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# Implementation of a City Information Model on a Micro-Urban Scale: Qualitative Streetscape Analysis using the SSSEIC Method

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## 1 ABSTRACT

Semantically rich 3D models at the building scale have long been established through Building Information Modelling (BIM), which has become a standard in interdisciplinary planning practice. By contrast, City Information Modelling (CIM) at the urban scale has yet to reach comparable consolidation or widespread use. Existing frameworks vary in focus and integrate a multitude of different datasets, yet they typically operate at similar scales: large urban areas or even entire cities. Consequently, these models often support only low levels of detail, with buildings represented as simple volumes and public space reduced to terrain surfaces.

Between the building and urban scales lies a critical but underrepresented level: the street or neighbourhood scale. The spatial characteristics of streets are central to urban quality of life, shaping potential uses, social interaction, mobility, and environmental performance. It is therefore crucial to understand and capture the built environment at this level. Detailed modelling of streetscapes offers a unique opportunity to represent fine-grained physical and perceptual characteristics, enabling digital environments that more authentically reflect human experience. Such models facilitate comprehensive analyses and the identification of potentials within street spaces – factors that are increasingly vital in the context of climate change, where street-level morphology and materiality directly affect heat exposure, shading, ventilation, and overall resilience.

This paper provides a review of the existing CIM frameworks and presents the implementation of a City Information Model on a micro-urban scale using the SSSEIC method as a framework for qualitative (and quantitative) streetscape analysis. The method provides a systematic approach to describing and evaluating the spatial configuration and perceptual attributes of streets, bridging the gap between CIM and BIM to form a consistent modelling logic at the street scale. It includes street uses and surfaces, underground installations (pipes and cables), facades of the adjacent buildings and organisation of the ground floor area including uses, all objects in public space (street furniture), and ecological aspects which inlcude all plants and green spaces. Through this comprehensive structure, the SSSEIC method supports the creation of a semantically rich micro-urban CIM that serves both as an analytical tool and as a foundation for future design processes.

Keywords: CIM, 3D Model, Streetscape, Public Space, qualitative analysis

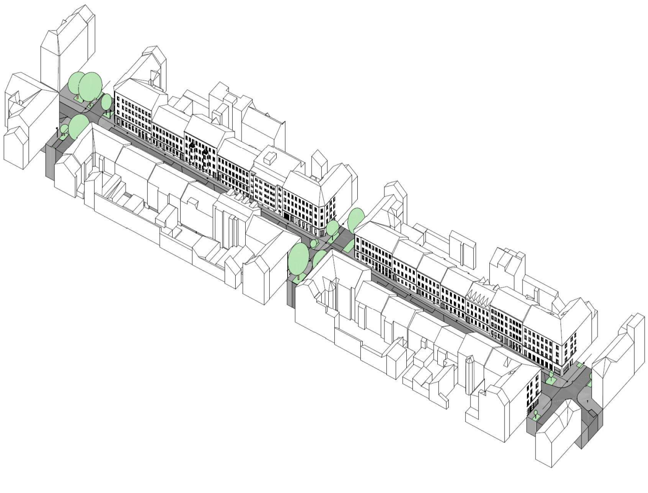

Fig. 1: Street space model created following the SSSEIC method © Tobisch, Löschenbrand, Psenner

# 2 INTRODUCTION

Over the past few decades, new planning methods and tools have emerged in the conceptualisation, planning and construction of the built environment. Individual 2D drawings were replaced by 3D models and the resulting plan views. The digital models were gradually provided with more and more data that went far beyond purely geometric information.

At the building scale Building Information Modelling (BIM) has established itself as the semantically enriched successor to 2D and 3D CAD drawings and has long since become the standard, particularly in interdisciplinary planning processes. In contrast, urban planning continues to rely predominantly on GIS-based tools. Semantically enriched 3D models on the city scale, so called City Information Models (CIM) also are available and used, but they are far from having the same standardisation or prevalence as those at the building scale. Although existing frameworks differ in their focus and integrate various data sets, they generally operate at the level of large urban areas or even entire cities. Consequently, these models frequently support only a rudimentary level of detail, with edifices commonly depicted as elementary volumes and public spaces simplified to terrain surfaces.

Meanwhile, an all-important level remains largely unexplored by widespread new modelling approaches: the streetscape. Whilst the relevance of street space features (adjacent buildings, the ground floor zone and its use, street furniture, the presence and arrangement of vegetation and the like) for the perception of public space, social participation and, in general, the quality of urban life has long been established (Jacobs 1961, Rudofsky 1969, Gehl 1971, Anderson 1978, Jacobs, Whyte 1980, Appleyard/Gerson/Lintell 1981, Jacobs 1993) and urban designers increasingly advocate for design on a human scale, placemaking and highlight the importance of livable cities (Stojanovski et al. 2020) outdated technologies are still used for its analysis, planning and potential assessment.

## 2.1 A Model for Streets

Detailed modelling of streetscapes can represent a powerful approach for capturing the physical, spatial and perceptual nuances of urban environments in one place. It can enable the creation of digital representations that more accurately reflect how streets are experienced by people. By incorporating elements like geometries of the street and surrounding buildings, materials, functions and vegetation these models can offer a richer, more nuanced understanding of street spaces than traditional representations using 2D plans. Consequently, they can facilitate an in-depth analysis of a variety of aspect like environmental or traffic performance, spatial comfort, and social functionality, while also supporting the identification of existing and potential street uses within the urban fabric.

Beyond the involvement of planners and municipal actors, there is a wide range of other stakeholders like entrepreneurs, residents, and passers-by within the streetspace. Given this number of actors, the organization of participation and influence within public street space becomes a critical question. In current practice, opportunities for multidisciplinary collaboration and co-creative processes remain limited, as responsibilities are typically divided into discrete segments of the street and addressed in a largely sequential manner. (Tobisch/Löschenbrand/Psenner 2025A) Various aspects of interdisciplinary collaboration can be addressed with the help of street space modelling. Firstly, connections and interrelationships between different disciplines and their areas of influence can be visualised. Furthermore, the use of a model that provides all participants with real-time access enables direct collaboration without the need to exchange plans from different programmes in various data formats.

