-Zidan, 2025; Lam et al., 2024).

Importantly, this AI-assisted synthesis enabled categorisation of complex, overlapping keywords into higher-order thematic categories, reducing fragmentation and enhancing interpretability prior to detailed screening. To ensure scientific rigour and eliminate potential AI bias or hallucinations, a strict human-in-the-loop validation protocol was implemented. The researchers independently reviewed, verified, and cross-examined all AI-aggregated thematic clusters against the primary source texts. Any conceptually misaligned keywords or ambiguous nodes generated during the automated mapping phase were manually corrected and reclassified by the authors.

Consequently, these emergent thematic categories were not treated as final analytical outputs, but rather as an intermediate conceptual layer that informed the subsequent stages of the research (Lam et al., 2024). The categories derived from the conceptual mind maps were subsequently used to inform the coding framework of the qualitative content analysis. Specifically:

- They guided the identification of key variables (e.g., exposure types, health outcomes, transformation patterns)
- They ensured conceptual consistency between the initial bibliometric exploration and the in-depth thematic analysis

This integration established a methodological bridge between data-driven exploration and interpretive analysis, enabling the study to systematically transition from broad keyword structures (n = 122) to detailed content coding.

2.2.3 Content Analysis–the Third Track

Following the exploratory bibliometric and validated conceptual mapping, a qualitative content analysis was conducted to systematically examine the literature and uncover underlying conceptual patterns linking urban transformation processes to environmental exposure and public health outcomes. To ensure a rigorous, highly comparable, and consistent interpretation, this analysis was strictly performed on the titles, abstracts, and keywords of the selected manuscripts (n = 89).

The screening and data extraction process followed a systematic three-stage workflow:

- Title and Abstract Screening: The initial 122 manuscripts retrieved from Scopus were rigorously evaluated against explicit inclusion criteria to exclude irrelevant literature, specifically excluding studies lacking a distinct urban context or focusing solely on clinical, clinical trial, or laboratory-based pathology. This systematic filtration yielded a finalised dataset of 89 papers (n = 89), which are fully documented in the supplementary spreadsheet (Appendix 2). This refined sample explicitly represents literature tracking urban-scale transformations alongside their associated environmental and health implications, thereby enabling a structurally coherent comparative analysis across disparate transformation pathways, exposure dynamics, and spatial methodologies.
- Hybrid Coding Application: A structured data extraction framework was applied to the selected abstracts and keywords. While primary coding tracks were established deductively based on the study's core objectives, specific sub-codes emerged inductively during the thematic evaluation.

- Pathway Categorisation: The analysis structured urban transformation into three distinct pathways:
  1. Pathway 1: uncontrolled sprawl (the governance gap): characterised by rapid conversion of natural/agricultural lands and high patch density.
  2. Pathway 2: controlled/infrastructure-led (the planning paradox): characterised by formal master plans and densification.
  3. Pathway 3: human-centred (the mitigation path) was characterised by walkability, green infrastructure, and public-space interventions, often associated with reduced exposure levels and improved health outcomes.

These pathways enabled a structured comparison of how different urban transformation processes generate distinct patterns of environmental exposure. To operationalise this comparison, a structured data extraction framework was developed and applied to the final dataset (n = 89 studies).

To operationalise the comparative synthesis across these three pathways, six explicit analytical variables were extracted and coded: (1) study characteristics (publication year, geographic location, and case study scale, categorized as regional, national, or local/project level); (2) urban transformation pathway; (3) environmental exposure type (e.g., air pollution, heat stress, noise); (4) methodological approach (e.g., GIS, remote sensing, statistical modelling, simulation); (5) temporal scope of analysis (short-term ≤5 years, medium-term 5–15 years, long-term ≥15 years); and (6) reported health outcomes.

To better capture how studies conceptualise the exposure–health relationship, health outcomes were further classified into three categories:

- Direct health outcomes, where studies explicitly measure health indicators such as mortality, morbidity, or hospital admissions;
- Indirect health impacts, where environmental exposure is linked to intermediate indicators such as thermal discomfort, behavioural change, or exposure risk without direct measurement of health outcomes; and
- Environmental stress indicators in which studies focus exclusively on environmental variables (e.g., Particulate Matter, land surface temperature) without establishing explicit health linkages.

To map the cross-disciplinary flows and quantify the structural interconnections among these variables, Sankey diagrams were constructed. These diagrams visually conceptualise the proportional distribution and flow of the evaluated literature, demonstrating exactly how specific transformation pathways systematically channel into distinct exposure types and subsequent health classifications. The extracted data were systematically organised and synthesised to identify recurring themes and patterns across the included studies.

A comparative and interpretive analytical approach was employed to identify dominant trends across urban transformation pathways, examine variations in exposure types and their associated health outcomes, and detect areas of fragmentation within the existing literature. This process also enabled the identification of key gaps, particularly the limited integration of multiple transformation pathways into a single analytical framework, thereby supporting the development of a conceptual framework linking urban transformation pathways to environmental exposures and subsequent health outcomes.

3 Results

3.1 Results for VOSviewer

To map the field's intellectual structure, a keyword co-occurrence analysis was conducted using VOSviewer. The results were interpreted through thematic clustering, revealing the dominant research domains and their interconnections within the urban transformation–public health nexus. As illustrated in Figure 2, the network visualisation identified three primary and interconnected thematic clusters that define the core structure of the literature.

The first cluster represented the morphological–thermal nexus, linking urbanisation processes—such as land-use change and urban growth—to their climatic consequences, particularly land surface temperature (LST), urban heat islands (UHI), and heatwaves. This cluster reflected a strong methodological reliance on geospatial techniques, including remote sensing and machine learning, to quantify the physical expansion of urban areas and their thermal impacts. The second cluster captured the atmospheric–health nexus, focusing on the relationship between air pollution and human health. Key terms such as particulate matter (PM2.5), air quality, and epidemiology indicate a well-established link between urban environmental degradation and respiratory and cardiovascular outcomes. The presence of COVID-19-related terms further reflected the recent expansion of this research domain toward understanding vulnerability in dense urban environments.

