a dynamic framework, digital tool and prototype for iterative, place-based and holistic sustainable neighbourhood design in the UK

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Fig. 1
Shaping Place cover

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Personal statement and acknowledgements

This research is one I came in to MSc MADE wanting to conduct. Despite this, I never foresaw the depth of it, or anticipated the incredible result I could achieve.

Of course, I received some help: I was guided by two brilliant women in their respective fields, my supervisors Birgit and Maryam, and could not have chosen a better team with which to experience the epitome of my MSc studies, bringing me knowledge, inspiration, moral support and endlessly wise and relevant advice. Further, Ryder / Okana gave me such precious resources, via a study bursary, flexibility in work arrangements; sharing networks for data collection; granting me precious time for interviews / a co-creation session; or simply by providing words of encouragement and feedback. Graham, Jon and Cathy, your kindness, support and mentorship are inspiring my professional, academic and life journeys. There are more people I am grateful for of course. To my guides, mentors, family, friends, business partner... merci!

The journey to sustainable cities is one that concerns us all. This thesis is my small contribution to the collective action. Enjoy the read, and please feel free reach out to me for any question or if you want to discuss!

Abstract

Neighbourhoods, design, and sustainability are all inherently dynamic: with multiple constantly evolving interrelated dimensions. As such, digital tools supporting sustainable neighbourhood design in the UK should also be dynamic. Digital tools and data driven technologies can enable sustainable urban design, however, a key metropolitan challenge is ensuring responsible such urban digitalisation is achieved responsibly.

For this, digital tools must integrate three essential components: holistic sustainability, place-based approach, and iterative design. Currently, no existing tool combines all three elements.

This research addresses this gap by developing a Dynamic Framework and Digital tool prototype through interviews, literature review, software analysis, co-creation, GIS data coding, and a case study application.

The research analyses current urban design workflows for sustainable neighbourhoods in the UK, investigates innovative combinations of existing digital tools (Python coding, GIS, Rhino with Grasshopper), and establishes applicable sustainability criteria.

The resulting Dynamic Framework and Digital tool successfully demonstrate: holistic sustainability through comprehensive assessment of criteria which contribute to 10 sustainability themes and their interdependencies; place-based approach via customizable local values (theme weights) derived from community engagement while maintaining holistic oversight; and iterative design capability through option geometry modelling and impact simulation. The Dynamic Digital tool prototype was applied on the Hirst Regeneration case study, providing project insights and recommendations..

Contents

1. introduction - TOWARDS SUSTAINABLE NEIGHBOURHOOD DESIGN

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland Report, 1987).

Cities, both key contributors and victims of climate change, need to become sustainable in the face of their environmental, societal and economic impacts (Axinte et al, 2019; IPCC, 2023; Kaefer, 2021; UN Environment Programme, 2017). Specifically, urban neighbourhoods receive worldwide interest in sustainability transitions as they serve as the foundational units where daily life unfolds (Khatibi et al., 2023; Smaniotto-Costa et al., 2024; Switalski et al. 2023). Addressing sustainability at this scale, specifically focusing on existing neighbourhoods, is not merely an option but a necessity to improve quality of life and mitigate environmental decline (Mahmoud et al, 2022). Indeed, investing in existing communities is more sustainable than promoting ever-increasing urban sprawl, and a place-based approach amplifies this potential by tailoring solutions to the distinct characteristics and actual needs of each neighbourhood (Ellery et al., 2020; Hamdan et al., 2021). This method emphasizes people-oriented and participatory approach to design and sustainability, integrating environmental, social, economic considerations and therefore fostering sustainable outcomes that resonate with local contexts (Khatibi et al., 2023; Amirzadeh & Sharifi, 2024; Switalski et al., 2023).

In the UK, place-based design is gaining popularity in governmental directives and in practice, marking this research's societal gap. Indeed, GOV.UK's guidance publications emphasize the need for place-based approaches to design, such as the National Design Guide (Ministry of Housing, Communities and Local Government, 2021) and the Royal Institute of British Architects (RIBA)'s Engagement overlay (RIBA, 2024). Additionally, key UK based firms are increasingly offering specialist place-based services, specifically in globally established practices like Foster and Partners, Atkins Réalis, Arup, MSP and emerging firms like Okana Global Consultancy (Ellery et al, 2020; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025). In parallel, projects like the regeneration of the Woodberry Down residential neighbourhood in London have ignited public discourse, and media outlets such as Architect's Journal, ArchDaily and Dezeen underscore this trend. Despite knowing the importance and urgent need for place-based sustainable urban neighbourhood development, it is difficult to achieve in practice (Aernouts et al., 2023).

This difficulty to successfully approach sustainable neighbourhood design is partly due to the dynamic nature of the task. Indeed, sustainability, often qualified as a wicked problem, involves the consideration of a high number of complex, non-linear, ever-changing and interconnected variables (e.g., changing climate, societal needs, political uncertainty, economic values, technological advances) to address evolving environmental, economic and social issues (Axinte et al., 2022; Bibri, 2020; Gruis et al., 2006; Khatibi et al., 2023; Wissen Hayek et al, 2016). Adding to this, neighbourhoods are also dynamic, complex systems of intertwined physical infrastructure, evolving social needs and economic activities (Goldstein & Khan, 2017). Finally, design is an inherently iterative and therefore dynamic process (Chouki et al., 2023; Hamdan et al., 2021; Meineil, 2022; Oswald et al., 2023). According to these, this research uses the term dynamic, antonym to "static", to refer to the notion of variability, change through time, non-linearity, interconnectivity / interdependence and iterative interactions with other elements. Overall, this dynamic nature of sustainable neighbourhood design demands the implementation of new tools (Gruis et al., 2006; Smaniotto-Costa et al., 2024).

Digital tools, long established in the architecture and construction industries, can provide a solution to this, as they enable design cooperation, advanced modelling and scenario testing, and therefore provide an opportunity to facilitate the achievement of the Sustainable Development Goals (SDGs) via increased efficiency of processes for urban situations (Zhang, 2021; Zhang & Liu, 2019). Indeed, digital tools and data driven technologies can enable sustainable urban design, however, a key metropolitan challenge is ensuring such urban digitalisation is achieved responsibly, by contributing to community empowerment and place-based design (AMS Institute, 2025; Founder, personal communication, March 19, 2025; Smaniotto-Costa, et al., 2024). For this, digital tools must dynamically integrate three essential components: holistic sustainability, local values, and iterative design. Currently, no existing tool combines all three elements, constituting this research's scientific gap.

This research aims to examine the way dynamic digital tools can be built to enable the holistic sustainable design of existing neighbourhoods through an iterative and place-based approach. This involves the development of a framework and prototype script for a tool that supports a dynamic operation at the neighbourhood scale, incorporates local values, integrates multiple interrelations of holistic sustainability and iteratively interacts with design models.

While rooted in the UK context, the framework and tool aim for transferrability, subject to similar societal and scientific gaps for the sustainable design of everyday life urban neighbourhoods, and with availability of comparable data.

2. problem definition - THE NEED FOR A DYNAMIC DIGITAL TOOL

For a digital tool to effectively advance sustainable neighbourhood design by addressing its dynamic nature, it should fulfil three core requirements at the neighbourhood scale: a place-based approach; a holistic sustainability view and an iterative relation to design models.

2.1 Place-based approach

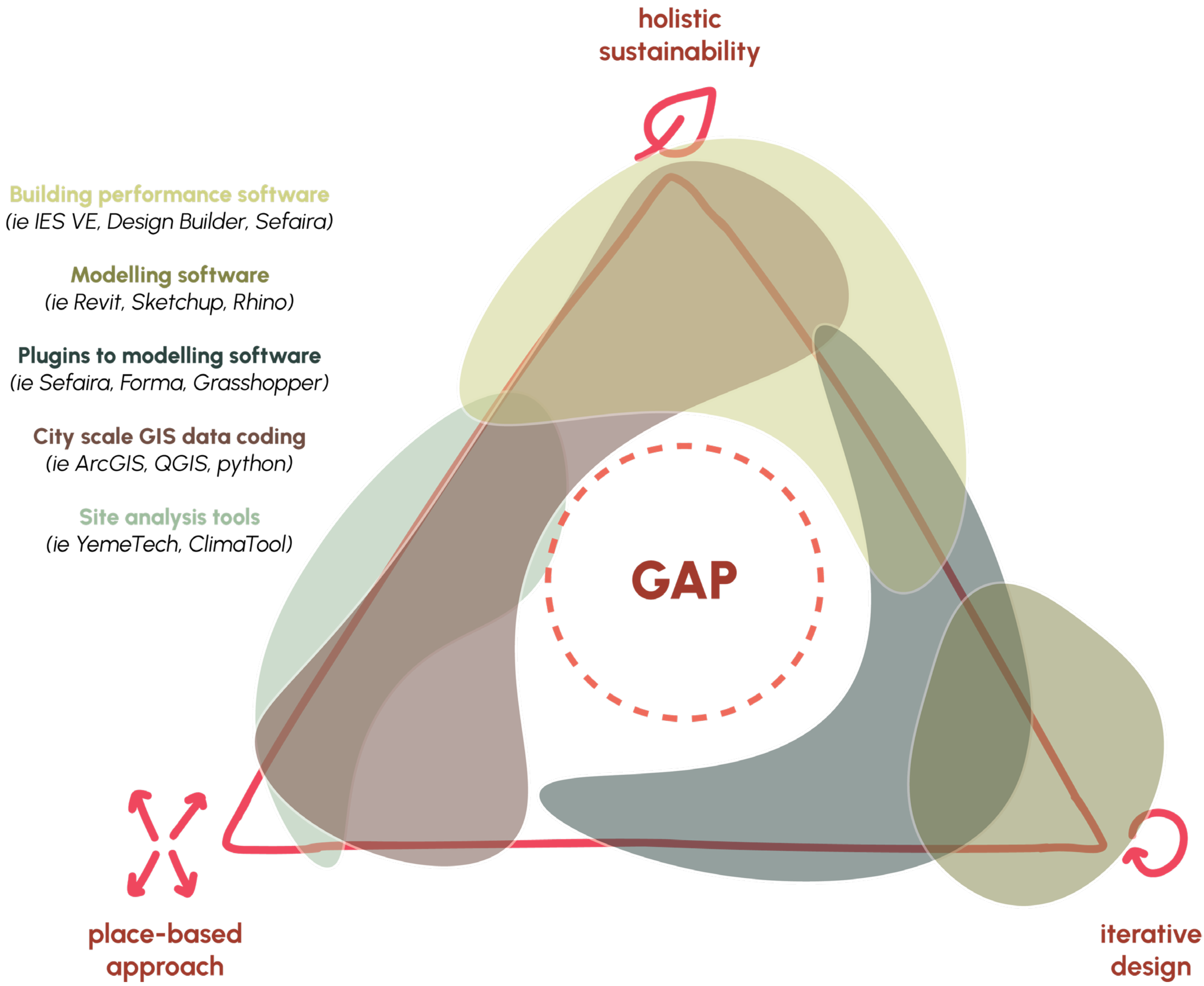
A dynamic digital tool must account for the local specificities of the neighbourhood scale, embedding the tangible physical and spatial place-specific features as well as the intangible local values, to ensure design interventions reflect the unique and context specific identity and needs of each community, as well as builds on the specific assets of a place (e.g., local amenities, cultural mix, landscape quality), for sustainable design (Axinte et al., 2022; Ilovan & Markuszewska, 2022; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, March 27, 2025; Smaniotto-Costa et al., Sustainability Director, personal communication, March 27, 2025; 2024; Zhang & Liu, 2019). However, such a place-based approach is not currently the norm in design with digital design tools, as few successfully integrate those complex interrelationships between place and people, instead favouring the short term decision making cycles of business and politics (Amirzadeh & Sharifi, 2024; Wissen Hayek et al., 2016; Zhang & Liu, 2019). Reasons for this include the complexity of the task to quantify the quality of the heterogeneous relation between people and place, as lived experiences are subjective; as well as the practical / logistical / economical / benchmarking benefit in adopting a less bespoke "one size fits all" or "checklist" approach on projects (Head of Innovation, personal communication, March 13, 2025; Khatibi et al., 2023; Marique & Teller, 2014; Mateo-Babiano & Palipane, 2020; Switalski et al., 2023).

2.2 Holistic sustainability

A dynamic digital tool should offer a complete and comprehensive perspective on sustainability, integrating environmental, social and economic factors and accounting for their interdependencies to support balanced and equitable decision-making (Founder, personal communication, March 19, 2025; Gruis et al., 2006; McElvaney & Rouse, 2015). Traditionally, a narrow and simplified approach to sustainable development is promoted, with "sustainable" limited to efficient resource use and "development" understood as economic growth – this approach fails to consider and coordinate the multiple components of neighbourhood sustainability to establish more equitable strategies and informed trade-offs (e.g., trading upfront carbon emissions for high durability and resilience) (Axinte et al., 2022; Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Khatibi et al., 2023; Sustainability Director, personal communication, March 27, 2025; Switalski, et al., 2023; United Nations, 2015). Currently, at the neighbourhood scale, though the demand is there, there is a lack of holistic sustainable design software, and recently, many practitioners, academics and researchers have begun to point out the shortcomings of existing tools including: bias towards environmental sustainability; focus on ecological parameters of a city; and lack of consideration for the local context, as seen above (Computational Design Lead, personal communication, March 11, 2025, Khatibi et al., 2023; Li & Milburn, 2016; Sustainability Director, personal communication, March 27, 2025; Zhang, 2021).

2.3 Iterative design

A dynamic digital tool should enable iterative interaction with design models in order to allow for early stage optioneering via the exploration of multiple design scenarios, evaluate impacts, compare performance and refine solutions appropriately (Bibri, 2020; Computational Design Lead, personal communication, March 11, 2025; Goldstein & Khan, 2017; Head of Innovation, personal communication, March 13, 2025). Indeed, continual testing and redesigning as time progresses are considered essential to accomplish sustainable urban transformations, especially for neighbourhood design where the physical interventions highly affect local environmental quality and social well-being (Amirzadeh & Sharifi, 2024; Khatibi et al., 2023; Wissen Hayek et al., 2016). Despite this, although dynamic digital tools for iterative design exist, tools which integrate analysis of neighbourhood sustainability are predominantly static digital tools which analyse and visualise a fixed data set and do not relate to a design model (Zhang, 2021).



2.4 Combining the 3 features: the gap triangle

When looking for a tool which meets the above conditions, a significant gap appears. Current offerings do not address all three features (place-based approach, holistic sustainability, iterative design) simultaneously which limits their ability to support sustainable neighbourhood design comprehensively, as seen the Software Review Matrix (**Appendix A**). This matrix is summarised in The Gap Triangle (**Fig. 2**) and **Table 1** with detailed explanation below.

Fig. 2
The Gap Triangle
three-fold definition of the current gap in digital design tools for sustainable neighbourhoods in the UK, accross place-based approach, holistic sustainability and iterative design requirements.

Building performance software such as Integrated Environmental Solutions (IES) and Design Builder excel at dynamic sustainability analysis with design interaction - exploring the fields of energy systems, occupant behaviour, thermal comfort and air quality – but fail to scale up to neighbourhood, adopt a place-based approach or embrace sustainability holistically (Sustainability Director, personal communication, March 27, 2025; Zhang, 2021).

Modelling software such as Revit, Sketchup or Rhino generally focus on iterative design, though Revit for example provides a built-in shading visualisation. Any further inching towards holistic sustainability is done via specific plug-ins.

Plug-ins to modelling software, such as Forma (CAD/Revit), Sefaira (Sketchup) or Grasshopper (Rhinoceros 3D) bridge design modelling and sustainability analysis software. However, they offer a silo-ed approach to sustainability and do not enable place-based design at the neighbourhood scale. Specifically, Rhinoceros 3D (Rhino) and Grasshopper show potential in the ability to code ad hoc analysis scripts, on top of modelling and visualising, at the neighbourhood scale (Elkhuizen et al., 2024; Zhang & Liu, 2019). Despite this, they face practical limitations in the place-based approach, offering only local weather station granularity (for reference, local weather stations are typically present in airport complexes, and thus do not provide neighbourood scale data / resolution). The practical limitations are due to compatibility issues with Grasshopper's Python (Iron Python in lieu of the usual C Python) packages, essential for complex geospatial analysis workflows and large dataset processing (Computational Design Lead, personal communication, March 11, 2025). Theoretical solutions like GH Python Remote often fail and the result is that Grasshopper is often seen as inadequate for such complex analyses, and "normal" python coding Is preferred (GitHub Issues, 2019; McNeel Forum, 2018a, 2018b, 2019; Head of Innovation, personal communication, March 13, 2025; McNeel Wiki, 2020; PyPI, 2022).

City-scale tools such as Geospatial Information Systems (GIS) software (e.g., ArcGIS, QGIS) or data coding in Python (C Python) provide robust data analysis and visualisation, which, while applicable to 3D models, do not directly interact with modelling software and as such, lack the iterative design features necessary for this study (ESRI, 2025; QGIS, 2025).

Digital tool (neighbourhood scale)	place-based approach	holistic sustainability	iterative design
Grasshopper plugins	0.5	0	1
ArcGIS / QGIS	1	1	0
Python libraries	1	1	0
Revit / Rhino / Sketchup	0	0	1
YemeTech	1	0.5	0
CityEngine	0.5	0	0.5
PlaceMaker	0.5	0	0
PlaceChangers	0.5	0	0
Healthy Streets	1	1	0.5
Plan4Better	0.5	1	0.5
Urban Footprint	0.5	0.5	0
15mincity.ai	0.5	0.5	0
Spacio	0	0	1
Healthy cities	0.5	1	0.5
Urban Calculator	0.5	0	1
Decoding Spaces	0.5	0	0
Envision Tomorrow	0.5	1	0.5
OSCI Local Insight	0.5	1	0
Infrared City	0.5	0	1
Bang the Table	1	1	0
Forma	0	0	1

Table 1
Summary Software Review
summary of the full software review matrix seen in Appendix A, assessing the suitability of existing digital tools at the neighbourhood scale to dynamically provide the 3 points of the gap triangle. 0 means not compliant; 0.5 means some elements or potential but fully dynamic approach missing; 1 means compliant

Even site analysis tools designed to consider neighbourhoods' spatial factors and their contribution to sustainability fall short (Moroke et al., 2019): YemeTech offers a highly valuable and holistic overview of place-based sustainability factors, yet it remains static and aimed at reporting rather than iterative design, lacking integration with design model and the dynamic integration of local priorities (Head of Innovation, personal communication, March 13, 2025). Similarly, HealthyStreets and Plan4Better incorporate some dynamic elements but overlook the local nuances central to a place-based approach, such as local priorities / specific needs, and do not iteratively integrate with design models. Finally, CityEngine, a modelling tool for urban projects, is too inflexible to control complex urban forms as it only allows for built-in modelling rather than imports from design software (Zhang & Liu, 2019).

Evidently, both a societal and scientific gap recorded through industry voices and academic literature, no existing tool fully aligns with the dynamic demands of sustainable design for existing neighbourhoods, though the demand is there (Amirzadeh & Sharifi, 2024; Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Head of Innovation, personal communication, March 13, 2025; Khatibi et al., 2023; Li & Milburn, 2016; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025; Wissen Hayek et al., 2016; Zhang, 2021 Zhang & Liu, 2019), revealing a clear need for innovation to establish ongoing collaborative design processes and tools that take into account multiple economic, environmental and social urban neighbourhood aspects (Wissen Hayek et al., 2016).

This research addresses this deficiency by proposing a digital tool that dynamically:

1. Offers a place-based approach, operating at the neighbourhood scale and prioritizing place-specific features and local values;
2. Delivers a holistic picture of sustainability across environmental, social and economic domains; and
3. Facilitates iterative design via interaction with design models.

By developing a framework and prototype script of a dynamic, holistic and place-based digital tool, this study aims to empower sustainability consultants, urban designers and engagement specialists with a solution that bridges current gaps; paving the way for sustainable neighbourhood design.

3.0 research questions - QUESTIONING THE STATUS QUO

Following from the above statement, this research answers:

What dynamic framework and digital tool prototype can support the iterative, place-based and holistic sustainable design of neighbourhoods in the UK?

1. What is the urban designer's workflow for sustainable neighbourhood design projects in the UK?

2. What are the current digital tools for sustainable neighbourhoods' strengths, what are they lacking and how might they complement each other?

3. Which criteria of a sustainable neighbourhood could a dynamic digital design tool for sustainable neighbourhoods in the UK consider?

4. What dynamic framework and underlying logic should guide a digital tool to integrate iterative design processes, place-based approach, and holistic sustainability for neighbourhood design?

5. What value does the application of a prototype dynamic digital tool bring to the Hirst Residential regeneration case study project?

4.0 theoretical framework – TOOLS FOR DYNAMIC URBAN DESIGN: PLACE-BASED SUSTAINABLE NEIGHBOURHOODS

This research focuses sustainable urban neighbourhoods, therefore, defining neighbourhood is necessary. However, despite extensive research, the definitions and boundaries of a neighbourhood vary greatly. This is because neighbourhoods are equally physical and social / psychological concepts (Khatibi et al., 2023), as seen below. The following subsections cover the components, the performance and finally the relevance of neighbourhoods.

4.1 Components of a neighbourhood: the "hard", the "soft" definitions

Neighbourhoods can be described as a group of buildings bound by a political and physical boundary (Hamdan et al., 2021). Jurisdictionally, the concept of neighbourhood is used for planning and administrative purposes (Swisher, 2025), such as municipal budget allocation (Urban Designer, personal communication, March 24 2025). In this sense, neighbourhoods are a pragmatic way of structuring and organising urban areas into subsections which contribute to the larger city system (Carmona et al., 2010; Khatibi et al., 2023). Physically, spatial characteristics of a neighbourhood include: buildings, open spaces, blocks, roads, systems, infrastructure, natural features (Hamdan et al., 2021; Khatibi et al., 2023; Swisher, 2025; Zhang & Liu, 2019) all contributing to different functions such as residential, retail, business / industry and working-living mixed-use developments. However, Moudon (1994) emphasizes that neighbourhoods must also be understood through their morphological evolution over time, as the spatial relationships between these physical elements continuously transform through processes of urban development, renovation, and adaptation

Indeed, a neighbourhood corresponds to more than its administrative and physical attributes – it is an interaction between city and individual (Khatibi et al., 2023; Oliveira, 2016), characterised by social interactions between neighbours, a shared sense of community / identity and similar demographic characteristics regardless of its initial urban planning concept (Smaniotto-Costa et al., 2023; Swisher, 2025). A neighbourhood's identity and character therefore create or enhance a "sense of place" (Carmona et al., 2010). Indeed, the notion of "place" has become increasingly popular within human centred urban design thought leaders, such as Lynch and Jacobs in the 1960s (Smaniotto Costa et al., 2023). With it, a consensus that neighbourhoods are shaped and defined by their inhabitants and users, with intangible characteristics, a heritage and a community "soul" (Smaniotto Costa et al., 2024). The importance of understanding "place" for sustainable neighbourhoods will be further detailed in section 4.3.

The neighbourhood is therefore a combination of spatial / physical and social / psychological elements, dynamic by definition: evolving through time, interconnected and interdependent (for example a green area will not only affect the social well-being, but also contribute to flood prevention, air quality, views, biodiversity, thermal comfort, acoustic comfort...) (Carmona et al, 2010; Goldstein & Khan, 2017). As such, throughout this research, when "neighbourhood" is mentioned, it is understood as:

A dynamic sub-component of the urban fabric which combines physical (built environment, infrastructure, nature), social (administrative boundary) and psychological (community feeling, sense of place) attributes, connecting the individual home, the community and the overall urban environment.

To go further, achieving sustainable cities involves the shaping of sustainable neighbourhoods, which involves not only physical / spatial interventions but also social and economic motives and results (Gruis et al., 2006; Khatibi et al., 2023).

4.2 Performance of a neighbourhood: characteristics for sustainability

The following section considers academic research and industry guidance which define sustainable neighbourhood characteristics and concludes with those which will be taken forward in this research. Note that "sustainable place" guidance is applicable and included.

Firstly, in literature, there is no clear consensus on the exact exclusive list of characteristics of a sustainable neighbourhood (Computational Design Lead, personal communication, March 11, 2025; Gruis et al. 2006; Khatibi et al., 2023). In 2010, Carmona et al. describe "Comfort and image; access and linkage; uses and activity; and sociability" as key attributes of sustainable places. These core themes are still relevant now, though modern studies propose a more detailed understanding and classification: for example, Ortiz-Fernandez et al. (2023) identified 35 different indicators for a sustainable neighbourhood, categorised in: "Ecology, land use and occupation"; "Infrastructure and equipment"; "Transportation and mobility"; "Resources and energy"; "Participation and social well-being" and "Neighbourhood environment". Overall, though they will vary considerably, the key features for sustainable urban neighbourhood development are spatial / environmental, economic, social and physical (Moroke, et al., 2019).

Khatibi et al.'s 2023 systematic literature review on neighbourhood sustainability characteristics suggest the list of factors seen in **Table 2**, reproduced from their publication. Within that, they strongly emphasize the importance of urban form and morphology as a key contributing factor to the sustainability of a neighbourhood. They also highlight the influence of physical / spatial criteria onto the other, less tangible, factors, such as sense of place and community. This necessary interaction between tangible and intangible elements for sustainable neighbourhoods is also mentioned by Smaniotto-Costa et al. (2023), Ilovan & Markuszewska (2022), Amirzadeh & Sharifi (2024), Strydom et al. (2018), Switalski et al. (2023), and takes into account the full definition of the neighbourhood as physical, social and psychological.

Secondly, this capacity for physical design to enhance the social liveability of neighbourhoods is reflected in practice, gaining significant traction in major international agendas (SDGs, UN Habitat, UN Environment Programme) (Amirzadeh & Sharifi, 2024). In March 2025, the UK government published their Plan for Neighbourhoods – a 1.5 billion pounds programme to invest in 75 areas over the next decade (GOV.UK, 2025). This programme builds on GOV.UK publications from 2021, such as the National Design Guide which outlines the 10 key themes seen in **Fig. 3**, successfully representing a holistic view of sustainable urban neighbourhoods accounting for physical, social and psychological elements (Ministry of Housing, Communities and Local Government, 2021). The 10 themes are loosely classified in 3 core axes of Climate, Character and Community, though the guidance states the different interrelations between themes, ensuring the dynamic element of sustainability is conveyed.

Category	Factor	Frequently measured criteria
Neighbourhood creation	Sustainable form and morphology	*Environmental Quality, Density, Spatial Integration and Connectivity, Mixed Land Uses, Green Spaces and Building Form and Typology*
	Community	*Community participation, Social interaction and Social cohesion*
	Sense of Place	*Sense of attachement, Satisfaction and Heritage preservation*
Sustainability Outcome	Liveability	*Walkability, Environmental quality (Air Quality, Thermal Comfort, Lighting and Visual Comfort, Acoustic Comfort, Psychological Comfort), GHG emissions, Waste management, Water management and Water pollution*
	Equity	*Accessibility, Affordability, Safety, Security, Diversity and choise, Income rate, House ownership and rent, Employment rate and Education level*
	Viability	*Renewable energy, Energy-conscious or responsible behaviour and Economic performance (Creation of Agricultural green space, Installation of photovoltaic (PV) systems a`nd Installation of water harvesting systems)*

Table 2
Characteristics of a sustainable neighbourhood
reproduced from Khatibi et al. (2023)

Fig. 3
10 Characteristics of sustainable neighbourhoods
reproduced from Ministry of Housing, Communities and Local Government (2021)'s "10 characteristics of a well designed place"

This publication provides a clear, comprehensive and actionable set of design guidance and interventions and is accompanied by further detail in the National Model Design Code (Ministry of Housing, Communities and Local Government, 2021). Also in 2021, Scottish Futures Trust published its "Place Guide", detailing the process of designing sustainable neighbourhoods, as well as providing the link to the Place Standard tool (**Fig. 4**): a dynamic and interactive excel sheet to assess the quality of a place (Our Place.Scot, 2025). Finally, the globally influential Project for Public Spaces (PPS) has released its own wheel (**Fig. 5**), divided in key factors of Sociability, Uses and Activities, Comfort and Image, and Access and Linkages (PPS, 2025).

While there is little consistency in the expression of the characteristics of a sustainable neighbourhood, the core intention remains the same: ensuring the physical environment contributes to durable social and economic fulfilment of the community. As such, sustainable urban neighbourhoods are defined as:

Neighbourhoods within the urban fabric which enable all users to meet their context specific needs and enhance their own and the community's well-being, in line with sustainable development goals.

This research postulates that the GOV.UK National Design Guidance "10 characteristics of well-designed places" (**Fig. 3**) (Ministry of Housing, Communities and Local Government, 2021) fulfils the above definition. As such, any mention of sustainable neighbourhoods refers to the above stated definition, and sustainable neighbourhood characteristics refer to the 10 themes as base from the local and governmental guidance, strengthened and completed by literature such as Khatibi et al.'s review (2023) or Ortiz-Fernandez et al.'s work (2023).

Though adopting one definition and set of characteristics, this research understands sustainable neighbourhood design should be site and user specific, as sustainability cannot be achieved without considering "place" (Ilovan & Markuszewska, 2022; Mateo-Babiano & Palipane, 2020). As Carl Steinitz said: "one size fits all does not belong to a design dictionary" (Haddad, 2012). This further emphasizes the dynamic nature of sustainable neighbourhoods, which need to account for the people and therefore place they are designed for (Partner, personal communication, March 27, 2025).

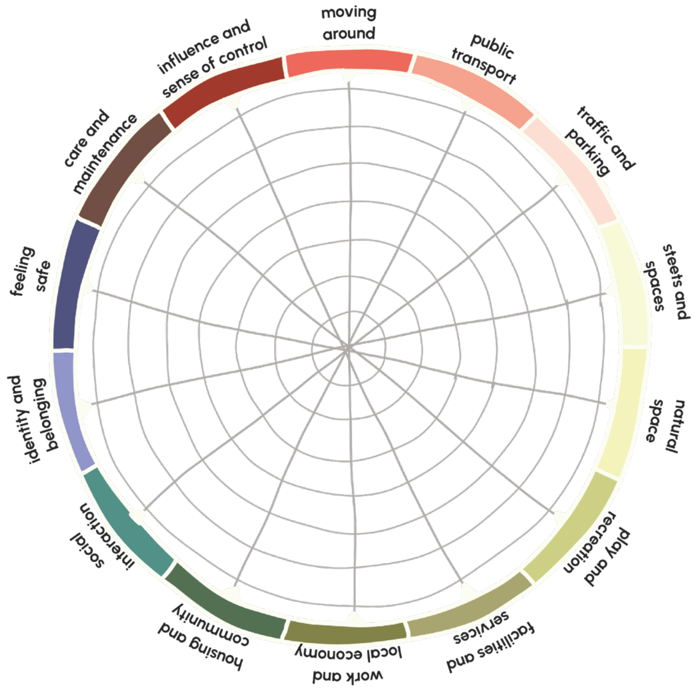


Fig. 4
Place Standard Tool
reproduced from Our Place.Scot (2025)

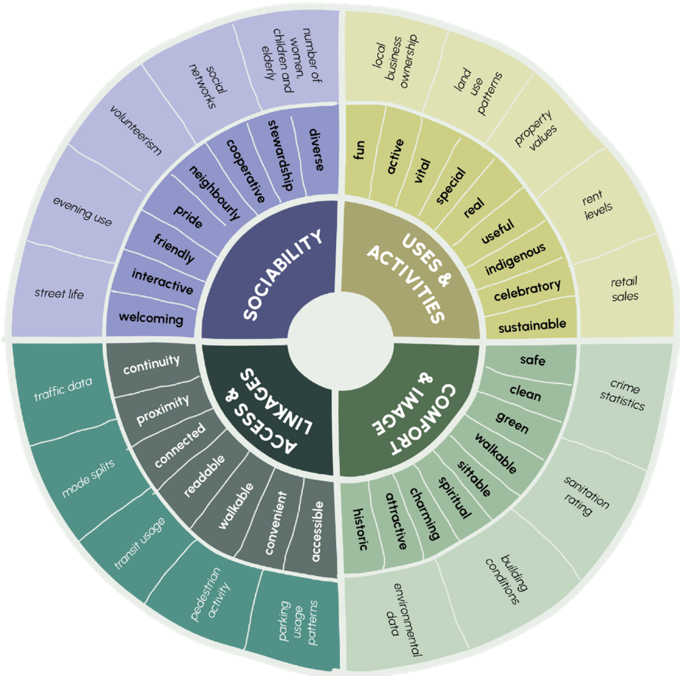


Fig. 5
PPS sustainable neighbourhoos wheel
reproduced from PPS (2025) "What makes a great place?"

4.3 Relevance of sustainable neighbourhood design: the importance of place

There is a gap between local community needs and values, and the designed urban neighbourhoods in practice (van Ameijde, 2022). This was demonstrated in the award-winning Woodberry Down estate regeneration project in the UK, which, after getting planning approval in 2024, received high criticism from local residents, calling the scheme inappropriate for the Hackney area and accusing it of disregarding the community's interests (Hackney Citizen, 2024; Hackney GOV.UK, 2024; Mykkanen, 2024). One way to bridge this gap is "place-based" design, which is sensitive to the differences in contexts and the relations between neighbourhoods, leading to more sustainable built environment (Axinte et al, 2019; Ellery et al, 2020). "Placemaking", a comprehensive application of place-based urban design (Amirzadeh & Sharifi, 2024), is gaining popularity globally and in the UK, both in academic research and in practice (Ellery et al, 2020; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025). Originating in the 1960s from thought leaders such as Jane Jacobs, Kevin Lynch and later Jan Gehl, placemaking is a human-centred approach to the design of community spaces which aims to create better places for people by shaping quality places to live, work, play and learn (Ellery et al., 2020; Moreira, 2021; Smaniotto Costa et al., 2024; Strydom et al., 2018). Community engagement, participation and emphasis on social and environmental aspects are core elements of placemaking, ultimately connecting people to place (Armizadeh & Sharifi, 2024; Axinte et al., 2019; Mateo-Babiano & Palipane, 2020).

To conclude, this research postulates that sustainable neighbourhoods should involve a place-based, and therefore inherently dynamic, design process. Going forward, any mention of sustainable neighbourhood design implies a place-based approach. Now that the theoretical base for sustainable neighbourhood design is established, the next section provides a framework to build on: Steinitz's Geodesign.

5.0 theoretical framework – TOOLS FOR DYNAMIC URBAN DESIGN: STEINITZ'S GEODESIGN FRAMEWORK

5.1 Steinitz' Geodesign framework

Geodesign – design that considers geography – is a dynamic design method that uses stakeholder input, geospatial modelling, impact simulations, iterative loops and real-time feedback to facilitate holistic designs and smart decisions (Haddad, 2012; Jorgensen, 2012; Li & Milburn, 2016; McElvaney & Rouse, 2015), as an effort to emphasize the interconnectedness between humans and the natural and built environment, as well as account for different stakeholders of an urban design project (Haddad, 2012; Li & Milburn, 2016; McElvaney & Rouse, 2015). In practice, Steinitz' model involves 6 steps (**Fig. 6**): the first half aim to describe the world as it is, assessing its condition and performance; the latter half then describe the world as it could be, evaluating proposed design alternatives and their impacts. For each step, a model helps represent, process, evaluate, change, impact and decide on design direction. With these, Geodesign aims to implement data-driven digital tools and approaches using geographic / spatial knowledge in order to collaboratively design and improve future environments via stakeholder engagement inputs (Li & Milburn, 2016; McElvaney & Rouse, 2015; Wissen Hayek et al., 2016).

As such, Geodesign is a response to the need for a place-based, holistic, integrated approach to planning, one that accounts for the interdependencies between systems, helps identify and anticipate the unintended consequences of our planning and policy decisions, and leverages results for a positive change by enabling public participation as integral part of the framework (Haddad, 2012; Li & Milburn, 2016; McElvaney & Rouse, 2015). This echoes the above definition of sustainable neighbourhoods, and Geodesign has proved particularly useful for design optioneering at the neighbourhood scale and addressing complex challenges such as climate change, economic inequality and declining public health (Haddad, 2012; Jorgensen, 2012; Li & Milburn, 2016; McElvaney & Rouse, 2015).

Overall, the Geodesign framework enables a comprehensive approach to addressing place-based, holistic sustainability and iterative design for neighbourhoods and will:

- guide this research's process
- act as a base for the proposed framework and urban design workflow in combination with the prototype tool
- determine the tool prototype's key steps and inputs

To continue, since the foundation for Geodesign and this study is data-driven design and the use of digital tools, these concepts are further explained below.

5.2 Data-driven digital tools for dynamic urban design

Data-driven urban design processes are open-ended tool-kits to achieve various user-driven outcomes, leading to more resilient, liveable, and participatory urban spaces (Ameijde, 2022; Maheshkar et al. 2024; Zhang, 2021).

Indeed, digital tools and digitization can improve the sustainability and quality of life of local communities as well as creating a common language (Smaniotto-Costa et al. 2024). From a designer's point of view, digital tools and other computational aided techniques help form-based planning projects via the development of analytical models to dynamically simulate, predict and optimize the performance of buildings and cities as complex multidimensional systems (Goldstein & Khan, 2017; Zhang, 2021 ; Zhang & Liu, 2019). Unfortunately, though digital tools can arguably play an important role in urban development, there is most focus on the potential for digital design tools to contribute to building scale, rather than community or urban scales (Toukola & Ahola, 2022).