The importance of such detailed representation and interdisciplinary methods is ever growing in the face of rapid climate change. Street-level morphology, material characteristics as well as the presence and placement of vegetation play a critical role in shaping microclimatic conditions, directly influencing heat accumulation, solar exposure, shading patterns, airflow and as a result thermal comfort of street users and residents. Accurate streetscape models therefore provide an essential foundation for evaluating climate resilience and informing design strategies aimed at mitigating heat stress, improving ventilation, and enhancing overall environmental performance. In this context, detailed streetscape modelling becomes not only an analytical tool for assessing current circumstances and potentials, but also a key instrument for supporting more adaptive, resilient, and human-centred urban design. This is particularly relevant because municipalities have limited time and financial resources, yet time is of the essence when it comes to maintaining quality of life in cities amid changing conditions. The number of streets that can be adressed at any given time is limited, so in addition to quickly implementable and inexpensive interventions using tactical urbanism, the targeted use of resources for permanent redesign is crucial. Priority should be given to those street spaces that, on the one hand, have a high need for intervention, but on the other hand also have the most potential and promise the greatest impact. Through the accurate presentation and processing of systemic information, both the suitable street spaces and the most sensible interventions can be selected in a targeted fashion.

### 2.2 Relevant Aspects

In order to enable analysis and comparison of different streets, including those with very different basic conditions, it is crucial to enable both qualitative and quantitative assessments. But before the issue of a suitable framework of consideration and modelling approach can be addressed, the relevant aspects within the streetspace have to be identified. The focus here is on all those aspects that constitute the real-life qualities street spaces as perceived by its users. For the identification of these qualities, interviews with experts from different disciplines were conducted and a workshop was held.[1] The resulting findings were complemented and refined by additional literature analysis and together form the basis for the qualities to be considered in the modelling. This quite extensive is by no means considered exhaustive and will be expanded further in the future. Nevertheless, it provides a useful overview of the range of topics and will therefore be used as a starting point for an initial examination of the subject. In this process, over 250 qualities or parameters of the street space have been identified (Tobisch/Löschenbrand/Psenner 2025A). Since most qualities can be viewed from different perspectives, it is not possible to separate them into distinct categories. Nevertheless, for the purpose of illustrating the range of aspects, the following broad thematic groups could be identified: relevant geographical information (i.e. street orientation and topography), the public space itself and its uses (i.e. surfaces, furniture, distribution of space and traffic volume), the adjacent buildings (i.e. facades, ground floor zone and uses), the urban infrastructure (i.e. underground installations, lighting), ecological topics (i.e. vegetation, microclimate, wind, sun exposure and shadows), matters related to perception (i.e. visual relationships, noise, temperature) and sociological factors (user groups, frequencies as well as quality of stay).

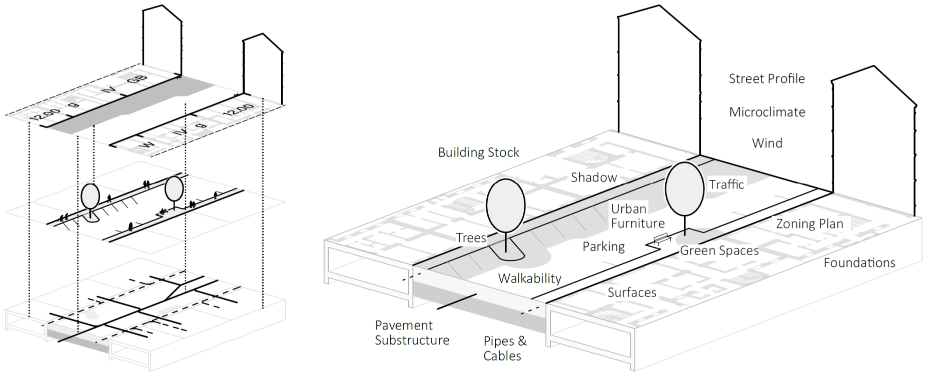

Fig. 2: A wide range of different aspects are represented in the street space, which a framework for a qualitative street space model is required to reflect. © Löschenbrand, Tobisch, Psenner

It is important to highlight that a combination of physical and non-physical aspect was identified. For the first category, the depiction within a 3D model and an underlying object-oriented database is straightforward, while the latter requires an alternative approach of consideration. Thus, a framework suitable for qualitative and quantitative street space analysis needs to be able provide a structure for both cases.

### 2.3 Research Questions and Methods

This paper aims to explore street space modelling by addressing questions that appear straightforward but, when examined in depth, reveal the underlying complexity of the topic:

What modelling frameworks and tools are currently available (BIM, CIM, etc.), what are their capabilities and limitations in relation representing street spaces on a micro-urban scale? What are the challenges with regard to methods, technical feasibility, data availability and workflow when modeling street spaces? How

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[1] A comprehensive discussion of the interviews conducted (the fields of expertise covered, the questionnaire and the survey results) and a description of the setting and results of the workshop was already published. (Tobisch/Löschenbrand/Psenner 2025A)

can a suitable framework for semantic street space modelling be conceptualised, and which components are required to support qualitative and quantitative analysis?

The methodological approach of this paper is exploratory and iterative in nature, combining a review of existing modelling concepts with the development and testing of a conceptual framework for street space modelling. The first step, existing concepts and tools for modelling the built environment are analysed with regard aspects relevant to street space considerations, including examination scale, representational accuracy, and the ability to capture semantic information. Based on the limitations identified, the methodological, technical, and organisational challenges associated with detailed street space modelling are subsequently examined. In a second step, questions of data availability, data quality, and data handling are explored using the case study of Vienna. The case study serves as test field for assessing the feasibility, limitations, and practical implications of implementing a detailed, semantically enriched street space model under real-world conditions. The findings from the review of existing frameworks and from the case study are then brought together to develop a proposed method for street space modelling. The resulting framework is subsequently applied in the construction of micro-urban CIM models for selected streets, allowing its internal logic, representational capacity, and analytical capabilities to be tested and reflected upon. In this way, the modelling process itself becomes an integral part of the methodological inquiry, informing both the refinement of the framework and the discussion of its potentials and limitations.

