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INTERFACE BETWEEN HOUSES AND STREETS: UNDERSTANDING THE SPATIAL ORGANISATION OF ENGLISH SPECULATIVE ESTATES, 1880-2018

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INTERFACE BETWEEN HOUSES AND STREETS: UNDERSTANDING THE SPATIAL ORGANISATION OF ENGLISH SPECULATIVE ESTATES, 1880-2018

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Abstract

This thesis examines the spatial relationship between houses and streets in housing estates in Gosforth, Newcastle upon Tyne between the 1880s and 2018. Urban form can be perceived as a bi-polar system of continuous open spaces of streets and discontinuous enclosed spaces of buildings. These two significantly different elements can be seen as fundamental parts of the spatial organisation of every city. Their distinction and interdependence is most visible on the interface between the two, as the interface not only divides but also forms and defines the spaces on both of its sides.

The aim of this work is to examine how the interface between the architectural and urban form affects the structure and use of both. To achieve this two configurational approaches are combined in GIS: space syntax for the urban scale and graph representation for the architectural scale. In order to allow for comparison between the three urban elements: streets, houses and interfaces, the typologies of each were developed based on their topological characteristics.

This work concludes with four main contributions to the body of knowledge. Firstly, it is observed that there is a fundamental mismatch between the architectural and urban scale in English housing estates. This is manifested as an increase over time in the number of important streets lined with passive interfaces, and in the number of houses that interface with the street network in an atypical manner. This highlights the importance of studying the way urban elements interact in order to assure that the full potential of both elements is met. Secondly, the mismatch between those scales progressively worsened over time. Thirdly, this thesis contributes an original dataset on the interfaces between houses and streets. Finally, an original methodological framework is proposed that allows for integration of the architectural and urban analyses in GIS.

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Author's declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty Ethics Committee on 02.08.2016.

I declare that the Word Count of this Thesis is 47,713 words.

Name: Agnieszka Wir-Konas

Signature:

Date: 30 September 2019

Chapter 1

Introduction and problem definition

1.1. Research background

This thesis is a study of spatial interfaces between houses and streets in Newcastle upon Tyne between 1880s and 2018. The aim of this work is to investigate how the relationship between the architectural and urban form affects the structure and use of both. To achieve this an integrated methodological framework is developed to conceptualise and analyse the relationship. As spatial relationships are the main focus of the thesis, two configurational approaches were combined: space syntax for the urban scale and graph representation for the architectural scale. The integration of both methods is achieved through the study of the interfaces between houses and streets using a geographic information system (GIS). The main contributions to the body of knowledge in this thesis are fourfold. Firstly, a mismatch between architectural and urban scales in English housing is recognised and supported by empirical study. Secondly, it is observed that the mismatch between those scales progressively worsened over time. Thirdly, the thesis contributes an original dataset on the interfaces between houses and streets which was compiled through direct observation. Finally, a new methodological framework is introduced that allows for the integration of the analyses of architectural and urban forms.

1.1.1. Between buildings and streets

Urban form can be perceived as a bi-polar system of continuous spaces of streets and discontinuous enclosed spaces of buildings (and plots). These two significantly different elements can be seen as fundamental parts of the spatial organisation of every human settlement. The buildings are private sets of static events centred on the individual, while the continuous unbuilt space is a dynamic public realm of the society (Hillier and Hanson, 1984, pp.95-97). The difference between those two realms is therefore spatial, but also social and legal.

The existence of the binary distinction between the built and the unbuilt, the private and the public lies in the concept of a boundary (referred to as an *interface* in this thesis). The erection of boundaries is a key aspect in the development of cities, as society delimits and arranges the space and people in relation to each other (Hillier and Hanson, 1984, p.72; Kent, 1991). The distinction and interdependence of buildings and streets is thus most visible on the edge between the two elements, as the edge not only divides but also forms and defines the spaces on both of its sides. In the academic literature the interface between buildings and streets was recognised as a key aspect of urban studies and it was argued that its quality is important in: shaping social identities (Hillier and Hanson, 1984, p.19), controlling and regulating social interaction (Altman, 1975; Madanipour, 2003, p.53), supporting street activity (Bentley et al., 1985, p.69; Jacobs, 1961; Skjaeveland and Garling, 1997), and urban safety (Hanson and Zako, 2007; Hillier, 1988; Jacobs, 1961). While the spatial relationship between buildings and streets has been studied under many terms, in this thesis it is defined as an *interface*: a space where two elements meet and interact.

1.1.2. The macro- and the micro-scale

The spatial division between the continuous space of streets and discontinuous space of buildings can also be observed in the methods and tools used to analyse urban form. Urban studies are most commonly divided into macro- and micro-analyses, where macro is concerned with the study of large-scale systems (neighbourhoods, cities, regions), and micro describes studies on a small scale, such as an individual building. While in most cases the existence of the other scales is implied, it is not uncommon for the analyses to be wholly isolated, which may cause any findings to be misinterpreted. To investigate the importance of the analysis of the parts of the system in relation to the whole, and the whole in relation to its parts this thesis studies the impact of the relationship between the macro-scalar street networks and micro-scalar internal house layouts on the configuration and use of both.

1.1.3. English housing and the socio-cultural context

Even though the main approach to the analysis of the interface between houses and streets is spatial, cities are complex entities and their physical form is a manifestation of socio-cultural phenomena. Therefore it is necessary to ground this thesis in its local context, which in the case of this study is housing development in Newcastle upon Tyne, England between the late nineteenth and early twenty-first century.

Since the Industrial Revolution, urbanisation in England sky rocketed as a result of a rising population and changes in working patterns from agricultural to industrial. As houses were necessary to accommodate the growing number of people, the majority of urban expansion was an outcome of residential speculative development. Residential speculative development introduced new urban and architectural forms to English cities, and popularised mass-constructed housing estates of single-family houses. Throughout the twentieth century, the housing estate became an identifiable urban unit commonly used in the design of the new housing developments to this day.

The accelerated urbanisation and residential development between the end of the nineteenth and early twenty-first century stimulated the introduction and adaptation of new urban and architectural forms in England. In English housing, there are three main time frames, when new building types, architectural styles and street layouts were introduced and replicated on a large scale (also called ‘morphological periods’ (Whitehand et al., 2014)). Morphological periods tend to coincide with important changes in legislation, international and national political events, changing socio-cultural context and technological innovation. Between the late nineteenth century and the First World War byelaw terraced houses became the most common form of housing in England, mostly as means of combating the unsanitary conditions and overcrowding common in nineteenth-century cities. Between the First World War and the late twentieth century the majority of English people lived in a semi-detached house in the suburbs. This was influenced mostly by social and legislative changes in housing patterns, innovation in architectural and urban disciplines and the popularisation of the private car. Since the late twentieth century the detached house became the most common new built house, and it remains so. The division between those three morphological periods and three single-family house types is important to the understanding of residential development in England, therefore, the distinction between those three types dictates the structure of the main analysis chapters.

1.2. Research aims and objectives: problem definition

This thesis examines the relationship and the mismatch between houses and streets in English speculative housing estates built between 1880 and 2018. This relationship was chosen as the focus of this work because there is a lack of quantitative academic study that investigates the relationship between the architectural and urban scales. This led to a following research question:

> Does the spatial relationship between houses and streets affect the configuration and use of both?

This question can be more easily addressed if we split it in four:

> (1) Does the way in which a street interfaces with houses affect the activity on the street and how does it do this?
> (2) Does the way in which a house interfaces with streets affect its internal configuration and how does it do this?
> (3) By what means can the macro-scalar analysis of streets and the micro-scalar analysis of houses be integrated?
> (4) Does the interface between houses and streets differ across different morphological periods?

In morphological studies of cities, the street is most commonly understood as a part of a larger street network. The understanding of the street in relation to the whole network tends to be prioritised over the understanding of the street in relation to the adjacent buildings. This thesis argues that it is equally important to understand the street in relation to the adjacent buildings that constitute it as it is to consider a street in relation to the whole street network. This hypothesis is investigated under the first research question: *does the way in which a street interfaces with houses affect the activity on the street and how does it do this?*

The morphological analyses of buildings and houses tend to emphasise the importance of the internal configuration of the floor plan and the relationships between certain rooms, functions and activities. While in most studies it is implied that a building is in some way connected to the public realm, this information is either simplified or omitted. Therefore, it is not uncommon to design and study houses and other buildings as isolated entities without any consideration of their context. This thesis argues that it is as important to understand a house as an element of a larger system - an estate, a neighbourhood, or a district, as it is to understand it as a configuration of internal rooms and activities. This hypothesis is investigated under a second research question: *does the way in which a house interfaces with streets affect the internal configuration of the houses and how does it do this?*

In addition to the conceptual dichotomy between houses and streets described in the previous section, this thesis argues that there is a methodological dichotomy between the urban and architectural scale. In addition it observes that urban morphology lacks an integrated methodological framework that allows for the analysis of both scales in relation to each other. While in many methods the relationship is implied, it is uncommon for a method to explicitly consider integrating both macro- and micro-scales. Therefore, the introduction of a methodological framework that integrates both houses and streets through the concept of the interface is one of the main objectives in this thesis, posed as a third research question: *by what means can the macro-scalar analysis of streets and the micro-scalar analysis of houses be integrated?*

Finally, this thesis investigates if the change in urban and architectural forms between the morphological periods of terraced, semi-detached and detached houses can also be observed in the interfaces between the houses and the streets. This is posed in the fourth research question: *does the interface between houses and streets differ across different morphological periods?*

To answer all of these questions a new methodological framework that combines the macro-scalar syntactic analysis of street networks (space syntax) and the micro-scalar graph representation of built form is proposed in order to show effectively the impact of the relationship between houses and streets on the configuration and use of both.

1.3. Research methodology and data collection

This study empirically investigates morphological relationships between houses and streets in Newcastle upon Tyne, England, and is grounded in the field of urban morphology - a study of the forms of human settlements. As discussed in the previous sections, this thesis argues that there is a need for an integrated methodological framework that addresses the methodological dichotomy between the urban macro-scale and architectural micro-scale analyses. In the configurational approach the relationship between the street network and the internal configuration of houses is implied and tends to be either simplified or omitted, therefore the methods used to analyse both scales are mostly separated from each other. In space syntax the analysis of settlements (alpha-analysis) is focused primarily on the relationship between the spatial configuration of the street network and movement and although the buildings that constitute the streets are implied they are not explicitly studied. In the analysis of buildings in space syntax (gamma-analysis) the relationship of the internal configuration and the outside context is acknowledged, but simplified. In the graph representation of built form the external regions and outside context can be acknowledged as a part of a graph, but it is unusual.

In this thesis the combination of the macro- and micro-scale analyses is achieved in a geographic information system (GIS) through cross-tabulation, a method which allows for a quantitative analysis of the relationship between two variables. In order to utilise cross-tabulation the streets, houses and interfaces need to be categorised into types. The typology of the streets is based on their movement potential derived from the syntactical analysis. The typology of the houses is based on the unique configuration of the floor plan, represented as a graph. Finally, the typology of the interfaces is based on the topological relationship between the houses and the streets, which is comprised of three variables: proximity, physical permeability, and visual permeability (discussed in detail in Chapter 2). Therefore, the methodology proposed in this thesis is a combination of the configurational and typological approaches.

As the methods in this thesis combine different scales of physical form, data is collected from different sources. The data, regardless of the source and scale, was stored in a GIS database. The interfaces were mapped on the plot boundary map that was automatically generated based on the topographic map of the sampled housing estates in Gosforth.

For the macro-scale analysis of the street network the necessary data was derived from the Ordnance Survey map provided by the Digimap Ordnance Survey Collection by EDINA. The topographic map of Gosforth, downloaded from the Ordnance Survey map served as a basemap. Land use, housing typologies and house age were mapped onto the basemap, while the street network (axial map) was automatically generated based on the topography layer. Each street was assigned an unique identifier that allows for cross-tabulation with the other layers in GIS.

For the micro-scale analysis the graphs of the floor plans were manually input into GIS, this allowed for the automated analysis of the relationships necessary for the analysis in Chapter 5. The floor plans were acquired through the Newcastle City Council planning application database and databases of property websites, such as Zoopla or Rightmove. Each floor plan was converted to a graph and stored in GIS for the analysis.

As urban form is a result of the social changes that are intertwined with the physical representation of them, each analysis is set in the specific context derived from the study of the historico-geographical context of England and Newcastle upon Tyne.

1.4. Thesis outline

This thesis consists of six chapters and following the introductory Chapter 1, is structured as follows:

Chapter 2 provides an overview of the related academic literature and methodologies that address the morphology of the urban and built form, in particular the concept of the interface between the buildings and streets. The importance of the studies of the interface between the built and the unbuilt was observed through the investigation of the bi-polar socio-spatial organisation of the city. The review of the methods that analyse the morphology of cities led to the conclusion that urban morphology lacks an integrated methodological framework that investigates the relationship between different scales of analysis. Based on the review of the literature and methodologies, the methodological framework of this thesis is presented.

Chapter 3 provides a contextual overview of the history and general characteristics of suburban speculative housing in England between the late nineteenth and early twenty-first century. Firstly, the historical and legislative development of the housing estate as a unit of analysis and design is discussed. Next, the historical background and general characteristics of three main house types between 1880s and 2018 (byelaw terraced, semi-detached and detached houses) in England and in Newcastle upon Tyne are described.

Finally, the choice of Gosforth as a sample area is discussed and the morphological characteristics of the case studies (18 housing estates) is examined. The chapter aims to provide a socio-cultural context to the following analysis chapters.

Chapter 4 addresses the first, third and fourth research question outlined in this chapter. The syntactical analysis of street networks (space syntax) in each of the sampled housing estate is integrated in GIS with the interface map. Cross-tabulation is used in order to relate the data on the micro-scalar form into the macro-scalar urban analysis. The analysis of the housing estates is divided into three sections that correspond to the three main house types and is structured chronologically, from the terraced houses to the detached houses. The main findings in the chapter are that the aggregation of ill-designed interfaces along one street is not uncommon and, worryingly, became more common in the recent estates of detached houses. The passive blank interfaces reduce the potential for long-duration activities and co-presence in the street, therefore affecting the generation of local pedestrian movement, which because of the importance of the street in the network is likely to be substituted by solely vehicular movement. The findings in this chapter reveal the need for a widely available, comprehensive and systematic method to assess the impact of the interfaces (especially passive) on the life and activities on the streets.

Chapter 5 considers the second, third and fourth research questions. The focus of this chapter is on the integration of the internal analysis of the houses with their context through a combination of graph representation and interface mapping in GIS. The analysis of the houses is structured chronologically in relation to the three main English house types: terraced, semi-detached and detached. The main finding of the chapter is that there is a mismatch between the design of the house and that of the housing estate. In many cases the configuration of the estate and the internal configuration of the house are misaligned which may affect the use of both spaces. In most cases this is a result of the design of urban blocks which creates atypical relationships between houses and the street network, especially in the recently built estates of detached houses.

Chapter 6 concludes the arguments and discusses the contributions of this thesis. The analysis chapters 4 and 5 are revisited in order to discuss how the findings could be interpreted in relation to the main research question: *does the spatial relationship between houses and streets affect the configuration and use of both?* Finally, limitations, practical implications and prospects for future work are discussed.

Chapter 2

Interface in urban morphology: literature review and methodology

2.1. Between buildings and streets

Urban form can be described as a bi-polar physical system with a continuous open space of streets meandering between discontinuous enclosed spaces such as buildings (Berghauser Pont et al., 2019; Hillier and Hanson, 1984, pp.95-97; Krüger, 1979; Palaiologou et al., 2016)[1]. Thus the spatial development of cities can be understood as creating physical discontinuities in the previously unoccupied continuous space through aggregation and arrangement of enclosed spaces (Hillier and Hanson, 1984, p.72; Kent, 1991). The continuous space is a dynamic realm focused on movement and perceived sequentially, while the discontinuous spaces are a set of static events concentrated mainly on occupation (Bobić, 2004; Hillier and Hanson, 1984, p.144; Palaiologou and Vaughan, 2014). The bi-polarity in the organisation of the urban form can be also approached from a legal and social standpoint, as a relationship between public and private spaces (Madanipour, 2003, p.1). The public space mostly coincides with streets, while the private spaces correspond to buildings and plots. In the academic literature the definition of public and private spaces varies depending on the approach. From the legal perspective, the private and public spaces are defined based on land ownership (ibid., 2003, p.39). Sociologically, public and private spaces are determined by the relationship between two types of users: strangers and inhabitants (Hillier and Hanson, 1984, p.17), and between polar concepts such as: the society and the individual, the outside and the inside, the social and the personal, and the profane and the sacred (Lawrence, 1981; Lawrence, 1984). As Ali Madanipour observed in the book *Public and Private Spaces of the City* (2003, p.1), the organisation of the city into private and public spaces is almost universal to all cultures and historical periods, however, the nature and relationship between those spaces can differ. The perception of the relationship between the public and private might also differ depending on whether we

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1. In the academic literature the discontinuous spaces of buildings and plots are also referred to as "primary cells - X" (Hillier and Hanson, 1984, p.95) and "built-form galaxy" (Krüger, 1979) while the continuous space is also referred to as "the carrier - Y" (Hillier and Hanson, 1984, p.95) and "the channel network" (Krüger, 1979). Similar bi-polar division of the city is maintained when we consider the urban form in terms of built and non-built spaces (Bobić, 2004).

conceptualise and analyse those spaces spatially, legally or socio-psychologically. Even though, in theory, buildings should overlap with both legally and socially defined private space and streets should overlap with the public space, the relationship is more ambiguous. This ambiguity stems from the lack of clear demarcation between socially understood public and private spaces. While in the academic literature we can find advocates of a clear cut demarcation between private and public realms (Anderson, 1978; Jacobs, 1961; Newman, 1972), more commonly the transition between those domains is considered as a spectrum (Arendt, 1958; Habraken, 1998; Marshall, 2009), as described by Madanipour (2003, p.239):

> ‘In practice, public and private spaces are a continuum, where many semi-public or semi-private spaces can be identified, as the two realms meet through shades of privacy and publicity rather than clear cut separation’.

This ambiguity is particularly visible on the figure-ground maps popularised by Koetter and Rowe in their book *Collage City* (Rowe and Koetter, 1978). On the figure-ground maps the polar organisation of the cities is represented as a juxtaposition of solids (in black) and voids (in white)[2]. While this portrayal is clear and intuitive, the definition of what we consider as solids and voids is more ambiguous. The traditional representation defines the built space as solids and the unbuilt space as voids, however, this definition can be altered. For example, solids can portray buildings and plots, while the definition of voids can be narrowed down to only public open space. Conversely, solids can represent private spaces, while voids depict public spaces, whether they are built or not. The best known example of this type of figure-ground map is the New Plan of Rome (Nuova Pianta di Roma) by Giambattista Nolli (see Figure 2.1).

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2. The relationship in the figure-ground map can also be reversed, where the buildings are shown as voids, while the open space is solid. This reverse figure-ground representation was proposed by Gibberd (1955) with the aim to shift the emphasis from the buildings to the open space.


PIAZZA NAVONA
PIAZZA MADAMA
PIAZZA COLONNA
PANTEON
MINERVA
S. Ignazio
COLLEGIO ROMA
PIAZZA DI PIETRA
MONTE CITORIO
P. della Cancellaria
CAMPO DI FIORE
PIAZZA FARNESE
S. Andrea
S. Carlo
GESU
Pal. di Venezia
PITO
ISOLA
Ponte Quattro Capi
R. VI. PARIONE
R. VIII. S. EUSTACCHIO
R. IX. PIGNA
R. XI. S. ANGELO
R. VII. REGOLA
CAMPITELLI
TEVERE
605
799
806
834
837
844
847
846
861
902
903
979

While the bi-polar understanding of the urban form is similar regardless of the approach, it is important to note that they are not identical, which may lead to confusion and misinterpretation. Consequently, even though this thesis focuses on spatial understanding of the city and the study of the physical form of buildings and streets, it is recognised that other factors, such as social and legal, are equally important. Only a comprehensive study including all possible factors can bring us closer to understanding the complexity of the city.

The polarity between buildings and streets indicates fundamental differences between those spaces but also their interdependence. The existence of one shapes the other. This combination of duality and interdependence is especially visible on the edge between the two entities. It can be argued that the difference between the building and the open space would not be apparent if not for the concept of the boundary (Hillier and Hanson, 1984, p.19; Madanipour, 2003, p.60). The urban form can be thus defined solely in relation to boundaries:

> 'The simplest building is the structure consisting of a boundary, a space within the boundary, an entrance, and a space outside of the boundary defined by the entrance, all of these spaces being part of a system which was placed in a larger space of some kind which 'carried' it.' (Hillier and Hanson, 1984, p.19).

The importance of the boundary between buildings and streets has been recognised as a key aspect of urban design and urban studies since the 1960s (Dovey and Wood, 2015; Kamalipour, 2016). In the academic literature it is argued that the edge between buildings and streets is important in: shaping social identities (Hillier and Hanson, 1984, p.19), controlling and regulating social interaction (Altman, 1975; Madanipour, 2003, p.53), supporting street activity (Bentley et al., 1985, p.69; Jacobs, 1961; Skjaeveland

Figure 2.1 - (On the left) New Plan of Rome (Nuova Pianta di Roma) by Giambattista Nolli (1748).

and Garling, 1997), and urban safety (Hanson and Zako, 2007; Hillier, 1988; Jacobs, 1961). The boundaries, as Madanipour (2003, p.70) describes are ‘the most visible spatial manifestations of the division of social life’, and they embody and signify social relations (Gehl, 2011; Nooraddin, 1998; Madanipour, 2003, p.70). As discussed by Bill Hillier and Julienne Hanson in the book *The Social Logic of Space* (1984, p.19), the spaces within and outside of the boundaries are associated with different social identities: inhabitants and strangers, respectively. The boundaries thus not only shape the identity within and outside, but also, when crossing the edge, provide means to convert, e.g. from a stranger to a visitor (ibid., 1984, p.19). The edge between buildings and streets can also regulate social interaction between the inhabitants of the system and between the inhabitants and strangers (Altman, 1975; Hillier and Hanson, 1984, p.19; Madanipour, 2003, p.53). The design of the edge can accommodate different types of social interaction, ranging anywhere between openness and social stimulation to impermeable boundary, anonymity and intimacy. As the concept of privacy is understood as a constantly changing boundary between self and others that depends on the needs of the person in a specific moment in time (Altman, 1975, p.207), the design of the edge should incorporate elements that allow for flexible adjustments. For example, the door is a design element that allows for flexible regulation of social interaction and permits, as Irwin Altman states in the book *The Environment and Social Behaviour*, ‘easy alternation between a state of separateness and a state of togetherness’ (Altman, 1975, p.207).

The concept of ‘liveable streets’ (Appleyard, 1981) is one of the key interests in urban studies. In the academic literature the variables that may affect the levels of activity in the streets were widely studied (Anderson, 1978; Appleyard, 1981; Gehl, 2011; Jacobs, 1961), and, while the concept of liveable streets is complex and multifaceted, the design of the edge between buildings and streets was described as an important factor (Can and Heath, 2015; Hillier and Hanson, 1984, p.143; Kamalipour, 2016; Palaiologou et al., 2016). The street activity is associated with the number of encounters and interaction between users.

For an encounter to occur users have to be physically co-present in one space (Hanson, 2000; Hanson and Zako, 2007; Hillier et al., 1987; Madanipour, 2003, p.235). Therefore there needs to be enough space to accommodate social contact (Skjaeveland and Garling, 1997) in order for potential interaction between users to occur. It was strongly articulated by Julienne Hanson (2000) that the fundamental relationship between urban space and society is not encounter but co-presence. The potential for co-presence and encounter was termed as 'virtual community' by Hillier et al. (1987) in the article *Creating life: Or, does architecture determine anything.* A virtual community was defined as a form of unrealised, but possible, community in the same physical space. The authors argued that the spatial design directly affected the possibility for encounter and interaction (Hillier et al., 1987; Hillier, 1996, p.141). The factors that affect the generation of co-presence in space are likely to be complex. In the academic literature, however, there are two factors that are commonly referred to: movement (Hillier, 1996; Marcus and Legeby, 2012) and long duration activities (Gehl, 2011). Naturally, co-presence is a result of the movement of different groups of people through a certain space, which can be stimulated by architectural and urban design (Hillier, 1996, p.4). However, Gehl (1986; 2011) argues that short-term activities, such as walking and driving, are insufficient to encourage encounter and interaction. The author argues that an increase in the number of encounters and interactions can be achieved through the encouragement of long duration activities. In the study of 17 streets in Melbourne, Gehl (1977, in Gehl, 1986) observed that 70% of long-duration activities (e.g. talking, staying, doing, playing) occurred in the semi-private gardens on the edge between buildings and streets. The importance of the design of the edge in order to support the street activity was also argued by Jacobs (1961), Bentley et al. (1985, p.69), and Alexander (1977, p.754).

> 'The building with a lively building edge, is connected, part of the social fabric, part of the town, part of the lives of all the people who live and move around it' (Alexander, 1977, p.754).

Moreover, the design of the edge between the buildings and streets was deemed as key when it comes to urban safety (Dovey and Wood, 2015; Hillier, 1988; Hillier and Hanson, 1984, p.140; Jacobs, 1961; Newman, 1972; van Nes and López, 2007). It was most famously expressed by Jane Jacobs in the book *The Death and Life of Great American Cities* (1961, p.35):

> 'There must be eyes upon the street, eyes belonging to those we might call the natural proprietors of the street. The buildings on a street equipped to handle strangers and to insure the safety of both residents and strangers, must be oriented to the street. They cannot turn their backs or blank sides on it and leave it blind.'

Jane Jacobs associated urban safety with co-presence, high encounter rates, and more importantly, with the quality of the edge between buildings and streets. Hanson and Zako (2007) also discussed the importance of the interface between the buildings and street in prevention of crime and antisocial behaviour in the journal paper *How public open space shapes awareness and behaviour in residential developments*. The authors argued that social interaction and urban safety are influenced by co-presence, the interface between inhabitants and strangers, and natural surveillance (Hanson and Zako, 2007). The authors observed a shift in the treatment of the design of the edge in traditional street and modernistic estates. The modernism 'ruptured the spatial interface between inhabitants and passers-by' (ibid., 2007) with an abundance of blank impermeable walls. This resulted in lack of natural surveillance and in order to counter antisocial behaviour, the community had to rely on cameras and monitoring (ibid., 2007).

As discussed in this section, the edge between the buildings and streets is an important aspect of urban form. As Alexander mentions in the book *The Pattern Language* (1977, p.755) a well-designed edge is a 'realm between realms' that can facilitate and mediate the relationship between inside and outside, maintain co-presence through accommodation of long and short duration activities on both sides, or on the edge itself. However, as Can and Heath (2015) rightfully point out, even though the design of the edge between buildings and streets is important to the building, street life and urban safety, it is not the only factor that impacts those phenomena and should be considered in relation to other characteristics of the urban form: such as land use, density, movement potential etc.

2.1.1. Terms and definitions

As noted by Can and Heath (2015), and observed in this literature review, the spaces between buildings and streets have been studied under a variety of different names, such as: edges, boundaries, thresholds, in-between spaces, frontages, interfaces, and a few of the other less common terms. In this sub-section, each term is discussed in order to select the definition which is most appropriate to this thesis.

An *edge* and a *boundary* are both terms that indicate a limit to an area. According to the Oxford Dictionary (2018) a *boundary* is ‘a line which marks the limits of an area, a dividing line’, while an *edge* is ‘the outside limit of an object, area, or surface’. Those terms can be treated as synonymous. They signify separation and disconnection between two elements, while simultaneously defining those elements (Hillier and Hanson, 1984, p.144; Madanipour, 2003, p.240; Palaiologou et al., 2016). In the urban context, boundaries are mainly considered as physical objects, such as external walls. However, boundaries can also describe a ‘symbolic and judicial differentiation of space’ (Lawrence, 1981). Julienne Hanson and Reem Zako (2007) identified two types of boundaries: primary boundaries that correspond with the building line, and secondary boundaries that coincide with fences or walls erected on the plot boundaries.

A *threshold* is ‘a strip of wood or stone forming the bottom of a doorway and crossed in entering a house or room’ (Oxford Dictionary, 2018) and a ‘physical link between different people’s domains’ (Bentley et al., 1985, p.103). The threshold indicates physical access and a potential for transition between two different domains.

An *in-between space* is a term that describes a space or area between two polar domains. In the context of urban studies the in-between spaces are defined as areas between the private indoor space and public outdoor space (Can and Heath, 2015; Nooraddin, 1998). The in-between space is where the public and private domains are superimposed (Bobić, 2004), and the distinction between those two realms is not clear-cut, e.g. semi-private front yards.

A *frontage* tends to describe a façade of a building (Oxford Dictionary, 2018), however, it can be used to describe the plot boundary line directly adjacent to public space (Berghauser Pont et al., 2019; Vialard, 2015), sometimes referred to as *plot* or *lot frontage*.

An *interface* is ‘a point where two systems, subjects, organizations, etc. meet and interact’ (Oxford Dictionary, 2018). In the urban context, the interface describes a point, a line or an area that is a spatial realisation of the relationship between buildings and public space (Bobić, 2004; Carmona, 2010; Dovey and Wood, 2015; Kamalipour, 2016). The definition of the interface signifies physical adjacency with the potential for the interaction by means of accessibility, visibility or context (Bobić, 2004; Dovey and Wood, 2015; Palaiologou et al., 2016).

Out of the terms above the *interface* was chosen as the most suitable, because the term signifies not only adjacency between buildings and streets but also possibility for interaction without imposing the type of interaction. The interface can describe a wide range of relations between the buildings and streets being physical, symbolic or judicial, whether indicating accessibility, visibility or both. Therefore, this term encompasses the complex relationship between buildings and streets that was explored in this section.

2.2. Approaches to the study of urban form

Urban morphology is a study of forms and systems in human settlements (Batty, 2013; Moudon, 1997; Kropf, 2009). The principles of urban morphology were succinctly described by Karl Kropf in the book *The Handbook of Urban Morphology* (2017, p.16) as ‘notions of a formative/transformative process and the relative positions or configuration of the parts making up the whole form as it grows and changes’. In other words, morphologists are interested in the characteristics, formation and transformation of urban form, whether it is studied in parts or as a holistic system. The concept of the study of form was introduced as *morphology* by Johann Wolfgang von Goethe in the book *Metamorphosis of Plants* (1790 in Kropf, 2017, p.16) and has been widely adopted in many academic fields. Uniquely, urban morphology did not develop within one field. The study of urban form is a key subject in different academic and professional disciplines, such as architecture, geography, and urban studies (ibid., p.16). Therefore, a large number of different methods and approaches was developed across those three fields. Even though each field is interested in a slightly different aspect of urban form, it was agreed across the approaches that there are three primary units of morphological analysis: streets, buildings and blocks (Conzen, 1960; Kropf, 2009; Kropf, 2017; Moudon, 1994; Whitehand, 2001)[3].

Urban form is complex and many different methods and approaches have been introduced in order to understand this complexity (Kropf, 2009). Kropf (2009) proposed a way to classify the multitude of methods and approaches into three categories: social, economic and environmental. He further divided these into the following aspects: statistical, spatial/geographical, formal, historical, psychological, informational, and aesthetic. Different categorisation was proposed by Bobić (2004) who divided the approaches into: spatial, social, cultural, economical and psychological. Regardless of any major or minor

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[3] The definition of the key urban elements changed in time and at one point street-blocks were counted as a key element (Berghauser Pont et al., 2019). However, Panerai et al. (2004) argued that street-blocks cannot be treated as a key element as it is rather a group of plots defined by the street network.

differences between the methods and approaches, they share a common reference - physical form (Kropf, 2009). The following broad approaches to urban morphology, which are widely accepted in the academic literature, were introduced by Kropf (2009; 2017) as: configurational, typo-morphological (or process typological), historico-geographical, and spatial analytical[4]. In the study of the interface between buildings and streets in this thesis we utilise three of those approaches: configurational, typo-morphological and historico-geographical, which are briefly described in the following sub-sections.

2.2.1. The configurational approach

The configurational approach originated from an assumption that space is a set of configured and interconnected elements that form arrangements and can be studied through different quantitative methods (Hillier, 1996; Hillier and Hanson, 1984, pp.82-175; Karimi, 2012). The main principals of the approach were to understand the relationships between the configured elements, their position and importance as parts of the system. The urban form was treated as a conceptual model represented mathematically and studied analytically. The origins of the configurational approach can be traced to the quantitative studies such as Euler's Königsberg Bridge Problem[5] and D'Arcy Wentworth Thompson's allometry[6] (Kropf, 2017, p.17). The popularisation of the configurational approach in urban studies can be traced back to the 1970s, primarily in the UK. Two research centres began to study different aspects of the topology of urban form: researchers at the University of Cambridge were interested in graph representation of built form, while researchers at Universal College London (UCL) were developing the theory of space syntax. While the two methods differed, they shared a common interest in the importance and impact of

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[4] Another framework was proposed by Moudon (1997) where urban morphology was divided into three main schools of morphology: British, Italian and French. Even though those two frameworks are different, some of the same approaches are categorised under a different name. For example, the British School of Morphology is simultaneous with the historico-geographical approach, while the Italian School is simultaneous with typo-morphological approach.

[5] The Seven Bridges of Königsberg was a mathematical problem solved by Leonhard Euler in 1736 using graph representation. This led to the development in graph theory.

[6] Allometry is the study of change in the organisms in relation to their growth.

topological characteristics on our understanding of buildings and urban spaces (Kropf, 2017, p.17).

The configurational approach developed at the University of Cambridge, by researchers such as Lionel March, Leslie Martin and Philip Steadman were concerned primarily with the application of graph theory in architecture. As March and Steadman stated in their book *The Geometry of Environment* (1971, p.8):

> 'Perhaps the chief difference between the traditional treatment of geometry in architecture and the one presented here, is that, previously, geometry was employed to measure properties of space such as area, volume, angle, whereas the new mathematical theories of sets, groups and graphs - to name but a few - enable us to describe structural relationships which cannot be expressed in metrical forms, for example, 'adjacent to', 'in the neighbourhood of', 'contained by'.'

The graphs can be used to represent and analyse topological relationships (e.g. adjacency or connectivity) between rooms in buildings (March and Steadman, 1971). A graph consists of a set of nodes that represent elements and links, which signifies topological relationships between two elements. While nodes and links could represent various forms and relationships depending on the purpose of the analysis (Krüger, 1979; Steadman, 1984), nodes were typically used to represent rooms, while links illustrated the relationship (e.g. adjacency or accessibility) between a pair of rooms. The main objective of this approach, as defined by Steadman in the preface to his book *Architectural Morphology* (1983), is to investigate 'the limits which geometry places on the possible forms and shapes which buildings and plans may take'. Graph theory could be, therefore, used as a tool to help tackle design problems. For example, to find all possible configurations of a floor plan based on requirements of adjacency between specific functions or rooms.

The main aim of space syntax was to develop a theory that studied spatial configurations in relation to social phenomena. One of the most important arguments in space syntax is that space has ‘a direct relation - rather than a symbolic one - to social life’ (Hillier and Hanson, 1984, p.ix). Because ‘human societies are spatial phenomena’ (ibid., 1984, p.26) the configuration of spaces reflects the arrangement of the social relations. One of the aims of space syntax was to provide a set of tools, methods and measures that can help to describe and visualise the topological characteristics of the space (Bafna, 2003; Hillier and Hanson, 1984).

One of the most important findings in space syntax was the correlation between spatial configuration and movement in the city, coined as ‘natural movement’ (Hillier et al., 1993) and emphasised by Hillier in the book *Space is a machine* (1996, p.113):

> ‘The fundamental correlate of the spatial configuration is movement. This is the case both in terms of the determination of spatial form, in that movement largely dictates the configuring of space in the city, and in terms of the effects of spatial form, in that movement is largely determined by spatial configuration’.

However, the configurational studies in space syntax did not concentrate solely on the relationship between spatial configurations and movement. Correlations were found between spatial configurations and other aspects of urban life, such as: crime (Hillier and Shu, 2000), social segregation (Vaughan, 2007) and way-finding (Conroy Dalton, 2003).

Similar to the graph theory, the main methodological concerns had to do with the means of translating space into a graph (Bafna, 2003). In the early days of space syntax the continuous space was sub-divided either into a set of convex spaces (convex map) or a set of axial lines (axial map). The convexity (or ‘beadiness’) describes ‘the extension of space in two dimensions’ (Hillier and Hanson, 1984, p.91). It refers to the local organisation of the spaces, the dimension of the inhabitants and of the micro-scalar relations between the buildings. On the other hand, the axiality (or 'stringiness') describes the maximum 'extension of space in one dimension' (ibid., 1984, p.91). Therefore, it describes the global organisation of the space 'as it provides information about what lies ahead and how to find one's way' (Hanson, 2000) and refers to the dimension of visitors and strangers.