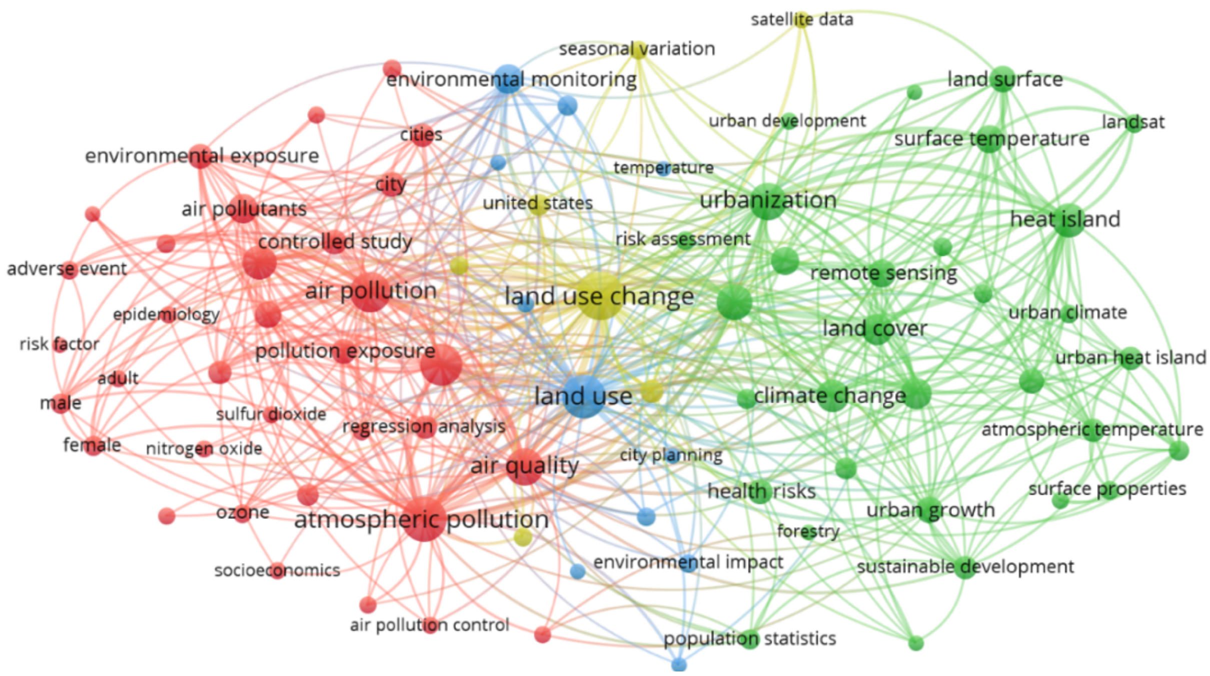

Figure 2. VOSviewer network visualisation of keyword co-occurrence (indexed keywords) showing major research clusters (Source: authors based on VOSviewer, version 1.6.20).

The third cluster represented a monitoring and planning dimension, linking environmental assessment to policy and urban management. Concepts such as environmental monitoring, pollution control, and urban planning served as operational tools that link environmental data to decision-making processes. This cluster highlighted the applied dimension of the literature, where analytical outputs are translated into planning interventions. Figure 3 reveals that "land use change," "public health," and "health risks" act as central bridging nodes within the network. Their high connectivity indicated that literature has evolved from isolated analyses of urban growth toward a more integrated understanding that incorporates environmental exposure and health outcomes.

Despite this integration, the network also revealed important thematic imbalances. Strong linkages existed between air pollution and health impacts, while weaker connections were observed between climate-related factors—such as heat stress—and specific health outcomes. These results demonstrated that although environmental drivers were extensively studied, their translation into health-based evidence remained uneven. As such, the VOSviewer illustrated the dominant research streams focused on either environmental processes or health outcomes, with limited integration across multiple exposure pathways. These patterns provided the foundation for the subsequent content analysis, which further examined how these thematic domains were operationalised across different urban transformation pathways.

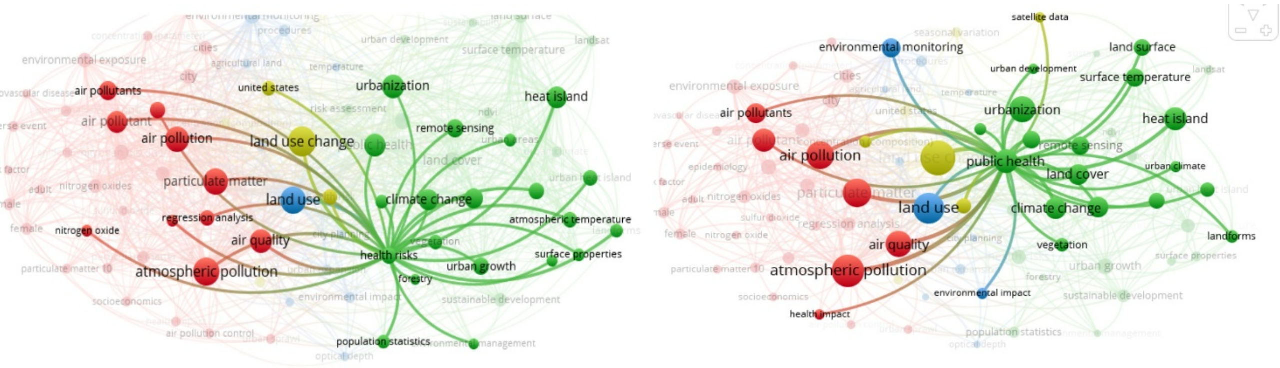

Figure 3. Public health and health risks in selected literature (Source: authors based on VOSviewer, version 1.6.20).

3.2 Results from NotebookLM

To synthesise the relationships between urban transformation and public health, an AI-assisted conceptual mapping was conducted using NotebookLM. The resulting framework organises the literature into a multi-layered structure linking land-use change, environmental processes, exposure pathways, health outcomes, and response strategies (Figure 4).

The analysis identified urban form and land-use change as the primary drivers of environmental transformation. Factors such as urban expansion, building density, and the proliferation of impervious surfaces are consistently linked to thermal alterations, particularly the intensification of urban heat islands (UHI) and rising land surface temperatures (LST). These findings established the physical basis through which urban form shapes environmental conditions. Building on these drivers, the mapping highlights environmental exposure pathways as a central connecting layer. Air pollution emerged as the dominant pathway, characterised by increased concentrations of particulate matter (PM2.5, PM10) and gaseous pollutants (NO_2, SO_2). This domain functions as a bridge, translating spatial and morphological changes into measurable environmental risks.

Then links these exposures to public health outcomes, where respiratory and cardiovascular conditions remain the most consistently reported impacts. At the same time, the analysis identified an expansion in research scope toward broader health dimensions, including cognitive impacts and lifestyle-related conditions such as obesity. This indicated a gradual shift from traditional epidemiological outcomes toward a more comprehensive understanding of urban health.

