Ref. Ares(2024)7762661 - 31/10/2024

Evidence-Based Design and Planning; Reflections from past and current theories and practices.

1. Abstract:

The growing availability of urban data and urban analytic methods presents an opportunity for urbanists and urban planners to more effectively use evidence during the design and planning process. This offers a means to better inform decision-making processes in response to topical issues such as adaptation to climate change, the impact of urban form on public health, and the liveability of cities in the context of rapid urbanisation.

We present a vantage point of emerging evidence-based urban design and planning (EBDP), considering both historical and contemporary perspectives in theory and practice. We emphasise the need for evidence and analysis to be rooted in pedestrian-scale urbanism to avoid perpetuating spatial patterns of development at cross purposes to walkable, vibrant, and liveable cities. Examples of implemented projects from practitioners of EBDP are then shared to illustrate typical approaches to evidence-based workflows in practise. Finally, we propose a methodological framework to incorporate evidence as part of the design and planning process, framing EBDP as a dynamic and iterative pipeline which balances design goals with real-world constraints.

2. Grounding EBDP

The use of analysis and evidence to inform the urban design and planning process has emerged over an extended duration of time. The use of observational analysis in the planning process can be seen, for example, in the work of Patrick Geddes, whose now familiar dictums of "survey before plan", "diagnosis before treatment" and "conservative surgery" (Batty and Marshall, 2017) emphasise forms of socio-demographic and spatial analysis to inform the planning process. These approaches, rooted in contextually sensitive analysis of social and spatial factors, are in contrast to modernist ideologies popularised after World War II, which emphasised larger-scale and more heavy-handed interventions which resulted in spatially disjoint forms of urbanism which fragmented the pedestrian realm (Harvey, 1989; Beauregard, 1991; Carmona, 2014; Højriis *et al.*, 2014). At inception, modernist ideas on architecture and planning were seen to be rational, progressive, and, in a sense, evidence based.

It can be argued that these were well-intentioned attempts to leverage technological progress to improve the quality of life and the health of citizens through high quality housing with improved sanitation, ample daylight, lower exposure to air-pollution, access to generous green spaces, access to employment opportunities, and, in some cases, mass transportation. These ideas were enshrined in the tower and motorway proposals associated with modernist architects such as Ludwig Hilberseimer and Le Corbusier (Corbusier, 1967) and have widely influenced generations of architects, planners, and civic officials since. However, in reality, the manner in which these concepts were implemented caused tremendous damage to cities because they were conceptualised in a reductionist and de-contextualised manner which undermined the finer-scaled spatial interconnectivity necessary for human-scaled streets and communities to function (Rowe and Koetter, 1984; Jacobs, 2011; Alexander, 2012). These forms of urbanism have resultantly been the subject of intensive critiques (Whyte, 1980; Jacobs, 2011; Alexander, 2012);

nevertheless, spatially fragmented forms of urbanism continue to persist in contemporary car-centric urban development.

An important aspect of evidence-based urban design and planning is therefore not the use of evidence or ideologically driven analysis for its own sake, but the derivation and application of evidence in a manner supporting human-scaled urbanism (Jacobs and Appleyard, 1987). These principles are increasingly linked through evidence to outcomes compatible with sustainability and health, broadly consisting of compact cities with walkable streets and access to amenities in a spatially cohesive public realm. It is necessary to frame and measure these characteristics at a sufficient level of spatial precision if related forms of evidence and analysis are to be effective as urban design and planning tools. Failing to do so risks their watering-down or misapplication under the guise of evidence and technological progress, potentially echoing the failings of modernism. Planning policies may often articulate aspirations in keeping with high quality urbanism but tend to lack clear targets and provide vaguely defined benchmarks with little explanation for how these were selected (Lowe *et al.*, 2022).

Many forms of research and related statistical information are generated for larger scales of spatial aggregation (e.g. neighbourhoods or entire cities), therefore lacking direct applicability or relevancy for interpretation at the scale of streets. This conundrum is potentially alleviated by the growing availability of higher resolution datasets and spatially precise urban analytic toolsets providing more reproducible and actionable local scale benchmarks which can be used by urban designers and planners to test street-scale interventions (Boeing *et al.*, 2022). A significant upside of successfully coupled evidence-based insights with analytical evaluation of street-scale urban interventions is the improved accountability and transparency for decision making, which is otherwise easily politicised in a vacuum of demonstrable forms of information.

3. Perspectives on EBDP

It is necessary to distinguish between evidence-based design in architecture and the application of evidence in urban design and planning. In architecture, the scale and impact of evidence is more contained, allowing for more direct evaluation and control within the design process. This narrower scope has enabled architects to systematically incorporate empirical findings and evaluate outcomes, such as derived from post-occupancy evaluations. In contrast, evidence-based approaches in urban design and planning have evolved more gradually due to a wider range of variables, less easily defined data parameters, and more difficult to predict emergent effects (Batty and Marshall, 2012). This complexity makes it more challenging to frame clear metrics and evaluate results, both as part of the design process and when evaluating outcomes post-completion.