In order to produce a convex map, the continuous space has to be divided into convex spaces, starting from the largest (referred to as 'fattest[7]' (Hillier and Hanson, 1984, pp.97-98) to the smallest[8]. Next, each convex space is represented by a node, while the links represent an access-based relationship between two convex spaces. The concept of the convex space and convex map can be applied both to the macro-analysis of settlements (alpha-analysis) and micro-analysis of buildings (gamma-analysis) (Hillier and Hanson, 1984, pp.82-175). The convex spaces are much easier to define in the analysis of buildings, as in most cases a convex space directly corresponds to a room. The axial maps are mostly utilised in the analyses of settlements. The definition of the axial lines is ambiguous with two common interpretations. An axial line either reflects the line of unobstructed sight (Bafna, 2003; Batty, 2004), or it represents the line of unobstructed sight and movement (Karimi, 2012). The set of axial lines creates a network which can be converted into a graph. Each axial line can be represented as a node, while the links correspond to junctions between the lines. This form of representation of a street network is counter-intuitive and opposite to the graph representation common in transport studies, where nodes represent junctions and links street segments. However, the advantage of the axial maps is that the emphasis is shifted from the junctions onto the streets. Considering a street as a discrete entity can prove useful in studies focused on the local characteristics of streets. The usage of axial lines as main units of the topological analysis was, however, the main criticism of space syntax, as it could not utilise the widely popular road-centreline maps (Turner, 2007). Since

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[7] The fattest convex space can be determined through use of a circle template. The fattest convex space is that one fits the largest circle.

[8] The main critique of the concept of the convex space in the literature is that it is subjective. The fattest convex space is not formally defined and thus might be difficult to reproduce (Bafna, 2003; Batty, 2004)

then researchers within the space syntax community developed methods to incorporate the road-centrelines into the space syntax analysis either through the introduction of angular segment analysis (ASA) that divides axial lines into segments (Hillier and Iida, 2005; Turner, 2007), or by joining segment lines into ‘continuity lines’ (Figueiredo and Amorim, 2005), or ‘threads’ (Thomson, 2003). While the syntactic analyses of axial lines and road-centrelines proved to be similar (Turner, 2007), Vialard (2015) argued that the shift between the representations corresponds to a change in the perception of the street as an entity. The axial line can be associated with a pedestrian experience, as it corresponds directly to the adjacent buildings, while the road-centreline, being more directional, is connected with a vehicular experience (ibid., 2015).

Space syntax offers a number of syntactic measures to more precisely describe and compare the topological properties of space. The logic of the axial line was based on the assumption that the depth of the route, defined as a number of turns, is more important than the metric distance of the route (Bafna, 2003). The depth in space syntax can be understood as the number of topological steps between the axial line or convex space to the destination (Hillier and Hanson, 1984, pp.104-108). Based on that logic, a measure of *integration* (also called relative asymmetry or relative depth) was developed. It describes ‘distance from any space of origin to all others in a system’ (ibid., 1984, pp.108-109). Therefore, integration can predict potential to-movement, in other words the potential of a node to be a destination from all other nodes (Hillier et al., 1987). While integration predicts potential movement, Bafna (2003) pointed out that empirical studies showed correlation between integration values and the relative volume of movement.

In the study of built forms, an access-based graph was developed in order to determine the depth of a node in relation to a chosen base node (Hillier and Hanson, 1984, p.106). In this graph representation, coined as ‘justified access graph’ or a ‘j-graph’, each internal space is conceptualised as a node, while links depict relations of permeability between the spaces. The choice of the base node depends on the purpose of the analysis, if the study is concerned with the depth of the rooms in relation to the public space, the base node is the public space.

Another important syntactic measure is *choice* or *betweenness centrality*. Choice was defined as a measure that describes 'how likely a node is passed through on all shortest routes from all spaces to all other spaces in the system' (Hillier et al., 1987). The importance of the node in this case is measured by how frequently the node is passed on the shortest path from point A to point B (Turner, 2007). In other words, choice predicts potential through-movement (Hillier et al., 1987). To determine the importance of the node based on both to- and through-movement potential the measures of integration and choice can be combined[9].

2.2.2. The typo-morphological approach

The typo-morphological approach (also referred to as process typological approach) is grounded in the work of the Italian School of Saverio Muratori (Cataldi, 1998; Kropf, 2017; Moudon, 1997). The approach considers the urban form as a multi-scalar hierarchical structure that is rooted in local historical context and should be understood as continuously changing (Moudon, 1994; Kropf, 2017). The origins of the typo-morphological approach lay in the comprehensive classification of built form based on their form, scale and time (Cataldi, 1998). The main concepts, which stemmed from the classifications, are *type* and *typological process*. In typo-morphology, type is considered as a mental and cultural construct (Kropf, 2017; Steadman, 2014, p.354) rather than a concrete and physical one. According to de Quincy (1977, in Steadman, 2014):

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[9] The combined integration and choice can be calculated based on the formula (Al-Sayed, 2014; Palaiologou, 2015, p.365):

$$(NC/MD) * (\log(CH+2)),$$

where NC - node count, MD - mean depth, CH - choice.

> ‘The word ‘type’ presents less the image of a thing to copy or imitate completely than the idea of an element which ought itself to serve as the rule for a model’.

The type can be thus understood as a synthesis of the experiences from previous types as well as a vessel for the development of any future types (Gauthier, 2005). This feedback loop was termed by Gianfranco Caniggia and Gian Luigi Maffei (1979) as a *typological process*. The typological process describes the development of new types which is founded on the adjustments, alterations and changes to the existing forms (Gauthier, 2005; Kropf, 2001; Whitehand, 2001). Thus the new idea of form relies heavily on the reaction and feedback to the existing forms. As Kropf aptly described based on the views of Gianfranco Caniggia and Gian Luigi Maffei (2001): ‘a type is the result of a number of different people making objects according to a shared conception of the object’ (Kropf, 2001). The generation of the new types relies heavily on the repetition of a certain form. While that repetition can be a result of a collective cultural background, Philip Steadman argues in his book *Building Type and Built Forms* (2014) that the reasons for the repetition might be more complex. Firstly, the forms might have been reproduced from the existing forms, as it is not uncommon for architects and builders to be inspired by existing built form. To some degree this reason coincides with the notion of collective cultural background proposed by the Italian School. Secondly, Steadman argues that there are certain ‘constraints of geometry and generic functions’ (Steadman, 2014, p.357) that limit the development of the forms.

In the academic literature, it is widely agreed that a type is defined as a mental model, however, Gauthier (2005) argued that in empirical typo-morphological studies an operational definition is more common. Practically, the type is treated in a simplified matter as a description of physical and spatial properties of concrete objects and is used as a classificatory unit (Gauthier, 2005; Steadman, 2014, p.353). As Gauthier (2005) further argues this simplification of the definition of the type can be rooted in the assumption that culture is expressed in the built form. De Quincy recognised this notion and introduced an alternative definition to the term ‘type’ which describes ‘certain general and characteristic forms of the building which receives them’ (1977, in Steadman, 2014).

The classification of the types varies and is based on many different factors and aspects of urban form. As Habraken (1998) specifies ‘types are not strict rules, but a direction, a framework for multiple variations’. In the academic literature, classifications of urban form are most commonly qualitative in nature and based on form and use (Steadman, 2014). However, in recent years there has been some development in the quantitative classification of types that focused mainly on the development of clustering methods (e.g. k-means clustering) (Berghauser Pont et al., 2019; Gil et al., 2012; Vialard, 2014).

2.2.3. Historico-geographical approach

The historico-geographical approach is concerned with study of forms, structures and processes in cities. An important factor in this approach is time and, therefore, one of the key aspects is the study of change in the urban form through systematic analyses of historical processes. The origins of the historico-geographical approach can be traced to the work of geographer M.R.G. Conzen, and was continued primarily by the researchers at the Urban Morphology Research Group (UMRG) at the University of Birmingham. Even though the origins are rooted in the British context, as Whitehand (2001) points out Conzen was largely influenced by the development of urban geography in Germany, especially work of Otto Schlüter on the urban ground plans and settlement geography. Crucial to the work of Conzen were the notions of geographical areas, their characteristics and differentiation (Larkham, 2006), tripartite division of the townscape[10] (Whitehand, 2001) and the processes of urban development (ibid., 2001). While the historico-geographical approach

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[10] Conzen described townscape as ‘a combination of town plan, pattern of building forms, and pattern of urban land use’ (Conzen, 1960, p.3).

introduced and developed many important concepts in urban morphology, such as burgage cycle, plan units, fringe belts, and the morphological frame[11] (Larkham, 2006, Whitehand, 2001), in this thesis two concepts are especially important: *morphological regions* and *morphological periods*. As defined by Whitehand (2001) a *morphological region* is 'an area that has a unity of respect of its form that distinguishes it from surrounding areas'. The *morphological period* is a specific time frame when various new urban forms were introduced, such as: building types, architectural styles and street layouts (Whitehand et al., 2014). Those forms and types were further repeated and reproduced until the next period began (Conzen, 1960, p.7; Whitehand et al., 2014). The transition between different morphological periods might be, in some cases, more ambiguous than in others. Moreover, the time frame of each morphological period might vary. Whitehand et al. (2014) estimated that for Great Britain the average time of a morphological period is two to three decades.

2.2.4. Macro- and micro-scales

As discussed above, the study of urban form is divided between a range of spatial scales, which can range as Kevin Lynch (1984) observed from the scale of a neighbourhood street or public square to large scale developments or entire cities. The analyses in urban studies are most commonly divided into macro- and micro-analyses. The macro-scale analyses are concerned with the study of large-scale systems, such as cities and settlements (Marshall and Caliskan, 2011), while the micro-scale studies focus on the individual buildings and plots (Conzen, 1960; van Nes and López, 2007; Whitehand, 2001). There are many ways in which an urban form can be divided based on scales and levels. It mostly depends on the granularity of the design or a study. Regardless of the classification of the scales, each level should be treated as a part of a whole system. However, it is not uncommon for the scales to be considered as isolated entities (Carmona, 2010; Palaiologou et al., 2016; van Nes and López, 2007). As Carmona (2010, p.6) points out:

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[11] Detailed definitions of those terms can be found in the journal paper *British urban morphology: the Conzenian tradition* by Jeremy Whitehand (2001).

> ‘Urban designers need to be constantly aware of scales, ... and also of the relationships of the parts to the whole, and of the whole to the parts’.

This sentiment was also emphasised by Alexander (1977, p.xiii) in the book *Pattern Language* where he described that no pattern can exist in isolation. The patterns either embed, are surrounded, or are embedded into other patterns (Alexander, 1977, p.xiii). In the morphological approaches, a dichotomy between macro-and micro-scales can be observed, even though in academic literature the transition between those scales is considered a continuum (Chisholm, 1972). Theoretically, it would be desirable to link all the approaches, methods and models, however, in practice it may be currently unachievable. However, making sure that the approaches are compatible and finding links between existing approaches, might allow us to capture the complexity of cities more comprehensively.

2.3. Interface in urban morphology

The interface is a spatial representation of the interrelationship between buildings and the streets and is constantly under the pressure of, what Alice Vialard (2012) calls, internal and external loads. The internal load describes the impact of the internal configuration of the building on the form and structure of the interface, while the external load defines the impact of the topological characteristics of the street (ibid., 2012). Despite being a product of the relationship between two elements, the interface should also be considered as a distinct physical object (Bobić, 2004; Vialard, 2014). In this section, the place of the interface in the morphological approaches is explored. In the configurational and typo-morphological approaches the concept of the interface is acknowledged and studied to a certain degree. In the historico-geographical approach the interface between buildings and streets is not directly addressed, even though it might be implied. Therefore, the following sub-sections focus on the description of the interface in relation to the configurational and typo-morphological analysis.

2.3.1. Interface and the configurational analysis

The interface is one of the early concepts in space syntax, discussed at length by Hillier and Hanson in the book *The Social Logic of Space* (1984). Similarly to the other syntactic concepts, the interface was defined as a spatial object in relation to the social phenomena. In the book *Space is the Machine*, Hillier (1996, p.198) emphasises this sociological dimension in his definition of the spatial interface:

> 'An 'interface' is a spatial relation between or among two broad categories of persons (or objects representing persons) that every building defines: inhabitants, or those whose social identity as individuals is embedded in the spatial layout and who therefore have some degree of control of space; and visitors, who lack control, whose identities in the buildings are collective, usually temporary, and subordinated to those of the inhabitants'.

The interface can be understood as a spatial realisation of the sociological relationships between certain groups of people, such as inhabitants and strangers, teachers and pupils, men and women, adults and children, and old and young (Hillier, 1996, p.147). This definition, however, does not specify a relation between concrete physical forms, but rather describes a possibility for spatial interfaces based on a specific social relationship.

The detailed description of the interface between buildings and streets in space syntax can be found as part of the configurational analysis of settlements (alpha-analysis) (Hillier and Hanson, 1984, p.104). In order to represent the configuration between the continuous space and the buildings (enclosed spaces), Hillier and Hanson (1984, pp.104-105) introduced interface maps. The convex interface map is a graph with two types of nodes signifying physical spaces (convex spaces and buildings) and links representing permeability-based relationships between those spaces (see Figure 2.2). A white node (a circle) corresponds to a convex space, while a block node (a dot) signifies a building. In addition to the convex interface map, a converse interface map was introduced, where the links signify impermeability between convex spaces and adjacent buildings (see Figure 2.3). The converse interface map can intuitively visualise the degree of disconnection between buildings and the public space. The interface map was introduced alongside the concept of 'constitutedness'. According to Hillier and Hanson (1984, p.105), the space is constituted when the buildings adjacent to a convex space or an axial line are directly permeable from the space. When the adjacent buildings are not directly accessible the space is unconstituted (Hillier and Hanson, 1984, p.106). In the space syntax literature it is argued that the 'constituted' spaces are important to the liveability of streets and urban safety (Gehl, 2011; Hillier and Hanson, 1984, pp.105-106; Jacobs, 1961; van Nes and López, 2007). Therefore, an interface map is useful as a visual and analytical tool when studying the character and use of public spaces. Outside of the early publications, the interface map was not computerised or widely developed, even though its introduction was crucial to the theory of space syntax, as voiced by Hanson (2000):

> 'The production of the interface map representations was a defining moment for 'space syntax', for the drawings seemed to capture the shift from a dense to a sparse urban surface more graphically than any narrative.'

The further development of the interface map in space syntax can be found only in a few publications (Hanson, 2000; Palaiologou et al., 2016; van Nes and López, 2007). The emphasis in most of those publications is on the introduction and development of new syntactic measures that complement the interface map[12].

The interface between buildings and streets is also a key part of the configurational analysis of buildings (gamma-analysis). The justified access graphs (j-graphs) not only represent

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[12] The syntactic measures were introduced as follows: topological depth between private and public space, inter-visibility of windows and doors (van Nes and López, 2007), constitutedness rate, neighbourliness score, interface decomposition score (Hanson, 2000). Detailed definitions of each measure are outside of the scope of this thesis and can be found in the respective publications.

the access-based relationships between internal spaces, but also between the private interior and public exterior. However, regardless of the structure and form, the external public spaces are commonly simplified to one node, which may lead to a misinterpretation of the relationship between the building and its context (see Figure 2.4a). The relationship between the inside and the outside is also acknowledged in the graph representation of the built form, for example in augmented dual adjacency graphs (Steadman, 1983, p.66). As shown in the Figure 2.4b, in the augmented dual adjacency graph external regions are introduced to the configuration of the internal spaces in a building. In this particular

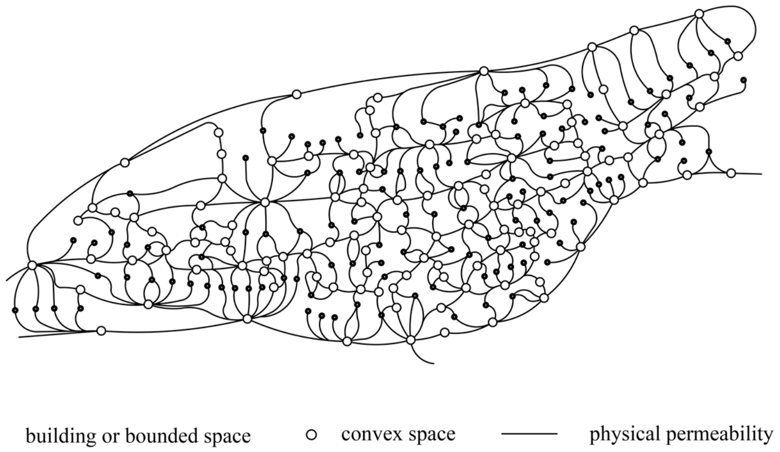


Figure 2.2 - Convex interface map of Gassin (reproduced from Hillier and Hanson, 1984, p.104).

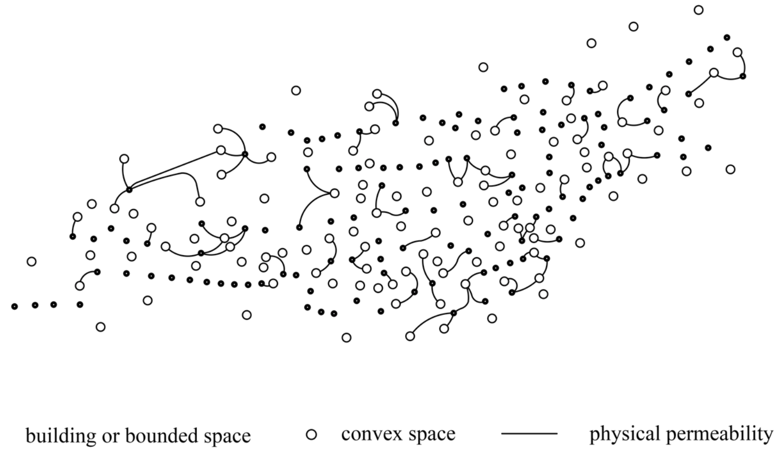
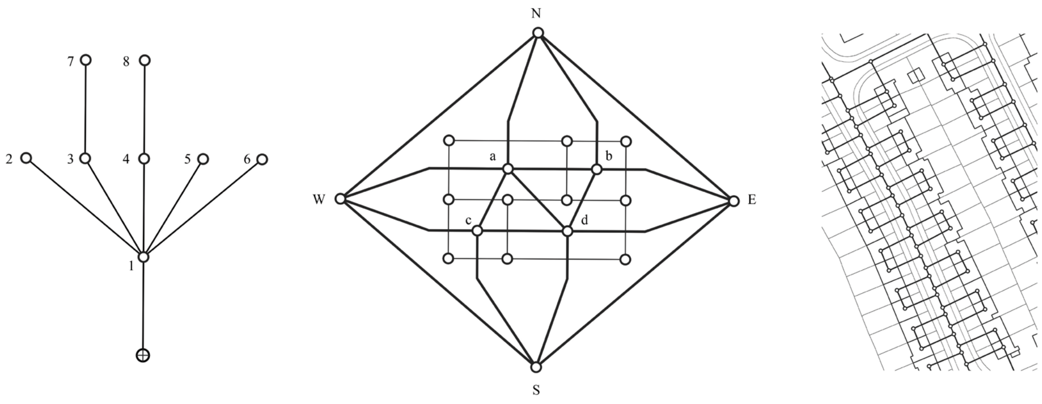


Figure 2.3 - Converse interface map of Gassin (reproduced from Hillier and Hanson, 1984, p.105).

case, four nodes represent regions corresponding with the cardinal directions in order to show the relationships of the rooms with the orientation of the building. Steadman notes (1983, p.65) that external regions can correspond to any defined areas around the internal plan, such as a yard, a garden, neighbouring buildings or streets. The concept of interfaces between buildings and their immediate context in graph representation was explored by Krüger (1979), who identified five types of graphs signifying relationships between: buildings and other directly adjacent buildings ('graph of type 1') buildings and plots ('graph of type 2'), buildings and adjacent streets ('graph of type 3'), roads ('graph of type 4'), and urban blocks ('graph of type 5') (Krüger, 1979) (see Figure 2.4c).

The concept of the interface has been acknowledged in configurational studies of the urban form, measures and tools were developed to map and analyse interfaces. However, since the early development of interface maps, there were very few empirical studies of the interface. In addition to the further development of measures and tools, it is important now, as pointed out by Hillier and Hanson (1984, p.190), to focus on the empirical and comparative analysis of the interface:



(a) (b) (c)

Figure 2.4 - Different types of graphs representing the internal configuration of buildings. (a) A justified access graph (reproduced from Hillier and Hanson, 1984, p.151). (b) A plan graph (thin links) and augmented dual adjacency graph (thick links) (reproduced from Steadman, 1983, p.66). (c) Graphs of types 1, 3 and 4, proposed by Krüger (1979) to describe interfaces between houses and their immediate context.

> ‘The species of interface is the most fundamental spatial feature of any building, and a comparative analysis of these is therefore a necessary step to any theory of building types.’

2.3.2. Interface and the typo-morphological analysis

Even though the interface is one of the key aspects of urban studies since the 1960s (Dovey and Wood, 2015; Kamalipour, 2016), a widely recognised classification of interfaces has not been developed (Dovey and Wood, 2015). This may stem from the nature of the interface. The interface can be perceived exclusively as an abstract relationship between buildings and streets, rather than a physical entity on its own. In this sub-section we briefly describe the existing interface typologies.

One of the first classifications of the interfaces was developed by Gehl (1986; 2011), and was based on the potential of the interface to accommodate activities. Gehl proposed two types of interfaces: a ‘soft’ interface which supports use and activity, and a ‘hard’, blank and empty interface with no possibility for activities to occur (Gehl, 1986; Gehl, 2011). This typology was developed to provide a framework for the design and evaluation of streets. Its main aim was to tackle blank façades, which, as Gehl (1986) argued, were detrimental to social activity and safety on the streets.

In the book *Between the Edges* Bobić (2004) argued that the complexity and ambiguity of the interface is the main obstacle in the selection of formal criteria for a comprehensive typology. He proposed his classification of the interfaces based on the spatial, visual and psychological ‘territorial depths of transition’ (ibid., 2004), which he argued were the most important aspects of every interface. The depth of the interrelation between private and public spaces became the main variable in his classification, which consisted of seven types (and forty sub-types) (Bobić, 2004, pp.89-126):

(1) Integrated interface: where public space penetrates into the private space,

> e.g. mews, courtyards, side yards, entrance patios, arcades, and courts.
>
> (2) Overlapped interface: where public and private spaces overlap, e.g. colonnades, Chester rows, carports, loggias, under the buildings, alcoves, and niches.
>
> (3) Confronted interface: where public and private spaces meet, e.g. frontage, doorway, and a hole in the wall.
>
> (4) Associated interface: where private space penetrates into the public space, e.g. stoops, pot-huis, edging, texture changes, raised platforms, exhibits, sidewalk cafés, Paris cafés, overhangs.
>
> (5) Inserted interface: where an additional space is added between private and public spaces, e.g. a deep front yard, small front garden, shallow front yard, area, porch, leaned-to, and a large garden.
>
> (6) Extended interface: where a group of private spaces penetrate into the public space, e.g. crescents, squares, alleys, 'woonerf', public lawns, and street markets.
>
> (7) Suspended interface: where the private space related to the building is situated on the other side of the street, while still being dependent on the building itself, e.g. allocated units, and communal gardens.

Bobić's classification is very complex and at times inconsistent. The scale of the interface varies across the classification as some types describe a relationship between an individual building and public space, while the others illustrate a relationship between a group of buildings and public space. Bobić (2004) does not incorporate the impermeable interfaces into his typology, and concentrates only on permeable transitions. Overall, the classification lacks clarity and would be difficult to map (Dovey and Wood, 2015).

The ‘façade evaluation scale’ proposed by Gehl, Kaefer and Reigstad (2006) classified interfaces between the street and aggregated buildings based on variables such as: number of units (buildings and doors), variety in land use and function, capability of the interface to accommodate activities (determined by the number of blank, blind or uninteresting façades), and the geometry of the individual façades (defined as façade relief, detailing and materiality). This classification was divided into five categories (Gehl et al., 2006):

> Category (a) describes an interface characterised by many small units (15 to 20 doors per 100 metres), a large variation in function, no or few blank units, complex geometry of the individual façades, and quality detailing and materiality of the façades.
>
> Category (b) describes an interface characterised by mostly small units (10 to 14 doors per 100 metres), some variation in function, few blank units, modest geometry of the individual façades, and few details.
>
> Category (c) describes an interface characterised by a mix of small and large units (6 to 8 doors per 100 metres), modest variation in function, some blank units, modest design of façades with few details.
>
> Category (d) describes an interface characterised by large units (2 to 5 doors per 100 metres), almost no variation in function, many blank units, simple façades with few or no detailing.
>
> Category (e) describes an interface characterised by large units (0 to 2 doors per 100 metres), no visible variation in function, blank and uniform façades with no detailing.

Dovey and Wood (2015) introduced a classification of the interfaces between an individual building and streets based on the physical permeability, visual permeability, proximity and access mode. These were divided into five types:

> (1) an 'impermeable/blank' type describes an interface with no access, visual link or setback between buildings and streets, which is common in industrial and commercial buildings.
>
> (2) a 'direct/opaque' type describes an interface, without setback between buildings and streets, that allows for physical pedestrian permeability but constrains visual permeability. It is common in residential, industrial and office buildings.
>
> (3) a 'direct/transparent' type describes an interface, without setback between buildings and streets, that accommodates both physical and visual permeability. It is common in retail buildings.
>
> (4) a 'pedestrian setback' type describe an interface, with setback between buildings and streets, that accommodates pedestrian access and is visually permeable. It is common in suburban residential areas.
>
> (5) a 'car setback' type describe an interface, with setback between buildings and streets, that accommodates vehicular access and is visually permeable.

Similar typology was proposed by Kamalipour (2016), however it was based on fewer variables: accessibility and proximity. Based on the matrix between the two properties, the author proposed six interface types: (1) adjacent/impermeable, (2) adjacent/accessible, (3) adjacent/porous, (4) distant/impermeable, (5) distant/accessible, and (6) distant/porous (see Table 2.1). The author proposed an interesting interpretation of the typically binary understanding of accessibility and proximity. While commonly, the interface is described as either permeable or impermeable, direct or distant (with or without setback), Kamalipour (2016) introduced a third degree, porous. A porous interface is defined as a relationship between public and private space where at least 50 percent of the total width of the interface is open. This adds a metric dimension to the inherently topological variables of the interface.

		connectivity		
		impermeable	accessible	porous
proximity	adjacent	adjacent impermeable	adjacent accessible	adjacent porous
	distant	distant impermeable	distant accessible	distant porous

Table 2.1 - Classification of interface types based on proximity and connectivity, proposed by Kamalipour (2016) (reproduced from Kamalipour, 2006, p.4).

The review of the existing interface typologies offers an interesting insight into our understanding of the interface between buildings and streets. If we aggregate every variable considered in each classification, the interface is most commonly analysed using topological, geometric and social variables, such as:

- physical permeability
- visual permeability
- proximity (setback or depth)
- access mode (pedestrian or vehicular)
- geometry of the façade
- capability to accommodate activities

The most common variable is physical permeability which is present in every classification, therefore whether a building is accessible from the street is one of the most important aspects of the interface, which was recognised in space syntax. Yet, the importance of accessibility does not diminish the value of the other variables, as similar to other aspects of urban form, the interface is a complex and multi-faceted element.

2.3.3. Individual and collective interfaces

As seen in the previous section, there are different approaches to the classification of interfaces in regards to their scale. Some typologies classify the interface between an individual building and the street (Dovey and Wood, 2015; Kamalipour, 2016), while others are concerned with the interface between a group of buildings and a street (Gehl, 1986; Gehl, 2011; Gehl et al., 2006). The difference in the scale of the spatial interface was recognised by Peponis (in Hillier, 1996, p.131) and Bobić (2004). Bobić distinguished two scales of the interface: the individual and the collective. The individual interface is established between an individual building and a street, while a collective interface is established between a group of buildings and a street. Bobić (2004) does not specify the limits of the number of buildings that can form a collective interface, but rather says that:

> ‘Any form of configuration contributing to a gradual transition between the street and a group of houses may be seen as a collective interface’.

The concept of the scales of the spatial interface was further developed by Palaiologou (2015, p.49; Palaiologou et al., 2016). Palaiologou introduced three scales of the interface: (1) building-street interface, (2) block-street interface, and (3) street interface (see Figure

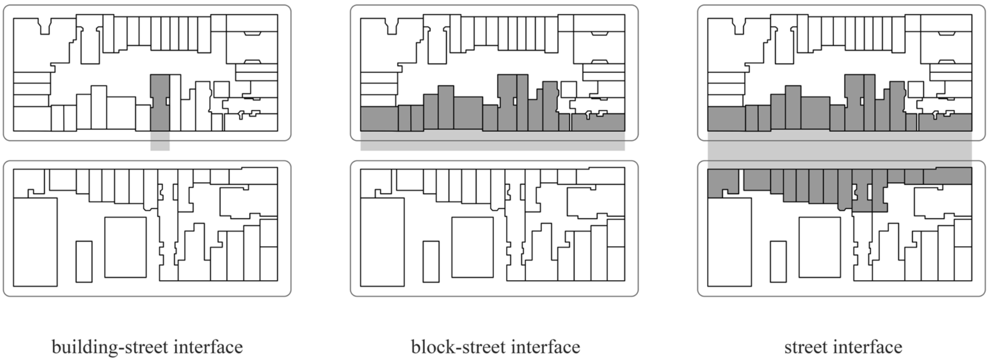


Figure 2.5 - Scales of the spatial interface: building-street interface, block-street interface, and street interface, proposed by Palaiologou (2015, p.49; Palaiologou et al., 2016) (reproduced from Palaiologou et al., 2016, p.35).

2.5). The building-street interface was defined as a space between the building façade and the street, and thus was an individual interface. The block-street interface was defined as a space between a group of building-street interfaces (along the same side of the street segment) and street segments. The street interface was defined as a space between a group of building-street interfaces (situated on both sides of the street segment) and the street segment. In other words, the space between façades of buildings on both sides of the street. Both the block-street interface and the street interface are forms of collective interface. The concept of understanding the interface as collective, rather than individual, was also explored by Vialard (2014) in the study of the block-face. The faces of a block are distinguished based on the number of street segments directly adjacent to an urban block. The author argued that studying the collective interface is likely to provide a more detailed account of existing conditions, especially macro-scalar ones (ibid., 2014).

2.4. Methodological framework

As introduced in Chapter 1, this thesis is investigating the impact and role of the spatial interface between buildings and streets. It poses the research question:

> Does the spatial relationship between houses and streets affect the configuration and use of both?

This question can be more easily addressed if we split it in four:

> (1) Does the way in which a street interfaces with houses affect the activity on the street and how does it do this?
> (2) Does the way in which a house interfaces with streets affect its internal configuration and how does it do this?
> (3) By what means can the macro-scalar analysis of streets and the micro-scalar analysis of houses be integrated?
> (4) Does the interface between houses and streets differ across different

morphological periods?

In this sub-section the methodological framework is discussed and methods are proposed to address these research questions. As explored in the literature review, the main challenge in the analysis of the relationship between houses and streets is scale. Streets are part of a macro-scale street network, while houses are micro-scalar elements, therefore each are analysed with different sets of tools. One of the ways to bridge those two scales is through the study of the interface. As it was emphasised in the literature review the interface carries information from both sides (Madanipour, 2003, p.70; Vialard, 2015): the building side and the street side. Thus, through cross-tabulation, data collected on the interfaces can be combined with the macro-scalar analysis of settlements and micro-scalar analysis of buildings in order to assess the impact of both elements on one another.

The methodology is divided into three general parts. Firstly, the typology of the interfaces is proposed. Based on the direct observation and current Ordnance Survey map, the established types are then mapped in a geographic information system (GIS). Secondly, the analysis of street networks is conducted using space syntax with the Space Syntax Toolkit for QGIS[13]. The results of the analysis are cross-tabulated with the interface types in order to assess the impact of the micro-scale on the streets. Thirdly, the analysis of the internal configuration of houses is conducted using graph theory and mapped in GIS. The results of the analysis are then cross-tabulated with the interface types in order to assess the impact of the micro-scale on the buildings. Additionally, this thesis investigates if the relationship between houses and streets changes between morphological periods.

2.4.1. Interface typology

The classification of the interfaces is based on the most common topological characteristics

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[13] The Space Syntax Toolkit was originally developed at the Space Syntax Laboratory at the University College London by Jorge Gil, Ioanna Kovolou, Abhimanyu Acharya, Stephen Law, and Laurens Versluis.

of the interface discussed in Section 2.3.2: physical permeability, visual permeability and proximity between buildings and streets.

> *Physical permeability* describes whether the interface between the buildings and streets is accessible by pedestrians. The interface can be either physically permeable or impermeable (accessible or inaccessible).
>
> *Visual permeability* describes whether an interface allows for inter-visibility between the private and public spaces. While the interface can be designed to allow for a partial visual connection between buildings and streets, in this work an interface is considered visually permeable when more than 50% of the façade (or fence) allows for inter-visibility. The interface can be either visually permeable or impermeable.
>
> *Proximity* (setback) describes the distance between buildings and streets. If the building is directly adjacent to the public space then the interface is direct (without setback). If there is any space (semi-private or semi-public) between the building and the street then the interface is distant (with setback).

Based on the interrelation between those three variables, ten types of interface were proposed and illustrated in Figure 2.6: (1) direct impermeable interface (0/0/0), (2) direct visually permeable interface (0/0/1), (3) direct physically permeable interface (0/1/0), (4) direct physically and visually permeable interface (0/1/1), (5) direct open interface (0/open), (6) distant impermeable interface (1/0/0), (7) distant visually permeable interface (1/0/1), (8) distant physically permeable interface (1/1/0), (9) distant physically and visually permeable interface (1/1/1), and (10) distant open interface (1/open). The interface types were categorised using a descriptor explained in Figure 2.7 and then mapped in GIS. The information on the relationship between houses and streets was not available through any digital mapping service, therefore data was gathered through direct observation in the

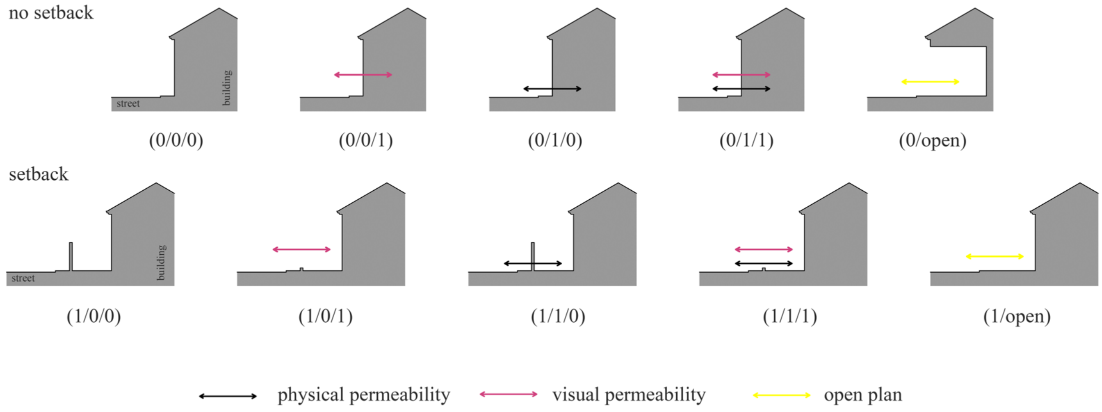


Figure 2.6 - Interface typology based on three variables: proximity, physical permeability, and visual permeability. Types of interfaces: (1) direct impermeable interface (0/0/0), (2) direct visually permeable interface (0/0/1), (3) direct physically permeable interface (0/1/0), (4) direct physically and visually permeable interface (0/1/1), (5) direct open interface (0/open), (6) distant impermeable interface (1/0/0), (7) distant visually permeable interface (1/0/1), (8) distant physically permeable interface (1/1/0), (9) distant physically and visually permeable interface (1/1/1), and (10) distant open interface (1/open).

period between June and October 2016. The data on the interface types was then added to the plot boundary map derived from the topographic layer of the Ordnance Survey map (2018) accessed through Digimap Ordnance Survey Collection by EDINA. The resulting map is referred to as the interface map throughout this thesis (see Figure 2.8).

The typology is scale-sensitive and can be applied to both individual and collective interfaces. In this thesis, the division between the individual and collective interfaces proposed by Bobić (2004) is combined with some of the scales of spatial interface

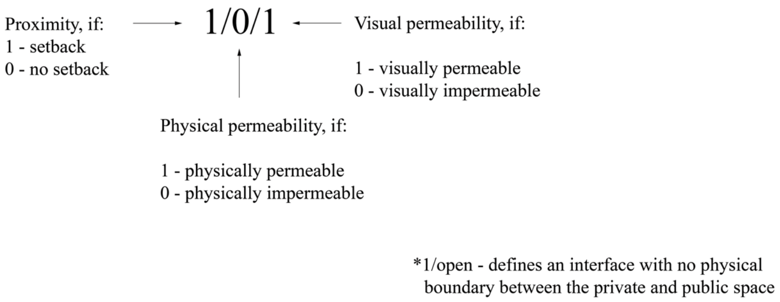
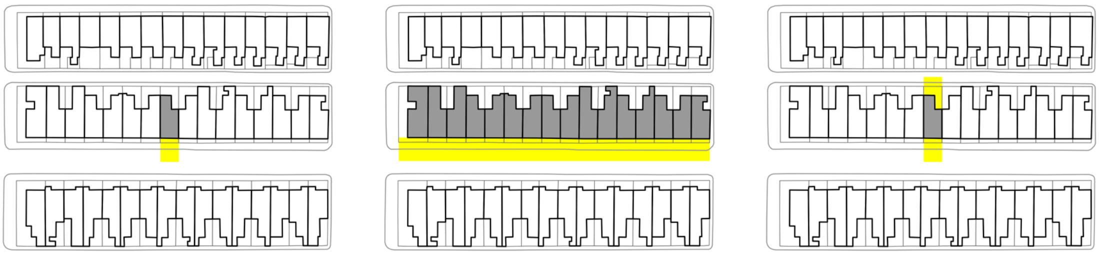


Figure 2.7 - Descriptor used to classify building-street interface types.