# 3 RESULTS

## 3.1 Review of Existing Frameworks

### 3.1.1 Building Models

Building Information Modeling (BIM) is a digital methodology for the integrated representation, management, and exchange of information related to the physical and functional characteristics buildings. (Xue et al. 2021) Unlike traditional CAD programmes, where elements are represented by blocks (composed of geometric elements), BIM programmes are based on architectural elements that can be placed freely from a prefabricated library. This object-oriented approach also reveals the roots of this approach, which can be traced back to the manufactoring industry (Eastman et al., 2011). For each of these elements, a range of information is stored in a database, which provides the model with its semantic properties. Today, BIM software for 3D modelling, such as Graphisofts ArchiCAD and Autodesks Revit, is more widely used than traditional CAD software, with the BIM standard having long been established in practice. IFC (industry foundation classes) define the corresponding standards for the both the structural framework and the file exchange format. They are structured hierarchically according to the requirements of building modelling (project, site, building, storey, element) and depict the relationships between elements and contain their underlying information. This allows data to be exchanged between different actors or even joint models to be operated. BIM thus functions not only as a three-dimensional modelling approach, but as an information management framework that supports process integration and data interoperability within the built environment. While BIM enables highly detailed representations, its structure is geared towards building production and management, and therefore does not offer modelling logic that goes far beyond the property scale, making it difficult to depict spaces that extend beyond that.

### 3.1.2 Urban Models

City Information Modeling (CIM) was introduced by Lachmi Khemlani in 2007 as an urban-scale counterpart to Building Information Modeling (BIM). Since its emergence, the concept has become increasingly prominent in academic urban research and has also gradually been adopted in urban design and planning practice (Souza/Bueno 2022, Xue et al. 2021). The initial approaches to CIM were strongly influenced by existing frameworks and combined Building Information Modelling (BIM) and Geographic Information Systems (GIS) data environment concepts (Xu et al., 2014). While often framed as a purely technical modelling approach, CIM can also been understood more broadly as a conceptual lens through which theories, methods, and tools from multiple disciplines can be integrated and examined on an urban scale analogues to BIM on the building scale (Stojanovski, 2013). It is described as three-dimensional model on an urban scale, that is based on city information data and has a multidisciplinary framework for collaboration (Xu et al. 2001).

Recent studies have a broader technical scope and emphasize advances in data acquisition and processing, including laser scanning, point clouds, artificial intelligence, and visual programming languages (La Russa et al. 2023), as well as the role of CIM in smart city initiatives and urban digital twins (Cureton/Hartley 2023). By now, CIM is also understood as a means of covering and illustrating a wide range of other topics. Omrany et al. (2023) made an effort to identify all topics within this increasingly broad field and have compiled the most important areas of application for CIM: natural disaster management, urban building energy modelling, urban facility and infrastructure management, land administration systems, urban microclimate improvement, smart cities and digital twins, improvement of social engagement, and urban landscaping design. However, the main applications remain often supporting urban planners in designing sustainable cities and enabling the technically informed governace of cities (Souza/Bueno 2022).

Despite this growing body of work, a clear and universally accepted definition of CIM has remained elusive. CIM can therefore be understood less as a single, well-defined methodology and more as an umbrella term encompassing a range of intelligent city modelling approaches. What all of them seem to have in common is a three-dimensional representation and the inclusion of other, not necessarily spatial data in a semantic database of some kind. Nevertheless, some standards are also gaining ground here, arguably the most commonly used standard for CIM is CityGML (Ohori et al. 2018) developed by the Open Geospatial Consortium (OGC). Similar to IFC it is an application independent framework and exchange format. A particular interesting feature in CityGML is its Level of Detail (LoD) concept, which describes the level of detail for different objects (such as buildings, vegetation and terrain). Starting with LoD0 (footprint and roof edge), through LoD1 (block representations), LoD2 (roof models), LoD3 (detailed models), levels of representation accuracy are classified using the example of a built structure (OGP 2021). With all LoD being able to represent indoor information as well.[2] While very different degrees of accuracy can be classified here, the high levels of detail in particular are rarely found in large scale applications. Therefore, an example for one of the various limitations in CityGML with regard for the modelling of street spaces is the missing representation of elements above the street surfaces i.e. objects in public space (Beil 2025).

Other terms for urban models, which are becoming increasingly popular, usually refer to similar concepts that cover partially the same subject areas, but differ in their scope or focus. One example is the term (urban) digital twin (UDT), which also describes a semantic 3D model of urban dimensions. However, digital twins generally represent the current state of a city, while CIM has no restrictions of this kind and therefore enables also representations of the past and simulations of the future. At the same time, UDTs usually represent a structure for the dynamic monitoring, management or development of urban space and are therefore anove all to be understood as a governance tool. However, as Cureton & Hartley (2023) emphasise, good CIM is a prerequisite for making the transition from static (GeoBIM) models to dynamic UDTs.

### 3.1.3 Street Models

In addition to BIM and CIM, which are both semantic 3D models, there are already several different approaches to representing street spaces using various methods, levels of detail and amount of information, which are examind in the following.

Street View Imagery (SVI) is the most commonly used representation od streets and readily available on a multitude of platforms.[3] It is deployed for a number of different uses, most prominently for the creation and mainteinance of spatial data infrastructure, but also for the extraction of greenery, urban morphology analyses, transportation and mobility analyses, urban perception and more (Biljecki/Ito 2021). As it contains detailed visual information, it is also suitable for for reviewing the built environment (Kelly et al. 2013). However, due to the manner in which SVI is recorded (georeferenced photos are stitched together to form panoramas) they do not inherently contain explicit geometrical data and can therefore not be classified as street models.

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[2] The original LoD4 class, which referred to interior models, was dropped in CityGML 3.0, as was the linking of semantic information with the level of detail in the modelling.

[3] The most widely used platforms are undoubtedly Google Street View and Apple Look Around, but Mapillary, which is based solely on images captured by users, also offers extensive coverage. Additionally, many municipalities conduct their own data collection, like the Kappazunder program by the City of Vienna (which simultaneously captures other data sets, such as 3D point clouds)

One step beyond this are representations that are constructed with (textured) 3D meshes – often created combining surveying methods like photogrammetry or LiDar scans – which makes them visually detailed and geometrically accurate. While these models feature a relatively high level of detail (that still seems to be lacking in the case of objects in public space accoring to Golombek/Marshall 2021) that makes them appealing for examining individual street spaces, they are missing a sense of depth that can be perceived in the street space (i.e. through the windows of adjacent buildings) and are usually lacking all semantic information. While a lot of information is discernable from these meshes (the human eye can differentiate between a tree and a house and is able to identify the permeable parts of facades from closed walls) this information cannot be automatically processed and analysed without performing additional processing steps (Babahajiani et al. 2017). In this regard, there are also efforts to develop a method for a pipeline from point clouds to the semi-automated creation of object-based 3D models using AI. (La Roussa et al. 2023) However, the focus here is on buildings and building blocks; modelling of public spaces is not (yet) included.