Overall, data-driven digital design tools complement Steinitz's Geodesign approach and have the potential to further enable sustainable neighbourhood design. To go further, another intrinsic element of Geodesign are collaborative design processes. The framework and digital tool of this research build on these but achieve a more directly impacful collaboration input as well as more precise analysis of the actual and potential built form. The collaborative design processes are detailed below

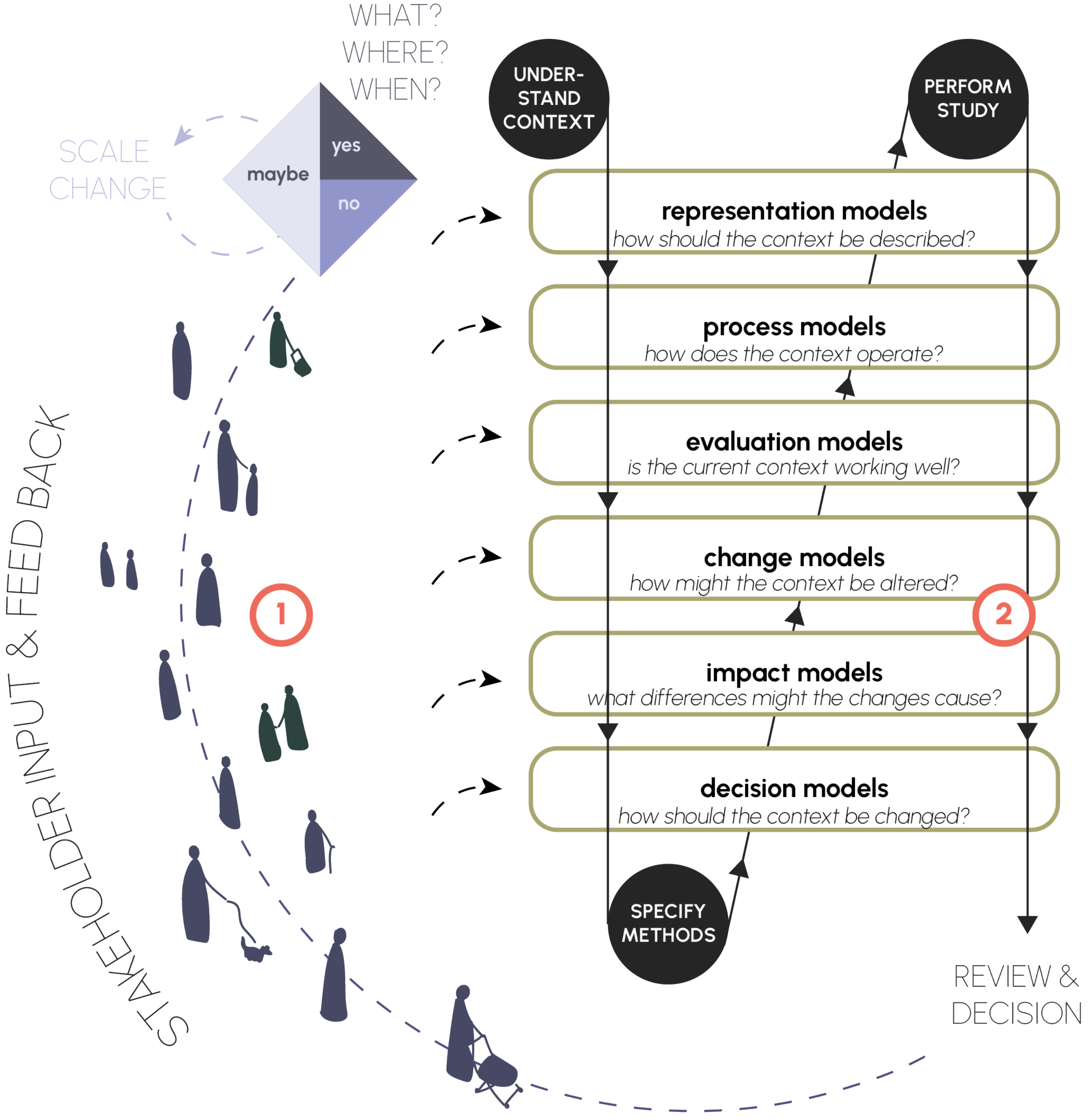


Fig. 6
Steinitz' Geodesign framework
adapted from McElvaney & Rouse (2015).
The numbers in red indicate this research's innovations:
1- direct local value input and weight into the analysis
2- detailed design option and built form models for precise neighbourhood resolution impact simulations

5.3 Collaborative design processes for dynamic urban neighbourhoods

The co-concepts are increasingly popular in public space and urban studies, with co-creation, co-production and co-design as tools to approach future-oriented problem solving between diverse stakeholders at all stages of a project (Brandsen, 2018; Carpenter et al., 2021; Lee et al., 2024; Michalik, 2023; Vargas et al., 2022). Collaborative design processes ensure the planning and delivery of effective public services by creating an environment of mutual respect and trust and building sufficient internal variety to address the complex urban challenges (Brandsen, 2018; Carpenter et al., 2021; Hamdan et al., 2021; Toukola & Ahola, 2022).

In practice, this collaborative result is achieved through "stakeholder engagement". Also called stakeholder participation, collaborative events, public engagement... stakeholder engagement refers to taking stakeholders into account during a project and involving them in its dynamic decision-making processes via a variety of methods such as interviews, forums, focus groups, workshops, 3D visualisations and Virtual Reality (VR) (Hamdan et al., 2021; Research Director, personal communication, April 8, 2025; Toukola & Ahola, 2022; Wissen Hayek et al., 2016). While urban development projects are usually initiated and led by municipalities, the public act as vital group of stakeholders and a variety of different stakeholders should be engaged with, despite concerns relating to expertise level, representation, interest and resources (Hamdan et al., 2021; Toukola & Ahola, 2022).

Although early-stage engagement sessions are the most impactful, the engagement process requires a dynamic approach, as the type of stakeholders involved and the issues they are concerned with change as the project develops, best practice being to engage in each stage of an urban design project, especially when aiming for sustainable neighbourhoods which are the direct link between people and city (Hamdan et al., 2021; Toukola & Ahola, 2022).

Still, engagement sessions are not enough to address the challenge of establishing integrated ongoing collaborative design processes which effectively take into account multiple economic, ecological and social aspects (Toukola & Ahola, 2022; Wissen Hayek et al., 2016). Indeed, the high complexity and temporal uncertainty of sustainability at the neighbourhood scale remain crucial difficulties which collaborative events alone cannot address (Hamdan et al., 2021).

To conclude this chapter, this research will be framed by the 10 characteristics of a sustainable neighbourhood and the Geodesign framework's core values: dynamic, place-based, collaborative, data-driven and digital tool enabled design. To continue, answering the research questions will involve a range or qualitative and quantitative methods, detailed below.

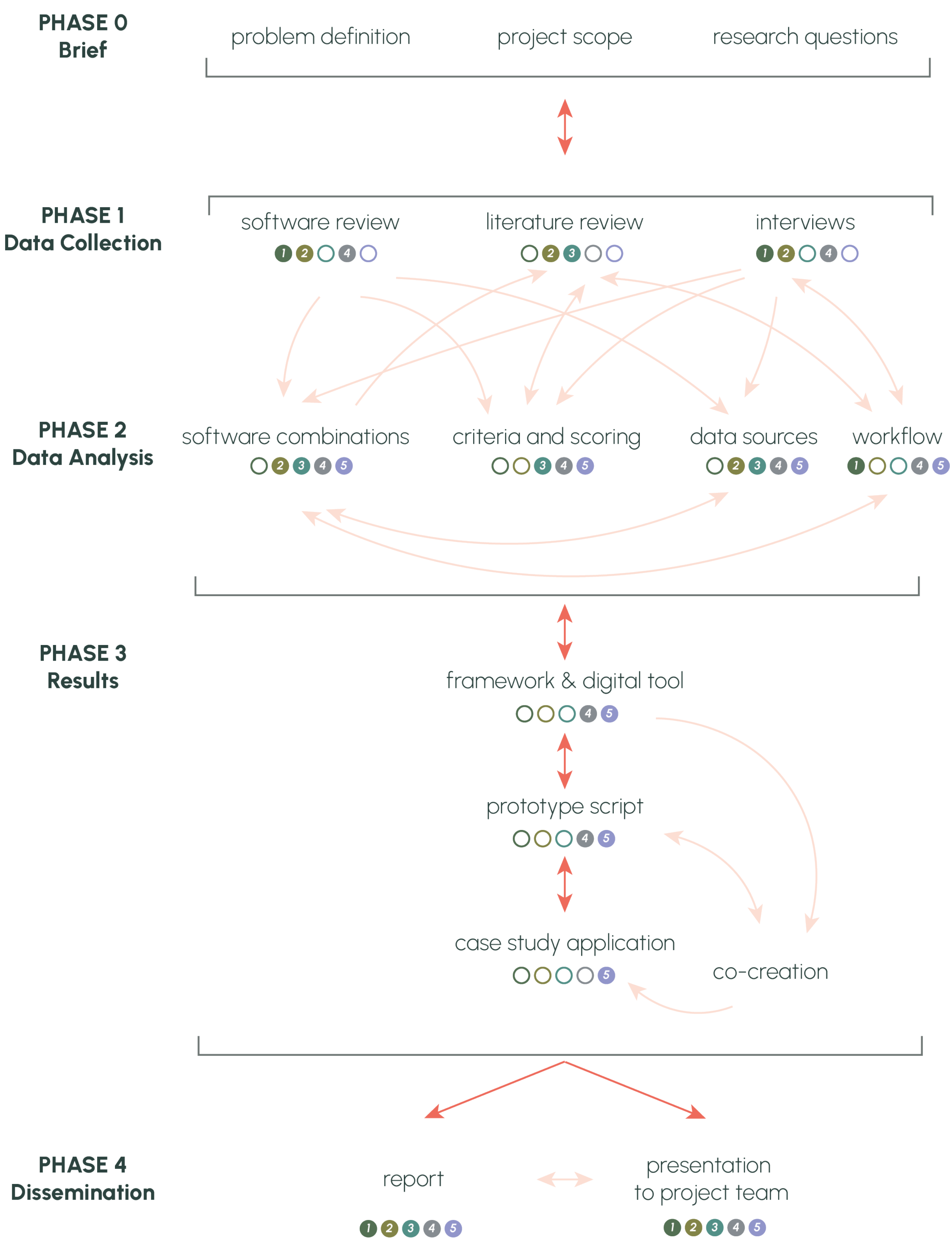
6.0 methodology - METHODS FOR A HOLISTIC CONTRIBUTION

Achieving the research aims and uncovering the dynamic framework and digital tool prototype which can support the iterative, place-based and holistic sustainable design of neighbourhoods in the UK is done via 4 key phases: brief, data collection, data analysis, results and dissemination. Throughout the entire process, a combination of qualitative and quantitative reseach methods are used and contribute dynamically to different research questions. This is illustrated in **Fig. 7** f

The methods chosen were framed by the scope of this research, which is as follows:

- Everyday-life neighbourhoods, in the UK
- Development of a digital tool used by sustainability consultants to facilitate design by combining existing software
- Research timeline of 6 months (February to July 2025) using most up to date literature, tools and data at the time of the research
- Research capability of an Architect / Engineer / Urban Designer with light programming experience and no prior software development theory
- Research output aimed for industry application

The research methods are interviews, literature review, software review, co-creation, tool development and case study, all of which further detailed below.



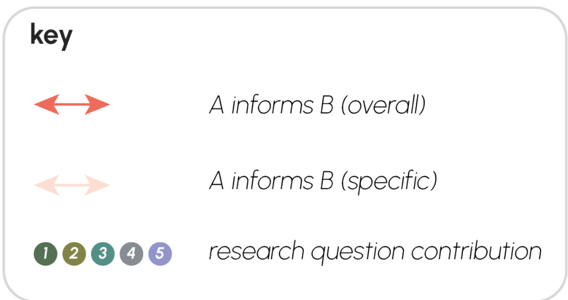


Fig. 7
Methodological framework
visual of how different methods complement each other for each phase of the research

6.1 Semi-structured interviews

Interviews are addressed at key industry experts (urban designers, partners, sustainability consultants, researchers, place-based digital tool designers, technological innovation leads) in the UK, or involved in UK based projects, as seen in **Table 3.** Interviews aim to clarify the urban design process, understand current use of digital tools in industry and inform in practice needs and requirements for the proposed framework and prototype. This informed all analysis sections by contributing the industry voice and view. Interviews ranged from 30 to 90 minutes and were in person where possible - via Teams if not. All interviews were recorded and transcribed via Microsoft Teams, with the explicit oral consent of the interviewee given before launching the recording. Explicit consent on detailed citations withn the report is also gathered pre-publication. Interview records (transcripts and meeting recordings) were saved in the research's Microsoft Teams project, integrally manually processed by the author, highlighting and classifying statements according to their contribution to the above mentioned aims. Records will be deleted after closure of the research project, in September 2025.

Questions were prepared and adapted for each interviewee, depending on their role and relevance and used as a guide / base, while not restricting the natural conversational flow, making the interviews semi-formal in nature. Questions based on relevance are in **Appendix B**, interviewee consent forms (interview + citation) are in **Appendix C**.

Role	Workplace	Relevance
Computational Design Lead	i2c	Digital tool development
Head of Innovation	YemeTech	Digital tool development
Urban Design Director	Ryder Architecture	Urban design
Founder	Urban Col.Labs	Digital tool development
Managing Partner	Martha Schwartz Partners (MSP)	Urban design
Sustainability Director	Okana Global	Sustainability consultancy
Urban Designer	Ryder Architecture	Urban design
Partner	Ryder Architecture	Urban design
Research Director	Ryder Architecture	Engagement process

Table 3
Interviewees
list of interviewees, their role and relevance to this research

6.2 In depth reviews

A literature review, conducted via WUR Library and Scopus search engines, contributed to identifying the research gap, providing a theoretical base, and answering sub research questions 1, 2 and 3 (workflow, digital tools combination and criteria). The search terms used include: *urban, neighbourhood, community, district, place-shaping, placeshaping, placemaking, place-based, Geodesign, digital tool, software, data-driven, simulation, design, design thinking, sustainable, built environment, co-creation, participation, criteria.*

While papers providing a holistic overview were prioritised (i.e., including notions of digital tools for sustainable neighbourhood design), literature was also selected for more specific knowledge of different relevant topics as per the key words above, with the author then combining information to form a coherent narrative. A total of 74 papers were reviewed in varying depth.

Similarly, the software review assessed digital tools available to the UK construction industry. To qualify for a review, a software / digital tool should address at least one of the identified gaps (holistic sustainability, iterative design, place-based analysis). A software review comprises of:

- software aim/purpose
- end user
- place in the designer's workflow
- dynamic versus static software statement
- physical scale statement
- sustainability scope statement
- conclusion on suitability for dynamic sustainable neighbourhood design

6.3 Collaborative events

A two hour co-creation session occurred on April 16th 2025; in Ryder Architecture offices in London (flyer in **Fig. 8**). The session aimed to collaboratively discuss and assess the progress to date and the prototype tool. While two urban designers (part of the interviewees) were invited, complications on the day meant that only one could attend. This meant there was more time to get full insight and offer a full prototype demo to the one attendee. However, it also means that only one voice was heard at that session, and post-session communication with the absentee as well as a presentation to and feedback session with Okana Global's partner council aimed to compensate this. The co-creation session consisted of a short presentation of the results and re-contextualization, followed by a demonstration of the prototype with critical feedback from the designer on the workflow details as well as digital tool features. Suggested improvements were applied when within the research scope, or recorded as part of further research opportunities. The co-creation inputs are cited throughout the report where relevant, and the raw hand recorded transcript is in **Appendix D**.

6.4 Prototype tool development

The output of this project is a prototype of a digital tool, which aims to enable sustainability consultants to collaborate with designers and engagement specialists to dynamically design sustainable neighbourhoods. The tool coding is in Python language and hosted both as a series of original Python (.py) and Grasshopper (.gh) scripts. The Grasshopper scripts include the innovative use of both existing and original Grasshopper modules. An AI (Claude.ai) was used to facilitate script development, assisting with coding language / vocabulary / grammar, with the overall system architecture, narrative, workflow and key functionality decisions determined by the author. In practice, this meant the creation of a Claude.ai Project with clear instructions and multiple conversations with targeted questions and troubleshooting prompts. Python scripts are developed and run using the free student license for PyCharm Integrated Development Environment (IDE). For non-students, another open-source IDE can be Visual Studio Code.

Fig. 8
Co-creation flyer
digital invitation to the Dynamic Digital tool prototype co-creation

The prototype includes: setup scripts (.py), analysis scripts (.py), visualisation scripts (.gh), design optioneering scripts (.gh), and optioneering analysis scripts (.gh and .py). The analysis scripts are developed according to the selected criteria from sub research question 2. Pseudo-codes of all original scripts are found in **Appendix E**.

Ease of use, modularity, automation in balance with customisation, results interpretation and transparency are key in the prototype development. This translates in a single input point for the python scripts and few clearly flagged / instructed input points for the Grasshopper script. Running the prototype requires the pip install of: *argparse; datetime; geopandas; geopy; logging; math; matplotlib; netowrkx; numpy; os; pandas; pathlib; shapely.geometry; scipy.spatial; subprocess; sys; time; tqdm; and warnings*. Data used in the tool is:

- open source
- nationally available (UK)
- neighbourhood resolution
- geospatial (i.e., not a statistic)
- relatable to design interventions and sustainability criteria
- from verified and regularly maintained sources

6.5 Case study project

As the final objective of this research is to have an actionable, real solution and impact, using a case study application for the project was essential. The case is an active project from Ryder Architecture's portfolio: the regeneration of the Hirst, a neighbourhood of Ashington in Northumberland, with client Northumberland County Council. This project aims to examine options for the regeneration of the Hirst housing estate in the town of Ashington to attract investment, involve the local community and drive forward the future of the area (Urban Design Director, personal communication, March 24, 2025).

Data used from the project includes insights into the engagement process, insights into the design process and design option models.

These methods contributed to a complete and holistic research. The next sections consecutively answer research questions, informed by the findings from the above methods. First, the urban design workflow is examined, then digital tools' potential is stated, followed by the establishment of detailed design criteria which can be used in this research for sustainable neighbourhood design. This all results in the Dynamic Framework and prototype for the Dynamic Digital tool for sustainable neighbourhood design, and their application on the case study project.

7.0 analysis - WORKFLOW FOR SUSTAINABLE NEIGHBOURHOOD DESIGN

This section answers the first research sub-question: *What is the urban designer's workflow for sustainable neighbourhood design projects in the UK?*

Solving complex interrelated problems within the design workflow with effective use of digital tools is yet to be addressed (Li & Milburn, 2016; Wissen Hayek et al., 2016). For this research, it is therefore essential to understand the current best practice urban design workflow for sustainable neighbourhood projects, in order to identify where might a Dynamic Digital tool be needed, and what it should do. Best practice urban design projects are those which involve a collaboration between engagement, design and sustainability flows (Head of Innovation, personal communication, March 13, 2025; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025), which contribute to, respectively, ensuring place-based; iterative; and holistic design for sustainable neighbourhoods - the three points of the Gap Triangle.

7.1 Iterative design - RIBA Stages

In the UK, the Royal Institute of British Architects (RIBA) provides a framework for all construction disciplines used as guidance for professional services, organising the process of briefing, designing, delivering, maintaining, operating and using a building into 8 stages (RIBA, 2020) (**Fig. 9**). The urban design workflow broadly follows those stages, typically going as far as stage 2, but with flexibility from the designers project per project (Founder, personal communication, March 19, 2025; Managing Partner, personal communication, March 20, 2025; Research Director, personal communication, April 8, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025).

In practice, for masterplans and urban regeneration projects, RIBA stages are mostly referred to for funding / communication / administrative purposes (Urban Design Director, personal communication, March 24, 2025), and the designers' workflow is mainly organised around the key tasks of (Hamdan et al., 2021):

1. Conceptualisation: framing initial expectations and achieving a common definition of the problem with key stakeholders. (Hamdan et al., 2021; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, April 8, 2025).

2. Preparation: setting the project direction: examines project assets, constraints, gaps, opportunities, with Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis, resulting in a clear brief and project timeline. During this stage, a site analysis is also conducted, typically via desktop studies and site visits. This can include spatial data, site history, urban context, culture, social patterns and environmental impacts (Founder, personal communication, March 20, 2025; Hamdan et al., 2021; Managing Partner, personal communication, March 19, 2025).

3. Implementation: ideating, visioning, conceptualising, optioneering, producing strategic solutions (Managing Partner, personal communication, March 20, 2025) in line with the defined brief and informed by the site analysis. This is iterative by nature and depends on regular communication within the project team itself and from the designers to clients and local stakeholders. Essentially, it involves following through on commitments for project delivery (Hamdan et al., 2021).

4. Closure: handing over the project, enabling user stewardship and once constructed, reflecting on the project success. This is done by contemplating the actual use of the designed spaces, any gaps with the design intention and transferring learned

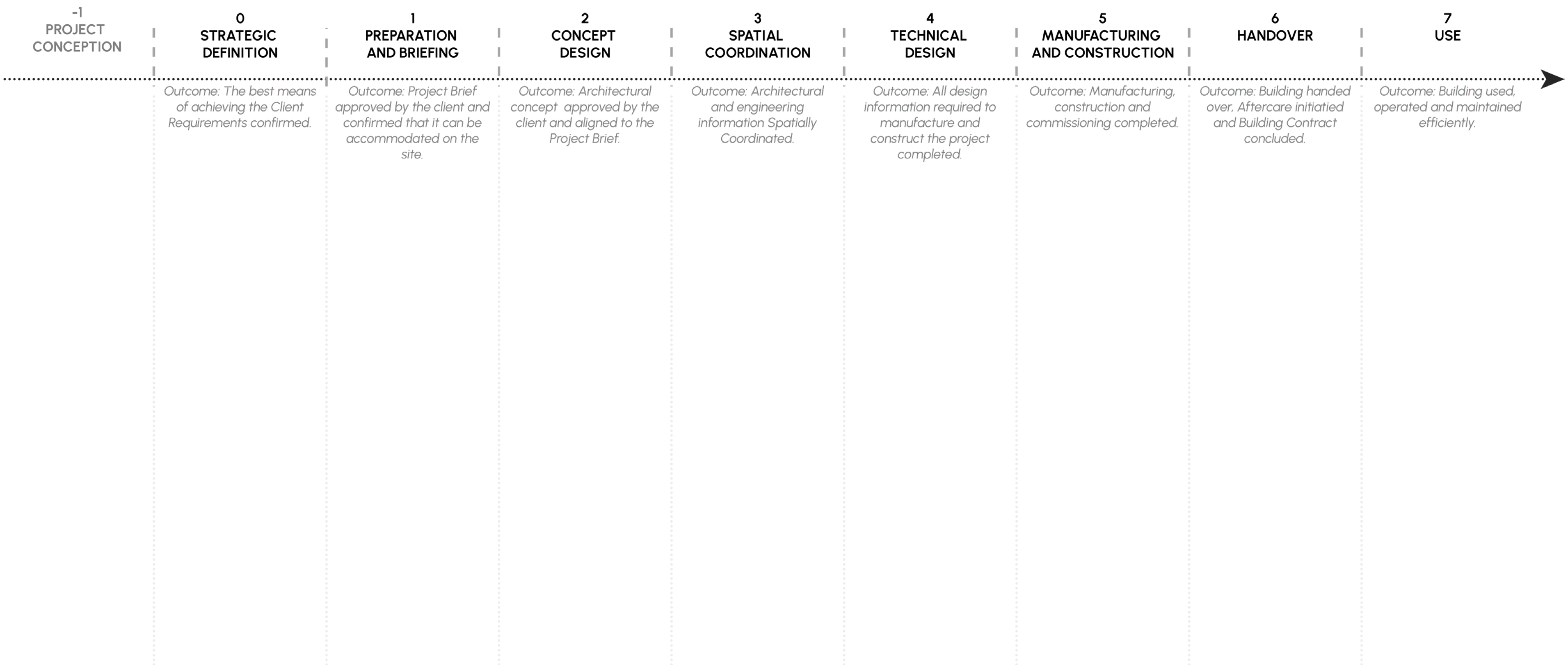


Fig. 9
RIBA stages
adapted from RIBA's Plan of Works (RIBA, 2020) with the addition of stage -1 project conception, derived from interview conversations with Partner and Research Director (April 8, 2025)

experiences forward to the broader project ecosystem (Founder, personal communication, March 20, 2025; Hamdan et al., 2021; Managing Partner, personal communication, March 19, 2025).

From this section, the iterative urban design workflow is clear, divided in 4 key steps: Conceptualisation, Preparation, Implementation and Closure. This will be used as a base to situate the two other flows of engagement and sustainability.

7.2 Place-based approach - Engagement sessions

To begin with, a core of the place-based approach are engagement sessions. Nevertheless, RIBA Stages do not require the incorporation of engagement sessions and while there is an Engagement Overlay to the Plan of Works (RIBA, 2024), it is not the industry default approach (Research Director, personal communication, April 8, 2025). It is clear that collaborating with engagement experts can be beneficial at every stage of an urban design project, on a case-by-case basis, ensuring a place-based approach and in line with the Geodesign framework (McElvaney & Rouse, 2015; Partner, personal communication, March 27, 2025; Research Director, personal communication, April 8, 2025; Urban Design Director, personal communication, March 24, 2025).

Indeed, although only scarce attention is paid to the engagement of various stakeholders in urban development projects (Toukola & Ahola, 2022), best practice projects involve engagement specialists for sessions potentially at every stage, but critically in early stages and genesis of the project often times happening at stages 0-1 or even "stage minus 1", determining the need itself for a project (Managing Partner, personal communication, March 20, 2025; Partner, personal communication, April 8, 2025; Research Director, personal communication, April 8 2025; Toukola & Ahola, 2022; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025).

For sustainable neighbourhood projects, stakeholder engagement can contribute to the design stages as follows:

1. Conceptualisation: identifying the stakeholders, their relations and resources, and collaboratively shaping the brief (Hamdan et al., 2021; Managing Partner, personal communication, March 20, 2025; Partner, personal communication, April 8, 2025; Research Director, personal communication, April 8, 2025; Urban Design Director, personal communication, March 24, 2025). In the more common case where the client has an existing vision, they want to make sure community voices are heard (Hamdan et al., 2021; Urban Designer, personal communication, March 24, 2025).

2. Preparation: complementing the desktop studies and site visits with local stakeholder interactions to gain a full picture of the site - published data can give part of the story but is not always representative of the reality (Research Director, personal communication, April 8, 2025). Collaborating with teams local to the project site can also help get a better understanding (Managing Partner, personal communication, March 20, 2025).

3. Implementation: collaboratively designing solutions and assessing options, with regular feedback between designers and stakeholders (Hamdan et al., 2021; Urban Design Director, personal communication, March 24, 2025).

4. Closure: contributing to user stweardship via regular engagement throughout the workflow, ensuring stakeholders feel involved and part of the project (Hamdan et al., 2021; Research Director, personal communication, April 8, 2025). Post-Occupancy Evaluations (POEs) – held a year after project completion – gather direct feedback from end users on the project success (Managing Partner, personal communication, March 20, 2025; Research Director, personal communication, April 8, 2025).

There are a range of stakeholders that can participate in and benefit from local engagement sessions and their resulting common language. Different stakeholders have different perceptions of the ongoing challenges although there is often a core of 60-70% common to all (Partner, personal communication, 27 March, 2025). Academic research emphasizes the importance of engaging with local residents and the project client (often local council), to which industry professionals add speaking to service providers such as police and health departments, as they dispose of a combination and condensed amount of knowledge from the site's use, needs, values and mid to long term development plans, which contrasts with residents' immediate, day-to-day needs - both are equally important to consider, though with the understanding that immediate needs might become redundant in time and not relate a broader interconnected sustainability picture (Hamdan et al., 2021; Partner, personal communication, March 27, 2025; Research Director, personal communication, April 8, 2025; Sustainability Director, personal communication, March 27, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025). Another challenge is hearing all the voices, as certain groups can be unintentionally marginalised from the engagement process (Ellery et al., 2020). The importance of engaging with the local youth was also highlighted (Urban Designer, personal communication, March 24, 2025). Finally, it is common, although not mandatory, for designers of the project team to attend engagement sessions (Research Director, personal communication, April 8, 2025).

While the organisation and coordination can be challenging, processing the data is currently the biggest pain point (Hamdan et al., 2021; Research Director, personal communication, April 8, 2025; Urban Designer, personal communication, March 24, 2025; Partner, personal communication, April 8, 2025; Urban Design Director, personal communication, March 24, 2025). Indeed, while conducting sessions physically ensures best interactions and results, this causes challenges for data recording (Michalik, 2023; Research Director, personal communication, April 8, 2025). Notes, written on post its and flip chart pages, have to be sorted and digitised manually so that they can be communicated and used by the design team and clients / stakeholders (Partner, personal communication, April 8, 2025; Research Director, personal communication, April 8, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025). In the digitisation there is a subjective filtering and simplification of information done by the expert and the designers (Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025).

As such, the workflow for integrating engagement results in the project design can be more streamlined and effective (Partner, personal communication, April 8, 2025; Research Director, personal communication, April 8, 2025; Urban Design Director, personal communication, March 24, 2025). Nevertheless, throughout project stages, and given best practice planning of engagement sessions, the engagement specialist is able to represent the voices of the local community and identify their priorities, which can then be communicated to designer and sustainability consultant (Research Director, personal communication, April 8, 2025).

The next section looks at the use of digital tools for holistic sustainability used within the current best practice urban design workflow at the neighbourhood scale.

7.3 Holistic sustainability - Digital tools

The tools for sustainable design used throughout the workflow are mainly concentrated at the early stages, where they are most impactful (Founder, personal communication, March 19, 2025; Managing Partner, personal communication, March 20, 2025; Sustainability Director, personal communication, March 27, 2025).

For urban neighbourhood scale projects, digital tools contribute to sustainability by:

1. Conceptualisation: facilitating the engagement process via council driven applications such as "Bang the Table", a tool which gathers feedback from the local community (Research Director, personal communication, April 8, 2025). Digital tools used to process engagement data and communicate results after a session are currently insufficient or inadequate: for example, AI brings some data privacy concerns, as well as concerns that certain key information or tone of voice will not be picked up, though it has the potential to output vocabulary statistics (e.g., "50% people mentioned transport as a current pain point") (Research Director, personal communication, April 8, 2025). As such, a hybrid approach is usually preferred - written results can be digitalised via Miro (web-based whiteboard) and visualised on Powerpoint presentations (Research Director, personal communication, April 8, 2025; Urban Design Director, personal communication, March 24, 2025). The sustainability consultant uses the results of early engagement to establish goals.

2. Preparation: facilitating site analysis via web-based digital tools to understand the environmental and socio-economic contexts. For the former, Forma, ClimaTool and PreDesign allow various levels of local weather file interpretation (Sustainability Director, personal communication, March 27, 2025). For the latter, YemeTech aims to provide comparable quantities of a neighbourhood's quality, providing local data insights for a range of themes (Head of Innovation, personal communication, March 13, 2025; Partner, personal communication, April 8, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025). Finally, geolocated visualisation tools such as Google Maps or Google Earth can also contribute to early-stage site analysis (Toukola & Ahola, 2022; Urban Designer, personal communication, March 24, 2025).

3. Implementation: 3D modelling of site local context with web data bases like Cetopo, Overture Maps or Open Street Maps (OSM), which allows the download of topographic models in formats compatible with common modelling software (Revit, Sketchup and Rhino) (Computational Design Lead, personal communication, March 11, 2025; Head of Innovation, personal communication, March 13, 2025). During the design stage, environmental analyses can be conducted with Grasshopper's Ladybug suite (Computational Design Lead, personal communication, March 12, 2025; Sustainability Director, personal communication, March 27, 2025; Zhang & Liu, 2019), while geodata manipulations can be done with GIS software such as ArcGIS or QGIS (Zhang, 2021). Detailed sustainability analysis, like LCAs or energy performance software require separate modelling

4. Closure: after occupancy, collecting user experience via digital surveys, enabled by digital applications like Qualtrics (Research Director, personal communication, April 8, 2025).

It should be noted that only the design modelling tools are used by default in the urban design workflow. Indeed, the use of engagement and sustainability analysis tools as part of an integrated process from the outset, remain applied to a minority of projects (though increasing) and rely on the personal interest and own initiative of design members to use certain tools themselves and / or consult a sustainability expert, who will be brought in and out at a point in time in a project to try and bring all the information together into a coherent narrative, using tools where available, noticeably biased towards environmental sustainability (Co-creation, personal communication, June 16, 2025; Computational Design Lead, personal communication, March 12, 2025; Sustainability Director, personal communication, March 27, 2025).

Overall, it is a sporadic and sometimes crude process, which could be more streamlined, but this sustainability workflow, with these tools, is currently the best option (Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025).

7.4 Current workflow for sustainable neighbourhood design

Concluding this chapter, the current workflow for sustainable neighbourhood design is illustrated in **Fig.10**.

While similarities to the Geodesign framework can be drawn, notably with stakeholder input and regular use of digital tools, the current best practice urban design workflow lacks the systematic integration of those, as current projects tend to rely on linear development templates (Hamdan et al., 2021). Indeed, though parallel, these workflows remain somewhat isolated, converging to a single target (the designer) rather than iteratively and dynamically informing each other, with knowledge acquired at the beginning of the project – from either engagement sessions or environmental analyses – often not being integrated in a holistic manner (Co-creation, personal communication, June 16, 2025; Hamdan et al., 2021).

Consequently, there is a clear opportunity and need for a systematic, iterative and dynamic framework for the urban designer's workflow which enable sustainable neighbourhood design by dynamically interweaving the engagement, design and digital tools for holistic sustainability flows, ensuring knowledge integration and avoiding discontinuities (Head of Innovation, personal communication, March 13, 2025; Hamdan et al., 2021; Sustainability Director, personal communication, March 27, 2025). This would contribute to addressing urban digitalisation responsibly, integrating data and design in a way which responds to community needs.

The following section examines the potential of existing digital tools to provide this dynamic and integrated approach; and how a combination of these might become the base for a Dynamic Framework and Digital tool for sustainable neighbourhood design.

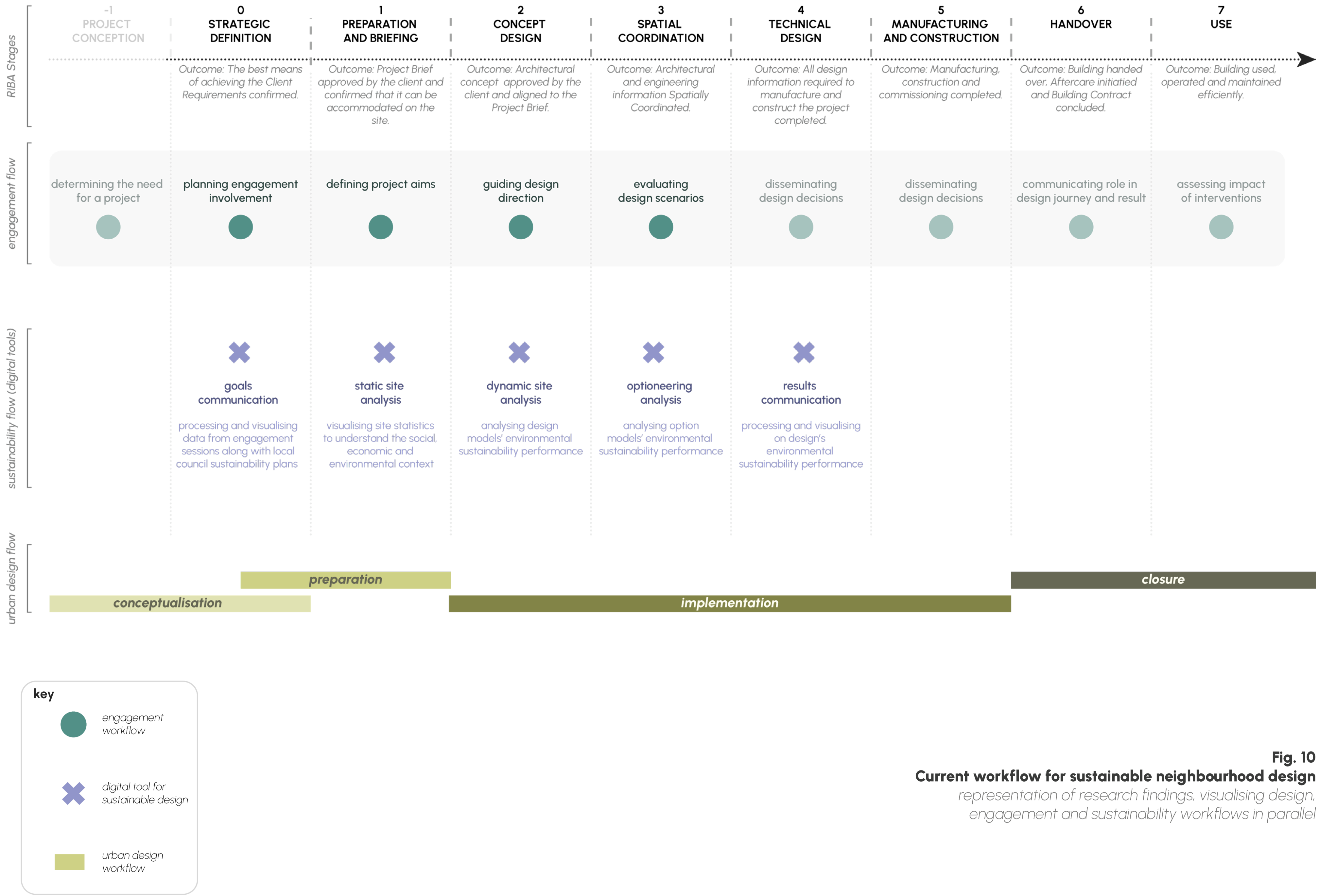


Fig. 10
Current workflow for sustainable neighbourhood design
representation of research findings, visualising design, engagement and sustainability workflows in parallel

8.0 analysis - DIGITAL DESIGN TOOLS FOR SUSTAINABLE NEIGHBOURHOODS

This section answers the second research sub-question: *What are the current digital tools for sustainable neighbourhoods' strengths, what are they lacking and how might they complement each other?*

As seen in the Gap Triangle, in order to complement the design workflow, a digital tool for sustainable neighbourhood design should dynamically provide a holistic, place-based and iterative interaction with the design model. Currently, there is no digital design tool which covers all three requirements, however, existing digital tools might be combined and used together (Computational Design Lead, personal communication, March 11, 2025).

8.1 Iterative design – Rhino with Grasshopper

For a digital tool to dynamically integrate into the urban design workflow, it needs to be compatible with the modelling software used by designers in practice (Revit, Sketchup, Rhino) (Urban Designer, personal communication, March 24, 2025; Co-creation, personal communication, June 16, 2025; Sustainability Director, personal communication, March 27, 2025). While these lack an environmental analysis scripting environment, they can be used in conjunction with Grasshopper, an open source add on to Rhino, back-end coded in Python, offering a user-friendly and visualised coding interface (Zhang & Liu, 2019). These range from parametric modelling to environmental analyses thanks to open-source plug-ins such as the Ladybug suite (Ladybug, HoneyBee, Butterfly). As such, Rhino used with Grasshopper is better for multi-scenario testing than non-algorithmic modelling software (Zhang & Liu, 2019). More than the analysis potential, Grasshopper can be used to import modelled geometry from Revit (most common) and Sketchup, making it the perfect translation platform between design models and place-based sustainability analysis scripts. **Fig. 11** visualises a typical urban project analysis workflow and the different software involved at each step:

This workflow has been proven to work in practice at the neighbourhood scale (Sustainability Director, personal communication, March 27, 2025), and is therefore selected for this study as the key to the dynamic model analysis features. However, grasshopper analyses currently have a bias towards environmental sustainability (with micro-climate analysis or building scale user comfort indicators) and does not present the capacity to operate neighbourhood specific simulations, both key for holistic sustainability and place-based requirements of the dynamic digital tool (Sustainability Director, personal communication, March 27, 2025). Nevertheless, though place-based and holistic sustainability analyses are not possible in grasshopper, there is potential to import pre-processed OSM data and .geojson files for visualisation, through the plugins Elk and Heron (Zhang & Liu, 2019).

As such, to meet the aims of this research, Grasshopper can be used in combination with separate GIS data analysis.

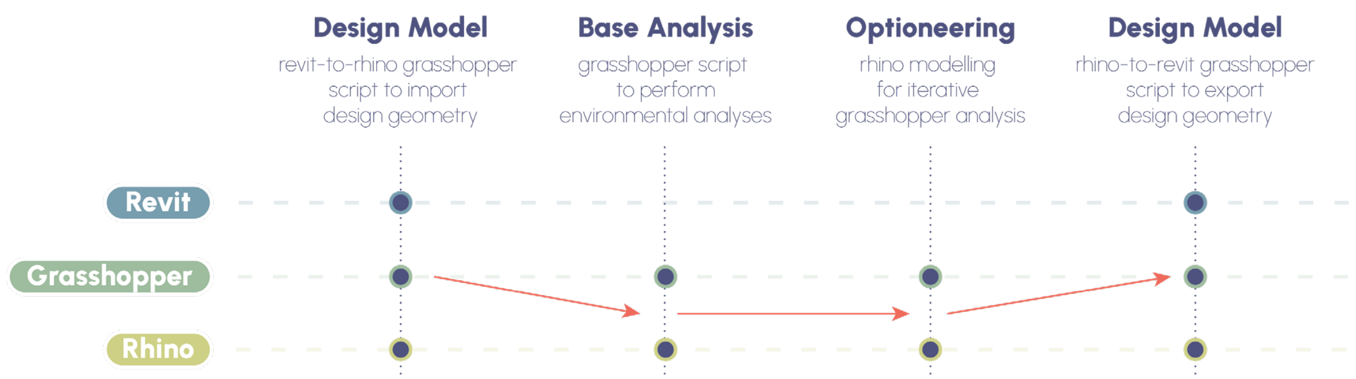


Fig. 11
Digital tools - current
current workflow for integrating design iterations with sustainability analysis software. Revit (most common modelling software in practice in the UK), and Rhino with Grasshopper are core to navigating the Deisgn Model, Base Analysis, Optioneering and back to Design Model steps.