Figure 2.8 - Example of interface mapping on the plot boundary map derived from the topographic layer of the Ordnance Survey map (2018). Accessed through Digimap Ordnance Survey Collection by EDINA.

proposed by Palaiologou (2015; Palaiologou et al., 2016). Depending on the scale and subject of the analysis, the study can examine individual building interfaces (Figure 2.9a), street-buildings interfaces[12] (Figure 2.9b), or building-network interfaces (Figure 2.9c)., which are defined as follows:



(a) building-street interface (b) street-buildings interface (c) building-network interface

Figure 2.9 - Scales of the spatial interface (yellow): (a) building-street interface (individual), (b) street-building interface (collective), and (c) building-network interface (collective).

---

[12] The street-buildings interface corresponds to the block-street interface in Palaiologou's classification (Palaiologou, 2015, p.49; Palaiologou et al., 2016).

> *Building-street interface* is an interface between an individual building and the street that encompasses the space between the façade of the building and the road.
>
> *Street-buildings interface* is a collective interface that describes an aggregate of building-street interfaces alongside one side of a street.
>
> *Building-network interface* is a collective interface that describes an aggregate of building-street interfaces of a single house.

In addition to the data on the interface types, the plot boundary map was updated with historical and social data, such as the age of buildings, land use, house types, number of households, number of storeys. Each interface was assigned a unique identifier (ID) in order to allow for cross-tabulation with the further analyses of street networks and houses.

2.4.2. Street network analysis

The street network analysis and micro-morphological analysis of interfaces is combined in Chapter 4 in order to answer the research question: *does the way in which a street interfaces with houses affect the activity on the street and how does it do this?* The main characteristic of a street is its capability to accommodate movement; pedestrian and vehicular movement is the most common activity associated with streets. However, streets are more than just linear thoroughfares, they are 'containers of urban life' (Marshall et al., 2018). Therefore, to assess the activity on the streets two factors, movement and long-duration activities, are analysed. The academic literature argues that those two factors are necessary to generate co-presence, which then creates possibility for encounter, interaction and activity, and are likely to be accommodated along the edges of the streets (Gehl, 2011; Hanson, 2000; Hillier, 1996; Marcus and Legeby, 2012).

The analysis of the street network is conducted at the local scale of a housing estate and represented as an axial map. The local scale was chosen because the relationship between the street and adjacent buildings is more important to pedestrian local movement than vehicular global movement. For the same reason, the axial line was chosen as a form of representation, as in this study the street is the main focus of the analysis and is treated as a discrete element. In order to determine the potential of each axial line to accommodate movement, a syntactic measure of *combined integration and choice* is used. This measure determines the possibility for both to- and through-movement and therefore assess the importance of an axial line in the whole network. The higher the value the higher the possibility for potential movement and thus potential activity on the street. The analysis is conducted using the Space Syntax Toolkit for QGIS. In order to compare the results of the syntactical analysis to the characteristics of the interfaces, the logic of Hillier and Hanson's convex interface map (Hillier and Hanson, 1984, p.104) is utilised using GIS. Individual building-street interfaces along one street are amalgamated into a single street-buildings interface in order to related it to the adjacent axial line using unique identifiers. The micro-morphological characteristics of interfaces are then collated and cross-tabulated with the information on the potential movement of the axial line.

Additionally, the relationship between the potential movement of an axial line and the interface type is investigated across morphological periods, which addresses the question: *does the interfaces between houses and streets differ across different morphological periods?*

2.4.3. Graph representation of the floor plans

The analysis of the internal configuration of houses and micro-morphological analysis of interfaces is combined in Chapter 5 in order to answer the research sub-question: *does the way in which a house interfaces with streets affect the internal configuration of the houses and how does it do this?* In order to function, each house needs to be connected and accessible from the street network. Therefore the relationship between a house and the street network is always implied, even if simplified or omitted from the analysis. To analyse the internal configuration of domestic floor plans in relation to the adjacent streets, the graph representation developed by Seo (2003; 2007) is utilised and expanded, as it combines the adjacency-based (Steadman, 1983) and access-based (Hillier and Hanson, 1984) graph representations. Seo not only combines different types of relations within a graph, but also preserves the geometry of the boundary by aligning the nodes and links in relation to the simplified outline of the house (Seo, 2003; Seo, 2007). This allows graph to be orientated in relation to the external context.

The floor plans are collected from the Newcastle City Council planning application database and property websites, such as Zoopla and Rightmove. The plans are converted into graphs, where a node signifies a convex space and an link describes a relationship between two spaces. The nodes are categorised as either an internal node (white) - which represents internal spaces within a house, an external node (black) - which represents external spaces outside of a house but within the boundaries of the private property, or an outside node (cross-hair) - which represents a public space outside of the boundaries of the private property, such as a street. All of the links signify direct adjacency between two spaces, however, they are differentiated based on the physical and visual connection between the rooms. The links can be described as either physically and visually permeable, only physically permeable, only visually permeable, impermeable, or open plan. This graph representation contains information on the adjacency, access, and visual connection between private internal, private external and public spaces while retaining the information on the geometry of the boundary, which allows us to understand the graph in relation to its context.

After each floor plan is converted into a graph and mapped using GIS, the next step is to find a shared morphology of the floor plan in each housing typology. Finding a shared morphology allows us to determine the underlying spatial and social logic of the organisation of the floor plans. After establishing the typical morphological characteristics of each housing type, the configuration of houses with different building-network interfaces is compared in order to determine the impact of the streets on the internal organisation of the house.

Chapter 3

Housing in Newcastle upon Tyne: history and general characteristics

3.1. Housing development in English suburban areas

At the end of the eighteenth and the beginning of the nineteenth century England was confronted with an unprecedented housing challenge due to rapid population growth (see Figure 3.1). The population growth between 1891 and 1901 (3,286,686) was similar to that of the eighteenth century (3,229,907). The challenge was to accommodate this booming population in adequate housing. Until the First World War the majority of housing in England, regardless of the social status of renters and buyers, was provided by private speculative developers. In the 1880s, it was estimated that 99 per cent of houses in the suburbs of London were built by the private sector (Dyos, 1961, p.219). However, with the inflation of building costs and the scarcity of materials and labour after the First World War, it was no longer profitable for private speculative firms to supply affordable housing for working class families (Burnett, 1986, p.220). To aid the speculative builders, the government introduced the 1919 Addison Act which allowed local authorities to build new housing developments within their governed area. Throughout the majority of the twentieth century new housing developments were built by both the private and public sector. In the late twentieth century economic depression deepened and the attitudes towards public housing changed. With the Housing Act of 1980 the government began to reduce the role of the local authority in the supply of housing by encouraging owner-occupation (e.g. Right to Buy scheme) and private housing development (ibid., p.289; ibid., p.315). The definition of public housing changed from accommodation for 'households on a range of incomes (...) to allocating new lettings to those in the greatest need' (Hills, 2007, p.2). Those measures resulted in a substantial fall in the construction of public housing by local authorities between 1980 and 1993 from 37% to 1% where it has remained[1]. In the late twentieth and the early twenty-first century the responsibility for the supply of housing lay again solely with the private sector.

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[1] The data was accessed in March 2019 through the Ministry of Housing, Communities & Local Government - *Table 244: permanent dwellings started and completed, by tenure, England, historical calendar year series*.

There are many social and economic differences between private and public housing that are not discussed in detail in this thesis. For example, private developers favoured traditional and tested designs that were more likely to sell, while local authorities were more likely to incentivise architectural and urban innovation (Burnett, 1986, p.87; Rudin and Falk, 1999, p.68). Regardless of the multifaceted differences, housing developments shared two characteristics important to this thesis. Firstly, houses in both sectors were developed for an unknown client, meaning that designs were based on the interpretation of social, economic and physical context rather than individual taste. Secondly, both private and public houses were organised into housing estates (also known as housing neighbourhoods).

In the eighteenth and nineteenth century, it was common for different private speculative builders to be involved in the construction of one housing estate, which was developed until 'the land ran out' (Burnett, 1986, p.255). While there was some form of communication between those small companies in regards to the overall layout of

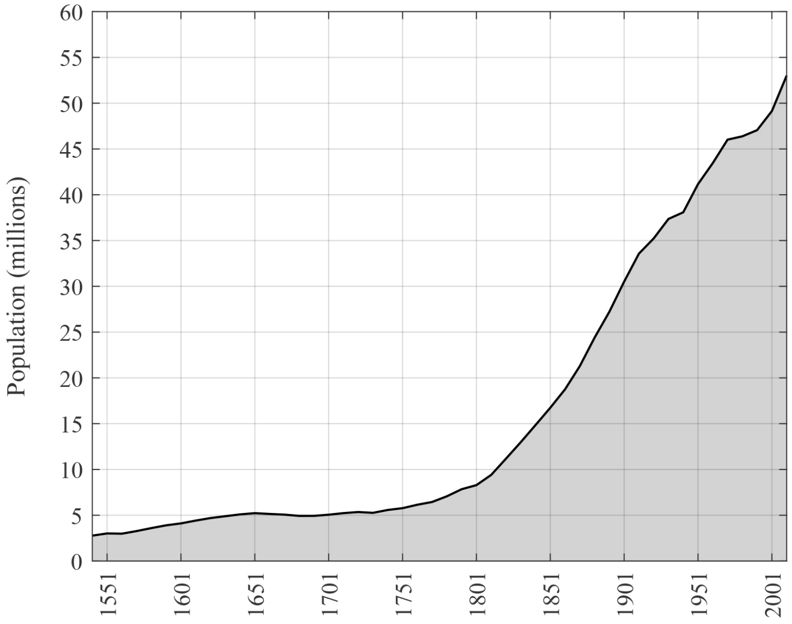

Figure 3.1 - The population growth in England between 1541 and 2011. The area graph is based on data gathered from UK Censuses between 1801 and 2011 and pre-census sources in (Mitchell, 1988, p.7). For detailed data see Appendix A.1.

the streets and allocation of the non-residential functions (Muthesius, 1982, p.68), there was no appropriate administrative and legal framework to control and enforce proper estate planning (Burnett, 1986, p.11). At the end of the nineteenth and early twentieth century a more holistic approach to housing development can be observed in the two important movements in English urban planning: the Garden City movement and the Modern Movement. Despite having a different approach to the design of cities, in both movements new housing development was treated as an identifiable neighbourhood unit (Rudin and Falk, 1999, p.39), rather than an amalgamation of separate smaller developments built in one area at the same time. That shift was further supported by the changes to planning and legislation after the Second World War. Since the 1947 Town and Country Planning Act the local authorities controlled the land use and all developments required planning permission. After the 1947 Act, planning controls were updated to address new planning and development challenges. The introduction of those controls reinforced the concept of neighbourhood units.

In this thesis a housing estate is the unit of analysis and is defined as:

> A housing estate (or housing neighbourhood[2]) is a residential area where the majority of houses have been erected in a similar time period by one or more developers.

Until the twentieth century, housing in England did not follow the morphological patterns typical for almost every European country. It was described by Stefan Muthesius in his book *The English terraced house* as ‘widely spaced, detached houses in the outer suburbs and in the countryside, contrasting with dense blocks of flats in the inner urban and

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[2] The term housing neighbourhood is included in the definition because of the pejorative association that the term ‘housing estate’ acquired in the late twentieth century. Estates began to be associated with deteriorating crime-ridden public housing, therefore many private speculators adopted a new term in order to avoid a potential stigma that could have affected their sales. However, to assure consistency throughout the thesis, housing neighbourhoods are referred to as housing estates.

suburban areas' (Muthesius, 1982, p.1). While the reason for this difference is complex, the history of speculative housing in England is intertwined with the changes in popularity between three house types: terraced, semi-detached and detached houses (see Figure 3.2). While multi-family housing was always part of the English housing stock, it was never a dominant type[3], nor was it widely accepted. Flats were seen as an unavoidable result of Industrial Revolution and the rapid population growth (ibid., 1982, p.3). As shown in Figure 3.2, the popularity of terraced, semi-detached and detached houses is connected to certain time periods. The peak popularity of terraced houses can be associated with the period between the Industrial Revolution and the First World War. The inter-war period, on the other hand, was associated with semi-detached houses, and while terraced houses were still being built, their popularity visibly diminished. Between 1945 and 1980, semi-detached was still the most commonly built housing type, however, its popularity started to decline. Since the 1980s, the detached houses became the most popular choice in new housing developments, and has remained so.

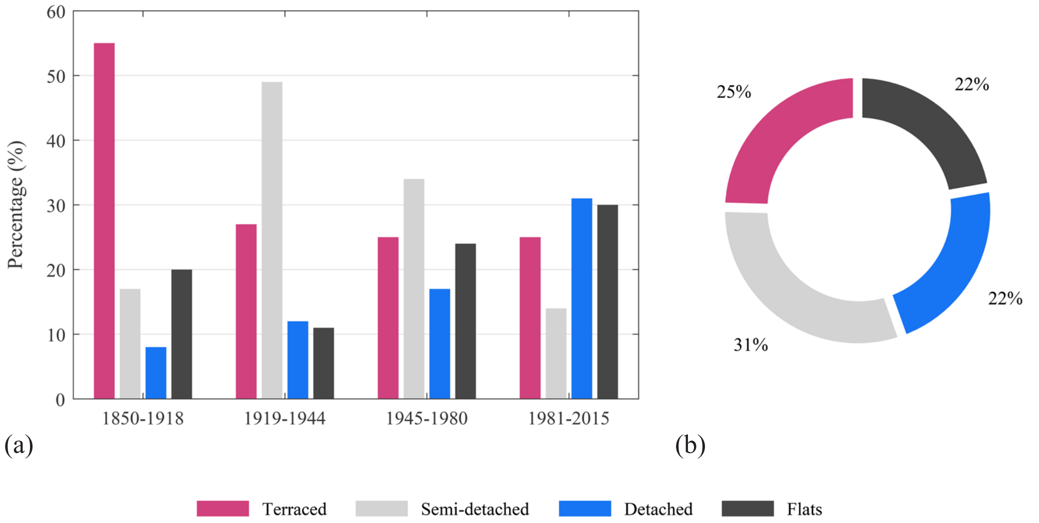

Figure 3.2 - Distribution of common English house types. Figure 3.2a shows age and type of English houses. Figure 3.2b shows distribution of types of English houses in 2011. For detailed data and sources in (a) see Appendix A.2 and in (b) see Appendix A.3.

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[3] Flats and apartments constituted 20.2% of all new build houses in England between 1850 and 1918, 10.9% between 1919 and 1944, 20.2% between 1945 and 1980 and 27.3% between 1980 and 2015 (see Figure 3.2a). In the distribution of housing stock in 2011 in England, flats and apartments constituted 22.2% of all housing stock (see Figure 3.2b).

NUNSMOOR PARK
526
7·057
Bowling Greens
F.S
Tennis Court
523
·703
Urinal
D.Fn
Lodge
Div. of Parly Boro Bdy
535
9·161
Recreation Ground
533
3·198
Bowling Green
B.M. 277·4
GROVE
C.R.
522
3·021
STUDLEY TERRACE
L.B
534
·686
372
6·612
Military
Recreation Gro
520
·656
Chap.
of E.)
WALTER TERRACE
Ward Bdy.
SHUTTLEWORTH ST.
BARRINGTON STREET
519
·775
GAINSBRO' GROVE
GROVE
BRIGHTON
FENHAM ROAD
L.B
P.O.
HUR'S HILL
WARD
SIDNEY
St. Augustine's Church
PHILIP STREET
MONDAY STREET
Div. of Parly. Boro Bdy
Ward Bdy.
THORPE STREET
JEFFERSON STREET
HAMILTON STREET
upon Tyne
Workhouse
DILSTON ROAD
CROYDON ROAD
TAMWORTH ROAD
STANTON STREET
BEACONSFIELD STREET
C.R.
CROSSLEY TERRACE
TRAMWAY
STANHOPE STREET
L.B.
STONE STREET
2978
BELSAY PLACE
LONGLEY STREET
BRIGHTON GROVE
Fn
Fn
CALLERTON PLACE
Sun. Sch.
Meth. Church
WELLESLEY TER.
PROSPECT PLACE
LID
ice & Fire Station
Ward Bdy.
B.M. 356·7
C.R.
355
B.M. 356·9
354
CHELSEA GROVE
BISHOPS AVENUE
School
NORTHCOTE STREET
Presb. Church
COOKSON ST.
Vicarage
L.B
349
Cen. Ry. Sta. 1
P.H.
M.P.
B.M. 355·0
B.M. 341·6
ARTHUR'S HILL
LYNNWOOD TERRACE
P.O.
Baptist Church
Prospect Villa
LYNNWOOD AVENUE
ROAD
329
B.M. 323·6
Ward Bdy.
Schools
LANE
STREET
ELLIOTT TERRACE
NTINCK
311

In the next three sub-sections the history and general characteristics of terraced, semi-detached and detached houses in speculative housing developments is described, in order to understand the social, political and economic factors that affected the morphology, development and changes in popularity of each house type.

3.1.1. Byelaw terraced houses (1875-1918)

The early terraced houses can be traced to the development of grand palaces in seventeenth century London. Grand palaces were inspired by classical architecture and were inhabited by the most affluent households (Muthesius, 1982, p.7)[4]. They were located close to the town centre, and were likely to enclose an important square or park. Prior to the Industrial Revolution social status was measured by the proximity to the town centre (Fishman, 1987). Upper class households aspired to buy a house as close as possible to those focal points of wealth, commerce and power, but could not afford to live in a grand palace. To meet the growing demand, in the eighteenth century private speculators turned to the construction of large and medium sized Georgian grand terraces (Gorst, 1995, p.2; Muthesius, 1982, p.1). Georgian terraces consisted of identical houses arranged in a continuous row and embellished with classical decorative elements previously seen in the English grand palaces (Muthesius, 1982, p.7). Even though a terrace was a group of houses, it was designed to give an illusion of unity and to resemble one cohesive ‘palace’ rather than an amalgamation of individual houses (Gorst, 1995, p.2; Muthesius, 1982, pp.7-14). The origin of the name ‘terrace’ is not fully understood, however, it can be traced to houses built on elevated grounds (terraces). In the book *The English terraced house* Stefan Muthesius associates the earliest use of the term ‘terrace’ with the Adelphi Terrace of

Figure 3.3 - (On the left) Byelaw estate of terraced houses in Arthur’s Hill, Newcastle upon Tyne. Source: Ordnance Survey County Series 1:2500, 2nd Revision 1906-1939. Published: 1919, Landmark Information Group, Using: EDINA Historic Digimap Service.

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[4] Bedford House was an example of a Georgian grand palace. It enclosed the northern edge of the Bloomsbury Square in London (Muthesius, 1982, p.7). In the late eighteenth century the House was demolished.

1769[5] (Muthesius, 1982, p.14), which was situated on a platform overlooking the river Thames in London. However, the importance of the topographic elevation of the terraced house was lost, and nowadays a ‘terrace’ is defined by the Oxford Dictionary (2018) as: ‘a row of houses built in one block in a uniform style’. In the late eighteenth and early nineteenth century the construction of Georgian terraces was further fuelled by the emergence of a new upper middle class, e.g. lawyers, doctors, government officials and merchants (Muthesius, 1982, p.7). They aspired to live near the most affluent households, however could not afford to rent a large grand palace or terrace. A smaller terraced house located in a respectable area was a compromise that many aspired to.

During the Industrial Revolution important changes to the structure of the city and its perception amongst different social classes can be observed. With the increasing population growth many cities struggled to accommodate growing numbers of inhabitants in the pre-Industrial urban core. The perception of the advantages of the city started to fade when compared to its growing negatives: overcrowding, pollution, noise and unsanitary conditions. The city began to be viewed as corrupt and foul rather than as a place of social and economic opportunity. In the 1840s, most likely influenced by this negative perception, the popularity of terraced houses amongst the upper and middle class diminished (Muthesius, 1982, p.249). The new ideal was a detached, or at least a semi-detached, villa situated in a picturesque low density outer suburb (Muthesius, 1982, p.30; Rudin and Falk, 1999, p.14). In the book *Bourgeois Utopias: The Rise and Fall of Suburbia* Robert Fishman observed that during the Industrial Revolution the polarity of the English towns was reversed with status being measured by the distance from the urban core rather than proximity (Fishman, 1987). While the aspiration of the upper class to live in the countryside could be observed as early as the sixteenth century (Muthesius, 1982, p.3), the majority could not afford to move far away from the city. New advancements in private transport and road improvements coupled with the increasing separation of work and living

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5. Demolished in 1936 (Gater and Wheeler, 1937, pp.103-108).

enabled more upper and upper middle class households to move to outer suburbs and commute everyday to the city centre. The growing popularity of the Garden movement, suburban development and the increasing dissatisfaction with urban life affected the organisation of the estates of terraced houses. While the houses were always aggregated in continuous rows, the majority of Georgian grand terraces were part of square urban blocks. In order to shift the perception of a terraced house from an urban to a suburban dwelling, the houses were arranged in long linear blocks, which allowed for simultaneous access to the street from the front and the back. The blocks consisted solely of terraced houses, which simulated the homogeneity popular in the suburban areas. In order to further resemble the outer suburbs small gardens were introduced to the front of the houses to create an impression of a countryside. This type of arrangement can be seen for the first time in terraces alongside the Regent's Park in London, designed by the architect John Nash in the 1820s (Jensen, 2007, p.34; Muthesius, 1982, p.16).

With the flight of the upper class to the fringes, abandoned large houses in town centres were often subdivided and served as tenements for working class households. However, the rapid growth of the working class during the Industrial Revolution meant that the pre-Industrial urban cores were not capable of accommodating the increasing number of households. Because working class families relied on proximity to their workplaces as they could not afford a non-pedestrian commute, the subdivided tenements in city centres were overcrowded and increasingly unsanitary[6]. To combat those inhumane conditions the government introduced the Public Health Act in 1875. The Act enabled local authorities to improve sanitation, drainage and control newly built streets and houses in order to provide sufficient space for families. Byelaw housing, which came as a result of the new local laws, provided a distinct improvement to working class living conditions. Instead

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[6] Detailed study of the sanitary conditions of working class households was presented to the Houses of Parliament by Edwin Chadwick in his publication *Report on the sanitary conditions of the labouring population of Great Britain* (Chadwick, 1842). The study not only described the conditions of the homes but also the effects that those environments can have on the inhabitants' health.


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of enclosed courts and narrow dead end alleys, byelaws required wider and connected streets (Burnett, 1986, p.161) and introduced minimum (not mandatory at first) standards for internal and external domestic spaces (Brown and Steadman, 1987). The byelaws did not introduce rigorous constraints to the layout of the estate or the design of the house, however, private speculators used the minimum requirements to serve as a pattern for the majority of the new byelaw terraces. The mass development of the estates of byelaw terraced houses was aided by major advancements in public transport. Throughout the nineteenth century omnibuses, horse-drawn trams and railways were popularised (Muthesius, 1982, p.38). Further advancements in the late nineteenth and early twentieth century led to the electrification of trams and a substantial reduction in commuting costs for workmen in the Cheap Travel Act of 1886, which meant that majority of working

Figure 3.4 - Floor plan of a byelaw terraced house with two rooms and a scullery on the ground floor and three bedrooms on the first floor in Longford, Coventry, 1911. Based on the figure in (Burnett, 1978, p.165).

Figure 3.5 - (On the left) Byelaw terraced houses on Harley Terrace in Newcastle upon Tyne (Photograph by Author, taken on 28.09.2019).

class households could afford to move to the developing inner suburbs. At the turn of the twentieth century the estates of byelaw terraced houses sprouted in the inner suburbs of almost all English towns (an example is shown in Figure 3.3). Even though terraces were not fashionable amongst the upper class anymore, by the end of the nineteenth century the majority of English society lived in a byelaw terraced house (Muthesius, 1982, p.11) (Figure 3.5). Because byelaw terraced houses were so widespread when compared to the pre-regulation Georgian terraces, they are the subset of terraced houses focused on in this thesis.

The principle of the spatial organisation of the plan in an early terraced house is quite straightforward and can be summarised as two-up-two-down (Brown and Steadman, 1987; Muthesius, 1982, p.79), with a front and back room on the ground floor and two bedrooms on the first floor. However, the growing specialisation of functions and separation of sexes and ages in the nineteenth century influenced the fragmentation of the layout and the number of rooms increased. The typical byelaw terraced house with a back projection consisted of two rooms and a scullery on the ground floor and two (or three) bedrooms on the first floor (see Figure 3.4). Most of the byelaw terraced houses were two storeys high[7] with a narrow frontage, typically between 3 and 5 metres (Brown and Steadman, 1987). The aggregation of terraced houses in rows allowed them to achieve high densities, with a typical density for byelaw terraces being between 60 and 80 du/ha (dwellings per hectare) (URBED, 2005, p.6). The length of the row depended solely on the availability of the land and the design decision of the speculator, as there were no imposed limits. In some cases the length of a terrace could surpass 800 feet (244 metres), like in Silkstone Row[8], in Altofts, West Yorkshire (Muthesius, 1982, p.5) or in Holly Avenue, in Jesmond, in Newcastle.

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[7] Interestingly, the height of the pre-regulation Georgian terraces varied significantly. The terraces had between one and six storeys (Muthesius, 1982, p.6).

[8] Demolished in the late nineteenth century.

The inter-war period marked a decline in the popularity of the terraced house, which in the early decades of the twentieth century was associated with accommodation for the poor. The popularisation of private and public semi-detached houses after the First World War amongst all the social classes made the terraced house undesirable even for the working class families. However, the house type was not completely abandoned but rather transformed into shorter rows of six to eight houses and incorporated into predominantly semi-detached estates. In the mid and late twentieth century short terraces were encouraged by the housing manuals as ways to break monotony in the estates of predominantly semi-detached houses[9]. With time the terraced house slowly lost the pejorative association and was even preferred over a smaller semi or detached house (Burnett, 1978, p.341). In the late twentieth and early twenty-first century new housing estates consisted mostly of detached houses with the short terraces included as a more affordable option.

3.1.2. Semi-detached houses (1918-1980)

The history of a semi-detached house is intertwined with the history of suburban development, the Industrial Revolution and the emergence of a new middle class. The earliest examples of semi-detached houses can be found between late seventeenth and late eighteenth century in the English countryside (Jensen, 2007, pp.26-27). In the majority of cases the early semi-detached cottages were built for labourers by the affluent rural landowners (ibid., p.142)[10]. At the turn of the seventeenth century, semi-detached houses were also built in towns, however as Alan Jackson remarks in the book *Semi-detached London,* it was 'an exception rather than a rule' (Jackson, 1991). Finn Jensen, in the book *The English Semi-Detached House,* adds that until the late eighteenth century, and thus

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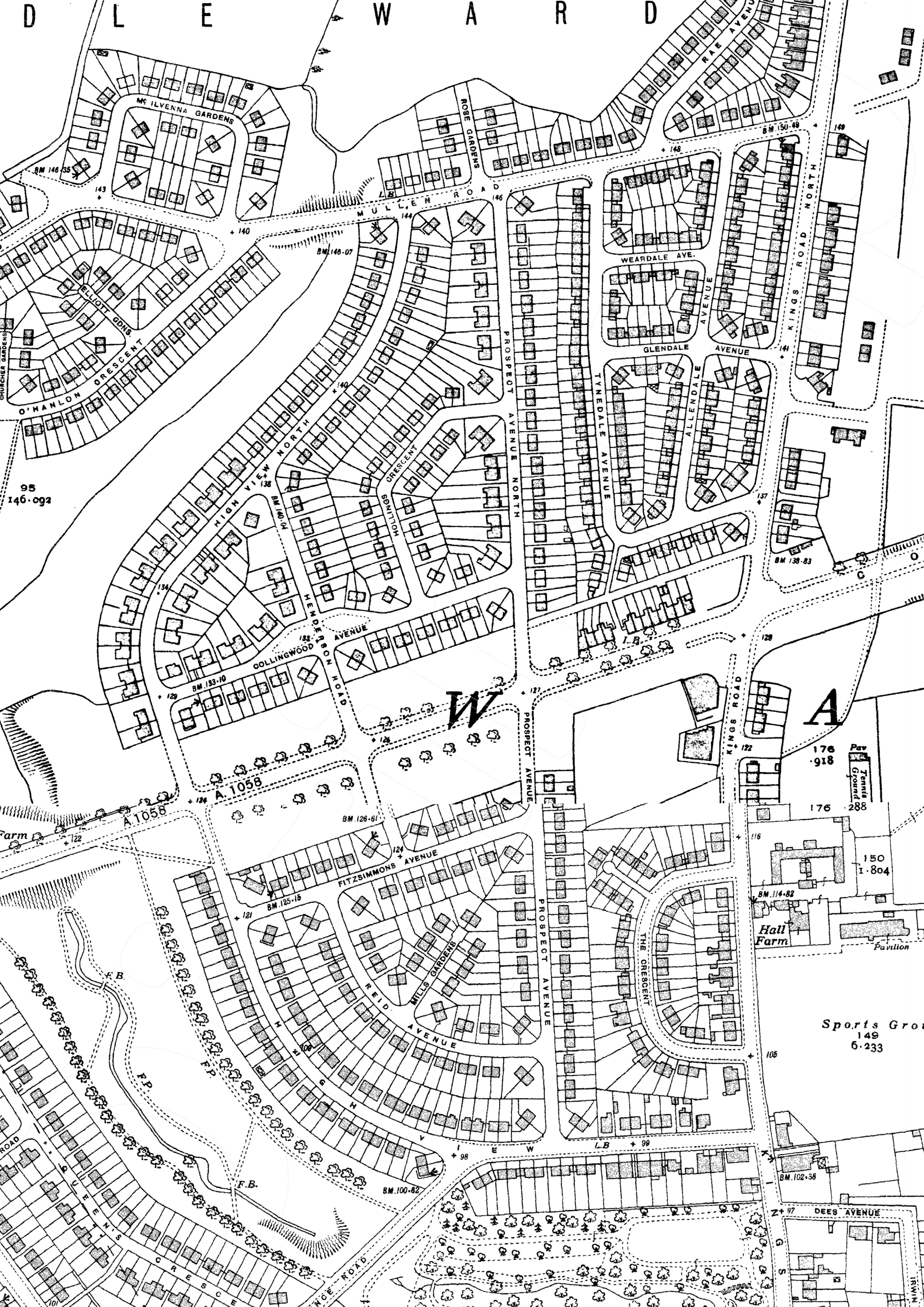
[9] For example, in the Dudley Report of 1944, there is a section solely dedicated to the advantages of incorporating terraced houses in the design of the new estates.

[10] Finn Jensen in his book *The English Semi-detached House* provides examples of rural estates of semi-detached houses, e.g. at Chippenham, Cambridgeshire built by Lord Oxford in the late seventeenth century (Jensen, 2007, pp.26-27), in Houghton Village built in the early eighteenth century (ibid., p.28), and at the village of Milton Abbas built by Earl of Dorchester between 1771 and 1790 (ibid., p.29). John Burnett in his book *A Social History of Housing* mentions an estate of semi-detached cottages in Holkham, Norfolk built by Earl of Leicester in the early nineteenth century (Burnett, 1978, p.51).


D L E W A R D
McILVENNA GARDENS
ROSE GARDENS
RAE AVENUE
BM 146·35
143
MULLEN ROAD
L.B
144
146
+ 140
BM 146·07
ELLIOTT GDNS
O'HANLON CRESCENT
CHURCHIER GARDENS
95
146·092
HIGH VIEW NORTH
138
134
BM 140·04
140
HOLLINGS CRESCENT
PROSPECT AVENUE NORTH
TYNEDALE AVENUE
WEARDALE AVE.
GLENDALE AVENUE
AVENUE
ALLENDALE AVENUE
KINGS ROAD NORTH
BM 150·49
+ 148
149
141
137
BM 138·83
C
O
HENDERSON ROAD
COLLINGWOOD AVENUE
133
BM 133·10
129
L.B.
128
W
127
126
A
KINGS ROAD
122
176
·918
Pav
Tennis Ground
176
·288
A.1058
124
A.1058
Farm
122
BM 126·61
124
FITZSIMMONS AVENUE
BM 125·15
121
PROSPECT AVENUE
116
150
1·804
BM 114·82
Hall Farm
Pavilion
MILLS GARDENS
REID AVENUE
THE CRESCENT
Sports Grou
149
6·233
105
HIGH VIEW
F.B.
F.P.
F.P.
L.B
99
98
BM 100·62
F.B.
KINGS
BM 102·38
97
DEES AVENUE
ROAD
QUEEN'S CRESCE
NCE ROAD
101
IRWIN

well into the Industrial Revolution, it was difficult to find any significant number of semi-detached houses in towns (Jensen, 2007, p.30), and the Georgian terrace was still the preferred housing type for the upper and middle class.

At the end of the eighteenth and early nineteenth century estates of semi-detached houses started to be developed in and around London (ibid., p.33). With the construction of estates of semi-detached houses for affluent Londoners by architects like John Nash[11], the semi-detached house gained respectability in the eyes of the upper class (ibid., p.34). By the 1840s the popularity of Georgian terraces among the upper and middle class diminished (Muthesius, 1982, p.249) and while the detached villa was still the ideal house type, it was unachievable for most who were happy to settle for a semi-detached house located in a respectable suburban estate (Burnett, 1978, p.251). This change in taste cannot be attributed only to the influence of the most popular architects at the time. It is undoubtedly connected to a number of socio-economic changes that took place in the late eighteenth and early nineteenth century, for example: increased segregation between social classes and the emergence of a new middle class (Burnett, 1978, p.251; Carr and Whitehand, 2001, p.7), an increasing separation between work and domestic life, and religious and ideological movements that asserted that, in comparison to the suburban, 'urban life is fundamentally corrupt' (Carr and Whitehand, 2001, p.7). Developments in public transport, especially electric trams, extended the possible commute between work and home (Burnett, 1978, p.191) and thus made it achievable to live further away from the city and closer to the idealised countryside. The Garden City movement (in particular the 1906 Hampstead Garden Suburb Act) influenced the design of new estates

Figure 3.6 - (On the left) An estate of semi-detached houses in Wallsend, Newcastle upon Tyne. Source: Ordnance Survey County Series 1:2500, 3rd Revision 1924-1949. Published: 1937, Landmark Information Group, Using: EDINA Historic Digimap Service.

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[11] Examples of the first estates of semi-detached houses in London are e.g.: the St. John's Wood estate built in the early nineteenth century (Jensen, 2007, pp.35-36), the Eyre estate which was designed in 1794, however, the construction was delayed by the war with France and resumed between 1830s and 1840s (ibid., pp.35-36), and the very influential Park Village West and Park Village East built on the east side of Regent's Park by John Nash in 1824 (ibid., p.34).

which was characterised by a curvilinear loop pattern with a few cul-de-sacs instead of a highly interconnected street network of the Victorian estates. The newly built estates were generously laid out with houses organised in low (when compared to the Victorian terraces) densities of 30 to 40 du/ha for Garden cities and 15 to 30 du/ha for suburban estates of semi-detached houses (URBED, 2005, p.6). The suburban estates were viewed as a retreat from the overcrowded, stressful, noisy and unhealthy urban life. Additionally, they allowed for the community of certain social classes to create private homogeneous enclaves (Burnett, 1978, p.255). It was as Lewis Mumford described in the book *The City in History* ‘the collective attempt to lead a private life’ (Mumford, 1961, p.486).

In the aftermath of the First World War, England had to face multi-layered housing problems: housing shortage, overcrowding, and a growing population that could not afford to live in healthy and satisfactory housing (Burnett, 1978, p.140). The popular perception that market forces can sustain the provision of houses was challenged and the government decided to aid the private speculative developers in the construction of new houses. Local authorities became an important provider of housing and because of governmental involvement in the inter-war period, semi-detached houses became widely accessible to working-class households (Carr and Whitehand, 2001, p.6). During the inter-war period estates of semi-detached houses were developed by both the private and public sector, and the semi-detached house became the most popular housing type, surpassing the terraced house.