In parallel, the mapping highlights the dominant methodological approaches used across the literature, particularly the reliance on remote sensing, Geographic Information System (GIS)-based modelling, and machine learning to quantify environmental exposure. These tools enable large-scale and data-driven analysis but are often applied independently of health-based evaluation. The mapping identifies a set of mitigation and planning strategies, including green infrastructure, nature-based solutions (NbS), and walkability-oriented interventions.

Consequently, the resulting conceptual map delineates a linear yet weakly synthesised research landscape, characterised by the isolated analysis of urban land-use change, environmental stressors, and health endpoints. This baseline assessment directly justifies the transition from broad conceptual mapping to a rigorous content analysis, which further examines these literature gaps across specific spatial and planning dimensions.

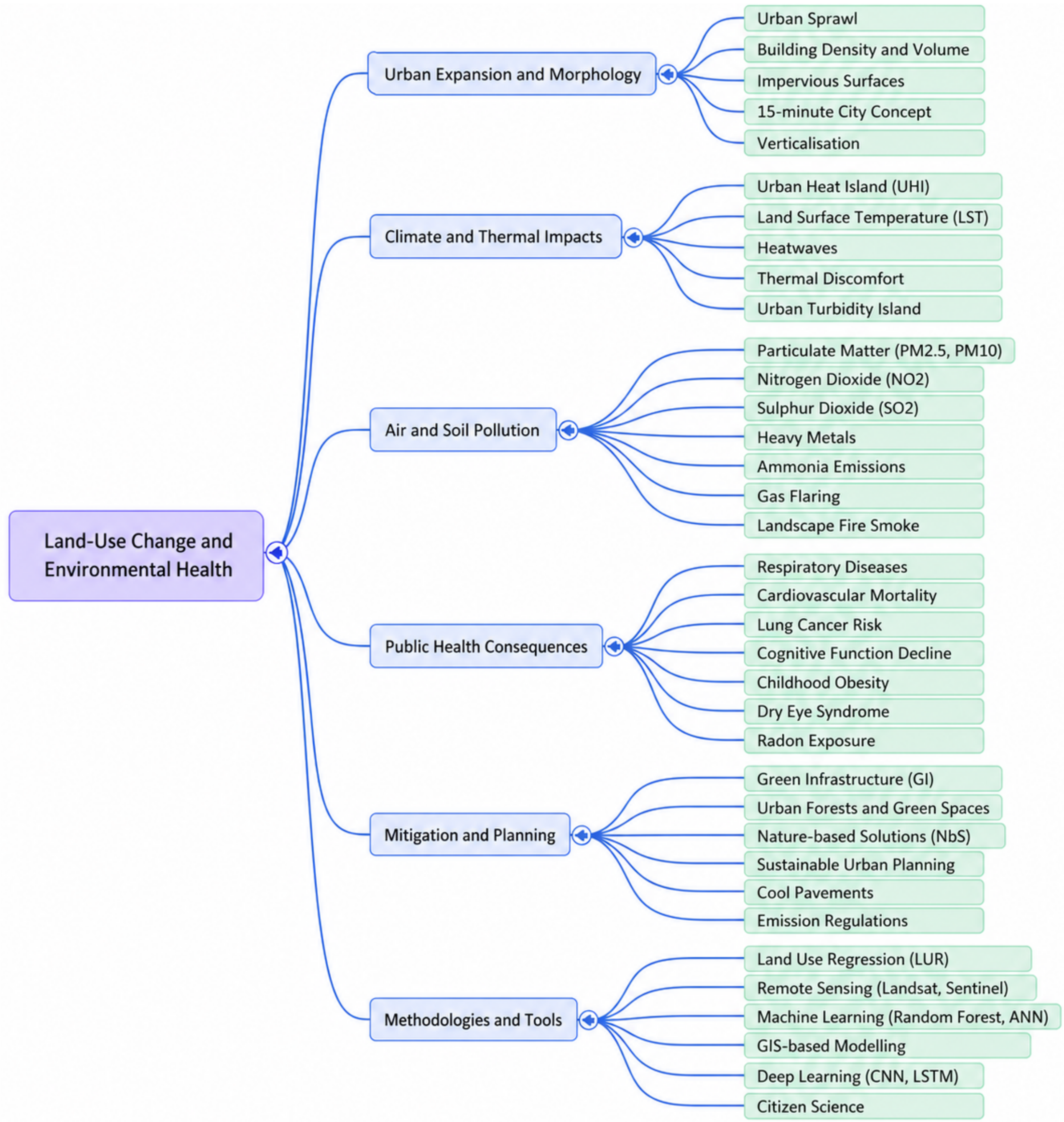

Figure 4. The Conceptual mind map of the thematic interconnections among land-use change, environmental stressors, and public health outcomes was synthesised from the raw keywords of a review of 122 manuscripts (Source: authors based on NotebookLM).

3.3 Results from Content Analysis

3.3.1 Temporal and Spatial Patterns of Research

The temporal and spatial distribution of the reviewed studies reveals a rapidly evolving research landscape shaped by recent global health and urbanisation dynamics. As shown in Figure 5, publication output increased significantly after 2020, with a pronounced peak between 2023 and 2025. This surge reflected a post-pandemic shift toward examining urban environments as determinants of environmental exposure and public health, rather than purely spatial or infrastructural systems.