Historically, evidence-based design gained prominence in architecture during the 1980s. The consequences of non-evidence-based approaches in design—particularly within healthcare facility design—catalysed a paradigm shift towards the systematic and rigorous analysis of precedents, with a focus on examining the relationship between realised design outcomes and their effects on health conditions through verified indicators. A distinct body of research emerged, emphasizing the integration of evidence-based principles into design practices, providing the foundation for a broader application of evidence-based design within the field (Viets, 2009; Wiley, 2017; Pilosof and Grobman, 2021; Tvedebrink and Jelić, 2021).

With regards to urban spaces, Zeisel (1984) suggests four categories of evidence that can enrich the design process: personal experiences (Jones, 1970; Korobkin, 1976), observations

(Zeisel, 1975), the thoughts and writings of designers (Foz, 1972), and analytical reviews of implemented designs (Foz, 1972). Whereas these forms of evidence are indirectly derived, he emphasises their value in enriching the design process through a cyclical feedback loop, wherein initial concepts are continuously refined. The more recent emergence of computational and data-driven methods has further accentuated the role of iterative evaluative models by introducing reproducible evidence-based analytical procedures that are easier to scale.

Carmona (2021a) categorises the urban design and planning process as either self-conscious or unselfconscious. The former shapes the urban environment through a more deterministic lens applied through structured “top-down” planning interventions. In contrast, and in the spirit of Christopher Alexander’s ideas (Alexander, 1964), the unselfconscious planning approach evolves more incrementally through iterative adaptive changes which are implicitly evaluated and refined over larger timescales. Due to contemporary planning policy and development practices, the self-conscious mode has increasingly shaped cities because it renders the design and planning process more predictable and controllable. This approach requires minimising deviations from established objectives by accounting for stakeholder influences, budget constraints, and political regulations, but limits the opportunity for trial-and-error adaptive learning because it does not accommodate iterative feedback as part of the process. Carmona therefore proposes an integrated urban design methodology featuring a learning feedback loop for continuous learning and improvement, for which he delineates six stages: goal setting, analysis, visioning, synthesis and prediction, decision-making, and evaluation.

Considering evidence informed design processes, it should be noted that distinctions exist between EBDP, research-informed design (RID), and data-driven design (DDD). EBDP integrates evidence into the iterative evaluation and selection of design and planning proposals, aiming for adaptive learning and scenario testing to best meet design objectives. Research Informed Design, as described by Peavey and Vander Wyst (2017), focuses on research into specific issues to understand defined topics of interest and then applies these findings more broadly. Data Driven Design emphasises data and technologically driven methods and computational thinking (Sailer *et al.*, 2009), thereby focusing on the procedural analysis of extensive data sets to inform design decisions. Whereas subtle distinctions and perspectives exist between these approaches, we discourage overly prescriptive or divisive attempts to ringfence EBDP and related concepts because there are strongly overlapping regions of interest, and their delineations will continue to shift in response to rapid ongoing evolution prompted by emerging data sources and computational methods.

As explained by Marshall (2012), there are potential caveats in the general adaptation of quantitative methods to fields such as urban design and planning. Pitfalls include over reliance on abstracted data representations to the exclusion of ground-truthing, oversimplification in the representation of urban models, spurious levels of technicality or precision, and overstating findings to the ignorance of already prevalent scholarship within the field. Even where suitably applied, challenges remain to the adoption of scientific methods in urban planning and design practice. Raford (2010) explains these challenges in relation to the high degree of complexity, lack of trialability, and limited financial headroom, which potentially hinder the adoption of evidence-informed approaches. Further, the considerable time gap between when urban design or planning projects are conceived, implemented, and occupied complicates the empirical evaluation of outcomes (Bolton, Francis and Froy, 2017).

4. Bridging qualitative precedents to EBDP

Several established theories in urbanism are not only compatible with evidence-based methods but are necessary anchors if EBDP is to be applied in a judicious manner consistent with walkable forms of urbanism. Whereas these ideas are often qualitatively framed, it is increasingly feasible to apply these using measurable forms of analysis which can be applied at a high resolution of analysis. The proceeding discussion shows that these theories can be bridged to an evidence-informed design process through two complementary strains of evidence in EBDP:

- First, the increasing availability of evidence-based scientific studies, which provide validation and strategic clarification on points such as walkability, density, mixed-uses, and green spaces in relation to outcomes such as health and sustainability.
- Second, the development of high resolution urban analytical methods allows associated spatial and functional characteristics to be measured and demonstrated as part of design options exploration and iterative design refinement.

4.1. Walkable streets and cohesive public space

Successful forms of urbanism acknowledge the pedestrian's vantage point regarding the arrangement of spaces and the consequent interrelation and navigability of a city's parts. Walkable and interconnected streets networks are, in effect, the glue which binds a city's parts together yet are continually undermined by car-centric forms of development. The erosion of public space not only undermines walkability but also the potential for spontaneous social interaction while negatively affecting civic identity and wayfinding (Lynch, 1964; Jacobs, 2011; Alexander, 2012) . Notable advocates of walkable cities have contributed observational analysis in support of their theories (Whyte, 1980; Gehl, 1987), which has since been bolstered by scientific research studies showing that the pervasive "engineering-out" of walkability (in favour of cars) has detrimental effects for health, congestion, and pollution (Saelens, Sallis and Frank, 2003). Likewise, pedestrianisation confers positive outcomes for streets and the economic performance of retail establishments (Volker and Handy, 2021; 'Walking & cycling: the economic benefits', no date; 'The economic benefits of sustainable streets', no date). Recent research has suggested increasingly actionable thresholds for factors such as density (5700 people per km^2), street intersections (100 per km^2), and public transport (25 stops per km^2) associated with walkability (Cerin *et al.*, 2022). The development of analytical design tools supports the generation and testing of design scenarios for their impact on walkability. Of note has been the implementation of Hillier and Hanson's space syntax theory (1984), which draws on network theory, social studies, and environmental research (Hanson, 1990; HILLIER *et al.*, 1993; Hillier, 1996, 1999; Penn and Turner, 2004), proposing that space is intrinsic to human activity and that its configuration can be quantified and analysed to predict movement and behaviour (Karimi, 2012).