8.2 Place-based approach – GIS data processing and coding

In line with the Geodesign framework, the digital tool's place-based approach manifests in 2 ways:

- the use of local GIS data within the analysis
- the integration of local values within the analysis

There are a number of digital tools which provide in depth (static) analysis of the local context: for example, YemeTech is a web-based digital design tool which translates community data into measurable insights, evaluating the quality of a space, with focus on demographic elements (Head of Innovation, personal communication, March 13, 2025; Research Director, personal communication, March 27, 2025). Though highly relevant to the topic of sustainable neighbourhood design, this tool is not able to seamlessly integrate into a dynamic design workflow as the results cannot be downloaded in formats compatible with further data processing and analysis scripting (Head of Innovation, personal communication, March 13, 2025; Urban Designer, personal communication, March 24, 2025).

In order to use local spatial data within the analysis, GIS software, such as ArcGIS or QGIS (free), are suitable in geoprocessing and manipulation of geodata (ESRI, 2025; QGIS, 2025), and python coding displays libraries such as osmnx, geopy, overpy, networkx and geopandas which enable complex analysis of geodata. These tools can be used to ensure the neighbourhood's place-based and holisitc sustainability data is successfully pre-processed and integrated into a dynamic analyses and calculations, before being integrated within a host modelling software. GIS software and python coding are therefore suitable for the inclusion of local geospatial data for sustainable neighbourhood projects.

The integration of local values, as an output of engagement sessions, is however more innovative as no tool currently does so, despite this data being most representative of neighbourhood context and specific needs, avoiding the tick-box approach (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Head of Innovation, personal communication, March 13, 2025; Partner, personal communication, March 27, 2025; Research Director, personal communication, April 8, 2025; Sustainability Director, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025). The ad hoc input of project specific local values requires a flexible and transparent tool which allows for pre-determined and intuitive user input, which Grasshopper's visual coding environment offers.

As such, python coding and GIS software processing can be used to pre-process local GIS data, and Grasshopper scripting can be designed to dynamically integrate local values within the analysis.

8.3 Holistic sustainability – Python calculations and data processing

Finally, achieving holistic sustainability depends on the analysis script design, the themes covered by data and the ability to integrate or relate the analysis results to the design brief and workflow (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Head of Innovation, personal communication, March 13, 2025; Sustainability Director, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025).

For this, it is crucial to avoid the current silo-ed approach and keep the overarching and dynamic definition of sustainability in mind when intervening in urban settings, especially as tunnel vision decisions can be counterproductive (Axinte et al., 2019; Bibri, 2020; Khatibi et al., 2023; Partner, personal communication, March 27, 2025; Smaniotto-Costa et al., 2024; Sustainability Director, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025; Zhang, 2021). Despite this knowledge, the complexity of the task makes it hard to address as it requires the coordinated consideration of multiple interconnected strands as eluded to in the 10 themes of the National Design Guide (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Head of Innovation, personal communication, March 13, 2025; Sustainability Director, personal communication, March 27, 2025).

As such, existing software which allow for customised data input, processing and analysis are favoured. Python, GIS software and Grasshopper propose this malleability and, importantly, the former two have a capacity to operate complex calculations with neighbourhood scale datasets.

As seen before, Grasshopper's place-base analysis potential by the in app coding is limited to only IronPython libraries. CPython's matplotlib, shapely, and pandas libraries provide the functions for extensive data analysis; and folium, geoplot and leaflet allow for visualisation of these analysis results. Results can also be saved as geopackages or in .geojson formats which are then compatible for visualisation, import and manipulation in GIS and Rhino with Grasshopper, closing the loop (Computational Design Lead, personal communication, March 11, 2025).

8.4 Combination of existing digital tools

In conclusion, a clear red thread points to the use of the following combination of existing digital tools: Grasshopper (with Rhino) enables the dynamic integration within the urban design workflow, interacting with design models. Grasshopper also provides a basic python coding environment and most importantly the ability to import and visualise pre-processed geodata, therefore acting as the essential connecting point between modelling software and data manipulated in GIS and analysed in python, ensuring a dynamic place-based approach at the neighbourhood scale. Finally, dynamic and holistic sustainability can be achieved by using varied sources of data, appropriately processed with Python and visualised in Grasshopper. The results can then be re-integrated within the Rhino/Grasshopper environment, ensuring the iterative loop into the design workflow. The combinations involved for each point of the Gap Triangle are represented in **Fig. 12** – essentially, this research is trying to build a common platform or interface of existing tools, connecting the dots to facilitate a dynamic iterative, place-based and holistic sustainable neighbourhood design (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Partner, personal communication, April 8, 2025).

Such a combination contributes to responsible urban digitalisation, offering the digital foundation which allows for the required dynamic processes (place-based, iterative design, holistic sustainability). Now that the technical possibility of achieving a dynamic digital tool for sustainable neighbourhoods is confirmed via the combination of existing software, the next chapter examines the specific criteria of sustainable neighbourhoods that such a tool could consider.

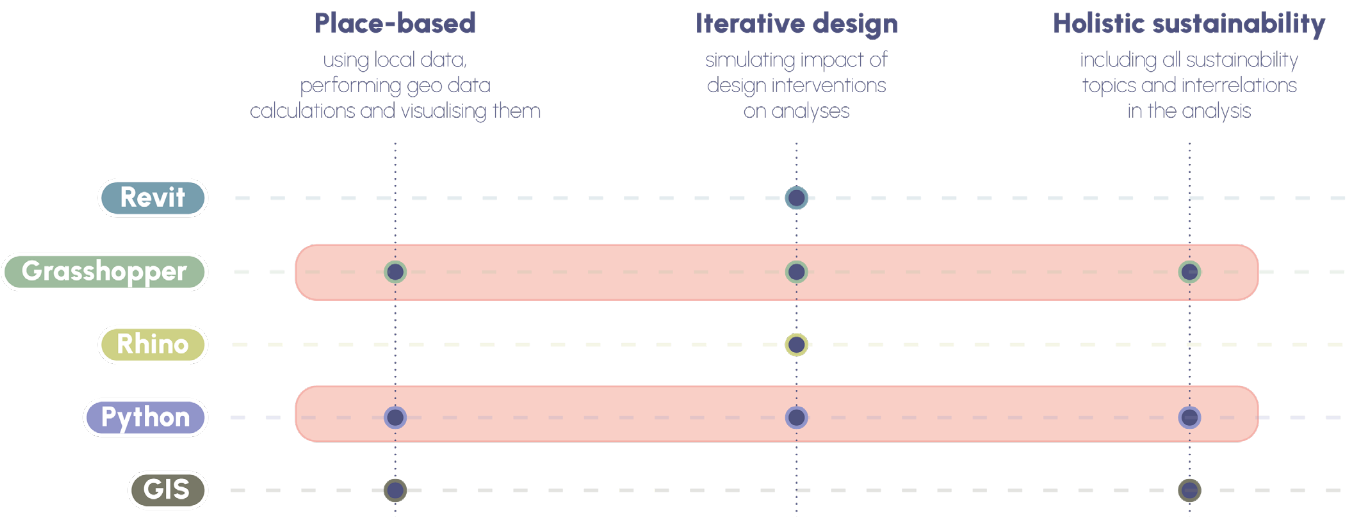


Fig. 12
Digital tools - Dynamic potential
Grasshopper and Python as red threads for a Dynamic digital tool in the urban designer's workflow

9.0 analysis – CRITERIA FOR SUSTAINABLE NEIGHBOURHOODS

This section answers the third research sub-question: *Which criteria of a sustainable neighbourhood could a dynamic digital design tool for sustainable neighbourhoods in the UK consider?*

The characteristics of a sustainable neighbourhood are known and have been described in the theoretical framework, using the 10 themes of the National Design Guide as base (Context, Identity, Built Form, Movement, Nature, Public Spaces, Uses, Homes and Buildings, Resources, Lifespan) (Ministry of Housing, Communities and Local Government, 2021). Now, the detailed criteria which contribute to sustainable neighbourhoods should be determined, meeting the following conditions:

- quantifiable: able to translate qualitative elements into specific measurable criteria under the National Design Guidance's 10 themes of sustainable neighbourhoods.
- spatial: relating to the designer's workflow, as in, being an intervention which the designer can implement
- neighbourhood scale: place-based data availability and resolution

9.1 Holistic sustainability - quantifiable criteria

The first condition is for the criteria to be quantifiable to reflect the sustainability of a neighbourhood. For this, existing frameworks, such as Neighbourhood Sustainability Assessments (NSAs), provide guidelines, categories, indicators, numerical value thresholds and benchmarks for designers to evaluate their project's sustainability performance (Founder, personal communication, March 19, 2025; Head of Innovation, personal communication, March 13, 2025; Khatibi et al., 2023; Marique & Teller, 2014; Ortiz-Fernandez et al., 2023). The key NSAs are examined below, acting as a first step to selecting criteria for the Dynamic Digital tool.

THe UK based Building Research Establishment (BRE)'s BREEAM Communities standard provides a framework to support planners, local authorities, developers and investors to integrate and assess sustainable design in the masterplanning of new communities and regeneration projects (BREEAM, 2025). Initially only for new builds, this world's first environmental assessment method expanded to communities with a more holistic approach to sustainability, featuring 6 categories: governance, social and economic well-being, resources and energy, land use and ecology, transport and movement and innovation (BREEAM, 2025). Completion of these categories' quantified criteria, with validation of submitted evidence, leads to an internationally recognised certification, with scores ranging from Unclassified (<30%) to Outstanding (≥ 85%) and serve as a global metric and reference for projects, with BREEAM score ambitions often cited as part of the client brief / vision. Similarly, LEED for Cities and Communities is an NSA from US Green Building Council (USGBC) that aims to provide local leaders, developers and practitioners with a powerful sustainability framework and certification program aligned with the SDGs (USGBC, 2025). They propose separate guidance and assessments between cities and communities, and within the latter differentiate between new and existing. Though the themes broadly relate to BREEAM's, LEED also proposes a number of credits awarded for effective integration of the guidelines within the design process. This is however not part of the "required" steps. Other NSAs include Japan-developed CASBEE-UD and Australia's Green Star-Communities (Khatibi et al., 2023; Marique & Teller, 2014; Ortiz-Fernandez et al., 2023).

While NSAs contribute to the quantification of neighbourhood quality, they receive a number of criticism, including environmental sustainability bias and lack of consideration of the local context (Khatibi et al., 2023; Ortiz-Fernandez et al., 2023). The NSAs are often pejoratively regarded as "checklists" of which disregard human priorities and local values and lack a spatial approach and iterative relation to design. (Khatibi et al., 2023; Marique & Teller, 2014; Ortiz-Fernandez et al., 2023; Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025). Other limitations of NSA include the lack of consideration for the interlinkages of neighbourhood sustainability; the non-transparent and top-down approaches; the lack of consideration of government management culture and institutional dimensions as critical aspects of neighbourhood sustainability; and for UK's BREEAM-C specifically, the lack of emphasis on social sustainability questions such as gentrification, equity, happiness (Khatibi et al., 2023; Urban Design Director, personal communication, March 24, 2025). Finally, the lack of consensus on one approach and the existence of many scoring systems and certificates make it challenging for designers to approach sustainability (Computational Design Lead, personal communication, March 11, 2025).

For this project, holistic sustainability is essential. To avoid any bias, criteria are selected and classified along the 10 themes of the National Design Guide in thorough consultation of their other published documentation (Ministry of Housing, Communities and Local Government, 2021) – for example, the criterion "Public Transport Access" contributes to the themes "Context", "Built Form" and "Movement").

Overall, NSAs provide a strong base for quantification of neighbourhood sustainability, but fail to address holistic, place-based and iterative sustainable neighbourhood design. For this, other criteria are used, such as those from Khatibi et al.'s (2023) literature review, Ortiz-Fernandez's (2023) case study research, Marique & Teller's (2014) design guidance and the National Design Guide documentation (Ministry of Housing, Communities and Local Government, 2021).

9.2 Iterative design - spatial expression and impact

For this to be a dynamic design tool (rather than site analysis tool), the criteria on which it is based should allow for iterative interaction with spatial design models and decisions (Co-creation, personal communication, June 16, 2025). As such, any holistic sustainability quantifiable criteria is filtered to only keep those relating to and directly influenced by urban design interventions. This eliminates organisational / social / political criteria such as: user stewardship, governance, job creation, cost of living, culture and community incentives despite being key contributors to neighbourhood sustainability (Partner, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025).

Therefore, though filtered out of the quantifiable, spatial criteria for a sustainable neighbourhod, the social, intangible elements are captured in the system design of the Dynamic Digital tool, by including local values via engagement sessions, as well as by the design and engagement flow contributions of the current workflow, which the tool does not aim to replace, but rather, complement.

To continue, despite certain quantifiable and spatial criteria being relevant (e.g., crossing path placement, access to benches, sidewalk width, car parking spaces, cycle parking, cycle amenities, urban cycle paths, street lighting, waste management...), often the right data is not available, which leads to the following section (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Head of Innovation, personal communication, March 13, 2024).

9.3 Place-based approach - data availability, granularity/resolution and coverage

As this tool is open source, so should its data. This, however, means that data limitations are great (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025). Indeed, a lot of the site analysis software reviewed previously purchase data from third-party providers (Data Blur in YemeTech's case) in order to have a high-quality product (Computational Design Lead, personal communication, March 11, 2025; ; Head of Innovation, personal communication, March 13, 2025). Open-source data is available, for example via Open Street Map (OSM) but often less accurate and reliable than paid data (Computational Design Lead, personal communication, March 11, 2025). This forced simplification and the need for assumptions are key challenges for sustainability tools in general (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025).

Going further, certain UK data sources, had to be discarded for either too low granularity / resolution (i.e., The Met Office proposes air quality of a whole town, more detailed data sets offer only partial coverage only with council specific data formats rather than one uniform data for the UK, and Data.Police.UK's crime statistics are not spatial / do not have coordinates, address or distinctive localisation code). Nevertheless future integration of any emergent data source is made possible as demonstrated by the tool's transparent, modular and flexible system design, described in **Section 10**.

Overall, for the Dynamic Digital tool, only open data available at the UK wide neighbourhood scale and resolution was kept, which further filtered out the quantified and spatial criteria.

9.4 Criteria for a Dynamic Digital tool

Finally, of the 79 criteria originally considered, only 31 met all the above conditions and were kept as core criteria for the tool. The filtering process is illustrated in **Fig. 13**; the final criteria, categorized under the 10 sustainability themes of the National Design Guidance, can be found in **Tables 4-13**, and the data sources for the criteria are cited in **Table 14**. The data sources are all official (i.e., from UK governmental bodies) and are therefore judged to be the most complete and reliable data available for the UK. However, as it is only the official data, informal arrangements might not be reflected (i.e., a socially accepted cycle path, but not marked as such in the road type data). This potential gap with the "informal" space use is true with all data and has to be examined on a case by case basis while using the Dynamic tool by the GIS contextualisation as illustrated in the case study analysis in **Section 11**. Filtered out criteria can be found in **Appendix F**.

To conclude this section, the criteria considered by the Dynamic Digital tool is quantifiable, spatial and based on available data. The use of open, official data and criteria which holistically cover the 10 themes of sustainable neighbourhood deisgn ensure responsible urban digitalisation, by addressing the community needs as a whole and using non intrusive, public data.

Fig. 13
Criteria filtering process
steps to choose criteria for the Dynamic Digital tool

CONTEXT - enhances the surroundings

Based on sound understanding of features of the site and surrounding context, using baseline studies as a starting point for design. Integrated into their surroundings to they relate well to them. Influenced by and influence their context positively. Responsive to local history, culture and heritage

Criterion	Measure	Threshold (source)	Data
Green area	m^2	20-25% of urban area (United Nations Environment Programme, 2025)	Green Areas
Green access	m	≤ 300m to closest (United Nations Environment Programme, 2025)	Green Areas
Blue access	m	≤ 600m to closest (Volker and Kistemann, 2011)	Blue Areas
Flood risk	low, medium, high	high risk	Flood
Street width	m	≥ 70% of streets should be <12m wide (United Nations Environment Programme, 2025)	Roads + Buildings
Cycle path access	m	≤ 400m to closest (Ortiz-Fernandez et al., 2023)	Roads
Public transport access	m	≤ 800m to to closest rail station or 400 to to closest bus/ tram stops (National Design Guide, 2021)	Public Transport
Heat stress	UTCI	< +38 (Brode et al., 2012)	Grasshopper analysis
Wind tunnel	m/s	< 9.8m/s (Laswson & Penwarden, 1976)	Grasshopper analysis
Amenity access	m	≤ 300m to mininimum 3 daily commerces* and ≤ 600m to 3 community equipment** (Ortiz-Fernandez et al., 2023)	Buildings
Amenity mix	number / km^2	≥ 1 school and 15 amenities in area with 700m buffer (Marique & Teller, 2014)	Buildings
Density	dwellings / ha	60-120 dwellings / ha (Dempsey et al., 2012)	Buildings
Land use mix	%	Housing: 25% ; Econ, health, educ, civic 25% ; streets for community life, people movement and public transport 25-30% ; Green or open spaces 20-25% (United Nations Environment Programme, 2025)	Green areas + Roads + Buildings
Cycle path connectivity	m	in 4km distance, path connected to ≥1 school, job center or public transport stop or 10 housing (Ortiz-Fernandez, J. et al.,2023)	Roads + Buildings

*daily commerce = supply / provision of products, personal services and other

**community equipment = ducation, cultural, sports, social, well-being, provision, leisure, public restrooms, social org, public security, public spaces, health, administration

Table 4
Criteria for Context theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

IDENTITY - attractive and distinctive

Have a positive and coherent identity that everyone can identify with, including residents and local communities, so contributing towards health and well-being, inclusion and cohesion. Have a character that suits the context, its history, how we live today and how we are likely to live in the future. Are visually attractive, delight their occupants and other users.

Criterion	Measure	Threshold (source)	Data
Distinctive elements / landmarks	m	≥ 1 distinctive element or landmark in the neighbourhood (Lynch, 2008)	Buildings
Green access	m	≤ 300m to closest (United Nations Environment Programme, 2025)	Green Areas
Blue access	m	≤ 600m to closest (Volker and Kistemann, 2015)	Blue Areas
Solar access	direct sun hours	min. 60% of residential buildings have direct sunlight 2m from the ground (Marique & Teller, 2014)	Grasshopper analysis

Table 5
Criteria for Identity theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

NATURE - enhanced and optimised

Integrate existing and incorporate new natural features into multifunctional network that supports quality of place, biodiversity and water management, and addresses climate change mitigation and resilience. Provide attractive open spaces in locations that are easy to access, with activities for all to enjoy, such as play, food production, recreation and sport, so as to encourage physical activity and promote health, well-being and social inclusion

Criterion	Measure	Threshold (source)	Data
Green area	m^2	20-25% of urban area (United Nations Environment Programme, 2025)	Green Areas
Green access	m	≤ 300m to closest (United Nations Environment Programme, 2025)	Green Areas
Blue access	m	≤ 600m to closest (Volker and Kistemann, 2015)	Blue Areas
Green variety	m	≥ multiple green space types within 300m walking distance (Konijnendijk, 2023)	Green Areas
Biodiversity	%	Minimum 10% net increase in biodiversity (National Design Guide, 2021)	Green Areas

Table 6
Criteria for Nature theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

BUILT FORM - a coherent pattern of development

Compact forms of development that are walkable, contributing positively to well-being and placemaking. Accessible local public transport, services and facilities to ensure sustainable development. Recognisable streets and other spaces with their edges defined by buildings, making it easy for anyone to find their way around, promoting safety and accessibility. Memorable features or groupings of buildings, spaces, uses or activities that create a sense of place, promoting inclusion and cohesion

Criterion	Measure	Threshold (source)	Data
Green access	m	≤ 300m to closest (United Nations Environment Programme, 2025)	Green Areas
Blue access	m	≤ 600m to closest (Volker and Kistemann, 2015)	Blue Areas
Cycle path access	m	≤ 400m to closest (Ortiz-Fernandez et al., 2023)	Roads
Public transport access	m	≤ 800m to to closest rail station or 400 to to closest bus/ tram stops (National Design Guide, 2021)	Public Transport
Amenity access	m	≤ 300m to mininimum 3 daily commerces* and ≤ 600m to 3 community equipment** (Ortiz-Fernandez et al., 2023)	Buildings
Amenity mix	number / km2	≥ 1 school and 15 amenities in area with 700m buffer (Marique & Teller, 2014)	Buildings
Density	dwellings/ ha	60-120 dwellings / ha (Dempsey et al., 2012)	Buildings
Street network connection	number / km^2	>1 node to other street (National Design Guide, 2021)	Roads
Land use mix	%	Housing: 25% ; Econ, health, educ, civic 25% ; streets for community life, people movement and public transport 25-30% ; Green or open spaces 20-25% (United Nations Environment Programme, 2025)	Green areas + Roads + Buildings

*daily commerce = supply / provision of products, personal services and other

**community equipment = ducation, cultural, sports, social, well-being, provision, leisure, public restrooms, social org, public security, public spaces, health, administration

Table 7
Criteria for Built Form theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

MOVEMENT - accessible and easy to move around

Safe and accessible for all. Functions efficiently to get everyone around, takes into account diverse needs of all its potential users and provides a genuine choice of sustainable transport modes. Limits the impacts of car use by prioritising and encouraging walking, cycling and public transport, mitigating impacts and identifying opportunities to improve air quality. Promotes activity and social interaction, contributing to health, well-being, accessibility and inclusion. Incorporates green infrastructure, including street trees to soften the impact of car parking, help improve air quality and contribute to biodiversity

Criterion	Measure	Threshold (source)	Data
Green area	m^2	20-25% of urban area (United Nations Environment Programme, 2025)	Green Areas
Street width	%	≥ 70% of streets should be <12m wide (United Nations Environment Programme, 2025)	Roads + Buildings
Cycle path access	m	≤ 400m to closest (Ortiz-Fernandez et al., 2023)	Roads
Public transport access	m	≤ 800m to to closest rail station or 400 to to closest bus/ tram stops (National Design Guide, 2021)	Public Transport
EV charging	m	≤ 800m to EV charging point (He et al., 2022)	Technology
Street network connection	number / km^2	>1 node to other street (National Design Guide, 2021)	Roads
Air pollution barriers	m	vegetated buffer between major roads and residential areas (Abhijith et al., 2017)	Pollution + Roads + Buildings
Biodiversity	%	≥ 10% net increase in biodiversity (National Design Guide, 2021)	Green Areas
Cycle path connectivity	m	in 4km distance, path connected to ≥ 1 school,job center or public transport stop or 10 housing (Ortiz-Fernandez, J. et al.,2023)	Roads + Buildings

Table 8
Criteria for Movement theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

PUBLIC SPACES - safe, social, inclusive

Include well located spaces that support wide variety of activities and encourage social interaction to promote health, social and civic inclusion. Have a hierarchy ot spaces that range from large and strategic to smal local spaces, including parks, squares, greens and pocket parks. Have public spaces that feel safe, secure and attractive for all to use. Have trees and other planting within public spaces for people to enjoy, whilst also provifing Microclimate shading and air quality and climate mitigation

Criterion	Measure	Threshold (source)	Data
Street width	%	≥ 70% of streets should be <12m wide (United Nations Environment Programme, 2025)	Roads + Buildings
Street network connection	number / km^2	>1 node to other street (National Design Guide, 2021)	Roads
Shading	% coverage	≥ 25% public spaces shaded during summer months (United Nations Environment Programme, 2025)	Grasshopper analysis
Heat stress	UTCI	< +38 (Brode et al., 2012)	Grasshopper analysis
Safety coverage	number/ km^2	≥ 1 security unit*** / km2 (Ortiz-Fernandez et al., 2023)	Buildings
Social interaction spaces	number/ ha	≤ 400m to designated social spaces (United Nations Environment Programme, 2025)	Buildings
Air pollution barriers	count	vegetated buffer between major roads and residential areas (Abhijith et al., 2017)	Pollution + Roads + Buildings
Solar access	direct sun hours	min. 60% of residential buildings have direct sunlight 2m from the ground (Marique & Teller, 2014)	Grasshopper analysis
Wind tunnel	m/s	< 9.8m/s (Laswson & Penwarden, 1976)	Grasshopper analysis
Flood risk	low, medium, high	high risk	Flood

***security unit = police station, fire department

Table 9
Criteria for Public Spaces theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

USES - mixed and integrated

Mix of uses including local services and facilities to support daily life. An integrated mix of housing tenues and types to suit people at all stages of life. Well designed housing and other facilities that are designed to be tenure neutral and socially inclusive. Complement rather than conflict neighbourhing uses in terms of noise, servicing, ventilation.

Criterion	Measure	Threshold (source)	Data
Amenity access	m	≤ 300m to mininimum 3 daily commerces* and ≤ 600m to 3 community equipment** (Ortiz-Fernandez et al., 2023)	Buildings
Amenity mix	number / km^2	≥ 1 school and 15 amenities in area with 700m buffer (Marique & Teller, 2014)	Buildings
Density	dwellings/ ha	60-120 dwellings / ha (Dempsey et al., 2012)	Buildings
Land use mix	%	Housing: 25% ; Econ, health, educ, civic 25% ; streets for community life, people movement and public transport 25-30% ; Green or open spaces 20-25% (United Nations Environment Programme, 2025)	Green areas + Roads + Buildings
Housing price	£	< highest 25% in site	Buildings
Adjacent use	m	≥ 150m between (heavy) industrial uses and residential areas (Hess et al., 2001)	Buildings
Circular economy facilities	m	≤ 1km to closest repair café, tool library or material resuse centre (Williams, 2019)	Buildings

*daily commerce = supply / provision of products, personal services and other

**community equipment = ducation, cultural, sports, social, well-being, provision, leisure, public restrooms, social org, public security, public spaces, health, administration

Table 10
Criteria for Uses theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

HOMES AND BUILDINGS - functional, healty and sustainable

Include well located spaces that support wide variety of activities and encourage social interaction. Provide good quality internal and external environments for their users, promoting health and well-being. Relate positively to the private, shared and public spaces around them, contributing to social interaction and inclusion. Resolve the details of operation and servicing so that they are unobtrusive and well-integrated into their neighbouhoods.

Criterion	Measure	Threshold (source)	Data
Energy perfor-mance	EPC	≤ B for new developments and C for existing (HM Government, 2022)	Buildings
Solar access	Direct sunlight	min. 60% of residential buildings have direct sunlight 2m from the ground (Marique & Teller, 2014)	Grasshopper analysis
Private area	m^2 / dwelling	≥ 6m2 of external space / dwelling (Marique & Teller, 2014)	Buildings
Solar energy potential	solar radiation	south facing +- 30 degrees (United Nations Environment Programme, 2025)	Grasshopper analysis
Smart in-frastructure	connec-tivity index	5G coverage (GOV.UK, 2023)	Technology
Housing price	£	< highest 25% in site	Buildings
Density	dwellings/ ha	60-120 dwellings / ha (Dempsey et al., 2012)	Buildings

Table 11
Criteria for Houses and Buildings theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

LIFESPAN - made to last

Designed and planned for long term stewardship by landowners, communities and local authorities from the earliest stages. Robust, easy to use and look after, and enable their users to establish a sense of ownership and belonging, ensuring places and buildings age gracefully. Adaptable to their users' changing needs and evolving technologies. Well managed and maintained by their users, owners, landlords and public agencies

Criterion	Measure	Threshold (source)	Data
Green permeability	%	≥ 30% surface is permeable (National Design Guide, 2021)	Green Areas + Blue Areas
Flood risk	low, medium, high	high risk	Flood
Heat stress	UTCI	< +38 (Brode et al., 2012)	Grasshopper analysis

Table 12
Criteria for Lifespan theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

RESOURCES - efficient and resilient

Have a layout, form and mix of uses that reduces their resource requirement, including for land, energy and water. Are fit for purpose and adaptable over time, reducing the need to revelopment and unnecessary waste. Use materials and adopt technologies to minimise their environmental impact.

Criterion	Measure	Threshold (source)	Data
Amenity access	m	≤ 300m to mininimum 3 daily commerces* and ≤ 600m to 3 community equipment** (Ortiz-Fernandez et al., 2023)	Buildings
Amenity mix	number / km^2	≥ 1 school and 15 amenities in area with 700m buffer (Marique & Teller, 2014)	Buildings
Density	dwellings/ ha	60-120 dwellings / ha (Dempsey et al., 2012)	Buildings
Solar energy potential	solar radiation	relative to dataset: lowest 25% = low potential	Grasshopper analysis
Smart in-frastructure	connec-tivity index	≥ 85% buildings with coverage (Bibri & Krogstie, 2017)	Technology
EV char-gring	m	≤ 800m to EV charging point (He et al., 2022)	Technology
Circular economy facilities	m	≤ 1km to closest repair café, tool library or material resuse centre (Williams, 2019)	Buildings

*daily commerce = supply / provision of products, personal services and other

**community equipment = ducation, cultural, sports, social, well-being, provision, leisure, public restrooms, social org, public security, public spaces, health, administration

Table 13
Criteria for Resources theme
theme description (Ministry of Housing, Communities and Local Government, 2021), criteria, sources and relevant data group from Table 14

FLOOD			
Name	**Surface**	**Rivers and Seas**	
Source	Environment Data gov.uk	Environment Data gov.uk	
Link	*https://environment.data.gov.uk/explore/b5aaa28d-6eb9-460e-8d6f-43caa71fbe0e?download=true*	*https://environment.data.gov.uk/explore/de4079f2-3569-45b2-8009-a00bccc520a1?download=true*	
Format	*.shp*	*.shp*	
Coverage	*UK but local download*	*UK but local download*	
Date	*2025*	*2025*	
ROADS			
Name	**OS OpenRoads**	**OS OpenURSN**	**Cycle Network**
Source	OS	OS	Sustrans
Link	*https://www.ordnancesurvey.co.uk/products/os-open-roads*	*https://osdatahub.os.uk/downloads/open/OpenUSRN?_gl=1*17jc53c*_gcl_au*OTczMTUwMjMyLjE3NDM0NDk4MTQ.*_ga*MTEzNjIwNDMwMC4xNzQzNDM5NzEy*_ga_59ZBN7DVBG*MTc0NDU0NDI0OS4xMS4xLjE3NDQ1NDQzODAuMTUuMC4w*_ga_E5T3PCFCG7*MTc0NDU0NDI0OS4xMS4xLjE3NDQ1NDQzODAuMC4wLjA.*	*https://data-sustrans-uk.opendata.arcgis.com/*
Format	*.shp*	*.shp*	*.shp*
Coverage	*GB*	*GB*	*UK*
Date	*2025*	*2025*	*2024*
BUILDINGS			
Name	**OS OpenMapLocal**	**Points of Interest**	**Listed Building Points**
Source	OS	CDRC	Historic England
Link	*https://osdatahub.os.uk/downloads/open/OpenMapLocal?_gl=1*hxxywv*_gcl_au*OTczMTUwMjMyLjE3NDM0NDk4MTQ.*_ga*MTEzNjIwNDMwMC4xNzQzNDM5NzEy*_ga_59ZBN7DVBG*MTc0NDUzOTcyNi4xMC4xLjE3NDQ1NDA1NDMuNDkuMC4w*_ga_E5T3PCFCG7*MTc0NDUzOTcyNi4xMC4xLjE3NDQ1NDA1NDMuMC4wLjA.*	*https://data.geods.ac.uk/dataset/point-of-interest-data-for-the-united-kingdom*	*https://opendata-historicengland.hub.arcgis.com/datasets/historicengland::listed-building-points/explore?location=52.653878%2C-2.508121%2C5.92*
Format	*.shp*	*.shp*	*.shp*
Coverage	*GB*	*UK*	*England*
Date	*2025*	*2024*	*2025*
			PUBLIC TRANSPORT
Name	**Housing Price**	**Energy Performance**	**Stops**
Source	HM Land Registry	EPC Open Data	NaPTAN gov.uk
Link	*https://landregistry.data.gov.uk/app/ppd/?et%5B%5D=lrcommon%3Afreehold&et%5B%5D=lrcommon%3Aleasehold&limit=all&min_date=2020-01-01&nb%5B%5D=true&nb%5B%5D=false&ptype%5B%5D=lrcommon%3Adetached&ptype%5B%5D=lrcommon%3Asemi-detached&ptype%5B%5D=lrcommon%3Aterraced&ptype%5B%5D=lrcommon%3Aflat-maisonette&ptype%5B%5D=lrcommon%3AotherPropertyType&relative_url_root=%2Fapp%2Fppd&tc%5B%5D=ppd%3AstandardPricePaidTransaction&tc%5B%5D=ppd%3AadditionalPricePaidTransaction&town=Ashington*	*https://epc.opendatacommunities.org/login*	*https://beta-naptan.dft.gov.uk/Download/National*
Format	*.csv*	*.csv*	*.csv*
Coverage	*UK but local download*	*GB*	*GB*
Date	*on or after 2020*	*2025*	*2025*

Table 14
Data Sources
Data group names referred to in Tables 4-13. The name, source, link, format, coverage and date are indicated

GREEN AREAS			
Name	**OS Open Greenspace**	**Habitat Networks**	**Local Nature Reserves**
Source	OS	Natural England	Natural England
Link	*https://www.data.gov.uk/dataset/4c1fe120-a920-4f6d-bc41-8fd4586bd662/os-open-greenspace1*	*https://naturalengland-defra.opendata.arcgis.com/datasets/fceb93850462454ab3fb5accea2be35b_0/explore?location=55.028269%2C-1.477663%2C13.60*	*https://naturalengland-defra.opendata.arcgis.com/datasets/b1d690ac6dd54c15bd-d2d341b686ecd7_0/explore?location=52.514926%2C-1.948537%2C6.74*
Format	*.shp*	*.shp*	*.shp*
Coverage	*GB*	*England*	*England*
Date	*2025*	*2023*	*2025*
BLUE AREAS			
Name	**OS OpenMapLocal**	**OS OpenRivers**	
Source	OS	OS	
Link	*https://osdatahub.os.uk/downloads/open/OpenMapLo-cal?_gl=1*hxxywv*_gcl_au*OTczMTUwMjMyLjE3NDM0N-Dk4MTQ.*_ga*MTEzNjIwNDMwMC4xNzQzNDM5NzEy*_ga_59ZBN7DVBG*MTc0NDUzOTcyNi4xMC4xLjE3NDQ1N-DA1NDMuNDkuMC4w*_ga_E5T3PCFCG7*MTc0NDUzOTcy-Ni4xMC4xLjE3NDQ1NDA1NDMuMC4wLjA.*	*https://www.data.gov.uk/dataset/dc29160b-b163-4c6e-8817-f313229bcc23/os-open-rivers1*	
Format	*.shp*	*.gpkg*	
Coverage	*GB*	*GB*	
Date	*2025*	*2025*	
TECHNOLOGY			
Name	**OS OpenMapLocal**	**Broadband Speed**	
Source	OS	CDRC	
Link	*https://osdatahub.os.uk/downloads/open/OpenMapLo-cal?_gl=1*hxxywv*_gcl_au*OTczMTUwMjMyLjE3NDM0N-Dk4MTQ.*_ga*MTEzNjIwNDMwMC4xNzQzNDM5NzEy*_ga_59ZBN7DVBG*MTc0NDUzOTcyNi4xMC4xLjE3NDQ1N-DA1NDMuNDkuMC4w*_ga_E5T3PCFCG7*MTc0NDUzOTcy-Ni4xMC4xLjE3NDQ1NDA1NDMuMC4wLjA.*	*https://data.geods.ac.uk/dataset/broadband-speed*	
Format	*.shp*	*.csv*	
Coverage	*GB*	*UK*	
Date	*2025*	*2016-2022*	

Table 14 (continued)
Data Sources
Data group names referred to in Tables 4-13. The name, source, link, format, coverage and date are indicated

In conclusion, this research's analysis sections provided: an understanding of the urban designer's workflow, its gaps and opportunities; the current digital tools for sustainable neighbourhood design and their combined potential; and the sustainable neighbourhood design criteria which can be included in a Dynamic Digital tool. The next sections present this research's results, by first introducing the Dynamic Framework and Digital tool, and then the learnings from the Case study application in the Hirst neighbourhood.

10.0 results 1 – DYNAMIC FRAMEWORK AND DIGITAL TOOL

This section answers the fourth research sub-question: *What framework and underlying logic should guide a digital design tool to integrate iterative design processes, place-based approach, and holistic sustainability in neighbourhood design?*

The previous sections provided essential analysis results to understand opportunities within the urban design workflow, digital tool combinations and criteria for sustainable neighbourhoods. These result in the Dynamic Framework and Dynamic Digital tool. After presenting the overall framework which guides the digital tool, this section will take the reader step by step through the proposed workflow.

The Dynamic Framework proposes to systematically and dynamically integrate the different strands of the current best practice urban design workflow (namely, engagement flow, sustainability flow, design flow), allowing them to communicate and inform one another (**Fig. 14**). This is achieved by a collaboration between engagement specialist, urban designer and sustainability consultant. The latter acts as the bridge and the driver for the sustainable design narrative (Sustainability Director, personal communication, March 27, 2025), notably through the collaborative use of the Dynamic Digital tool.

The framework and tool relate to Steinitz's Geodesign by following the core flow and logic. Indeed, the Dynamic Framework and Digital tool first aim to understand the current situation, then explore options for change, and finally assess the impact of those all in a continuous iterative process, supported by the Dynamic Digital tool at every stage. However, the Dynamic Framework innovates on Geodesign by the detailed implementation of local values as well as option model optioneering, with the whole framework backed up by a detailed Dynamic Digital tool designed to fit in the workflow, rather than staying at theory only. The underlying logic and key decisions for the Dynamic Framework and Dynamic Digital tool are detailed below, in a step by step description of intended use and key considerations. All scripts mentioned in the next sections can be found in **Appendix E**. This results section is driven by interviews, co-creation, literature and where all the above were inconclusive, author's own knowledge- and experience-driven judgement.