The name ‘semi-detached’ stems from the position of the house on the plot in relation to the neighbouring units. Instead of being positioned in the middle of the plot and thus detached from both neighbours, the semis were organised in pairs and shared a common wall with one neighbouring house. The coupling of two semis in a pair meant that they were a less expensive alternative for those who aspired to but could not afford a detached house. The illusion of separateness between two houses was very important for the inhabitants, thus the front entrances were mostly positioned as far apart as possible, preferably on the opposite sides of the house (Carr and Whitehand, 2001, p.50). The private speculators quickly realised that visible separateness and individuality were more important to the potential buyers than internal layout and economic factors. Since the Addison Act of 1919 until the late twentieth century, the majority of semi-detached houses shared similar standardised room configuration with little variation, called the universal plan (see Figure 3.7). The plan of a universal semi consisted of three rooms on the ground floor, and three bedrooms and a bathroom on the first floor (Allen, 1934, p.145; Burnett, 1978, p.276; Carr and Whitehand, 2001, p.49; Jensen, 2007, p.151). The main differences in the floor plan between semi-detached houses were not in the configuration of the rooms but rather their sizes (Jensen, 2007, p.158). Despite the lack of variation in the layout, the three bedroom semi was sufficient in the eyes of the middle-class. It provided space to accommodate different ages and sexes, separate living from eating, and proper lighting and ventilation of the rooms (Burnett, 1978, p.277). The front of the house was still perceived as a status symbol that represented outwards the social class, taste, wealth and aspirations of the household (Prizeman, 1975). As Gordon Allen pointed out, the design of a façade was a matter of psychology rather than architecture (Allen, 1934, p.149). The private speculators understood that the social significance of architectural styles and external elements on the façade can be more important than practical and economic considerations[12] (Brown and Steadman, 1987). For example, a two-storey bay window was an obvious indication of a semi built in a private, rather than public, estate (Burnett, 1978, p.271).

The popularity of semi-detached houses meant that vast numbers of new houses were built and many of them were built hastily in order to meet the increasing demand. The quality of houses and streets suffered, especially in the estates built by private speculators

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12. During the inter-war period the local authorities built houses in a neo-Georgian style. The private speculative builders tried to avoided the neo-Georgian features and instead applied Tudorbethan or mock-Tudor style to façades of their houses (Jensen, 2007, p.151). After the Second World War the local authorities abandoned the neo-Georgian style, which was promptly adopted by the private speculators (or a similar neo-Queen Anne style) (ibid., p.217).


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(Horsey, 1985, p.154), which, in most cases, lacked a plan and were developed until the 'land ran out' (Burnett, 1978, p.255). The monotony of many estates of semi-detached houses was recognised by many anti-suburb architects and town planners in the 1930s (Allen, 1934, p.140; Carr and Whitehand, 2001, p.17) and captured by George Orwell in a novel *Coming Up for Air* (Orwell, 1939):

> 'Do you know the road I live in – Ellesmere Road, West Bletchley? Even if you don't, you know fifty others exactly like this. You know these streets fester all over the inner-outer suburbs. Always the same. Long, long rows of little – semi-detached houses'.

Even though the semi-detached house and the suburban lifestyle was discouraged by the architects, planners, and governmental reports and manuals (e.g. 1944 Dudley Report), a survey conducted by the National Housebuilders Registration Council in the 1970s showed that 85 per cent of respondents would rather live in a detached or semi-detached house in

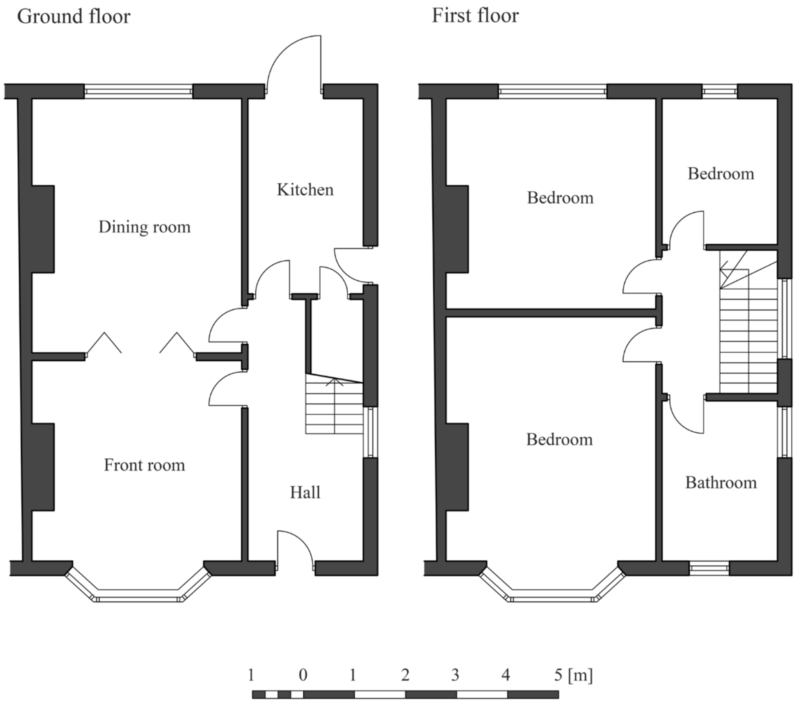

Figure 3.7 - Universal floor plan of a semi-detached house based on a figure in (Jensen, 2007, p.159).

Figure 3.8 - (On the left) Semi-detached houses on Belle Vue Avenue in Newcastle upon Tyne (Photograph by Author, taken on 28.09.2019).


BOLDON COLLIERY
Allotment Gardens
Homes
Shelter
West View
Bedeburn
Westholme
Montrose
Tyneholme
Normount
Airville
Vicarage
29.3m
Hedworth Parish Church St Nicholas
118
29.0m
28.0m
Shelter
Hedworth Lane Primary School
Crown Hotel (PH)
Wilton Cottages
El Sub Sta
Cross Lodge
PH
TCB
LB
30.2m
29.6m
29.3m
1 to 4
Shelter
Coronation Park
Donkins Street
Toppings Street
Fenwicks Street
El Sub Sta
Drain
ETL
Ward Bdy
CR
El Sub Sta
Henley House
Play Area
Shelter
10 to 30
L Twr
Ramp
Cinema
Shelters
El Sub Sta
Filling Station
The Storybook (PH)
El Sub Sta
LBs
Leven House
7
8 & 9
10
11a
11b
12
13
14
15
16
1
2
3
Boldon Business Park

the suburbs than in a larger terraced house in the city centre (Edwards, 1981, p.234).

In the late twentieth century the popularity of semi-detached houses amongst the middle class started to fade. The semi-detached houses started to be pejoratively associated with public housing estates for the lower classes, mainly because it became difficult to distinguish between private and public developments. In the 1980s the new Conservative government encouraged private housing development mostly through a relaxation of planning controls (e.g. abolished mandatory Parker Morris recommendations) (Jensen, 2007, p.220). The detached house became the preferred housing type in the new private speculative estates (ibid., p.220). Even though the popularity of the semi-detached houses diminished, the type was not abandoned. In estates of predominantly detached houses in the late twentieth and early twenty-first century semi-detached houses were often provided as a more affordable option.

3.1.3. Detached house (1980-2018)

In a similar manner to early semi-detached houses, the speculative development of detached houses can be traced to the countryside where affluent landowners built detached cottages for the labourers (Burnett, 1978, p.32)[13]. In the eighteenth century small estates of detached houses were built in and around London (e.g. Belsize estate in Hampstead) (Carr and Whitehand, 2001, p.3; Olsen, 1976, p.187; Thompson, 1974, pp.32-33), however their number was negligible. In the end of the nineteenth century an interesting sub-type of the detached house was brought to England from colonial India - a single-storey bungalow[14]

Figure 3.9 - (On the left) An estate of detached houses in Boldon Colliery, County Durham. Source: OS MasterMap. Scale 1:2500. Updated: 2018, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service.

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[13] In the late eighteenth century a few affluent landowners introduced the model cottage movement to combat the unsanitary conditions in labourers' cottages (Burnett, 1978, p.47), e.g. Blaise Hamlet commissioned by John Harford (ibid., p.49), cottages at Cadrington in Bedfordshire commissioned by John Howard in 1760s (ibid., p.44), and Charist Land Company cottages built in 1847 (ibid., p.52).

[14] Bungalows were mainly detached, however, a significant number of semi-detached bungalows was also constructed (Jensen, 2007, p.22).

(Burnett, 1978, p.211). In the early stage of development, the bungalow was mostly built for the upper class, however by the first decade of the twentieth century speculative builders, like P. H. Harrison, introduced bungalows to the wider middle class as a more affordable alternative to a suburban villa or as a retirement home (ibid., p.212). Until the late twentieth century the number of detached houses in speculative estates was still small and they were largely incorporated into the estates of predominantly terraced or semi-detached houses (Carr and Whitehand, 2001, p.41; Jensen, 2007, p.14).

The last two decades of the twentieth century were a period of economic volatility and ideological change. House prices fluctuated and the housing boom of the 1980s was quickly followed by the recession in the early 1990s. In the 1980s the government heavily encouraged owner-occupation (Burnett, 1987, p.289; Burnett, 1987, p.315) and, through the Right to Buy scheme, allowed tenants of public housing estates to buy back their homes for a discounted rate. Moreover, local authorities were no longer developing new houses and the responsibility for the provision of public housing was transferred to housing associations. Public housing was no longer perceived as accommodation for households with different social statuses but rather for 'those in the greatest need' (Hills, 2007, p.2). The late twentieth century was also a time of many technological advancements which were reflected in improved regulations and guidelines, e.g. performance-based 1985 Building Regulations (NHBC, 2015, p.25). Safety and security became very important in the design of houses. The rising concerns about security were reflected by 1989 Secure by Design scheme, which aimed to reduce crime not only through preventive measures within each house (more robust locks, windows and doors) but also the design of housing estates. The concept of designing out crime was popular at the end of the twentieth century and was being explored in the US since the 1970s as a theory of defensible space (Newman, 1972). The perpetuated fear of crime and strangers was one of the causes for the change of layouts in housing estates into non-connecting cul-de-sac designs (see Figure 3.9). The aim of such design was to discourage strangers from entering the estate in order to create an isolated environment for the inhabiting community. The isolationist design of the estate was partly enabled by the widespread ownership of cars. In the 1980s 60% of English households owned at least one car, with this number growing to 73% by the end of the century[15]. New estates continued to be built on the fringes of cities, however, because of the increase in the car ownership, the development was not constrained anymore by the reach of public transport. In the late twentieth century a sharp increase in the construction of detached houses can be observed, which rose from 22 per cent in 1969 to 41 per cent in 1980 (Burnett, 1978, p.327). Between 1987 and 2005 more than half of all new build single family houses in the private speculative developments were detached[16].

The detached houses were situated in the centre of the plot and thus physically detached from the neighbouring units. Separation was something that English people strived for since the beginning of the speculative mass housing. In the late twentieth century it was finally achieved by the many, not only the most affluent. As anthropologist Kate Fox in her book *Watching the English: The Hidden Rules of English Behaviour* stated ‘the English all want to live in their own private little box with their own private little green bit’ (Fox, 2014). However, the physical separation from the neighbours resulted in a decrease in the size of houses[17]. Moreover, the detachment of the house from neighbouring units was in many cases symbolic, with side yards not wide enough to allow for incremental extensions. As shown in the Figure 3.10, the organisation of the common floor plan resembled that of the universal plan in the semi-detached houses with three rooms on the ground floor (kitchen, living room and dining room) and four rooms on the first floor (three bedrooms and a bathroom). The detached houses while typified were characterised by more complex exteriors (NHBC, 2015) that varied depending on the individual housing estates.

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15. The data was accessed in March 2019 through the Department for Transport - *NTS0205: Household car availability: England*.
16. The data was accessed in March 2019 through the National House Building Council - *NHBC New Home Statistics Review Q1 2018.*
17. In 2011 the Royal Institute of British Architects published a report which concluded that the average three bedroom detached house was smaller than the recommended by space standards minimum (Roberts-Hughes, 2011).

In the early twenty-first century Nicholas Stern published a report on *The Economics of Climate Change* (Stern, 2006) in which he concluded that climate change is going to have a severe impact on the economy and livelihood of the United Kingdom. The report affected the housing industry and environmental issues and sustainability became important considerations in the design of new homes. To guide private speculators, the government introduced a number of environmental sustainability standards and policies, with the most notable being the Code of Sustainable Homes of 2006. The concerns about the environmental sustainability of housing extended to the use of land. To combat extensive urban sprawl and development on the greenfield sites, the government began to encourage, through regulations and guidance, housing development on previously-developed brownfield sites (e.g. through Planning Policy Guidance 3 introduced in 1992) (Wong and Schulze Bäing, 2010). In addition to sustainability, affordability of new build houses became important. In 2002 it was estimated that only 37% of households could afford to purchase a house, which was 10% less when compared to the late 1980s (NHBC, 2015,

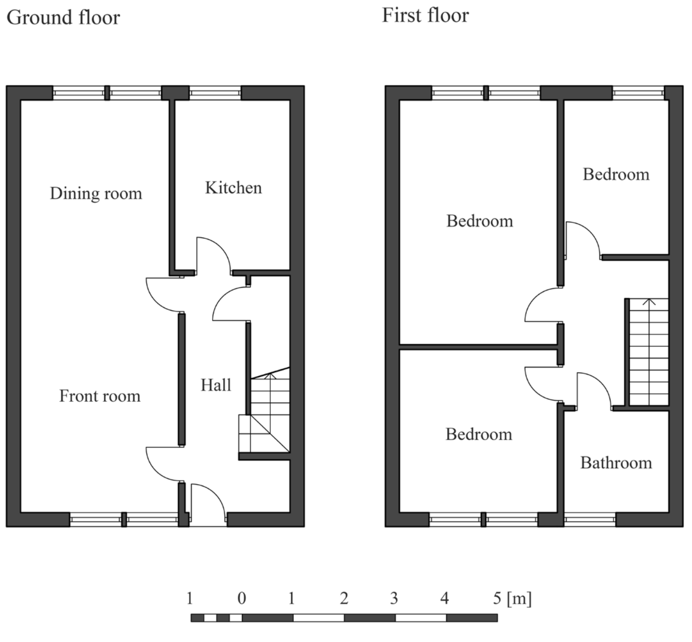
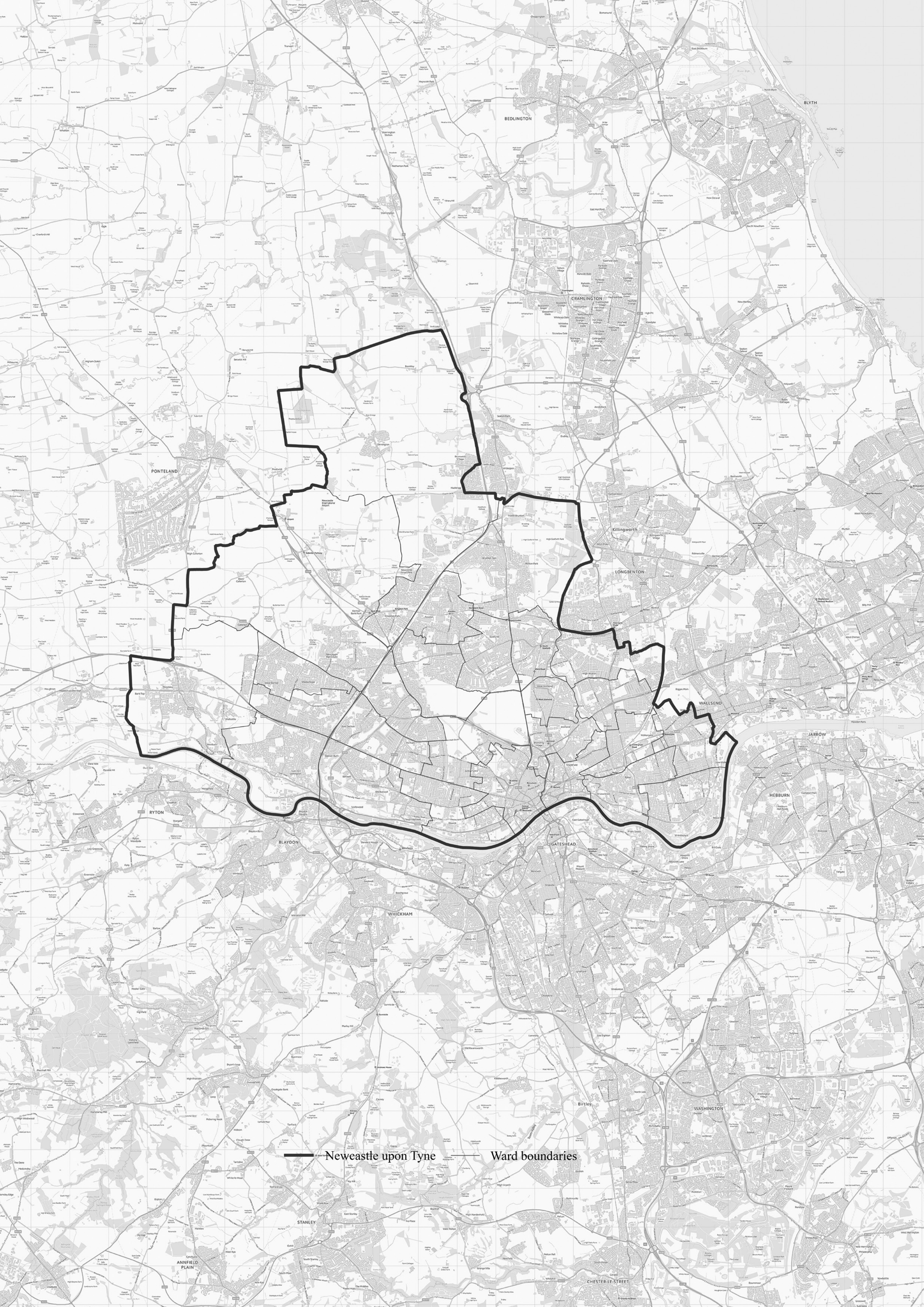


Figure 3.10 - Floor plan of an average three bedroom detached house based on a figure in (Roberts-Hughes, 2011, p.29).

Figure 3.11 - (On the left) Detached houses on Yeavering Close in Newcastle upon Tyne. (Photograph by Author, taken on 28.09.2019).


BLYTH
BEDLINGTON
CRAMLINGTON
PONTELAND
Killingworth
LONGBENTON
WALLSEND
JARROW
HEBBURN
RYTON
BLAYDON
GATESHEAD
WHICKHAM
Birtley
WASHINGTON
STANLEY
ANNFIELD PLAIN
CHESTER-LE-STREET
Newcastle upon Tyne
Ward boundaries

p.32). The government began encouraging the private speculators through guidelines and planning policy to include affordable options when developing new housing estates. Paired with the growing concerns on the increasing social and economic inequalities between neighbourhoods (Meen et al., 2005), the homogeneity common to the housing estates was challenged and mixed communities were encouraged. As a result, the number of detached, semi-detached and terraced houses built between 2006 and 2018 was comparable[18].

The development of housing estates between the nineteenth and early twenty-first century is a history of mass construction of compact small to medium-sized individual houses (Muthesius, 1982, p.145) in three types: terraced, semi-detached and detached. The changes in popularity between types was dictated by socio-economic changes and shifts in attitudes towards neighbours, community and strangers. The next section investigates whether housing development in Newcastle upon Tyne followed the patterns observed on the national scale.

3.2. Housing development in Newcastle upon Tyne

While the origins of Newcastle can be traced to Roman times, the spatial structure of the town that we can see today emerged under Norman rule in the eleventh century (Buswell, 1992a, p.15). Since the founding of the town, Newcastle was closely tied to the river Tyne as the wealth came mainly from coal mining and (national and international) coal shipping (Buswell, 1992b, p.19). In the seventeenth century Newcastle still showed characteristics of a medieval town, with most of the urban tissue contained within the city walls and not much suburban development. The street network of Newcastle was organised around an important north-south route which connected London and Edinburgh.

Figure 3.12 - (On the left) Newcastle upon Tyne. Source: OS MasterMap. Scale 1:25000. Updated: 2018, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service.

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[18] The data was accessed in March 2019 through the National House Building Council - *NHBC New Home Statistics Review Q1 2018.*

In the mid to late eighteenth century the economic activity in Newcastle was transformed. Affected by the Industrial Revolution, Newcastle was to experience extensive development in heavy engineering, shipbuilding and chemical industries, while still keeping an important role in coal mining and coal shipping (Austin, 1992, p.42). The rapid population growth during the Industrial Revolution resulted in the increasing overcrowding and worsening sanitary conditions in the city centre. Many affluent people started to move to the newly developing suburban areas outside of the city walls. At that time, we can observe important changes to the morphology of Newcastle. The demolition of the medieval city walls resulted in accelerated suburban growth and reorganisation of the urban core (Sill, 1992a, p.25). In the nineteenth century the rapid population growth and industrialization alongside the river led to the extensive growth of the town to the east and the west (Sill, 1992b, p.28). Outward suburban development led to the incorporation of five townships into the borough of Newcastle in 1835 (Byker, Elswick, Jesmond, Heaton and Westgate) (ibid., p.28). The growth to the north was constrained by extensive moorlands, Town Moor and Nuns Moor, and to the south by the river Tyne. In addition to the outward development, in the mid nineteenth century the town centre underwent major spatial reorganisation to accommodate new commercial and financial functions in order to attract more affluent people back to the urban core (ibid., p.28). The redevelopment and construction of neoclassical buildings, like Grainger Market and Central Station, elevated the status of the centre and drew in banking and financial services (Taylor and Buswell, 1992, p.31). However, the redevelopment did not change the attitude of the upper classes towards living in the city centre.

In the first half of the nineteenth century the upper and middle class favoured living in a Georgian terraced house in the inner suburbs outside of the city walls, while the working class families mostly lived in the tenements in the town centre. The majority of those tenements were subdivided older houses abandoned by the affluent upper class (Taylor, 1992, p.40). Following national trends, in the second half of the century the majority of the Victorian households, including the lower middle and working class families, lived in a byelaw terraced house. The typical floor plan of a byelaw terraced house in Newcastle did not differ from the terraces seen in the other parts of England. The simple two-up-two-down layout with a kitchen and a scullery in the back projection was common (ibid., p.40). Moreover, many working class households in the Tyneside area lived in terraced houses that consisted of two flats, one situated on the ground floor and the second on the first floor. This regional variation was called a Tyneside flat and was a response to the 1850-1871 Town Improvement Acts (ibid., p.40). The origin of this type is difficult to trace, however the proximity to Scotland where flats were more common than in England might have been an important factor (Muthesius, 1984).

With the rapid suburban development of Newcastle and nearby satellite villages (e.g. Gosforth and Kenton) in the late nineteenth century, there was an increasing demand for better public transport. At that time Newcastle relied on the coast railway line between Newcastle and Monkseaton (known later as North Tyneside Loop) and on the horse-drawn trams (France, 1992a, p.44). At the turn of the twentieth century the horse-drawn trams were substituted by electric trams, which allowed for further extension of the tram lines into the fringes of the city (ibid., p.44). The popularisation of the motor car and high maintenance cost led to the reduction of the number of trams in favour of buses and trolleybuses, and finally their discontinuation in the 1950s (ibid., p.44). To aid the growing number of commuters a metro line was constructed in the 1980s (France, 1992b, p.69) in place of the North Eastern Railway.

The twentieth century witnessed an important change in the economic activity of Newcastle. The decline in manufacturing and coal trade was followed by a shift into service-orientated employment, with the majority of jobs being in retail, administration and governmental agencies (Austin and Buswell, 1992, p.66). The city centre and the riverside, previously accommodating the heavy industries, were transformed to accommodate offices and shops.

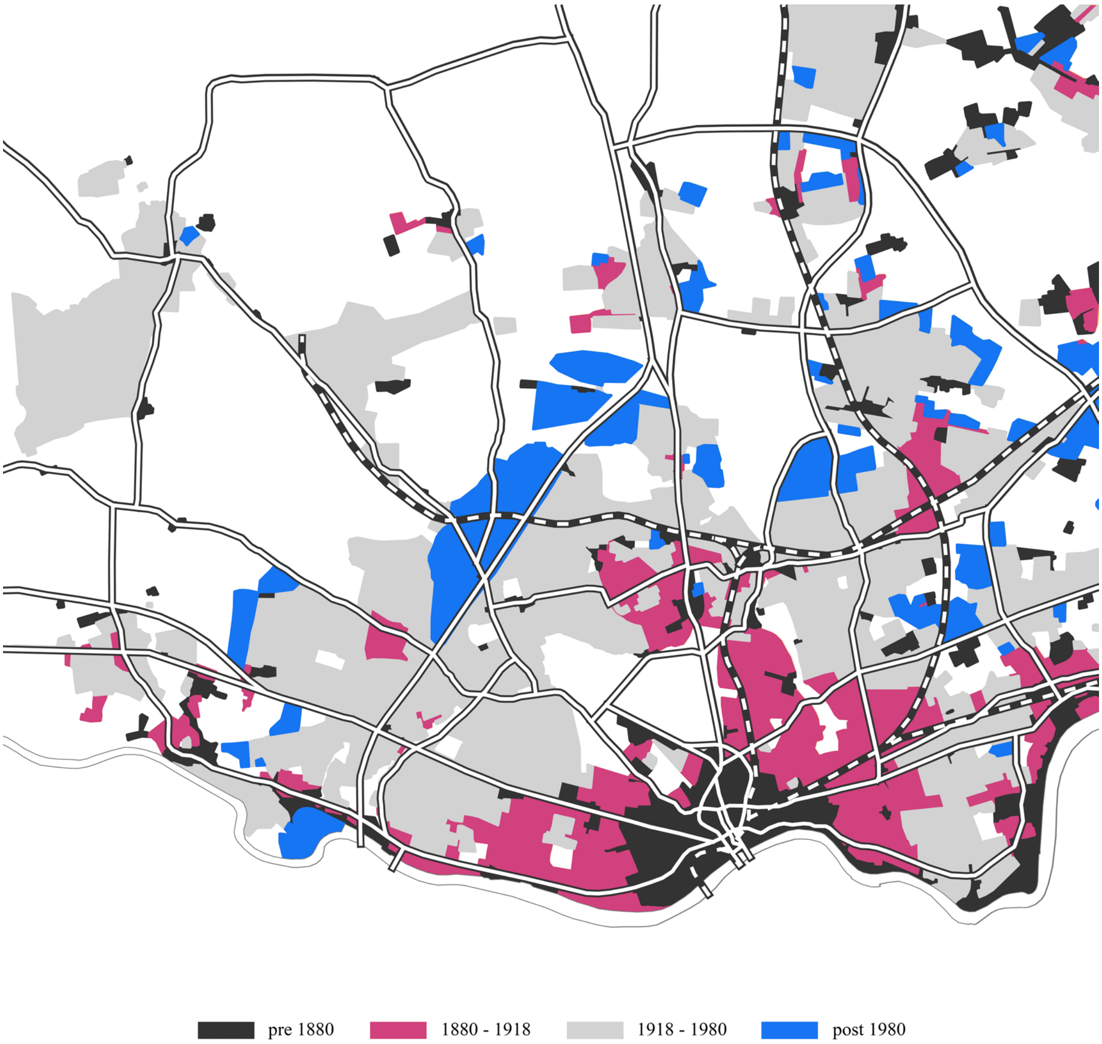


Figure 3.13 - Development of built-up area in Newcastle upon Tyne based on the Ordnance Survey maps.

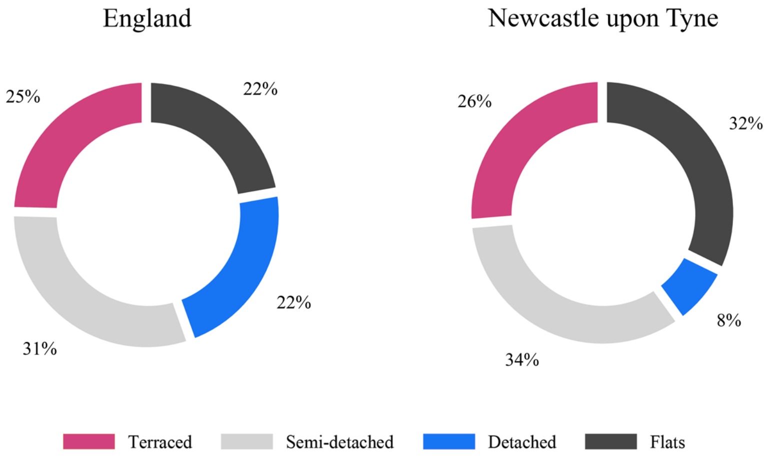
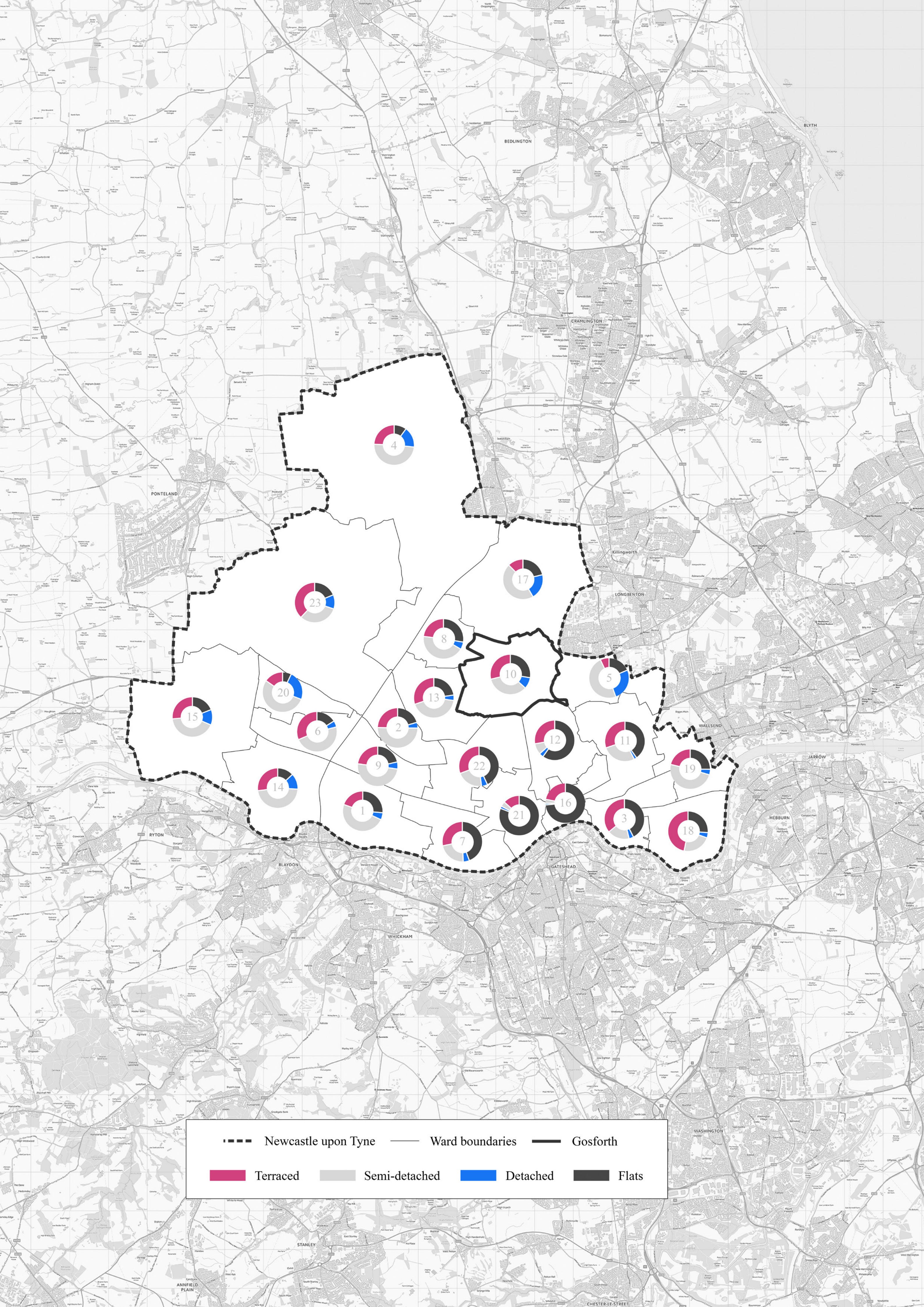


Figure 3.14 - Distribution of types of houses in England and Newcastle upon Tyne in 2011. For detailed data and source, see Appendix A.3 and A.4.

In 1904 and 1935 Newcastle expanded further incorporating more townships (Benton, Benwell, Denton, Fenham, Kenton, and Walker). During the inter-war period, in line with the national trends, the local authority in Newcastle became a large contributor in the provision of housing and the semi-detached house became the most popular housing type in both private and public estates. The development of the suburban estates was, as in other parts of England, heavily influenced by the Garden City movement and many housing estates were built as low density areas with semi-detached houses organised around curvilinear roads and cul-de-sacs. However, there were many housing estates where recommendations of the Garden movement on layout and streetscapes were not applied and the emphasis was placed on building as many semi-detached houses as possible. Private and public semis in Newcastle were built according to the universal plan with three rooms on the ground floor and three bedrooms on the first floor. After the Second World War suburban development on the fringes of the city continued and was heavily influenced by the popularisation of the private motorcar. The rise of car ownership led to high congestion in the centre of Newcastle, which prompted significant changes in the structure of the street network, with the most important one being the construction of the East Central Motorway in the 1970s (France, 1992c, p.57).

In the 1980s the United Kingdom entered an economic recession. Manufacturing, engineering and shipbuilding industries in Newcastle declined with many companies closing down. The unemployment in the manufacturing sector was high and many jobs in the service sector were laid off (Peck and Morphet, 1992, p.82). Local authorities no longer contributed to the development of new housing and the responsibility for the construction of new public housing was transferred to housing associations. The suburban development of private speculative estates continued on the fringes of the city alongside important routes and the metro line with detached houses being the most common house type in the new build estates. At the turn of the twenty-first century the service sector in Newcastle underwent major changes when 'night life' emerged as a new popular type


BEDLINGTON
BLYTH
CRAMLINGTON
PONTELAND
KILLINGWORTH
LONGBENTON
WALLSEND
JARROW
HEBBURN
RYTON
BLAYDON
GATESHEAD
WHICKHAM
STANLEY
WASHINGTON
ANNFIELD PLAIN
CHESTER-LE-STREET
4
23
17
8
10
5
20
15
13
6
2
12
11
19
9
22
14
1
21
16
3
18
7
Newcastle upon Tyne
Ward boundaries
Gosforth
Terraced
Semi-detached
Detached
Flats

of leisure targeting mainly the youth (Barke and Buswell, 1992, p.84). The city centre witnessed extensive residential development of smaller dwellings in multi-family houses related to social changes such as a decrease in household size (ibid., 1992, p.84). In the early twenty-first century, in line with the national trends, the environmental sustainability and affordability through a range of housing was encourage by the local authority (NCC and GC, 2015, pp.28-34).

Overall, the development of housing in Newcastle followed the national patterns described in Section 3.1 and is summarised in Figure 3.13. In 2011, the housing stock in Newcastle consisted of terraced houses (26%), semi-detached houses (34%), detached houses (8%) and flats (32%). When compared to the distribution of house types in England (see Figure 3.14), Newcastle has a higher number of flats and lower number of detached houses. The higher number of flats is most likely connected to the popularity of Tyneside flats, which were common in estates of terraced and semi-detached houses.

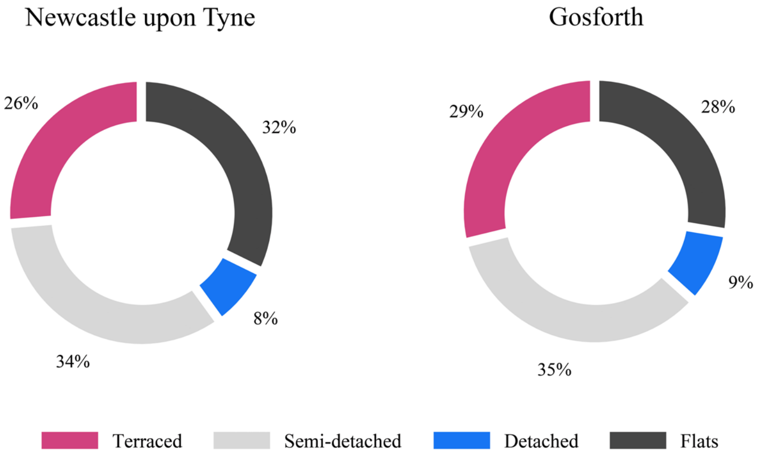


Figure 3.15 - Distribution of types of houses in Newcastle upon Tyne and Gosforth in 2011. For detailed data and sources see Appendix A.4 and A.5.

Figure 3.16 - (On the left) Gosforth. Source: OS MasterMap. Scale 1:25000. Updated: 2018, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service. For detailed data and sources see Appendix A.6.
The numbers indicate wards: 1-Benwell and Scotswood, 2-Blakelaw, 3-Byker, 4-Castle, 5-Dene, 6-Denton, 7-Elswick, 8-Fawdon, 9-Fenham, 10-Gosforth (West and East Gosforth), 11-Heaton (North and South Heaton), 12-Jesmond (North and South Jesmond), 13-Kenton, 14-Lemington, 15-Newburn, 16-Ouseburn, 17-Parklands, 18-Walker, 19-Walkergate, 20-Westerhope, 21-Westgate, 22-Wingrove, and 23-Woolsington.

3.3. Housing estates in Gosforth - case studies

As described in Section 3.1, the unit of analysis is a housing estate. In order to limit the impact of politico-geographic factors on the morphology of the estates, the choice of the housing estates was restricted to one geographic district in Newcastle. To allow for generalisation, we chose a district with population density and distribution of types of houses closest to the average for Newcastle as a whole. In the chosen districts every distinguishable housing estate is treated as a case study.

