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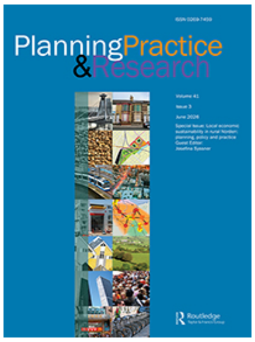

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Operationalising the 'Movement and Place' framework: from functional to configurational street types in urban design and planning practice

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ABSTRACT
Street design guidelines aim to balance the two dimensions of streets, as movement corridors and as public places. The widely adopted Movement and Place framework seeks to integrate these dimensions but overlooks the configurational and multiscalar nature of streets. Drawing on space syntax and the theory of natural movement, this paper extends the framework by defining street types through network centrality: closeness (place) and betweenness (movement). Gothenburg is used as case study to demonstrate how this approach addresses these two gaps, resolving transport-oriented biases to support pedestrian-oriented street design, particularly in early planning stages and in data-scarce urban contexts.

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Street design guidelines; configurational street types; Movement and Place framework; pedestrian movement; network centrality

> *"a very different understanding of the urban surface: as a dynamic spatial field, organised around the interaction between movement networks, rather than as a neutral surface on which functional facilities are distributed and then connected."*
> (Read & Budiarto, 2003, p. 13.7)

1. Introduction

Street design guidelines are widely used in international street design practice with the aim of offering a coordinated and consistent design process, where professionals from different disciplines and different levels of planning understand how their roles are brought together in the design of streets. Guidelines have in general adopted the sustainability agenda and propose an integrated planning (i.e. ensuring equal opportunities towards economic, social, and environmental development) and a holistic design approach (i.e. emphasizing the interrelationship between the parts and the whole).

The Agenda for Sustainable Development dictates that urban environments should, besides providing good and equal access to services, become more walkable to reduce car-dependency and CO_2 emissions, given that cars and trucks account for 40% of all CO_2

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emissions across the globe (NACTO and GDCI, 2016) There is consensus in planning practice and urban studies that well-connected streets and dense mixed-use neighbourhoods contribute to an increase in walking, cycling, and the use of public transport, reducing car ownership and vehicle miles travelled (NACTO and GDCI, 2016; Berghauser Pont *et al.*, 2021; Rostang *et al.*, 2021).

In general, walkability has been brought to the forefront and has become a central issue in urban design, planning, and policy (Stavroulaki, 2022) as an essential aspect of sustainable mobility and active travel, contributing to the Agenda for Sustainable Development, addressing aspects related to the environment and climate (e.g. Litman, 2020), health (e.g. Bird *et al.*, 2018; Roe *et al.*, 2020), social inclusion (e.g. Legeby, 2013; Legeby *et al.*, 2015), and thriving local economies (e.g. Hillier *et al.*, 1993; Hillier, 1996; Litman, 2020).

Despite consensus about the importance of the streets for sustainable urban development, the paradigm shift from a traffic-based towards a pedestrian-oriented street design practice has yet to fully materialize. The primary reasons for this delay stem from conflicts between the key disciplines involved in street design: urban design and planning on the one hand, and transport planning and traffic engineering on the other (Dumbaugh & Gattis, 2005; Nielsen, 2007; Dumbaugh & King, 2018).

Bobkova *et al.* (2024) identify these conflicts already in the definition of the street design types that play a key role in street design guidelines. Normally, the guidelines introduce specific street types (i.e. classifications), for which they later prescribe different design principles and design actions. A comprehensive review of international street design guidelines revealed that this initial street type definition is biased towards the 'movement' function of streets (88% of all the reviewed documents based their street classification on their transport function), compared to its 'place' function (i.e. the street as a destination with social, economic, or ecological functions) (Bobkova et al., 2024).

The 'Movement and Place' framework (Jones *et al.,* 2007, 2008), that has been adopted by several countries as a general planning framework for street design guidelines, is among the most advanced frameworks that conceptualizes the street as having these two primary functions of equal importance: the street as a movement conduit (referred to as 'Link' or 'Movement',) and the street as a destination (referred to as 'Place'). The pedestrian perspective is broadly referred to through the Place category, i.e. how the street functions as a destination in its own right (Jones *et al.,* 2007, 2008). To describe 'Place', the framework relies on a combination of variables such as density, land use, catchment areas of different radii, and various zoning plans that are used as indicators for pedestrian movement. However, numerous studies in the field of space syntax (e.g. Hillier *et al.*, 1993; Hillier, 1996; Peponis *et al.*, 1997; Hillier & Iida, 2005; Serra & Pinho, 2013; Ozbil *et al.*, 2019; Stavroulaki *et al.*, 2019; Berghauser Pont *et al.,* 2019b) have shown that it is not the *functional characteristics* that contribute to foot traffic in the first place, but the *configurational properties* of the street (calculated with different measures of network centrality) that serve as powerful indicator for the patterns of movement in cities and, in turn, play an important role for the performance of streets as 'Place' or carrier of activity. Theoretically, this is framed in the space syntax theory of 'natural movement' (Hillier *et al.*, 1993; Hillier, 1996). Two measures of network centrality have been proven important: closeness centrality that is also referred to as a measure of attraction or 'to-movement' and captures how well a street is connected to all surrounding streets, and betweenness centrality that is also described as a measure of 'through-movement', describing how well a street acts as connector between all other streets in the system. These two measures are very much in line with the concepts used in the 'Movement and Place' framework, where to-movement aligns with the street as destination or place, while through-movement aligns with the street as link.

Finally, studies have shown that the street's foot traffic and, in accordance, the activities taking place in this street, depend highly on the street's multiscalar network properties (Berghauser Pont *et al.*, 2019a; Ozbil *et al.*, 2011; Stavroulaki *et al.*, 2019; Stavroulaki, 2022). Although the Movement and Place approach includes different planning scales, it does not consider how place and movement are defined by their characteristics *across* scales.

Therefore, the aim of this study is to demonstrate how multi-scalar space syntax descriptions of streets including the two measures of network centrality, and the theory of natural movement (Hillier *et al.*, 1993; Hillier, 1996), can be used to address the theoretical shortcomings of the Movement and Place framework. This will be demonstrated on three levels: first, on a theoretical level; second, on a methodological level proposing concrete methods to generate configurational street types based on their multiscalar network centrality; third, on a practical level by applying the method in the case study of Gothenburg, Sweden.

Gothenburg is a port city built along the Göta River, with a monocentric, radial 'finger' structure. Its urban fabric ranges from highly connected, grid-like districts in the historic center, to modernistic, car-oriented suburbs and low-density villa areas, making it an ideal laboratory for studying the diverse street patterns that are characteristic of contemporary cities. In addition, using Gothenburg as a case study, allows us to build upon earlier morphological studies by Berghauser Pont *et al.* (2019a, 2019b), ensuring a solid foundation for the analysis presented in this paper.

The outline of the paper is as follows. Section 2 will present the theory of natural movement and highlight the theoretical gaps of the Movement and Place approach. In Section 3, we concretise the problem, using the exemplary Road and Street Framework (RASF) from New Zealand, based on the Movement and Place approach. Section 4 discusses how the theory of natural movement can be integrated within the Movement and Place approach using the two key measures of network centrality. Finally, in Section 5, practical implications and the broader relevance of the study is discussed.