In comparison, the semantic road model as described by Beil (2025:81) and based on CityGML in fact contains solid three-dimensional elements instead of surface meshes. In addition to the street surface, various objects in public space, like street signs and traffic lights are represented, as well as the adjacent buildings as simple volumes. In this case, the term semantic refers mainly to information concerning transport infrastructure, such as the hierarchies of functions when two streets meet. This approach does not include the detailed modelling of adjacent buildings, ground floor zones or the space underneath the surface. Vegetation, however, is included, but only visual factors are taken into account here; the underlying ecological data is not recorded.

The procedural modelling of street spaces is another approach, that enables the creation of detailed 3D models using 2D map data and a set of rules to generate a model for example using 3D-GIS aplications like Esri CityEngine (Badwi/Elliaty/Youssef 2022) or using OpenStreetMap data and Houdini (Gao/Gao/Yu 2022). These necessary parameters and variables can relate to the design of the street space itself (lanes, sidewalks) as well as the design of the adjacent buildings (building age, style, façade elements) and elements in public space (street lighting and furniture). This approach is generally also able to produce solid 3D elements equipped with semantic information. Although these models can sometimes be highly detailed they remain a generated approximation of reality and do not represent the actual qualities of the real location (Kelly 2021).

There are a number of other modelling approaches on a similar scale, worth mentioning here is the Neighbourhood Information Model (NIM) by Cookes (2025) and the Settlement Information Model (SIM) concept described by Sattler (2024). The aim in both approaches is to model entire neighbourhoods of settlements (in the latter case post-war housing estates), including their buildings, the associated open spaces and street spaces using a BIM-based method. In addition, Sattler aims to incorporate social aspects and parameters relevant to quality of life. While both these approaches still appears to be very much in the conceptual phase (with the authors mainly reflecting on existing tools and frameworks themselves), they also reflects the desire to create a semantic model on a similar scale that achieves a high level of detail and combines several domains (buildings, open spaces, streets) that are traditionally treated separately as well as non-physical aspects.

Outside of the field of modelling the built environment for research and design purposes, there is other use cases for highly sophisticated visual models of street spaces, most notably the gaming sector.[4] Procedural modelling using a set of rules or predesigned module libraries is in this case employed to generate realistic representations (in terms of geometries and surfaces) of spaces without any reference to real-life locations ( whereby not only the street itself, but the entire city's street network is created). While in this context, the richness of detail serves as a backdrop for the gameplay only, but it does, in fact, reveal how these spaces need to be modelled in order to be representative to how public spaces are actually perceived – in great detail.

Due to the absence of a clear definition for CIM, there is also a lack of distinction from street space models. At the same time, approaches for street models often often use the same modelling logic as either building-

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[4] Impressive examples of this can be found particulary on media platforms: e.g. https://80.lv/articles/001agt-006sdf-procedural-brooklyn-in-houdini

related or city-wide models, and the limiting factor in applying detailed road space models to entire cities seems to be mainly computing power. At the same time, modelling concepts for settlements (Sattler 2024) or building blocks (La Roussa et al. 2023) are also being considered in a similar scale and level of detail (in CityGML terms this corresponds to LoD3). Therefore, street space models are described here as CIM on a micro-urban scale in order to also incorporate similar concepts within this superordinate terminology.

While the existing frameworks analysed cover various aspects that are relevant to a qualitative street space model, there does not appear to be a comprehensive compilation of these in a single framework to date. The various authors identify numerous difficulties and limitations of their respective methods. While none of these frameworks were developed with the intention of creating a qualitative street space model, some of the limitations mentioned above also apply in this context. Further challenges anticipated the creation of a detailed, semantically rich 3D street model are highlighted in the following section.

### 3.2 Challenges

The challenges involved in creating a new framework are manifold. This section will address those that have already emerged from the analysis of existing frameworks. Others that only arose during the course of the process can be found in the subsequent chapters.

#### 3.2.1 Depicting non-physical aspects

Arguably the greatest challenge for a framework for the analysis of street spaces from a qualitative perspective is that of integrating non-object-related or non-physical aspects. The aim of any semantic model is to attach all relevant aspects to modelling objects. These modelling objects do not necessarily have to be real-life physical objects – examples include the road centre lines frequently used in GIS analyses or the representation of uses as spatial volumes in BIM applications – but spatially precise delimitation is still a prerequisite for the representation as a modelling object.

Therefore all the identified relevant aspects were examined with regard to their representability. Different groups were identified: those aspects that can be represented in 3D objects, groups of 3D objects or can be calculated from them, those for which non-physical modelling objects can be created, and those that cannot be represented at all on a street segment basis. As will be outlined below in 3.3.2 all these aspects are covered in the theoretical framework, but the latter group had to be left out of the modelling logic for the time being. The information relating to these aspects cannot therefore be processed and evaluated directly in the model and must still be covered in another form.

#### 3.2.2 Data availability and handling

One challenge concerning street space modelling is the data, since an accurate model on that scale requires a rather large amount of highly detailed data. Many of the methods examined use only specially created data sets (i.e. LiDar scans). These are often technically demanding, expensive or time-consuming to produce. Therefore, the present study strives to acquire as much data as possible from existing and publicly available data sets, only when no data is available, additional data is collected. Since data availability can vary greatly from municipality to municipality, making it difficult to draw general conclusions, this study focuses on the case of Vienna. A total of three research streets was investigated, and all data-related challenges that arose in the process are outlined here, including availability, compilation, handling, processing and collection.

The data review was carried out in the following steps. First, the digital data sets that are publicly available as open government data (OGD) on the platform data.gv.at were examined, starting with the 3D data sets and continuing with the 2D datasets. Then, analogue data sets from archives were consulted. Finally, any missing data was supplemented by manual collection on site.