4.2. Compact and mixed-use urbanism

The walkability of streets and the integrity of public spaces shows strong complementarity to related factors such as population densities and the presence of mixed-uses. The benefits of land-use diversity in the context of compact and walkable urbanism was famously espoused by Jane Jacobs (Jacobs, 2011), with studies confirming clear associations between physical activity, population density, and mixed land-uses (Frank *et al.*, 2005). Recent computational urban analytic toolsets are now capable of precisely measuring access to land uses and mixed-uses (Simons, 2023; Stahle *et al.*, 2023). Density is further associated with public transport, active transportation, access to public amenities and infrastructure, and economic benefits such as rates of innovation, levels of productivity, and environmental benefits such as lower greenhouse gas emissions.

It should be noted that higher levels of density may include negative effects such as increased congestion or decreased access to green spaces, though these can often be mitigated through design strategies (e.g. pocket parks, pedestrianisation) where suitable awareness exists. (*Demystifying compact urban growth: Evidence from 300 studies from across the world*, 2018; Berghauser Pont *et al.*, 2021). Berghauser and Haupt's *Spacematrix* (2023) develops the concept of density beyond the simple use of density measurements, emphasising that density can be understood as a multidimensional concept relating to various urban indicators such as land use intensity, building height, and population density. They have proposed a three-dimensional framework—FSI (Floor Space Index), GSI (Ground Space Index), and street network density—which provides a nuanced framework for understanding the impact of density on urban form and related metrics.

4.3. Urban form impacts on health and climate

In a similar manner to how healthcare architecture provided a strong impetus for the emergence of evidence-based approaches to architecture, recent medical and health research into the effect of urban form factors on health have the potential to become a major driver of evidence-based approaches to urban design and planning. These studies are potentially large-scale, span numerous continents, and are increasingly replicable. By way of example, a study of 14,000 participants across 5 continents documents the impact of urban form factors such as density, street network, mixed-uses, access to parks, and access to transport on physical activity and weight (Sallis *et al.*, 2020). The emerging literature is extensive, covering diverse aspects such as the impact of trees and nature on mental health (Bratman *et al.*, 2019) and anti-depressant prescriptions (Marselle *et al.*, 2020). Urban interventions are increasingly evaluated for their impact, such as reductions to premature deaths due to Barcelona's superblock interventions (Mueller *et al.*, 2020) due to related changes in factors such as increased green spaces (Gascon *et al.*, 2016) and physical activity (Woodcock *et al.*, 2011), combined with decreased air pollution (Atkinson *et al.*, 2018) and air temperatures (Guo *et al.*, 2014).

A second wellspring of potentially actionable evidence is emerging from climate research which outlines the benefits of active and public transportation in tangible terms, such as percentages of emission reductions achievable through transportation mode-shifts (Brand *et al.*, 2021). These forms of evidence are important for policy, for example, showing that a dramatic and significant reduction in automobiles will be necessary to meet emissions reduction targets even with electrification, underscoring the importance of active and public transportation strategies combined with urban form interventions to encourage walkability and improved access to local amenities (Winkler *et al.*, 2023). Many of these forms of evidence are actionable with conventional spatial analytic approaches, potentially conferring significant support for healthier and more sustainable forms of urbanism where policy makers are aware of these findings and where urban designers and planners are provided with basic quantitative and spatial analytic skills.

5. Projects review from Space Syntax Ltd.

More recent analytical methods, such as street network analysis (Hillier *et al.*, 1976) and spatially-granular accessibility analysis (which quantifies street-level access to land uses, transport, green spaces, etc.), incorporate a contextual approach towards analysis that is grounded in the pedestrian streetscape and the spatial configuration of urban form. These approaches provide street-level insights on the potential impact of interventions at the pedestrian-scale. Whereas this represents a distinct opportunity to test and evaluate urban interventions in a manner consistent with good urban planning, the methods can be challenging to adopt because they rely on potentially complex analytical tools and datasets requiring skillsets beyond the traditional purview of architects, urban designers, and planners.

Developers of these tools and methods have increasingly engaged with disciplines not historically associated with urbanist fields; discourse previously dominated by art, philosophy and humanistic theories has therefore embraced a wider assortment of influences from fields such as computer science, data science, and complexity science, spanning topics such as network analysis (used to assess walkability) and species diversity indices (used to calculate mixed-use measures) as encompassed by the emerging "science of cities" (Batty, 2013). It is therefore helpful to see how related approaches have been applied in practice. To this end, we review four projects from Space Syntax Ltd., a London-based firm that has been at the forefront of integrating analytical approaches into urban design and planning through research, consultancy, and technological innovation. The intention is to understand typical approaches to EBDP in practise and to discern commonalities and differences across project implementations.