2. Theory of natural movement

2.1. The relation between configuration, attraction and movement

The theory of natural movement refers to the dependency between the street network configuration, pedestrian movement and urban attractions (such as different land uses and density), where street network configuration is argued to be the main driver of the other two factors (Hillier *et al.*, 1993; Hillier, 1996). Street configuration in principle describes the relative position of each individual street in the entire street network system and increases our understanding of the relation between parts and whole.

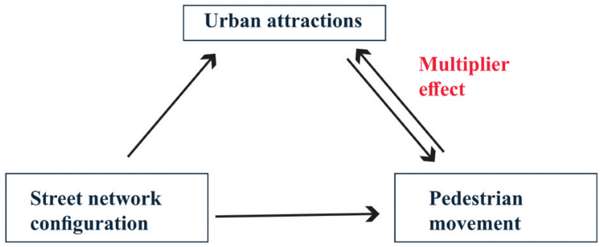

Figure 1. Natural movement theory (adapted from Hillier *et al.*, 1993, p. 31).

The argument is that well-functioning cities can be described as economies of movement: the spatial configuration of the street network determines how movement flows of various kinds are distributed and how this, in turn, shapes the distribution of urban functions (Hillier *et al.*, 1993; Hillier, 1996). Streets, whose location on the global structure makes them more generally accessible, are travelled many times in each origin-destination trip, and 'profit' from the by-product of that movement by attracting movement-seeking functions, such as commerce or services (Hillier *et al.*, 1993; Hillier, 1996). These functions then act as destinations and attract even more movement, creating a multiplier effect (Figure 1), which allows for the emergence of multi-functional and high-density urban centres. This has been supported by numerous empirical studies in space syntax research proving the significant correlation between street centrality and the intensity and distribution of pedestrian flows in cities, as well as the streets' social and economic performance, such as the presence of local markets (Peponis *et al.*, 1997; Hillier & Iida, 2005; Chiaradia *et al.*, 2009; Ozbil *et al.*, 2011; Scoppa & Peponis, 2015; Sevtsuk *et al.*, 2016; Stavroulaki *et al.*, 2019; Berghauser Pont *et al.*, 2019b).

Other land uses, that do not directly gain from movement, such as residential uses, often tend to be located in the less accessible areas. As Hillier and Vaughan (2007) state, this dual process tends to be invariant across different cultures and 'leads to the emergence of the also dual structure of urban grids: a foreground network of highly accessible spaces linking centres at all scales, and a more segregated background network of primarily residential space in which the foreground network is embedded' (Hillier & Vaughan, 2007, p. 218).

The configurational properties of street network allow us to capture those differences in movements of various kinds and distinguish streets and places with high or low centrality, and hence high or low potential for attracting pedestrian flows and pedestrian-oriented functions (Hillier *et al.*, 1993) as confirmed in various empirical studies (e.g. Ozbil *et al.*, 2011; Scoppa & Peponis, 2015; Stavroulaki *et al.*, 2019; Berghauser Pont *et al.*, 2019b).

2.2. Nested centralities

Importantly, the systemic or configurational dimension of streets reflects their multiscale nature, since streets and places may be meaningful at the local, neighbourhood, and city/metropolitan scale *at the same time*. The same street may act as a local meeting place for a few surrounding urban blocks, as a high street serving several neighbourhoods, and as a city-scale transit corridor that also accommodates global-scale commerce. In other words, streets and places are neither local nor global; they are essentially *both*.

The notion of street multiscalarity has been elaborated by Read (1999) as 'nested' centrality (Read, 1999; Read & Budiarto, 2003) and by Hillier and Vaughan (2007) as 'pervasive' centrality. According to Read and Budiarto, '*urban places are capable of being nested within one another at different scale levels, and this would suggest that the regions that places depend on also stack over and nest into each other according to the scales at which they are defined*' (Read & Budiarto, 2003, p. 13.5).

Consequently, urban centres may have many roles, beyond their mechanistic classification into local/neighbourhood/city/global. Further, Read (1999) introduces the idea of *co-incidence and non-coincidence* of those scales, which is central to the topic of this paper and is explained as follows. In the areas, that can be broadly referred to as 'traditional city centres', global scale or 'supergrid' networks overlap with local or neighbourhood scale networks; consequently, multiscale centres emerge that offer both local and global scale accessibility (Read, 1999). Read and Budiarto (2003) also refer to this phenomenon as '*explorable city space*', meaning that in the case of such a natural overlap of various scales, one can easily shift from a quiet local street to a more vibrant high street or even jump on the tram and travel to another part of the city. In other words, this multiscale nature of streets in traditional cities '*orients them simultaneously to the city and to the neighbourhood and supports the evolution and maintenance of, for example, neighbourhood high streets whose street-edge economies are supported by city-scale passing trade at the same time as they become local centres for shopping and gathering*' (Read & Budiarto, 2003, p. 13.7).

In traditional urban fabrics, supergrid networks are an integral part of a more general urban fabric, and local-scale centres and city-scale through movement coexist in the same space. The process is rather different in many areas designed after the Second World War, where supergrid high-speed networks are, to varying degrees, separated from the more general urban fabric, which can be described as a typical pattern of peripheral areas (Read & Budiarto, 2003). This results in specialised large-scale mobility networks connected to enclaves of living, working, or shopping areas, distributed following the logic of the mechanistic distribution of functions: these are spaces, that offer functional accessibility without explorability (Read & Budiarto, 2003).

In those areas of *non-coincident spatial scales*, global networks are not supported by local movement and eventually turn into high-speed barriers. Local places, in turn, that are disengaged from global scale through-movement, fail to support a whole range of urban functions that benefit from higher-scale accessibility, and their further development is eventually blocked, turning them into monofunctional enclaves of living, offices, or industries (Read & Budiarto, 2003).

The phenomenon of '*coincident*' and '*non-coincident*' spatial scales[1] is well illustrated by Read and Budiarto (2003) using two extreme examples: a so-called traditional city example on the one hand and a peripheral urban area on the other. Cities are, of course, much more complex than that, as urban places can be described by all kinds of combinations of high and low centralities across several scale levels. The configurational approach in space syntax is capable of revealing those structures in all their complexity, across all scale levels, ranging from local micro-centres up to macro, regional centres (Serra, 2013). To give an example, a local residential street may be naturally integrated into a vibrant neighbourhood centre, or it may be functionally connected to a highway passing by/through that area. In both cases, it remains the same quiet residential street, but its systemic dimension differs. It is precisely this systemic dimension that becomes relevant when making decisions about future local design improvements of that street.

3. Movement and Place framework and natural movement theory

3.1. Deconstructing Movement and Place based on the Roads and Streets framework from New Zealand

The Movement and Place approach, originally developed in the UK by Jones *et al.* (2008) has been adopted by several countries, not only to classify streets in cities but as a general planning framework, supporting several planning scales, from strategic visions and plans to concrete design guidelines and design codes for streets. It is mostly used in the UK (Department for Transport, 2007; Transport for London, 2013), Ireland (Government of Ireland, 2019), Australia (Victoria State Government, 2019; NSW Government, 2022, 2024), New Zealand (Auckland Transport, 2020, 2022) and, to some extent, Canada (City of Toronto, 2017).