The identified relevant 3D datasets are the terrain model (Geländemodell Dreiecksvermaschung) and, because the building model only has a low level of detail, the roof model (Generalisiertes Dachmodell LOD2.1).[5] However, neither of these two data sets can be imported directly into the street space model, as they are surface meshes (instead of solids) and do not provide the desired level of detail. For example, the

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[5] Geländemodell Dreiecksvermaschung Wien (https://www.data.gv.at/katalog/en/dataset/bb86970f-3cef-4f9a-a79b-ff277ea925c8), Generalisiertes Dachmodell (LOD2.1) Wien (https://www.data.gv.at/katalog/dataset/86d88cae-ad97-4476-bae5-73488a12776d)

terrain model is only a rough approximation that does not show any height differences within the street space (such as kerb edges). Similarly, although the roof model shows the volume and approximate shape of the buildings (sometimes even including bay window), it does not provide any further information (balconies, façade design, entrances etc are missing). Therefore, both data sets can only be used as crude basis for modelling. Some of this missing information can directly be supplemented from 2D data sets. For example, the 2D city map (Mehrzweckkarte)[6] contains additional elevation points that enable more accurate modelling of the road surface, but even here the exact difference in height at the kerb is not specified. However, this map does indicate the division of the street space itself, i.e. the location of the kerb, the existing green areas, the arrangement of some elements in the street space (such as meter boxes or lampposts), and the building plots, footprints and position of the entrances and is therefore one of the key sources of data. Aerial photographs[7] were also used to obtain additional information about the street space, such as the number and type of parking spaces, the location of garage entries and additional objects in public space that are not already covered by the 2D city map (such as traffic signs, rubbish bins or benches). The records of cables and pipes (Zentrales Leitungskataster&Digitales Kanalinformationssystem)[8] provide information about underground infrastructure in the street space. These data sets are also only provided in 2D, and the availability of information for modelling (dimensions, height information) varies greatly. Since this data cannot be corrected manually, some assumptions have to be made in order to approximate the real situation. For more detailed information about the existing trees, beyond that provided by the 2D city map, such as tree species, tree height and age, the tree cadastre[9] was consulted. The City of Vienna maintains its own non-public application for image and Lidar data (Kappazunder[10]), where the surveys from 2020 are also available as OGD, but since the data is outdated and requires intensive pre-processing due to the large data volume, it was not used in this case. The spatial OGD datasets are generally available as dxf and, in some cases, as shp, allowing them to be opened and edited using standard CAD or GIS programmes, the aerial photos are available as jpeg. Some data can also be read directly via a web application (i.e. kanis) although this has to be done manually, it is the simplest method for manageable research areas.

In addition to digital data sets, analogue sources were consulted. Plans of all buildings adjacent to the streets, which can be accessed in the archives of the Building Department (Baupolizei – MA37), enable the three-dimensional construction of the façades and, on the ground floor, the spatial structures behind them. Since these building plans are sometimes very old, there are often discrepancies to other datasets that become apparent when combining them. A common example is the representation of floor plans on a perfectly rectangular plot of land, even though in reality the lengths of the plot sides and angles of the corners vary. In these cases, abstraction and approximation of the information is necessary.

All data necessary for a qualitative analysis that has not been mentioned above was collected on site. This includes photographic documentation of the façades, which allows for the precise reconstruction of detailed structures such as placement and appearance of doors, windows, balconies and mouldings. In addition, all furniture in the public space was recorded and the use of the ground floor zone as perceived from the street was documented. For more accurate modelling of the street surface, kerbs and other height differences were also measured. The remaining data was checked against reality and corrected where necessary.

## 3.3 Towards a Street Space Model

Based on the information obtained from the review and with the results of the investigation of the challenges in mind, a framework for a semantically rich street space model was developed.

### 3.3.1 Spatial and Conceptual scope

Since street spaces are in some cases highly specialised for specific purposes and the relationships between different streets in the network lead to diverse dependencies, restrictions have been set for the area under consideration. Given that the analysis is aiming to focus on the individual street itself, all streets whose use

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[6] Mehrzweckkarte Vektordaten (https://www.data.gv.at/katalog/dataset/stadt-wien_mehrzweckkartevektordatenwien)

[7] Orthofotos 2024 (https://www.data.gv.at/katalog/datasets/81868c1e-ce21-4c57-b53b-09fd5ffa0d0d)

[8] Zentrales Leitungskataster (https://www.wien.gv.at/verkehr/strassen/leitungskataster/), Digitales Kanal Informationssystem (https://kanis.at/)

[9] Baumkataster bzw. Bäume Standorte Wien (https://www.data.gv.at/katalog/en/dataset/c91a4635-8b7d-43fe-9b27-d95dec8392a7) or in the web viewer (https://www.wien.gv.at/umweltgut/public/grafik.aspx?ThemePage=11)

[10] Description of the Kappazunder application (https://digitales.wien.gv.at/projekt/kappazunder/)

and design is primarily guided by higher-level systemic considerations, such as transport axes or shopping streets, are therefore excluded for the time being. Thus, the framework was limited to the consideration of secondary streets that mainly reflect local needs and conditions.

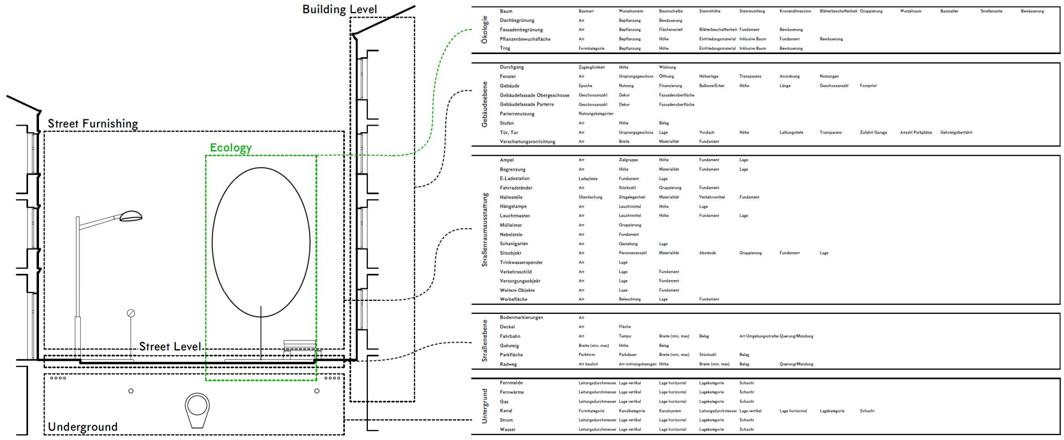
The smallest possible area of consideration that allows for the desired qualitative analysis and is therefore sufficient for the creation of the framework was determined in the next step. In order to perform the analysis, at least one street segment (i.e. from intersection to intersection) is needed to be able to identify the qualities present and their interrelationships. As corner situations hold a distinctive position within the urban fabric – historically significant functions were often situated on the ground floors of corner buildings. (Psenner 2023) Information regarding the hierarchies between different user groups can also be found at this intersection of different streets. It is essential that these intersections are also included in a 3D street model. The street segments to be examined therefore need to have intersections at both ends that creates a corner situation on both sides of the street (meaning T-intersections are not suitable end points). Since, in addition to the façades, the connections and relationships with the ground floor zone and its uses are particularly relevant to the quality, functionality and design of the street space (Tobisch/Psenner 2021, Psenner 2023), they are modelled in their entirety and their uses are also documented.