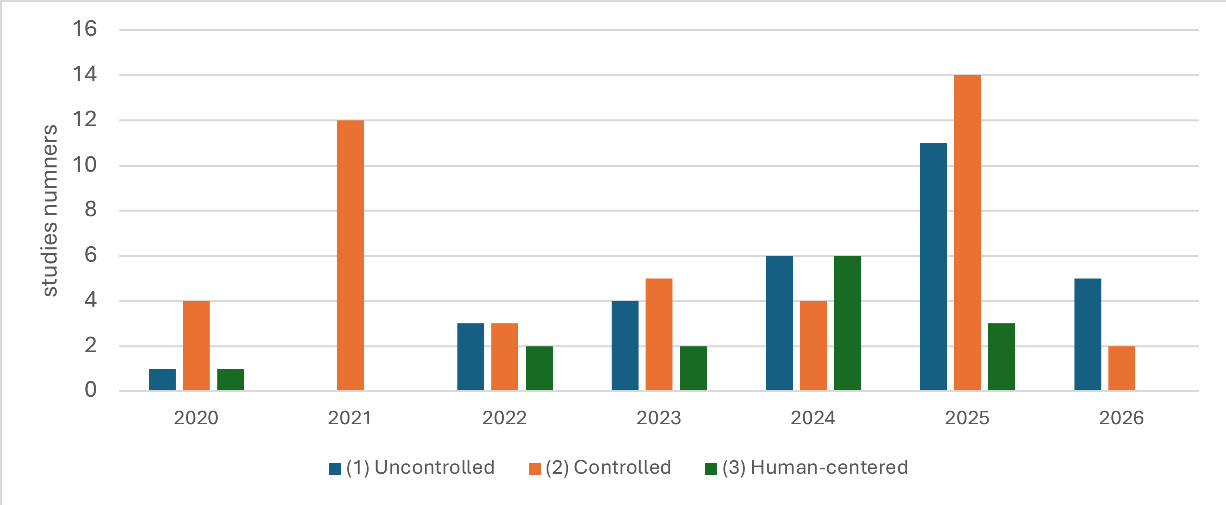

Figure 5. The Temporal distribution of research discussed urban transformation (2020–2026) (Source: authors).

Throughout the study period, research attention was unevenly distributed across the three urban transformation pathways. Controlled and infrastructure-led transformation (Pathway 2) consistently dominated the literature, reflecting a global focus on large-scale development and its environmental externalities. Studies on uncontrolled transformation (Pathway 1) show a steady increase over time, highlighting growing concern over informal expansion and its associated risks. In contrast, human-centred approaches (Pathway 3) remained limited across all years, indicating a persistent gap in research addressing health-oriented urban interventions.

The distribution of studies was highly uneven (Figure 6). Research was concentrated in a limited number of regions, with China, the United States, and India leading in publication output. While the Global North maintained a stable research presence, the most rapid growth was observed in parts of the Global South, particularly East Asia and the Pacific.

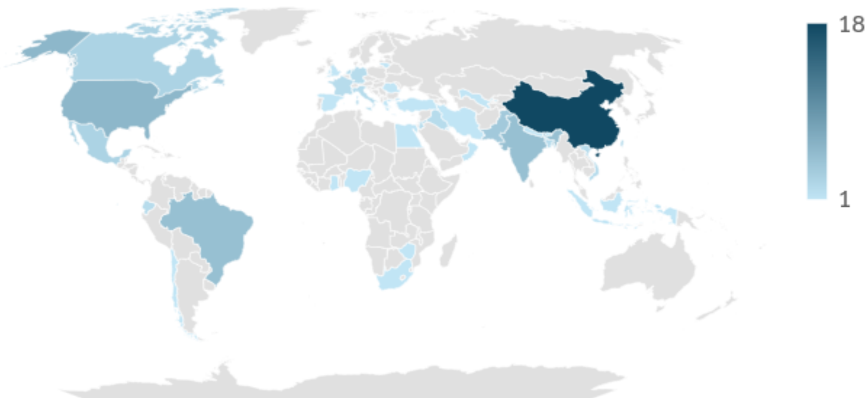

Figure 6. The heat map of the Global distribution of research intensity (Source: authors).

Despite this growth, significant regional disparities persisted. In the MENA region, research was predominantly focused on uncontrolled, infrastructure-led transformations, reflecting ongoing challenges posed by rapid urban expansion and large-scale development. Human-centred approaches were notably underrepresented, indicating a gap in addressing urban health from a wellbeing-oriented perspective. Comparative analysis across global regions highlighted distinct research profiles (Figure 7). East Asia and the Pacific led in studies of both uncontrolled and controlled transformations, largely driven by rapid urbanisation. In contrast, human-centred research was more established in North America and Europe, though it remains limited in rapidly urbanising regions such as Sub-Saharan Africa and South Asia.

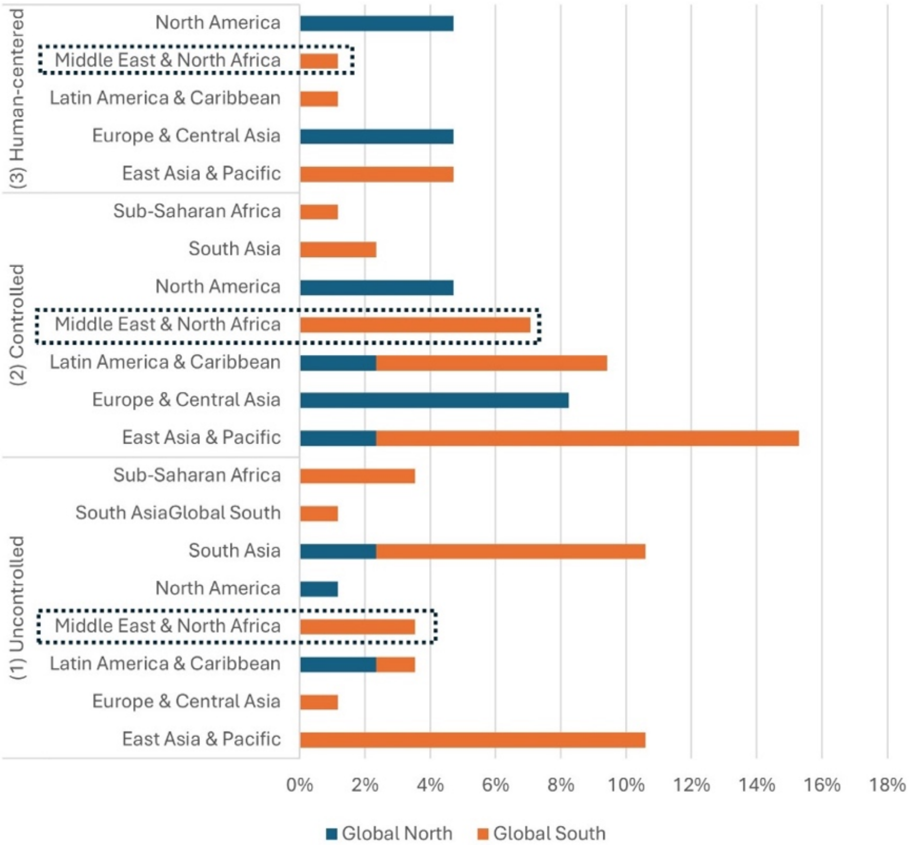

Figure 7. Comparative distribution of urban pathways across the Global North and South regions, illustrating the specific research profile of the MENA region (Source: authors).