Newcastle upon Tyne is divided into administrative districts, known as wards, which are

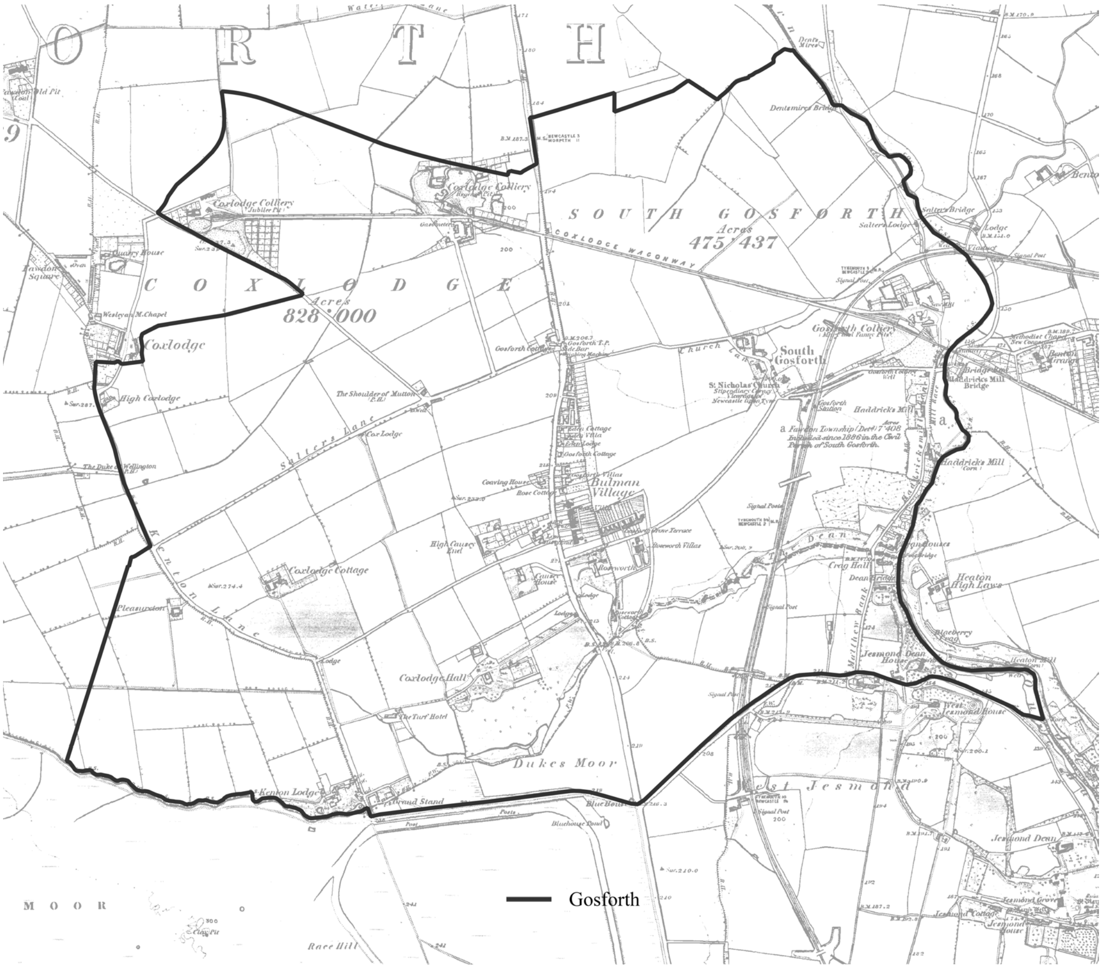


Figure 3.17 - Gosforth in the mid-nineteenth century. Source: Ordnance Survey County Series 1:10560, 1st Edition 1849-1899. Published: 1862, Landmark Information Group, Using: EDINA Historic Digimap Service.

designated to assure fair representation in the City Council (see Figure 3.16). Gosforth was chosen as a target district for this research since it has a population density[19] and a distribution of house types closest to the average for Newcastle as a whole (see Figure 3.15). It is a suburban district made up of two administrative wards: West and East Gosforth. The district is located north from the city centre and has developed on both sides of the Great North Road, an important trade route between London and Edinburgh. The origins of Gosforth can be traced to Saxon times when two townships of North and South Gosforth were found on the banks of the river Ouseburn (Welford, 1879, p.3). Gosforth as an administrative district was established in 1777 as a parish that consisted of seven townships: North Gosforth, South Gosforth, Coxlodge, Kenton, Fawdon, East Brunton and West Brunton (ibid., p.3). In the late eighteenth and through the majority of the nineteenth century Gosforth was predominantly agricultural with few villages and hamlets owned by affluent families, such as Brandling and Lisle. The development of the coal trade and opening of collieries and pits in Gosforth parish in the 1830s[20] stimulated rapid population growth in the district. On the six-inch Ordnance Survey map from 1862, shown in Figure 3.17, we can observe the beginnings of housing development around the pits and alongside the Great North Road. The urban core of modern Gosforth developed along the east side of the Great North Road (now the junction of High Street and Church Road) since 1825 (ibid., p.62). Further development continued to the south with the construction of multiple villas and grand terraces (e.g. ‘Gosforth Villas’) (ibid., p.63), which attracted upper and upper middle class families of merchants and tradesmen from Newcastle (ibid., p.63). Even though Gosforth became a desirable location for affluent households, the majority of males living in the parish at that time were either labourers or servants (87%)[21].

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[19] 19. According to the 2011 UK census, population density of Newcastle upon Tyne is 25 persons per hectare, while population density of Gosforth is 39 p/ha. For detailed data on each ward see Appendix A.7.

[20] 20. Fawdon and Coxlodge collieries were opened by 1831 (Welford, 1879, pp.4-5), while the Gosforth colliery opened in 1829 (ibid., p.48).

[21] 21. Based on the 1831 Census of Great Britain, ‘Population Abstract’ for the Gosforth Civil Parish.

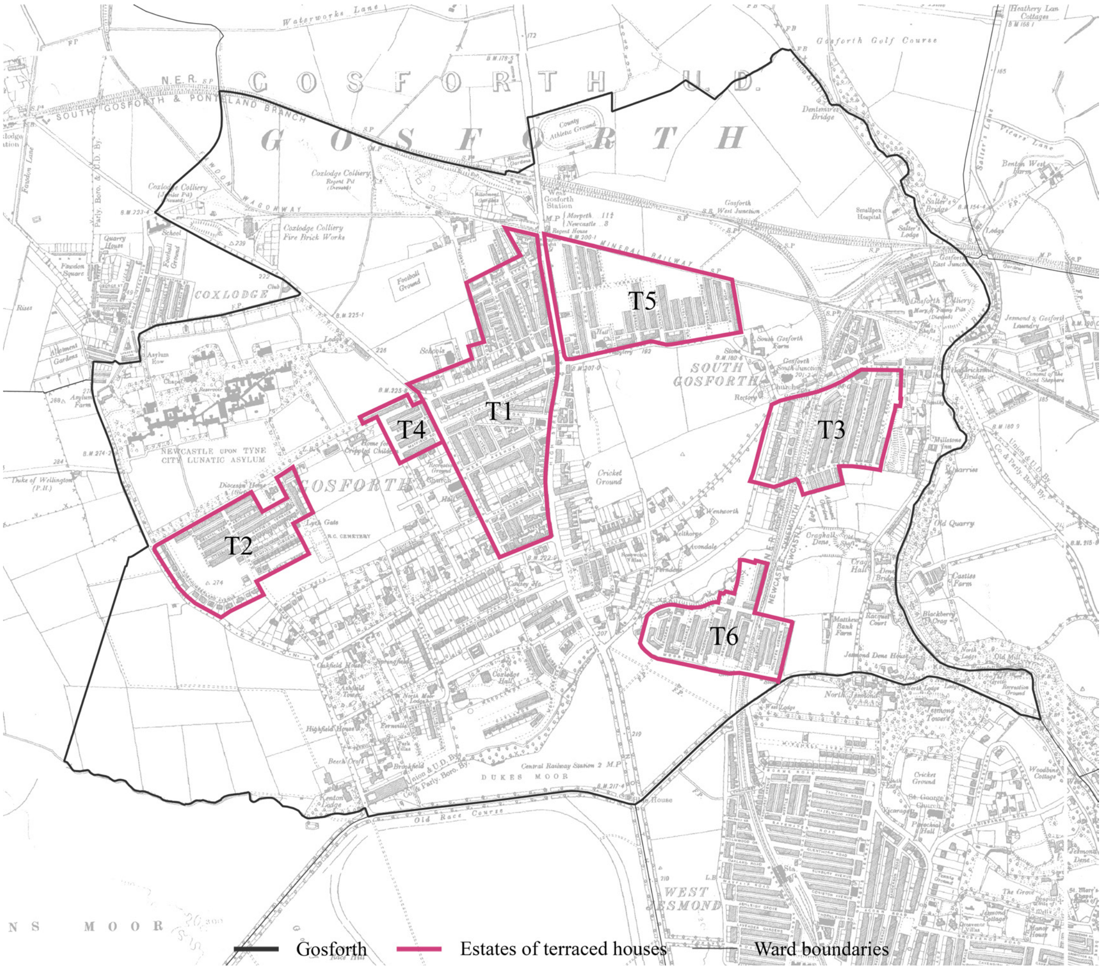

Figure 3.18 - Estates of terraced houses in Gosforth. Source: Ordnance Survey County Series 1:10560, 2nd Revision 1900-1949. Published: 1921, Landmark Information Group, Using: EDINA Historic Digimap Service.

Housing estate	T1	T2	T3	T4	T5	T6
Age	late XIX c.			early XX c.		
Gross area (ha)	22.5	10.2	10.6	2.4	13.8	8.6
Net area (ha)	15.3	7.6	6.5	1.4	9.6	4.5
Houses	550	347	347	112	464	327
Dwellings	693	443	515	155	662	409
Net Density (du/ha)	45	58	79	111	69	91
Land use						
Residential use (ha)	71.6%	97.8%	93.4%	97.4%	92.8%	96.4%
Non-residential use (ha)	24.8%	0.5%	5.1%	0.8%	5.8%	2.1%
Mixed use (ha)	3.6%	1.7%	1.5%	1.8%	1.4%	1.6%
Type of houses						
Terraced houses	85.3%	29.7%	59.9%	63.4%	73.3%	75.2%
Semi-detached houses	4.4%	42.7%	2.9%	0.0%	9.7%	1.8%
Detached houses	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%
Tyneside flats	7.5%	23.3%	34.6%	36.6%	12.7%	18.0%

Table 3.1 - General characteristics of estates of terraced houses in Gosforth.

3.3.1. The estates of byelaw terraced house (T1-T6)

Gosforth parish consisted of small villages dispersed in the rural area until the late nineteenth century. In 1872 the Local Board of Health consolidated the townships of Coxlodge and South Gosforth into Gosforth Urban District[22]. The rising interest in Gosforth as a residential suburb influenced the development of transport allowing for everyday commuting. In the 1860s an omnibus service between Gosforth and Newcastle was established (ibid., p.64), which was later superseded by a horse-drawn tram, and at the beginning of the twentieth century by an electric tram. At the same time the most common occupation amongst men in Gosforth was still related to coal mining (27.7%)[23], however the number of workers in the service sector was increasing. At the end of the nineteenth century rapid urbanisation occurred around the collieries, pits, quarries and the City Lunatic Asylum built in 1869 (now St. Nicholas Hospital) (ibid., p.74). Seven estates of terraced houses were developed on the agricultural land on both sides of the Great North Road, as shown in Figure 3.18. The housing estates were constructed alongside existing roads, e.g. Great North Road (now High Street), Salters Road, Church Road, and along the North Eastern railway tracks (now a metro line). As there were not many built-up areas, the only constraints to the development of new estates were the existing scarce street network and availability of the land.

The estates vary in size and occupy on average a gross area (total land area) of 11.4 hectares with an average net area (land available for development) of 7.5 ha. The average net density is 76 du/ha which corresponds to the densities of Victorian byelaw terraces (URBED, 2005, p.6). As shown in Table 3.1, the density varies between the estates and is affected by the number of either non-terraced houses or non-residential buildings. In

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[22] The name Gosforth Urban District was adopted in 1895, prior to that the district was called South Gosforth Local Board in 1872 and South Gosforth Urban District in 1894.

[23] Based on the 1881 Census of England and Wales, ‘Occupations of Males and Females in the Division and its Registration Counties’ for the Coxlodge Township/Civil Parish and South Gosforth Township/Civil Parish.

nearly all of the estates more than 90% of the net area is residential. The unusually high percentage of non-residential buildings can be observed in the estate T1 and was influenced by its location alongside the Great North Road, an important trading route between London and Edinburgh. Nearly all of the non-residential buildings in the estate T1 were positioned on, or in a close proximity to, the Great North Road. Most of the estates built in the late nineteenth and early twentieth century in Gosforth consisted predominantly of terraced houses. In each estate, however, there are a significant percentage of houses that are either semi-detached or Tyneside flats (on average 10.2% and 22.1% respectively). Tyneside flats were a popular alternative for working class households in the Tyneside area that could not afford to live in a terraced house, but from the early twentieth century semi-detached houses started to gain popularity influenced by the Garden City movement. In estates T1, T2, T3 and T5, semi-detached houses were built in undeveloped blocks at the later stages[24], because the housing preference amongst the middle class changed during the development of the estates.

The characteristics of the terraced houses in the sample can be categorised into two groups: late nineteenth century two-storey houses cladded with stone or buff-brickwork and early twentieth century two-storey houses with red brick façades and detailing around the openings. The red brick terraces can be found in the estates T2, T3, T4, T5 and T6, while the earlier terraced houses with stone or buff-brickwork cladding can be seen mostly in the estate T1[25]. Most of the terraced houses in the studied estates have a bay window, however whether it is a ground floor or two storey bay window varies within each estate.

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[24] In the estate T1 semi-detached houses were built in the west part of the estate along Linden Road and Elmfield Road in the early twentieth century. During the inter-war period semi-detached houses were built in the undeveloped blocks of the estates T2 (along Elmfield Grove, Elmfield Gardens, Glendale Avenue, Northumberland Avenue, and Oakfield Terrace) and T5 (alongside Alwinton Terrace and Bath Terrace). This late addition to the estate development resulted in the estate T2 being the only estate from the late nineteenth century in the sample that consisted predominantly of semi-detached houses (42.7%). In the estate T3 five pairs of semi-detached houses were constructed in the late twentieth century to occupy an empty block along Audley Road.

[25] Few terraces with façades cladded with buff-brickwork can be found on Wolsingham Road in the estate T2 and along the north side of Mayfield Road in the estate T4. In the estate T3 there is a row of stone terraced houses on the Rectory Road.

The bay window did not only allow for better ventilation and lighting in the sitting room but was also an expensive addition to the façade of the house which reflected the status of the household (Muthesius, 1982, p.198). In the sample terraced houses without a bay window are scarce and can be only found in the north parts of the estate T1 (along Elsdon Road, Hedley Terrace and Regent Road). Those differences in the treatment of the façades (variety in height of bay window, cladding or detailing) between the rows of terraced houses within an estate are likely to be caused by two factors. The estates were designed to accommodate all social classes and the houses intended for a particular social class were grouped along one street. This resulted in differences in the size of the houses and the façade treatment between streets within the same estate. Additionally, it was very likely that the estates in the late nineteenth and early twentieth centuries were developed by many small private speculators, rather than one, which would explain differences in character along the same street.

The majority of the urban form in the analysed estates is preserved in its original state with the exception of the northern part of the estate T1. In the 1970s nine rows of terraced houses and Tyneside flats in the estate T1 were demolished in the slum clearance programme. The blocks north of Henry Street were consolidated and office and public buildings (Gosforth Library and Gosforth Leisure Centre) were constructed. In the 1980s the urban blocks on the south side of Henry Street were consolidated and two rows of single-storey terraced houses and a block of flats were built. The terraced houses built at the end of the twentieth century are excluded from the analysis.

3.3.2. The estates of semi-detached houses (S1-S8)

The extensive residential development in Gosforth continued throughout the majority of the twentieth century with estates of semi-detached houses being built between the existing estates of terraced houses. Eight estates of semi-detached houses were developed

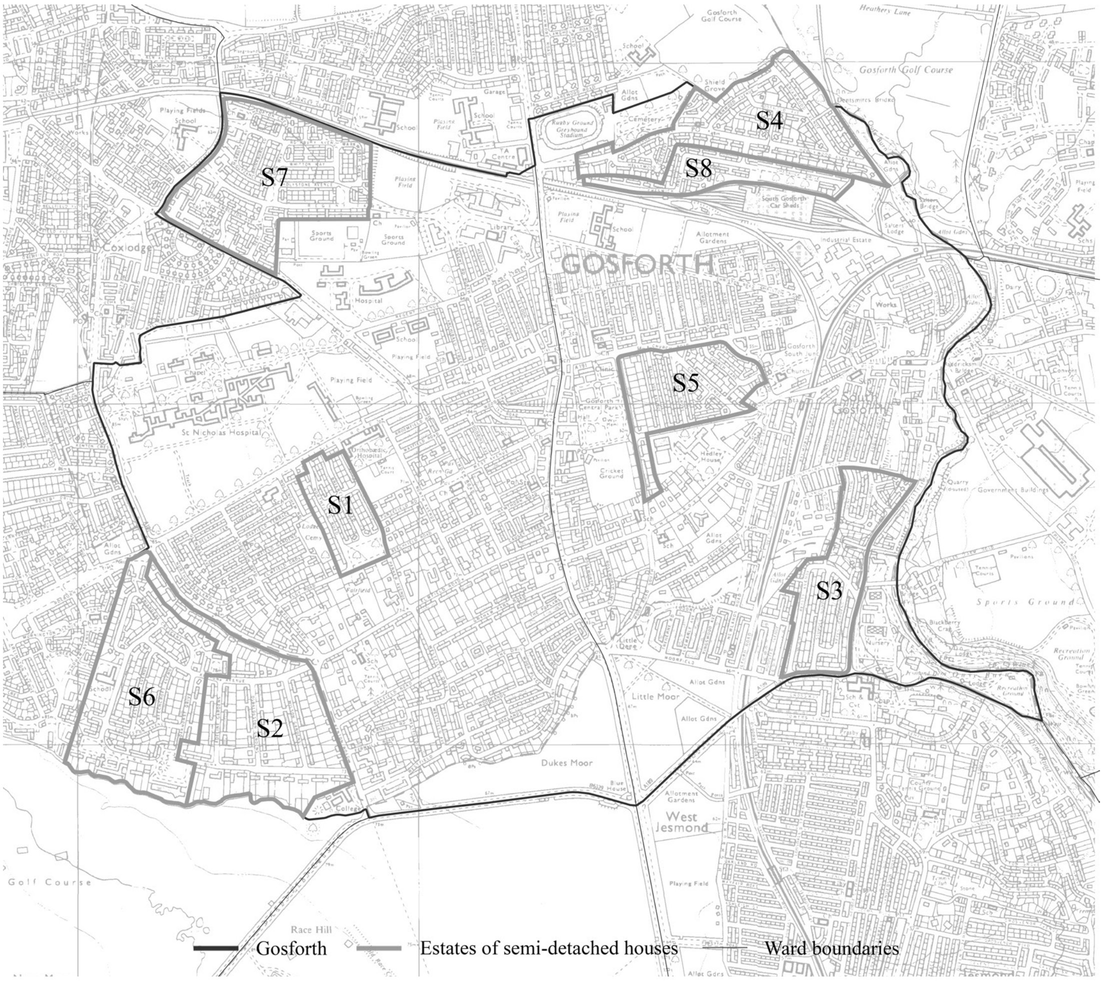

Figure 3.19 - Estates of semi-detached houses in Gosforth. Source: Ordnance Survey National Grid 1:10000, 1st Edition 1969-1996. Published: 1975, Landmark Information Group, Using: EDINA Historic Digimap Service.

Housing estates	S1	S2	S3	S4	S5	S6	S7	S8
Age	early XX c.					late XX c.		
Gross area (ha)	5.4	18.5	10.4	14.7	9.2	19.1	17.8	5.7
Net area (ha)	4.0	16.4	8.7	11.3	7.8	16	13.9	4.6
Houses	141	207	344	334	250	327	450	153
Dwellings	145	207	346	335	272	422	589	153
Net Density (du/ha)	36	13	40	30	35	26	42	33
Land use								
Residential use (ha)	100.0%	100.0%	99.4%	95.8%	100.0%	93.1%	93.0%	100.0%
Non-residential use (ha)	0.0%	0.0%	0.0%	3.9%	0.0%	6.9%	7.0%	0.0%
Mixed use (ha)	0.0%	0.0%	0.6%	0.3%	0.0%	0.0%	0.0%	0.0%
Type of houses								
Terraced	0.0%	0.0%	0.0%	9.6%	2.0%	7.0%	12.9%	0.0%
Semi-detached houses	96.5%	66.7%	98.8%	89.5%	88.0%	85.0%	77.6%	98.7%
Detached	0.7%	33.3%	1.2%	0.9%	1.2%	6.4%	0.0%	1.3%
Tyneside flats	2.8%	0.0%	0.0%	0.0%	8.8%	0.0%	4.4%	0.0%

Table 3.2 - General characteristics of estates of semi-detached houses in Gosforth.

in Gosforth between the early and late twentieth century (see Figure 3.19). The estates S1 to S5 were constructed during the inter-war period, while the estates S6-S8 were built after the Second World War in the mid to late twentieth century. During the inter-war period the most common occupation amongst the male population in Gosforth was in mining and quarrying (21.3%) and in commerce and finance (16.2%)[26]. Even though two World Wars boosted the production of coal in the North East, after the Second World War the majority of coal mines were closed. This affected many communities that relied solely on coal mining and employment in Gosforth in the mining sector fell to 5.6%. It was estimated that 20.9% of the male population were 'not gainfully occupied'[27]. The twentieth century was also a time of major changes in public and private transport. The electric tram that was popular in Gosforth at the beginning of the century was slowly replaced by buses and private motor cars after the Second World War. Public transport was still the most common way to commute to work, however innovation in transport allowed for the development of new housing estates further away from the High Street and railway stations.

The estates of semi-detached houses vary in size and occupy areas between 5.4 to 19.1 hectares, with an average size of 12.6 ha. The average density is 32 du/ha which corresponds with the densities of the Garden Cities (URBED, 2005, p.6). The densities in most estates were similar apart from estate S2 where the low density of 13 du/ha was impacted by the high number of detached houses and large plots. It was most likely a result of the prestigious location of the estate facing the Town Moor. The estates were mainly developed on the agricultural land in between existing estates of terraced houses with the exception of the estate S7 which was partially developed on the site of the disused Coxlodge Colliery. Four of the sampled estates (S1, S2, S5 and S8) are exclusively residential (see Figure 3.19), while the remaining four are predominantly residential with

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[26] Based on the 1921 Census of England and Wales, 'Occupations' for the Gosforth Urban District.
[27] Based on the 1951 Census of England and Wales, 'Selected Occupations with Status Aggregates' for the Gosforth Urban District.

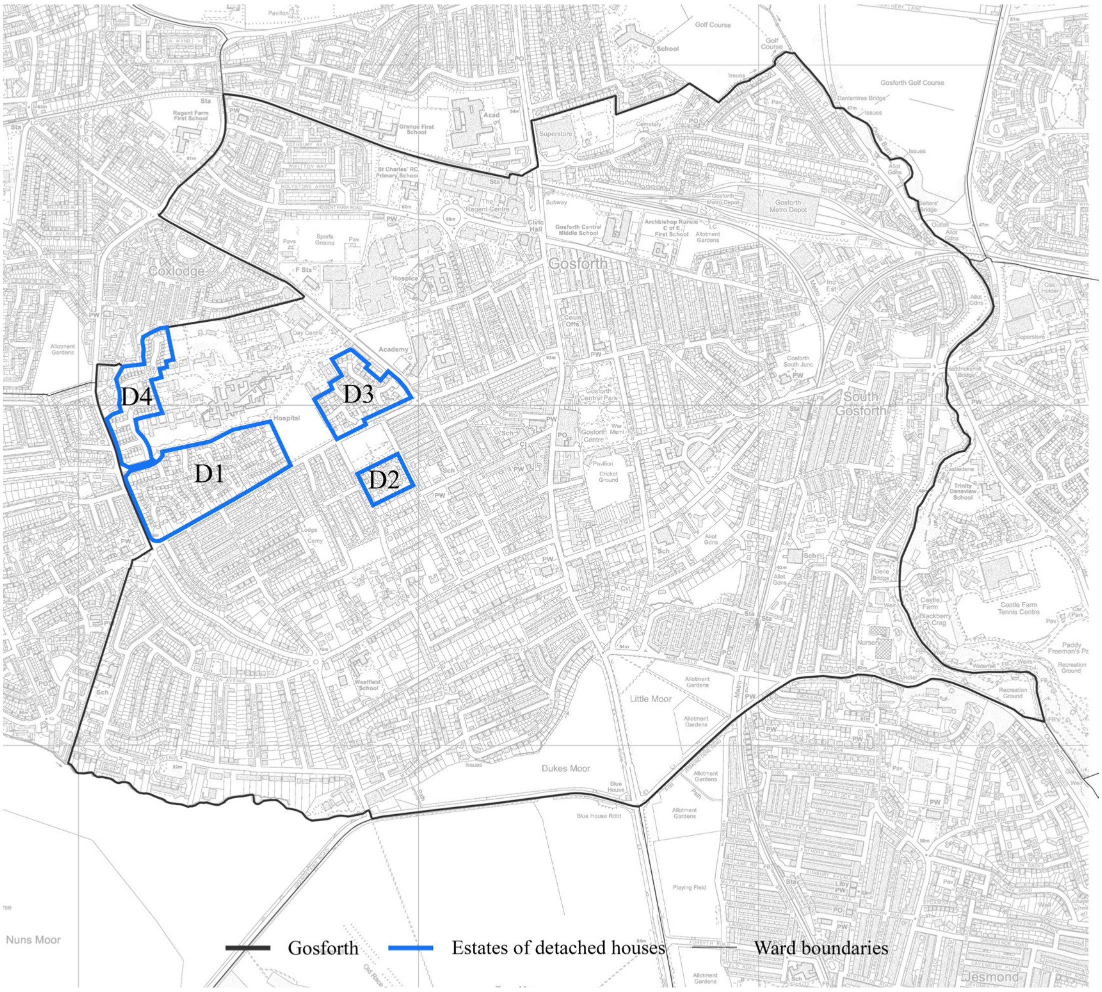

Figure 3.20 - Estates of detached houses in Gosforth. Source: OS MasterMap. Scale 1:10000. Updated: 2018, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service.

Housing estate	D1	D2	D3	D4
Age	late XX c.		early XXI c.	
Gross area (ha)	8.9	1.4	3.7	3.8
Net area (ha)	7.5	1.2	3.1	3.0
Houses	179	23	61	63
Dwellings	184	23	61	63
Net Density (du/ha)	25	19	20	21
Land use				
Residential use (ha)	100.0%	100.0%	100.0%	100.0%
Non-residential use (ha)	0.0%	0.0%	0.0%	0.0%
Mixed use (ha)	0.0%	0.0%	0.0%	0.0%
Type of houses				
Terraced houses	0.0%	0.0%	0.0%	0.0%
Semi-detached houses	0.0%	0.0%	0.0%	0.0%
Detached houses	92.7%	100.0%	100.0%	100.0%
Tyneside flats	2.8%	0.0%	0.0%	0.0%

Table 3.3 - General characteristics of estates of detached houses in Gosforth.

a small percentage of non-residential buildings, e.g. a cluster of corner shops in the estate S3, recreation grounds in the estate S4, and a shopping centre in the estates S6 and S7. The estates built in Gosforth after the First World War consisted predominantly, yet not exclusively, of semi-detached houses. In every estate there are examples of non-semis, e.g. short terraces, detached houses, or semi-detached Tyneside flats. In the post-World War II estates there are also few high rise blocks of flats, with The Annexe on Montagu Avenue in the estate S6 and a cluster of blocks of flats on Wansbeck Road in the estate S7.

The majority of semis were two-storey red brick houses with a bay window, however, there was a high degree of individuality in the detailing and decoration of the façades, especially in the houses built between the wars. In the same estate we can find plain red-brick semi-detached houses as well as semis with heavily embellished façades. Between the wars individuality in the façade was sought after and thus in the inter-war estates we can observe a high variety in detailing of the façades, e.g. pebble dash finishes, white render finishes, ceramic details, or mock-Tudor timber details. The treatment of the façade of the post-World War II semi-detached house changed. The importance of the individuality in the detailing of the façade diminished and developers preferred to incorporate a small number of different façade solutions distributed across an estate. The simple red brick house was still common, however in the late twentieth century façades with weatherboard timber cladding (known as Scandinavian style) gained popularity (Jensen, 2007, p.216).

3.3.3. The estates of detached houses (D1-D4)

In the late twenty-first century most of the agricultural land in Gosforth was urbanised and further residential development on greenfield sites was not possible within the administrative boundaries of Gosforth. With encouragement from the government, speculative developers began to situate new housing estates on brownfield sites. In the mid 1980s the government introduced a new strategy for mental health treatment, which affected large mental hospitals like St Nicholas Hospital in Gosforth. The ‘Care in the

Community' strategy favoured situating the mental health institutions in smaller buildings around the city, rather than combining them in one large hospital (Nicholas Hospital CA CS). In order to generate sufficient income and improve the health services in the St Nicholas Hospital, the National Health Service (NHS) released the surplus land for housing development. Similarly, in the 1980s Sanderson Orthopaedic Hospital sold half of its land for private housing development in order to avoid closure. Those brownfield sites were the main locations for development of new housing estates in Gosforth. As of December 2018, the local authority designated eight brownfield sites for potential residential development in Gosforth mostly clustered around the Regent Centre[28].

At the turn of the twentieth century the popularity of semi-detached houses diminished and the detached house became the most common house type in new built estates in England and Gosforth. Additionally, the socio-economic background of the inhabitants of Gosforth changed significantly. Between the 1981 and 2011 the majority of population in Gosforth worked in the tertiary sector, with both male and female inhabitants economically active. Moreover, the private motor car became widely available[29] and changed commute patterns by allowing for more flexible everyday travel. While housing development on greenfield sites continued on the fringes of Newcastle, in Gosforth new houses were built only on previously-developed land. In the late twentieth and early twenty-first century four estates of detached houses were developed to the west of the Great North Road (now High Street), as shown in Figure 3.20.

The estates of detached houses differ in size from 1.4 to 8.9 hectares, with an average of 4.5 hectares (see Table 3.3). The size of the estate in Gosforth was mostly reliant on the size of the land. The estates D1, D3 and D4 were developed on the former grounds of St

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[28] Brownfield Sites in Gosforth designated for future development (December 2018): Land on Salters' Road (Formerly known as Sanderson Hospital); Eldon House, Arden House, Dobson House, Eldon House East, Horsley House, Northumbria House, and Eagle Star House on Regent Farm Road.

[29] 2011 UK Census estimated that 76.5% of households in Gosforth owns at least one car. The data was accessed in March 2019 through the Department for Transport - *NTS0205: Household car availability: England*.

Nicholas Hospital, while the estate D2 was developed on the former grounds of Sanderson Hospital. The density was similar across all the sampled estates with an average of 21 dwellings per hectare. Even though the size and location of the estates differs, they share similar characteristics. All sampled estates were exclusively residential and consisted only of detached houses, with the exception of estate S1 where a small percentage of houses were short terraces and Tyneside flats (Emblehope Drive).

The detached houses in the sampled estates were all two-storey red brick houses, however, in most of the estates three or four types can be distinguished. The main difference between the types lied in the geometry and materiality of the façades. The most common ways that the geometry of the façade was altered was through the addition of bay windows, porches and changing the position of garages in relation to the house. The materiality of the façade varied from simple red or other colour bricks to a rendered finish. The estate D2 was the only one in the sample where the difference between the houses lay only in the occurrence and placement of details on the façade. The differences were subtle and included variation in the height of bay windows, different designs of porches and variation in the placement of mock-Tudor timber details.

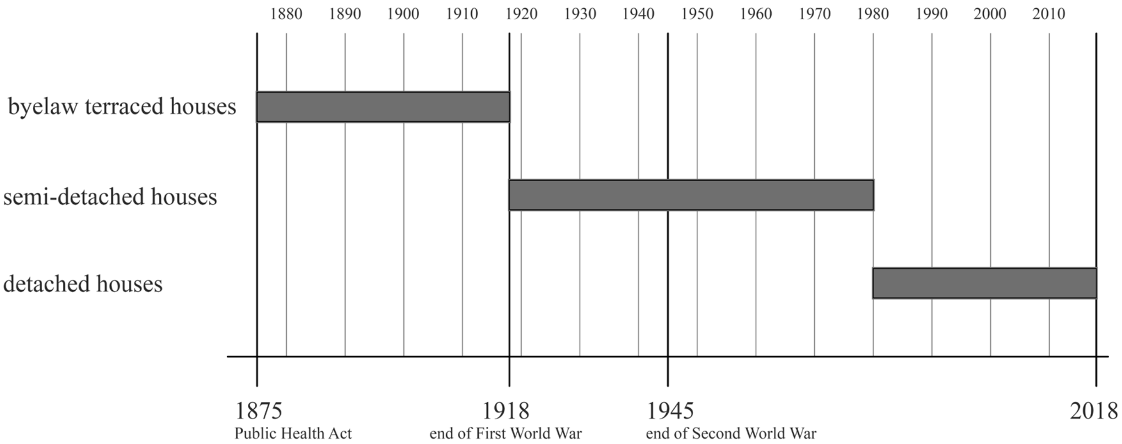

Figure 3.21 - The period of the highest popularity of the three suburban types of houses.

3.4. Summary

Suburban housing development in England, Newcastle and Gosforth between the nineteenth and early twenty-first century can be characterised as large-scale speculative construction of small to medium-sized individual houses (Muthesius, 1982, p.145) of three types: terraced, semi-detached and detached. As discussed in Section 3.1, the new built houses were organised as neighbourhood units (also known as housing estates) even when the development was conducted by many small private speculators and there was no administrative and legal framework to encourage or enforce a holistic approach. Thus the housing estate is chosen as the unit of analysis in this thesis. The history of English suburban housing is also intertwined with the rise and fall in popularity of three house types: terraced, semi-detached and detached (see Figure 3.21). The change between the house types is, in most cases, impacted by socio-economic changes following national and global political events. Byelaw terraced houses were most common between the late nineteenth century and the First World War. Semi-detached houses became the most popular during the inter-war period until the late twentieth century. Detached houses overtook semi-detached and since the late twentieth century are the most common house

Housing estates of:	terraced houses	semi-detached houses	detached houses
Number of sampled estates	6	8	4
Gross area (ha)	11.4	12.6	4.5
Net area (ha)	7.5	10.3	3.7
Houses	358	276	82
Dwellings	480	309	83
Net Density (du/ha)	76	32	21
Land use			
Residential use (ha)	91.6%	97.7%	100.0%
Non-residential use (ha)	6.5%	2.2%	0.0%
Mixed use (ha)	1.9%	0.1%	0.0%
Type of houses			
Terraced houses	64.5%	3.9%	0.0%
Semi-detached houses	10.2%	87.6%	0.0%
Detached houses	0.6%	5.6%	98.2%
Tyneside flats	22.1%	2.0%	0.7%

Table 3.4 - General characteristics of housing estates with different types of houses in Gosforth (2018).

type in the suburban development. The characteristics of the housing estates observed in Gosforth can also be seen at the national scale. As discussed in Sub-section 3.1.1, the byelaw estates of terraced houses have an interconnected ‘grid-like’ street network and areas with high densities, on average 76 du/ha in Gosforth and between 60-80 du/ha in England (URBED, 2005, p.6). Influenced by the Garden City movement and the concept of the idealised countryside we can observe changes in the estates of semi-detached houses, as described in sub-section 3.1.2. The density decreased to 32 du/ha in Gosforth and between 20 to 40 du/ha in English suburban developments or Garden Cities (ibid., p.6). The layout of the estates also changed into curvilinear loop patterns with a few cul-de-sacs that tried to embody the idyllic quiet and green countryside. Impacted by the popularisation of the private car and rising concerns with safety, estates of detached houses became more disconnected from the existing urban tissue and were characterised by networks of non-connecting cul-de-sacs. The ability to develop estates further away from the city enabled by the flexibility offered by cars allowed developers to decrease the densities of the neighbourhoods even further to the average of 21 du/ha in Gosforth and 20 to 33 du/ha in England[30]. The general characteristics of the housing estates in three time periods represented by the most common house types in Gosforth are summarised in Table 3.4.

Based on the historico-geographical analysis of housing in England, Newcastle upon Tyne, and Gosforth, three important morphological periods can be identified based on the rise and fall of three housing types: terraced, semi-detached and detached houses. The division between those periods and house types is crucial to the understating of residential development in England, therefore, it is used as an organisational principle for the structure of the main analysis chapters 4 and 5.