To ensure that the framework and modelling logic are able to represent a wide range of conditions, research streets from different eras of construction were selected (Gründerzeit, interwar period and present day).

### 3.3.2 Introducing the SSSEIC Method

The SSSEIC method framework structure makes use of various components from other concepts (such as BIM and CIM) and introduces new logic wherever no suitable elements exist. All of the aspects collected were divided into three categories: those that can be modelled within the area under consideration, those that apply to the entire street segment, and those that extend far beyond the spatial scope and must therefore be considered in a higher-level analysis. For clear identification, those groups were named modelling parameters, meta parameters and evaluation parameters.

The group of modelling parameters is further subdivided and structured hierarchically. While in building-related projects the IFC nested structure goes from project to site to building to storey to element, a different spatial organisation must be considered for the street space. For this purpose, the street space is divided into five different spheres: The street level itself (the surfaces of the street space and all its uses), the street furnishing (all objects that are located in the public space above the surface: lighting, traffic lights, signs, benches, etc.), the underground (everything below the streetlevel i.e. the pipes and cables), the building level (the facades and the ground floor zones including the uses), and ecology (all vegetation). These five groups were chosen on the one hand based purely on spatial considerations (e.g. separation of public space and its enclosing elements), and on the other hand because they represent the typical (main) areas of consideration for different experts, thus providing a logical basis for interdisciplinary collaboration. Also for this reason, ecology has been highlighted separately – it sometimes extends into several spatial spheres, but is addressed by one field and therefore forms its own unit.



| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ökologie | Baum | Baumart | Wurzelsystem | Baumscheibe | Stammhöhe | Stammumfang | Kronendimension | Blätterbeschaffenheit | Gruppierung | Wurzelraum | Baumalter | Straßenseite | Bewässerung |
| | Dachbegrünung | Art | Bepflanzung | Bewässerung | | | | | | | | | |
| | Fassadenbegrünung | Art | Bepflanzung | Flächenanteil | Blätterbeschaffenheit | Fundament | Bewässerung | | | | | | |
| | Pflanzenbewuchsfläche | Art | Bepflanzung | Höhe | Einfriedungsmaterial | Inklusive Baum | Fundament | Bewässerung | | | | | |
| | Trog | Formkategorie | Bepflanzung | Höhe | Einfriedungsmaterial | Inklusive Baum | Bewässerung | | | | | | |
| Gebäudeebene | Durchgang | Zugänglichkeit | Höhe | Widmung | | | | | | | | | |
| | Fenster | Art | Ursprungsgeschoss | Öffnung | Höhenlage | Transparenz | Anordnung | Nutzungen | | | | | |
| | Gebäude | Epoche | Nutzung | Finanzierung | Balkone/Erker | Höhe | Länge | Geschossanzahl | Footprint | | | | |
| | Gebäudefassade Obergeschosse | Geschossanzahl | Dekor | Fassadenoberfläche | | | | | | | | | |
| | Gebäudefassade Parterre | Geschossanzahl | Dekor | Fassadenoberfläche | | | | | | | | | |
| | Parterrenutzung | Nutzungskategorien | | | | | | | | | | | |
| | Stufen | Art | Höhe | Belag | | | | | | | | | |
| | Tür, Tor | Art | Ursprungsgeschoss | Lage | Vordach | Höhe | Laibungstiefe | Transparenz | Zufahrt Garage | Anzahl Parkplätze | Gehsteigüberfahrt | | |
| | Verschattungsvorrichtung | Art | Breite | Materialität | Fundament | | | | | | | | |
| Straßenraumausstattung | Ampel | Art | Zielgruppe | Höhe | Fundament | Lage | | | | | | | |
| | Begrenzung | Art | Höhe | Materialität | Fundament | Lage | | | | | | | |
| | E-Ladestation | Ladeplatze | Fundament | Lage | | | | | | | | | |
| | Fahrradständer | Art | Stückzahl | Gruppierung | Fundament | | | | | | | | |
| | Haltestelle | Überdachung | Sitzgelegenheit | Materialität | Verkehrsmittel | Fundament | | | | | | | |
| | Hängelampe | Art | Leuchtmittel | Höhe | Lage | | | | | | | | |
| | Leuchtmasten | Art | Leuchtmittel | Höhe | Fundament | Lage | | | | | | | |
| | Mülleimer | Art | Gruppierung | | | | | | | | | | |
| | Nebelstele | Art | Fundament | | | | | | | | | | |
| | Schanigarten | Art | Gestaltung | Lage | | | | | | | | | |
| | Sitzobjekt | Art | Personenanzahl | Materialität | Abstände | Gruppierung | Fundament | Lage | | | | | |
| | Trinkwasserspender | Art | Lage | | | | | | | | | | |
| | Verkehrsschild | Art | Lage | Fundament | | | | | | | | | |
| | Versorgungsobjekt | Art | Lage | Fundament | | | | | | | | | |
| | Weitere Objekte | Art | Lage | Fundament | | | | | | | | | |
| | Werbefläche | Art | Beleuchtung | Lage | Fundament | | | | | | | | |
| Straßenebene | Bodenmarkierungen | Art | | | | | | | | | | | |
| | Deckel | Art | Fläche | | | | | | | | | | |
| | Fahrbahn | Art | Tempo | Breite (min, max) | Belag | Art Umgebungsstraße | Querung/Mündung | | | | | | |
| | Gehsteig | Breite (min, max) | Höhe | Belag | | | | | | | | | |
| | Parkfläche | Parkform | Parkdauer | Breite (min, max) | Stückzahl | Belag | | | | | | | |
| | Radweg | Art baulich | Art richtungsbezogen | Höhe | Breite (min, max) | Belag | Querung/Mündung | | | | | | |
| Untergrund | Fernmelde | Leitungsdurchmesser | Lage vertikal | Lage horizontal | Lagekategorie | Schacht | | | | | | | |
| | Fernwärme | Leitungsdurchmesser | Lage vertikal | Lage horizontal | Lagekategorie | Schacht | | | | | | | |
| | Gas | Leitungsdurchmesser | Lage vertikal | Lage horizontal | Lagekategorie | Schacht | | | | | | | |
| | Kanal | Formkategorie | Kanalkategorie | Kanalsystem | Leitungsdurchmesser | Lage vertikal | Lage horizontal | Lagekategorie | Schacht | | | | |
| | Strom | Leitungsdurchmesser | Lage vertikal | Lage horizontal | Lagekategorie | Schacht | | | | | | | |
| | Wasser | Leitungsdurchmesser | Lage vertikal | Lage horizontal | Lagekategorie | Schacht | | | | | | | |