3.3.2 Methodological Trends and Multi-Scalar Analysis

The analysis revealed systematic relationships between urban transformation pathways, environmental exposure focus, and methodological approaches. As illustrated in Figure 8, each pathway was associated with distinct exposure priorities and analytical techniques, reflecting different research orientations within the literature. Uncontrolled urban transformation was predominantly assessed for air quality, with a strong reliance on remote sensing and large-scale spatial analysis. This reflected the need to capture widespread and cumulative environmental impacts associated with urban sprawl and land-use change. Heat stress was also examined within this pathway, though to a lesser extent, often using similar large-scale data-driven approaches.

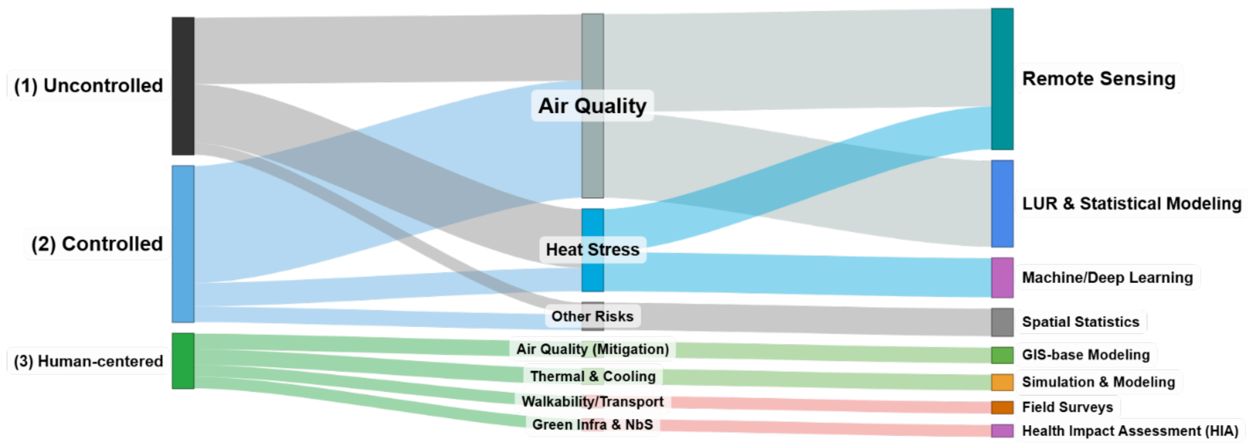

Figure 8. The urban transformation pathways, environmental exposure focus, and methodological approaches (Source: authors).

Uncontrolled urban transformation was predominantly assessed in terms of air quality, with a strong reliance on remote sensing and large-scale spatial analysis. This reflected the need to capture widespread and cumulative environmental impacts associated with urban sprawl and land-use change. Heat stress is also examined within this pathway, though to a lesser extent, often using similar large-scale data-driven approaches.

Controlled and infrastructure-led transformation demonstrated a more diverse methodological profile. While still strongly connected to air quality analysis, this pathway shows increased reliance on land-use regression (LUR) and statistical modelling, as well as emerging applications of machine learning. Studies within this pathway also address heat stress and localised environmental risks, reflecting a shift toward finer-scale assessment of urban form and infrastructure performance. In contrast, human-centred transformation is associated with a broader range of exposure categories, including air quality mitigation, thermal comfort, walkability, and green infrastructure. Methodologically, this pathway incorporated more applied and intervention-oriented approaches, such as simulation modelling, field surveys, and health impact assessment (HIA). This indicated a closer alignment between environmental analysis and public health evaluation, although such studies remain limited.

Our results highlighted the distribution of exposure types and methods across pathways; a deeper structural pattern emerges when incorporating spatial and temporal dimensions. As shown in Figure 9, the relationships among pathways, scale, time, and methodology revealed a clear stratification in knowledge production. Uncontrolled transformation was primarily studied at regional and global scales, using long-term temporal frameworks spanning 15 years or more.

These studies relied heavily on remote sensing and large datasets to capture cumulative environmental change. In contrast, controlled transformation is concentrated at local and project scales, with short-term timeframes (≤5 years), often focusing on the immediate environmental performance of specific developments. Human-centred approaches exhibited a mixed structure, combining local-scale, short-term intervention studies with broader regional or national analyses. However, even in these cases, methodological integration across scales remained limited.

Large-scale, long-term studies provide robust assessments of environmental exposure but often lack a direct connection to localised health outcomes. Conversely, small-scale studies offer context-specific insights but are constrained by short temporal scopes and limited longitudinal evidence. Based on the synthesis of findings, several gaps emerged. First, there was a limited integration of multiple environmental exposures within unified analytical frameworks. Second, a disconnect persisted between large-scale environmental assessments and localised health outcomes. Third, human-centred perspectives remain insufficiently incorporated, particularly in rapidly urbanising regions.

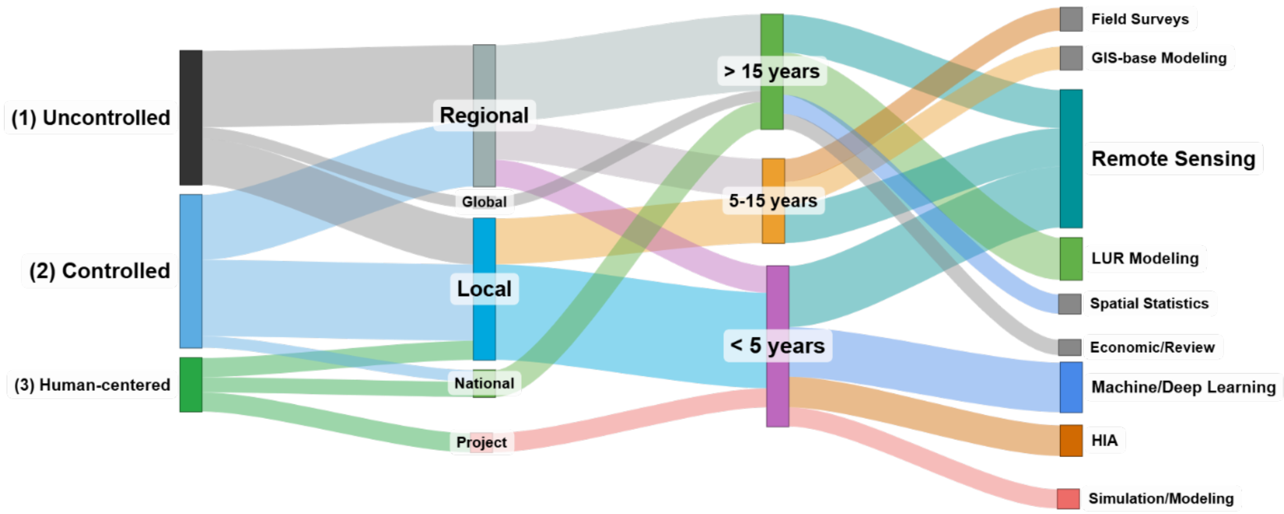

Figure 9. The relationship between pathways, scale, time, and methodology (Source: authors).