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30. The data was accessed in March 2019 through the Ministry of Housing, Communities & Local Government - *Table P231: Land Use Change: Density of new dwellings built, England, 1989 to 2011*.

Chapter 4

The morphology of streets in Newcastle: the interface between streets and houses

4.1. Introduction: the micro-scale of the macro-scale

A street can be defined as a linear element that mainly accommodates movement (Bobić, 2004; Marshall et al., 2018; Rapoport, 1991), and is a part of an interconnected system, a street network, which allows the users of the system to travel between different points. To represent, analyse and model streets and the street networks, many quantitative methods were developed, most of them based on graph theory and network analysis (Marshall et al., 2018), where the street networks are abstracted as a set of nodes and links.

In urban studies one of the most common methods used to analyse street networks is space syntax. In space syntax, streets can be conceptualised in two ways, either as axial lines or as street segments[1]. Axial lines represent the lines of unobstructed sight and movement (Karimi, 2012), while the street segments describe portions of the streets between two junctions. The difference between the two street models lays in the way they are abstracted as graphs. In the graph representation, the axial lines are converted into nodes, while the intersections become links. On the other hand, the street segments are treated as links between junctions, which are represented as nodes. The latter form of graph representation of the street network is more widespread, especially in transport studies, and is often referred to as the traditional graph representation (Marshall et al., 2018). While the axial representation dates back to the early publications of space syntax, the representation of the street networks in terms of street segments has become popular as it is based on the more easily available road-centrelines (Turner, 2007). However, there is an advantage to using axial maps when analysing the local properties of streets. In the axial representation streets are treated as discrete, rather than composite entities, and the emphasis is placed on the street rather than the junctions (Marshall et al., 2018; Vialard, 2015). In this chapter the main focus is the analysis of the streets as discrete and distinct elements, therefore, the axial, rather than segmental, representation is adopted.

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[1] Those are not the only ways of representing street networks, a comprehensive overview was conducted by Marshall et al. (2018).

The movement-related properties of a street are only part of a set of complex characteristics. Another aspect deals with the adjacent buildings that define the streets, as without them there is only a road, not a street. The streets by definition are linear elements lined with buildings (Bobić, 2004; Marshall et al., 2018; Oxford Dictionary, 2018). This highlights the importance of the relationship between the streets and the buildings and the role of the street as a 'not just a linear conduit, but ... also ... a container of urban life' (Marshall et al., 2018). In urban morphology, a growing number of studies argues that the micro-scalar aspects of the streets are an important supplement to the macro-scalar analysis of the street networks (Palaiologou et al., 2016; Ståhle et al., 2005; Vialard, 2015; Whitehand, 2001).

In this chapter a method is proposed that allows for the incorporation of micro-scalar properties into the analysis of the macro-scalar street network. Through the analysis of the street-buildings interface, this chapter addresses the first question of this thesis: *does the way in which a street interfaces with houses affect the activity on the street?*

4.2. Street networks and space syntax

The method proposed in this chapter combines the syntactical analysis of street networks represented as a set of axial lines (Hillier and Hanson, 1984) with the logic of the interface map (Hillier and Hanson, 1984) using a geographic information system (GIS).

As discussed in the literature review in Chapter 2, space syntax provides a set of measures and tools that allows for the determination of the potential of an axial line to accommodate movement. In this thesis, the topological characteristics of axial lines are examined using two syntactical measures: connectivity and combined local integration and choice. Connectivity describes the number of axial lines that intersect the line in question and is used to determine the general local structure of the street spaces (Al-Sayed, 2018, p.12). The measure of combined local integration and choice is used to determine the multi-modal potential of a street to accommodate to-movement (integration) and through-movement (choice). As the primary unit of the analysis is the housing estate, the examination of the street network is conducted on the local scale (radius 3). One of the drawbacks of the axial representation is that the lines positioned on the perimeter of the map appear to have lower movement potential, because not all of the intersecting lines are included on the map (Vaughan and Geddes, 2009). This anomaly is referred to as the edge effect. In order to address avoid edge effects, the analysis of the street network of the housing estates was conducted across the entire district of Gosforth, rather than in each estate individually (see Figure 4.1).

To compare the properties of the streets derived from the analysis of the street network to the micro-scalar characteristics of the buildings, the logic of Hillier and Hanson's convex interface map (Hillier and Hanson, 1984, p.104) is utilised using the geographic information system (GIS). The interface map represents the access-based relationship

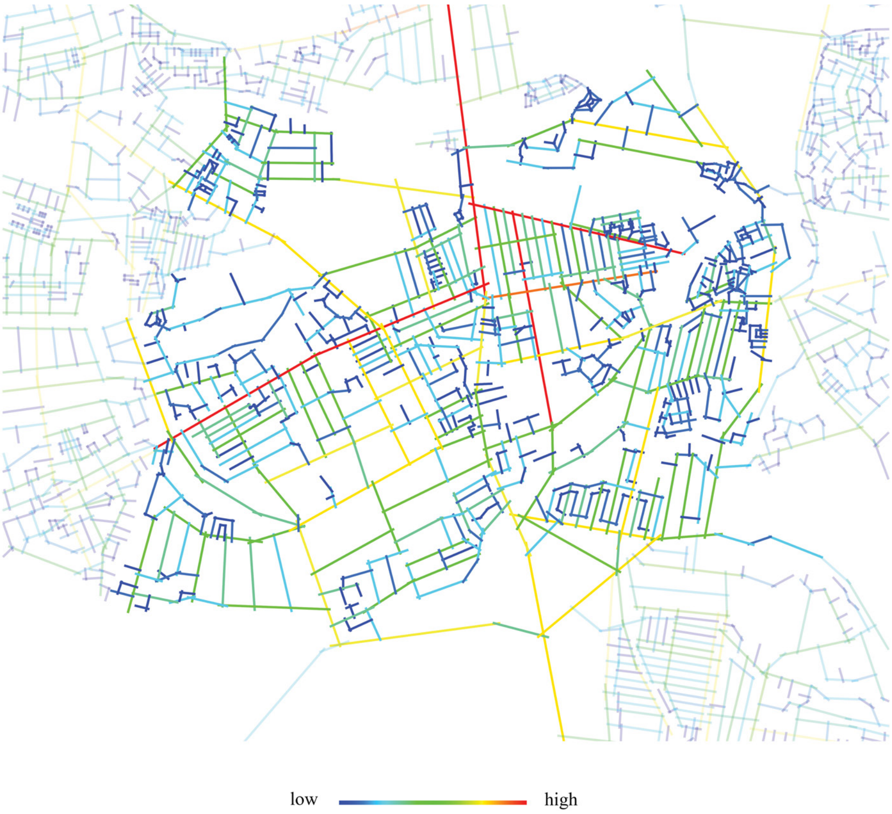


Figure 4.1 - Street network in Gosforth represented as sets of interconnected axial lines. Colour range indicates the degree of movement potential (combined integration and choice R3) from the lowest (dark blue) to the highest (red).

between buildings and convex spaces as a graph, where black nodes (dots) signify convex spaces, white nodes (circles) illustrate buildings, and links between those nodes signify physical permeability (see Figure 4.2). Expanding on and adapting the logic of the interface map to the geographic information system, the analysis method in this chapter is as follows:

(1) The axial lines are analysed using Space Syntax Toolkit for QGIS and assigned a unique identifier that allows for cross-tabulation with the non-syntactic measures.

(2) Topological properties of the individual building-street interfaces (proximity, physical permeability and visual permeability - discussed in Chapter 2) were

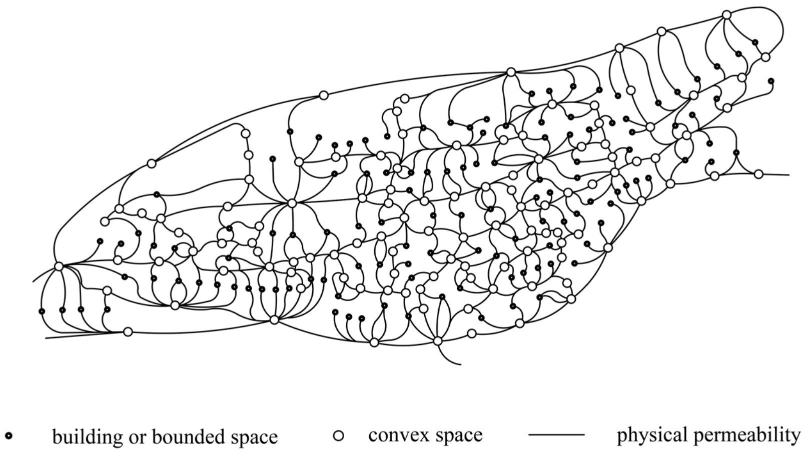
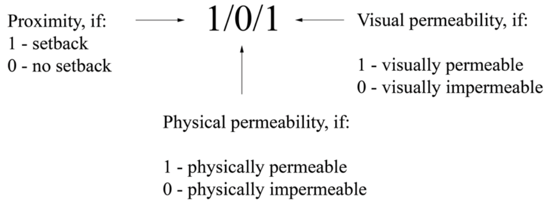


Figure 4.2 - Interface map of Gassin (reproduced from Hillier and Hanson, 1984, p.104)



*1/open - defines an interface with no physical boundary between the private and public space

Figure 4.3 - Descriptor used to classify building-street interface types.

collected during the direct observational studies conducted between June 2016 and October 2016 in Gosforth, and were mapped onto the plot boundary map derived from the topographic layer of the Ordnance Survey map (Digimap Ordnance Survey Collection, 2018), using the descriptor introduced in Chapter 2 (see Figure 4.3). The unique identifier of every axial line was then assigned to every adjacent building-street interface.

(3) Building-street interfaces that share the same axial line identifier and are situated on the same side of the axial line are then aggregated and equated to the descriptor of the most common building-street interface type. The aggregation of those building-street interfaces is referred to as a street-buildings interface.

(4) Based on the unique axial line identifier the axial lines are cross-tabulated with the generated street-buildings interfaces, in order to analyse the relationship between the streets and the adjacent buildings.

(5) The last step is evaluative and aims to provide a way to determine whether the street-buildings interface is active or passive, in other words whether it provides opportunities that support the activities on the streets, or not. The active interfaces are defined as those that provide access between the streets and adjacent buildings, visual connection between the public and private spaces and/or a space to accommodate long-duration activities. The passive interfaces are defined as those that do not generate or support co-presence and long-duration activities on the streets and are likely to negatively affect the street activity and thus the possibility for probabilistic interactions.

As discussed in Chapter 3, English speculative housing is connected to the development of three single-family house types: byelaw terraced, semi-detached and detached, which correspond to different periods between the late nineteenth and early twenty-first century (for more detail see Chapter 3). Based on that, the structure of this analysis chapter follows the chronological development in English single-family housing, and starts with the analysis of six estates of terraced houses, continues with the study of eight estates of semi-detached houses, and ends with the examination of four estates of detached houses.

4.3. Analysis of the estates of terraced houses

This section investigates the relationship between streets and houses in the six estates of terraced houses in Gosforth, identified in Sub-section 3.3.1 in Chapter 3. The estates vary in size between 2.4 and 22.5 hectares, with an average gross area of 11.4 hectares and average density of 76 dwellings per hectare. As seen in Figure 4.4, the majority of land in the sampled estates is residential and mostly comprised of terraced houses (for more details see Table 3.2 in Chapter 3).

4.3.1. The characteristics of the streets

The street network in each estate of terraced houses can be treated as a set of interconnected axial lines that create a larger street network, as shown in Figure 4.5. The number of axial lines (streets) per estate varies and ranges between 12 and 77, with an average number of 36 axial lines. Even though the total area of the estates and the number of axial lines per estate differs, the density of axial lines per hectare (axial/ha) is similar across the majority of the estates, with an average of 3 to 4 axial/ha. The exceptions can be observed in the estates T4 and T5 where the density is either higher (T4) or lower (T5).

In Table 4.1, the metric and topological properties of the streets in each estate of terraced houses are compiled. The analysis of the street networks begins with the examination of the metric length of the streets, and afterwards, the topological characteristics, which are investigated using syntactic measures of connectivity and combined local integration and choice. The length of an axial line ranges between 16.1 metres and 1336.6 metres, with an average length of 168.4 metres. On average, the majority of axial lines are shorter rather than longer, with approximately half of axial lines being shorter than 100 metres (44.3%) or measuring between 100 and 200 metres (27.1%). Only 3.3% of streets are longer than 600 metres. While a similar distribution can be observed in the majority of the sampled estates, some outliers are found. In the estate T4, a significantly higher percentage of long axial lines can be observed. While it might seem anomalous, it is not uncommon to observe 1 to 3 long global streets per estate, mostly situated on the perimeter. However,

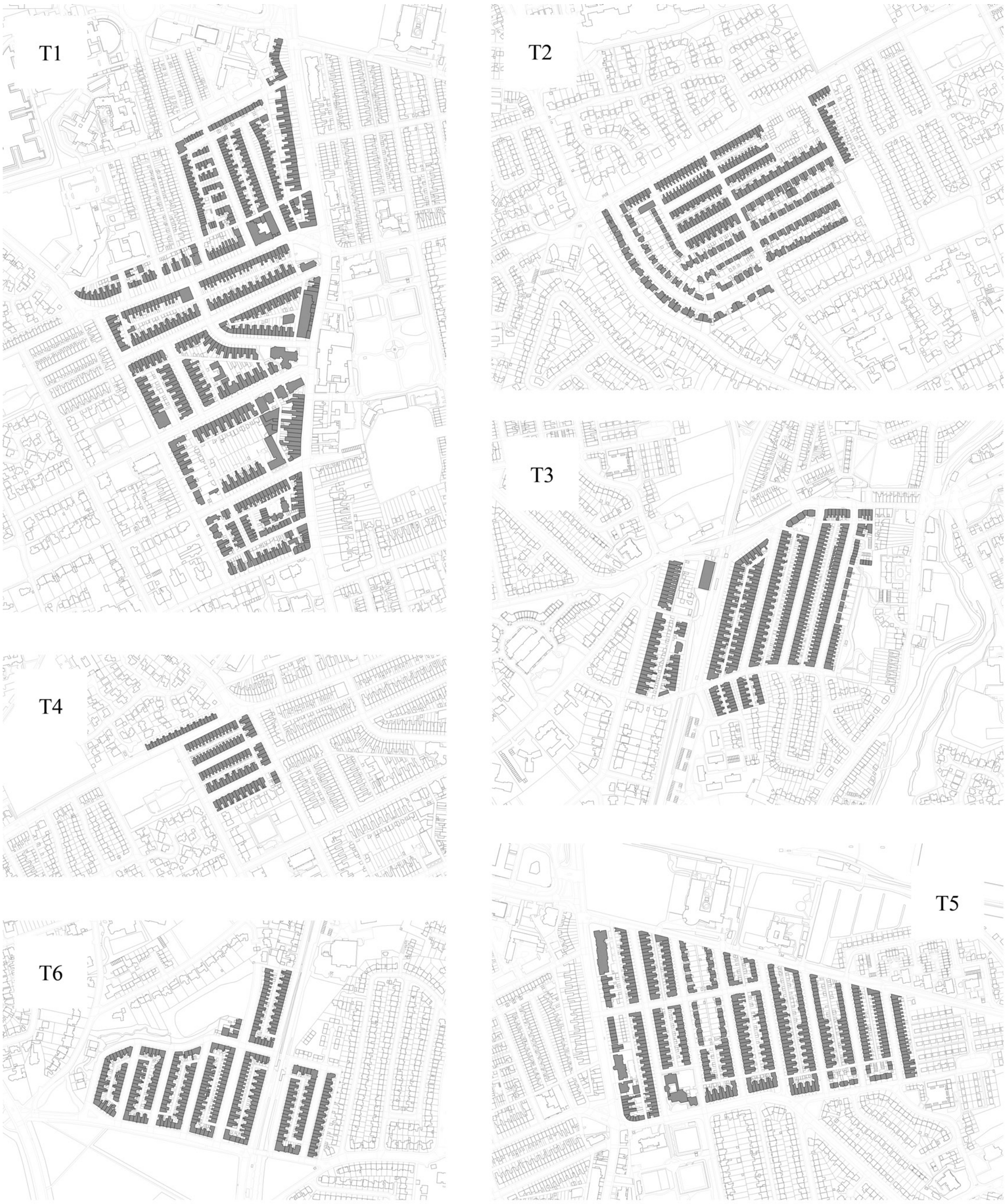


Figure 4.4 - Figure-ground maps of six estates of terraced houses in Gosforth (T1-T6).

because of the small size of estate T4, those three long streets skew the relative frequency distribution. In estate T5, the average length of axial lines is higher than in the studied estates, and the most common length for an axial line is between 200 and 350 metres (41.7%).

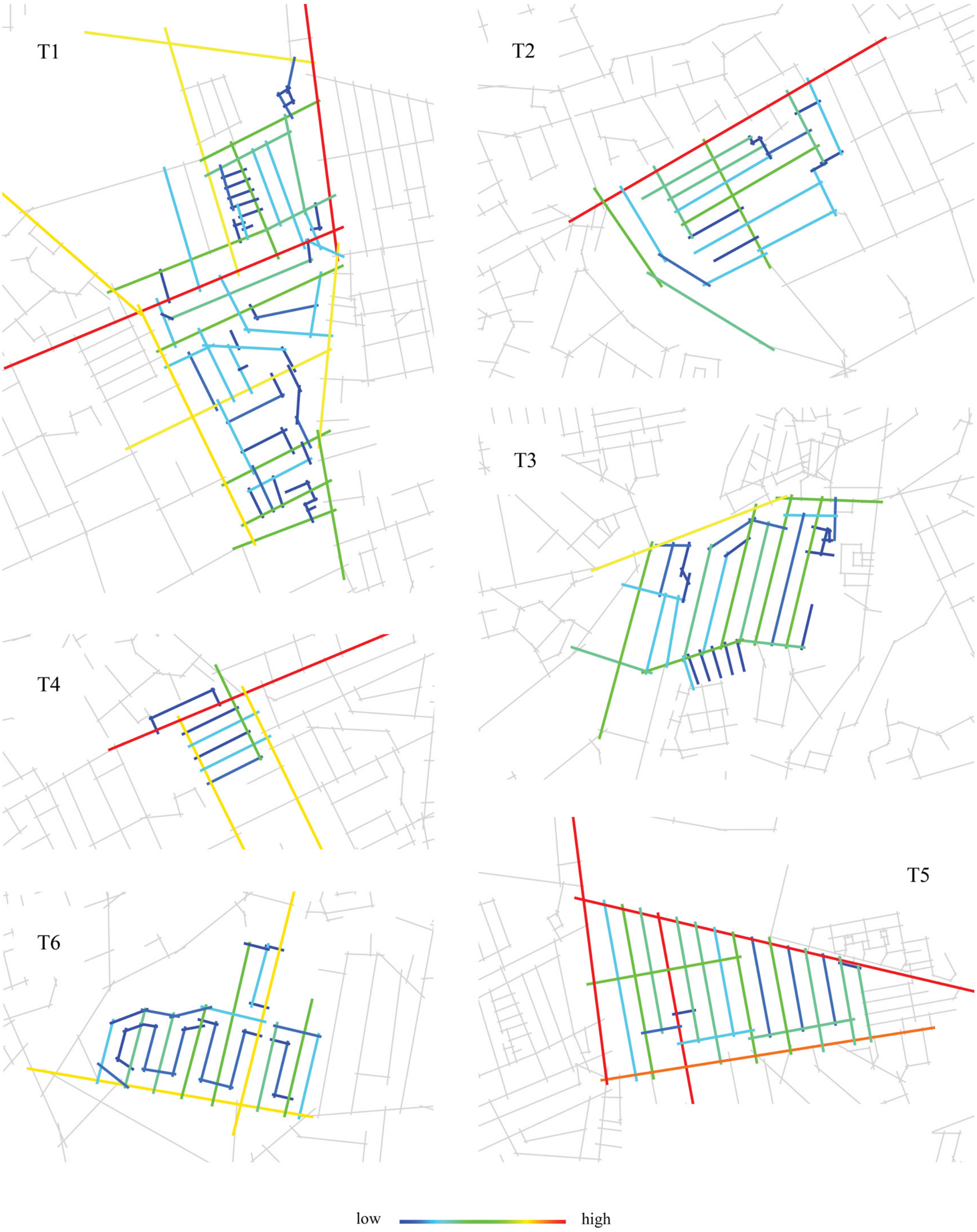


Figure 4.5 - Street networks of six estates of terraced houses (T1-T6) represented as sets of interconnected axial lines. Colour range indicates the degree of movement potential (combined integration and choice R3) from the lowest (dark blue) to the highest (red).

	T1	T2	T3	T4	T5	T6	All
Estate area (ha)	22.5	10.2	10.6	2.4	13.8	8.6	68
Number of axial lines	77	26	38	12	24	36	210
Density (axial lines/ha)	3	3	4	5	2	4	3
Length (m) - general							
Min length	16.4	16.1	17.6	34.2	42.9	32.2	16.1
Average length	164.5	177.3	139.4	242.0	327.3	128.8	168.4
Max length	1336.6	735.4	418.5	736.3	1336.6	640.6	1336.6
Length - frequency distribution							
0-100 metres	41	7	19	2	3	21	93
100-200 metres	17	10	8	6	5	11	57
200-350 metres	10	8	9	1	10	2	40
350-600 metres	7	0	2	2	2	1	13
600 metres and above	2	1	0	1	4	1	7
Length - relative frequency distribution							
0-100 metres	53.2%	26.9%	50.0%	16.7%	12.5%	58.3%	44.3%
100-200 metres	22.1%	38.5%	21.1%	50.0%	20.8%	30.6%	27.1%
200-350 metres	13.0%	30.8%	23.7%	8.3%	41.7%	5.6%	19.0%
350-600 metres	9.1%	0.0%	5.3%	16.7%	8.3%	2.8%	6.2%
600 metres and above	2.6%	3.8%	0.0%	8.3%	16.7%	2.8%	3.3%
Connectivity - frequency distribution							
Dead-ends (1)	5	1	6	0	0	0	12
Low connectivity (2)	27	11	11	6	5	17	77
Medium connectivity (3-4)	22	10	11	2	9	15	69
High connectivity (5-6)	9	2	6	0	4	1	22
Very high connectivity (7+)	14	2	4	4	6	3	30
Connectivity - relative frequency distribution							
Dead-ends (1)	6.5%	3.8%	15.8%	0.0%	0.0%	0.0%	5.7%
Low connectivity (2)	35.1%	42.3%	28.9%	50.0%	20.8%	47.2%	36.7%
Medium connectivity (3-4)	28.6%	38.5%	28.9%	16.7%	37.5%	41.7%	32.9%
High connectivity (5-6)	11.7%	7.7%	15.8%	0.0%	16.7%	2.8%	10.5%
Very high connectivity (7+)	18.2%	7.7%	10.5%	33.3%	25.0%	8.3%	14.3%
Combined integration and choice R3 - frequency distribution							
Very low (<63)	41	10	21	6	6	24	108
Low (63-203)	20	12	10	2	10	7	61
Medium (203-515)	8	3	6	1	4	3	25
High (515-1152)	6	0	1	2	1	2	11
Very high (10%) (>1152)	2	1	0	1	3	0	5
Combined integration and choice R3 - relative frequency distribution							
Very low (<63)	53.2%	38.5%	55.3%	50.0%	25.0%	66.7%	51.4%
Low (63-203)	26.0%	46.2%	26.3%	16.7%	41.7%	19.4%	29.0%
Medium (203-515)	10.4%	11.5%	15.8%	8.3%	16.7%	8.3%	11.9%
High (515-1152)	7.8%	0.0%	2.6%	16.7%	4.2%	5.6%	5.2%
Very high (10%) (>1152)	2.6%	3.8%	0.0%	8.3%	12.5%	0.0%	2.4%

Table 4.1 - Frequency and relative frequency distributions of metric and topological characteristics of the roads in six estates of terraced houses.

Across all the sampled estates, on average, the majority of axial lines have either low or medium connectivity (69.5%). In other words most of the axial lines intersect with between 2 to 4 other lines at a time. A very low number of dead-end streets (5.7%) can be observed in the sampled estates, and approximately 1 in 10 streets intersect with more than 7 other streets at a time. The relative frequency distribution of connectivity in the majority of the estates is similar, with an exception in the estates T4 and T5. In those estates, the average connectivity and the percentage of axial lines with very high connectivity is higher than in the other sampled estates. Moreover, the street network in the estate T5 consists mostly of medium connected streets, while in the estate T4 the percentage of the streets with medium connectivity is relatively low (16.7%), and the network is mostly a combination of streets with either low (2) or high (7+) connectivity. In the estate T3 an unusually high percentage of dead-end streets can be observed, which are situated along the southern perimeter of the estate (see Figure 4.5).

The combined syntactic measure of local integration (to-movement) and choice (through-movement) describes the multi-modal movement potential of axial lines. As illustrated in Figure 4.5, the potential for movement is assessed on a scale between very low (dark blue) to very high (red). Based on the distribution of movement potential in Table 4.1, it can be observed that the potential of the majority of axial lines across all the estates is either very low or low. In most cases there are only 1 to 3 axial lines with high or very high movement potential, with most of them situated on the perimeter of the estate. While the majority of the movement in the estates of terraced houses tends to be accommodated along the perimeter of the estate, there are some streets with high or very high movement potential going through the estates, as seen in Figure 4.5 in the estates T1, T4, T5 and T6. In the estates T5 and T6, those internal streets were not as important when the estate was built, however, they were further extended with the development of surrounding areas and became some of the most important local streets in the area.

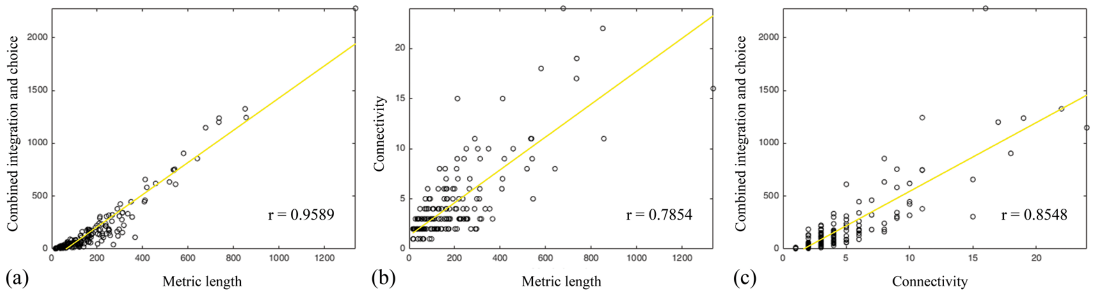


Figure 4.6 - Three scatter plots examine the strength of the relationships between three variables: metric length, connectivity and combined integration and choice, in sampled estates of terraced houses.

Based on the analysis of the metric and topological properties of the street networks in the estates of terraced houses, it can be concluded that there is a certain hierarchy in the estates and that there are streets that are more important than the others, regardless of the measure used. In order to examine this observation, the correlation between metric length, connectivity and combined integration and choice was explored on scatter plots in Figure 4.6. A strong linear relationship was observed between all those measures, with a correlation coefficient $r > 0.7$, which confirmed that certain streets in the estates of terraced houses have a higher importance with regard to metric length, connectivity and movement potential than the others. Those streets in most cases are situated on the perimeter of the estates, thus indicating that the large volume of movement tends to be allocated around each estate, rather than through it.

4.3.2. The interface between the streets and terraced houses

Analysis of the metric and topological properties of the streets revealed interesting information about the hierarchy and importance of streets in each estate of terraced houses. The roads are, however, just part of what defines the streets. The other important part is the buildings situated along the streets that delineate their bounds. This sub-section examines the relationship between streets and the adjacent terraced houses, through the study of street-buildings interfaces.

Street-buildings interfaces are defined as an aggregation of individual building-street interfaces along one side of a street (see Section 2.1 in Chapter 2 for more details). In order to determine the characteristics of the street-buildings interfaces and propose a typology,

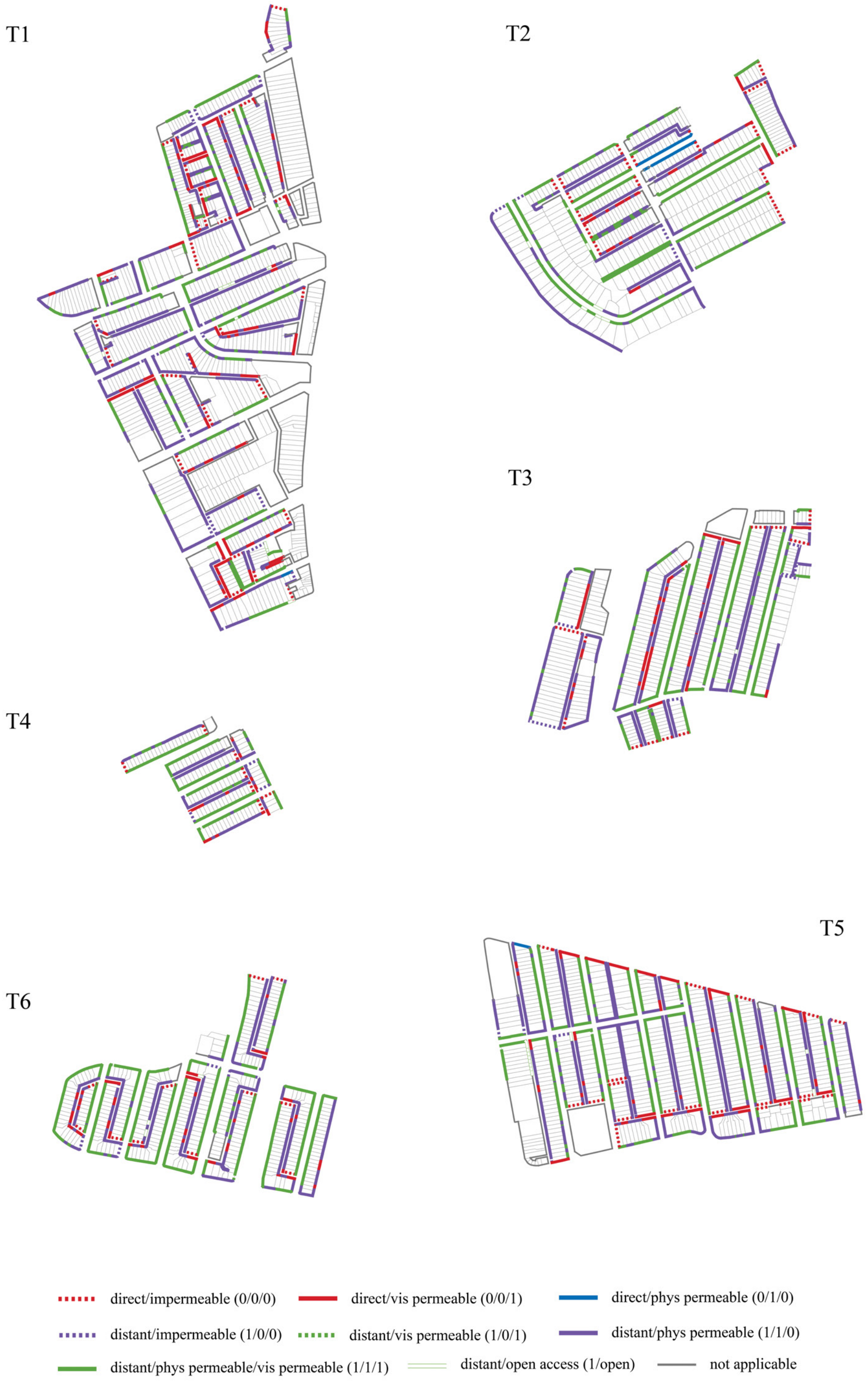


Figure 4.7 - Interface maps of individual building-street interfaces in six estates of terraced houses in Gosforth (T1-T6).

the data on proximity, physical permeability and visual permeability of individual building-street interfaces was compiled and mapped onto the plot boundary map in GIS[2] (see Figure 4.7). As noted in the historical analysis of terraced houses in Chapter 3, the orientation of the façades of a house in relation to its context is an important aspect of the bi-polar organisation of the terraced house. Therefore, the information on whether a house interfaces with a street through a front, side or back façade was added to the GIS database. A summary of the data on the characteristics of the building-street interfaces is shown in Table 4.2.

	T1	T2	T3	T4	T5	T6	Total
Plots	708	356	368	116	484	335	2367
Building-street interface	1485	634	766	250	1012	706	4853
Interface/Plot ratio	2.1	1.8	2.1	2.2	2.1	2.1	2.1
Building-street interface types - frequency distribution							
Direct impermeable (0/0/0)	30	19	11	7	21	11	99
Direct vis. permeable (0/0/1)	0	0	0	0	0	0	0
Direct phys. permeable (0/1/0)	110	23	56	12	39	42	282
Direct phys. and vis. permeable (0/1/1)	2	25	0	0	1	0	28
Direct open (0/open)	0	0	0	0	0	0	0
Distant impermeable (1/0/0)	32	5	15	5	9	9	75
Distant vis. permeable (1/0/1)	1	1	1	1	2	2	8
Distant phys. permeable (1/1/0)	668	267	360	97	514	299	2205
Distant phys. and vis. permeable (1/1/1)	304	264	269	117	367	323	1644
Distant open (1/open)	17	7	1	0	11	3	39
Non-applicable (n/a)	321	23	53	11	48	17	473
Building-street interface types - relative frequency distribution							
Direct impermeable (0/0/0)	2.0%	3.0%	1.4%	2.8%	2.1%	1.6%	2.0%
Direct vis. permeable (0/0/1)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Direct phys. permeable (0/1/0)	7.4%	3.6%	7.3%	4.8%	3.9%	5.9%	5.8%
Direct phys. and vis. permeable (0/1/1)	0.1%	3.9%	0.0%	0.0%	0.1%	0.0%	0.6%
Direct open (0/open)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Distant impermeable (1/0/0)	2.2%	0.8%	2.0%	2.0%	0.9%	1.3%	1.5%
Distant vis. permeable (1/0/1)	0.1%	0.2%	0.1%	0.4%	0.2%	0.3%	0.2%
Distant phys. permeable (1/1/0)	45.0%	42.1%	47.0%	38.8%	50.8%	42.4%	45.4%
Distant phys. and vis. permeable (1/1/1)	20.5%	41.6%	35.1%	46.8%	36.3%	45.8%	33.9%
Distant open (1/open)	1.1%	1.1%	0.1%	0.0%	1.1%	0.4%	0.8%
Non-applicable (n/a)	21.6%	3.6%	6.9%	4.4%	4.7%	2.4%	9.7%

Table 4.2 - Distribution of building-street interface types in six estates of terraced houses.

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[2] The plot boundary map was generated from the Ordnance Survey map (2018) access through Digimap Service by EDINA.

On average, 2.1 interfaces per plot can be observed in the estates of terraced houses. This means that terraced houses tend to connect to the street network through 2 interfaces, and in some cases through 3. Out of 10 possible building-street interface types based on the relationship between three variables: proximity, physical and visual permeability; 8 can be observed in the estates of terraced houses (see Table 4.2). However, only two types are found in the majority of the interfaces. 33.9% of interfaces are distant and physically and visually permeable (1/1/1), while 45.4% of interfaces are distant and only physically permeable (1/1/0).

As introduced in Chapter 3, an important aspect of the spatial organisation of the terraced houses is its bi-polar division between the formal front and everyday back. Thus both the front and back façades are an important socio-functional factor in the relationship between the terraced house and the adjacent streets. In the next step, the building-street interface types are cross-tabulated with the social types of façades (front, back and side). The front façade makes up 48.8% of the studied interfaces, while the back façades are incorporated into 45.4% of the interfaces. The side façade is part of the remaining 5.8% of interfaces. The cross-tabulation in Table 4.3 shows a strong relationship between certain building-street types and front and back façades. 73.6% of front façades are part of a distant, physically and visually permeable interface (1/1/1), while 83.8% of back façades are incorporated

Building-street interface types	front	side	back
Direct impermeable (0/0/0)	0.0%	36.4%	0.4%
Direct vis. permeable (0/0/1)	0.0%	0.0%	0.0%
Direct phys. permeable (0/1/0)	0.0%	13.8%	12.4%
Direct phys. and vis. permeable (0/1/1)	1.3%	0.4%	0.0%
Direct open (0/open)	0.0%	0.0%	0.0%
Distant impermeable (1/0/0)	1.3%	11.5%	1.0%
Distant vis. permeable (1/0/1)	0.3%	0.8%	0.0%
Distant phys. permeable (1/1/0)	22.9%	19.8%	83.8%
Distant phys. and vis. permeable (1/1/1)	73.6%	17.4%	1.3%
Distant open (1/open)	0.7%	0.0%	1.3%
Total	2139	253	1988

Table 4.3 - The relationship between the building-street interface types and the type of facade (front, side, and back) in terraced houses (source data can be found in Appendix A.8).

into a distant and physically permeable interface (1/1/0). Based on the cross-tabulation, it can be concluded that the bi-polar division between the front and the back, outlined in Chapter 3, can be also observed in the interfaces between the terraced house and the street network. The formal front accommodates not only movement between the street and the house, but also the visual connection necessary to communicate social cues embedded at the front of the house. On the other hand, the relationship between the back of the house and the street is more functional, thus, the interface facilitates only physical access without allowing for any visual connection between the street and the back of the house.