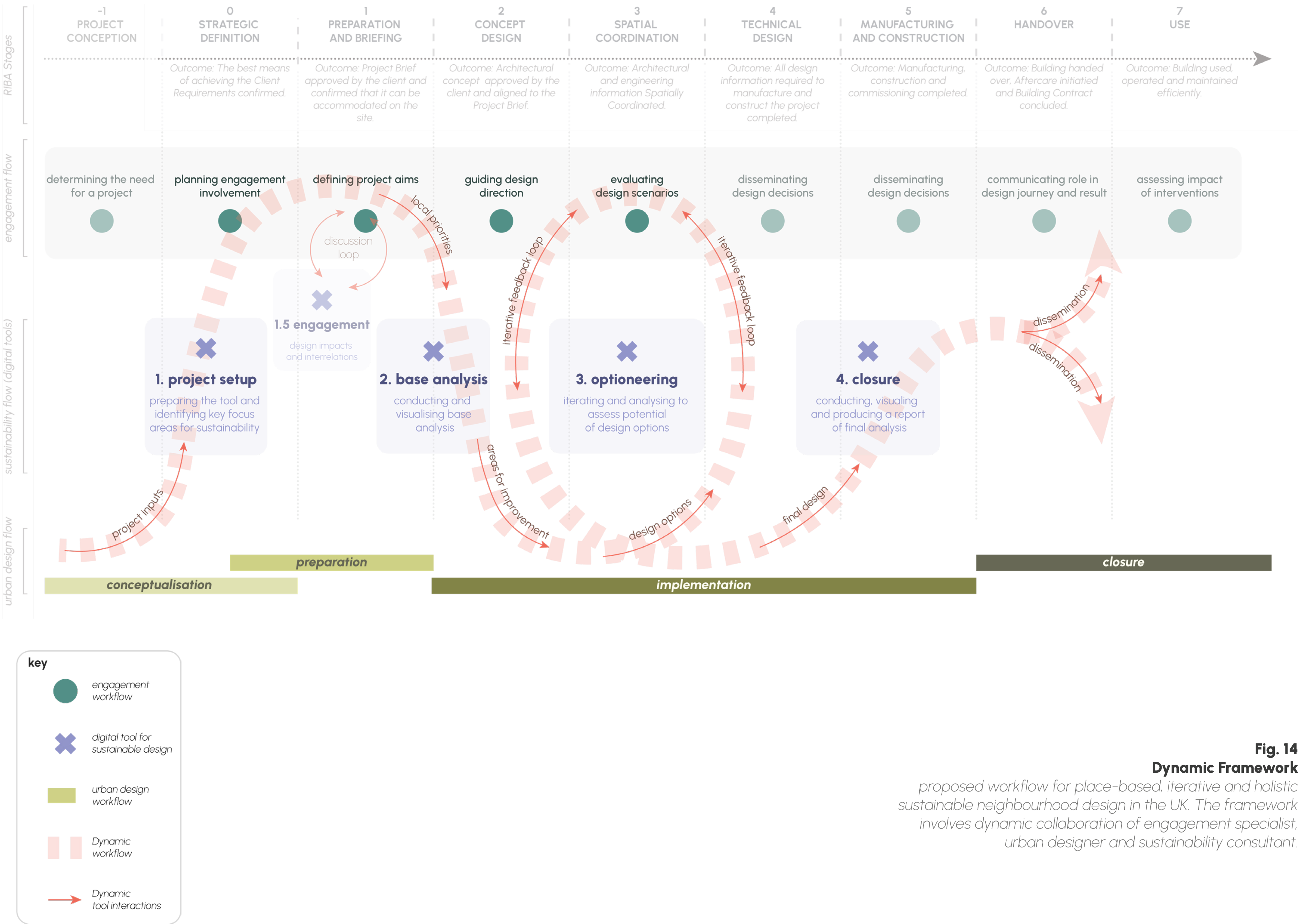


Fig. 14
Dynamic Framework
proposed workflow for place-based, iterative and holistic sustainable neighbourhood design in the UK. The framework involves dynamic collaboration of engagement specialist, urban designer and sustainability consultant.

10.1 Conceptualisation: Project Setup

At the beginning of a project - when the brief is being discussed and defined via stakeholder engagement and other discussions between engagement specialist, designer and client - the sustainability consultant can start with the Project Setup step within the Dynamic Digital tool. For this, a series of **Python "A" scripts** – gather project information (project number, site coordinates, grid size, folder location paths, key variables) and generate outputs (project boundaries; analysis grids; recurring functions, project folder structure and file naming conventions) which will be used to feed into each subsequent step of the Dynamic Framework. Though anodyne, this is the most critical step of the Dynamic Digital tool, the only place in all python scripts requiring manual input and running of the scripts via clear, minimal, centralised and modular prompts, along with a logical running sequence. The A scripts are detailed in **Fig. 15**. A0 is the requires user entries and provides all project variables. A1 uses the A0 inputs to create the grid (gpkg and .geojson) on which the rest of the analyses will be based. A2 relates the grid cells with other reference structures such as Unique Property Reference Number (UPRN) points and postcodes. A3 centralises key project functions (i.e., importing analysis data from a specific folder path with a spatial filter; running a network analysis...), contributing to making the tool more modular. A4 creates a single toggle point to run all analysis scripts, either for Base or Final analysis depending on the moment in the Dynamic Workflow.

The A scripts' design include a decision to use the British National Grid (BNG), using Easting and Northing rather than Longitude and Latitude, as core Coordinate Reference System (CRS) for the overall Dynamic Digital tool. Indeed, while CRS conversions between the UK data (based either in BNG, UPRN, postcode or full address) and the globally used WGS-84 (in which OSM and Overture data are based) were initially favoured in order to increase code modularity by basing in the global CRS, the conversions proved unreliable and approximate - specifically, the geocoding of addresses to points in WGS-84. Attempts made in ArcGIS and in python in both "directions" (ie points to addresses or addresses to points) resulted in imprecise results: with addresses from a whole street clustered into a single point. If it is necessary to use WGS-84 data, the A3_key_functions include a CRS conversion function. However, where available, BNG is preferred for higher precision.

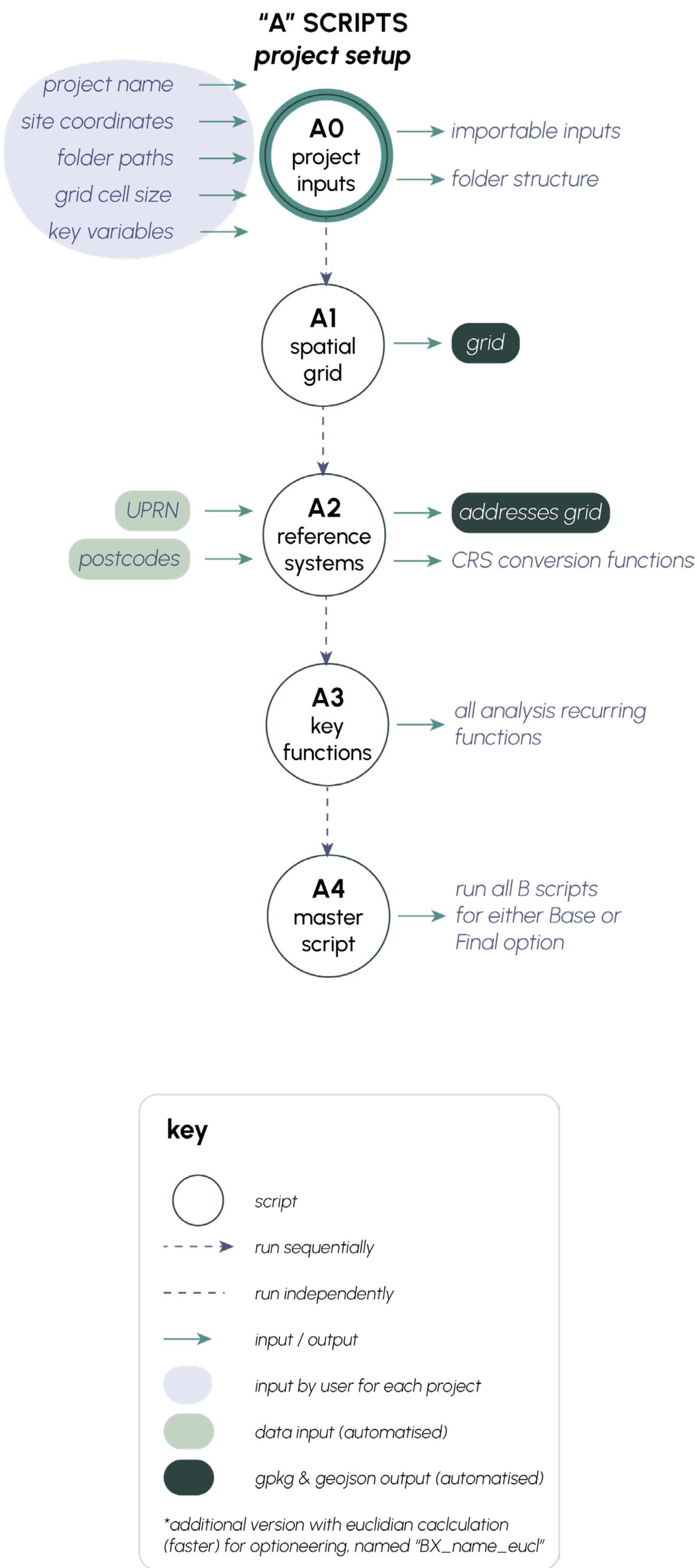


Fig. 15
Python - A Scripts
inputs, outputs and sequencing of the Dynamic Digital tool's A Scripts. Only A1 requires user input.

One of the key outputs of the Project Setup phase is the analysis grid which forms the basis for all calculations and visualisations. The choice to use a grid instead of building footprints enables reliability; inclusion of all urban areas rather than just built areas; compatibility with all datasets; and the ability to relate grid cells to addresses or UPRN points when needed. Though the project and its desired results are located within the site boundary (Site Bounding Box), it is essential to consider the built environment beyond that, true to the neighbourhood definition being more than the administrative boundary (Head of Innovation, personal communication, March 13, 2025; Urban Designer, personal communication, March 24, 2025). As such, A scripts enable the creation of a Study Bounding Box, drawn to match the furthest criteria threshold distance input in A0, therefore overcoming any site boundary limitations (e.g., having a grocery store right outside of the site boundary). This is illustrated in **Fig. 16**. This contributes to mitigating Modifiable Areal Unit Problem (MAUP), which refers to the statistical bias that occurs when point-based spatial phenomena are aggregated into areal units, where results vary depending on both the scale effect (the size of spatial units used for analysis) and the zoning effect (how those units are arranged or bounded) (Openshaw, 1984). First, the uniform grid approach mitigates the zoning effect by using consistent, non-arbitrary spatial units rather than administrative boundaries. Second, the Study Bounding Box buffer addresses the scale effect by ensuring that analyses extend beyond site boundaries to capture the full influence area of criteria, with buffer distances determined by the largest criteria threshold (e.g., 1 hectare for density analysis). This prevents edge effects and boundary-related bias that could occur if analysis were strictly contained within the Site Bounding Box. Finally, the code allows for sensity testing of different grid sizes and buffer distances which also contributes to addressing MAUP.

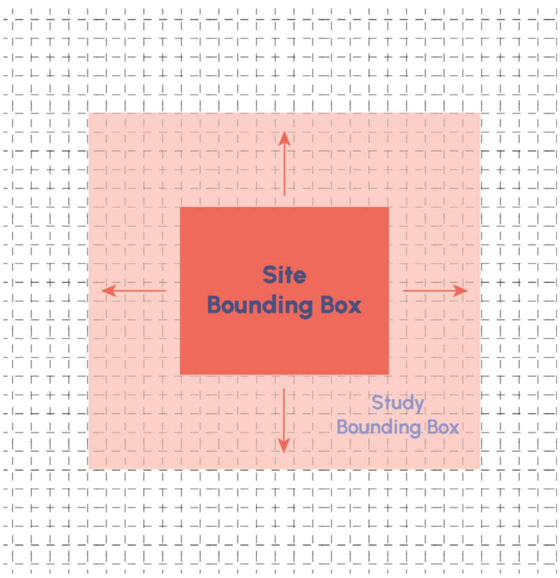


Fig. 16
Bounding Boxes
difference between Site Bounding Box and Study Bounding Box, contributing to mitigating MAUP.

Overall, the Project Setup stage enables a standardised and modular single input point, rendering all scripts dynamic by ensuring any iterations (for example a different folder path or project location) are handled fluidly, enabling the useability, transparency and iterative nature of the Dynamic Digital tool (Co-creation, personal communication, June 16, 2025; Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025; Urban Designer, personal communication, March 24, 2025). Not duplicating inputs also reduces the risk of errors or misalignments of information. With key inputs / outputs setup, the next step is to conduct a Base analysis.

10.2 Preparation: Base Analysis (python)

The Preparation stage involves the definition of the project brief, notably via engagement sessions resulting in clear local priorities communicated to the urban designer by the engagement specialist, to drive the project forward. Within the Dynamic Framework, the preparation stage is when the sustainability consultant uses the Dyanmic Digital tool to conduct a Base Analysis, informed by those local values. The results from the Base Analysis will in turn inform the next design stage: Implementation. The Base Analysis step regroups the use of python for analyses; grasshopper for visualisation, weight attribution and total score calculation; and, GIS software for detailed results interpretation and data contextualisation. This section 10.2 is on the python elements, and section 10.3 touches on the grasshopper scripts. GIS is used sporadically during each by the consultant.

Importing key outputs from the A scripts, **B scripts** perform analysis calculations based on the criteria and their relevant thresholds for sustainable neighbourhood design, as seen in **Section 9.** Each script corresponds to one criterion, which contributes to one or more sustainable neighbourhoods themes. The overview of A and B scripts can be seen in **Fig. 17**. The output of each B script is a performance score assigned to each cell of the grid: a binary pass / fail (0 / 1)method. This ensures score relativity between B scripts (i.e., a distance can be related to an energy rating), which will allow for a normalised final score calculation, avoiding bias in sustainability criteria weight to ensure a holistic approach. Additionally, this pass/fail eases the interpretation of results, by providing a clear objective performance threshold rather than raw metrics which leave more space for individual subjectivity.

The B scripts' analyses are optimised to ensure a dynamic approach: spatial filtering and data clipping to the Study Bounding Box reduce the run time drastically by avoiding to load data for the whole of UK on each analysis. Additional optimisation includes the simplification of certain complex analysis methods. For example, though it is known that accurately representing human behaviour and movement when simulating the trajectory from point A to point B involves a mixture of shortest path, fewest turns, road accessibility, terrain/ topography, road type / width, shading and so on (Managing Partner, personal communication, March 20, 2025; Research Director,

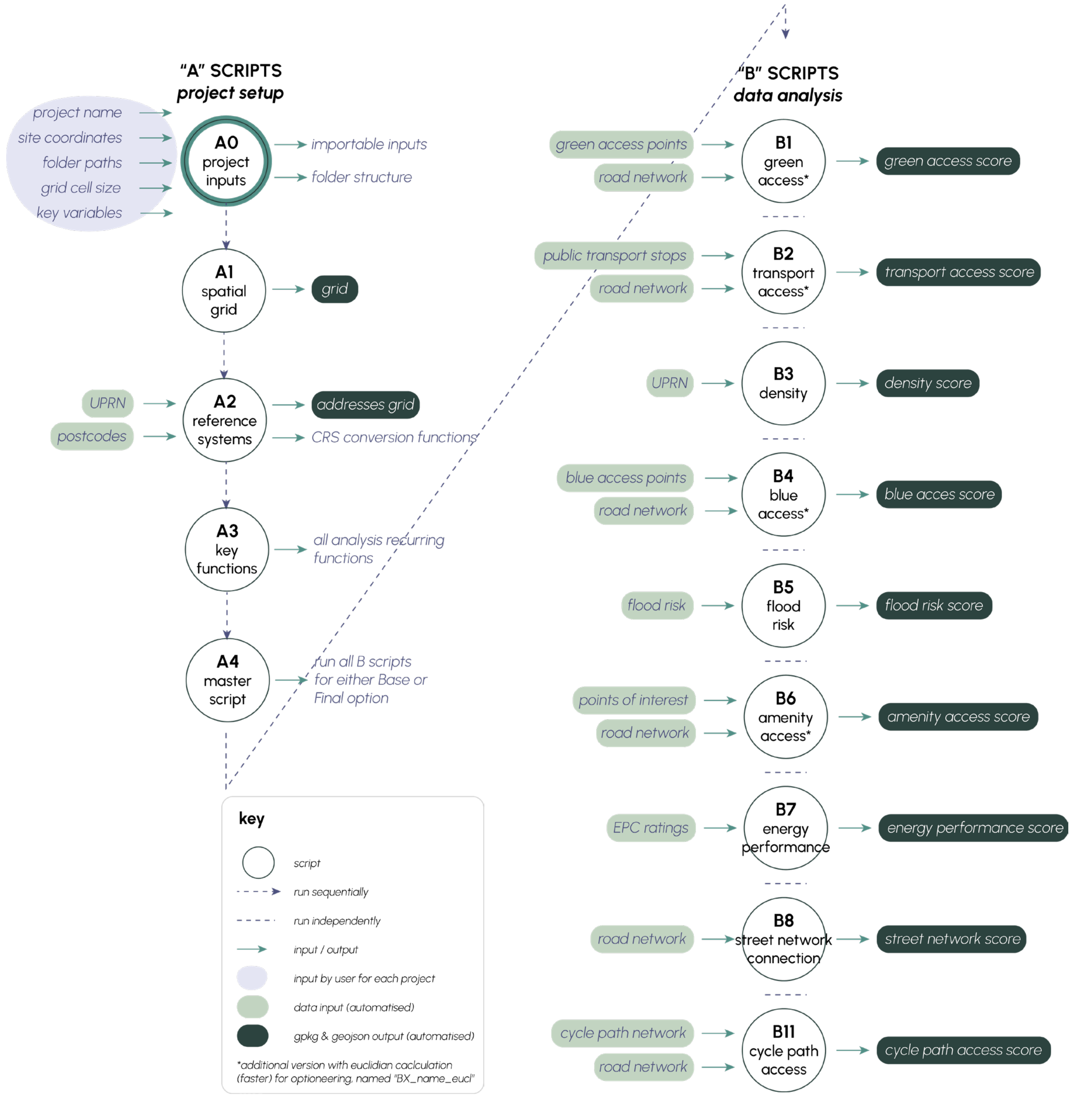


Fig. 17
Python - A + B Scripts
Interactions between A scripts and B scripts as well as data inputs and results outputs of B scripts. Scripts B9 and B10 are in development but chosen to not be illustrated as are still under testing..

personal communication, April 8, 2025; Sevtsuk & Kalvo, 2025), the B scripts' network analysis scripts use "shortest path" only, again increasing processing speed. The results of these efforts are undeniable and running A and B scripts takes up to 10 minutes each, as opposed to the previous 4 hour maximum analysis time. This was tested with a 3km2 site boundary and 10 meter grid

The choice of a 10 meter grid is the result of a sensitivity analysis, as per the MAUP mitigtions mentioned above, illustrated in **Fig. 18**. For this exercise, 4 grid sizes were tested (left to right: 100m, 50m, 25m, 10m) over 3 criteria (top to bottom: green access, amenity access, energy performance). The results show a clear benefit in the increased granularity and reduced edge effect, as pass / fail areas are better identifiedwhen shifting from 100 to 10 meter grid for all scripts. In particular, the energy performance results really benefit from the smaller grid, as the results are at the building scale based. A grid bigger than 10 meter would encounter edge effects might lead to focused efforts on more properties than needed, which is not sustainable. However, a grid smaller than 10 meter would produce excessive run times, incompatible with the reactive needs of the Dynamic Framework. As such, the 10m grid is recommended by the author, though grid size is a user input in A0 rather than hardcoded.

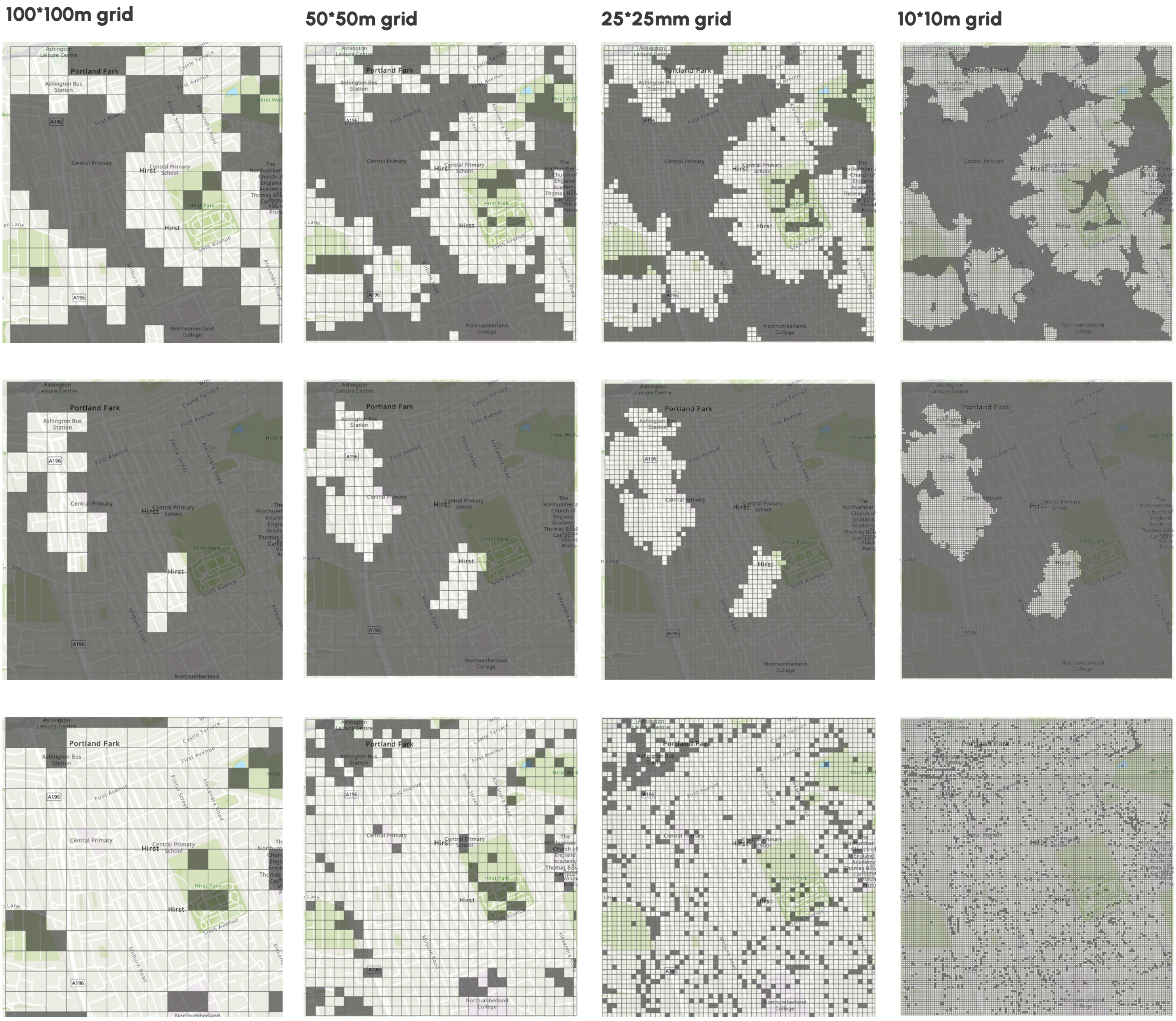


Fig. 18
Grid sensititvty analysis
impact of grid size variations (100, 50, 25, 10 meters) on three criteria (green access at the top row,, amenity access in the middle row, energy efficiency on the bottom row)

Overall, the Base Analysis step is divided in two parts: running the B script analyses, as explained above; and visualising the results in Grasshopper, detailed below.

10.3 Preparation: Base Analysis (grasshopper)

In urban projects, storytelling, visualisation and understanding site context are important, and a digital tool for sustainable neighbourhood design should dynamically illustrate and locate urban interventions and their impacts on the map (Computational Design Lead, personal communication, March 11, 2025; Founder, personal communication, March 19, 2025; Partner, personal communication, March 27, 2025). As such, the ability to easily, clearly and intuitively communicate results to designers and local stakeholders is crucial for the Dynamic Digital tool (Co-creation, personal communication, June 16, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025). The Base Analysis' visualisation marks the dynamic interaction and collaboration between sustainability consultant and urban designer. This is achieved thanks to the use of Rhino with Grasshopper as hosts of the visualisation, and later, modelling environment.

The Dynamic Design script in Grasshopper, made up of a mixture of author's original modules and plugin modules (with author's own titled in caps lock within the file), is divided in three parts: These are illustrated in **Fig. 19**, and the author original scripts in **Appendix G**. The three parts are:

1. **Project Setup**: establishing key project information to be used throughout the Grasshopper script. This has a similar role as the A0_project_inputs python script but focused on the Grasshopper script needs specifically.

2. **Analysis**: importing the B scripts' criteria analysis results, distributing them in their respective themes, assigning local values (weights) and calculating the total neighbourhood sustainability score.

3. **Optioneering**: exporting tagged design option geometry and re-running relevant B scripts to visualise intervention impacts to the neighbourhood.

The detailed components and underlying logic of each step are explained below.

To begin with, the **Project Setup** section requires three user inputs / actions. First, the path to the main project folder (which was created and standardised in the A0_project_inputs python script) is entered. This is then connected to all future file path elements within ght Grasshopper script, with additions as required to access specific folders (ie Base folder, Option A folder etc). Second, the project coordinates are entered - this is the WSG-83 coordinates of one point anywhere within the site boundary. Indeed, the Heron module "ImportCRS" uses this point to locate the project in OSM, import the site's physical context from OSM, and assign the CRS of choice to the whole Grasshopper script. Here, this has been preset to BNG. From there, the site context (i.e., buildings, roads, points of interest) can be imported into Rhino, appropriately geolocated, and used as base map for the subsequent analysis visualisation overlays. Third, though no user input is required there, the final element of the grasshopper script's Project Setup is the B script list (analysis scripts), which is used to inform any and all analysis name inputs, to reduce duplication of data and therefore risk of errors. In general, similarly to the python scripts, the Grasshopper script inputs are kept to a minimal, and clearly indicated via a red box, as per the visualisation in **Fig. 19**. The Grasshopper script's Project Setup successfully feeds other script modules and ensures a streamlined, centralised process.

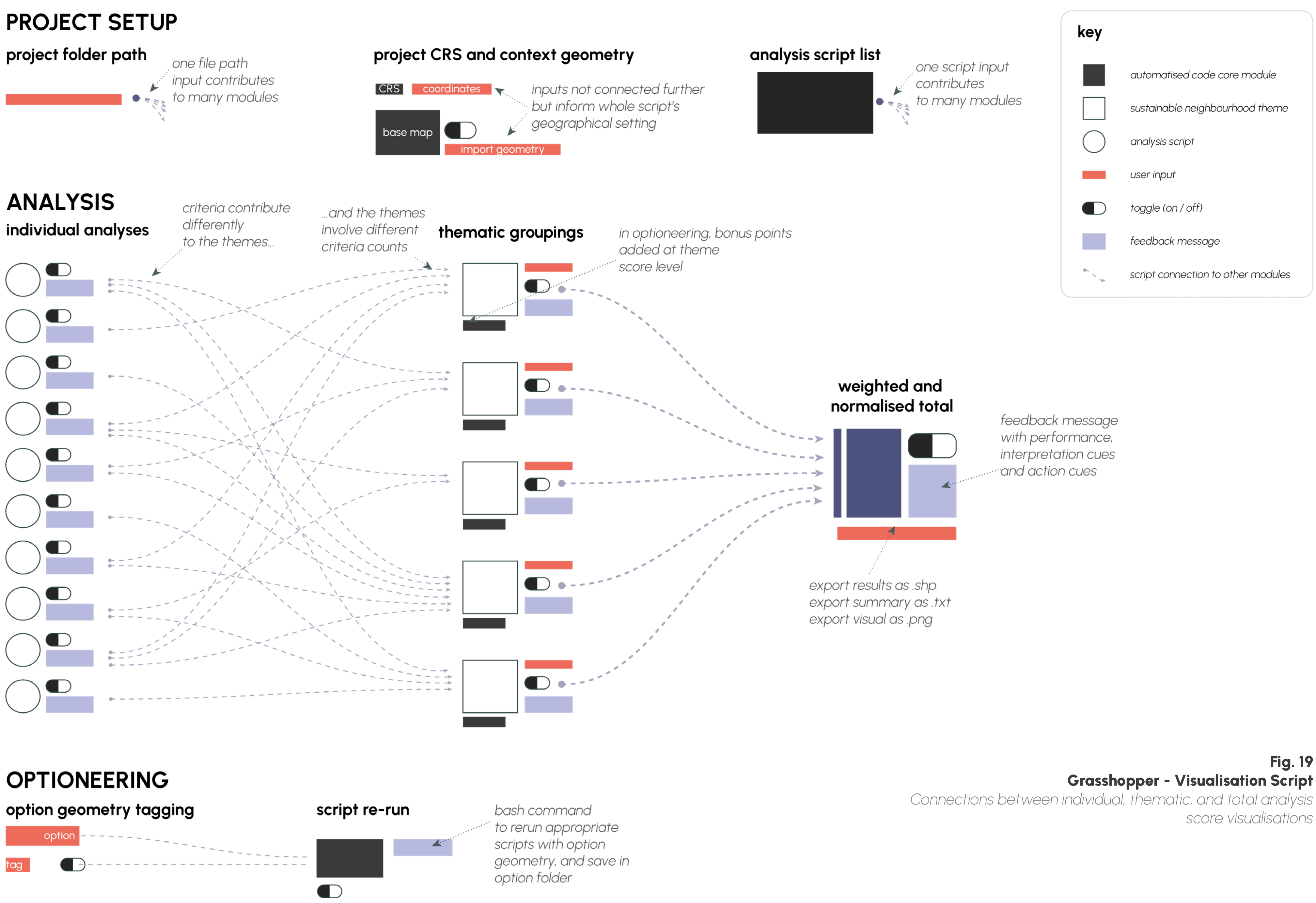


Fig. 19
Grasshopper - Visualisation Script
Connections between individual, thematic, and total analysis score visualisations

The next part in the Dynamic Design Grasshopper script is the **Analysis** part. This enables the import of criteria analysis (B script results), the score distribution, aggregation and normalisation into the 10 sustainable neighbouhood themes, and the calculation of the total performance score, while allowing for the results to be visualised at each step and exported as .shp, .png and .txt. At the start of the Analysis part, the design option to work on can be selected (i.e., Base, Recommendations, Option A-C, Final). This feeds the B analysis results imports as well as the optioneering geometry exports, again for a streamlined process. The Analysis section's B script import can be enabled by, author's own "LOAD ANALYSES" module which ensures files are only loaded and processed when desired, thanks to a "FalseStart" boolean toggle, therefore drastically improves the operational use of the Grasshopper script, reducing unnecessary time lag by constantly processing all B script results..

First, individual B analysis score files - input from the previously mentioned folder path and scripts name list and set in the correct location as per the Project Setup part - are retrieved via the "ImportVector" Heron module, in .geojson format., At this point, each criterion receives a feedback message on performance (e.g., "CRITICAL - 11% of cells score a pass on the density analysis") and displays the ability to visualise the scores in context.

Then, analysis scores are distributed across sustainability themes based on interrelations established from the National Design Guide (2021), scientific literature, interviews / co-creation and author experience. The distributions were established in the criteria tables in **Section 9.0** and are represented in **Table 15**'s Theme Dependencies matrix. Criteria naturally contribute to multiple themes—for example, green space access affects Context, Identity, Built Form, and Nature simultaneously. This intentional "multiple counting" reflects real-world interdependencies and indicates each criterion's holistic importance towards neighbourhood sustainability (i.e., if flood risk contributes to many themes, it is a reflection of its relative importance to holistic sustainability, therefore justifying its relative importance to the total neighbourhood sustainability score).

Once aggregated per theme, the criteria are normalised into a score out of 10, to ensure score granularity (i.e., resulting in theme scores which are not a simple pas or fail but a gradient of performance) and theme intercomparability (i.e., a theme with only 4 criteria can still be related to a theme with .7 criteria once they are both normalised out of 10).

Note that criteria which did not meet the spatial conditions in **Section 9** can still be part of B script analyses and visualised in Grasshopper, but simply not counted as part of the theme contributions. This compromise provides an additional analysis layer while keeping the spatial integrity and design focus of the Dynamic Digital tool.

	Context	Identity	Built Form	Movement	Nature	Public Spaces	Uses	Homes and Buildings	Resources	Lifespan
air pollution barriers				●		●				
biodiversity				●	●					
distinctive elements		●								
private area								●		
energy performance								●		
smart infrastructure								●	●	
solar energy potential								●	●	
circular economy facilities							●		●	
green permeability										●
green variety					●		●			
land use mix	●		●				●			
shading						●				
solar access		●				●		●		
safety coverage						●				
social interaction spaces						●				
EV charging				●					●	
street network connection			●	●		●				
amenity access	●		●				●		●	
amenity mix	●		●				●		●	
blue infrastructure access	●	●	●		●					
flood risk	●					●				●
heat stress	●					●				●
cycle path access	●		●	●						
density	●		●				●	●	●	
green area	●			●	●					
green infrastructure access	●	●	●		●					
wind tunnel	●					●				
public transport access	●		●	●						
street width	●			●		●				
cycle path connectivity	●			●						
housing price							●	●		

Table 15
Criteria Dependencies
criteria contributions to the different themes. The table also visually shows totals per criterion and per theme, informing on criteria relevance (colour gradient, the draker the criterion, the more relevant) and theme criteria count.

At this point, each theme is given an order of priority by the user from a drop down module within Grasshopper. The prioritisation is in the form of weights, based on the engagement specialist's engagement session syntheses, directly bringing the local values into the calculations and ensuring the dynamic place-based approach of the Dynamic Digital tool, by acknowledging that not every neighbourhood / client / community needs the same things. At the same time, the Dynamic Digital tool requires holistic sustainability. As such, in order to ensure both a distinct theme prioritisation as well as a holistic theme consideration, weights were discussed in the co-creation (personal communication, June 16, 2025), tested to ensure both local value emphasis and lower priority contributions (aiming for approximately 1/3 contribution of the lower 5 priorities, 1/3 contribution of middle 3 priorities and 1/3 contribution to the top 2 priorities) and determined as follows.

- Priority 1: score * 4
- Priority 2: score * 3
- Priority 3: score * 2
- Priority 4: score * 2
- Priority 5: score * 2
- Priority 6-10: score * 1

With this, a balance between local value prioritisation and holistic consideration is achieved throughout the 10 sustainability themes. Indeed, when changing priorities, the focus areas and their respective urgency shift, while still giiving a full picture, as illustrated in **Fig. 20** which used different priority orders.

The weighted scores are then added and normalised by dividing by the total post weight possible score (180 = 4*10 + 3*10 + 3*2*10 + 5*10) and multiplied by 100 to form the total sustainability score.

Overall, the calculations involved in the Analysis part are overviewd in **Fig. 21**. The transparency of the scoring process, including clear weight attributions and criteria / theme interrelations, is essential to enable productive conversations and informed contributions to design interventions (Co-creation, personal communication, June 16, 2025; Sustainability Director, personal communication, March 27, 2025).

The total score visualisation highlights the best and worst performing zones and provides a text summary feedback message automatically flags low scoring themes and their corresponding criteria, with a warning for any which contribute to the local values (themes 1 to 5). Once again, a balance must be kept between automating design prompts for ease of use and holistic consideration; and ensuring a place-specific response. Here, the aim is to flag key issues and provide insight into the critical criteria rather than attempt to provide an exclusive list of interventions or replace the design process. As such, communicaiting the Analysis part's results to the designer should be followed with in depth collaboration between sustainability consultant and designer to ensure sustainable neighbourhood design options respond to the site's needs, in the places which need it most.

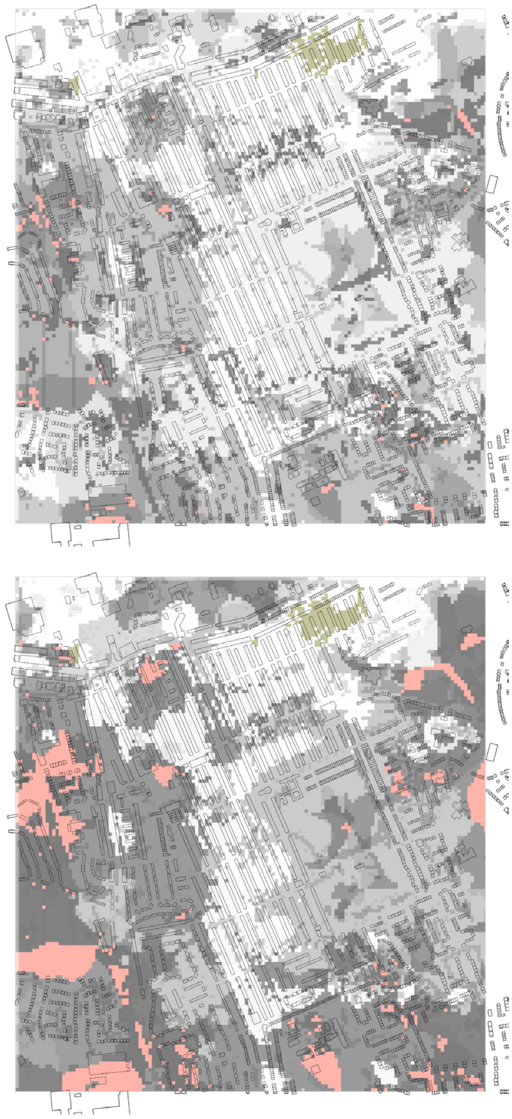


Fig. 20
Priority weights sensitivity testing
testing different theme priority orders to assess the effective application of place-based approach with holistic sustainability

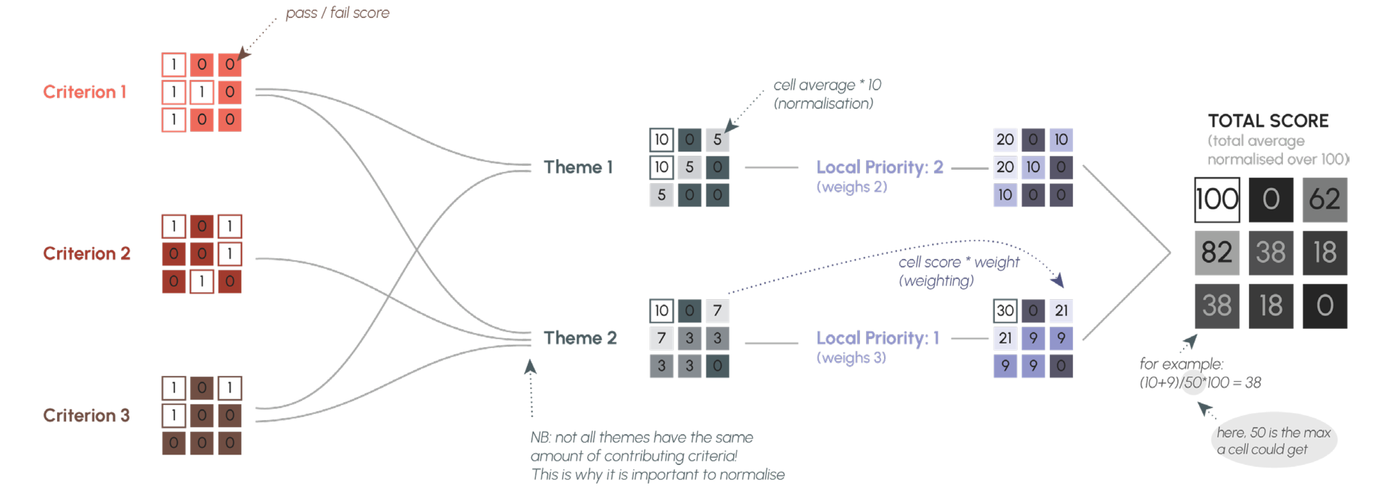


Fig. 21
Grasshopper - Weighing Script
Adding local values to theme scores and combining for the total

At the end of the Preparation stage, thanks to the Base Analysis (python and grasshopper), a thorough understanding of the neighbourhood's sustainability performance is acquired by the sustainability consultant, and communicated to the urban designer to take forward in the Implementation stage. Note that at the Preparation stage the Dynamic Digital tool's Base Analysis can also be used within the engagement sessions, to enable discussion between stakeholders and designers, to define a vision (Urban Designer, personal communication, March 27, 2025; Partner, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025; Research Director, personal communication, April 8, 2025).