Among the guidelines that apply the Movement and Place framework, the 'Roads and Streets Framework', or 'RASF' (Auckland Transport, 2020) is found to be the most concrete, addressing multiple aspects of streets (Bobkova *et al.*, 2024) and being most systematically developed across several planning levels (Auckland Transport, 2020, 2022). The RASF framework will be used in this paper as the exemplary document based on the Movement and Place approach.

RASF describes 'Place' as '*the catchment of a road or street and its adjacent land use as a destination in its own right, i.e. how far people are prepared to travel to go there*' (Auckland Transport, 2020, p. 9). 'Movement', in turn, is described as '*its level of strategic importance within the transport network, measured in terms of moving people, goods and services safely and efficiently between locations and accessing key destinations*' (Auckland Transport, 2020, p.10). Both Movement and Place functions of the street are divided into three categories of strategic importance, ranging from local to regional (Figure 2).

When it comes to Place categories, **P1** corresponds to a mainly local function with a small catchment of users; **P2** is referred to as attracting activity from across a subregion or neighbouring areas and it may be described as 'neighbourhood center'. Finally, **P3** describes central places in cities, since it is referred to as attracting activity from across the region.

Movement categories are, in turn, divided into **M1**, streets of low strategic significance, or, in other words, local streets; **M2**, of medium strategic network significance; and **M3**, of high strategic network significance.

When combined, these categories result in a matrix of nine street types (Figure 2). As an example, in this categorization the local street types (**P1M1**) have both low 'Place' and 'Movement' values, while city bypass roads have low 'Place' but high 'Movement' status (**P1M3**). The former are typically residential streets without a role in the main transport network, while the latter are typically monofunctional streets that are used for connecting neighbourhoods within the city. The city boulevard or public transit street[2] (**P3M3**) on

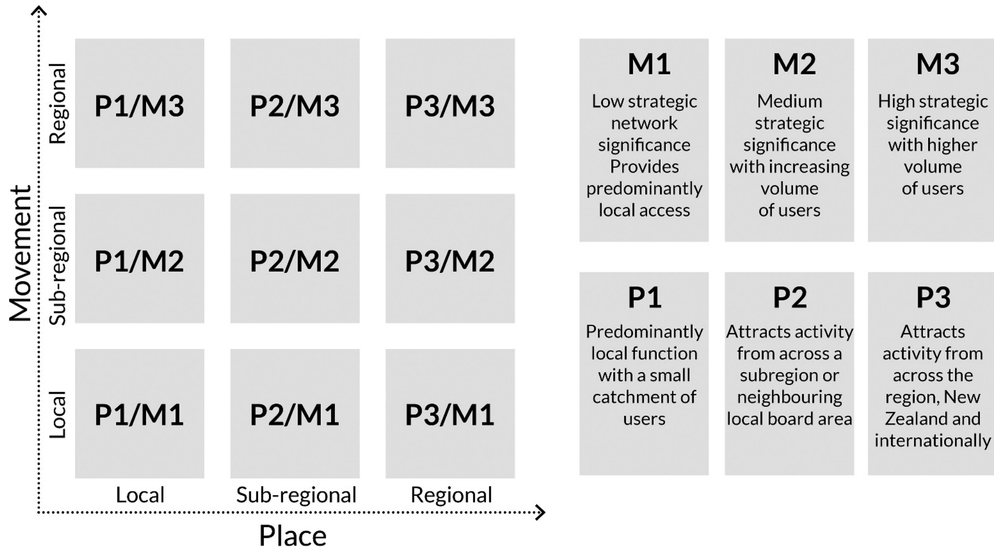

Figure 2. Movement and Place street hierarchy based on Auckland street design guide (Auckland Transport, 2022, pp. 128–129).

the other hand, has high values for both 'Movement' and 'Place', combining a high flow of through-movement with activities and attractions that make it a destination.

To measure the Movement and Place categories, the Roads and Streets Framework (RASF) uses a long list of spatial variables. In the case of Movement, it includes existing and future strategic networks for different transportation modes, traffic volume, and traffic counts for each modality (including heavy goods vehicles), pedestrian connections, various kinds of safety data, future travel forecasts, and regional land transport plan projects. It is stated that all modes of traffic should be assessed, including pedestrians, cyclists, public transit, cars, and freight (Auckland Transport, 2020). This means that, for instance, the M3 category represents the highest movement significance for all modes. However, in cities, there are high-speed connector roads with a high intensity of public transit and cars, but low levels of foot traffic. There are also multimodal streets with a high volume of all modes.

The RASF does not distinguish between them and classifies both highways and main streets as M3 (high Movement value). Their different roles at local, city-wide, and regional scales – that is, their different multiscalar strategic roles – are not considered.

Instead, the difference between highways and main streets is captured by combining the Movement value with the Place value, where a highway would have high Movement significance and low Place value (**P1 M3**), while main streets would score high both in Movement and Place value (**P3 M3)**. However, the lack of consideration for the multi-scalar function of streets is repeated in the Place hierarchy. Streets that serve as global attractors (high Place value, **P3**) but that are disconnected locally are not distinguished from streets that are both globally and locally accessible. The former can include newly developed CBDs, which attract population from across the region but often fail to be locally integrated. The latter are typically represented by traditional city centres that are well connected across several scales and therefore attract populations from across the region as well as from neighbouring districts.

This limitation stems from how Place value is captured in RASF. It is measured using local metrics; for instance, local catchment areas (i.e. how far people travel to visit the place), existing land uses, a variety of activities, frontage character (active/passive), kerbside uses, various zoning and planning documents, population density, diversity, and places of significance.

3.2. Theoretical gaps behind the of movement and place categorisation

The first theoretical gap in the RASF framework concerns the conceptualization of Place. There is an implicit assumption that pedestrian movement is dependent primarily on local Place characteristics rather than on the Movement value. Within this logic, high pedestrian flow is assumed in streets with high Place value, independent of the Movement category. However, the theory of natural movement, described in Section 2.1, demonstrates that Place value itself depends primarily on a street's capacity to attract and distribute movement through its position in the street network. We could thus say that RASF describes *the results* of the movement potential of a street – such as the mix of land uses or the presence of active frontages – while obscuring the *underlying factors that condition* this potential, i.e. its place in the network.

A second, closely related theoretical gap concerns the treatment of scale. RASF divides street types into scales ranging from local to regional significance. This overlooks their fundamental multiscale nature described in Section 2.2, disregarding that each street has distinct roles at multiple spatial scales simultaneously, both in terms of its Place and Movement functions.

In the next section, we demonstrate how integrating the theory of natural movement into the Movement and Place framework addresses these limitations by explicitly accounting for the configurational and multiscale properties of streets.

4. Integrated configurational and multiscalar approach

4.1. Measuring configurational properties: closeness and betweenness centrality

There are two principal centrality measures that are used in space syntax to capture the configurational properties of streets: closeness centrality (i.e. integration) and betweenness centrality (i.e. choice), which can potentially be used as measures of 'Place' (i.e. to-movement) and 'Movement' (i.e. through-movement) respectively.