5.1.1. Trafalgar Square:

The Trafalgar Square project was a pioneering application of analytical methods in urban design, aimed at addressing spatial and social challenges within these iconic public spaces (Space Syntax Laboratory, 1998). Through observation and testing, the project looked to enhance pedestrian movement and the use and overall functionality of the public space, demonstrating the value of syntactic analysis in revealing spatial configurations that influence social dynamics. These analytical observations were combined with socio-political knowledge of the project practitioners who concluded that the large volumes of fast traffic flow around the squares had effectively reduced the public use and local functionality of the space.

The method employed in this study involved the systematic observation of pedestrian movement patterns, followed by the development of hypotheses regarding the underperformance of the spaces. A notable aspect of this project is its strong emphasis on qualitative understanding, particularly in relation to the social and historical significance of the public realm in London. These narratives informed the hypothesis, which was evaluated using a spatial (axial line) model to refine the spatial analysis. A key contribution of the project is its accessibility to a general audience; avoidance of specialised terminology from space syntax jargon and a clear narrative facilitated effective communication with a broader audience. The scope of the analysis was purposively constrained to align with empirical evidence and the local context, therefore with minimal reliance on external factors beyond the scope of the design.

The design process integrated analytical results with local knowledge, ensuring that both analytical findings and experiential insight informed the decision-making process. The design process consisted of a targeted approach towards the refinement of the design strategy rather than an exploration of multiple iterations of analysis. This was influenced by computational constraints of the time but yielded well-considered design options. Public feedback, gathered through surveys and exhibitions, indicated broad support for the proposed changes, particularly among local workers and residents. The consultation process provided valuable input reinforcing the design proposals. This project exemplifies the initial stages of evidence-based urban design, where both descriptive and analytical data were incorporated into a transformative vision for the space.

5.1.2. Darwin city centre

The project commission was to advise on enhanced extension of the city centre which maximizes the use of city assets, connectivity and mixed-use density while creating a local high street. The strategy established several key design objectives based on an evaluation matrix, which was derived from precedents and expertise. Based on this matrix, the project sought to leverage the city's natural and existing features, emphasizing the importance of working with the unique geographical and environmental attributes of the area (Space Syntax Ltd., 2013b). Another priority was to enhance connectivity and increase density within the Central Business District (CBD), improving the flow of pedestrian movement and activity both within and surrounding the CBD. This informed a modelling approach comprising both pedestrian and vehicular movement that integrated multitude of attributes aggregated onto the spatial configuration using an angular segment model identifying location-based priorities. Several configurational options were tested iteratively identify opportunities and constraints helping with the design decision-making process.

A distinguishing element of the project involved integrating various modes of transport to ensure a seamless and efficient urban network. Additionally, the design proposed extending the CBD and linking it to adjacent areas to form a more cohesive urban fabric. Finally, the project aimed to improve and strategically plan the development of primary spine streets, which serve as key infrastructural corridors for both transportation and urban vitality. These objectives were supported by a thorough analysis of pedestrian and vehicular activity, which informed the current urban condition and guided future development plans. This analysis contributed to the creation of an urban performance index, evaluating the effectiveness of proposed improvements. Furthermore, a correlation analysis was conducted to develop a profit index, assessing the financial viability of the different proposed options.

The project's significance lies in its targeted approach to address high-level urban challenges. By providing decision-makers with a clear set of priorities and evidence-based options, it supported decision-making and strategic development planning for the city's future. The project was implemented and well received with the stakeholders and the public.

5.1.3. Jeddah Development Framework

The project's strategy was centred around an evidence-based method aimed at addressing unplanned settlements and integrating them into Jeddah's formal urban structure. The approach began by developing rigorous spatial interventions based on detailed analysis of spatial structure, land use mix, FAR, population density massing and public space network, ensuring that each intervention was grounded in a comprehensive understanding of the city's dynamics (Space Syntax Ltd., 2013a). A key goal was to reconnect Jeddah's central unplanned areas with their surrounding neighbourhoods, enhancing integration and improving the overall urban fabric while minimising physical intervention and any unnecessary loss of built fabric.

This strategy is aligned with broader, city-wide proposals that consider long-term urban growth, including plans for the historic core and the City Centre. The redesign of route networks and urban block structures is another major component, with the intention of optimising connectivity and accessibility across the city. Additionally, the project establishes detailed guidelines for land use, building heights, public spaces, and parking infrastructure, ensuring that future development aligns with the overall vision for urban growth.

As a part of implementing the overall scheme, the project identifies specific projects for development, selecting key areas that offer the greatest potential for transformation. These targeted interventions aim to incrementally improve unplanned settlements, gradually upgrading their infrastructure and urban quality, while coordinating with city-wide development goals. The method is tested through a pilot project, which serves as a prototype for the application of these design guidelines and spatial interventions, providing valuable insights for future, larger-scale implementation.