3.3.3 Urban Transformation Pathways and Exposure–Health Linkages

The analysis identified pathway-specific yet interconnected relationships between urban transformation, environmental exposure, and public health outcomes (Figure 10). These relationships differed not only in dominant exposure types but also in the extent to which environmental risks are translated into measurable health outcomes. This pathway is characterised by short-term, project-based assessments, with a predominant focus on environmental performance rather than health outcomes. As a result, most studies relied on indirect health linkages and integrated limited epidemiological data. Environmental risks are often evaluated post hoc rather than embedded within planning and design processes. Human-centred transformation emphasised mitigation strategies such as green infrastructure, nature-based solutions, and walkability. Unlike the previous pathways, this approach demonstrates a stronger alignment between environmental interventions and public health outcomes.

Studies consistently showed that urban greenery contributes to both air quality improvement and thermal regulation. For example, optimised urban green spaces have been shown to significantly reduce PM2.5 levels and mitigate heat stress in cities such as Wuhan and the Guangdong–Hong Kong–Macao region (Bi et al., 2024; Pasang et al., 2025; Zuo et al., 2023). Vegetation structure also played a role in enhancing thermal comfort through canopy shading and evaporative cooling processes (Mondanelli et al., 2025; Scheuer et al., 2024).

In addition, human-centred interventions such as walkable urban design and active transport were directly associated with improved health outcomes, including reduced obesity and enhanced wellbeing (Hegazy, 2024; Le et al., 2024; Khanh et al., 2025). Despite this, the pathway remained underrepresented in the literature. Across all pathways, air quality emerged as the dominant exposure category, followed by heat stress, while studies addressing combined exposures remain scarce. Only a limited number of studies explicitly examined the interaction between air pollution and thermal stress, indicating a lack of integrated approaches to compound environmental risk.

A smaller subset of studies addressed other environmental indicators, including water quality, soil and dust contamination (Kemal et al., 2026; Wang et al., 2023), and vector-borne disease risks (Andriulė et al., 2025). Although less frequent, these studies highlighted context-specific exposure mechanisms but remained weakly linked to direct health outcomes, being primarily framed as environmental stress or indirect impacts. The literature reviewed showed that environmental exposures were extensively quantified but inconsistently linked to measurable health outcomes. These results varied across pathways and limit a comprehensive understanding of the urban transformation–public health nexus.

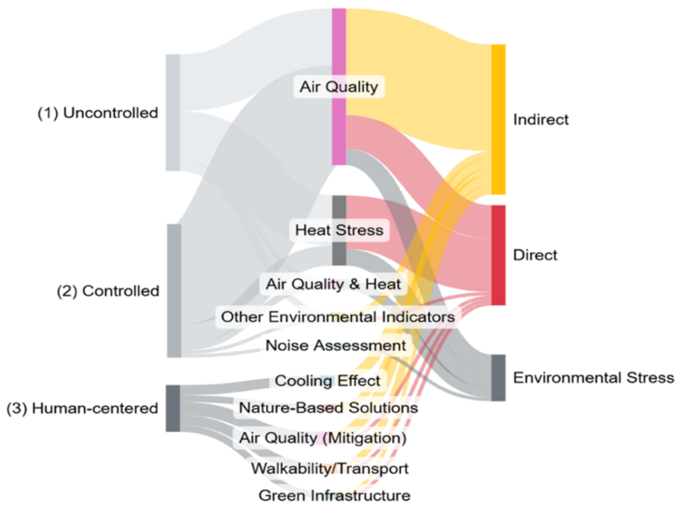

Figure 10. A Sankey diagram illustrates the thematic nexus between urban environmental indicators and health-related outcomes across the three identified research pathways (Source: authors).

4 Discussion: Pathways Synthesis and Gaps in the Literature

4.1 Interpretation of the Findings

The findings of this study provide a structured response to the two guiding research questions by synthesising the dominant pathways linking urban transformation to wellbeing and identifying key gaps in the literature. Regarding the first question—*what pathways have been identified in the literature to explain the relationship between urban transformation and public health*—the results reveal three interrelated yet distinct pathways through which urban transformation shapes environmental exposures and, consequently, health outcomes.

> **First**, the **uncontrolled transformation pathway** (Pathway 1) is primarily associated with rapid urban sprawl and informal expansion, which drive significant morphological changes, such as converting permeable land to impervious surfaces. This process intensifies land surface temperature and urban heat island effects, leading to heightened thermal stress and increased vulnerability to heat-related illnesses, particularly in socioeconomically disadvantaged populations.
>
> **Second**, the **controlled, infrastructure-led pathway** (Pathway 2) highlights a more complex dynamic in which planned urban development generates unintended consequences—a phenomenon known as the "planning paradox." Despite its formal structure, this pathway often produces localised concentrations of pollution, increased exposure to particulate matter and nitrogen dioxide, and elevated risks of chronic conditions, including cardiovascular and respiratory diseases.
>
> **Third**, the **human-centred pathway** (Pathway 3) represents a mitigation-oriented trajectory that emphasises green infrastructure, nature-based solutions, and walkability. This pathway demonstrates measurable benefits in reducing environmental exposures—such as lowering air pollution levels and mitigating urban heat—while also promoting physical activity and broader wellbeing outcomes. Across these pathways, results consistently show that urban transformation influences wellbeing through interconnected mechanisms of environmental exposure, particularly thermal stress, air pollution, and lifestyle-related factors.

In response to the second question—*what gaps persist in research at the intersection of urban transformation and public health*—the findings highlight several limitations. A major gap lies in the fragmentation of the literature**,** in which the three pathways are predominantly studied in isolation, limiting understanding of their cumulative and interactive effects. This is reinforced by the bibliometric analysis, which shows strong internal clustering (e.g., air pollution–health links) but weaker connections across domains, particularly between climatic processes and specific epidemiological outcomes. Besides, there is a persistent disconnect between environmental exposure and measurable health outcomes. While environmental variables such as air pollution and land surface temperature are extensively quantified, they are often not systematically linked to direct health indicators, resulting in an incomplete understanding of exposure–health pathways.