Closeness centrality generally captures the relative proximity of each street to all other streets (Figure 3(a)), based on selected distance criteria (Hillier, 1996; Hillier & Iida, 2005; Serra, 2013). It captures how physically accessible a street is in relation to all other streets in the system. Closeness centrality, therefore, corresponds to the place as a destination and measures the degree of connectivity of each street to all other surrounding streets, where higher values indicate that the street is spatially better integrated. Since streets with high closeness are more accessible to all other streets, closeness centrality describes the potential of a certain street to act as a destination (Serra, 2013) very much in line with the Place value in the Movement and Place

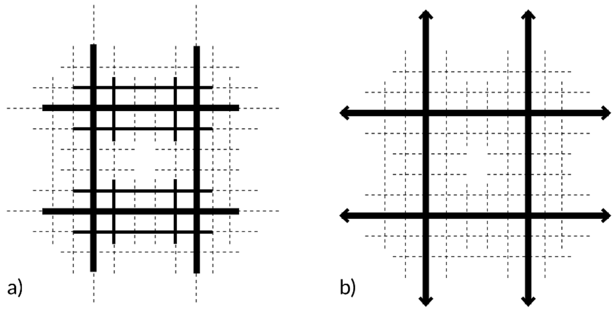

Figure 3. a) Closeness centrality (on the left) and b) betweenness centrality (on the right).

framework. Those highly accessible streets naturally attract movement and therefore commerce and tertiary urban functions, which in turn attract even more movement and activities (Hillier *et al.*, 1993; Scoppa & Peponis, 2015; Stavroulaki *et al.*, 2019). For this reason, closeness centrality can be used as a proxy to describe the street as a destination in itself, or the potential of that street to generate even more movement directed to it (Serra, 2013). It thus describes Place also as movement or, more precisely, as *to-movement*.

Another key network centrality measure is betweenness centrality, which describes the street in terms of its *through-movement* potential (Hillier, 1996; Hillier & Iida, 2005; Turner, 2007; Hillier *et al.*, 2012; Serra, 2013). It measures how often a street is part of the shortest path between all other streets in the network (Figure 3(b)). Higher values in this case indicate the importance of that street as a structuring artery connecting different parts of the city (Serra, 2013; Serra & Pinho, 2013; Serra *et al.*, 2015; Berghauser Pont *et al.*, 2019a, 2019b). Streets with high betweenness are often part of strategic movement networks, in line with the Movement value in the Movement and Place approach. They may also then attract activities that need to be exposed to high urban flows, or activities that benefit from a strategic location between major urban centres (Serra & Pinho, 2013; Serra *et al.*, 2015; Berghauser Pont *et al.*, 2019a).

4.2. Multiscale street centrality patterns in Gothenburg, Sweden

Both closeness and betweenness centrality can be measured across different scales or radii. High closeness centrality at local scales (such as 500 m, 1 km, or 2 km walking distance from each street) highlights local or neighbourhood centres and streets that are well connected to their local context (see Figure 4(a), example of Gothenburg). If measured at the global or metropolitan scale (such as 5 km,10 km, or even 50 km, depending on the size of the city), closeness highlights places that, due to their higher global connectivity, attract people and activity from the entire metropolitan area. In other words, it captures the 'agglomeration power' of that place, or how well it is connected to all surrounding suburbs in a given region (Figure 4(c)). Closeness measured at the neighbourhood level (such as 2 km walking distance) normally highlights areas that are

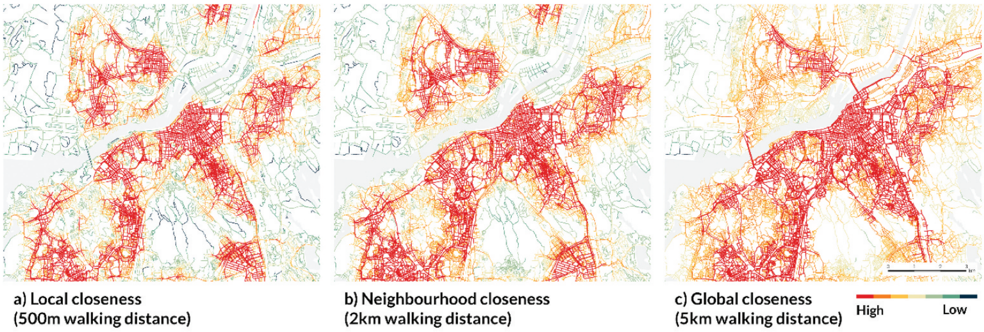

Figure 4. Closeness centrality in Gothenburg, Sweden, measured at local (a), neighbourhood (b), and city (c) scales. Image credits: Spatial Morphology Group, Chalmers University of Technology.

well integrated into surrounding neighbourhoods, but not to the rest of the metropolitan area (Figure 4(b)).

Betweenness centrality is also typically measured at different scales levels, where high betweenness at the global scale highlights global/regional transit roads, key urban arteries, and main streets or highways (Figure 5(c)), whereas high betweenness at lower radii (such as 2 km) highlights city and neighbourhood thoroughfares that are often correlated with high pedestrian traffic or key public transport routes.

As can be seen in the maps above (Figures 4 and 5), closeness often highlights *areas* based on the street's *to-movement* potential, while betweenness, in contrast, highlights *structures* or the street's potential for *through-movement*. Closeness is thus in line with the descriptions of Place in the Movement and Place approach, while betweenness is in line with the descriptions of Movement. At the same time, combining centrality measures across several scale levels allows for more nuanced descriptions of both the Movement and Place hierarchies of streets: such as a traditional high street that is oriented both to the strategic city network and

Figure 5. Betweenness centrality in Gothenburg, Sweden, measured at local (a), neighbourhood (b), and city (c) scale. Case of Gothenburg, Sweden. Image credits: Spatial Morphology Group, Chalmers university.

neighbouring side-streets, or a suburban arterial street that connects to other parts of the city but lacks pedestrian connectivity with its immediate vicinities.

4.3. Integrating configurational properties into the movement and place framework

Based on the above, we propose to use the two network centrality measures to identify street types in line with the intentions of the Movement and Place approach, addressing the two shortcomings identified in Section 2.2. By using closeness and betweenness centrality, one can describe the Place and Movement values of a street, respectively. Furthermore, one can measure these centralities for various scales and arrive at a multiscale description of the Movement and Place values. Thus, streets with high values at just one scale can be distinguished from streets with high values across scales.

4.3.1. Betweenness types as a proxy for movement significance

There have been a range of studies that introduce street types based on betweenness centrality across scales, where the most significant contribution was made by the work of Serra (2013) and Berghauser Pont *et al.* (2019a, 2019b). The generated types showed similar patterns across different European metropolitan areas including Sweden, the UK, and the Netherlands.

The current study builds on the work of Berghauser Pont *et al.* (2019a, 2019b) with the case of Gothenburg, Sweden, to further elaborate on how betweenness can be used as a proxy to describe Movement. Following the distinction of Berghauser Pont *et al.* (2019b), we here focus on the non-motorized street network,[3] excluding highways from the classification.

In their study (Pont *et al.*, 2019b), several street types were generated based on betweenness centrality measured across multiple scales using an unsupervised clustering method. The overall methodology of developing the types is summarized in Table 1 and explained in detail in **Annex A**.

Resulting street types are, in line with Berghauser Pont *et al.* (2019b), described as follows.[4] The streets that play the most important role in city-scale through-movement

Table 1. Summary of the workflow to develop the multiscalar betweenness and closeness centrality types.