5.1.4. Nur-Sultan Master Plan

The commission aimed to enhance the urban conditions of Nur Sultan (now Astana), designated as Kazakhstan's capital in 1997, by establishing guidelines for its development into a world-class urban centre (Space Syntax Ltd., 2020). The project began by identifying the intended outcome of development, before a comprehensive review of the city's status in delivering these outcomes. This comparative analysis resulted in a robust, evidence-based problem definition.

The review critically evaluated the masterplan's effectiveness in attracting residents and investments, improving liveability, sustainability, and urban health, while considering the geopolitical context. Although the overarching agenda was considered valid, issues such as the need for human-scale development, uncoordinated growth, and siloed urban systems meant these aims were not delivered. Consequently, strategies were designed to specifically address these challenges.

The method unfolds in four stages. The first, the *Vision Stage*, involves reviewing existing development documents to identify key indicators and study relevant precedents. The second, the *Baseline Analysis*, measures the city's current state against these indicators, implementing a baseline Integrated Urban Model (IUM) (Acharya *et al.*, 2017) and establishing key performance indicator (KPI) targets. The third stage, *Strategy*, helps the city's transition by iterating design solutions and addressing social infrastructure deficiencies. The *Masterplan Stage* develops detailed proposals, conducts environmental analyses, implements local regulations, updates the IUM, and initiates stakeholder communication. Finally, the fourth stage uses modelling to test how well the combination of proposals across the city creates the conditions to support the high-level aims.

Guided by three core ideas—evidence-based design, the city as interconnected urban systems, and cross-system integration—the project revealed significant challenges such as low density and poor walkability. In response, the strategy proposed reducing the urban growth boundary, implementing tactical interventions, and regenerating brownfield sites. Indicators were established to guide spatial configuration, mobility, and land use density. Rigorous testing against KPIs utilized advanced methodologies like machine learning and environmental analysis. Ultimately, the masterplan reflects evidence-based steps for sustainable urban growth, positioning Astana for future development.

5.1.5. Projects Summary

Figure 1 shows the sequence of the respective project development processes sorted by the scale of the projects. Over time, and as the scale of the projects increases, there has been an adoption of a predevelopment stage for gathering data and formulating an evidence based methodological framework in contrast to a more narrative-based formulation of the design question.

Secondly, for larger projects, the initial assessment and analysis phase leads into a design strategy – which creates a framework for the generation of design options – in contrast to smaller projects which have a closer coupling between the problem definition and options stages.

The overall review suggests that a practical framework for EBDP potentially has four stages:

- visioning and conceptualization
- baseline analysis and feasibility
- detailed analysis and option development
- evaluation and decision-making.

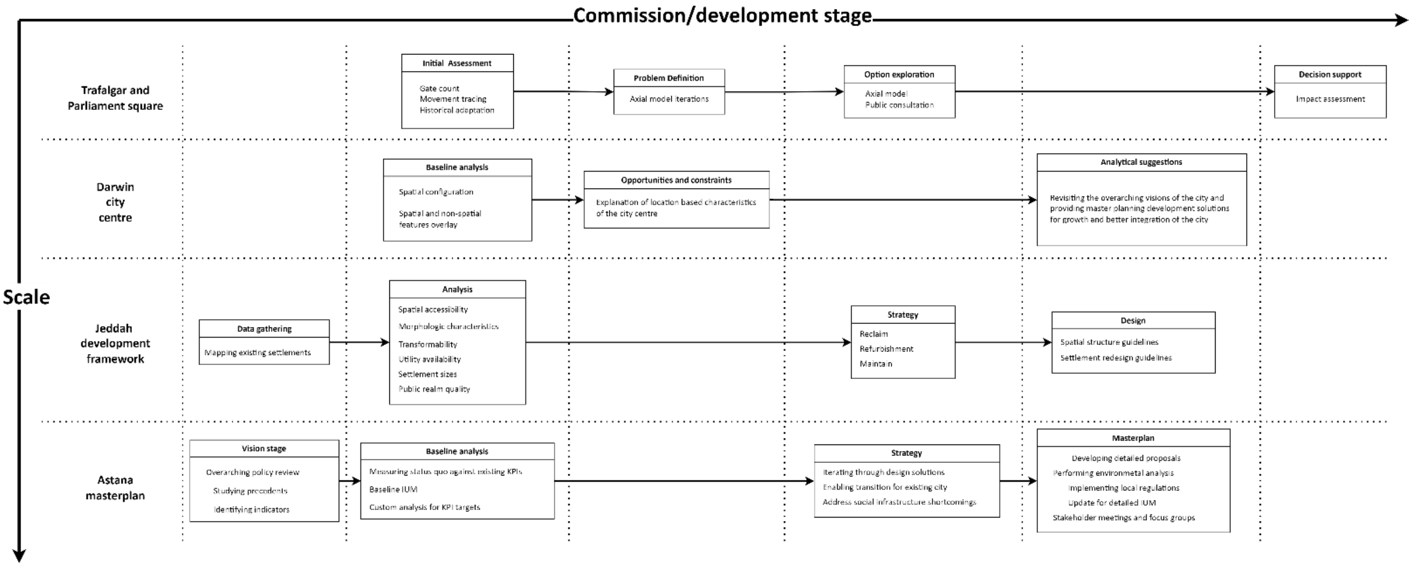

Figure 1 project implementation stages as per logical difference.