The analysis reveals methodological fragmentation, with studies varying significantly in spatial and temporal scales and analytical approaches. Exposure assessments are frequently based on static spatial units (e.g., residential locations or land-use categories), failing to capture dynamic, population-weighted exposure patterns shaped by mobility and temporal variation. Besides, there is a clear imbalance in exposure integration, with a strong dominance of single-exposure studies—particularly air pollution—while combined exposure to air and heat remains significantly underexplored, despite its relevance in rapidly urbanising contexts.

The literature exhibits a pronounced geographical bias, with a concentration of studies in China and the Global North. In contrast, rapidly urbanising regions in the Global South, particularly the MENA region, remain underrepresented—especially in research on human-centred, health-oriented urban strategies. Finally, there is limited attention to multi-scalar and long-term dynamics, including how urban form, infrastructure, and policy interventions co-evolve over time to shape environmental exposure and health outcomes.

4.2 A Three-Layered Framework

Building on the empirical findings and thematic synthesis presented in the results section, this section moves beyond descriptive analysis to interpret the identified patterns. It situates the three urban transformation pathways within broader debates on environmental exposure and health outcomes, highlighting their implications across different geographical and socio-economic contexts (Figure 11). In doing so, the discussion not only contextualises the findings within regions experiencing rapid urban change—particularly in the Global South and the MENA region—but also advances a forward-looking perspective on how urban planning frameworks can better integrate environmental health outcomes. This interpretive lens enables a more comprehensive understanding of the systemic relationships among urban transformation, exposure pathways, and health outcomes. This section advances the discussion by examining the findings across three interconnected dimensions: the growth–exposure dilemma and the regional inequalities shaping urban health outcomes, particularly in the MENA region.

The growth–exposure dilemma in urban transformation: The literature suggests a profound divergence in how different urban forms influence environmental hazards. While Uncontrolled Transformation (Pathway 1), characterised by informal sprawl, creates immediate thermal risks and exacerbates infectious disease hazards in the Global South (e.g., thermal stress in Bulawayo and/or in Mexico City), Controlled Transformation (Pathway 2) introduces a more complex challenge. Planned infrastructure and densification often lead to a 'densification paradox', where residents are inadvertently concentrated in high-exposure zones near major transit corridors or industrial hubs, as seen in cities like Paris and São Paulo. The essential mitigation strategies found in human-centred design (Pathway 3) remain chronically under-utilised. This is largely because air quality and thermal resilience are seldom integrated into the economic valuation of land-use decisions, treating them as secondary environmental concerns rather than core planning imperatives.

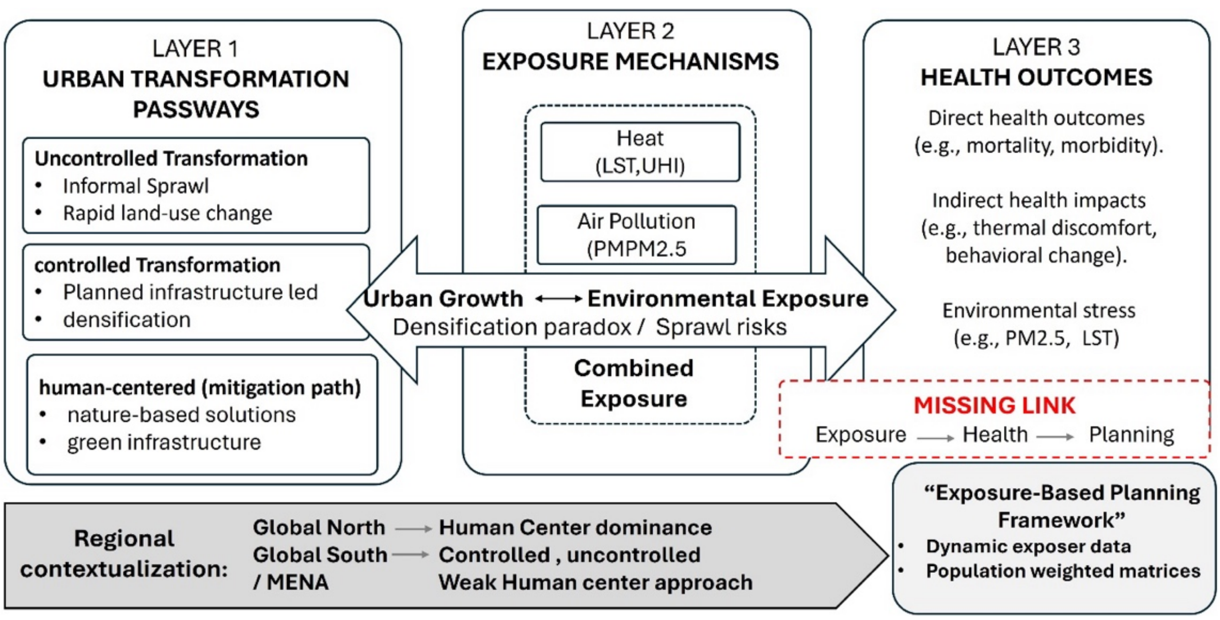

Figure 11. Urban transformation to public health outcomes: Bridging the exposure gap (Source: authors).

Uneven geographies of health outcomes in the MENA region—specifically in rapidly transforming cities such as Amman, Baghdad, Kuwait, and Jordan—made this missing link critical. The transition from cardominated sprawl toward a healthy environment requires a fundamental paradigm shift. Results indicated that urban greenery and walkability should move beyond being treated as aesthetic "amenities" and instead be reclassified as essential infrastructure. This reclassification is vital for managing the region's primary environmental health risks: extreme heat and degraded air quality.

Reframing planning from static models to exposure-based frameworks reconciles rapid urban growth with health outcomes. Recent studies suggest that planning should evolve from static spatial models to dynamic, evidence-based frameworks. Integrating population-weighted exposure data and dynamic time-activity patterns into regional master plans is the necessary step to bridge the gap between urban densification and healthy living environments. These findings underscore the need for a systematic integration of environmental health metrics into the earliest stages of urban design. The transformation of cities—whether controlled or uncontrolled—can continue to impose significant long-term public health costs on urban populations.