So far, the place-based approach and holistic sustainability have clearly been applied within the Dynamic Framework and Dynamic Digital tool. The next step introduces iterative design via the Optioneering part of the Grasshopper script.

10.4 Implementation: Optioneering

In the Dynamic Framework, at the Implementation stage, the urban designer - informed by the Base analysis and their own site analysis - iteratively develops design options, entering the iterative feedback loop, Within that loop, the sustainability consultant can use the Dynamic Digital tool's **Optioneering phase**. This is hosted by the Dynamic Design Grasshopper script's Optioneering section is constituted of: option geometry tagging / exporting and script re-run, after which the Analysis section enables the option score visualisation and feedback.

For the option geometry tagging, design option models can be imported to Rhino from Revit or Sefaira, or directly modelled into Rhino. Once in Rhino, geometry can be batch selected, tagged in standardised outputs compatible with the overall process (i.e., recorded as variables in A0) and exported. The tagged name displays geometry attribute (drop down pre-defined list of core urban design interventions) and type (selection of either surface, line or point). An example of a tagged geometry might be "BLUE_INF_l": a line representing blue infrastructure - a river or stream. The tagged geometry is automatically saved in the option folder, indicated previously when initiating the Analysis step.

Once exported, the Option geometry is instantly related to author's own "SCRIPTS TO RERUN", which compares the exports to a list of dependencies which establish which B scripts' analyses are affected by the option interventions. For example, any new GRN_INF (green infrastructure) geometry will affect the "B1_green_access.py" analysis, and any RD_ALL (road) geometry will affect all scripts with network analysis.

From there, the author's own "RERUN SCRIPTS" module can be launched to run a bash command which re-runs the affected analysis scripts, combining the base data with the optioneering geometry. The re-runs use the scripts' euclidean versions where applicable.

The euclidean scripts are absolutely key to the dynamic nature of the Optioneering stage, and the iterative design element of the Dynamic Digital tool in general, as they allow for a fast, non-intensive, scenario testing and impact simulation of design interventions – especially when ad hoc recommendations are directly modelled in the Rhino environment and instantly analysed by the "RERUN SCRIPTS" command. The difference between a euclidean distance and network distance is illustrated in **Fig. 22.** Additional optimisation measures of the optioneering scripts include the use of polygon cenroids rather than creating nodes around a polygon's edges to calculate the access routes from point A to B. Though evidently less precise and more generous (i.e., a 300m access threshold in network analysis will cover much less area than a 300m threshold in euclidean analysis), these differences enable the efficient comparison between design interventions, allowing for all optioneering scripts to be rerun in less than 5 minutes in total, with a 10m grid and site surface area of 3km2. Scripts not identified as needing to rerun see their results copied over to the appropriate option folder, avoiding duplication of work.

Further than adding the option geometry to the base data analysis, the Optioneering step accounts for new spatial interventions which weren't part of the base analysis criteria. Specifically, the criteria which were quantifiable and spatial but had gotten filtered out due to data limitations (i.e., crossing paths). The option design interventions which were not part of a B analysis is analysed as part of the C1_theme_contributions python script. The script checks for theme dependencies within the A0_project_inputs and assigns a "bonus" point (automatic 1, except for flood risk for which interventions can range from 0.5 to 1) to the affected cells and ultimately to the affected theme. For example, adding a bench contributes to the themes of Mobility, Identity and Public Spaces– the dependencies are currently based on a combination of industry guidance, academic literature and author's own judgement. Bonus points are capped to a maximum of 1 per cell per geometry input (i.e., putting 5 benches in the same cell contributes the same as putting 1). The bonus points are then directly added to the theme scores, all of which can be once again visualised.

Overall, the Optioneering step, as part of the Implementation stage, provides an iterative design environment, leading to high-positive-impact design interventions to be taken forward in the next phases of the design process. This implies constant communication, collaboration and feedback loops between sustainability consultant, urban designer and engagement specialist, as per the Dynamic Framework..

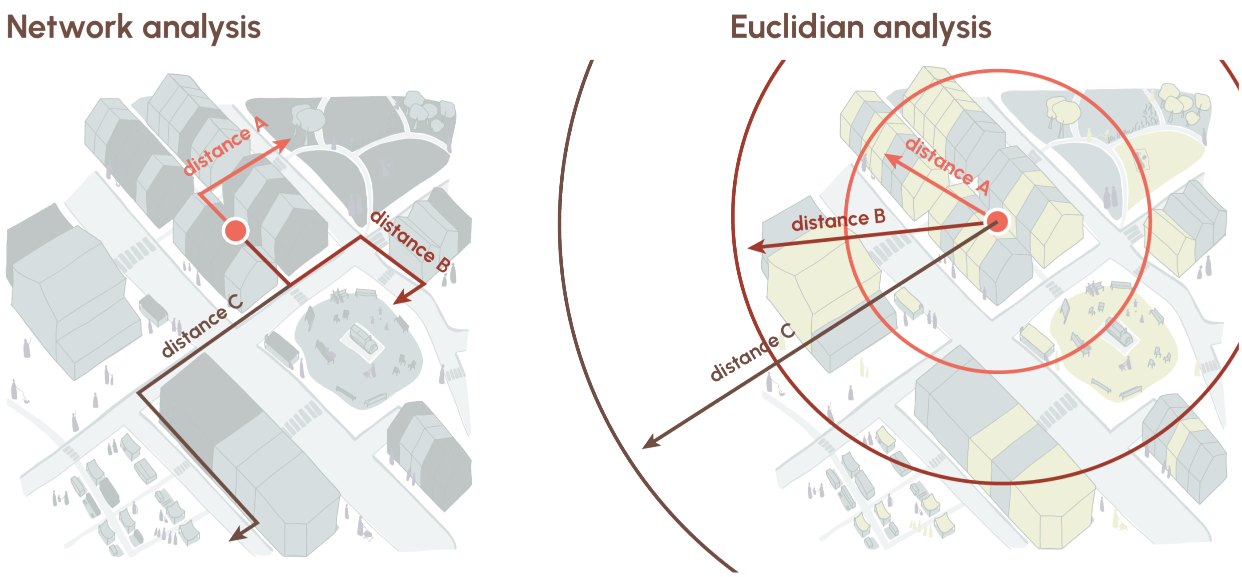


Fig. 22
Network v.s. Euclidean distance analysis
Difference in calculation between the network (distance along streets) and euclidean (bird's flight distance radius) distance analysis calculations and their impact on the scores

10.5 Closure: Project Closure

At the **Project Closure** stage, the design is finalised by the urban designer, and communicated to local stakeholders by the engagement specialist. The sustainability consultant can use the Dynamic Digital tool to run a final detailed analysis and provide a summary report, constituting the Project Closure step. Similar to the Base Analysis step, this is run in the python scripts directly, using the full detailed versions (network analyses rather than the euclidean used in Optioneering) and accounts for the final geometry previously exported to the "FINAL" option design folders via the Optioneering tagging steps.

At Project Closure, the full impact of the design interventions on the specific neighbourhood's sustainability level can be observed, interpreted, disseminated and fedforward to inform future design processes.

Indeed, the final score (normalised) can be compared with other projects' level of neighbourhood sustainability, with the understanding that the same interventions won't necessarily work the same for every project, thus ensuring a place-based approach despite the use of a performance scoring system which typically result in a check-list approach. This performance assessment is however not the purpose of the Dynamic Digital tool, and should be used for informative purposes rather than validation. It is also recommended that the final analysis is used in conjunction with a closing engagement session, for example a Post Occupancy Evaluation. It can also be used to quantify the benefit of certain design interventions to the client and community in order to contextualise final design decisions.

10.6 Results 1 - Conclusions

Therefore, the Dynamic Framework and Dynamic Digital tool as described above interrelate the workflows of engagement specialist, urban designer and sustainability consultant and contribute to responsible urban digitalisation by addressing each element of the Gap triangle, ultimately enabling sustainable neighbourhood design.

Local values are considered dynamically on a case by case basis and integrated into the total score calculations. Additionally, geodata is used as part of the analysis, providing a place-based analysis base.

Holistic sustainability is applied by analysing a variety of criteria across the 10 sustainability themes, as well as their different interrelations and interdependencies within the impact simulation. Moreover, the theme weights are designed to ensure holistic sustainability, rather silo-ing the top 5 local priorities.

Iterative design is ensured by integrating into and complementing the design workflow, thanks to the compatibility of the tool with the design software, which in turn enables the Optioneering step ensuring real time impact simulation of design interventions.

To continue, the next section details the case study application of the Dynamic Framework and Dynamic Digital tool, using a v.1 prototype on the Hirst Neighbourhood Regeneration .

11.0 results 2 - HIRST CASE STUDY

This section answers the fourth research sub-question: *What value does the application of the prototype script bring to the Hirst Residential regeneration case study project?*

11.1 Hirst Neighbourhood Regeneration

The below information was paraphrased from Fong (2023)'s design report: "Heart and Hopes of Hirst", which summarises the first step of Ryder Architecture's involvement in the regeneration of the Hirst area, driven by Northumberland County Council.

In the North East of England, near Ashington town centre, the Hirst neighbourhood (**Fig. 23**) comprises approximately 3300 terraced dwellings. With its strong mining history, the Hirst is the heart of a strong and long established community in Ashington. Nevertheless, the area faces high deprivation rates (top 10% in the UK), result of a number of social challenges (e.g., anti-social behaviour, crime, low incomes, energy poverty, street maintenance and empty properties). Over the past 20 years, Northumberland County Council addressed each issue in isolation. Now, Ryder Architecture take a holistic approach to the long term regeneration of the Hirst.

Ryder Architecture's involvement started in 2023 and involved the first stages of the urban design workflow (Preparation, Conceptualisation) during which the design team collaborated with an engagement specialist and a sustainability consultant, by including regular engagement sessions (i.e., conversations with the client (Northumberland County Council, discussions with local community groups, charities, local Councillors; drop in events) and environmental analyses (climate desktop study, local environmental goals, grasshopper climate simulations, proposed interventions and impacts). Note that the above process corresponds to the current workflow for sustainable neighbourhood design as detailed in **Section 7.4** and did not benefit from the Dynamic Framework or Dynamic Digital Tool. The outcome was a Final Masterplan vision and Business Case Reports.

Now, in 2025, the project is in the "Implementation" phase of the Dynamic Framework, with detailed design options for a pilot area emerging justifying further community engagement and sustainable design consultancy. This presents an opportunity to trial the Dynamic Framework, admittedly in a manner limited by the current project timeline rather than a full start-to-end project, as well as the v.1 prototype of the Dynamic Digital Tool, both as described in **Section 10.**

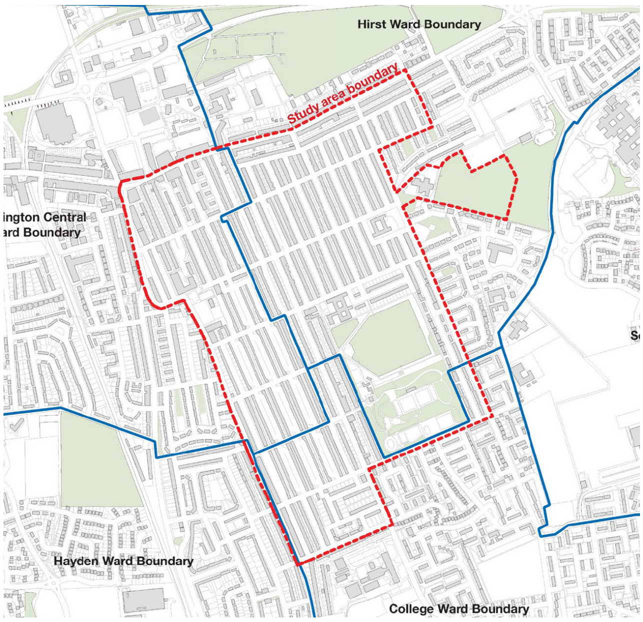


Fig. 23
Hirst Case Study - Site Boundary
Site boundary for the Hirst Neighbourhood regeneration case study, outlined in red dashes

11.2 Local Values

At this stage, further engagement was conducted with service providers, local community groups and a school session – with resident engagement still to be completed. Nevertheless, the current results already give an overview of the local values (Urban Design Director, personal communication, August 1, 2025).

The Urban Design Director assesses the local priorities to be the following , based on the findings from initital "place-based indicator" engagement sessions, and mapped across to the National Design Guide categories as closely as possible (Urban Design Director, personal communication, August 1, 2025):

1. Lifespan (this encompasses maintenance and place stewardship)
2. Homes and Buildings
3. Context
4. Movement
5. Nature

It should be noted that the engagement process results were categorised under another set of indicators (project confidential), themselves based on the 10 aims for the Hirst as above. This project having started based on different indicators makes it difficult to truly align with the 10 themes from the National Design Guide (Ministry of Housing, Communities and Local Government, 2021) and the Urban Design Director expressed concerns on this setup's true reflection of the local community's values (Urban Design Director, personal communication, August 1, 2025). This emphasizes the need to apply the Dynamic Framework and Digital Tool from the start.

Despite this, the Dynamic Digital Tool v.1 prototype was applied, as detailed in the next section, written as an example summary report a sustainability consultant would give as dissemination.

11.3 Sustainable Neighbourhood Report – Base Analysis

This is summary report on the sustainable design of Hirst Neighbourhood Regeneration Project. The analysis, conducted via the Dynamic Digital tool v.1 prototype, is based on a 10*10m grid across the project site area. The prototype currently includes the following analysis criteria, a per **Section 9.4**:

- Green Access: walking distance to the closest green infrastructure, from every point of the site, should be less than or equal to 300m (United Nations Environmental Programme, 2017)
- Transport Access: walking distance to public transport stops, from every point of the site, should be less than or equal to 400m for the closest bus or tram stops; and 800m for the closest rail station (National Design Guide, 2021)
- Density: urban dwelling density should be between 60-120 dwellings per hectare (Dempsey et al., 2012)
- Blue Access: walking distance to the closest blue infrastructure, from every point of the site, should be less than or equal to 600m (Volker and Kistemann, 2011)
- Flood Risk: the flood risk, based on gov.uk's model, should not be "high"
- Amenity Access: walking distance to the closest amenities, from every point of the site, should be less than or equal to 300m to minimum 3 daily commerces* and less than or equal to 600m to 3 community equipment** (Ortiz-Fernandez et al., 2023)
- Energy Performance: the building EPC, based on gov.uk's EPC Certificates, should be C or better for existing buildings, and B or better for new build (HM Government, 2022)
- Street network connections: each street should be connected to at least 2 other streets (i.e. avoid dead ends) (National Design Guide, 2021)
- Cycle path access: walking distance to the closest cycle path, from every point of the site, should be less than or equal to 400m (Ortiz-Fernandez et al., 2023)

Running the Base Analysis reveals that further consideration is needed for the themes of Context, Movement, Nature and Homes and Buildings, which are local priorities. Within these flagged themes, the low performing criteria are:

- Green Access (**Fig. 24**): moderate performance, 49%
- Blue Access (**Fig. 25**): critical performance, 16%
- Cycle Path Access (**Fig. 26**): critical performance 9%
- Density (**Fig. 27**): critical performance, 17%

Additionally, Lifespan is the highest local priority, and is composed of:

- Flood Risk (**Fig. 28**): good performance, 88%

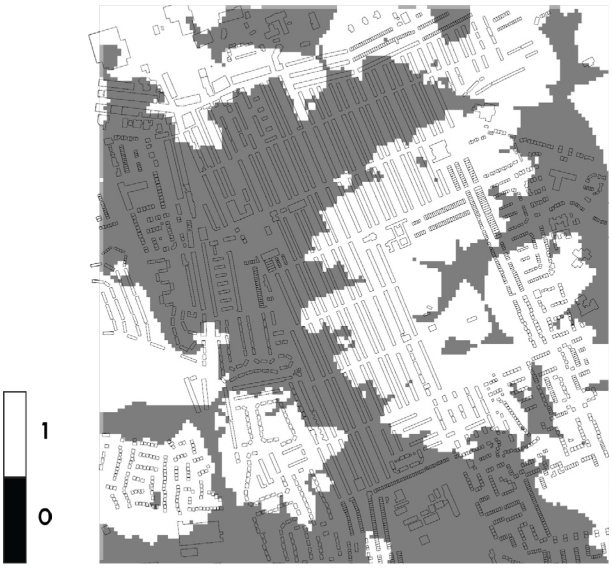


Fig. 24
Green Access
analysis results for the B1_green_access script

Fig. 25
Blue Access
analysis results for the B4_blue_access script

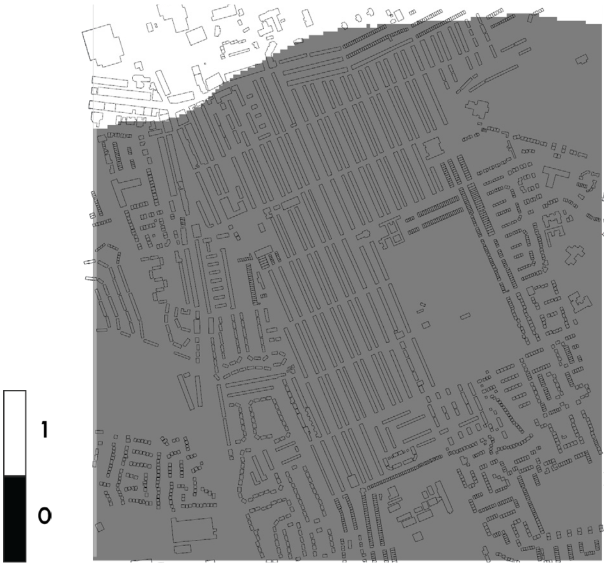


Fig. 26
Cycle Path Access
analysis results for the B11_cycle_path_access script

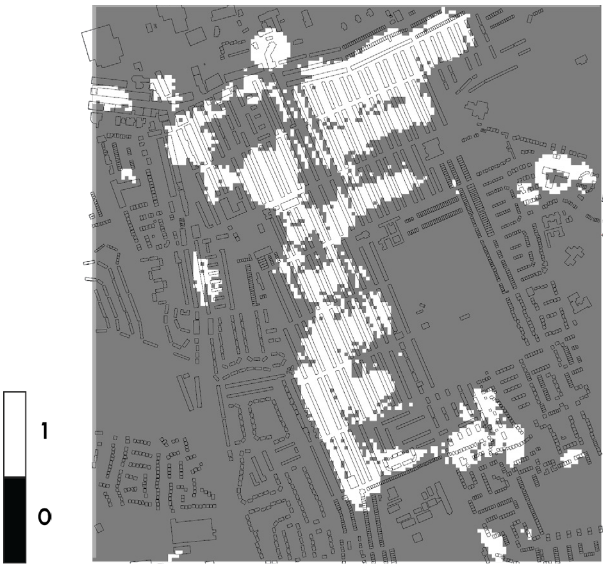


Fig. 27
Density
analysis results for the B3_density script

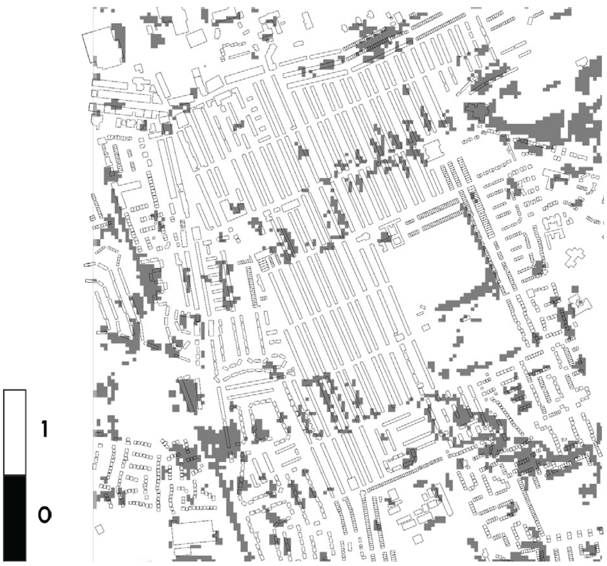
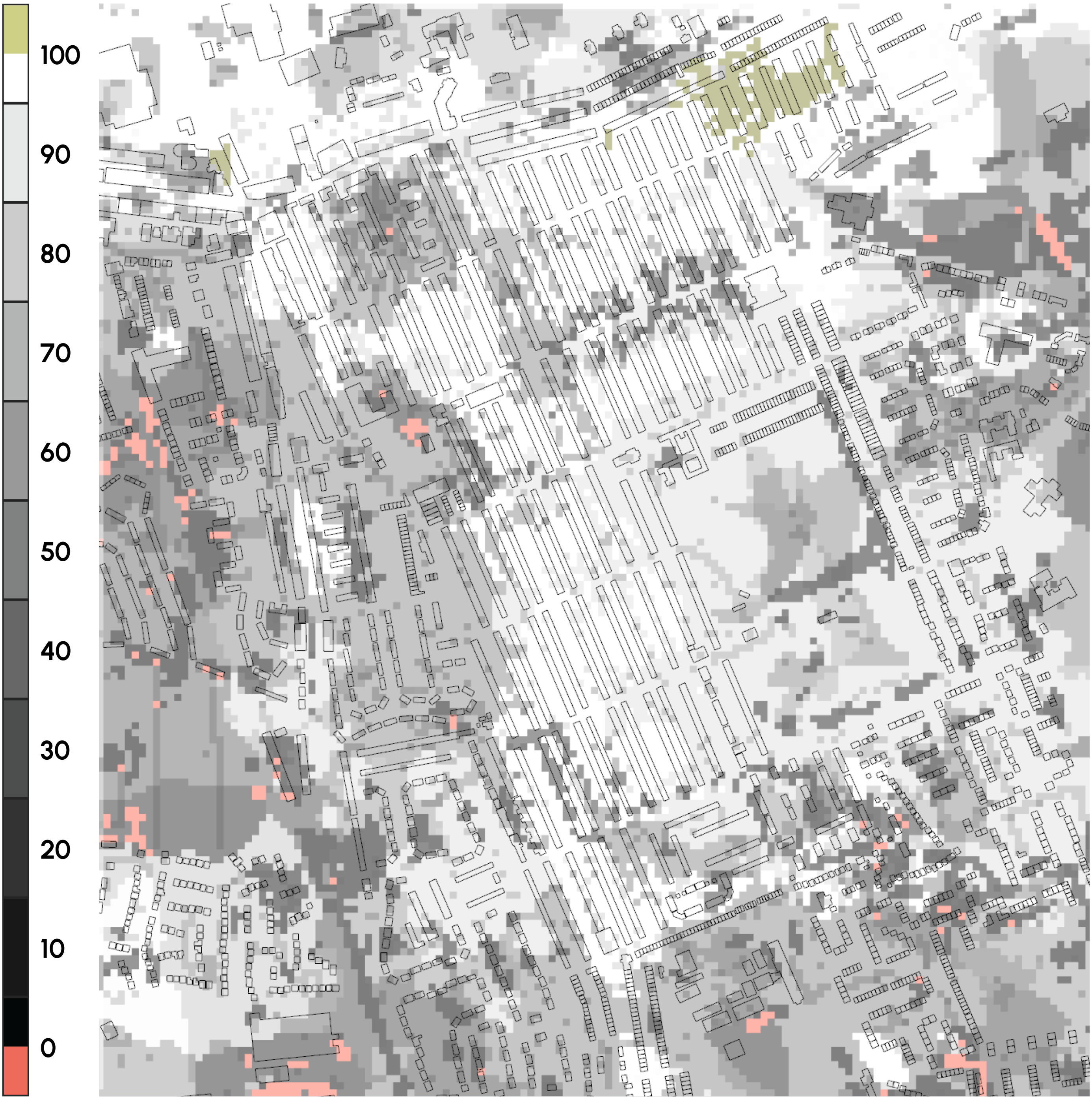


Fig. 28
Flood Risk
analysis results for the B5_flood_risk script

Overall, currently, the Hirst neighbourhood has a sustainability score of 42%. This means that 42% of grid cells score above 60/100 in the analysis across 10 sustainability themes, weighted according to the community's local values. The spatial representation of the score is seen in **Fig. 29**, where the key zones for priority intervention are highlighted in red.

```
==================================================
NEIGHBOURHOOD SUSTAINABILITY ASSESSMENT
==================================================

OVERALL PERFORMANCE: 42.0% of cells scoring 60+/100
(9237 out of 22010 cells)
Status: MODERATE
--------------------------------------------------

WARNING: The themes 'Context, Identity, Movement, Nature, Uses, Homes and Buildings, Resources'
are currently scoring low.

These themes include analyses of: Green Access, Transport Access, Density, Blue Access, Flood
Risk, Amenity Access, Green Area, Cycle Path Access, Street Network Connection, Green Links,
Energy Performance.

URGENT: 'Context, Movement, Nature, Homes and Buildings' are community priorities!

RECOMMENDED ACTIONS:
  - Green Access: Make green infrastructure accessible by ensuring they are well connected, have
clear entry points and are regular within the neighbourhood
  - Transport Access: Consider adding more public transport options and improving the routes that
lead to them
  - Density: Where possible, prioritise higher densities
  - Blue Access: Make blue infrastructure accessible by ensuring they are well connected, have
clear entry points and are regular within the neighbourhood
  - Flood Risk: Add flood mitigation measures like permeable surfaces, greenery or improved
drainage
  - Amenity Access: Ensure essential services and amenities are within walking distance by
reviewing location and connectivity
  - Green Area: Add green surface in the site where relevant
  - Cycle Path Access: Ensure cycle paths are within walking distance by creating new networks
where relevant
  - Street Network Connection: Ensure dead ends are avoided and create new relevant paths to
improve the street network
  - Green Links: Ensure green areas are regular and well connected with each other throughout the
site
  - Energy Performance: Retrofit existing houses (i.e. better fabric insulation, window double
glazing, lighting fixtures)
```

Fig. 29
Hirst Case Study - Base Analysis
visual, spatial and textual representation of the sustainability performance of the Hirst neighbourhood, with best (green) and worst (red) performing areas highlighted.



The total score visual reveals 7 key zones for urgent intervention – the lowest scoring zones of the Hirst neighbourhood.. Upon detailed investigation of the criteria and contextualisation within the site context via ArcGIS and Google Earth, recommendations to improve this neighbourhood's sustainability performance are illustrated in **Fig. 30**. These include the creation of pocket parks, better entrance access to existing parks, SUDS to mitigate floor risk, terraced apartments in strategic locations, a water feature and a cycle path network. It is recommended that the urban designer take these considerations forward in the design workflow, through the Preparation and Implementation stages. It is also recommended that the results

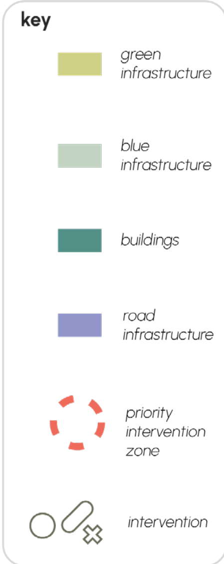
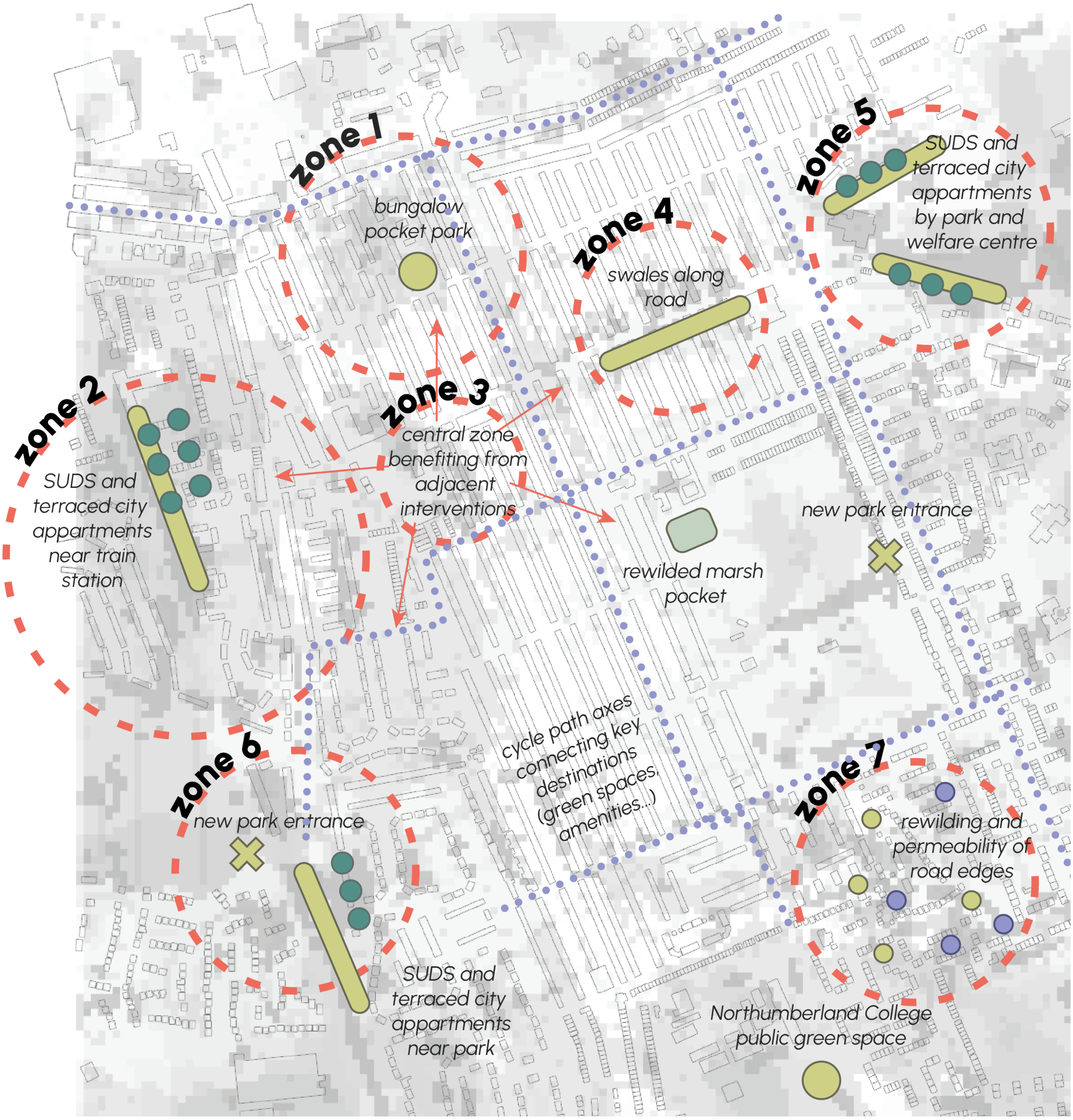


Fig. 30
Hirst Case Study - Base Recommendations
recommended interventions to improve the sustainability performance of the Hirst neighbourhood, based on the Base Analysis results

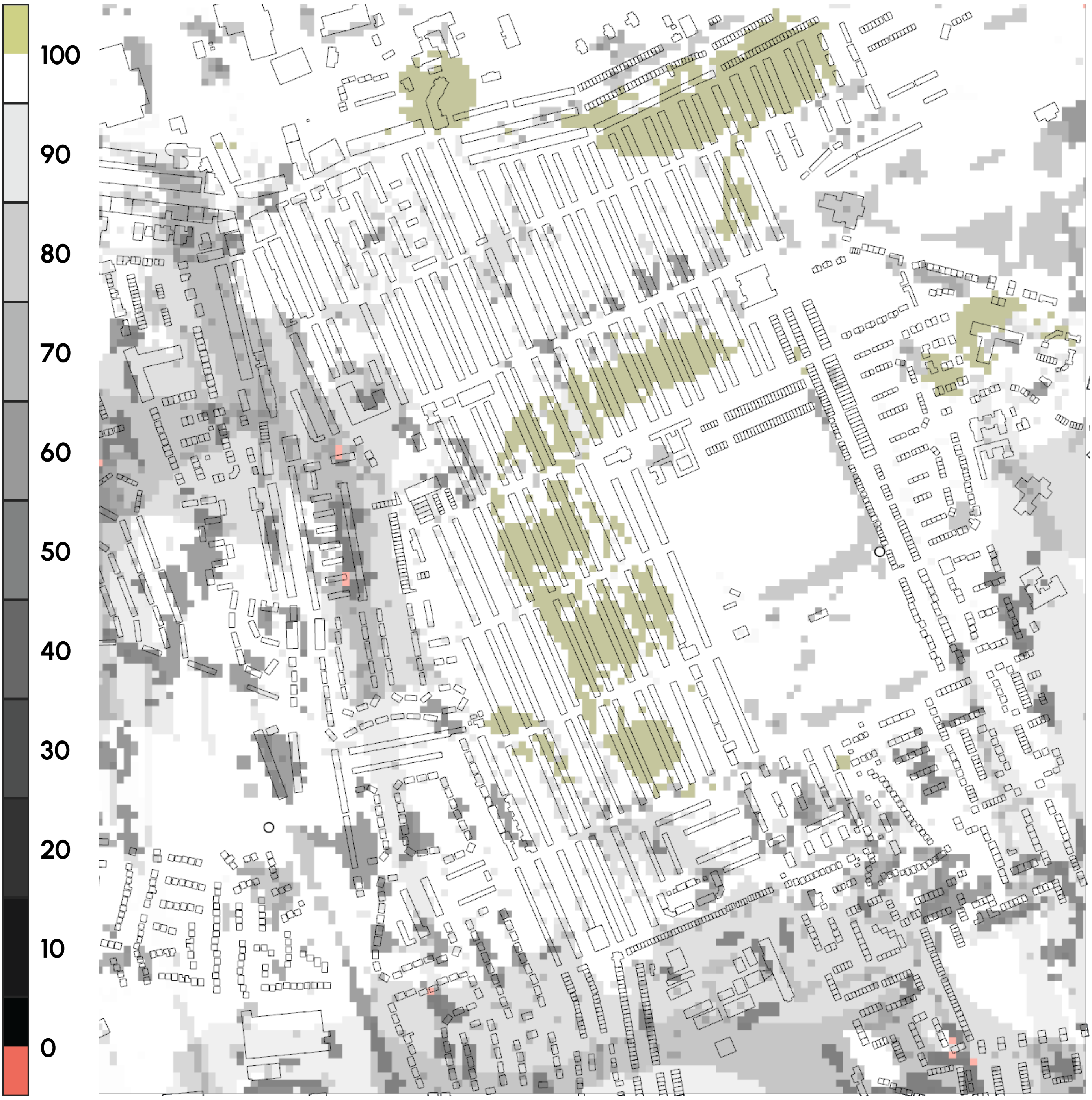


be shown in the next local residents stakeholder engagement, as a way to complete the data with the real felt experience of the community.

Applying the above interventions successfully improves the total performance score, based on a quick optioneering analysis, from 42% to 78% **(Fig. 31)**. More attention should be given to the west of the site which accumulates low scores from all the important criteria.

Fig. 31
Hirst Case Study - Base Recommendations Impact
sustainability performance of the Hirst neighbourhood when applying the Base Recommendations, using the euclidean distance scripts.

```
OVERALL PERFORMANCE: 78.8% of cells scoring 60+/100
(17956 out of 22800 cells)
Status: GOOD
--------------------------------------------------

WARNING: The themes 'Uses, Homes and Buildings, Resources' are
currently scoring low.

These themes include analyses of: Density, Amenity Access, Energy
Performance.

URGENT: 'Homes and Buildings' are community priorities!

RECOMMENDED ACTIONS:
  - Density: Where possible, prioritise higher densities
  - Amenity Access: Ensure essential services and amenities are
within walking distance by reviewing location and connectivity
  - Energy Performance: Retrofit existing houses (i.e. better
fabric insulation, window double glazing, lighting fixtures)

Implement these changes and re-run the analysis!
```



To conclude the Base Analysis, the Hirst currently has a few zones for priority intervention, and focus should be given to green spaces access, urban density and the cycle network, as key contributing factors to the local values of the community.

The next section examines the results from the 3 design options, produced separately to the Dynamic Digital tool results, as this information wasn't available to the urban designers as they entered the Implementation stage.

11.4 Sustainable Neighbourhood Report – Optioneering

For the optioneering stage, a pilot area was selected by the urban designers **(Fig. 32)**.and 3 design options were developed. (**Fig.33-35**) as described below:

Option 1 is the least intrusive for the community and proposes a rearranging of the current terraced houses rhythm, along with a pocket park.

Option 2 slightly less modest, splits the terracing to open up with a pocket park, creating at the same time a new access throughroute.

Finally, **Option 3** offers the most intensive change by completely reviewing the street morphology, including creating pocket park, south facing terraced apartments and multiple access routes through.

The results of the optioneering analysis show clear improvements from the Base analysis (using the euclidean scripts), as seen in Fig. **36-38** with all options now scoring 74%, against the 42% from the Base analysis.The key interventions which display a great positive impact are the creation of a pocket park and the addition of a cycle path which connects key destinations (the park, the grocery stores, the school and welfare centre).

However, the relative difference in impact between the different options is minimal, with Option 2 scoring one percent higher (75%) than the others. This lack of clear differenciaition is due to the concentrated nature of the pilot area and subsequent interventions, as well as the v.1 prototype's scope (such as not yet accounting for the solar access criteria). Indeed, the current differences in pilot options are mainly based on layout, orientation as well as new build vs retrofit decisions - all of which largely relevant, but not yet fully reflected in the prototype to a high, building scale refinement. Nevertheless, the Optioneering output is that currently, all options have an equally positive positive impact on the neighbourhood's sutainability, and the designers can apply further project requirements, which are not accounted for in the Dynamic Digital tool, as needed to complete the choice of the Final Option. A reminder that the tool is not aiming to replace the decision making process within the design flow, simply to inform it. For this project, with the v.1 prototype's considerations, the options' contributions to the Hirst neighbourhood's sustainability proved to be evenly beneficial. It is further advised to, where possible, reduce the carbon intensity of the project, by preferring retrofit to new build.

As such, the recommendation of this report is to prefer Option 2, which presents the benefits of all other options plus the new through route, as well as improved and larger housing, all without needing carbon intensive demolition and rebuild..