6. EBDP as iterative design process

A recurrent theme in the discussed EBDP literature and examples from practice is the use of iterative design processes which incorporate evaluation feeding-back into subsequent modifications and evaluation. The benefits of this process are manyfold: designs can be tested and refined internally, can be benchmarked, compared to other design proposals, and can be evaluated against defined metrics. Here we provide a theoretical framework for EBDP as an iterative process.

6.1. Visioning and conceptualization

In urban design and planning, a conceptualisation stage is necessary for aligning with the client's vision and setting design goals, guidelines, and strategies for the project. Analytical methods play a key role in the shaping and understanding of issues, using either empirical or quantitative approaches depending on the research questions and feasibility. Empirical methods involve "ground truthing," where researchers observe and collect data firsthand, making them ideal for smaller, detailed analyses of accessible sites. Quantitative methods, on the other hand, are used for larger-scale investigations where direct observation isn't practical. These rely on data from sources such as census and geospatial data. An example can be seen in two Space Syntax projects: the Trafalgar Square project, which used empirical observations, and the Nur-Sultan project, which relied on spatial modelling due to its larger scale. Table 1 shows the high-level classification of the analytical approaches to EBDP.

	Empirical approaches	**Quantitative methods**
Input data	Observation – Not reproducible	Numerical data – reproducible
Scale of analysis	Micro, Meso	Meso, Macro
Data collection	Observation, gate counting etc.	Official census, remote sensing, crowdsourcing etc.
Analytical techniques	Statistical method, participatory methods, Evaluation, and feedback loop	Spatial statistics, mathematical modelling, Geostatistics

Table 1 Analytical approaches employed in evidence-based design and planning.

6.2. Baseline analysis and modelling

After setting research objectives, the data collection phase gathers socio-demographic and spatial sources of data (Goodchild, 2007; Mennis and Guo, 2009). This comes in different formats and must be organized and pre-processed for analysis (Brisaboa *et al.*, 2015). Once collected, the data is modelled to inform a baseline analysis. Models act as simplified representations of reality (Haggett, 1965) arranged in logical frameworks (Sanders, 2007).

This process may be challenging in dynamic environments where information changes in meaning, identification, or size (Cheylan and Lardon, 1993). The data collection and modelling phase often leads to new insights, which may require further rounds of data collection and processing. Each iteration refines the approach, resulting in a more focused understanding of the issue. Figure 2 illustrates this iterative process.

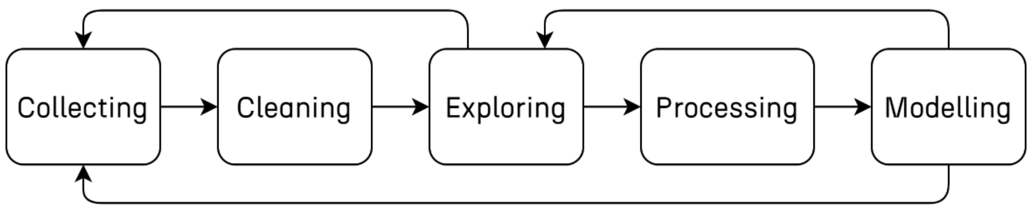

Figure 2 General EBDP data collection pipeline. Adapted from (David S. Jordan, 2023)

From a modelling perspective, methods for measuring change must be established. These methods fall into two primary categories: conceptual models and data-intensive models. Conceptual models link chosen indicators to the phenomena being investigated, while data-intensive models organize thematic and geometric information. Formalizing these models can be achieved through various approaches:

- Geomatics Approach: This utilizes GIS functionalities for spatial analysis to identify patterns and potential spatial regularities.
- Statistical Framework: This involves identifying explanatory and dependent variables, using statistical models to assess relationships between variables. These models range from simple correlations to more complex probabilistic analyses (Ripley, 2004).
- Dynamic Models: These are used to explore complex properties of spatial organisation, employing methods such as fractal analysis and percolation theory (Batty and Longley, 1994; Arcaute *et al.*, 2016).

- Computational Simulation (CS): This employs techniques such as cellular automata (White and Engelen, 1997) or multi-agent systems for simulation (Kowalski, 2019).

Spatial models can also be categorized based on their aggregation approach, level of determinism, and degree of dynamism. Sanders (2007) proposes a classification scheme based on these three criteria, providing a useful guide for model selection at the outset of a project.

Aggregated models	Static	Deterministic	Traditional models of geography – Christaller
		Probabilistic	Distribution models of random points digital terrain models
	Dynamic	Deterministic	Models with differential equation
		Probabilistic	Diffusion models
Disaggregated models	Static	Deterministic	Gravity model of spatial interaction
		Probabilistic	Choice models
	Dynamic	Deterministic	Cellular automata
		Probabilistic	Microsimulation

Table 2 Classification of spatial analysis models. Adapted from (Sanders, 2007)

After the issue is analysed using models, different options can be generated, refining the initial vision. These options provide measurable outcomes that guide decision-making by exploring various possibilities.