Methodological steps	Short description
Data extraction	• **Source**: OpenStreetMap (OSM), via Geofabrik (2016). Road Center lines, non-motorized street network • **Contents**: Gothenburg, Sweden, excluding all roads not accessible by pedestrians • **Coordinate system**: SWEREF99TM
Data processing	• **Software**: FME, MapInfo, PST (Place Syntax Tool) • **Processing**: Converting OSM data to pedestrian network model (line segment map) based on the principles of Stavroulaki *et al.* (2020)
Spatial analysis	• **Metrics**: Angular betweenness and angular closeness centrality, at 10 scales from 500 m to 5 km (500 m intervals) • **Software**: PST (Place Syntax Tool)
Cluster analysis	• **Betweenness**: K-medoids clustering. Silhouette plots used to define optimal number of clusters • **Closeness**: K-means clustering. Visual inspection to the define optimal number of clusters

are characterized by increasingly high betweenness across all scale levels (Figure 6, Type 1 'Increasingly High',[5] red). Streets, that have a relatively important function at the in-between neighbourhood level represent street segments with consistently high betweenness on most scales, but dropping on the lowest and highest scales. In this study, they are described as streets with 'Decreasingly high betweenness'[6] (Figure 6, Type 2 'Decreasing high', purple).

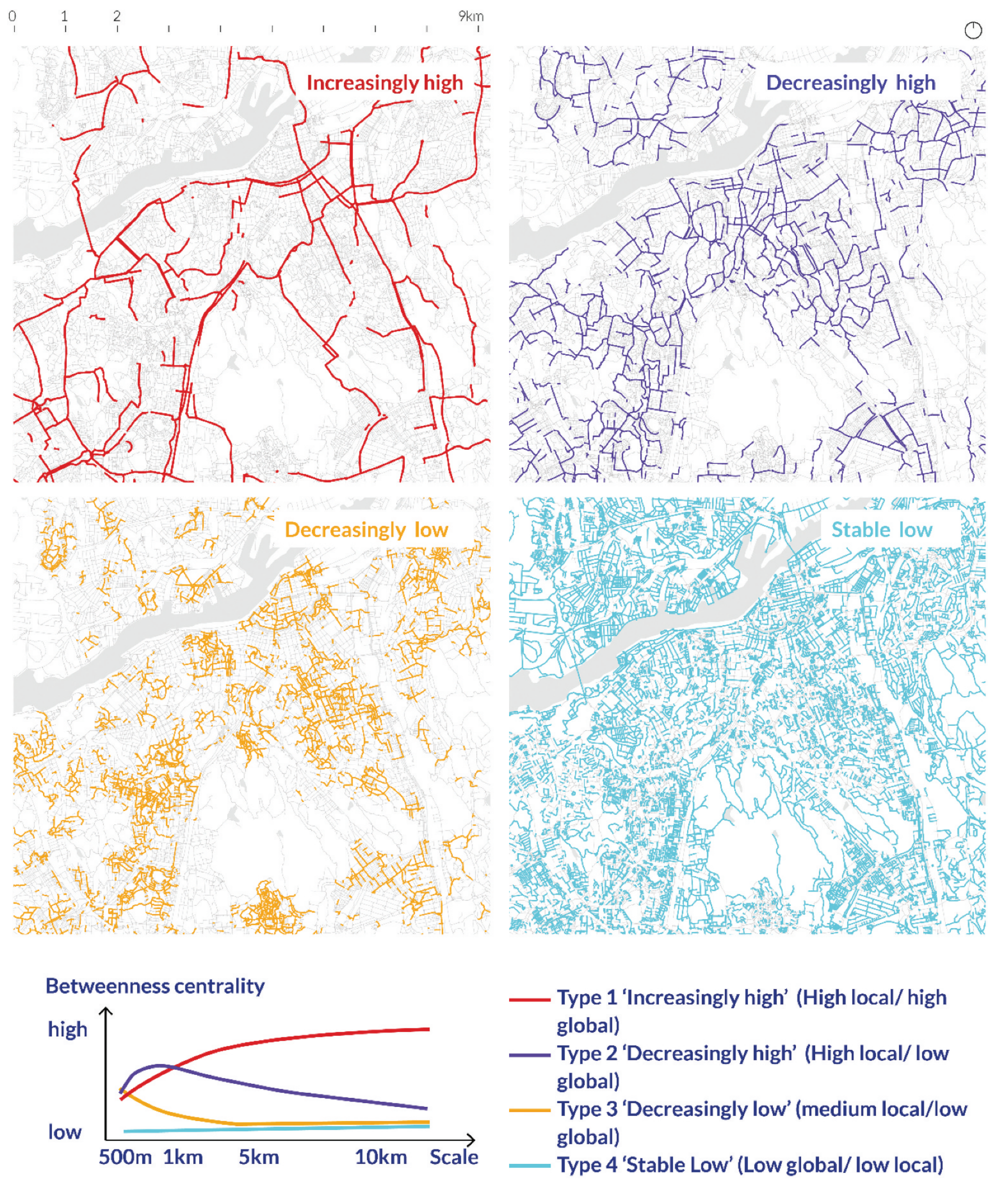

Figure 6. Multiscalar betweenness centrality types. Case of Gothenburg. Adapted from Berghauser Pont *et al.,* (2019b).

Further, streets with medium-high betweenness centrality at lower radii, but dropping at higher radii, are described as main 'local' streets within neighbourhoods (Figure 6, Type 3 'Decreasingly low',[7] beige). Finally, streets that do not play a significant role in any sort of transit movement demonstrate low betweenness scores across all scale levels. They normally represent the background street network of the city (Figure 6, Type 4 'Stable low',[8] cyan).

This classification into multiscalar betweenness types reveals streets with varying significance for movement in the network at multiple scales at once, differentiating streets with high importance for in-between city movement (Type 1), in-between neighbourhood movement (Type 2) and within-neighbourhood movement (Type 3).

4.3.2. Closeness types as a proxy for place significance

In a similar way that betweenness centrality can identify different types of movement, a streets' closeness centrality may vary from well-integrated (i.e. central) to segregated (i.e. non-central) places. We here build on the work of Serra (2013) who generated multiscalar closeness types (using the closeness centrality measure) for the metropolitan area of Porto in Portugal. We follow a similar methodology, to identify Place types based on the street's multiscalar closeness profiles. The overall methodology of developing the types is summarized in Table 1 above and explained in detail in Annex A.

The resulting four Place types based on the street's multiscalar closeness profiles are shown in Figure 7. The most central urban places (**Type A**), such as city centres, have high closeness values across several scales (i.e. both locally and globally); they often represent regular, well-connected urban grids and can be expected to have a higher building density in combination with a high degree of land use mix, since they offer good connectivity within immediate walking distance, but are also well-connected to the rest of the region (see example in Figure 7, Type A 'High Place', depicted in red). These areas are often characterized by a dense regular urban grid, such as Gothenburg's city centre.

Places that represent medium high levels of closeness across scales highlight neighbourhood centers, which can be within the urban core or in the suburbs (see example on Figure 7, Type B 'Medium place', purple). They can be described as less connected, and, in contrast to the High Place type, do not extend far beyond the neighbourhood. These areas are often characterised by a slightly deformed urban grid.