The relationship between the side façade and the building-street interface types is more complex, side façades can be observed in many different building-street interface types. This complexity stems from the origin of the side interface. While the front and back interface stemmed from the spatial organisation of the terraced house and the need for a formal entrance at the front and an informal entrance at the back, the side interface did not originate from the socio-functional requirements, but rather from the geometric constraints of the linear urban block. As most terraced houses are aggregated into linear blocks, this means that in each terraced row, there are two houses situated on the ends of the row (referred to as end terraces). Therefore, as seen in Table 4.3, there was no consensus on what role the side interfaces had in the relationship between the terraced house and the street network. In most cases (36.4%) the side façade was just an exposed impermeable party wall. However, there were clearly attempts to add more functionality to the side façade, for example through the introduction of an access point into the house or the back yard.

While the analysis of individual building-street interfaces resulted in some interesting findings about the relationship between the topological characteristics of the interface and the socio-functional understanding of the terraced house, the individual interfaces need to be aggregated into street-buildings interfaces to allow for cross-tabulation with

	T1	T2	T3	T4	T5	T6	Total
Streets	77	26	38	12	24	36	210
Interface	94	42	47	18	41	60	302
Interface/Street ratio	1.2	1.6	1.2	1.5	1.7	1.7	1.4
Street-buildings interface - frequency distribution							
0/0/0-back	0	0	0	0	0	0	0
0/0/0-side	17	8	3	3	7	10	48
0/1/0-back	5	0	1	0	0	2	8
0/1/0-side	0	0	1	0	1	3	5
0/1/1-front	0	0	0	0	0	0	0
0/1/1-side	0	0	0	0	0	0	0
1/0/0-back	0	0	0	0	0	0	0
1/0/0-front	0	0	0	0	0	0	0
1/0/0-side	1	0	5	0	0	0	6
1/0/1-front	0	0	0	0	0	0	0
1/0/1-side	0	0	0	0	0	0	0
1/1/0-back	38	18	18	7	16	24	121
1/1/0-front	10	2	3	0	0	0	15
1/1/0-side	0	0	0	0	0	0	0
1/1/1-back	0	0	0	0	0	0	0
1/1/1-front	20	14	12	7	15	21	89
1/1/1-side	3	0	4	1	2	0	10
1/open-back	0	0	0	0	0	0	0
1/open-front	0	0	0	0	0	0	0
Street-buildings interface - relative frequency distribution							
0/0/0-back	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0/0/0-side	18.1%	19.0%	6.4%	16.7%	17.1%	16.7%	15.9%
0/1/0-back	5.3%	0.0%	2.1%	0.0%	0.0%	3.3%	2.6%
0/1/0-side	0.0%	0.0%	2.1%	0.0%	2.4%	5.0%	1.7%
0/1/1-front	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0/1/1-side	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/0/0-back	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/0/0-front	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/0/0-side	1.1%	0.0%	10.6%	0.0%	0.0%	0.0%	2.0%
1/0/1-front	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/0/1-side	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/1/0-back	40.4%	42.9%	38.3%	38.9%	39.0%	40.0%	40.1%
1/1/0-front	10.6%	4.8%	6.4%	0.0%	0.0%	0.0%	5.0%
1/1/0-side	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/1/1-back	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/1/1-front	21.3%	33.3%	25.5%	38.9%	36.6%	35.0%	29.5%
1/1/1-side	3.2%	0.0%	8.5%	5.6%	4.9%	0.0%	3.3%
1/open-back	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/open-front	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4.4 - Distribution of street-buildings interface types in six estates of terraced houses.

Figure 4.8 - Three identified streetscapes in the estates of semi-detached house: (a) a back alley with a 1/1/0-back street-buildings interface on each side of the street, (b) a front street with a 1/1/1-front interface on each side of the street, and (c) a back-side alley with a 1/1/0-back interface on one side and a 0/0/0-side interface on the other side (Photographs by Author, taken on 28.09.2019).

the axial lines. As defined previously the street-buildings interface is an aggregate of individual building-interfaces along one side of the street. The informed classification of the street-buildings interfaces is based on the combination of the topological properties - proximity, physical permeability and visual permeability - and type of the façade that signifies the socio-functional context. The distribution of the street-buildings interface types is illustrated in Table 4.4.

Out of 19 informed building-street interface types, only 8 can be observed in the street-buildings interface types, as shown Table 4.4. There are three types of street-buildings interfaces that are common in the estates of terraced houses: a distant and physically permeable back interface (1/1/0-back), a distant, and both physically and visually permeable front interface (1/1/1-front), and a direct and impermeable side interface (0/0/0-side).

In the last part of this step, the likelihood of the same street-buildings interface types being situated on both sides of the same street is investigated. 54.5% of sampled axial lines are lined with houses on both sides of the street, 32.9% of axial lines are defined by houses on one side only. In those cases the other side of the street is either unbuilt, non-residential or lined with buildings that do not belong to the estate in cases of the axial lines situated on the perimeter of the estate. 17 unique types of streetscapes were distinguished with street-buildings interfaces on both sides of the street. Based on the socio-morphological characteristics, three common streetscapes can be observed (see Figure 4.8):

(1) A back alley, which consists of a 1/1/0-back (distant, physically permeable) interface on each side of the street (31.9% of cases).

(2) A front street, which consists of a 1/1/1-front interface (distant, physically and visually permeable) on each side of the street (27.6% of cases).

(3) A back-side alley, which consists of a 1/1/0-back interface (distant, physically permeable) on one side and a 0/0/0-side interface (direct and impermeable) on the

other side (17.2% of cases).

Cross-tabulation	side	back	side	side	back	front	side	front
	0/0/0	0/1/0	0/1/0	1/0/0	1/1/0	1/1/0	1/1/1	1/1/1
Total number	48	8	5	6	121	15	10	89
Length - frequency distribution								
0-100 metres	28	7	4	4	51	6	2	12
100-200 metres	14	1	0	2	43	5	3	27
200-350 metres	6	0	0	0	25	1	4	32
350-600 metres	0	0	0	0	2	3	1	9
600 metres and above	0	0	1	0	0	0	0	9
Length - relative frequency distribution								
0-100 metres	24.6%	6.1%	3.5%	3.5%	44.7%	5.3%	1.8%	10.5%
100-200 metres	14.7%	1.1%	0.0%	2.1%	45.3%	5.3%	3.2%	28.4%
200-350 metres	8.8%	0.0%	0.0%	0.0%	36.8%	1.5%	5.9%	47.1%
350-600 metres	0.0%	0.0%	0.0%	0.0%	13.3%	20.0%	6.7%	60.0%
600 metres and above	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	90.0%
Connectivity - frequency distribution								
Dead-ends (1)	1	2	0	0	10	0	0	4
Low connectivity (2)	19	6	3	2	63	7	1	7
Medium connectivity (3-4)	13	0	1	2	37	3	3	41
High connectivity (5-6)	7	0	0	2	9	2	0	15
Very high connectivity (7+)	8	0	1	0	2	3	6	22
Connectivity - relative frequency distribution								
Dead-ends (1)	5.9%	11.8%	0.0%	0.0%	58.8%	0.0%	0.0%	23.5%
Low connectivity (2)	17.6%	5.6%	2.8%	1.9%	58.3%	6.5%	0.9%	6.5%
Medium connectivity (3-4)	13.0%	0.0%	1.0%	2.0%	37.0%	3.0%	3.0%	41.0%
High connectivity (5-6)	20.0%	0.0%	0.0%	5.7%	25.7%	5.7%	0.0%	42.9%
Very high connectivity (7+)	19.0%	0.0%	2.4%	0.0%	4.8%	7.1%	14.3%	52.4%
Combined integration and choice R3 - frequency distribution								
Very low (<63)	27	8	4	4	77	7	2	14
Low (63-203)	17	0	0	2	40	4	3	33
Medium (203-515)	4	0	0	0	4	2	4	28
High (515-1152)	0	0	0	0	0	2	1	7
Very high (10%) (>1152)	0	0	1	0	0	0	0	7
Combined integration and choice R3 - relative frequency distribution								
Very low (<63)	18.9%	5.6%	2.8%	2.8%	53.8%	4.9%	1.4%	9.8%
Low (63-203)	17.2%	0.0%	0.0%	2.0%	40.4%	4.0%	3.0%	33.3%
Medium (203-515)	9.5%	0.0%	0.0%	0.0%	9.5%	4.8%	9.5%	66.7%
High (515-1152)	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	10.0%	70.0%
Very high (10%) (>1152)	0.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	87.5%

Table 4.5 - Cross-tabulation between the informed types of street-buildings interfaces and metric and topological characteristics of the streets in the estates of terraced houses.

4.3.3. The impact of terraced houses on the street activity

In the previous section 8 street-buildings interface types were identified based on the socio-morphological characteristics:

(1) a direct and impermeable side interface (0/0/0-side)
(2) a direct, physically permeable back interface (0/1/0-back)
(3) a direct, physically permeable side interface (0/1/0-side)
(4) a distant and impermeable side interface (1/0/0-side)
(5) a distant, physically permeable back interface (1/1/0-back)
(6) a distant, physically permeable front interface (1/1/0-front)
(7) a distant, physically and visually permeable side interface (1/1/1-side), and
(8) a distant, physically and visually permeable front interface (1/1/1-front)

In the next step of the analysis, those interface types are cross-tabulated with the metric and topological characteristics of the street (see Table 4.5).

Based on the cross-tabulation in the Table 4.5, we can observe a strong relationship between the importance of the streets and the type of the interface. In the majority of cases the most important streets in those estates, with regard to measures of metric length, connectivity and movement potential, were lined with distant, physically and visually permeable front interfaces. This means orientating active street-buildings interfaces towards important streets was a key factor in the organisation of the estates of terraced houses. On the other hand a strong relationship can be observed between the back and side interfaces and the shorter, less connected streets with very low to low movement potential. Which means that the back alley streetscapes were more likely to be quieter and more segregated in comparison to the front streets. The distant, physically and visually permeable side interface (1/1/1-side) is a curious case, because it relates to the more important, longer, very highly connected streets with high movement potential. It is interesting, because as mentioned above, the majority of side interfaces were found along the short, more segregated and quieter streets. This observation highlights again the lack of consistency in the design of the side façades, because they did not stem from the internal organisation of the terraced house, but rather from the urban geometric constraints. Therefore, it can be concluded that in the estates of terraced houses the design of the side façade varies depending on the street that it faces. If a side façade defines a street of lesser importance it tends to be, in the majority of cases, blank and impermeable. However, if it is adjacent to a more important street, the side interface mimics the morphology of the front interfaces. There is only one street that can be seen as an outlier to this hypothesis. This street situated on the northern edge of the estate T5, even though it is one of the most important local routes in Gosforth, it is defined by a visually impermeable side street-buildings interface (0/1/0-side), which can be described as an aggregation of many tall blank party walls along one side of that street. This design decision can be explained after consulting the historical Ordnance Survey map. When constructed, this route did not have as high degree of importance as it does in the present day. The further development of the area resulted in an extension to the length of the street and the construction of two additional housing estates and an industrial estate alongside.

As illustrated in Figure 4.9, the majority of streets in estates of terraced houses (83.7%) are defined by permeable interfaces, which means that those streets are constituted. However, more than half of those streets are visually passive, in other words there is an visually impermeable blank wall in between the public and private space. Most of those streets are segregated, quieter and less important back alleys. However, it is interesting that the number of those visually passive interfaces significantly outnumber the active ones.

As discussed in this section, the polar difference between the front and the back is evident in the structure of façades and interfaces of the terraced houses, but more interestingly it can also be observed in the topological and metric properties of the street. Additionally, there is an interesting distinction between streets that were influenced directly by the organisation of the terraced houses and those that emerged because of the geometric constraints of the urban block. While the interfaces that stemmed from the socio-functional requirements of

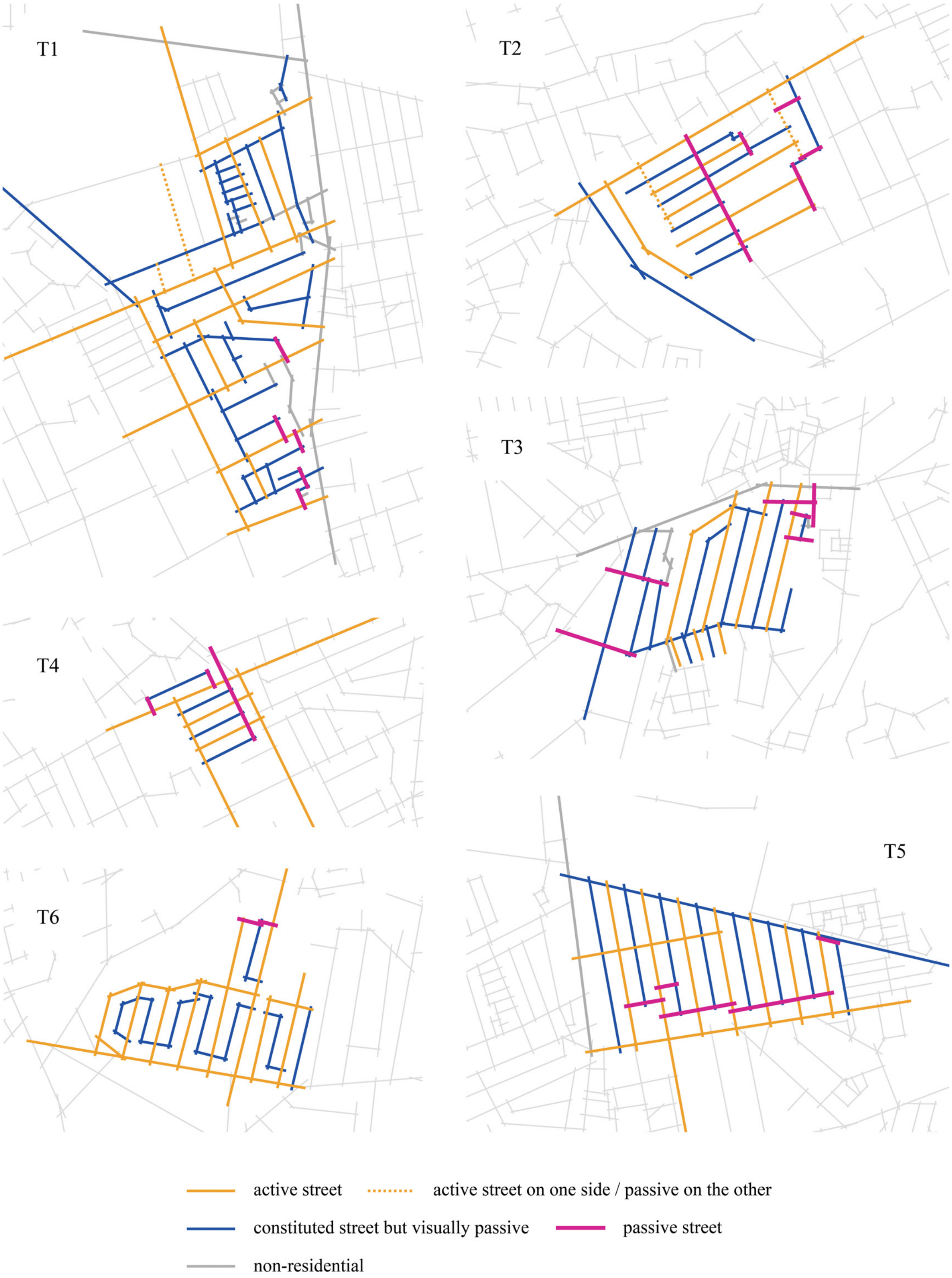

Figure 4.9 - Activity levels on the streets of six terraced estates in Gosforth (T1-T6) - determined through the analysis of street-buildings interfaces (source data can be found in Appendix A.9).

the terraced house seem to have a meticulously designed relationship between the house and the street, the interface type which emerged from the geometric constraints seems to be less developed and treated differently depending on the characteristics of the adjacent streets. When terraced houses are investigated the main emphasis seems to be placed solely on the front streets and back alleys. The side interfaces, and the side streets, tend to be omitted from the conversation, even though, as seen in this empirical study, it is possible for a passive side interface to define an important street in the network.

4.4. Analysis of the streets in the estates of semi-detached houses

This section examines the relationship between streets and adjacent houses in the eight estates of semi-detached houses in Gosforth. The eight estates, illustrated in Figure 4.10, vary in size between 5.4 and 19.1 hectares, with an average total area of 12.6 ha and an average density of 32 dwellings per hectare. The estates are predominantly residential and comprise mostly of semi-detached houses (for more details see Table 3.3 in Chapter 3).

4.4.1. The characteristics of the streets

The street network in each estate of semi-detached houses is represented as a set of interconnected axial lines, as illustrated in Figure 4.11. The number of axial lines per estate ranges between 8 and 66, with an average of 21 lines. The average density of axial lines per hectare is similar across the majority of the sampled estates and equals 2 axial/ha, with an exception of the estate S7. The increase in the density in estate S7 is impacted by the aggregation of many short axial lines in the blocks of flats situated in the south-western part of the estate (see Figure 4.11).

The metric and topological characteristics of the axial lines (streets) in each estate of semi-detached houses were compiled in the Table 4.6. The first part of the analysis of the street networks begins with the examination of the metric length of the streets. It is followed

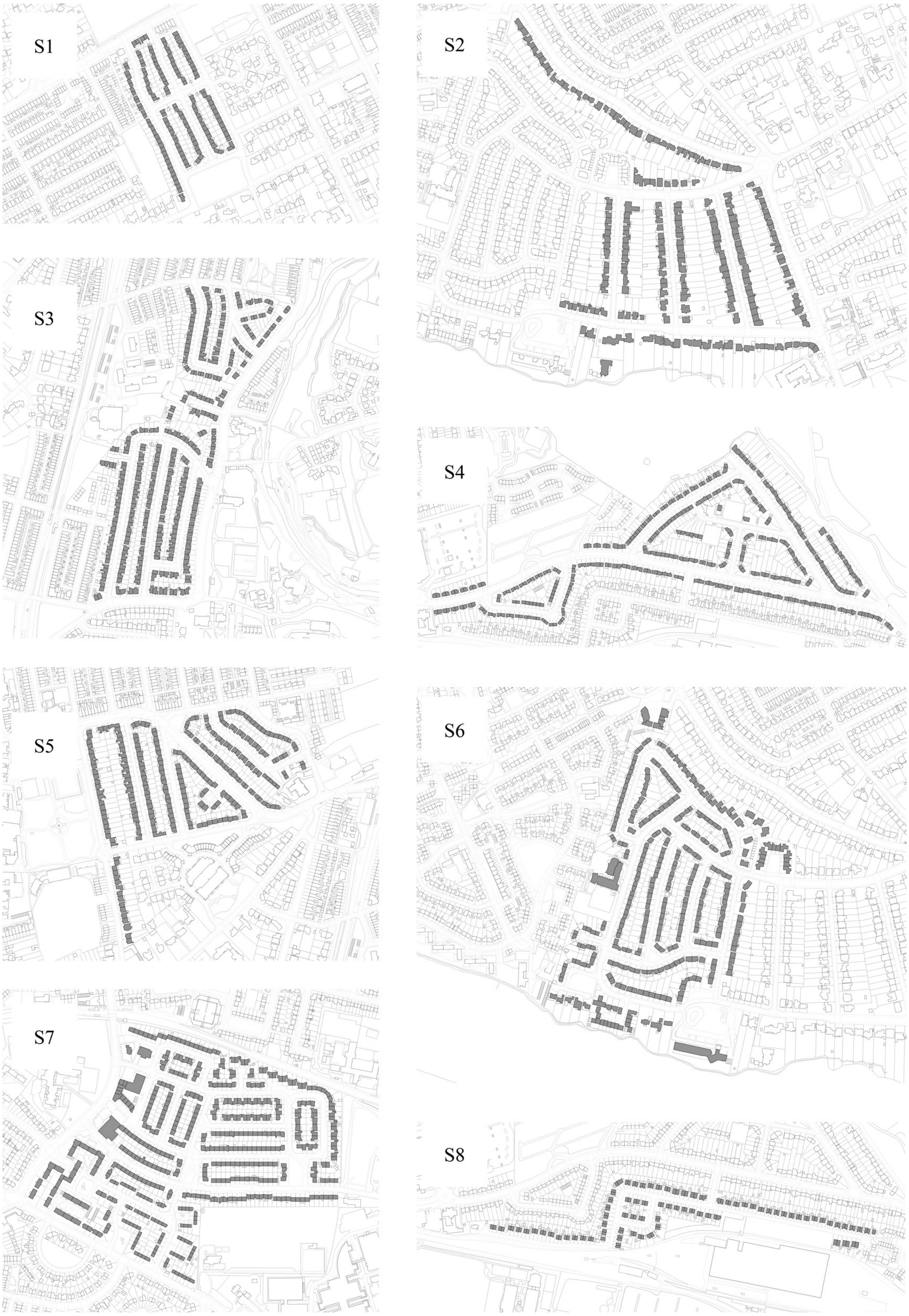

Figure 4.10 - Figure-ground maps of eight estates of semi-detached houses in Gosforth (S1-S8).

by the investigation of the importance of the streets using syntactic measures, such as connectivity and combined local integration and choice. The length of axial lines in the estates of semi-detached houses varies between 10.5 metres and 855.6 metres. Across all of the estates, the average length of the axial line is 142.1 metres. As shown in the relative frequency table in Table 4.6, the streets in those estates tend to be shorter rather than longer. 55.1% of all streets are shorter than 100 metres, and only a small percentage of the streets (2.0%) is longer than 600 metres. Exceptions to this pattern can be observed in two estates, S1 and S2, where the streets tend to be longer on average.

The majority of streets in each estate of semi-detached houses (70.4%) have either low or medium connectivity, meaning that axial lines tend to intersect with 2 to 4 other lines. 12.2% of streets across all of the estates have high connectivity and 10.7% of streets have very high connectivity. In some estates a deviation from this pattern can be observed. In estates S1, S2 and S5 the relative frequency of streets with high and very high connectivity is greater than the average. However, this relative frequency is skewed because of the low total number of axial lines (8 and 15 lines respectively in comparison to the average of 25 lines per estate). When the number of axial lines in the frequency table is considered instead, it can be observed that both those estates have 2 to 3 streets with very high connectivity, which is comparable to the other estates in the sample.

Through the measure of combined local integration and choice, the movement potential is determined for each street in the estates of semi-detached houses. On average, the majority of streets in the sampled estates have a very low or low movement potential (81.6%), and only a few streets per estate potentially accommodate high or very high volumes of movement (see Table 4.6). An interesting exception from this pattern can be observed in the estates S1 and S2, where the movement potential in the relative frequency table is spread more uniformly. However, as previously acknowledged, this is a result of a low total number of axial lines, which skews the relative frequency distribution. Thus, when

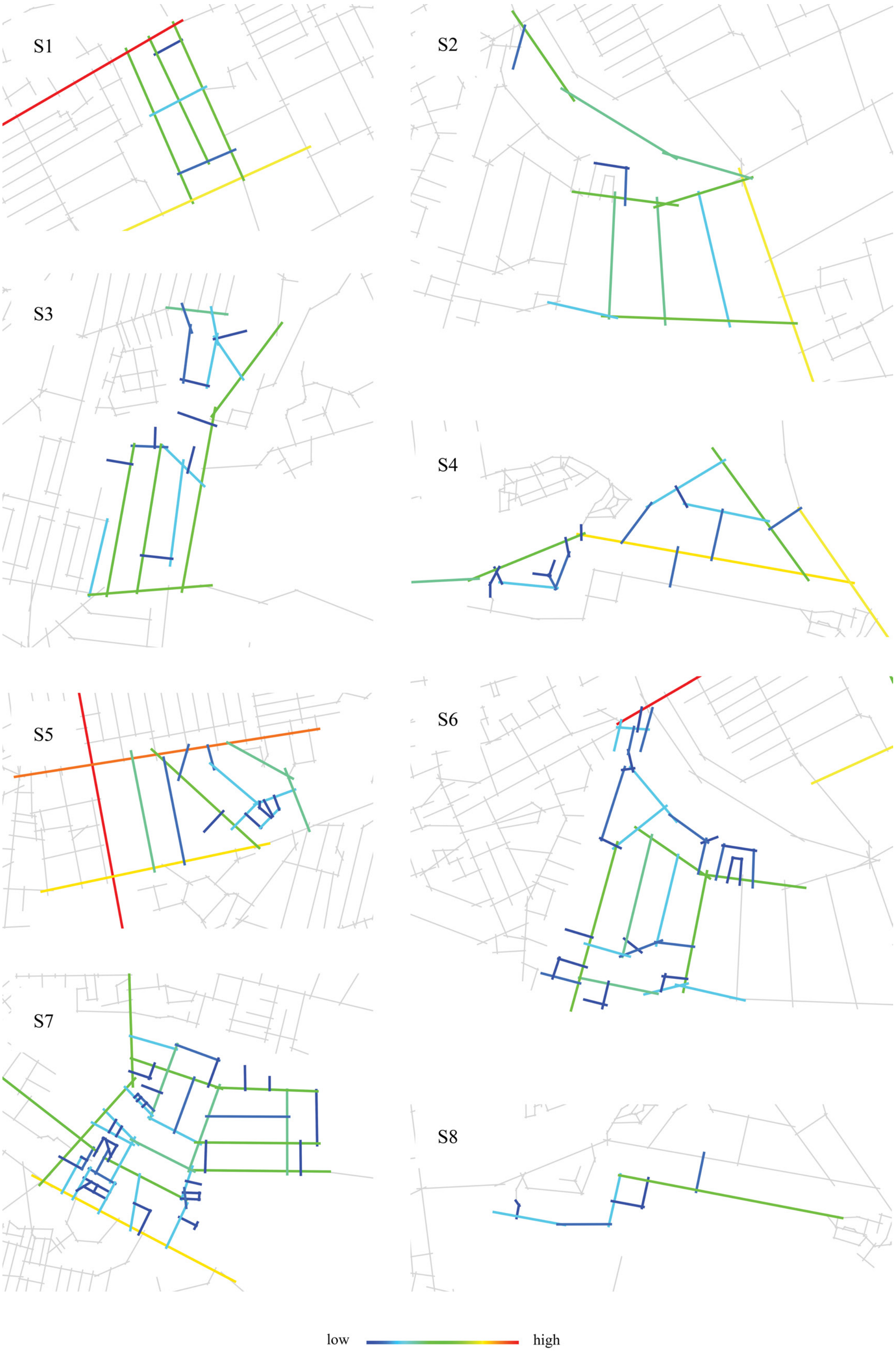

Figure 4.11 - Street networks of eight estates of semi-detached houses (S1-S8) represented as sets of interconnected axial lines. Colour range indicates the degree of movement potential (combined integration and choice R3) from the lowest (dark blue) to the highest (red).

	S1	S2	S3	S4	S5	S6	S7	S8	All
Estate area (ha)	5.4	18.5	10.4	14.7	9.2	19.1	17.8	5.7	101
Number of axial lines	8	14	22	22	20	42	66	9	196
Density (axial lines/ha)	1	1	2	1	2	2	4	2	2
Length (m) - general									
Min length	67.4	74.4	43.3	29.6	14.1	0.0	10.5	14.0	10.5
Average length	333.9	242.8	150.6	146.6	196.3	120.7	99.2	129.2	142.1
Max length	735.4	510.4	411.2	616.5	855.6	735.4	502.4	499.6	855.6
Length - frequency distribution									
0-100 metres	1	3	10	12	11	28	42	5	108
100-200 metres	2	1	6	5	3	8	14	3	41
200-350 metres	1	8	5	2	3	4	9	0	31
350-600 metres	3	2	1	2	1	1	1	1	12
600 metres and above	1	0	0	1	2	1	0	0	4
Length - relative frequency distribution									
0-100 metres	12.5%	21.4%	45.5%	54.5%	55.0%	66.7%	63.6%	55.6%	55.1%
100-200 metres	25.0%	7.1%	27.3%	22.7%	15.0%	19.0%	21.2%	33.3%	20.9%
200-350 metres	12.5%	57.1%	22.7%	9.1%	15.0%	9.5%	13.6%	0.0%	15.8%
350-600 metres	37.5%	14.3%	4.5%	9.1%	5.0%	2.4%	1.5%	11.1%	6.1%
600 metres and above	12.5%	0.0%	0.0%	4.5%	10.0%	2.4%	0.0%	0.0%	2.0%
Connectivity - frequency distribution									
Dead-ends (1)	0	0	4	0	1	2	6	0	13
Low connectivity (2)	1	5	4	8	8	18	22	7	69
Medium connectivity (3-4)	4	4	10	11	4	15	21	1	69
High connectivity (5-6)	1	2	2	1	3	4	10	1	24
Very high connectivity (7+)	2	3	2	2	4	3	0	0	21
Connectivity - relative frequency distribution									
Dead-ends (1)	0.0%	0.0%	18.2%	0.0%	5.0%	4.8%	9.1%	0.0%	6.6%
Low connectivity (2)	12.5%	35.7%	18.2%	36.4%	40.0%	42.9%	33.3%	77.8%	35.2%
Medium connectivity (3-4)	50.0%	28.6%	45.5%	50.0%	20.0%	35.7%	31.8%	11.1%	35.2%
High connectivity (5-6)	12.5%	14.3%	9.1%	4.5%	15.0%	9.5%	15.2%	11.1%	12.2%
Very high connectivity (7+)	25.0%	21.4%	9.1%	9.1%	20.0%	7.1%	0.0%	0.0%	10.7%
Ccombined integration and choice R3 - frequency distribution									
Very low (<63)	2	3	10	14	9	27	41	6	108
Low (63-203)	1	6	7	4	7	10	16	2	52
Medium (203-515)	2	3	3	2	0	3	6	0	18
High (515-1152)	2	2	2	2	3	1	3	1	16
Very high (10%) (>1152)	1	0	0	0	1	1	0	0	2
Combined integration and choice R3 - relative frequency distribution									
Very low (<63)	25.0%	21.4%	45.5%	63.6%	45.0%	64.3%	62.1%	66.7%	55.1%
Low (63-203)	12.5%	42.9%	31.8%	18.2%	35.0%	23.8%	24.2%	22.2%	26.5%
Medium (203-515)	25.0%	21.4%	13.6%	9.1%	0.0%	7.1%	9.1%	0.0%	9.2%
High (515-1152)	25.0%	14.3%	9.1%	9.1%	15.0%	2.4%	4.5%	11.1%	8.2%
Very high (10%) (>1152)	12.5%	0.0%	0.0%	0.0%	5.0%	2.4%	0.0%	0.0%	1.0%

Table 4.6 - Frequency and relative frequency distributions of metric and topological characteristics of the roads in eight estates of semi-detached houses.

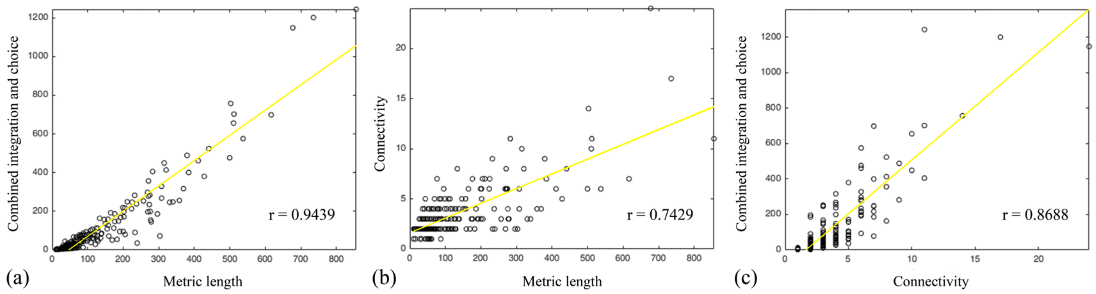

Figure 4.12 - Three scatter plots examine the strength of the relationships between three variables: metric length, connectivity and combined integration and choice, in sampled estates of semi-detached houses.

the number of axial lines is examined instead, it can be observed that there are 2 to 3 streets with high and very high movement potential in the estates S1 and S2, which is similar to the other estates.

The metric and topological analysis of the street networks of the estates of semi-detached houses yielded similar results. In most estates there is a high percentage of less important streets and a very small percentage of very important streets, regardless of the measure used. In some estates, this hierarchy is more pronounced than in others. In order to illustrate this conclusion, the correlation between the three measures was examined on scatter plots in Figure 4.12. A strong linear relationship (with a correlation coefficient $r > 0.7$) can be observed between each pair of measures. Thus, confirming that certain streets in the sampled estates have higher importance, while the majority of streets are of lesser importance regardless of the measures used.

4.4.2. The interface between streets and semi-detached houses

The study of the street as a part of a larger street system leads only to a partial understanding of the element. As discussed in the literature review in Chapter 2, streets are spatially defined by the adjacent buildings and are interdependent with them. Therefore, the next step of the analysis examines the relationship between the street and the adjacent semi-detached houses through the study of street-buildings interfaces.

As defined in Section 2.1 in Chapter 2, a street-buildings interface is a assemblage of individual building-street interfaces along one side of a street. Therefore, in order to determine the types of street-buildings interfaces, a classification of building-street interfaces is necessary. The data on the proximity, physical permeability and visual permeability of building-street interfaces was collected and mapped onto the plot boundary map in GIS (see Figure 4.13). Additionally, as discovered during the historical analysis of semi-detached houses in Chapter 3, the orientation of the façades of semi-detached houses is socio-functionally important. Therefore, information on the type of the façade (front, side or back) was added to the GIS database and compiled in Table 4.7.

	S1	S2	S3	S4	S5	S6	S7	S8	Total
Plots	142	207	346	343	252	335	469	154	2248
Building-street interfaces	174	233	442	383	289	410	627	165	2723
Interface/Plot ratio	1.2	1.1	1.3	1.1	1.1	1.2	1.3	1.1	1.2
Building-street interface types - frequency distribution									
Direct impermeable (0/0/0)	0	1	0	4	0	0	0	0	5
Direct vis. permeable (0/0/1)	0	0	0	0	0	0	0	0	0
Direct phys. permeable (0/1/0)	0	0	0	0	0	0	0	0	0
Direct phys. and vis. perm (0/1/1)	0	0	0	0	0	0	0	0	0
Direct open (0/open)	0	0	0	0	0	0	0	0	0
Distant impermeable (1/0/0)	4	25	43	13	8	36	46	11	186
Distant vis. permeable (1/0/1)	0	0	0	0	0	3	0	0	3
Distant phys. permeable (1/1/0)	30	17	50	12	17	12	18	0	156
Distant phys. and vis. perm (1/1/1)	136	190	345	335	257	322	428	153	2166
Distant open (1/open)	0	0	0	0	0	0	0	0	0
Non-applicable (n/a)	4	0	4	19	7	37	135	1	207
Building-street interface types - relative frequency distribution									
Direct impermeable (0/0/0)	0.0%	0.4%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Direct vis. permeable (0/0/1)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Direct phys. permeable (0/1/0)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Direct phys. and vis. perm (0/1/1)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Direct open (0/open)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Distant impermeable (1/0/0)	2.3%	10.7%	9.7%	3.4%	2.8%	8.8%	7.3%	6.7%	6.8%
Distant vis. permeable (1/0/1)	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.1%
Distant phys. permeable (1/1/0)	17.2%	7.3%	11.3%	3.1%	5.9%	2.9%	2.9%	0.0%	5.7%
Distant phys. and vis. perm (1/1/1)	78.2%	81.5%	78.1%	87.5%	88.9%	78.5%	68.3%	92.7%	79.5%
Distant open (1/open)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-applicable (n/a)	2.3%	0.0%	0.9%	5.0%	2.4%	9.0%	21.5%	0.6%	7.6%

Table 4.7 - Frequency and relative frequency distributions of building-street interface types in the estates of semi-detached houses based on proximity, and physical and visual permeability.