Fig. 3: The street is divided into different spheres within the framework. © Löschenbrand, Tobisch, Psenner

Within these spheres, there are sometimes further distinctions (individual buildings within the building level) followed by the individual modelling objects. These objects are equipped with a range of properties relating to the object type, dimensions, surface and context (there can always be several properties per category). Within the context category in particular, relevant information for qualitative analysis can be recorded that relates not just to individual objects but rather to the relationships between them (e.g. a bench is situated under a tree)

With this SSSEIC framework, streets could already be accurately and comprehensively described. In the next step, this framework was therefore be put to the test to determine its applicability for the construction of a CIM on a micro-urban scale.

### 3.3.3 Modelling Programme

Currently, since there is no framework specifically tailored to semantic 3D modelling of streets, there is also no suitable programme available on the market. Therefore, in some of the cases already described (see 3.1.3), as well as in the present study, programmes that were originally intended for a different use were adapted for this purpose. This of course introduces its own set of problems and challenges, one of the most complex of which is circumventing the modelling logic built into the programmes.

After an initial test of CAD and GIS programmes to identify their respective limitations, CAD programmes were given preference over GIS programmes due to their capability to produce detailed representations. Since the lack of detailed and semantically rich street space models was the initial motivation for this study, the focus was ultimately placed on this aspect of modelling over others. A detailed representation usually leads to a restriction of the manageable research area, but this was not a concern for the initial three research streets and was therefore tolerated as a limitation for the time being. Therefore, all programmes that enable fine-scale representation were selected for closer consideration.

The input of GIS data was of minimal benefit due to the high proportion of manual work required and was therefore not a decisive criterion, which is why Vectorworks (a CAD programme with GIS data embedding) did not have an advantage over other CAD programmes. Ultimately, ArchiCAD was selected because its semantic database structure, based on freely selectable ‘properties’, allowed for a relatively high degree of customisation to create a proprietary framework. Nevertheless, there were certain limitations, which will be described in more detail below.

### 3.3.4 From Framework to Model

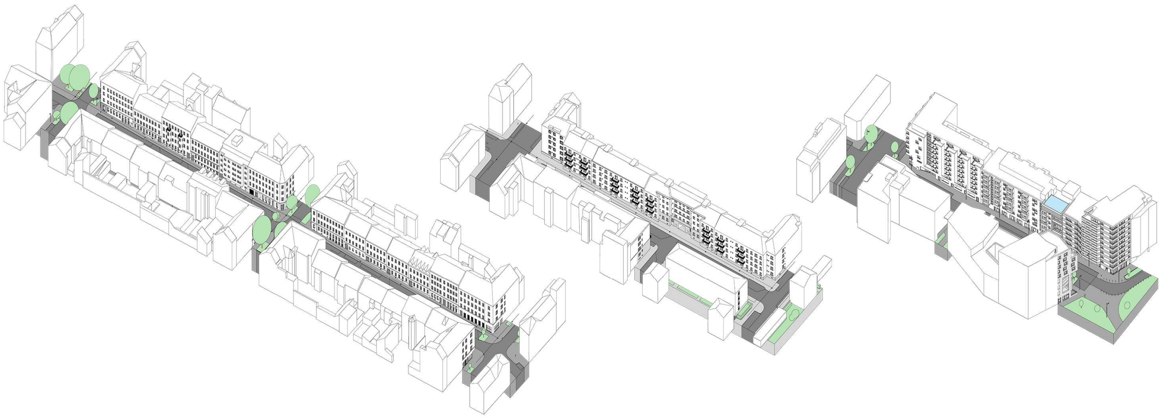


Fig. 4: Models of the three Viennese research streets © Tobisch, Löschenbrand, Psenner

For modelling purposes, ArchiCADs built-in logic, which is based on ifc standards was omitted as far as possible, therefore the parameters of the framework were established as properties. All modelled objects were assigned the properties, wherever the were known. For quantitative evaluation, apart from numerical values resulting from the geometry, only these properties were consulted. In addition, layers were used to display and hide elements during the modelling process, these were also based on the framework and are partially overlapping with the properties. In addition, layers were also used, which were also based on the framework and are partially congruent with the properties. They were mainly used to be able to show and hide elements, thus achieving a good view on the one hand, but also faster editability on the other. However, this revealed the first insurmountable issues with the logic inherent in the programme, as the layers cannot be freely selected for all elements. For example, doors and windows are designed as part of the wall and are therefore always located on the same layer. Similar challenges also arose with individual geometries, one example of which is the floor-by-floor structure of the model in the programme, which prevents openings that span several floors from properly displayed. To counter this problem, the façades above the ground floor were no longer modelled floor by floor, but in their entirety with wall elements spanning multiple floors. Since the same applies to the placement of windows and doors in wall bends, workarounds that are also common for BIM models were used for the ground floor zone itself, for example, placing a second, empty opening in the adjacent wall. Another difficulty was the mesh tool, which is intended for modelling terrain. Here, the triangulation of the surfaces seems completely arbitrary, and the surface can only be clicked on at elevation points but not elsewhere on the surface. As already mentioned, the entire model had to be built manually. Since ArchiCAD is a building oriented software, the workflow was, as expected, easiest for architectural elements that are mainly horizontal or vertical, while other elements that are angled or curved, such as underground pipes and cables that are aligned with the eleveation of the street were tedious to create. Ultimately, the morph tool was frequently used, as it allows for free modelling with only minimal restrictions.. This was particularly useful for decorative elements on the façade and for furniture in public spaces. Initially, the amount of work involved is considerable because objects first have to be modelled, but the elements can be stored in the object library and used repeatedly, even across different files.