Local places, that are generally segregated from the rest of the city demonstrate relatively low levels of closeness (Figure 7, **Type C** 'Medium/Low', beige). These areas are often characterized by street networks that can be described as deformed grids or tree-like structures, found mostly in suburban residential areas or small residential enclaves within the urban core.

Finally, the streets that are disconnected both locally and globally, and therefore do not attract any to-movement, demonstrate low levels of closeness across all scales of analysis (Figure 7, **Type D** 'Low place', cyan). In other words, they represent disconnected islands with relatively few streets that are weakly connected with each other, both locally and globally.

In a similar way as the classification of Movement types using betweenness centrality, the classification of Place types is based on the streets' multiscalar profiles, using closeness centrality. This allows us to distinguish between well-connected urban grids (**Type A** 'High Place') associated with high density and mixed-use, and less connected deformed grids of

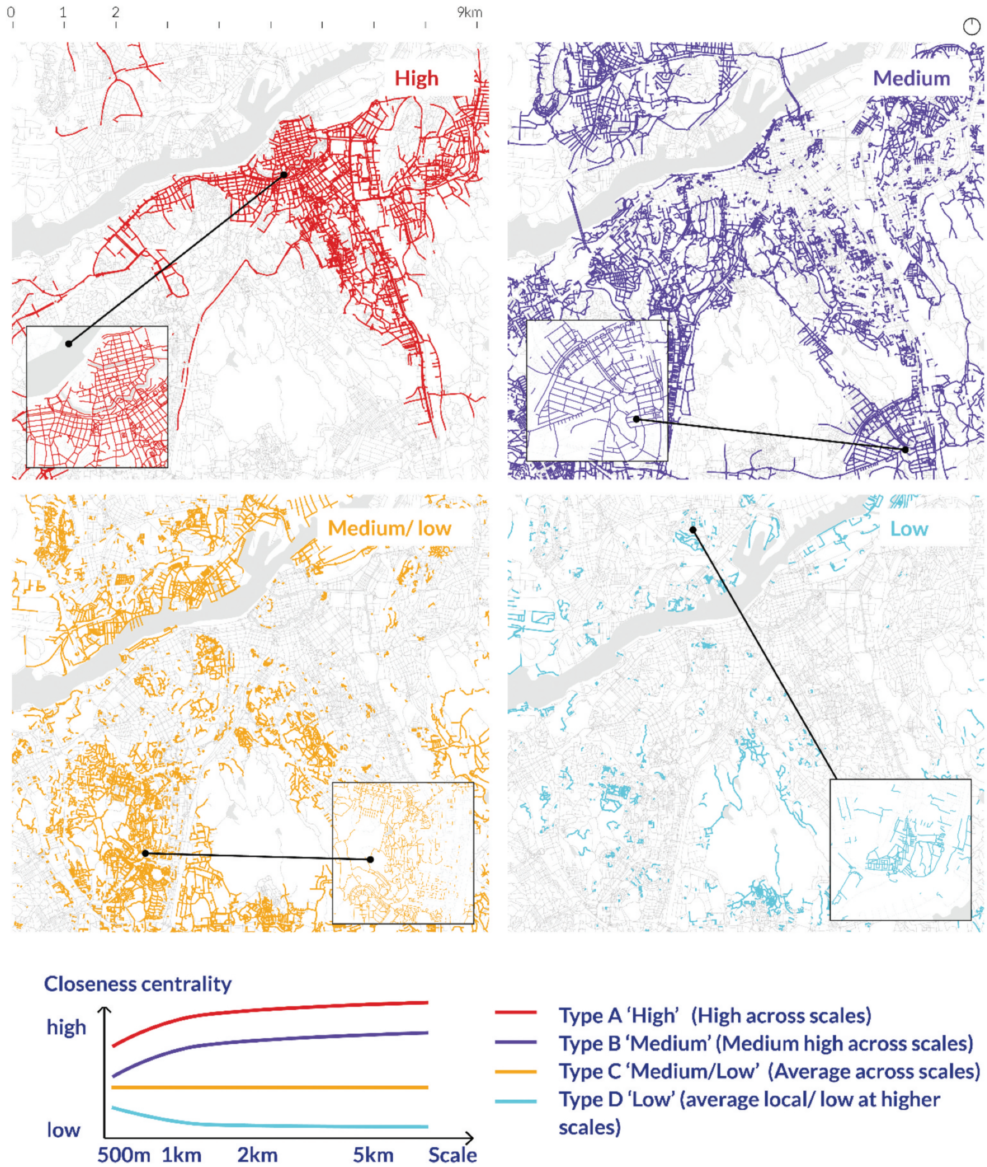

Figure 7. Multiscalar closeness types. Case of Gothenburg.

various kinds (**Type B** 'Medium'/ **Type C** 'Medium-Low'/ **Type D** 'Low Place') with medium to low densities and ranging from a low diversity of activities to monofunctional land uses.

4.4. Combining closeness as place and betweenness as movement into a street matrix of coincident and non-coincident spatial scales

Instead of the conventional planning scales (local/neighbourhood/city/global), the proposed multiscalar types capture the complexity of real streets, allowing us to distinguish between 'coincident' and 'non-coincident' spatial scales. Further, the descriptions of Movement and Place as proposed in this paper are more naturally intertwined, as they are based on the street configuration that fundamentally conditions both. Through this, one can distinguish between well-connected areas characterized by dense and regular urban grids that support intense movement and activity, and disconnected areas characterized by deformed grids and tree-like structures, that are less capable to attracting either.

Table 2 presents the numeric distribution of the combined multiscalar betweenness and closeness typology for Gothenburg, where some interesting patterns can be observed. We see, for example, that the 'stable low' betweenness type (**Type 4**), which does not play an important role for transit movement, is numerically the most prominent (approx. 70% of all streets in total), confirming earlier studies on the foreground/background network (Hillier & Vaughan, 2007). A similar pattern is observed for the streets with high place value, although the distribution between the types is more even.

When comparing the different betweenness types (Table 3), we can observe a strong pattern of correspondence between the street **Type 1** with 'increasingly high' betweenness across scales and street **Type A** with high closeness across scales. More than 50% of Betweenness **Type 1** streets have Closeness **Type A**. This combined type (**1A**) represents

Table 2. Numeric distribution of combined Betweenness (Movement) types 1,2,3 and 4 (horizontal) and closeness (Place) types A, B, C and D (vertical).

Total percentage (Total numeric distribution of types)					
Betweenness types / Closeness types	**Type 1** 'Increasingly High'	**Type 2** 'Decreasingly High'	**Type 3** 'Decreasingly Low'	**Type 4** 'Stable Low'	Total distribution of Closeness types
Type A 'High'	1.69%	2.01%	2.03%	4.15%	9.89%
Type B 'Medium'	1.30%	3.95%	6.72%	16.77%	28.73%
Type C 'Medium/Low'	0.23%	1.71%	7.02%	24.12%	33.09%
Type D 'Low'	0.04%	0.27%	2.84%	25.14%	28.29%
Total distribution of Betweenness types	3.26%	7.94%	18.61%	70.19%	100.00%

Table 3. Numeric distribution of closeness types (A, B, C and D) per each betweenness type (1,2,3 and 4).