4.3 Policy Implications

Translating the developed exposure-based framework into actionable urban governance yields implications across public policy and spatial planning practice. The primary users of this framework include urban planners, municipal authorities, and health policymakers seeking to bridge institutional silos, as well as interdisciplinary researchers using it as a blueprint for empirical modelling. The core beneficiaries are vulnerable urban populations in rapidly transforming, data-scarce contexts, whose micro-climatic and pollution exposures can be directly mitigated through health-responsive governance. Accordingly, these actionable insights serve as the "missing link" between environmental exposure metrics and land-use decisions, operationalised through specific scales and empirical tools extracted from the analysed literature:

In bridging micro-to-macro scales, the application for urban planners provides a systematic blueprint to shift from descriptive environmental monitoring to a proactive approach to health outcomes. By bridging explicit spatial scales—ranging from broad Regional and National growth dynamics to Local and site-specific Project interventions—it shows how metrics can be operationalised across scales. Planners can strategically deploy macro-level GIS-based Modelling alongside micro-level simulation and modelling tools to design continuous green infrastructure and optimise transport planning, ensuring that high-exposure transit corridors are decoupled from dense residential areas.

Empirical tools and mitigation screening provide an application for public health professionals. The framework provides an operational bridge to embed exposure theory directly into spatial practice. Rather than relying on post hoc observations, health professionals can leverage the specific methodologies synthesised in the literature—such as Land Use Regression (LUR), Statistical Modelling, Remote Sensing, and Health Impact Assessments (HIA). These empirical tools allow health professionals to collaborate early with spatial designers, utilising them as predictive screening methods to evaluate how different physical urban transformation pathways alter exposure risks before projects are implemented.

The application can also be for policymakers (evidence-based policy instruments). This research serves as a transferable blueprint for dismantling institutional silos among environmental monitoring, health outcomes, and municipal authorities. The synthesis provides a robust evidentiary basis for transitioning from isolated, single-exposure regulations to cross-sectoral policy instruments. By shifting focus toward targeted human-centred pathways—which integrate cross-scalar data tracking across various temporal horizons (<5 years, 5–15 years, and >15 years)—policymakers can mandate legal frameworks that tie macro-level land-use approvals directly to measurable micro-climate regulation and air-quality mitigation parameters.

4.4 Research Limitations

This study presents some limitations to consider when interpreting the findings.

First, the literature search was limited to the Scopus database. While Scopus provides broad coverage of peer-reviewed research, relying on a single database may have excluded relevant studies indexed in other sources, such as Web of Science. However, this choice was made to ensure consistency and comparability in data retrieval.

Second, the study's temporal scope was restricted to publications from 2020 to the first quarter of 2026. Although this timeframe was intentionally selected to capture recent developments in urban transformation and health outcomes, it may overlook earlier foundational work that shaped the field.

Third, to maintain strict procedural control and prevent thematic drift, the search strategy was rigorously restricted to explicit physical planning and exposure keywords. Consequently, the automated query intentionally excluded broader medical literature, general environmental epidemiology, and health impact assessments. Furthermore, while planning research successfully isolated physical pathways, it did not comprehensively evaluate the underlying dimensions of environmental/climate justice, mobility-related exposures, or the social determinants of health outcomes.

Fourth, the qualitative content analysis primarily relied on titles, abstracts, and keywords, with full-text review conducted only when necessary. This approach was adopted due to the relatively large sample size (89 manuscripts) and the study's exploratory nature. However, it may limit the depth of interpretation and overlook nuanced findings presented in full-text discussions.

5 Conclusion

This study examines the relationship between urban transformation and public health, as addressed in planning research. It synthesises evidence from 122 manuscripts and conducts content analysis of 89 of them. The findings demonstrate that urban transformation operates through three primary pathways—uncontrolled, controlled, and human-centred—each generating distinct patterns of environmental exposure associated with health outcomes. Across these pathways, air pollution and thermal stress emerge as the dominant mechanisms mediating the link between urban form and public health outcomes. However, the analysis reveals that these relationships are not systematically integrated within existing planning frameworks.

While environmental exposures are extensively measured and modelled in the investigated literature, the results are rarely internalised into land-use planning as explicit, quantifiable health parameters. This 'missing link' results in a persistent disconnect between urban development decisions and their long-term health outcomes, particularly in rapidly urbanising contexts. Moreover, the findings highlight multiple layers of these missing links—conceptual, methodological, and geographical. The dominance of single-exposure studies, the limited integration of air and thermal risks, the reliance on static analytical models, and the underrepresentation of regions such as the Global South and MENA collectively constrain the development of comprehensive and actionable planning strategies.

Based on data retrieved from investigated manuscripts, our suggested frameworks integrate dynamic, population-weighted environmental data into spatial decision-making processes. Such an approach enables a more accurate representation of how environmental risks are distributed across space and time, and how they translate into health outcomes. From a practical perspective, this framework repositions environmental health considerations. Air quality and thermal conditions are considered core planning parameters rather than secondary environmental concerns. This shift was evident in the manuscripts we investigated from regions experiencing rapid urban transformation, where the long-term health outcomes of current planning models are likely to intensify. In doing so, it reinforces the argument that urban transformation is inherently about health outcomes and that designing healthier cities requires embedding environmental exposure metrics at the heart of planning practice. Given its focus on theoretical and conceptual integration rather than primary empirical modelling, this framework serves as a conceptual blueprint.

Future research should broaden the evidence base by using multiple databases beyond Scopus and extending the timeframe to include earlier foundational studies, enabling more comprehensive and longitudinal insights. It should also incorporate full-text analysis to capture deeper, more nuanced findings that may be missed in abstract-level reviews. Furthermore, expand the study scope and search strategy to explicitly integrate environmental justice, health outcomes, and the social determinants of health into spatial planning frameworks. Investigating how vulnerable populations experience disparate levels of exposure across different urban transformation pathways remains a frontier for establishing healthy cities. Finally, more flexible and context-sensitive frameworks—potentially inductive or mixed-methods approaches—are needed to better reflect the complexity of urban transformation and the relationships to health outcomes while reducing categorisation bias.

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Ethical Approval Declaration
The study was conducted in accordance with established standards for research integrity and ethics. The authors declare that this research did not involve human participants or animals, and therefore, ethical approval was not required

Informed Consent Statement
Not Applicable

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Data Availability Statement
The data supporting the findings of this study are available from the author upon reasonable request, subject to ethical and privacy considerations. In addition, Appendices 1 and 2 are publicly available via Zenodo at: https://doi.org/10.5281/zenodo.19799003.

Conflicts of Interest
The authors declare no conflict of interest.

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