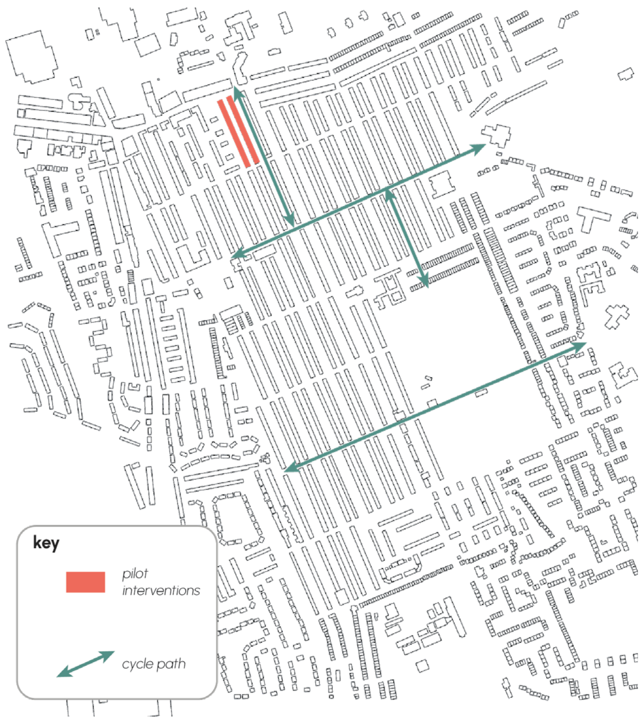


Fig. 32
Hirst Case Study - Pilot area
pilot area for the design options of the Hirst (red dashed circle). Each design option features a cycle path, as indicated by the blue line..

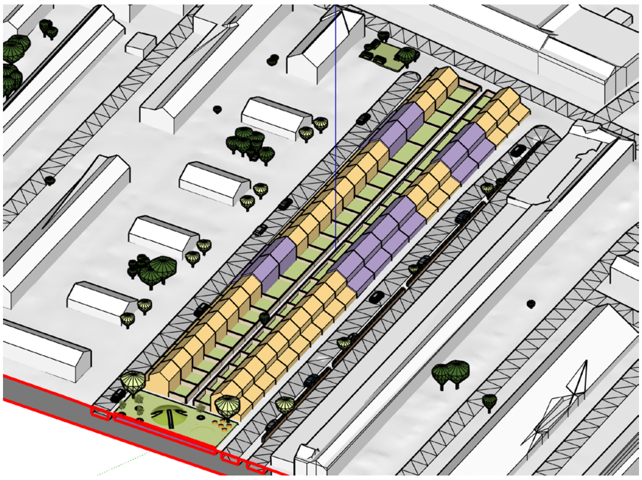


Fig. 33
Hirst Case Study - Design Option 1
first design option for the pilot intervention area in Hirst. The option involves the creation of a pocket park and ten two-into-three homes (in purple)

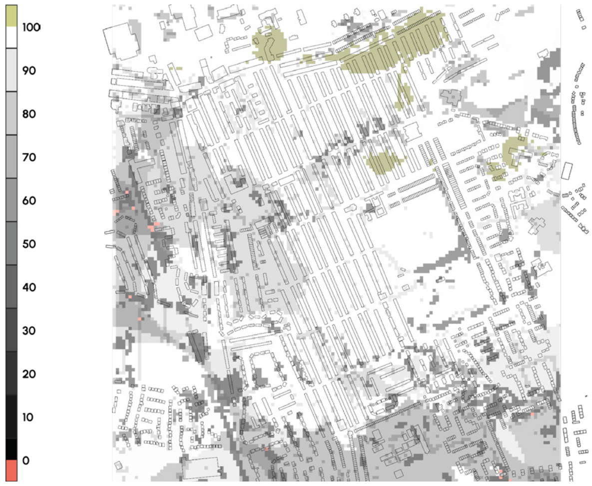


Fig. 36
Hirst Case Study - Design Option 1 Results
sustainabillity performance results of the Hirst neighbourhood after the Option 1 interventions

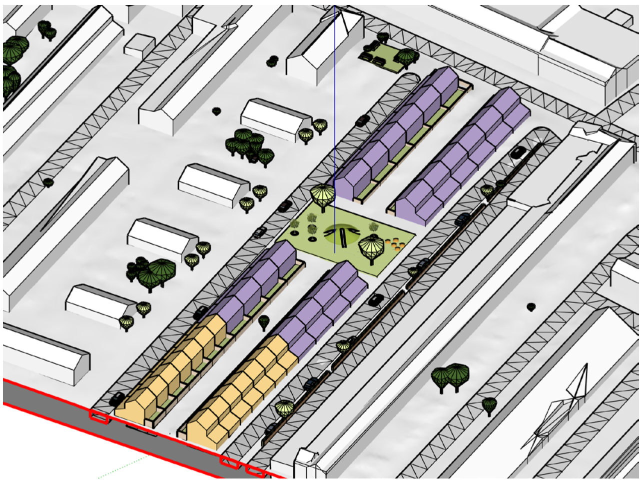


Fig. 34
Hirst Case Study - Design Option 2
second design option for the pilot intervention area in Hirst. The option involves the creation of a pocket park, new access through routes and twenty two-into-three homes (in purple)

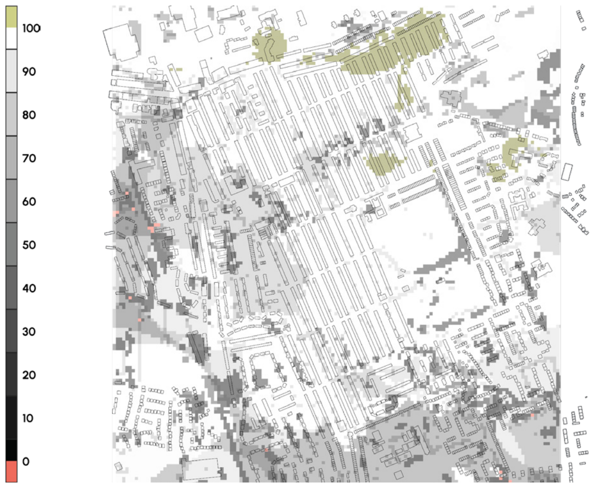


Fig. 37
Hirst Case Study - Design Option 2 Results
sustainabillity performance results of the Hirst neighbourhood after the Option 2 interventions

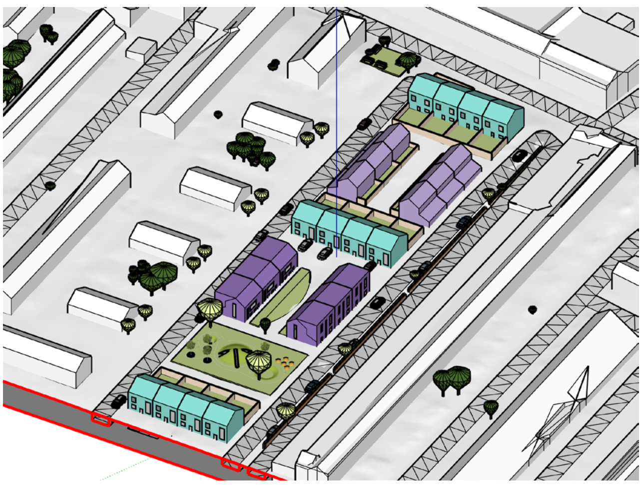


Fig. 35
Hirst Case Study - Design Option 3
third design option for the pilot intervention area in Hirst. The option involves the creation of a pocket park, new access through routes, six two-into-three homes (in purple), six new build large homes, and twelve new build South facing homes

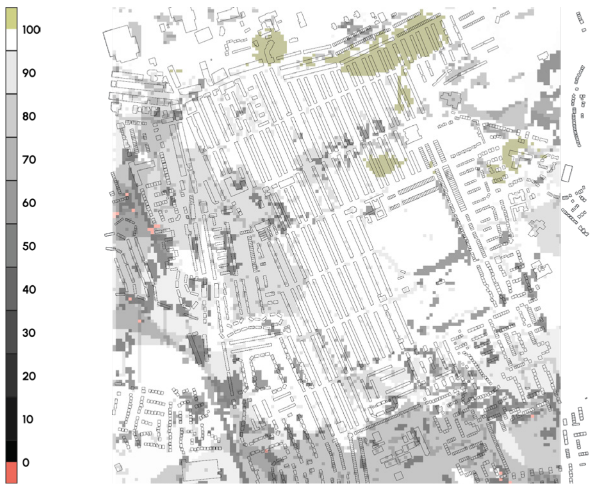


Fig. 38
Hirst Case Study - Design Option 3 Results
sustainabillity performance results of the Hirst neighbourhood after the Option 3 interventions

11.4 Sustainable Neighbourhood Report – Closure

Though the Hirst project isn't finalized, Option 2 is treated as the final design for this case study analysis.

The results show positive impacts, primarily improving green space and cycle path access, contributing to the local values of Context (3), Movement (4) and Nature (5). Though green spaces do contribute to mitigating flood risk, key criteria in Lifespan (1), the pilot area was not in a high flood risk zone. In total, sustainability performance increased from 42% to 49% (**Fig. 39**), with green access improving from 49% to 53% and cycle path access from 9% to 30%. However, these improvements had moderate impact on the total score since the site's highest priorities are Lifespan and Homes and Buildings. While the pilot area was prioritized, it wasn't the lowest-scoring area, limiting community-wide impact. More design interventions should extend beyond the pilot area, like the cycle path did, for a more holistic approach to improving Hirst's sustainability.

Overall, the design options successfully increase the neighbourhood sustainability score (**Fig. 40**). It is recommended to extend beyond the pilot area, ensuring a holistic approach and response to the Hirst's needs to become a more sustainable neighbourhood.

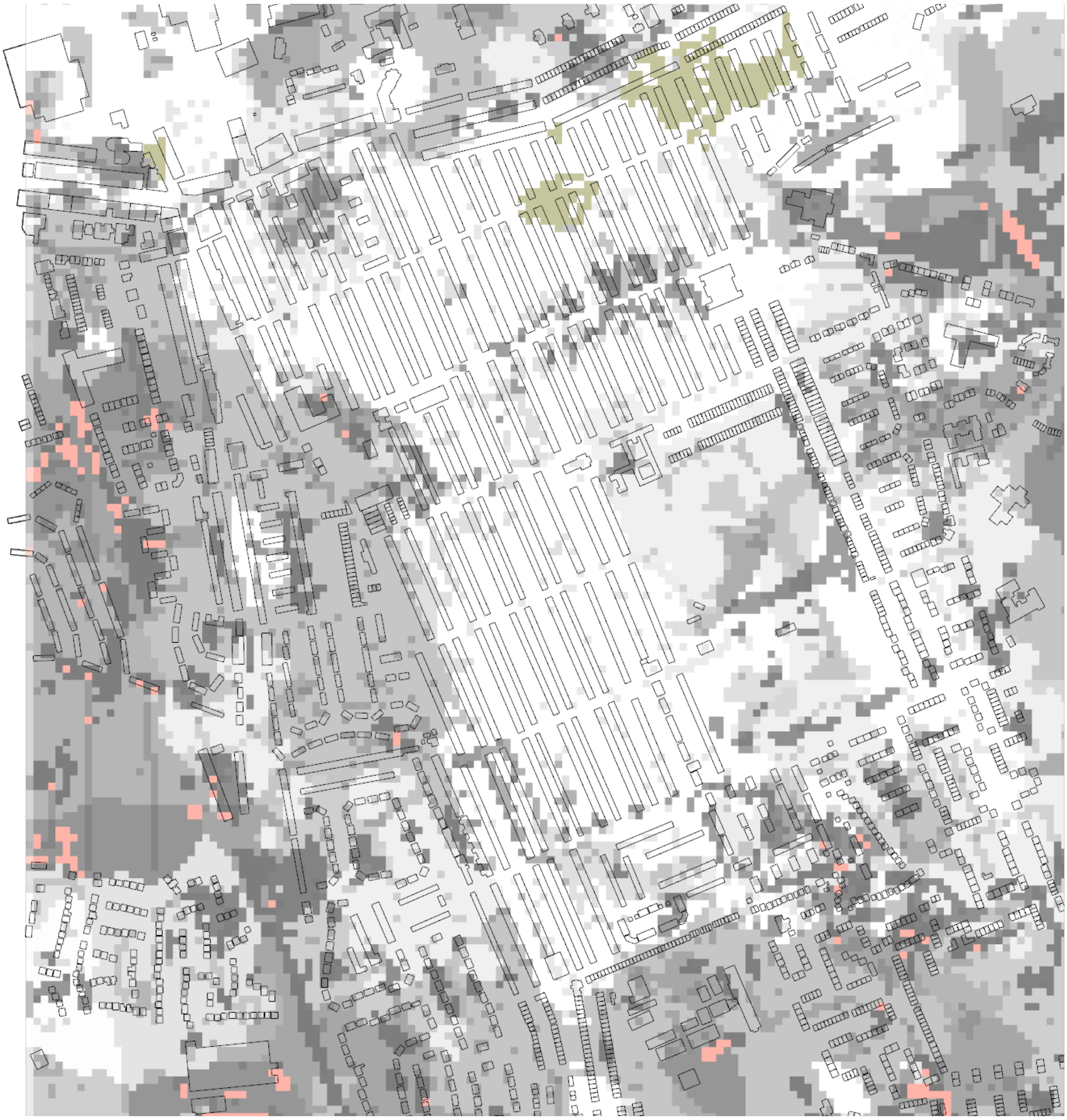


Fig. 39
Hirst Case Study - Final Analysis
visual, spatial and textual representation of the sustainability performance of the Hirst neighbourhood, with best (green) and worst (red) performing areas highlighted.

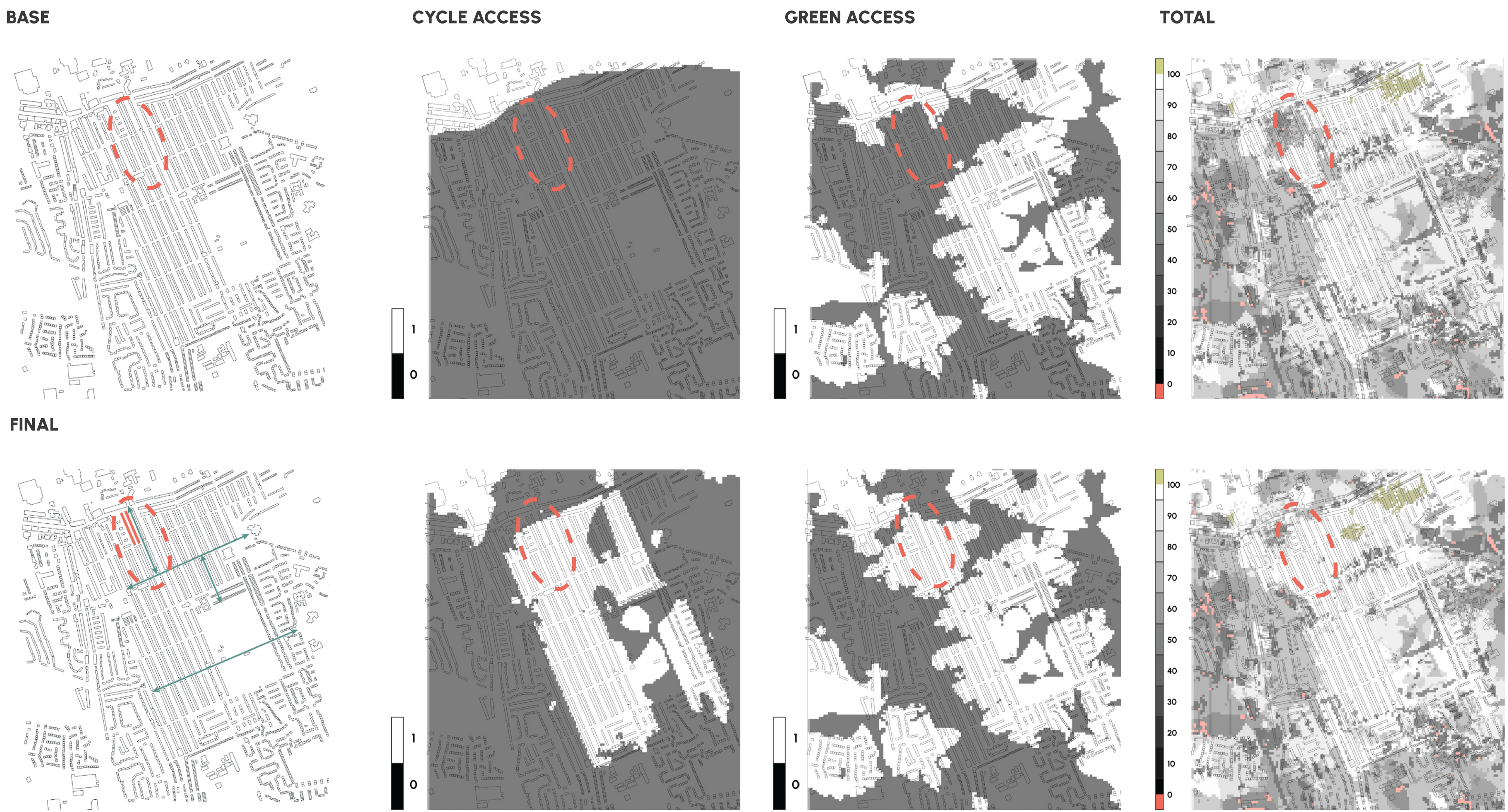


Fig. 40
Hirst Case Study - Results Comparison
base analysis versus final option analysis , showing the impact of the design interventions and zones which still require attention for the Hirst sustainability.

11.5 Results 2 - Conclusions

To conclude, the use of the Dynamic Digital tool prototype on the Hirst case study project highlighted key findings and considerations.

First, on the workflow application, the case study confirmed that the Dynamic Digital tool should be applied in line with the Dynamic Framework, from the ignition of a project, to most effectively guide the design process towards sustainable neighbourhoods. Indeed, results from the Base analysis successfully identified priority areas in red and provided criteria performance warnings. This could have better informed the direction of the design, though the pilot area was in fact in a priority area. Further interventions, such as those represented in the sustainability consultant's recommendations could have been considered had the Dynamic Framework been followed. The key to the Dynamic Digital tool is the integration within the workflow, complementing it by adding data-driven knowledge to the design considerations.

Second, the v.1 prototype only displayed 9 analysis scripts, plus the C1 Theme Contributions script. Though already an extensive display, having more analysis scripts, thus covering more criteria, would have helped to differentiate options better – specifically the solar access script which was not part of the v.1 and would have contributed to seeing the impact of the more intensive interventions in Option 3, shifting the housing from an East/West axis to a North/South one, beneficial for indoor comfort and energy performance and contributing to Homes and Buildings and Resources; or the options' improvement of dwelling private area, which, if in the v.1 prototype, would have benefited the area's living quality and wellbeing, also contributing to Homes and Buildings. Other differentiating factors not currently in the prototype include the carbon impact of building demolition and new building construction which would have been most visible for Option 3, as well as the positive impacts of street traffic flow reduction in all Options. While a number of these are part of the Dynamic Digital tool's planned design and future prototypes (i.e. solar access, private area), others will need further reflection and slight tool re-design, for example the inclusion of "malus" points to account for demolitions or density reduction.

Third, the use of GIS software (ArcGIS or QGIS), though seemingly anodyne in the Dynamic Digital tool, proved extremely important in order to contextualise certain "surprising" results by layering the analysis outcome with raw data. For example, **Fig. 43** illustrates insights from the B1_green_access criteria results alongside the base data of green space access and the road network, used in the calculation of the green access performance score. This layering of information provides additional insights, ranging from design intervention focus (i.e. adding better routes and entrances to parks rather than creating new ones (red circles)); or data gap awareness (i.e. the network line not fully reaching the park entrance (purple circles), park entrances not modelled in the data, the data showing a greenhouse area as a public green space (blue circle), or certain green spaces not modelled at all (informal green spaces throughout)). These further prove the need to see the Dynamic Digital tool as an addition / a help to the design of sustainable neighbourhoods rather than the exclusive solution replacing all other flows and thought processes. This was pointed out by literature, indicating that no tool could solve everything. In this light, the Base Analysis step, and its deep inspection by the sustainability consultant and communication with the urban designers, hold a central role in the potential to design sustainable neighbourhoods. The value of the tool is in its capacity to show an overview of many different criteria and assess design impact onto those (Co-creation, personal communication, June 16, 2025)

Fourth, the actual use of the Dynamic Digital tool was smooth, specifically thanks to the addition of the "load" function which contributed to reducing lagging time. Centralised inputs provided a seamless experience. The running of the masterscript in the Base analysis and Final analysis steps also worked efficiently, providing all results in under an hour (3 A scripts, 9 B scripts). The Grasshopper script interface's clear inputs and, once again, centralised information, reduced the risk of user input / coordination errors. The designers' option models were in Sketchup and were imported easily within Rhino as polysurfaces, compatible with the Option Geometry export functions of the Grasshopper script.

To conclude, the benefits of applying the Dynamic Framework and Digital tool on this project can be described in comparison to the current best practice workflow (design, engagement and sustainability isolated).:

In comparison to the design-only workflow, the tool allowed for the effective highlighting of priority intervention zones Not having this overview led to a lack of holistic consideration of the design option interventions. This is clear by the relatively low impact of the current options when looking at the neighbourhood sustainability as a whole, though the options successfully improve the pilot area itself. Assessing the option impacts also allows for more informed optioneering and dynamically integrates sustainability and the design flows.

In comparison to the GIS-only workflow, the tool allowed for the comparative analysis of design options and the dynamic input of local values in order of priority. This allowed to truly contribute to the iterative design process, rather than be limited to static site analysis.

As such, this research's products successfully innovate on the existing tools and workflow. The innovations and limitations are fully detailed in the next section.

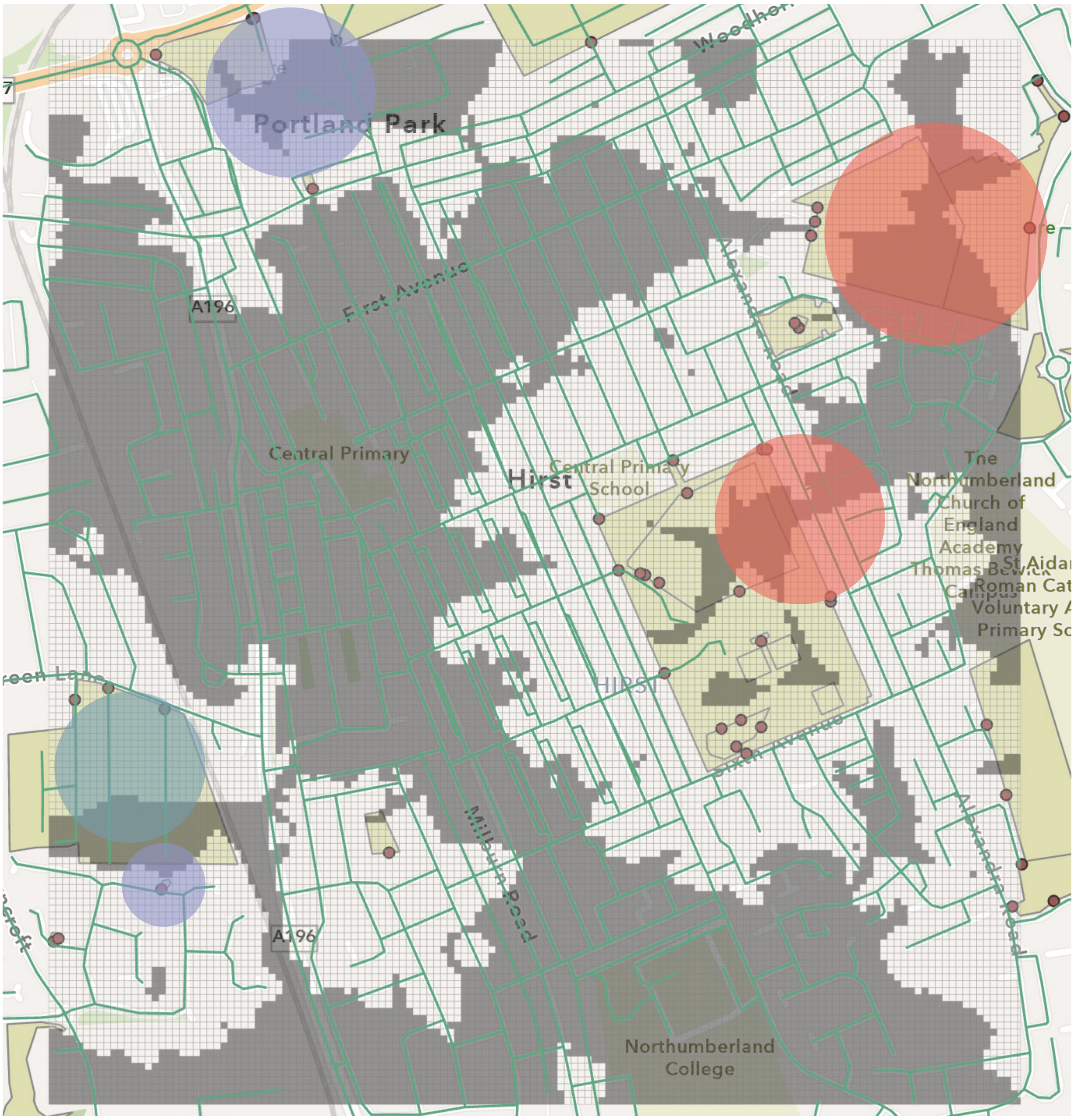


Fig. 43
Green access GIS contextualisation
importance of using GIS software to visualise the results alongside the base data (green space access nodes and road network). For example, the recontextualisation of the green access results / data showed the need for better access paths and points into the existing green spaces, (red circles), the data errors where nodes are not appropriately identified as connected to the road network therefore showing lack of access (purple circles) and finally a mis-tag of base data, as the blue circle is in fact a greenhouse area rather than a public park. (evidenced via Google Earth)

12.0 discussion - REFLECTING ON IMPACT

12.1 Innovations

The conclusions of this prototype are overall positive, as it successfully addresses the three points of the Gap Triangle, making for an innovative approach to sustainable neighbourhood design which is in line with responsible urban digitalisation: the dynamic approach to place-based, holistic sustainability and iterative design. The provision of each element individually in a digital tool is not currently achieved, and so the combination of the three provides a core societal innovation, as demonstrated by literature, which mentioned the lack of dynamic digital tools for sustainable neighbourhood design, and the lack of consideration of local values, the focus on environmental sustainability (Amirzadeh & Sharifi, 2024; Khatibi et al., 2023; Li & Milburn, 2016; Wissen Hayek et al., 2016; Zhang, 2021; Zhang & Liu, 2019); interviewee testimonies (throughout this research, introduced in **Table 1**); and software reviews (**Appendix A**). The Dynamic Digital tool opens the doors to a potential novel industry use of design tools, guided by the Dynamic Framework which represents best practice workflow for sustainable neighbourhood design in the UK. In the next paragraphs, this research's results' innovations are confronted to both scientific literature, which re-state the current gaps and needs, and industry professionals' interview testimonies, which validate the relevance in practice and actual impact.

Firstly, the **place-based approach**, so essential for sustainable neighbourhood design, is currently not commonly achieved in digital design tools, due to the complex interrelationships between place and people (Amirzadeh & Sharifi, 2024; Wissen Hayek et al., 2016; Zhang & Liu, 2019). Rather than intend to digitally replicate and quantify this relationship fully, this research adopted an integrated approach: not replacing, but complementing the current place-based processes, such as engagement sessions within the urban design flow.

For this, the first key innovation is the **integration of local values into the analysis programme in the form of priority weights**. Indeed, while Geodesign emphasizes engagement at every step of the process, the results were not (able to be) directly input in the data-driven digital tools' analysis (McElvaney & Rouse, 2015). This digital design tool allows for customisation of score weights based on the local values, and the weighting system informed by the engagement session results successfully incorporates engagement results into a dynamic digital tool for sustainable neighbourhoods (Partner, personal communication, March 27, 2025; Research Director, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025).This differentiates the Dynamic Digital tool from current tools, which adopt a one size fits all approach by default (Head of Innovation, personal communication, March 13, 2025; Khatibi et al., 2023; Marique & Teller, 2014; Mateo-Babiano & Palipane, 2020; Switalski et al., 2023). While doing this, the Dynamic Digital tool still applies best practice sustainability metrics, relevant to industry and academic literature (BREEAM, 2025; Ortiz-Fernandez et al., 2023) Indeed, the ideal tool has both quantitative and qualitative parts, complementing data-driven analyses with community engagement (Head of Innovation, personal communication, March 13, 2025).

Secondly, the **holistic approach to sustainability** is innovative in the **interrelations and transparency** of criteria which contribute to all branches of sustainability rather than examining elements in silo, at the loss of an integrated and holistic picture (Founder, personal communication, March 19, 2025; Gruis et al., 2006; Li & Milburn, 2016 McElvaney & Rouse, 2015), especially environmental sustainability, like is the case with highly performing digital tools like IES VE or Design Builder (**Appendix A**) (Computational Design Lead, personal communication, March 11, 2025; Khatibi et al., 2023; Sustainability Director, personal communication, March 27; Zhang, 2021). This lack of holistic sustainability overview is a key challenge in current digital tools for sustainable neighbourhoods (Axinte et al., 2022; Computational Design Lead, personal communication, March 11, 2025; Khatibi et al., 2023; Founder, personal communication, March 19, 2025; Sustainability Director, personal communication, March 27, 2025; Switalski, et al., 2023; United Nations, 2015). The interrelations are accounted for by directly distributing criteria to the relevant sustainability themes they contribute to (e.g., amenity access contributes to Context, Built Form, Uses and Resources). The tool is also different to NSAs, in which the grading system is based on indicators (issuing scores based on compliance) and multiplied by weightings (BREEAM, 2025; Ortiz-Fernandez et al., 2023). Here, apart from the additionally weighted themes based on the results of the engagement session, as part of the place-based approach as seen above, each theme is equally as important within the scoring system thanks to the normalised pass/fail scores. This holistic view was not seen before at the neighbourhood scale (Founder, personal communication, March 19, 2025; Gruis et al., 2006; Li & Milburn, 2016 McElvaney & Rouse, 2015) and current neighbourhood scale analysis tools alone like Grasshopper were focused on environmental analyses (Solar access, Wind turbulence, UTCI, Daylight access) (Ladybug Tools, 2025). Designers also emphasise the benefit of a consistent vision and objective, as often sustainability goals and / or local priorities set in the conceptualisation stage get overridden by the deep consideration of technical elements within the implementation stage (Co-creation, personal communication, June 16, 2025; Research Director, personal communication, April 8, 2025).

To continue, all of the above – the interrelations and weightings – are openly visible to the user, with transparency emphasized throughout the Dynamic Digital tool. Having direct insight to the tool code, calculation thresholds, the detailed and multiple feedback opportunities as well as interpretation cues for the results were key necessities expressed by industry professionals (Partner, personal communication, March 27, 2025; Research Director, personal communication, April 8, 2025; Sustainability Director, personal communication, March 27, 2025). The industry was lacking a sustainable design tool at the neighbourhood scale (Computational Design Lead, personal communication, March 11, 2025; ; Khatibi et al., 2023; Zhang, 2021; Sustainability Director, personal communication, March 27, 2025) and the Dynamic Digital tool, in combination with the Dynamic Framework, address this scientific and societal gap.

Thirdly, this need for a new solution (Gruis et al., 2006 Smaniotto-Costa et al., 2024) could only be fully bridged by providing a solution which **integrates and enhances the current urban design workflow,** rather than attempting to replace core parts of it or doing engagement, design and sustainability separately and with lack of interoperability of tools, as is currently the case (Partner, personal communication, March 27, 2025; Sustainability Director, personal communication, March 27, 2025; Urban Designer, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025; Wissen Hayek et al., 2016; Zhang, 2021). This integration is achieved by the Dynamic Framework design, as well as the Dynamic Digital tool's compatibility with design software via Rhino and ability to perform optioneering simulations with quasi-direct feedback (Computational Design Lead, personal communication, March 11, 2025; Partner, personal communication, April 8, 2025). Additionally, the criteria considered by the digital tool are compatible with BREEAM Communities' ones, with this research's thresholds equal to or stricter than BREEAM's, although BREEAM being a validation list does allow to consider the non-spatial elements that the Dynamic Digital tool had to filter out. Nevertheless, this shows further compatibility with the current workflow, as it aligns with key sustainable design certifications. As such, the current process is not undermined or changed, but enhanced to enable designers to focus on better sustainability outcomes (Partner, personal communication, April 8, 2025). The ability to assess the sustainability performance of design iterations at the neighbourhood scale dynamically is novel and highly valuable (Founder, personal communication, March 19, 2025).

Indeed, validating the societal contribution, **industry experts' feedback** - gathered during the co-creation, informal discussions with academic researchers and a presentation to the partner council of a global consultancy - includes:

¬ very positive, wants to use it already (Co-Creation, personal communication, June 16, 2025);

¬ even just having the holistic list of criteria to look at during projects is amazing (Co-Creation, personal communication, June 16, 2025);

¬ addresses a current gap between data and design, which will also have demand for GIS integration (Informal discussion with academic researchers, personal communication, July 18, 2025);

¬ can see direct need / relevance in the industry, though user experience could be improved (Presentation to global consultancy, personal communication, July 2, 2025);

¬ transparency is the key benefit (Co-creation, personal communication, June 16, 2025);

¬ looks amazing and can be part of services, directly in line with the current UK industry needs (Presentation to global consultancy, personal communication July 2, 2025);

In conclusion, the research objectives were successfully met. At the start of this research, one overarching challenge mentioned was that of **responsible urban digitalisation**, which involved the use of digital tools and data driven approaches to urban design in ensuring a community priority approach (AMS Institute, 2025; Smaniotto-Costa, et al., 2024). The Dynamic Framework provides responsible urban digitalisation by ensuring that there is a community driven methodology to applying the Dynamic Digital tool, which itself ensures a place-based approach to digital design tools, as seen above (i.e., local priorities input, dynamic nature..). It is therefore expected (or hoped) that the products of this research have a positive impact on both the scientific and societal spheres, addressing current gaps in both, as seen above. Nevertheless, with these innovations and successes, this research of course faces limitations.

12.2 Limitations

Limitations of this research typically originate from the limitations of the Dynamic Digital tool itself, which impact the rest of the workflow.

Firstly, the **place-based approach**, core to this project, involves a **high reliability on geodata**, which in turn comes with a range of limitations. These were explored in **Section 9.0**, however, more than simply limiting the criteria, these have scientific and societal implications. For one, the Dynamic Digital tool, and consequently the Dynamic Framework, can currently only be applied to the UK – both in the data used as well as the framework approach (i.e., based on the National Design Guide themes and as such not always applicable to Global South needs/priorities (Ortiz-Fernandez et al., 2023; Strydom et al., 2018); code designed to use UK specific data like UPRN which might not be available everywhere). This said, the tool was designed for modularity and so, given the correct geodata and national priorities, the tool can be seamlessly modified to fit other countries, with any changes concentrated to the A0 script.

Additionally, because of the open-source nature of the tool and its data inputs, there are great limitations in the **completeness of these datasets**. Though obtained from official and reliable sources, certain data sets do not fully capture local details (e.g., the OS Road Network didn't represent the back alleys). In this case, datasets would have benefited from being combined for further accuracy, however, CRS or structural differences made this operation faulty, unreliable and as such undesirable. For example, the OSM, OpenRoads and USRN network data complete each other well, but could not be merged in the context and workflow of the tool. In this example, OpenRoads is used for the network analysis though incomplete, therefore rendering the results less reliable / truthful, until better data is published. In other cases, data was there and not available to the general public, but accessible to Local Councils. The provision of such data from the Local Council as part of the Project Setup step could greatly improve the coverage and reliability of the Dynamic Digital tool (e.g., accessing OS Building Height data, which would enable much more reliable density indications, such as Floor Space Index (FSI) and Ground Space Index (GSI).

To continue, data, even when complete, compatible and available, might have a **bias**, for example not accounting for certain community groups' or their interests (Head of Innovation, personal communication, March 13, 2025; Mateo-Babiano & Palipane, 2020). These are common limitations and criticism in data-driven approaches, as well as in any qualitative data collection, especially on the positive effect in practice of collaborative sessions and public engagement (Toukola & Ahola, 2022), and focusing on the neighbourhood data can leave out context specific valuable information of the broader urban system (Switalski et al., 2023). Also, the classification of the neighbourhood into themes may oversimplify the complexity of placemaking, potentially overlooking nuanced aspects of sustainability and not always aligning exactly with local values (Amirzadeh & Sharifi, 2024; Urban Design Director, personal communication, July 31, 2025). This is however addressed to the best of the author's capability in the Dynamic Framework, which clearly indicates that the Dynamic Digital tool is not replacing the whole urban design workflow, therefore allowing for those broader system analyses to take place as part of the urban designer's core tasks, and hold value in the project, rather than claim the Dynamic Digital tool covers it all..

Therefore, the place-based limitations mainly involve the data quality, or broader ongoing scientific reservations on the techniques used. The scripts and overall tool have been designed with replicability and adaptability in mind, and the tool's transparency as well as optimised / streamlined design (i.e., centralised inputs, automatised calculations and clear logging) allow users to complete and improve it when further needs or opportunities arise. In fact, the question of replicability and adaptability is one which came almost at each presentation of the tool's v.1 prototype (Co-creation, personal communication, June 16; Presentation to global consultancy, personal communication, July 2, 2025).

Finally on the place-based approach, scientific literature warns on the **use of digital tools at the neighbourhood scale**, as it might alienate the community (Smaniotto-Costa et al., 2023). Place-based research remains largely speculative with the least amount of explicitly collected and systematised data (Switalski et al., 2023). Both of these raise concerns and limitations on the core of this research: the use of a digital tool to enable place-based design. This is a deeper dilemma and reflection the author developed throughout – the balancing act between place-based approach and holistic digital tool, the first of which requires a unique, ad hoc approach for each project, and the second proposes automation and to an extent standardisation of performance. When too automated, a digital tool can quickly become irrelevant to a lot of situations (Research Director, personal communication, March 24, 2025; Urban Design Director, personal communication, March 24, 2025). However in order to remain applicable to most urban designers' workflows, and as such be most useful / impactful, the tool needs to have a broad coverage. A similar debate drove a lot of this research, notably in the determination of weights, trying to effectively represent local values and their additional weight, versus ensuring a holistic consideration of sustainability, and therefore considering all themes (Co-Creation, personal communication, June 16). Nevertheless, the decisions taken throughout the conception of the Dynamic Framework and Digital tool were deemed by the author as the best options to achieve the desired balance, though the author acknowledges the potential benefit a statistical approach like the Monte Carlo analysis would have provided in the weights justifications and discussions..

Secondly, this leads to the limitations on the **holistic sustainability** topic, both in the practical application as well as in the scientific discourse. Once again, **data limitations** compromised the effective application of truly holistic sustainability, which then corroborates with the idea that "wicked problems" such as the one of sustainable urban neighbourhood design can't be tackled through "optimal solutions" (or even just solutions) (Aernouts, 2023). Plus, the Dynamic Digital tool's application of holistic sustainability does not give "malus" points, essentially not accounting for the counterproductive interventions and trade-offs which are core parts of the interrelated sustainability system (Axinte et al., 2022; Khatibi et al., 2023; Switalski, et al., 2023). Though certain elements like the "malus" points can be added into the system design, there might just be too many things to consider (e.g., weather conditions, urban layout, demographics, economic flows, community arrangements...) and it is consequently impossible to accurately reflect the reality (Switalski et al., 2023, Zhang, 2021). Again, this further emphasizes the need for the Dynamic Digital tool to be used in line with the Dynamic Framework, complementing the workflow and in constant collaboration between designer, engagement specialist and sustainability consultant's combined knowledge.