Percentage of Closeness types per Betweenness type				
Betweenness types / Closeness types	**Type 1** 'Increasingly High'	**Type 2** 'Decreasingly High'	**Type 3** 'Decreasingly Low'	**Type 4** 'Stable Low'
Type A 'High'	**51.9%**	25.3%	10.9%	5.9%
Type B 'Medium'	39.7%	49.7%	36.1%	23.9%
Type C 'Medium/Low'	7.1%	21.6%	37.7%	34.4%
Type D 'Low'	1.3%	3.4%	15.3%	35.8%

main streets of strategic importance and consists of only very few streets in total in Gothenburg (1,69% of all streets, see Table 2).

Next, streets with high betweenness centrality but decreasing values towards higher radii, which generally represent important connections between neighbourhoods (**Type 2** 'Decreasingly High') are mostly found in medium closeness places **(Type B** 'Medium', 49.7%). There is only a small share of those in the 'Low' closeness **Type D**.

The local streets with low betweenness and where centrality decreases even further at higher radii (**Type 3 'Decreasingly Low**') are found mostly in places of medium to low closeness across scales (**Types B, C**), and, to a lower extent, in disconnected urban grids (**Type D**). Finally, the background network of streets with 'Stable Low' betweenness is mostly found in low closeness types (**Type C, D**) and is largely absent in the high closeness **Type A**.

When the different closeness types are compared (Table 4), an interesting observation is that in places of high and medium closeness across scales (**Types A and B**) all four betweenness types are relatively evenly distributed. This supports earlier findings by Read and Budiarto (2003) regarding the 'coincident' multiscalar movement function of this kind of urban network, supporting both local, neighbourhood, and city movement and activity.

In contrast, in the places of medium to low closeness across scales (**Types C and D**), stable low streets in terms of betweenness prevail (**Type 4**), while the number of streets with high betweenness and increasing centrality at higher radii is close to zero (**Type 1**), confirming earlier work by Hillier and Vaughan (2007).

To demonstrate the spatial distribution of the combined types described above, we extracted each multiscalar closeness type (i.e. Place type) separately and overlaid it with the multiscalar betweenness types (i.e. Movement types) 1, 2, 3, and 4 (Figure 8).

Places of Type A and Type B, dominated by streets with medium and high closeness across scales (high integrated places, Figures 8A and 8B), represent well-connected places both locally and globally. With regard to the previous observation regarding the numeric distribution of betweenness types in those two Place types, it is noted again that all four Movement types (i.e. betweenness types) are concentrated here, representing coincident street networks of 'nested' spatial scales. In other words, the well-integrated places have a clear street hierarchy that allows for different kinds of movement (city transit, transit between and within neighbourhoods).

Table 4. Numeric distribution of betweenness types (1,2,3 and 4) per each closeness type (A,B,C and D).

Percentage of Betweeenness types per Closeness type				
Betweenness types / Closeness types	**Type 1** 'Increasingly High'	**Type 2** 'Decreasingly High'	**Type 3** 'Decreasingly Low'	**Type 4** 'Stable Low'
Type A 'High'	17.1%	20.3%	20.5%	**42.0%**
Type B 'Medium'	4.5%	13.7%	23.4%	58.4%
Type C 'Medium/Low'	0.7%	5.2%	21.2%	72.9%
Type D 'Low'	0.2%	1.0%	10.0%	88.9%

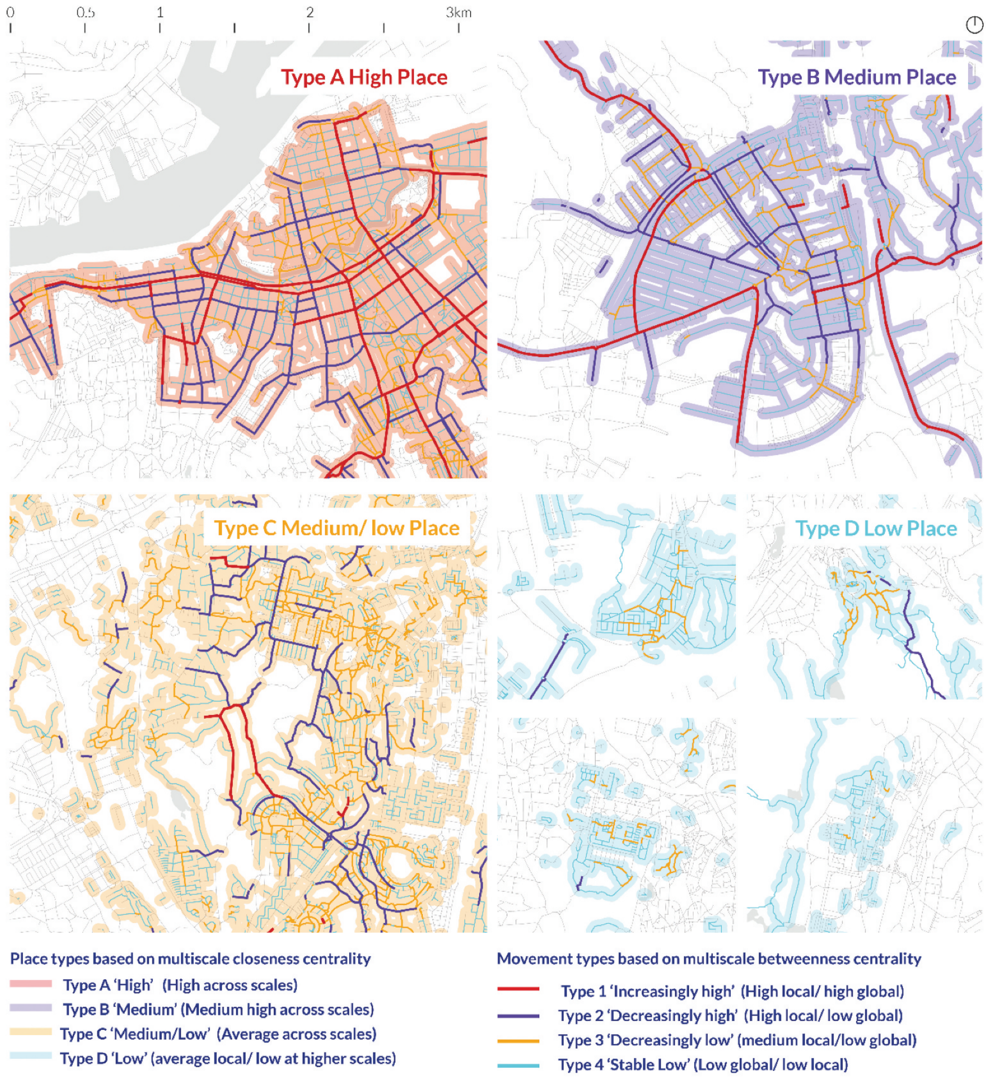

Figure 8. Combined 'Place' and 'Movement' street types in Gothenburg, Sweden, based on multiscalar closeness and betweenness centrality profiles.

In Figures 8C and 8D, all four Movement (i.e. betweenness) types are overlaid with Medium to Low Place types (**Type C and D**). Both Place types represent somewhat conflicted network patterns, where the area characterized by medium/low closeness can be described as a strongly deformed grid with weak connections within and between neighbourhoods, and the area of low closeness is characterized by smaller enclaves of deformed grids that are completely isolated from surrounding urban fabrics. In contrast to the well-integrated places discussed above, streets with strong movement characteristics (**Types 1 and 2**) are hardly present at all in these less connected places, while the multiscalar betweenness type characterized by stable low betweenness values (**Type 4**) is overrepresented, which also supports the earlier argument of Read and Budiarto (2003) about non-coincident spatial scales.