6.3. Options development

From a modelling perspective, various models have been proposed to generate options by varying a limited set of variables, thereby revealing potential outcomes in isolation. In smaller-scale design problems, such as architectural design, single-objective optimization methods like evolutionary systems (Janssen, 2009), parametric modelling (Turrin, Von Buelow and Stouffs, 2011), and generative design (Stouffs and Rafiq, 2015) are commonly used (Koenig et al., 2020). For larger-scale design problems, such as urban design and planning, exploration methods rely heavily on spatial analysis. However, due to the complexity of urban issues, hybrid models are often employed, optimizing multiple objectives simultaneously. Examples include Koenig et al.'s (2020) model, which integrates urban analysis, generative design, and evolutionary optimization, Celani et al.'s (2011) combination of shape grammar and genetic algorithms, and Motieyan and Mesgari's (2018) use of agent-based models to optimize land-use and transportation planning.

These approaches collectively suggest that, despite the complexity of design challenges, there are inherent limitations—such as constraints in input data and computational power—that affect optimisation. This issue, prevalent in both science and engineering, reflects a broader problem in options exploration and decision-making, where establishing a multi-attribute utility function (Von Winterfeldt and Fischer, 1975) is often difficult due to the lack of structured models for objective weighting. To address this, a multi-criteria average-weighted model (FILIP, 2018) offers a potential solution for optimizing design choices and the option-generation process. However, while this model originates from other disciplines, it must be adapted for use in spatial analysis models.

6.4. Evaluation cycle and iterative feedback

Given the complexity of urban systems (Forrester, 1969) and the vast array of analytical outputs and evidence that can inform the design and planning process, the iterative feedback process is potentially highly intricate. The diversity of data formats feeding into this iterative process adds further complexity, which may be particularly difficult when budgetary constraints must be considered. As a result, the design and planning process can be approached as a system dynamics problem, wherein iterative feedback loops serve to refine and optimise the process through evidence integration.

The complexity and sheer volume of inputs, coupled with the need to engage a broad community of stakeholders—planners, designers, policymakers, etc.—who may lack technical expertise or familiarity with such complexity, necessitate that the EBDP evaluation cycle and feedback loop evolve into distinct stages of intensity. This tiered approach allows for varying levels of technical depth, ensuring that the process remains accessible to all stakeholders while maintaining the necessary analytical rigor.

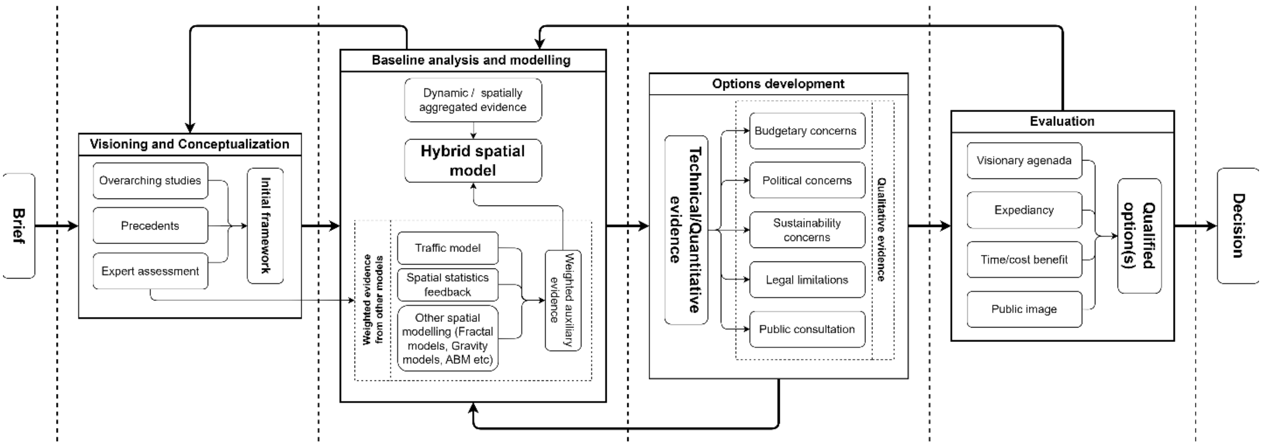

Figure 3 A conceptual model for evidence-based design and planning.

Figure 3 presents a conceptual model of the EBDP process, illustrating its iterative cycles and highlighting both the practical and theoretical complexities involved. This process reflects on previously suggested iterative pipelines (Zeisel, 1984; Karimi, 2018; Carmona, 2021b) while considering recent possibilities in cross-disciplinary modelling and data science methods. This is formulated based on the premise that there are inherent and yet non-negligible complexities in urban design and planning that increase with the scale of the problem. It also acknowledges that the information – either quantitative or qualitative – would have to be consumed and reflected upon, generating evidence for decision making at an appropriate stage.

This framework proposes that multiple layers of information should be systematically integrated to maintain a balance between efficiency and cost-effectiveness. In line with the framework, information in varying formats is best incorporated in a purposeful, sequential order. Notably, in Evidence-Based Design and Planning (EBDP) practice, qualitative insights can be assessed using quantitative methods, and vice versa, though this interplay is flexible rather than prescriptive. The framework further highlights that the initial stages of design and planning are not fixed; they can be revisited and revised as new evidence emerges, contingent on careful evaluation. Consequently, information flows both "backward" to inform earlier stages through iterative feedback and "forward" to guide the development of new alternatives.