Nevertheless, emerging from this, another core dilemma of this research, which is the actual **desirability of proposing a (partially) holistic tool**, rather than looking at elements in isolation for a more detailed view (Computational Design Lead, personal communication, March 11, 2025; Switalski et al., 2023). On this question, industry professionals judged that perfection can never be achieved, and, to an extent, having a partial (though still accurate) solution is better than having nothing, which is also why the transparency of the solution is essential (Founder, personal communication, March 19, 2025; Research Directly, personal communication, April 8, 2025). Overall, there is a consensus in the scientific community that quantifying urban quality facilitates the implementation of sustainability analyses and design interventions in the design process, but it does not provide a solution to all issues of the urban design workflow (Zhang, 2021).

Additionally, the Dynamic Digital tool proposes a **single definition of neighbourhood sustainability**, based on the 10 themes of the National Design Guide. Though, more importance can be given to certain themes based on the specific neighbourhood needs, this assumes the same performance expectations for every neighbourhood, regardless of their political, economic, social conditions and history – which is not always "fair" or representative of local abilities to meet national standards (Head of Innovation, personal communication, March 13, 2025). This also led to further discussions / debates, but it was judged by the author, and enhanced by personal communication throughout, that every neighbourhood should aspire to achieve these sustainability criteria, as it provides a common goal, with the added benefit of allowing for comparability (Head of Innovation, personal communication, March 13, 2025).

Finally, one core and systemic limitation to the application of this research's results is the fact that the outcomes and **added value of this research is only useful for keen designers**, rather than being a necessity in the workflow (Co-creation, personal communication, June 16, 2025). This is because in the UK, considering sustainability and holding engagement sessions, are not part of the required urban design process, as detailed in **Section 7.0**. Indeed, this, involving engagement and sustainability flows is the best case scenario and depends wholly on the direction chosen by the Project lead or Lead Designer. It is the author's expectation that, knowing this, having an operational framework and tool only make it easier and more seamless for sustainability and engagement to be included in the design process, until it becomes norm.

Thirdly, continuing on the above, the **integration within the iterative design workflow** faces limitations of its own.

One limitation is related to the **user experience** of the Dynamic Digital tool v.1 prototype: within the defined steps, multiple interfaces / environments are used and a few actions could be more streamlined, for example the tagging, which could be imported and assigned from a Revit model automatically and then exported with one click. However, Grasshopper's coding environment is limited in capacity, and even existing plug-ins to facilitate that prove unreliable (as seen previously, due to IronPython coding language). This is also expressed in the user interface, which currently features the full visual code, rather than a specific user experience, though steps have been taken to address this such as visual cues, headings and groupings. Nevertheless, the tool use can be "clunky" at moments (for example, when exporting the analysis results as .shp, numbers are exported as text for an unidentified cause, and a post-processing step needs to happen in GIS software to convert those to integers – a simple and quick step, but one regardless.)

Moreover, there are certain **requirements for using the tool** within the workflow, such as software installations (GIS software, Rhino, python libraries) of which Rhino is not open-source/free. Then, the data is locally saved and provided to users as a downloadable package – this local hosting of data is not considered best practice, and can be subject to outdating if not adequately managed (i.e., regular re-download, verification of the re-downloaded data structure to fit the system design). API calls would have been the better option, though out of the author's scope.

Then, the **spatial focus** of the Dynamic Digital tool's analysis, essential to address the iterative design gap, can limit the full consideration of certain sustainability themes, especially economic ones, as job creation, place stewardship, community feel etc are difficult to spatially represent. Designers re-emphasize the importance of understanding the impact of the tangible elements on the intangible ones (Co-creation, personal communication, June 16, 2025); Partner, personal communication, March 27, 2025; Urban Design Director, personal communication, March 24, 2025. This relates back to the dual definition of a neighbourhood, and though the author understands that physical interventions in a neighbourhood is not the only means of enabling sustainability (e.g., policy / organisational / political interventions) (Mateo-Babiano & Palipane, 2020; Switalski et al., 2023; Urban Design Director, personal communication, March 24, 2025), the design focus of the tool resulted both a key strength and weakness. To address this, the digital tool allows for analysis and visualisation of non-spatial data, but does not count them in the score calculations (and thus as part of the design optioneering loop).

Finally, a core dilemma again appears in the Dynamic Digital tool's integration in the design workflow – at what point are there **too many tools**? (Computational Design Lead, personal communication, March 11, 2025; Managing Partner, personal communication, March 20, 2025; Urban Design Director, March 24, 2025).

Nevertheless, throughout the core three themes of place-based approach, holistic sustainability and iterative design, the current limitations of the products only inform the necessary improvements and do not undermine the potential use of the Dynamic Framework and Dynamic Digital tool, as well as its capacity to address current societal and scientific gaps..

12.3 Transferability

As mentioned, the Dynamic Framework and Digital tool are designed based on the UK example, as place-based, holistic and iterative sustainable neighbourhood design is currently receiving national attention. The design of the Dynamic Framework and Dynamic Digital tool is made to be modular and transferable via the use of centralised and minimal project inputs, centralised variables / constants for ease of change, centralised functions and within those, CRS conversion functions. It should be noted that that CRS is also an input as part of the A0 rather than a hard coded decision. As such, in system design, the Dynamic Framework and Digital tool are transferable to countries which priorities are in line with those the Gap Triangle. This is however subject to:

- equivalent data (and review of their data structure to adapt the coding / scoring logic if needed)
- equivalent urban design workflow
- equivalent access to Rhino, GIS software and Python

In conclusion, the transferrability of the Dynamic Framework and Digital tool is made possible, but to be treated on a detailed, case by case basis, in order to validate the above requirements.

13.0 conclusion – A DYNAMIC DIGITAL DESIGN TOOL FOR SUSTAINABLE NEIGHBOURHOOD DESIGN

13.1 Answering research questions

To conclude, this research - through interviews, literature review, software review, prototype development and co-creation – successfully developed a Dynamic Framework, Dynamic Digital tool and v.1. prototype to support the iterative, place-based and holistic sustainable design of neighbourhoods in the UK. The UK is a current example where public and private actors nationally (i.e., government, architectural firms, consultancy firms) are pushing for an integrated, place-based and holistic approach – this research's findings and approach can contribute to other places with similar agendas, urban design workflow, and open source data.

This research is trying to fill the core gap of the need for a dynamic approach to the design of sustainable neighbourhoods in the UK – this involves dynamically ensuring : place based design; holistic sustainability and iterative design. This gap can be addressed by digital tools, which provide the ability for dynamic analyses. Using digital tools in urban contexts should be achieved in a responsible way: ensuring it relates and benefits the community. As such, the outcome of this research is the development of a Dynamic Framework, Dynamic Digital tool and v.1 prototype which address this gap for the design of sustainable neighbourhoods.

First, **Section 7.0** provides an understanding the urban designer's workflow, putting light on its current lack of integration between engagement, design and sustainability (supported by digital tools). Answering the first sub-question provided insights on where a dynamic digital tool might contribute to the existing workflow and help integrate these 3 separate streams. The engagement results are challenging to effectively translate into the design, due to the intensity of the data processing, and the use of digital tools is sporadic, creating parallel strands of knowledge. Finally, an urban design project's early stages are where a dynamic digital tool would most be beneficial and impactful (brief definition, site analysis and early design) and this is therefore the target of this research's solution. The answer to the question What is the urban designer's workflow in a sustainable neighbourhood project in the UK is illustrated in **Fig. 10**, where engagement, design and digital tools for sustainability are shown in their respective lanes.

This chapter addresses the metropolitan challenge of responsible urban digitalisation by firstly critically analysing the current streams which contribute to sustainable neighbourhood design, essential for community and people centred urban digitalisation.

Second, **Section 8.0** assesses existing digital tools, specifically GIS software, Rhino with Grasshopper, and Python language. These have individual strengths in geodata coding, analysis and visualisation as well as in design and analysis interaction. While lacking in their ability to seamlessly provide all three elements and thus integrate into the design workflow, these show strength in their ability to separately cover all three points of the Gap Triangle (holistic sustainability, place-based approach, iterative design), and potential for compatibility, with python as the catalyst outside and inside of Grasshopper which ensures design interaction. This answers the question What are the current digital tools for sustainable neighbourhoods' strengths, what are they lacking and how might they complement each other, and is illustrated in **Fig. 11** and **12**.

This chapter addresses the metropolitan challenge by providing the digital tool combination to responsibly digitalise urban processes, ensuring a flexible tool design base which meets the requirements of the research.

Third, **Section 9.0** establishes the criteria for a dynamic digital tool for sustainable neighbourhood design by filtering through key constraints including data type (quantifiable, spatial), availability (open source, UK) and granularity (neighbourhood scale). The selection of criteria was guided by existing frameworks such as NSAs and academic literature. The final list of criteria and their respective conditions is indicated in **Tables 4-13**, with key data sources in **Table 14**. From this, a clear definition of general conditions to meet for neighbourhood sustainability and the potential to represent those in a Dynamic Digital tool was provided. This answers the question Which criteria of a sustainable neighbourhood should a dynamic digital tool for sustainable neighbourhood design in the UK consider.

This chapter addresses responsible urban digitalisation by using open-source, place-based , holistic, spatial and most importantly viable criteria to use in a digital tool.

Fourth, **Section 10.0** provides the first part of the results. The Dynamic Framework proposed offers a revision of the current workflow and use of digital tools, by integrating place-based approach (stakeholder engagement), iterative design and holistic sustainability. This is supported by the use of a Dynamic Digital tool, which is designed to fit industry demand – with transparency and modularity. The four steps (Project Setup, Base Analysis, Optioneering and Closure) are supported by the combination of python scripts (A, B, C scripts), grasshopper scripts (Setup, Analysis, Optioneering) and the base of Rhino and ArcGIS, designed to integrate into the urban design workflow and enhance it. This answers the question What framework and underlying logic should guide a dynamic digital tool to integrate iterative design processes, place-based stakeholder engagement and holistic sustainability considerations in neighbourhood design in the UK, illustrated in **Fig. 14**.

This chapter addresses the metropolitan challenge by completely incorporating the three points of the Gap Triangle into a functional framework and digital tool, thus directly ensuring responsible urban digitalisation.

Fifth, **Section 11.0** applies a v.1 prototype of the Dynamic Digital tool on a case study project. This is the second part of the results. The prototype application revealed key benefits of the tool on a live project, as well as key areas for improvement. order. The tool's value proved to be in the identification of the urgent focus zones thanks to the Base analysis, and the impact assessment of design interventions (separated in 3 options) in comparison to the base. The 3 options provided similar performance results, all an improvement compared to the base, urging the designer to consider the neighbourhood more holistically. This answers the question of What value does the application of the prototype script bring to the Hirst neighbourhood regeneration project? This is illustrated in **Fig. 40** which shows the base assessments in comparison to the final option results.

This chapter addresses the metropolitan challenge by assessing the relevance of this research's outputs on a real project, informing on and assessing the contribution of responsible urban digitalisation.

Sixth and finally, the discussion in **Section 12.0** elaborates on the core innovations and limitations of this research's products in relation and in answer to the three points of the Gap Triangle, as follows. Innovations include the dynamic integration of local values into the analysis via weights informed by engagement sessions; the dynamic accounting for sustainability interrelations in a transparent way which allow for clear interpretation and feedback; and the dynamic integration into the design workflow, by combining different tool and allowing for design option scenario testing. However, limitations include the necessary reliability on geodata, which comes with challenges of completeness, accuracy and bias; the general questions on effectively balancing between automation of data-driven processes and ad hoc, place based approaches; the difficulty to accurately truly represent all the interrelations of holistic sustainability and thus potentially negative effect of a partially holistic tool; the lack of adaptation of criteria threshold "strictness" based on project site; the systemic issue of sustainability not necessarily being part of the workflow; the tool's user interface and maintenance; the spatial focus; and the final question of whether there are simply too many tools.

Overall, the main research question was What framework and digital tool prototype can be developed to support the iterative, place-based and holistic sustainable design of neighbourhoods in the UK? This research answered this question via the development of the Dynamic Framework, Dynamic Digital tool, and the application of a v.1. prototype on a case study, providing a path to responsible urban digitalisation.

13.2 Products

The products of this research are currently locally saved by the author but will be uploaded to Github.

In the mean time, the user guide can be found in **Appendix G**, and the pseudo scripts can be found in **Appendix E and F**.

13.3 Further research recommendations

There are a number of ways to complete this research.

To start with, future research should investigate the potential and impact of the Dynamic Framework and Dynamic Digital tool via a case study portfolio, with involvement from beginning to end of the framework steps, to better understand what exact design and engagement sessions / actions (e.g., design sprints, workshops, community engagement) should be taken for the best practice application of the Dynamic Framework (Co-creation, personal communication, June 16, 2025). This would also bring a new dimension to the future prototype versions, by including access to more data from the local council (i.e., sidewalk width, road width) as well as design models, which are more detailed than OSM (e.g. they show roof pitch and thus orientation, useful for calculating solar energy generation potential). These additions would result in the inclusion of more criteria, bridging part of the data gaps. Finally, in a further case study portfolio research, more voices could be included. Speaking with landscape architects, as those who would typically take on projects from the Urban designers, would be beneficial to understand the tools they use and see how effectively the urban design vision is kept throughout, or if it is diluted, why (Co-creation, personal communication, June 16, 2025). Also, the interaction and feedback of clients (local councils) and local communities (residents) in the use of the tool as part of engagement sessions would contribute to a future research and case study portfolio.

Additionally, more than further insights on the Dynamic Framework and Digital tool's application, future research could focus on the software development part and introduce new features in the tool such as:

- the ability to include social media data as part of the base analysis to gain further knowledge on how people interact with a neighbourhood (e.g., community events, general feedback) (Computational Design Lead, personal communication March 11, 2025).
- accounting for the embodied carbon of materials and general carbon impacts of interventions to give a more holistic picture of the design interventions' sustainability impact (Computational Design Lead, personal communication, March 11, 2025)
- including notions of 15min neighbourhoods (Head of Innovation, personal communication, March 13, 2025; Managing Partner, personal communication, March 19, 2025; Sustainability Director, personal communication, March 27, 2025)
- a way to better represent and consider the impact of non spatial criteria (Urban Design Director, personal communication, March 24, 2025), such as the element of beauty (Managing Partner, personal communication, March 19, 2025).
- a way to better introduce the time notion and different climate scenarios or the lifecycle of certain (temporary) interventions, as the tool currently assumes a permanent situation (Computational Design Lead, personal communication, March 11, 2025; Research Director, personal communication, April 8, 2025; Urban Designer, personal communication, March 24, 2025).
- a way to understand why a neighbourhood is this way, rather than simply observe the facts (i.e., a lot of low energy performance houses could indicate low income or low awareness or lack of local incentives) (Research Director, personal communication, April 8, 2025).

Further relevant features which exist in tools like YemeTech, such as stakeholder mapping, also raise the potential for collaboration with neighbourhood scale static analysis tools, informing the base view of the site, which the Dynamic Digital tool could complement.

Finally, still on the Dynamic Digital tool, future research and future prototypes could incorporate better system design such as:

- the use of API calls rather than using locally saved data. This would benefit the workflow by adding further automation and reducing the need for maintenance and risk of outdated data (and therefore errors/incorrect results). Indeed, API calls directly pull the data from the online sources. The OS data sources and others like the EPC data are known by the author to have API links.
- a more rounded approach to the local values integration by including engagement digitalisation processes within the tool itself, such as automatically identifying priorities from the engagement session transcripts and cross referencing those with local council's improvement plans, as well as gathering user experience from online platforms such as trust pilot (Computational Design Lead, personal communication, March 11, 2025; Head of Innovation, personal communication, March 13, 2025; Partner, personal communication, April 8, 2025). These would however need deep consideration in the balance between facilitating the time intensive engagement processes while not replacing them and not seeking full automation which would loose the place-based approach.

- a better and simpler user interface and clearer results comparison via colour coding the optioneering impacts to make the tool more accessible to non sustainability consultants (Co-creation, personal communication, June 16, 2025). Part of these user experience improvements would also be the integration of a dynamic map rather than just the building footprints, to provide further context within the analysis results.
- the development of a GIS compatible extension which would host the python calculations and analyses. This would smoothen the workflow, avoiding the need to run analyses through the python IDE or command prompt.

The final step of future research with regards to system design would be the development of an independent software, rather than the current "clunky" combination of existing tools. Indeed, apart from the python backbone, present in the python scripts and the grasshopper scripts, Rhino is simply used for its ability to import design models and create very simple geometry (surfaces, lines, points) and ArcGIS is used for its ability to easily view and contextualise data - none of the more complex features of either software, such as further modelling commands in Rhino or geodata processing in ArcGIS, are used in the Dynamic Digital tool.

Overall, there are a lot of potential future research venues which would contribute to the base laid out by Shaping Place: a dynamic framework, digital tool and prototype for iterative, place-based and holistic sustainable neighbourhood design in the UK.

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15.1 Appendix A - software review matrix

Software / Digital tool	Type	Aim / purpose	End user	Place in workflow	Dynamic analysis?	Geog scale?	Sustainability scope?	Conclusion on suitability for dynamic sustainable placeshaping
Revit	Software	Building modelling, coordination and drawings	Designers	All stages	yes	[Building]	Social	None
IES VE	Software	Energy performance modelling	Engineers / Consultants	End stages	yes	[Building]	Environmental	None
Sefaira	Plugin (Sketchup)	Modelling, climate / comfort analysis, energy performance modelling	Designers	Early stages	yes	[Building]	Environmental	None - too many building inputs for it to run at bigger scale + no costumisation
Design Builder	Software	Energy performance modelling	Engineers / Consultants	Developped Design	yes	[Building]	Environmental	None - too many building inputs for it to run at bigger scale + no costumisation
Ladybug Suite	Plugin (Grasshopper)	Parametric modelling, climate analysis, some social scripts (ie movement, views, proximity to transport), energy modelling... customisable	Designers and Engineers / Consultants	Any	yes	]Neighbourhood]	Environmental	Suitable - script not yet developed to have place based inputs
ArcGIS / QGIS	Software	Geodata visualisation	Designers	Any	no (though GIS has potential for code)	]City]	All	Correct mindset although not a design tool, missing the dynamic ability
Python with OSM	Coding language family	Geodata visualisation	Engineers / Consultants	Any	no	]City]	All	Correct mindset although not a design tool, missing the dynamic ability
YemeTech	Web based	Quantify community quality and visualise it	All	Early stages	no	]Neighbourhood]	Social	Correct mindset although not a design tool, missing the dynamic ability
CityEngine	Web based	Modelling urban environments	Designers	Early stages	no (modelling only)	]City]	Social & Economic	Correct modelling features but no analysis
PlaceMaker	Web based	Modelling urban environments	Designers	Early stages	no (modelling only)	]City]	Social & Economic	Correct modelling features but no analysis
PlaceChangers	Web based	Support engagement and access to location data	Designers	?	no (it seems)	]Neighbourhood]	Social	
Healthy Streets	Excel based	Quantify streets quality and assess design impact	Designers	Any	yes (but excel based)	]Neighbourhood]	All	Correct approach but wrong scale (street only) and though dynamic, doesn't interact with a model
Plan4Better	Web based	Quantify community quality and assess design impact	Designers	Early stages	yes (but inside software only)	]Neighbourhood]	All	Correct approach but the scenario analyses are based on design iterations made within the tool
Urban Footprint	Web based	Quantify community quality and visualise it	Designers	?	no (it seems)	]Neighbourhood]	Resilience (so a bit of all)	Correct mindset although not a design tool, missing the dynamic ability

Software / Digital tool	Aim / purpose	End user	Place in workflow	Dynamic analysis?	Geog scale?	Sustainability scope?	Conclusion on suitability for dynamic sustainable placeshaping
15mincity.ai	Analyse 15min concept suitability	All	Early stages	no	]Neighbourhood]	15min city (spatial)	Smart data interpretation with the use of ai - Could be solution to the integration of engagement results and interpretation of design interventiond
Spacio	Building modelling	Designers	Early stages	yes	[Building]	Environmental	Nice comparative analysis potential
Healthy Cities	Quantify urban quality and assess design impact	All	Early and End stages	yes (but not from a spatial model - just list of interventions)	]City]	All	Good candidate but doesn't interact with designer's model
Urban Calculator	Analyse and test urban street designs	All	Early stages	yes (centrality, accessibility to services, density, proximity)	]City]	Social	Correct approach but not iterative design or and holistic sust
Decoding Spaces	Algorithmic architectural and urban planning	Designers	Design stages	no (algorithmic generation)	]City]	Economic	None - algorithmic generation
Green Score Captial	Assess environmental impacts of interventions	Consultants	Developped Design	no (business)	[Building]	Environmental & Economic	None - for businesses
CityEngine	Create and iterate on urban environments and scenarios using GIS data	All	Early stages	yes (zoning, nature, views)	]City]	Environmental & Economic	Good candidate but holistic sustainability or interaction with designer's model
GeoPlanner (retiring)							
Envision Tomorrow	Scenario planning package to analyse impact of growth on community	Planners	Early stages	yes (but excel based)	]City]	All (at least they say, but looks more Econ)	Correct approach with scenario testing but no interaction with design and more geared for planning
Wallacei	Evolutionary simulations based on desired output	Designers / Consultants	Early stages	no (algorithmic generation)	]City]	Social	None - outcome driven rather than design facilitation
Elk	Generate map and topographical surfaces using OSM	Designers / Consultants	Early stages	yes (can enable it)	]City]	Social & Economic	Suitable for OSM imports

Software / Digital tool	Aim / purpose	End user	Place in workflow	Dynamic analysis?	Geog scale?	Sustainability scope?	Conclusion on suitability for dynamic sustainable placeshaping
Giraffe	Integrate mapping, modelling and analytics in one platform	Designers / Planners / Developpers	Early stages	yes (but not on surrounding impacts)	]Neighbourhood]	Economic	Correct mindset, just no holistic sustainability or interaction with designer's model
Heron	Import GIS data into Rhino/Grasshopper	Designers / Consultants	All stages	yes (can enable it)	]City]	All	Suitable for GIS data imports
OSCI Local Insight	Analyse and visualise local neighbourhood data	Designers	Early stages	no	]Neighbourhood]	All?	Similar to YemeTech - no interaction with design and scenario testing
Infrared City	Simulate climate scenarios	Designers / Consultants	Early stages	yes	]Neighbourhood]	Environmental	Correct mindset, just not holistic sust
Bang the Table	Engagement (community feedback and data gathering)	Designers / Planners / Developpers	Any	no	]City]	All	None - feedback tool

15.2 Appendix B - interview questions

DIGITAL TOOLS

1. What digital tools do you use for a sustainable neighbourhood regeneration project? How do they meet (or not) the needs of urban designers?

2. What tools do you feel you are missing, or would need?

3. What is the benefit of using digital tools for sustainability consultancy project work?

4. Who should use these tools / who should these tools be designed for?

5. At what stage in the design process should these tools be used / are they most beneficial? How might such a tool fit in a designer's workflow?

6. What should such a tool consider / offer / do?

7. Why doesn't such a tool exist? What are the challenges of such a tool? What might be feasible for a neighbourhood scale tool?

8. Is justifying the value of certain design interventions a problem/difficult?

9. In your view, are intervention (sustainability) impacts considered holistically or in silos (i.e., social vs env vs econ)

10. What is the right balance between place-based and automatisaton?

11. What data/criteria do you use to assess the success of a project? Which data sources do you use?

12. Do you have any experience using OSM within Grasshopper? What is your experience with building your own Grasshopper coded modules / plugins? How could grasshopper be combined with python coding?

13. How do you envision the role of local stakeholders and public engagement in the use of a digital design tool?

SUSTAINABLE NEIGHBOURHOODS

14. What is your definition of sustainable urban neighbourhoods?

15. What is involved in having a place-based approach // placemaking approach?

16. What approach to sustainability do you have on projects? (ie social mainly, involving experts etc)

URBAN DESISN WORKFLOW

1. How do you, at Ryder and with your team, approach a neighbourhood regeneration project

2. What are the key moments for design decisions

3. What tools do you use for each moment of the workflow? What is working well, what is missing?

4. When in the design process would a tool for place based sustainable neighbourhoods be most useful? (show my little diagram)

5. What should such a tool do/provide to be deemed useful by designers/clients?

6. Why doesn't such a tool exist? Lack of need or challenging

7. Why doesn't such a tool exist? Lack of need or challenging task...?

ENGAGEMENT SESSIONS

1. At which points in the workflow are engagement sessions organised

2. Who is present (from the team and from community)

3. How are the results from engagement sessions captured / processed?

4. How are the results from engagement session integrated in the project outcome?

5. How are local qualitative results translated into quantifiable interventions?

6. Would place-based weights be enough to account for the local values?

DESIGN INTERVENTIONS

1. Are the client priorities often the same as the priorities that came out from the stakeholder engagement sessions?

2. What are typical spatial interventions for urban neighbourhood regeneration projects? (or what are case study projects I could look at to create a database?)

3. Is justifying the value of certain intervention a problem/difficult?

4. In your view, are intervention (sustainability) impacts considered holistically or in silos (ie social vs env vs econ)

5. What data/criteria do you use to assess the success of a project?

15.3 Appendix C – interview consent

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

The results of this interview will support the research and might inform one or more of the key outputs:

- Gap analysis on state of digital tools for sustainable neighbourhoods
- Spatial interventions for a "good place"
- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: ALEJANDRO QUINTO

Date: 11 - MARCH

Place: SPAIN

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

☑ Name
☑ Role
☑ Workplace
☐ None of the above – cite anonymously
☐ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

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- Spatial interivientions for a "good place"
- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: Andrew Fong

Date: 24 March 2025

Place: Cooper's Studio

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- ☒ Name
- ☒ Role
- ☒ Workplace
- ☐ None of the above – cite anonymously
- ☐ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

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- Spatial interventions for a "good place"
- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: Cathy Russell

Date: Twenty-fifth March, Twenty-Twenty-Five

Place: Ryder Architecture, Newcastle

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- ❑ Name
- ❑ Role
- ❑ Workplace
- ❑ None of the above – cite anonymously
- ❑ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

C.Russell .... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

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- Spatial interivientions for a "good place"
- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: Ceylan Belek Ombregt

Date: 20 March 2025

Place: London, UK

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- ☑ Name
- ☑ Role
- ☑ Workplace
- ☐ None of the above – cite anonymously
- ☐ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

Ceylan Belek Ombregt, ASLA PLA, Partner, Operations Director

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

The results of this interview will support the research and might inform one or more of the key outputs:

- Gap analysis on state of digital tools for sustainable neighbourhoods
- Spatial interventions for a "good place"
- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: CHRIS MALCOLM

Date: 27 MARCH 2025

Place: GLASGOW

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- [x] Name
- [x] Role
- [x] Workplace
- [ ] None of the above – cite anonymously
- [ ] None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

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Name:

Date:

Place:

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- ❑ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

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- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: Dr Jon Stinson

Date: 27th March 2025

Place: Okana Global. Glasgow Office

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- ☑ Name
- ☑ Role
- ☑ Workplace
- ☐ None of the above – cite anonymously
- ☐ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

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- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: Leyla Saai

Date: 14/07/2025

Place: Barcelona

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- ☑ Name
- ☑ Role
- ☑ Workplace
- ☐ None of the above – cite anonymously
- ☐ None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

.... (Interviewee)

This interview is in the context of data collection for Romane Sanchez' MSc Metropolitan Analysis, Design and Engineering thesis: Shaping Place – dynamic digital tools for sustainable neighborhoods in the UK. This thesis is driven and owned by Romane Sanchez. If publication opportunities arise, this will be considered, and consent will be further discussed with the interviewee.

The results of this interview will support the research and might inform one or more of the key outputs:

- Gap analysis on state of digital tools for sustainable neighbourhoods
- Spatial interventions for a "good place"
- Prototype script development
- Case study project application

As such, it is important to explicitly gather the interviewee's consent. Any data used in this interview will be sent to the interested party before any use.

Name: Soo Darcy

Date: 16 July 2025

Place: Ryder Architecture, 14-18 Westgate Road, Newcastle upon Tyne, NE1 3NN

I hereby consent to my information being cited with the following elements, in the context of this thesis project only:

- [x] Name
- [x] Role
- [x] Workplace
- [ ] None of the above – cite anonymously
- [ ] None of the above – do not cite

Signed,

Romane Sanchez (Interviewer)

Soo Darcy .... (Interviewee)

15.4 Appendix D – co-creation notes

WORKFLOW

0-3 mostly for urban designers

Most most: 0-1, then bit of 1-2 and bit of 2-3

The Post Occupancy Evaluation is good to have to go back to at moments in time to see evolution of the project

Depends what type of urban design project – might start at 0

=> Speak to landscape team to find out what digital tools they use at later stages

More than just digital tools, maybe interesting to ask about what other things come up and dilute the initial vision, specifically for sustainability

=> Imaginary project and see how my proposed workflow looks like in terms of workshops, design sprints etc

CRITERIA

Place where other criteria can go (non-spatial ones)

=>Show it as a separate analysis visualisation but not part of the total calculation

Tool for designers, fine – but can make it useful for local authorities too by providing other factors not just design

House price factor actually came up in Hirst when talking about avoiding gentrification (more social housing = lower house prices)

TOOL

Giraffe free trials -> aimed more at developpers

User interface: some people will love being able to get into all the details, but some people will be scared by that

Weighting:

- Tracks across very well with objective setting and prioritisation
- Number of priorities depends on sample size and interpretation
- Most helpful to have it ranked 1-10? Difficult to say without knowing project but more than 2 for sure
- Weighting can vary based on the project => should be fully customisable
- Ensuring we're not losing the engagement story
- Tool to support designers – it's an added value but not part of "required" flow but best practice
- -> goes in discussion, it's part of the problem
- Benefit of tool is its transparency in terms of weighting and total score calculation

Green access example:

- How do you know the details?
- Dangers of being too automated
- Prompts / follow up questions
- Would be a really good engagement tool

Re-run scripts:

- Geometry: revit-rhino geometry tagging automatic
- Colour to see the difference / the impact of option design
- What would the map be telling us and how would that be visible without having to compare the two pictures together?
- => score + description
- => summary text box at the end with impacts

Total score visual:

- Possible to layer it up rather than just the total?
- Aerial views / plan integrations? (being able to zoom in and see the details of streets etc)
- Make interface more user friendly
- Grid size: best practice is urban blocks

Score calculations/inputs:

- How do you account for the benefits or for example repurposing a building/retrofitting, or other community elements such as signage etc
- -> make sure can account for design interventions that aren't part of the analysis data input

OVERALL FEEDBACK

Very positive, will want to use it

Brilliant amount of work and thought into it

Even just having the list of everything is amazing (ref criteria)

Can be used to update the PlaceMaking toolkit based on the 10 categories

Figure out/clarify how it is actually being used, by who, in what situation etc

Case study mid-July

15.5 Appendix E – PseudoScripts

A0_project_inputs.py

Purpose:

Central configuration file containing all project parameters, file paths, thresholds, and constants used across all analysis scripts.

Structure:

DEFINE project metadata (name, code, CRS)

DEFINE geographic bounds (site bounding box, study area with buffer)

DEFINE grid parameters (spacing, coordinate system)

DEFINE file paths for:

- Input data sources (OS OpenMap, NAPTAN, EPC, etc.)

- Output destinations (base folder, option folders)

- Geometry folders for design options (FINAL_GEOMETRY_FOLDER)

DEFINE analysis thresholds:

- Access distances (green: 300m, transport: 400m/800m, blue: 800m, etc.)

- Density ranges (60-120 dwellings/ha)

- Energy performance (EPC rating C or better)

- Connectivity (>50% nodes with >1 connection)

DEFINE geometry prefixes for design integration

DEFINE theme dependencies and buffer distances for contributions analysis

CREATE boundary polygons from coordinate bounds

Key Assumptions

- **CRS Assumption**: All analysis conducted in British National Grid (EPSG:27700) for accurate distance measurements

- **Threshold Values**: Derived from UK planning guidance and National Design Guide standards

- **Walking Factor**: 1.3 multiplier applied to Euclidean distances to approximate actual walking routes

- **Theme Dependencies**: Geometry prefixes linked to specific sustainability themes for design impact analysis

A1_generate_spatial_grid.py

Purpose

Creates regular spatial grid covering the project site for consistent spatial analysis framework.

Structure

LOAD project boundary from A0_project_inputs

VALIDATE boundary geometry and CRS

GENERATE regular grid cells within boundary:

FOR each grid position within boundary:

CREATE rectangular polygon cell

ASSIGN unique grid_id

CALCULATE cell centroid coordinates

STORE geometric properties

SAVE grid as both GeoPackage and GeoJSON formats

GENERATE centroids as separate point dataset

VALIDATE output completeness and spatial coverage

Key Assumptions

- **Grid Spacing**: Fixed 50m x 50m cells provide sufficient resolution for neighbourhood-scale analysis

- **Boundary Intersection**: Cells partially outside boundary are included if centroid falls within boundary

- **Coordinate Precision**: Centroids calculated to ensure consistent spatial referencing

A2_reference_systems.py

Purpose

Relates different spatial reference systems (coordinates, addresses, postcodes, UPRNs) with their corresponding grid cell for future use

Structure

LOAD generated grid cells from A1

LOAD OS postcode and UPRN reference data

CLIP reference data to study area boundary

CREATE spatial lookup tables:

FOR each grid cell:

IDENTIFY intersecting postcodes and UPRNs

COUNT reference points per cell

STORE actual postcode and UPRN values (not just counts)

CREATE linkage records for EPC data integration

SAVE reference lookup tables for subsequent analyses

VALIDATE referencing completeness

Key Assumptions

- **Point-in-Polygon**: Uses centroid intersection for postcode/UPRN assignment to grid cells

- **EPC Linkage**: UPRN values stored to enable energy performance certificate matching

- **Data Currency**: Assumes reference data represents current administrative boundaries

A3_key_functions.py

Purpose

Centralized library of reusable functions for spatial operations, data loading, and analysis workflows.

Structure

DEFINE spatial data loading functions:

load_with_spatial_filter(file_path, bbox)

load_option_geometry_by_prefix(folder, prefix)

DEFINE coordinate system functions:

ensure_project_crs(geodataframe)

calculate_accurate_distance(point1, point2)

DEFINE network analysis functions:

build_network_graph_with_options(network_file, option)

simple_network_distance(graph, origins, destinations)

DEFINE geometric processing functions:

create_access_points_from_lines(geometries)

create_access_points_from_polygons(geometries)

simplify_complex_geometries(geodataframe)

DEFINE analysis workflow functions:

setup_analysis_parser()

get_output_path()

save_analysis_results()

Key Assumptions

- **CRS Consistency**: All spatial operations assume British National Grid coordinate system

- **Network Topology**: Assumes road network data has proper geometric connectivity

- **Performance Optimization**: Spatial indexing and filtering used throughout for large datasets

- **Option Integration**: Functions handle both BASE and FINAL phase analysis with design geometry

A4_masterfile_run.py

Purpose

Orchestrates execution of all analysis scripts in correct order for BASE and FINAL analysis phases.

Structure

DEFINE script execution order:

prerequisite_scripts = [A1, A2_reference_systems, A2b_reference_mappings]

analysis_scripts = [B1 through B12, C1]

CLASS MasterAnalysisRunner:

INITIALIZE phase (BASE or FINAL)

SET environment variables for geometry source

METHOD check_prerequisites():

VALIDATE all required scripts exist

METHOD run_script(script_name):

BUILD command with appropriate arguments

SET ANALYSIS_PHASE='FINAL' for FINAL phase

SET USE_FINAL_GEOMETRY='TRUE' for design integration

EXECUTE script with error handling and timeout

LOG results and capture output

UPDATE success/failure tracking

METHOD run_analysis_sequence():

RUN prerequisite scripts first

IF successful:

RUN comprehensive network analysis scripts

GENERATE execution report with phase-specific recommendations

MAIN execution:

PROMPT user for phase selection (BASE/FINAL)

RUN complete analysis sequence with 1-hour timeout per script

REPORT final results and troubleshooting guidance

Key Assumptions

- **Sequential Execution**: Scripts must run in specific order due to data dependencies

- **Error Handling**: Individual script failures don't halt entire analysis sequence

- **Environment Variables**: FINAL phase sets flags to incorporate geometry from FINAL_GEOMETRY_FOLDER

- **Timeout Management**: Network analysis scripts given extended timeouts due to computational complexity

B1_green_access.py through B11_cycle_path_access.py

Purpose

Comprehensive accessibility analysis using road network routing for accurate walking distances.

Structure (Common Pattern)

LOAD grid cells and infrastructure data (green spaces, transport, etc.)

IF design_option provided:

AUGMENT infrastructure with design geometry (GRN*, TRS*, RD*, etc.)

AUGMENT road network with RD* geometry for improved connectivity

BUILD road network graph from OpenRoads data

CREATE access points from infrastructure geometries

FOR each grid cell centroid:

FIND nearest network node

CALCULATE shortest path distances to infrastructure access points

IDENTIFY distance to nearest facility

ASSIGN binary score (1 if accessible, 0 if not)

SAVE results with distance values and binary scores

GENERATE summary statistics and validation

Key Assumptions

- **Network Connectivity**: Assumes pedestrians can access all parts of road network

- **Access Point Density**: Multiple access points per facility improve accessibility accuracy

- **Walking Speed**: Network distances represent actual walking routes better than Euclidean

- **Threshold Validity**: Distance thresholds derived from UK planning guidance and user research

B12_private_area.py

Purpose

Analyzes private external space per dwelling at the building block level using adjacency logic.

Structure

LOAD building blocks and dwelling points (UPRNs)

FOR each building block:

COUNT dwelling points within/intersecting block

IDENTIFY cells adjacent to (but not within) building blocks

FOR adjacent cells:

CALCULATE available space after subtracting road buffers

SUM total adjacent private area

DIVIDE by dwelling count in block

IF private area per dwelling ≥ threshold:

ASSIGN score = 1 to adjacent cells

ELSE:

ASSIGN score = 0 to adjacent cells

ALL other cells keep default score = 1

Key Assumptions

- **Adjacency Logic**: Only cells adjacent to building blocks are evaluated for private space

- **Space Allocation**: Private area divided equally among dwellings in each block

- **Default Scoring**: Non-residential areas automatically pass private space test

C1_theme_contributions.py

Purpose

Analyzes theme contributions based on design option geometry using dependency rules for 10 sustainability themes.

Structure

LOAD grid cells and initialize 10 theme score columns:

Context, Identity, Built Form, Movement, Nature,

Public Spaces, Uses, Homes and Buildings, Resources, Lifespan

LOAD design option geometry from specified folder

FOR each geometry prefix with defined dependencies:

LOAD geometry features matching prefix

GET affected themes from THEME_DEPENDENCIES

GET buffer distance from DEPENDENCY_BUFFERS

IF buffer_distance > 0:

CREATE buffered influence area around geometry

ELSE:

USE original geometry as influence area

FIND grid cells intersecting with influence area

FOR each affected theme:

ADD 1 point to theme score for each intersecting cell

CALCULATE total theme contribution across all themes

SAVE results with individual theme columns and total contribution

Key Assumptions

- **Dependency Mapping**: Geometry prefixes accurately mapped to relevant sustainability themes

- **Buffer Influence**: Different infrastructure types have different influence radii on sustainability

- **Additive Scoring**: Multiple geometry features provide cumulative but separate theme contributions

- **Design Integration**: Theme contributions only calculated for specified design options

Euclidean Distance Scripts (General Pattern)

Purpose

Provides computationally efficient alternative to network analysis using Euclidean distances with walking factors.