5. Conclusion and discussion

5.1. Summary of results and next steps

The aim of this study was to demonstrate how introducing configurational street types can better inform street design practice by aligning the Movement and Place approach with the theory of natural movement. Utilizing the two network centrality measures, closeness and betweenness, we proposed a different classification logic: multiscalar closeness as a proxy for Place value, and multiscalar betweenness as a proxy for Movement value. Using Gothenburg, Sweden, as an exemplary case study, we demonstrated how the introduced method addresses two theoretical gaps in the Movement and Place framework.

First, the street typology based on network centrality measured across scales, captures the multiscalar function of streets, recognizing that a street can be important for local and global movement simultaneously. In addition, streets can function both as local and global centres, attracting local and global activities and serving multiple catchment areas at the same time.

Second, the method introduces the systemic dimension to the Place category, in line with the theory of natural movement. It acknowledges the fundamental role of movement for placemaking, while the existing framework, in contrast, describes Place in primarily functional terms.

Furthermore, the typology resolves transport-oriented biases in the existing framework. By using network centrality measures across scales, we can integrate all modes of transport into both dimensions, distinguishing instead between to-movement and through-movement as proxies for Place and Movement values, respectively.

In the next step, the intertwined logic of to-movement and through-movement can be extended with the role that attractions play, in line with the theory of natural movement. This would mean that some of the original variables used to describe Place value can be reintroduced to identify the potential for the multiplier effect.

Another important next step to further validate the findings of this paper is to add more cities. However, while the analysis is limited to a single city, which may affect the generalizability of cluster analysis outcomes, this study serves as a necessary proof of concept. It demonstrates a robust methodology for operationalizing the theory of natural movement within the constraints of practical urban planning.

5.2. Practical implications

The combination of multiscalar closeness and betweenness types serves as a proxy for Place and Movement values, enabling planners to categorize urban streets in relation to their Place and Movement value and potential. It allows them to guide spatial interventions focusing on to-movement or through- movement and identify the relevant spatial scale to do so, distinguishing between the need for local design interventions and the need for systemic network changes.

For example, urban fabrics of 'coincident' spatial scales (street types A and B), which accommodate diverse transit flows (street types 1–3), have the potential to support more intensive land uses. In these cases, investments in local design improvements, such as sidewalk widening or reducing street parking, are well justified, especially in streets with higher through-movement potential (street types 1 and 2).

In contrast, disconnected urban fabrics of 'non-coincident' spatial scales (street types C and D) are less in need of such interventions. Besides low to-movement, these areas also lack significant through-movement, often because traffic flows are separated, with transit movement diverted to arteries that are inaccessible for pedestrians. Without first improving strategic street connectivity (increasing Place value) and reintroducing through-movement (increasing Movement value), local street redesigns will have a negligible impact on walkability.

Because only 25% of contemporary street design guidelines introduce the systemic dimension of streets, and none link it directly to street design types (Bobkova *et al.*, 2024), they often incorrectly imply that *any* street can be redesigned to attract foot traffic through local improvements alone (Bobkova *et al.*, 2024). The configurational approach to defining Place and Movement value is crucial to better understanding what kind of intervention (e.g. local or system-level) is needed.

5.3. Broader relevance of the study: simple and complex models for urban planning practice

The developed configurational street types are particularly relevant for urban design and planning practice because they allow planners to describe complex phenomena of Place and Movement using a minimal set of variables. This simplicity is crucial for two reasons.

First, overly complex functional street classifications that rely on long lists of variables are hard to apply in planning contexts with data scarcity (i.e. no access to extensive spatial data), or limited resources, for example, smaller cities (Klosterman, 2012; Morales *et al.*, 2019; Ricchiardi *et al.*, 2024). Second, such complex functional classifications are ill-suited to the early stages of the design and planning process when the most fundamental decisions – such as the structure of the street network – are made, while other variables are still unknown (e.g. details of land use and density, speed, street width). Overly detailed models lack the flexibility needed during these early phases and can hinder decision-making (Stavroulaki, 2022). This is problematic, because it is easier to change urban development projects to increase performance without high extra costs during the early design phases; as planning progresses, the costs for such changes increase exponentially (CURT, 2004; Stavroulaki, 2022).

Related to this is the need for planning tools that can be updated frequently to reflect rapid urban development and test alternative scenarios. Digital models to support street classifications based on numerous variables – including zoning regulations and detailed development plans – tend to be rigid and difficult to update in time, which can render planning documents obsolete shortly after their release.

In contrast to conventional functional classifications, the developed configurational street types rely solely on street network properties, which can be derived using a simple road-center-line representation. This makes them easily applicable in early planning stages, data-scarce planning contexts, and/or rapidly developing cities. By reducing data requirements, they help operationalize the Movement and Place approach across a wider range of countries and make it more adaptive to the early stages of the planning process.

It is important to acknowledge, though, that the practical use of configurational analysis has previously been hindered by the time-intensive process of generating pedestrian street network models, which often requires extensive manual editing. However, recent advances in street network processing (e.g. Simons, 2023; Boeing, 2024; Fleischmann *et al*., 2026) and the increasing availability of open data, combined with the development of automated protocols for spatial and typological analysis, have now radically reduced the resource and time effort, turning this approach into a viable tool for contemporary planning practice.

Notes

1. Also described as 'differentiated' and 'polarised' networks by Peponis *et al.* (2016)
2. In the original guide, street types do not have any names except matrix indicators.
3. Street network types were generated both for motorised street networks that include the highway system, but exclude pedestrian-only streets and paths (Berghauser Pont et al., 2019a) and for non-motorised networks that include all pedestrian-only streets and paths, but exclude highways (Berghauser Pont *et al.,* 2019b; Stavroulaki *et al*., 2019). The general street network that is shared by all modes is the basis for both.
4. In the original article (Berghauser Pont *et al.,* 2019b), Type 1 'Increasingly high' is referred to as 'City', Type 2 'Decreasingly high' is referred to as the 'Neighbourhood' type, Type 3 'Decreasingly low' is referred to as 'Local' and Type 4 'Stable low' is referred to as the 'Background' street network type (Berghauser Pont *et al*., 2019b).
5. In the original study they are referred to as 'City' streets (Berghauser Pont *et al.*, 2019b).
6. In the original study they are referred to as 'Neighbourhood streets' (Berghauser Pont *et al.*, 2019b).
7. In the original study they are referred to as 'Local streets' (Berghauser Pont *et al.*, 2019b).
8. In the original study they are referred to as 'Background streets' (Berghauser Pont *et al.*, 2019b).

Authors' contribution

EB, MPB and IS designed research; EB conducted research and performed spatial and statistical analysis; and EB, MBP and IS wrote the paper. EB has primary responsibility for final content. All authors read and approved the final manuscript.

Disclosure statement

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Data availability statement

Network data for the city of Gothenburg, described in the manuscript, is publicly and freely available without restriction at https://doi.org/10.5878/x49h-pv07. Spatial analysis results are available upon request.

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