As already mentioned, no elements could be directly incorporated (ultimately, there was one exception: the roof model was used to represent the envelope for the roof and the backside of the buildings adjacent to the street and also the surrounding buildings). Therefore, a large amount of modelling work was necessary for the model creation. Similar to BIM models, populating the database remains in part a manual task. For aspects that are non-physical but can be represented in the model and within one street segment, a series of modelling objects (mostly zones) were created for evaluation. While consistent objects are preinformed with semantic content from the get-go, aspects with changing information (such as zones that can have different uses) or the relationships between elements have to be added by hand. Nevertheless, the CIM models on a micro-urban scale could generally be created based on the framework, and corresponding quantitative and qualitative evaluation was also possible.

| A.Leu - Leuchtmasten | |
|---|---|
| A.Leu.01 - Art | Gehwegbeleuchtung |
| A.Leu.02 - Leuchtmittel | LED |
| A.Leu.03 - Höhe | ≤4m |
| A.Leu.04 - Fundament | Wahr |
| A.Leu.05 - Lage | Gehsteig |

| A.Vsg - Versorgungsobjekt | |
|---|---|
| A.Vsg.01 - Art | Hydrant |
| A.Vsg.02 - Lage | Gehsteig |
| A.Vsg.03 - Fundament | Wahr |

| A.Mül - Mülleimer | |
|---|---|
| A.Mül.01 - Art | Abfallhai |
| A.Mül.02 - Gruppierung | Einzeln |

| A.Wei - Weitere Objekte | |
|---|---|
| A.Wei.01 - Art | Poller |
| A.Wei.02 - Lage | Gehsteig |
| A.Wei.03 - Fundament | Wahr |

Fig. 5: View of a street space model superimposed with semantic information from the database © Tobisch, Löschenbrand, Psenner

## 4 DISCUSSION

So far, the framework has proven useful for the qualitative description of street spaces, but there are still a number of challenges that are the subject of ongoing conceptual efforts.

### Methodological Limitations

The method itself has not yet been finalised in terms of workflows and thereofre still exhibits some limitations. For example, although the evaluation parameters are included in the framework, their integration or relationship to the model has not yet been further elaborated. An analysis workflow that reincorporates these parameters that cannot be depicted within the model itself is presently under active development.

### Technical Limitations

The technical limitations mainly include programme-related challenges. The use of a BIM programme was feasible for modelling individual road segments, albeit not ideal, but would lead to performance issues in larger sections. In past modelling approaches, streets were at times modelled in sections and divided into several files to avoid this problem. (Psenner 2023) Even though a considerable effort is currently being made by various parties, at the time of writing this text, no adequate programme is yet in sight. Although there are some concepts that have been announced as being in development, including a CIM by Stojanovski et al. (2025) that covers the relevance of detailed morphological elements, at least in theoretical considerations, and could therefore potentially be a step in the right direction.

Organisational Limitations

Creating the models and the underlying databases is an extremely labour-intensive process. The data imported from the data sets merely serves as a basis for the manual creation of the model. In addition, all elements of the 3D model (modelling objects) are manually assigned their corresponding properties, with up to ten different variables available per object. It is evident that modelling a single street requires a considerable amount of time. Consequently, extending the analysis to several interconnected roads or entire urban areas is only feasible if data sets are automatically integrated into the 3D model, such automation (possibly involving the use of AI) represents a promising area for future academic research.

In addition to the aforementioned limitations, further noteworthy insights can be derived from the present study. The different construction ages of the street spaces did not result in a significant difference when creating the models; it was simply a matter of using different objects (i.e. lampposts instead of suspended lights). However, the building structures differed significantly in terms of the modelling effort required – the smaller and older the structures were, the greater the effort required. However, this was mainly attributable to the quality of the planning documents. As anticipated, the qualitative analyses did reveal significant differences in the qualities of the street space from different eras and, consequently, differing potentials for redesign. (Tobisch/Löschenbrand/Psenner 2025B)

## 5 CONCLUSION

This paper set out to investigate the potential of detailed, semantically enriched 3D modelling approaches for the analysis and evaluation of street spaces, a scale that remains insufficiently addressed by existing BIM- and CIM-based frameworks. While building-scale BIM and city-scale CIM have become well established for their respective purposes, the streetscape – despite its central importance for urban life, perception, and climate resilience – continues to be analysed using fragmented, largely outdated methods. The findings of this research confirm that this gap is not merely technical, but conceptual, rooted in the lack of a modelling logic that adequately reflects the spatial, functional, perceptual, and social complexity of street spaces.

Through the review of existing frameworks, it became evident that none currently offers a comprehensive solution for qualitative street space modelling. BIM provides high geometric and semantic detail but is limited by its building-oriented logic, while CIM approaches typically operate at a scale and level of abstraction that precludes meaningful representation of street-level qualities. Existing street modelling approaches, although diverse, either lack semantic depth, sufficent level of detail or were created for a different purpose entirely. Against this backdrop, the SSSEIC method was developed as an attempt to systematise and integrate relevant aspects of street spaces within a coherent framework that is compatible with semantic 3D modelling.

The application of this framework in a micro-urban CIM, using ArchiCAD as a test environment, demonstrated that detailed and qualitatively rich street space models can indeed be created and evaluated, albeit with considerable effort and technical limitations. In particular, the integration of non-physical aspects, data availability, and the lack of dedicated modelling software remain significant challenges. Nevertheless, the results show that the proposed framework enables a holistic description of street spaces and supports interdisciplinary analysis, prioritisation, and decision-making – an increasingly urgent need in the context of climate adaptation and constrained municipal resources.

Ultimately, this research should be understood as a foundational step rather than a finished solution. Further work is required to refine evaluation workflows, incorporate automation, and, last but not least develop tools specifically tailored to a CIM on a micro-urban scale. Even so, the study demonstrates that treating streets as a distinct and central scale of urban modelling holds substantial promise for more resilient, human-centred, and informed urban design practice.

## 6 ACKNOWLEDGEMENTS

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