Structure (B1_eucl, B2_eucl, B4_eucl, B6_eucl, B10_eucl, B11_eucl)

LOAD grid cells and infrastructure data with spatial pre-filtering

IF design_option provided:

AUGMENT infrastructure with appropriate design geometry

CREATE infrastructure access point coordinates

BUILD KD-Tree spatial index for extremely fast distance calculations

FOR each grid cell centroid:

QUERY KD-Tree to find nearest infrastructure access points

CALCULATE Euclidean distances

APPLY walking factor (1.3x) to estimate actual walking distances

APPLY infrastructure-specific thresholds

ASSIGN binary score based on accessibility criteria

SAVE results with optimized performance logging

Key Assumptions

- **Performance Optimization**: KD-Tree indexing provides sub-second analysis for large datasets

- **Walking Factor Accuracy**: 1.3x multiplier provides reasonable approximation of actual routes

- **Spatial Pre-filtering**: Bounding box filtering reduces data loading time significantly

- **Trade-off Acceptance**: Slight accuracy reduction acceptable for massive performance gains

Summary of Key Cross-Cutting Assumptions

Spatial Analysis Assumptions

- **Coordinate System**: All analysis conducted in British National Grid (EPSG:27700) for accurate distance measurements

- **Spatial Resolution**: 10m x 10m grid cells provide appropriate resolution for neighbourhood-scale analysis

- **Boundary Definitions**: Study area buffer ensures complete analysis coverage without edge effects

Network Analysis Assumptions

- **Road Network**: OpenRoads data represents available pedestrian routes with reasonable accuracy

- **Walking Factor**: 1.3 multiplier on Euclidean distances approximates actual walking route lengths

- **Network Connectivity**: Assumes pedestrian access throughout road network without barriers

Threshold and Scoring Assumptions

- **Binary Scoring**: Simplified pass/fail scores reflect planning decision-making context

- **Threshold Sources**: Distance and performance thresholds derived from UK planning guidance and research

- **Cumulative Scoring**: Individual indicator scores can be combined for holistic sustainability assessment

Design Integration Assumptions

- **Geometry Augmentation**: Design option geometry represents realistic additions to existing infrastructure

- **Performance Benefits**: New infrastructure provides expected accessibility and sustainability improvements

- **Phase Differentiation**: BASE phase establishes baseline, FINAL phase incorporates selected design geometry

- **Environment Variables**: FINAL phase uses FINAL_GEOMETRY_FOLDER with USE_FINAL_GEOMETRY='TRUE'

Data Quality Assumptions

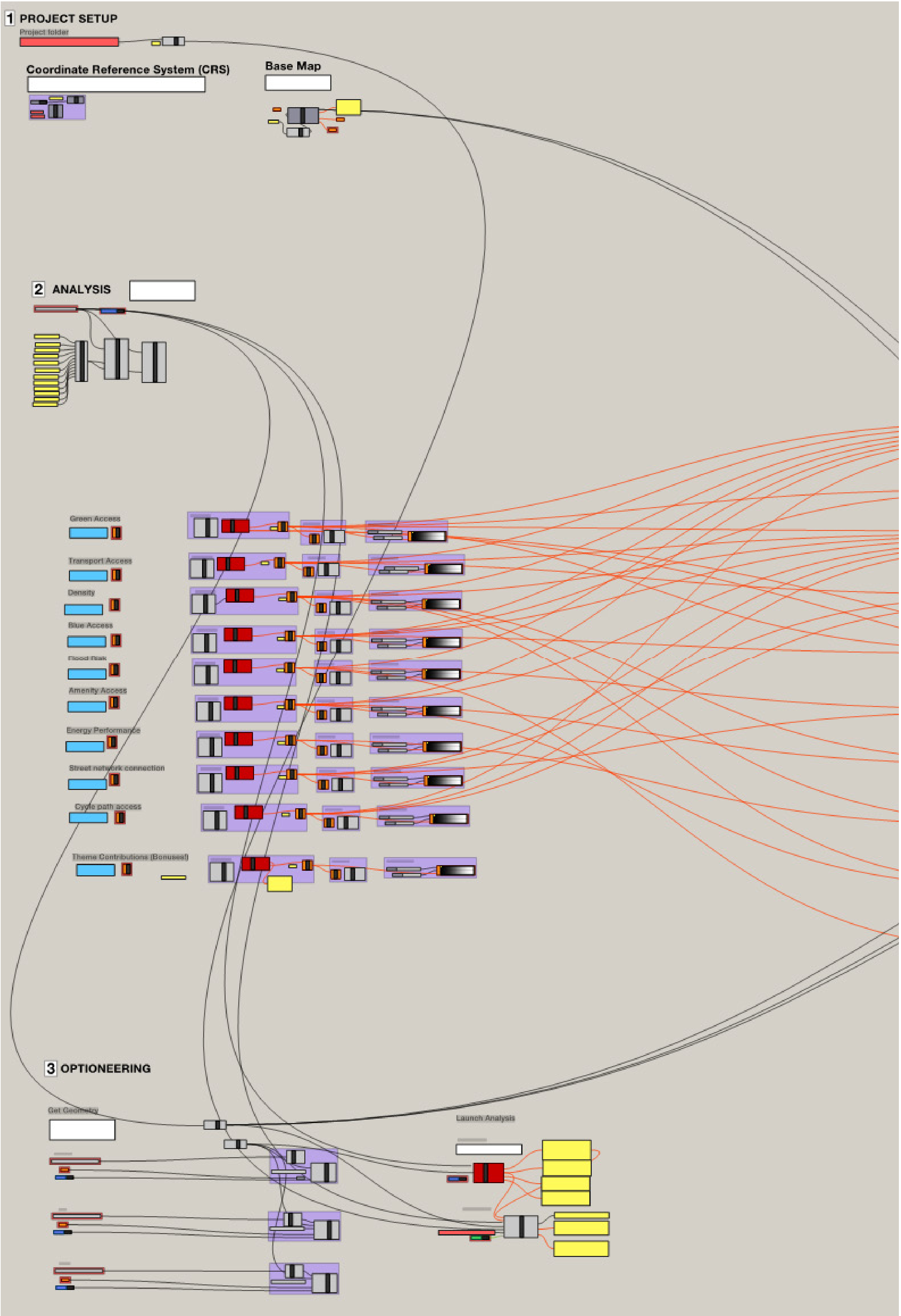
- **Data Currency**: Input datasets represent current conditions within acceptable tolerance

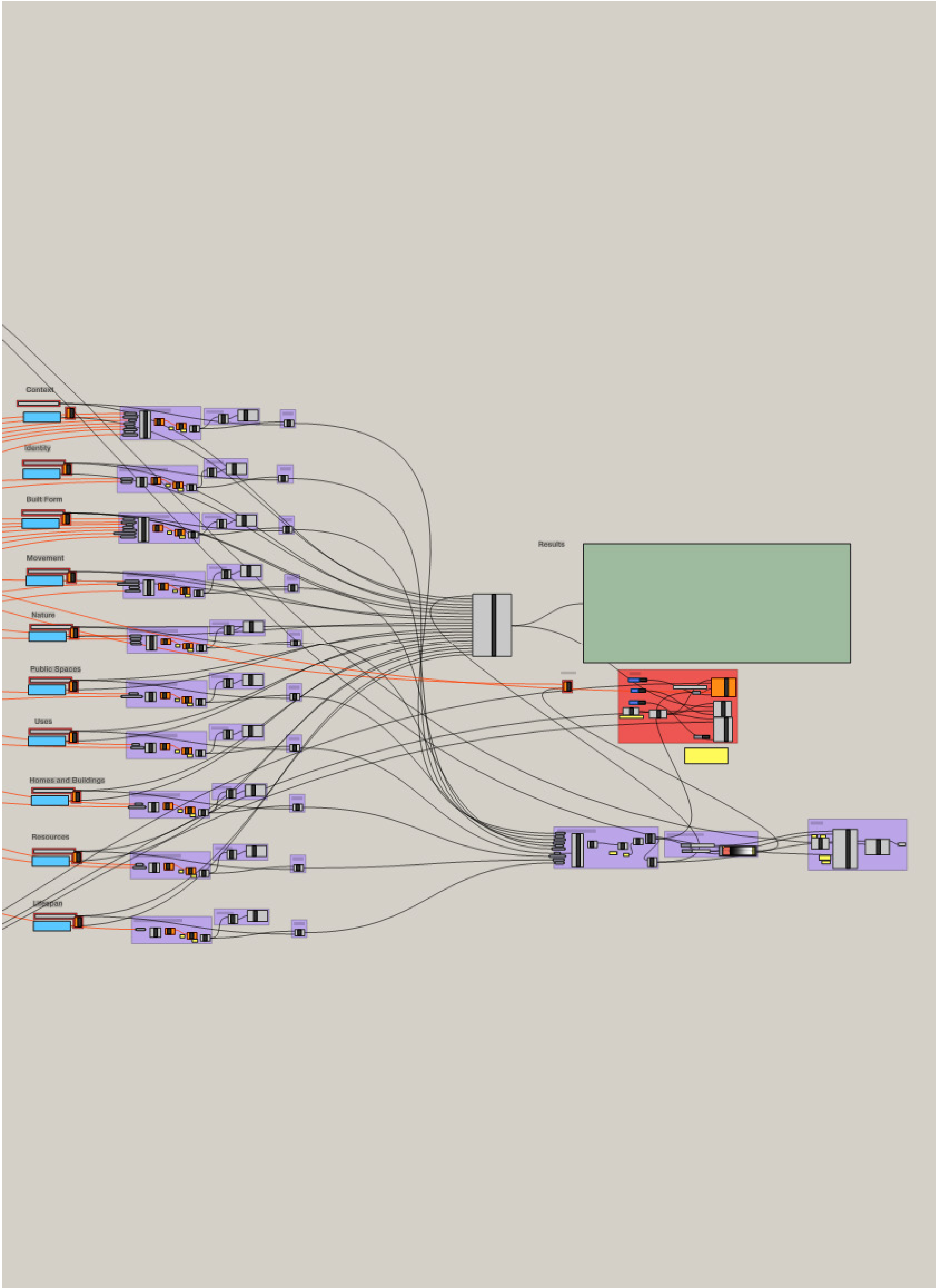
- **Spatial Accuracy**: GPS coordinates and boundary definitions meet analysis requirements

- **Completeness**: Missing data handled through proxy methods or conservative scoring approaches

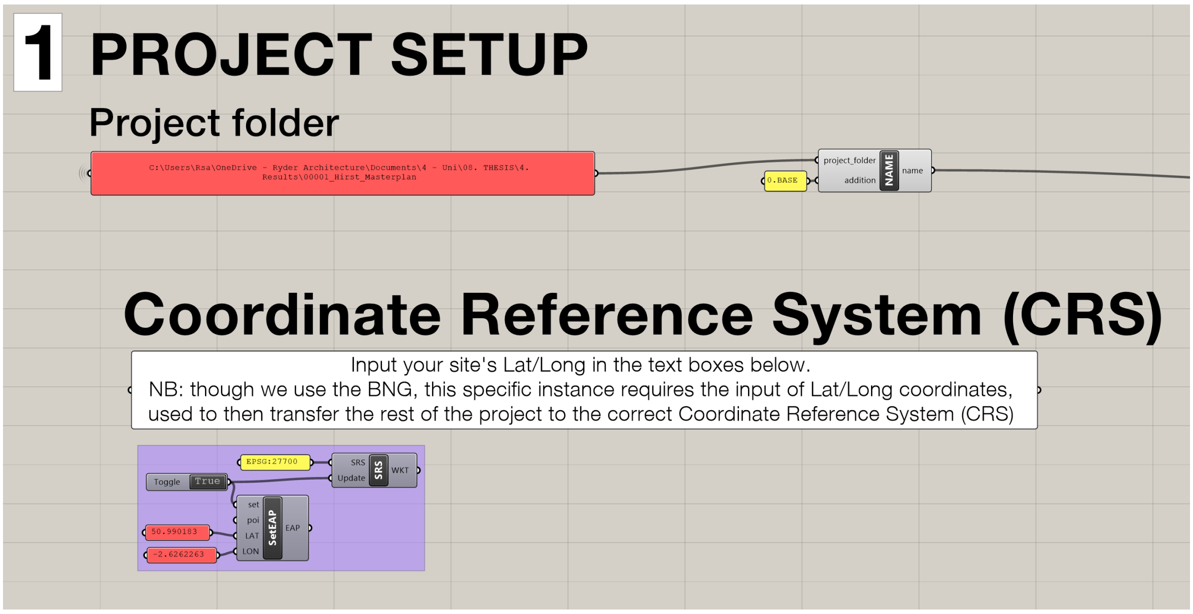
15.6 Appendix F – Grasshopper Script

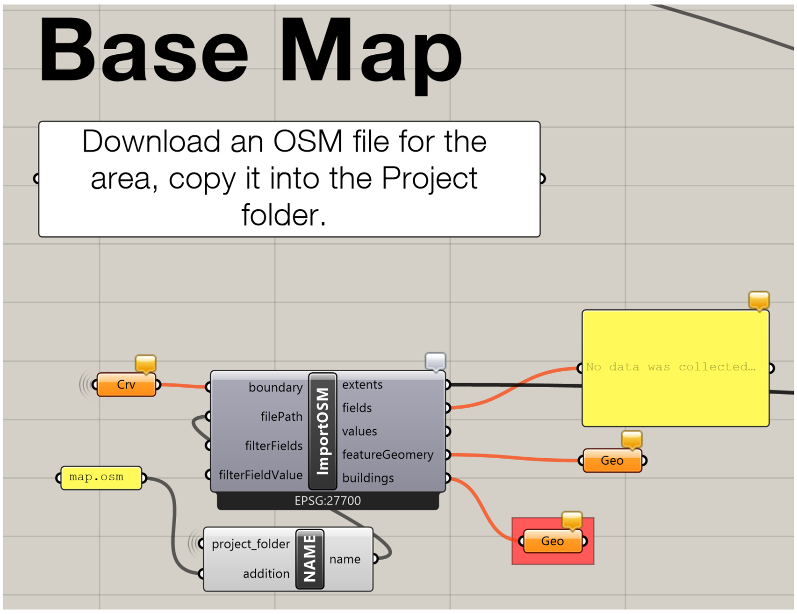
Overview



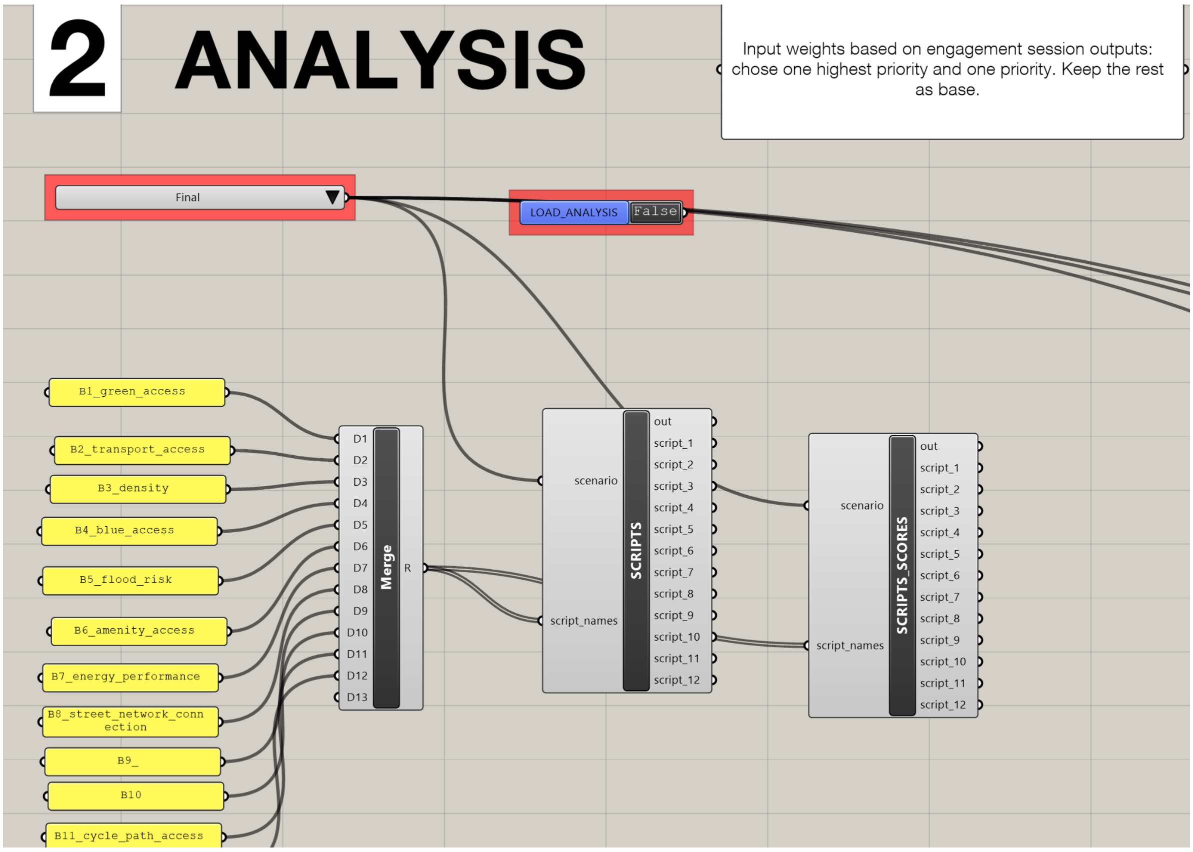


Context
Identity
Built Form
Movement
Nature
Public Spaces
Uses
Homes and Buildings
Resources
Lifespan
Results

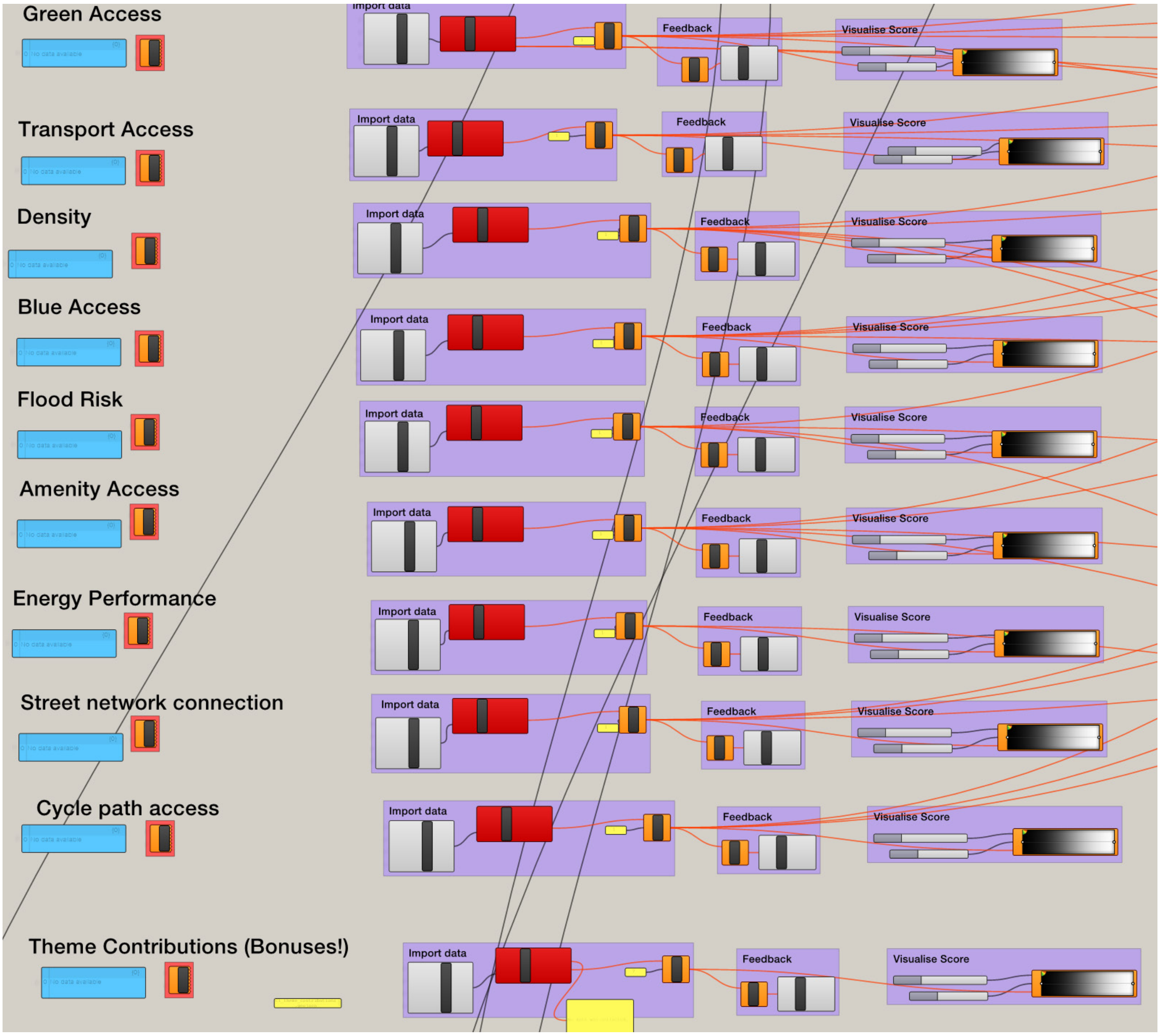

1
PROJECT SETUP
Project folder
C:\Users\Rsa\OneDrive - Ryder Architecture\Documents\4 - Uni\08. THESIS\4. Results\00001_Hirst_Masterplan
project_folder
addition
NAME
name
0.BASE
Coordinate Reference System (CRS)
Input your site's Lat/Long in the text boxes below.
NB: though we use the BNG, this specific instance requires the input of Lat/Long coordinates, used to then transfer the rest of the project to the correct Coordinate Reference System (CRS)
EPSG:27700
SRS
Update
SRS
WKT
Toggle
True
set
poi
LAT
LON
SetEAP
EAP
50.990183
-2.6262263

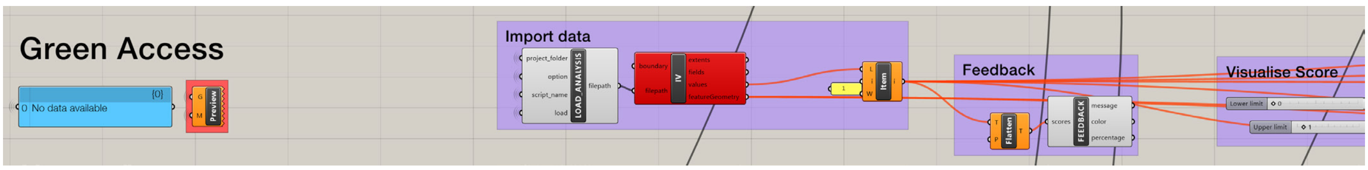

Base Map
Download an OSM file for the area, copy it into the Project folder.
Crv
boundary
filePath
filterFields
filterFieldValue
ImportOSM
extents
fields
values
featureGeomery
buildings
EPSG:27700
No data was collected…
Geo
Geo
map.osm
project_folder
addition
NAME
name

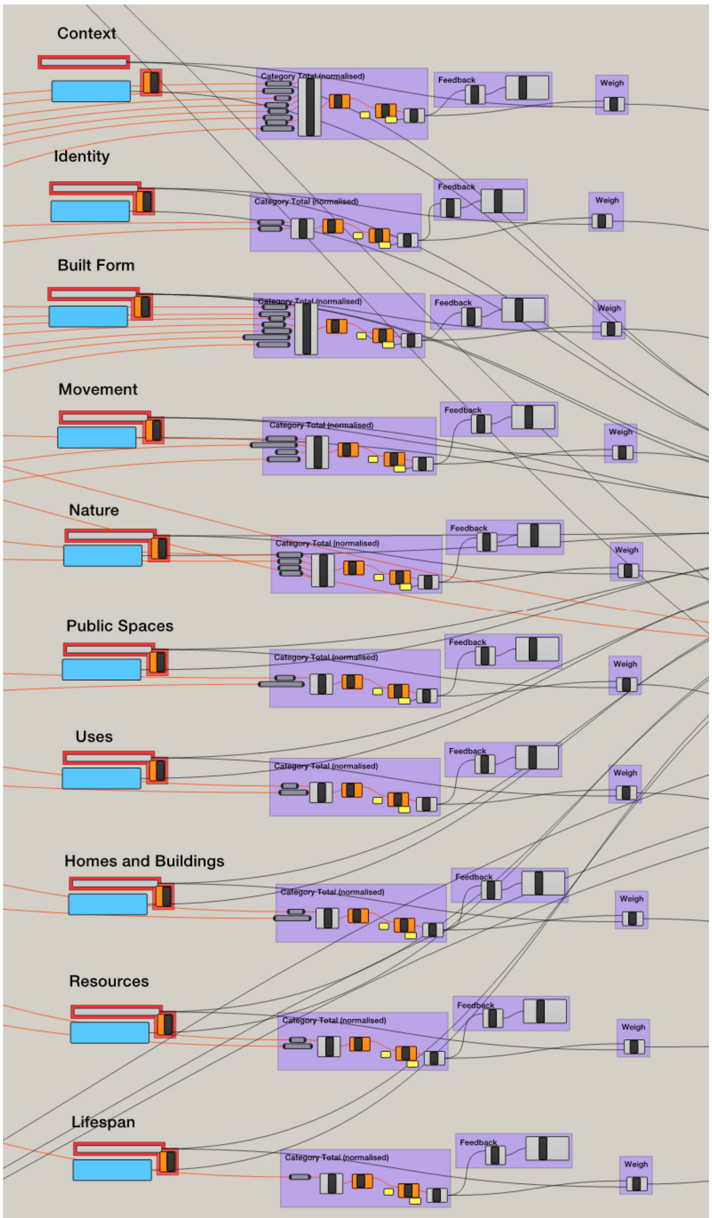
Analysis

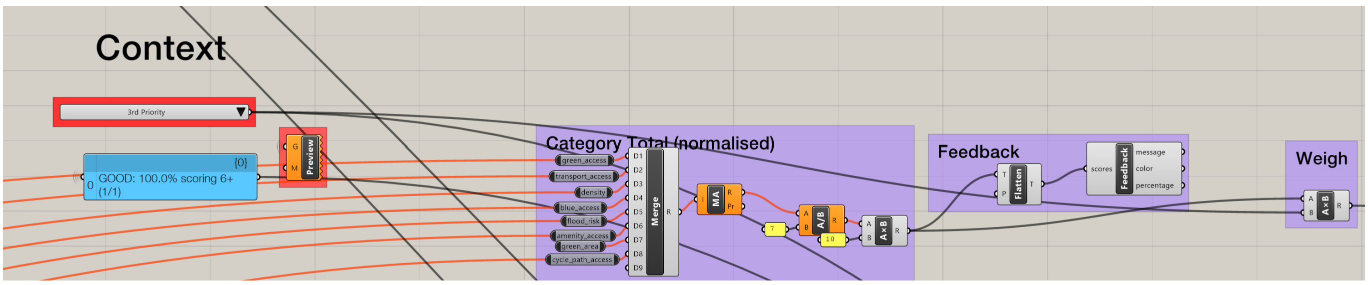


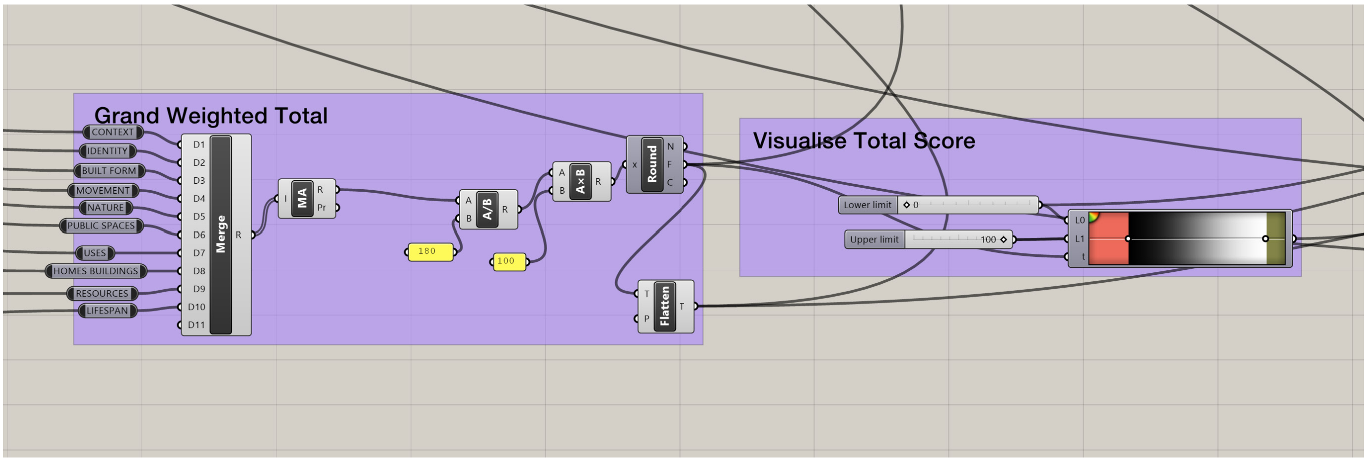
2 ANALYSIS
Input weights based on engagement session outputs: chose one highest priority and one priority. Keep the rest as base.
Final
LOAD_ANALYSIS
False
B1_green_access
B2_transport_access
B3_density
B4_blue_access
B5_flood_risk
B6_amenity_access
B7_energy_performance
B8_street_network_connection
B9_
B10
B11_cycle_path_access
Merge
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
R
SCRIPTS
scenario
script_names
out
script_1
script_2
script_3
script_4
script_5
script_6
script_7
script_8
script_9
script_10
script_11
script_12
SCRIPTS_SCORES
scenario
script_names
out
script_1
script_2
script_3
script_4
script_5
script_6
script_7
script_8
script_9
script_10
script_11
script_12

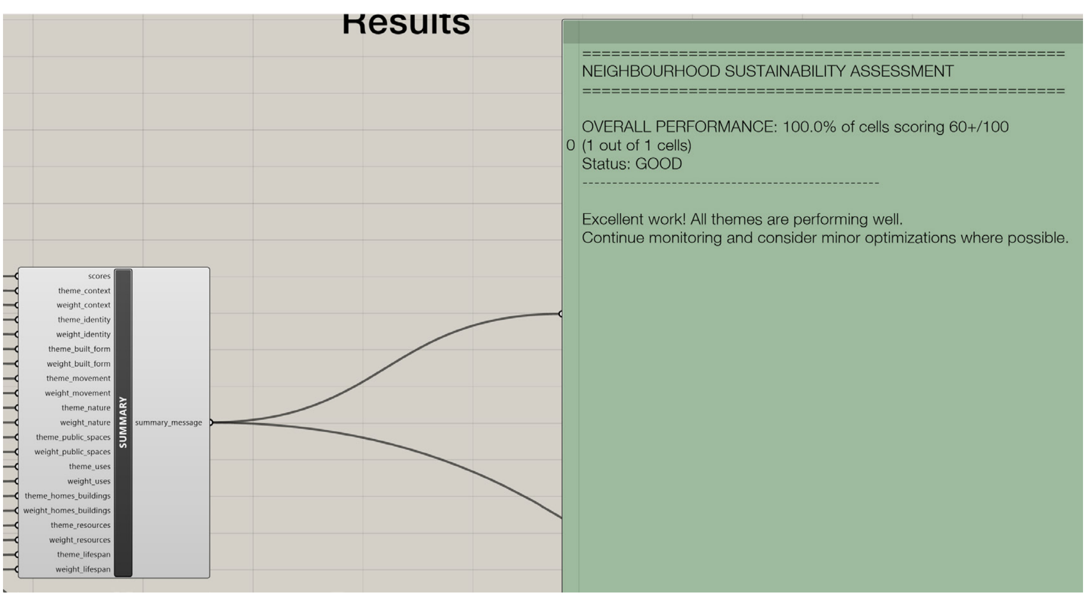

Green Access
Transport Access
Density
Blue Access
Flood Risk
Amenity Access
Energy Performance
Street network connection
Cycle path access
Theme Contributions (Bonuses!)
Import data
Feedback
Visualise Score


Green Access
No data available
Import data
Feedback
Visualise Score

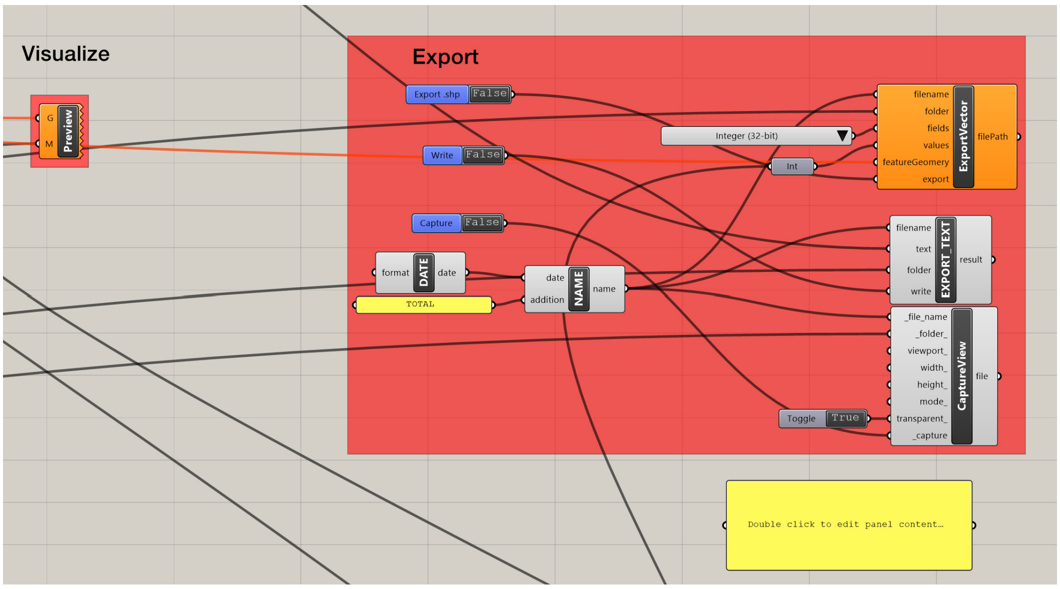

Context
Identity
Built Form
Movement
Nature
Public Spaces
Uses
Homes and Buildings
Resources
Lifespan
Category Total (normalised)
Feedback
Weigh


Context
3rd Priority
Preview
GOOD: 100.0% scoring 6+
(1/1)
Category Total (normalised)
green_access
transport_access
density
blue_access
flood_risk
amenity_access
green_area
cycle_path_access
Merge
MA
A/B
A×B
Feedback
Flatten
scores
message
color
percentage
Weigh


Grand Weighted Total
CONTEXT
IDENTITY
BUILT FORM
MOVEMENT
NATURE
PUBLIC SPACES
USES
HOMES BUILDINGS
RESOURCES
LIFESPAN
Merge
MA
A/B
180
100
A×B
Round
Flatten
Visualise Total Score
Lower limit
Upper limit
100


Results
==
NEIGHBOURHOOD SUSTAINABILITY ASSESSMENT
==
OVERALL PERFORMANCE: 100.0% of cells scoring 60+/100
(1 out of 1 cells)
Status: GOOD

Excellent work! All themes are performing well.
Continue monitoring and consider minor optimizations where possible.
SUMMARY
summary_message
scores
theme_context
weight_context
theme_identity
weight_identity
theme_built_form
weight_built_form
theme_movement
weight_movement
theme_nature
weight_nature
theme_public_spaces
weight_public_spaces
theme_uses
weight_uses
theme_homes_buildings
weight_homes_buildings
theme_resources
weight_resources
theme_lifespan
weight_lifespan


Visualize
Export
Preview
Export shp
Write
Capture
False
Integer (32-bit)
Int
ExportVector
filename
folder
fields
values
featureGeomery
export
filePath
EXPORT_TEXT
text
write
result
DATE
format
date
TOTAL
NAME
addition
name
CaptureView
_file_name
folder
viewport_
width_
height_
mode_
transparent_
_capture
file
Toggle
True
Double click to edit panel content…

15.7 Appendix G – User Guide

This is a guide on using the Shaping Place Dynamic Digital tool prototype. For any questions, please contact Romane Sanchez (linkedin: romane-sanchez) using the header SHAPING PLACE.

FIRST TIME USER

If you are running the tool for the first time on your laptop, please ensure that you have the following:

Data

Files downloaded from X and stored in original setup

File path to the data and file path to the project folders

Python

A python user interface (PyCharm (best but not free) or Visual Studio Code (free))

The following libraries installed using the command "pip install"

pathlib; shapely.geometry; geopandas; os; sys; pandas; numpy; tqdm; warnings; logging; time; network; argparse; spicy.spatial

Rhino/Grasshopper

Ensure you have access to Rhino and Grasshopper as well as the following grasshopper plugins, downloaded from Food4Rhino

NEW PROJECT SETUP

A0_project_inputs

Conceptualisation stage

1. Fill in the project details

2. Fill in the data directories

3. Fill in the British National Grid (BNG – easting and northing) coordinates using this https://gridreferencefinder.com

4. Check the project constants and variables – you shouldn't need to change any

5. Check the data inputs and file paths – you shouldn't need to change any if you followed the download instructions above.

6. RUN the A scripts

7. Check results in GIS software (recommended) or Rhino using grasshopper

At the end of the new project setup, you should have a grid for your project site and the references to all the future scripts will need (imbedded).

BASE ANALYSIS

Preparation stage

1. Run A4 Masterscript

2. Open a new Rhino project and a copy of "Dynamic_Design.gh"

3. In the "Dynamic_Design", fill in the following elements of "1. PROJECT SETUP":

a. Written path to your project folder – this is the folder where are your results are saved

b. Lattitude and Longitude for a point in your project – this is just to give the software a reference frame and the exact location of the point is not important. NB: though we use the BNG, this specific instance requires the input of Lat/Long coordinates, used to then transfer the rest of the project to the correct Coordinate Reference System (CRS)

c. Visualise and bake elements from the base map. Recommended to keep to Buildings geo to avoid overclogging.

4. Check the results in the "2. ANALYSIS" section. Here you can read feedback message of Individual analyses and view the results by turning on the "Preview" element.

5. Turn off any previews from the Individual analyses and head to the Thematic previews. Here you can check the results and feedback message of Thematic analyses by turning on the "Preview" elements

6. Set the priority rating for the themes (only

one of each).

7. Turn off any previews from the Thematic analyses and head to the Total Score visualisation. Turn the preview on.

At the end of the base analysis, you should be able to visualise the analysis results: individually, thematically and as part of a weighted total.

NB: in the "Dynamic Design" file, you only need to alter the elements in red.

OPTIONEERING

Implementation stage

1. Import your project's design options. If needed, use the "Revit to Rhino" script, ensuring you cluster your baked imports into functionality layers to facilitate the next steps (ie: greenery; street furniture; housing; lighting…).

2. Set your design option.

3. Tag and export your design geometry

4. Identify which design scripts are affected by your design geometry and will therefore need to be rerun. NB: at the optioneering stage, the Euclidian scripts are run to provide faster feedback and enable iterative design.

5. Run the optioneering analyses and check the results in a similar fashion to the Base analysis. Should take less than a minute.

At the end of the optioneering, you should have been able to iteratively explore the impacts of your design decisions on the site.

FINAL ANALYSIS

Closure stage

1. Select which design option to run the analysis on. STILL TO DO THIS!!

2. Complete the steps of the Base Analysis. The scripts will take in the Option geometry and input it to the analysis.

At the end of the final analysis, you should have a clear visualisation of the impact of your design interventions. This can/should be compared to the base analysis visual.