7. Discussion:

Evidence-based design and planning (EBDP) has become necessary for addressing pressing urban challenges, moving beyond a suggestive approach to a necessary method (Rogers, 1999). The complex political, economic, and social processes involved in creating functional urban environments require a systematic approach that leverages evidence to inform design decisions (Clarence, 2002; Faludi and Waterhout, 2006). While the integration of analytical and scientific methods in urban planning is not new, their isolated use has often led to spatial configurations that focus primarily on physical aspects, neglecting critical social and political considerations (Krizek, Forysth and Slotterback, 2009).

In response to the limitations observed in late 20th-century design approaches, a body of knowledge emerged that critique modernist planning for overlooking the interaction between spatial and social structures (Whyte, 1980; Gehl, 1987; Jacobs, 2011; Alexander, 2012). These critiques led to theoretical developments aimed at addressing the socio-political dimensions of urban design by analysing spatial patterns, relationships, and the broader impacts of design decisions through analytical methods. We show that these human-scale perspectives on urbanism – which place the emphasis on compact, walkable, and mixed-use urbanism – are supported by emerging forms of evidence: both from the perspective of scientific studies which bolster and clarify related design strategies, and from the perspective of urban analytics toolsets which increasingly provide measurable insights for comparing design options and iterative evaluation as an integral part of the design process.

The advancements in computational techniques and the availability of data have propelled the evolution of EBDP, as exemplified by firms such as Space Syntax Ltd. (Space Syntax Laboratory, 1998; Space Syntax Ltd., 2013a, 2013b, 2020), which have integrated both practical and theoretical dimensions of analytical design. A review of their projects reveals a shift from narrative-based problem definition and interpretation of analytical results in earlier work to a more analytic process, characterized by iterative feedback loops that not only inform future decisions but also allow for ongoing iteration and refinement.

The review of EBDP theory and practice highlights the importance of a self-improving (Zeisel, 1984) iterative cycle in creating a feasible framework for evidence-based planning. This process must be informed by a range of evidence, while recognizing that constraints such as economics, feasibility, and liability may influence decision-making (Karimi, 2023). Therefore, optimizing planning decisions using appropriate evidence is critical to the framework’s success.

One key factor in facilitating this framework, particularly in the initial conceptualisation stage, is the potential usage of emerging automated and open-source data and toolsets to inform experiential insights (European Commission and Directorate-General for Regional and Urban Policy, 1999; Gramacki *et al.*, 2023; Simons *et al.*, 2024). This facilitates earlier stage feasibility assessments before commencing detailed location-specific analyses in later stages of the project. Furthermore, incorporating standardised tools, datasets, and indicators at early stages of the project can significantly enhance the efficiency of the proposed framework by informing a well-documented feasibility study and modelling phase (Bibri, 2018). This approach may significantly reduce project costs through easier availability of insights, though its effectiveness can be limited by varying open data quality.

In conventional design and planning practices, a common oversight is the lack of a logical progression throughout the project, where the urgency to meet deadlines often outweighs the benefits of thorough optimization (Cao, Li and Church, 2020). However, standardised feedback process may facilitate ongoing refinement across projects.

One major challenge for any design and planning framework is the effective communication of design objectives to stakeholders and clients (Bryson, 2004; Innes and Booher, 2010). As highlighted in the discussion on integrating scientific methods into urban design and planning, obtaining valuable feedback from individuals unfamiliar with technical or scientific terminology can be problematic (Marshall, 2012). Since evidence-based approaches depend on data analytics and automation, the use of highly customizable methods—often requiring knowledge of programming languages—becomes crucial. This not only creates difficulties for clients but also for traditionally trained practitioners, as it necessitates a deeper understanding of statistical and data science concepts. Consequently, the success of EBDP hinges on both technical proficiency in analytics and the ability to communicate these insights effectively to diverse audiences.

Building on the proposed framework for Evidence-Based Design and Planning (EBDP), we conclude with three key insights. First, we advocate for the development of design and planning schemes as intersectional processes leveraging expertise across disciplines. Given the increasing complexity of urban growth, particularly with respect to environmental and political considerations, it is essential to seek guidance on the long-term and cross-scalar impacts of design decisions. While meeting regulatory requirements is often the primary focus for developers, it is crucial to also consider the broader implications of design and planning on urban systems.

Second, based on our review of current practices, we emphasize the importance of efficient resource allocation in practical terms. While it is ideal to incorporate as much data and evidence as possible into EBDP decision-making, we recognize that real-world project constraints may limit this. Therefore, we recommend the use of automated, cost-effective baseline analyses and informed prioritization (or triage) to shape detailed analytical models without overburdening resources.

Lastly, we underscore the importance of not only developing sophisticated analytical models but also ensuring their proper interpretation. As discussed in the challenges of adopting scientific methods, it is critical to tailor models, algorithms, and methods to the specific issues being addressed (Davoudi, 2006). A thorough understanding of both the limitations of algorithms and datasets is essential to avoid mistaking complexity for accuracy. Effective EBDP requires both technical proficiency and an informed, critical approach to the tools being used. Therefore, project development should incorporate adaptability and flexibility, allowing the feedback loop to continuously refine and improve the process.

8. Acknowledgements

The research which this paper is based on has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101078890, UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee under grant numbers 10052856 and 10050784.

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