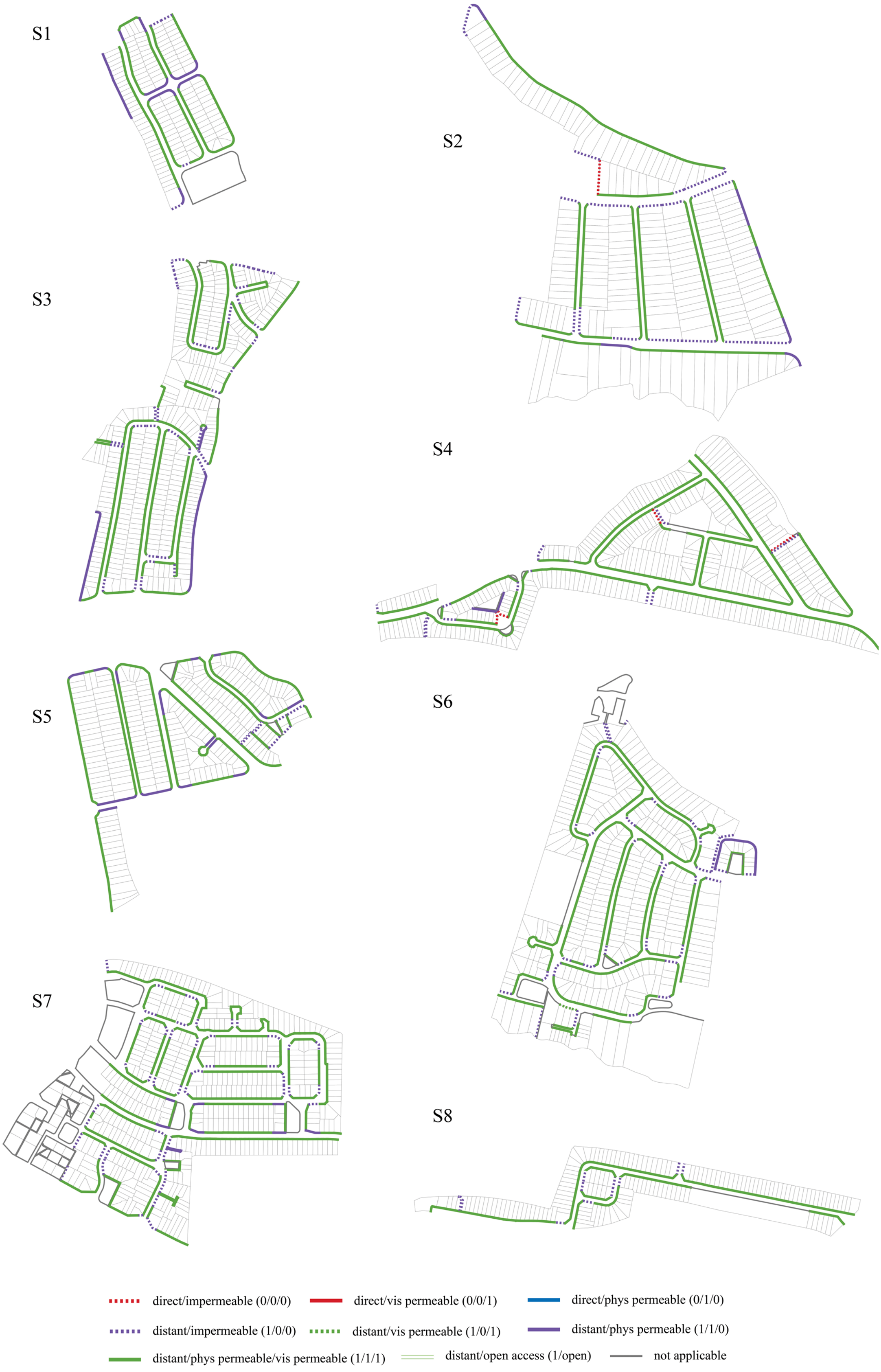

Figure 4.13 - Interface maps of individual building-street interfaces in eight estates of semi-detached houses in Gosforth (S1-S8).

There are on average 1.2 building-street interfaces per plot in the estates of semi-detached houses, which means that in the majority of cases one plot links with the street network through only one building-street interface. However, there are also cases where a single plot links with the street network through more than one building-street interface. Based on the relationship between three variables: proximity, and physical and visual permeability, 10 types of building-street interfaces are possible. Out of the possible types, in the estates of semi-detached houses 5 building-street interface types can be observed. As shown in Table 4.7, the majority of building-street interfaces (79.5%) in the estates of semi-detached houses can be characterised as distant, and physically and visually permeable (1/1/1). In other words, most of the houses are set back from the streets and allow for physical and visual connection between the private and public space.

As discussed in Chapter 3, the front façade is an important part of the socio-functional relationship between the semi-detached house and the adjacent street. Therefore, in the next step the established building-street interface types are cross-tabulated with three types of façades (front, side and back), in order to inform the topological classification of the interfaces with social context. The front façade is a part of the majority of observed interfaces in the estates of semi-detached houses (86.7%). The side and back façades are less frequently incorporated into the building-street interfaces (in 8.0% and 5.3%

Building-street interface types	front	side	back
Direct impermeable (0/0/0)	0.0%	2.5%	0.0%
Direct vis. permeable (0/0/1)	0.0%	0.0%	0.0%
Direct phys. permeable (0/1/0)	0.0%	0.0%	0.0%
Direct phys. and vis. permeable (0/1/1)	0.0%	0.0%	0.0%
Direct open (0/open)	0.0%	0.0%	0.0%
Distant impermeable (1/0/0)	0.0%	78.7%	20.3%
Distant vis. permeable (1/0/1)	0.0%	0.0%	2.3%
Distant phys. permeable (1/1/0)	1.0%	18.8%	72.2%
Distant phys. and vis. permeable (1/1/1)	99.0%	0.0%	5.3%
Distant open (1/open)	0.0%	0.0%	0.0%
Total number of interfaces	2181	202	133

Table 4.8 - The relationship between the building-street interface types and types of façade (front, side, and back) in the estates of semi-detached houses (source data can be found in Appendix A.10).

of interfaces, respectively), however, they are not completely insignificant. As shown in Table 4.8, there is a strong relationship between the building-interface types and the types of façades. Nearly all of the front façades are part of distant, physically and visually permeable interfaces (1/1/1). The side façades tend to be parts of distant and impermeable interfaces (1/0/0), while back façades are likely to be a part of distant and physically permeable interface (1/1/0). Based on this cross-tabulation, it can be concluded that the majority of semi-detached houses link to the street network through a front interface that allows for not only physical access to the house but also permits the passers-by to see the socially important front of the house, which may be used to exhibit the social status of the household. The setback between the semi-detached house and the street is a spatial buffer that allows for a controlled transition between the public and private spaces but also serves other socio-functional purposes, e.g. as a place for longer duration activities, such as car maintenance on the drive, or gardening in the front yard. Thus, the purpose of this interface stems from the house itself. On the other hand the side and back interfaces have a different origin. In most cases the side façade of a semi-detached house is part of a distant and impermeable interface. Which means that the interface was established to isolate the house from the street as a result of decisions on the urban scale of the design process. The side interface would not exist if not the rectangular geometry of the urban block commonly seen in estates of semi-detached houses. Four properties are situated in the corners of the block and, therefore, link to the adjacent street through two building-street interfaces, rather than one. As this link does not come from the socio-functional needs of a semi-detached house, it is in the majority of cases designed to isolate the private space of the house from the public street. In some cases, the side interface can be physically permeable in order to allow for additional vehicular access to the property. The back interface is a result of the direct adjacency of estates of semi-detached houses to estates of terraced houses. It was not uncommon for part of the perimeter of estates of terraced houses to be formed by back alleys. Therefore, with continuous residential development, newly built estates of semi-detached houses had to relate to the existing street network, including the back alleys. In most cases, when adjacent to a back alley, the semi-detached houses mimicked the building-street interface at the back of the house seen in terraced houses, hence the significant percentage of distant and physically permeable interfaces at the back of the house.

The next step of the analysis is concerned with the aggregation of individual building-street interfaces into street-buildings interfaces. The aggregation is performed in GIS and the data on the street-buildings interface types is added to the axial lines. The classification of the street-buildings interfaces is based on a combination of the topological properties (proximity, physical and visual permeability) and the socio-functional context. The distribution of the street-buildings interface types is shown in Table 4.9.

	S1	S2	S3	S4	S5	S6	S7	S8	Total
Streets	8	14	22	22	20	42	66	9	196
Domestic street-building interface	9	21	39	40	30	57	57	16	269
Interface/Street ratio	1.1	1.5	1.8	1.8	1.5	1.4	0.9	1.8	1.4
Street-buildings interface types - frequency distribution									
0/0/0-side	0	1	0	4	0	0	0	0	5
1/0/0-back	0	2	0	0	2	2	0	0	6
1/0/0-side	0	4	6	9	4	6	5	7	41
1/0/1-back	0	0	0	0	0	0	0	0	0
1/1/0-back	0	0	3	2	0	2	2	0	9
1/1/0-front	0	0	0	0	0	0	0	0	0
1/1/0-side	2	0	0	0	1	0	0	0	3
1/1/1-back	0	0	0	0	2	0	0	0	2
1/1/1-front	7	14	30	25	21	47	50	9	203
Street-buildings interface types - relative frequency distribution									
0/0/0-side	0.0%	4.8%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	1.9%
1/0/0-back	0.0%	9.5%	0.0%	0.0%	6.7%	3.5%	0.0%	0.0%	2.2%
1/0/0-side	0.0%	19.0%	15.4%	22.5%	13.3%	10.5%	8.8%	43.8%	15.2%
1/0/1-back	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/1/0-back	0.0%	0.0%	7.7%	5.0%	0.0%	3.5%	3.5%	0.0%	3.3%
1/1/0-front	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1/1/0-side	22.2%	0.0%	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%	1.1%
1/1/1-back	0.0%	0.0%	0.0%	0.0%	6.7%	0.0%	0.0%	0.0%	0.7%
1/1/1-front	77.8%	66.7%	76.9%	62.5%	70.0%	82.5%	87.7%	56.3%	75.5%

Table 4.9 - Frequency and relative frequency distributions of street-buildings interface types in the estates of semi-detached houses based on proximity, physical and visual permeability, and social context.

The most common street-buildings interface type is a distant, physically and visually permeable front interface (75.5% of cases), with the second most common being a distant impermeable side interface (15.2% of cases). The remaining 6 types are found less frequently across all estates.

The final aspect of this part of the analysis is to determine whether two similar street-buildings interfaces are likely to be situated along the same street. In the analysed estates of semi-detached houses, 52.7% of streets are defined by houses on both sides. In 25.9% of cases the street is defined by houses on one side only. The other side is either unbuilt, or defined by residential buildings or buildings that belong to another estate. 25.9% of the streets are defined by non-residential buildings or unbuilt space, therefore, they are not applicable to the analysis in this thesis. When only the streets with street-buildings interfaces on both sides are considered, three common streetscapes can be distinguished (see Figure 4.14):

> (1) A front street, which consists of a 1/1/1-front (distant, physically and visually permeable) interface on each side of the street, observed in 70.4% of cases.
>
> (2) A front-side street, which consists of a 1/1/1-front interface (distant, physically and visually permeable) on one side and a 1/0/0-side interface (distant and impermeable) on the other side of the street, seen in 11.1% of cases.
>
> (3) A side street, which comprises of a 1/0/0-side interface (distant and impermeable) on each side of the street, found in 9.3% of cases.

Therefore, even though it is likely that a street will be defined by the same street-buildings interface type on both sides, there are instances where that is not the case, and the street-buildings interface differs on each side of the street.

Figure 4.14 - Three identified streetscapes in the estates of semi-detached house: (a) a front street with a 1/1/1-front street-buildings interface on each side of the street, (b) a front-side street with a 1/1/1-front interface on one side and a 1/0/0-side interface on the other side, and (c) a side street with a 1/0/0-side interface on each side (Photographs by Author, taken on 28.09.2019).

4.4.3. The impact of semi-detached houses on the street activity

In the previous section 7 street-buildings interface types were identified in estates of semi-detached houses:

(1) a direct impermeable side interface (0/0/0-side)
(2) a distant and impermeable side interface (1/0/0-side)
(3) a distant and visually permeable back interface (1/0/1-back)
(4) a distant and physically permeable back interface (1/1/0-back)
(5) a distant and physically permeable side interface (1/1/0-side)
(6) a distant, physically and visually permeable back interface (1/1/1-back) and
(7) a distant, physically and visually permeable front interface (1/1/1-front)

In this sub-section those street-buildings interface types are cross-tabulated with the metric and topological characteristics of the streets (Table 4.10) in order to determine the impact of the semi-detached houses on the street activity through the evaluation of whether a street is defined by active or passive domestic interfaces.

The majority of streets in all of the sampled estates of semi-detached houses, regardless of their importance in the network, are defined by a distant, physically and visually permeable front interface (1/1/1) (see Table 4.10). It is interesting that the interface between a semi-detached house and a street does not change whether the street is potentially quiet and segregated or very busy and highly integrated. The other street-buildings interface types tend to define, in most cases, shorter, less connected streets with very low or low potential movement. However, some outliers can be observed. For example, some passive interfaces can be found along important streets with medium and high movement potential. Six distant impermeable (side and back) interfaces are found to be adjacent to streets with medium movement potential, and one long highly connected street with high movement potential is defined by a physically permeable but visually impermeable side interface, in other words a blank wall with an access point. While the majority of the streets in the estates of semi-detached houses are defined by active interfaces, regardless of the metric and topological characteristics of the streets, mismatches can still be observed in a few

Cross-tabulation	side	back	side	back	side	back	front
	0/0/0	1/0/0	1/0/0	1/1/0	1/1/0	1/1/1	1/1/1
Total number	5	6	41	9	3	2	203
Length - frequency distribution							
0-100 metres	5	5	33	7	0	2	75
100-200 metres	0	0	3	1	2	0	62
200-350 metres	0	1	4	0	0	0	48
350-600 metres	0	0	1	1	1	0	13
600 metres and above	0	0	0	0	0	0	5
Length - relative frequency distribution							
0-100 metres	3.9%	3.9%	26.0%	5.5%	0.0%	1.6%	59.1%
100-200 metres	0.0%	0.0%	4.4%	1.5%	2.9%	0.0%	91.2%
200-350 metres	0.0%	1.9%	7.5%	0.0%	0.0%	0.0%	90.6%
350-600 metres	0.0%	0.0%	6.3%	6.3%	6.3%	0.0%	81.3%
600 metres and above	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Connectivity - frequency distribution							
Dead-ends (1)	0	0	3	3	0	0	16
Low connectivity (2)	2	5	17	4	0	2	60
Medium connectivity (3-4)	3	0	12	1	2	0	77
High connectivity (5-6)	0	0	4	1	0	0	28
Very high connectivity (7+)	0	1	5	0	1	0	22
Connectivity - relative frequency distribution							
Dead-ends (1)	0.0%	0.0%	13.6%	13.6%	0.0%	0.0%	72.7%
Low connectivity (2)	2.2%	5.6%	18.9%	4.4%	0.0%	2.2%	66.7%
Medium connectivity (3-4)	3.2%	0.0%	12.6%	1.1%	2.1%	0.0%	81.1%
High connectivity (5-6)	0.0%	0.0%	12.1%	3.0%	0.0%	0.0%	84.8%
Very high connectivity (7+)	0.0%	3.4%	17.2%	0.0%	3.4%	0.0%	75.9%
Combined integration and choice R3 - frequency distribution							
Very low (<63)	5	5	28	7	0	2	93
Low (63-203)	0	0	8	1	2	0	64
Medium (203-515)	0	1	5	1	0	0	38
High (515-1152)	0	0	0	0	1	0	6
Very high (10%) (>1152)	0	0	0	0	0	0	2
Combined integration and choice R3 - relative frequency distribution							
Very low (<63)	3.6%	3.6%	20.0%	5.0%	0.0%	1.4%	66.4%
Low (63-203)	0.0%	0.0%	10.7%	1.3%	2.7%	0.0%	85.3%
Medium (203-515)	0.0%	2.2%	11.1%	2.2%	0.0%	0.0%	84.4%
High (515-1152)	0.0%	0.0%	0.0%	0.0%	14.3%	0.0%	85.7%
Very high (10%) (>1152)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

Table 4.10 - Cross-tabulation between the informed types of street-buildings interfaces and metric and topological characteristics of the streets in the estates of semi-detached houses.

Figure 4.15 - Activity levels on the streets of eight estates of semi-detached houses in Gosforth (S1-S8) - determined through the analysis of street-buildings interfaces (source data can be found in Appendix A.11).

cases which might negatively impact the potential activity on those few important streets. This can be seen on the map of the active and passive interfaces in Figure 4.15.

4.5. Analysis of the streets in the estates of detached houses

In this section the relationship between streets and houses in estates of detached houses is examined. As introduced in Chapter 3, there are four estates of detached houses in Gosforth (see Figure 4.16). The total area of each of those estates varies between 1.4 to 8.9 hectares, with an average area of 4.5 hectares and an average density of 21 dwellings per hectare. The estates are nearly exclusively residential and consist of mainly detached houses (for more details see Table 3.4 in Chapter 3).

4.5.1. The characteristics of streets

The street network of the estates of detached houses is depicted as an interconnected arrangement of axial lines, as shown in Figure 4.17. The number of axial lines that constitute a network in each estate ranges between 6 and 30, with an average number of

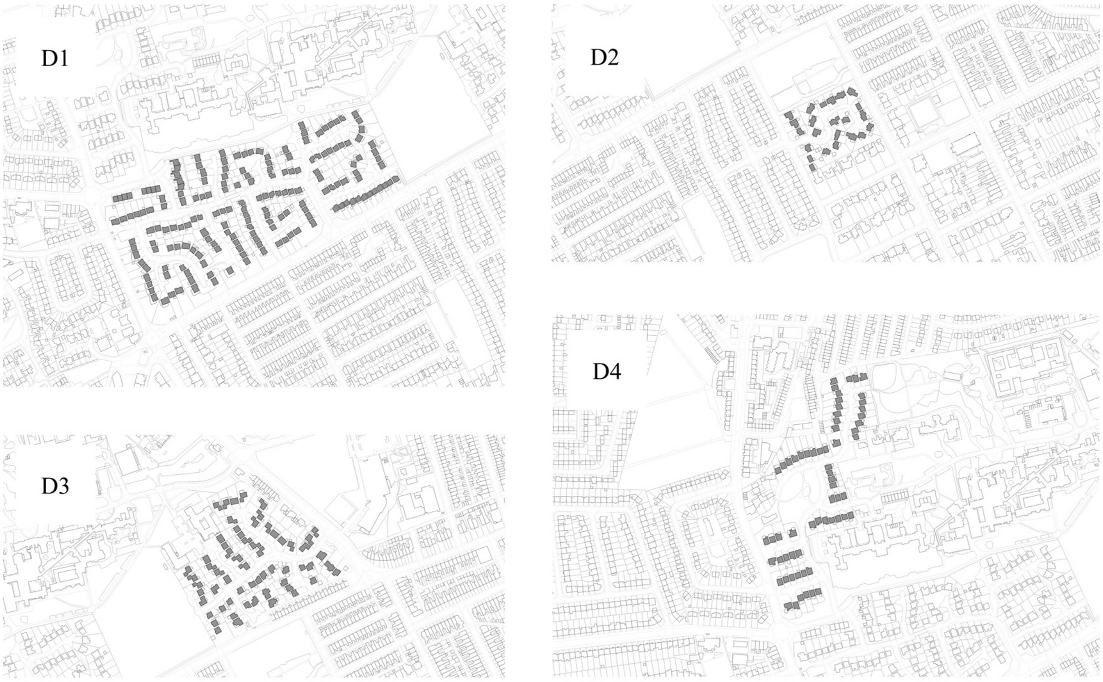

Figure 4.16 - Figure-ground maps of four estates of detached houses in Gosforth (D1-D4).

20 axial lines per estate. The average density of the streets in each estate is 4 axial lines per hectare. While in the majority of the estates similar densities can be observed, in the estate D4 the density is 7 axial lines per hectare. This increase was impacted by the incorporation of a small park and playground in the layout of the estate D4, which introduced multiple unconstituted axial lines to the network of the estate (see Figure 4.17).

The information on the metric and topological characteristics of streets (axial lines) in each estate of detached houses is presented in Table 4.11. The study of the metric length of the streets is the first part of the analysis of street networks in the sampled estates. The second part examines the importance of an axial line in the larger networks through the examination of the syntactic measures of connectivity and combined local integration and choice. The length of the streets ranges between 18.6 metres and 736.3 metres, depending on the estate, with an average length of 118.4 metres. The majority of the axial lines in the estates of detached houses (68.4%) are shorter than 100 metres, or between 100

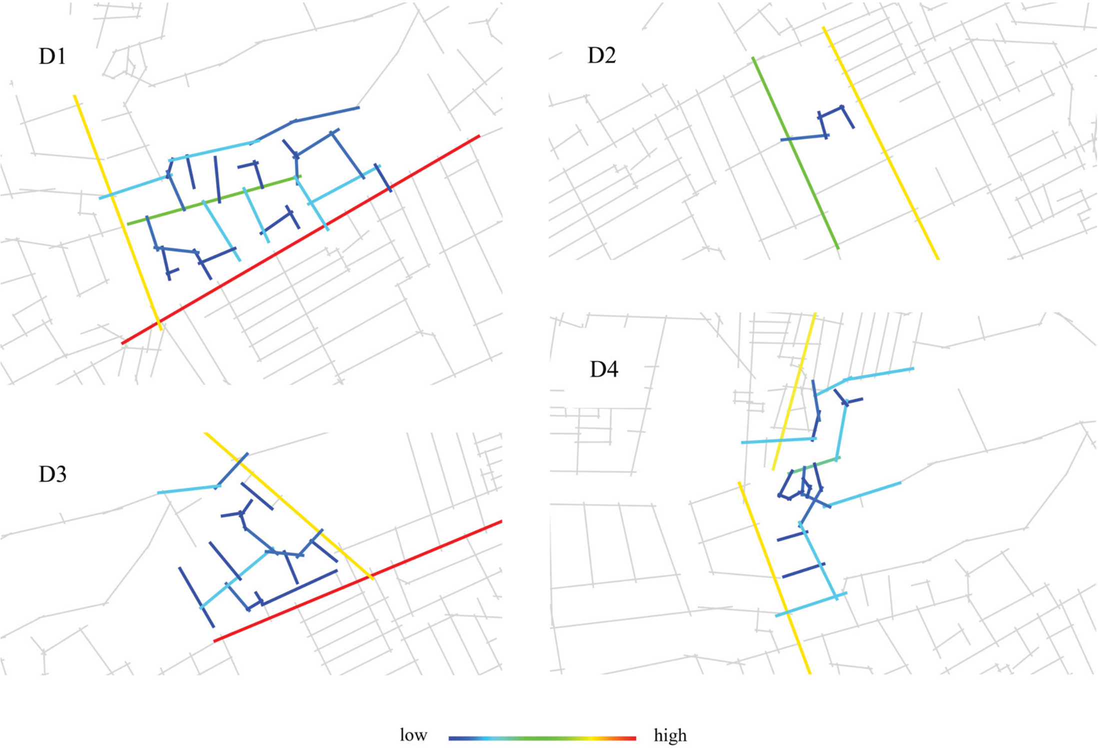

Figure 4.17 - Street networks of four estates of detached houses (D1-D4) represented as sets of interconnected axial lines. Colour range indicates the degree of movement potential (combined integration and choice R3) from the lowest (dark blue) to the highest (red).

	D1	D2	D3	D4	All
Estate area (ha)	8.9	1.4	3.7	3.8	18
Number of axial lines	30	6	20	25	79
Density (axial lines/ha)	3	4	5	7	4
Length (m) - general					
Min length	20.0	43.9	18.6	20.7	18.6
Average length	122.7	190.6	127.8	104.5	118.4
Max length	735.4	538.4	736.3	508.6	736.3
Length - frequency distribution					
0-100 metres	19	4	14	17	54
100-200 metres	8	0	4	6	17
200-350 metres	1	0	0	0	1
350-600 metres	1	2	1	2	5
600 metres and above	1	0	1	0	2
Length - relative frequency distribution					
0-100 metres	63.3%	66.7%	70.0%	68.0%	68.4%
100-200 metres	26.7%	0.0%	20.0%	24.0%	21.5%
200-350 metres	3.3%	0.0%	0.0%	0.0%	1.3%
350-600 metres	3.3%	33.3%	5.0%	8.0%	6.3%
600 metres and above	3.3%	0.0%	5.0%	0.0%	2.5%
Connectivity - frequency distribution					
Dead-ends (1)	5	1	5	2	13
Low connectivity (2)	13	2	6	7	28
Medium connectivity (3-4)	8	1	6	10	25
High connectivity (5-6)	1	0	1	4	5
Very high connectivity (7+)	3	2	2	2	8
Connectivity - relative frequency distribution					
Dead-ends (1)	16.7%	16.7%	25.0%	8.0%	16.5%
Low connectivity (2)	43.3%	33.3%	30.0%	28.0%	35.4%
Medium connectivity (3-4)	26.7%	16.7%	30.0%	40.0%	31.6%
High connectivity (5-6)	3.3%	0.0%	5.0%	16.0%	6.3%
Very high connectivity (7+)	10.0%	33.3%	10.0%	8.0%	10.1%
Ccombined integration and choice R3 - frequency distribution					
Very low (<63)	21	4	16	15	56
Low (63-203)	6	0	2	8	15
Medium (203-515)	0	0	0	0	0
High (515-1152)	2	2	1	2	6
Very high (10%) (>1152)	1	0	1	0	2
Ccombined integration and choice R3 - relative frequency distribution					
Very low (<63)	70.0%	66.7%	80.0%	60.0%	70.9%
Low (63-203)	20.0%	0.0%	10.0%	32.0%	19.0%
Medium (203-515)	0.0%	0.0%	0.0%	0.0%	0.0%
High (515-1152)	6.7%	33.3%	5.0%	8.0%	7.6%
Very high (10%) (>1152)	3.3%	0.0%	5.0%	0.0%	2.5%

Table 4.11 - Frequency and relative frequency distributions of metric and topological characteristics of the roads in four estates of detached houses.

and 200 metres long (21.5%). As presented in the relative frequency table in Table 4.11, only a small portion of streets are longer than 600 metres. An outlier can be found in the estate D2, where 33.3% of streets are between 350 and 600 metres long. However, when the number of axial lines, rather than their relative distribution, is considered, it can be observed that the number of longer axial lines is similar to that in the other sampled estates. The relative frequency distribution was, thus, skewed by the low total number of axial lines in estate D2.

The distribution of the connectivity in the estates of detached houses can be described as follows. The majority of streets have low or medium connectivity (67.1%), thus, the axial lines intersect between 2 to 4 other lines at a time in most cases. Approximately 1 in 5 streets is a dead-end or a cul-de-sac which connects to only one other street. On average, 10.1% of all streets are highly connected. A similar connectivity pattern can be observed in most of the sampled estates, with the exception of estate D2. As discussed previously, estate D2 comprises only of 6 axial lines, therefore, the relative frequency distribution is easily distorted. Thus the number of highly interconnected axial lines (2) in estate D2 is similar to the other sampled estates.

The combined syntactic measures of local integration and choice help to determine the movement potential of an axial line. As shown in Table 4.11, the majority of streets in the estates of detached houses (89.9%) have very low or low movement potential. The remaining percentage of streets have either high or very high movement potential. Interestingly, there is not a single axial line in the four sampled estates that has a medium movement potential. Therefore the overall configuration of movement in the estates of detached houses can be described as a combination of many internal streets with very low or low movement potential (dark blue and blue) with a few streets with high and very high movement potential situated on the perimeter of the estates (yellow and orange) (see Figure 4.17).

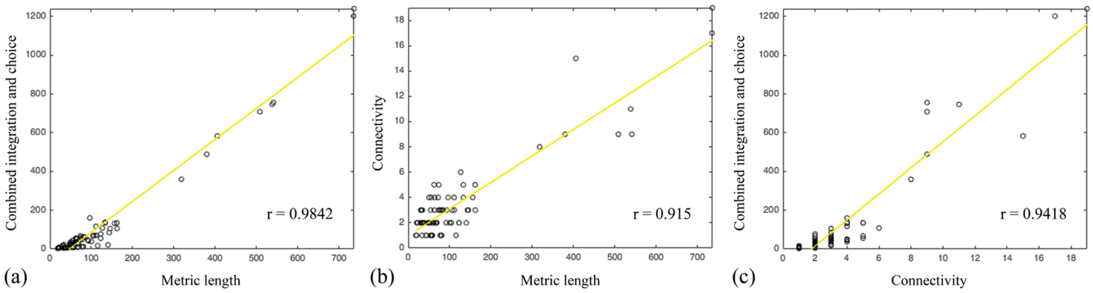

Figure 4.18 - Three scatter plots examine the strength of the relationships between three variables: metric length, connectivity and combined integration and choice, in sampled estates of detached houses.

Based on the analysis of the metric and topological characteristics of the street networks in the estates of detached houses, a similar conclusion can be drawn. Regardless of the measure utilised, the majority of streets have lower importance in the network, while only a few are long, highly connected with a high or very high movement potential. The streets with higher importance are located on the perimeter of the estate in most cases. To illustrate this conclusion, the measures were correlated on the scatter plots shown in Figure 4.18. A strong positive linear relationship with a correlation coefficient $r > 0.9$ is observed in all three pairs of variables, which means that the long streets tend to have high connectivity and high movement potential, while short streets are more likely to have low connectivity and low movement potential.

4.5.2. The interface between streets and detached houses

The analysis of the streets in the estates of detached houses provides an insight into the local structure of streets as parts of a larger interconnected street network. However, apart from the macro-scalar properties, the streets are also affected by the characteristics of the micro-scale, the buildings that define them. For that reason, in the next section the relationship between the street and detached houses is explored through the analysis of street-buildings interfaces.

As a street-buildings interface is an aggregation of individual building-street interfaces along one side of a street, the investigation begins with the analysis and classification of the building-street interfaces. Building-street interfaces are categorised based on the topological variables defined in Chapter 2: proximity, physical and visual permeability. The data on the individual interfaces are collected, mapped in GIS (see Figure 4.19) and compiled in Table 4.12.

Out of the 10 types of building-street interfaces established in Chapter 2, four types can be observed in the estates of detached houses: a distant impermeable interface (1/0/0), a distant physically permeable interface (1/0/1), a distant, physically and visually permeable interface (1/1/1), and a distant open interface (1/open). The two latter types are the most common in the estates of detached houses, found in 30.2% and 60.2% of cases respectively. Based on the distribution of the building-street interface types, the detached house appears to have two polar ways of interacting with the street network, either through complete openness without any physical boundary between the façade of the house and the public

Figure 4.19 - Interface maps of individual building-street interfaces in four estates of detached houses in Gosforth (D1-D4).

street, or through complete isolation with a blank impermeable wall between the house and street. As shown in Table 4.12, there are on average 1.6 interfaces per plot, therefore it is likely that most of the detached houses interface with the street network through both types of interface.

However, the relationship between the detached house and the street is more than the topological relationship. As explored in Chapter 3, the link between the front of the detached houses and the street is important socially and functionally. It provides access to the house and exhibits social cues about the status of the household. Moreover, the aggregated front façades and front lawns along one street are used to create a community-

Building-street interface types	D1	D2	D3	D4	Total
Plots	185	23	63	68	339
Building-street interfaces	289	32	95	111	527
Interface/Plot ratio	1.6	1.4	1.5	1.6	1.6
Building-street interface types - frequency distribution					
Direct impermeable (0/0/0)	0	0	0	0	0
Direct vis. permeable (0/0/1)	0	0	0	0	0
Direct phys. permeable (0/1/0)	0	0	0	0	0
Direct phys. and vis. perm (0/1/1)	0	0	0	0	0
Direct open (0/open)	0	0	0	0	0
Distant impermeable (1/0/0)	88	9	28	34	159
Distant vis. permeable (1/0/1)	0	0	0	0	0
Distant phys. permeable (1/1/0)	10	0	0	0	10
Distant phys. and vis. perm (1/1/1)	0	9	0	0	9
Distant open (1/open)	179	14	61	63	317
Non-applicable (n/a)	12	0	6	14	32
Building-street interface types - relative frequency distribution					
Direct impermeable (0/0/0)	0.0%	0.0%	0.0%	0.0%	0.0%
Direct vis. permeable (0/0/1)	0.0%	0.0%	0.0%	0.0%	0.0%
Direct phys. permeable (0/1/0)	0.0%	0.0%	0.0%	0.0%	0.0%
Direct phys. and vis. perm (0/1/1)	0.0%	0.0%	0.0%	0.0%	0.0%
Direct open (0/open)	0.0%	0.0%	0.0%	0.0%	0.0%
Distant impermeable (1/0/0)	30.4%	28.1%	29.5%	30.6%	30.2%
Distant vis. permeable (1/0/1)	0.0%	0.0%	0.0%	0.0%	0.0%
Distant phys. permeable (1/1/0)	3.5%	0.0%	0.0%	0.0%	1.9%
Distant phys. and vis. perm (1/1/1)	0.0%	28.1%	0.0%	0.0%	1.7%
Distant open (1/open)	61.9%	43.8%	64.2%	56.8%	60.2%
Non-applicable (n/a)	4.2%	0.0%	6.3%	12.6%	6.1%

Table 4.12 - Frequency and relative frequency distributions of building-street interface types in the estates of detached houses based on proximity, and physical and visual permeability.

focused environment that can be perceived as one communal semi-private space, rather than aggregation of small semi-private front gardens or drives. Therefore, the information on the type of the façade interfacing with the street network was added to the interface map and cross-tabulated with the building-street interface types.

As shown in Table 4.13, the majority of building-street interfaces (65.9%) link the front façade to the adjacent street. The percentage of the side and back façades that are incorporated into the building-street interfaces is not insignificant: 18.2% and 16.0% respectively. Moreover, a strong relationship can be observed between the building-street interface types and the types of façades seen in detached houses. In nearly all of the cases the front façades are part of a distant open interface (97.2%), in other words an interface that consists of a spatial buffer between the house and the street (setback), which does not have any physical boundary on the edge between the private and public spaces. The side and back interfaces are, in the majority of the cases, part of distant impermeable interfaces. Those patterns are very similar to those observed in semi-detached houses but more pronounced. Similarly to the semi-detached houses, in detached houses the front interface originated from the interior of the house and is directly impacted by the spatial organisation of the detached house. The side and the back interfaces are by-products of the layout of the estates of detached houses. As the aim of the design of the estates of detached

Building-street interface types	front	side	back
Direct impermeable (0/0/0)	0.0%	0.0%	0.0%
Direct vis. permeable (0/0/1)	0.0%	0.0%	0.0%
Direct phys. permeable (0/1/0)	0.0%	0.0%	0.0%
Direct phys. and vis. permeable (0/1/1)	0.0%	0.0%	0.0%
Direct open (0/open)	0.0%	0.0%	0.0%
Distant impermeable (1/0/0)	0.0%	100.0%	87.3%
Distant vis. permeable (1/0/1)	0.0%	0.0%	0.0%
Distant phys. permeable (1/1/0)	0.0%	0.0%	12.7%
Distant phys. and vis. permeable (1/1/1)	2.8%	0.0%	0.0%
Distant open (1/open)	97.2%	0.0%	0.0%
Total number of interfaces	326	90	79

Table 4.13 - The relationship between the building-street interface types and the type of facade (front, side, and back) in detached houses (source data can be found in Appendix A.12).

houses was to create community enclaves inside of each estate, one of the main aspects of the design process was to face the front of each house towards the internal streets, in order to create a communal character. However, if every house faces the interior of the estate through its front façade, there has to be a part of a house that faces the exterior of the estate and the existing urban tissue. Therefore, the detached houses link with the space outside of the estate through their side or back interfaces, depending on the position of the house on the plot. As the primary concept of the design of the estates of detached houses was to isolate the new community from the existing urban life and strangers on the streets, it is not surprising that the interfaces that link to the spaces outside of the estates are almost exclusively distant and impermeable.

The next step of the analysis focuses on the conversion of the aggregated individual building-street interfaces into street-buildings interfaces. In order to allow for cross-tabulation between the street-buildings interfaces and the metric and topological properties of the axial lines, the data on the street buildings interfaces is added to the axial line layer in GIS. The typology of the street-buildings interfaces is based on the combination of topological properties introduced in Chapter 2 and the socio-functional types of the façades. In Table 4.14, the frequency distribution of street-buildings interface types for the estates of detached houses is shown. The most common street-buildings interface type in the estates of detached houses is a distant open interface at the front of the house (64.7% of cases). Nearly all of the other interfaces are distant and impermeable linking either the side or back of the house to the adjacent street.

The last element of this part of the analysis is determining the likelihood of two similar street-buildings interface types being situated along the same street. Approximately half of the streets (53.8%) in the sampled estates of detached houses are defined by houses on both sides of the street. In 37.5% of cases, streets are defined by houses on one side only. The other side is either non-residential, does not belong to the analysed estate or is unbuilt.

The remaining 8.8% are streets defined by built or unbuilt form that is not applicable to the analysis in this thesis. If the streets with street-buildings interfaces on both sides are considered, three common streetscapes can be identified (see Figure 4.20):

(1) A front street, which consists of a 1/open-front (distant and open) interface on each side of the street (69.8% of cases).

(2) A front-side street, which consists of a 1/open-front (distant and open) interface on one side and 1/0/0-side (distant and impermeable) interface on the other side (16.3% of cases).

(3) A side street, which consists of a 1/0/0-side (distant and impermeable) interface on each side of the street (9.3% of cases).

Based on this categorisation, it can be concluded that it is likely that a street is defined by the same type of street-buildings interface. However, there is a high possibility (37.5%) that a street is defined by detached houses only on one side.

	D1	D2	D3	D4	Total
Streets	30	6	20	25	79
Domestic street-building interface	52	10	31	23	116
Interface/Street ratio	1.7	1.7	1.6	0.9	1.5
Street-buildings interface - frequency distribution					
1/0/0-back	4	1	2	6	13
1/0/0-side	11	3	7	4	25
1/1/0-back	2	0	0	0	2
1/1/0-side	0	0	0	0	0
1/1/1-front	0	1	0	0	1
1/open-front	35	5	22	13	75
Street-buildings interface - relative frequency distribution					
%	D1	D2	D3	D4	Total
1/0/0-back	7.7%	10.0%	6.5%	26.1%	11.2%
1/0/0-side	21.2%	30.0%	22.6%	17.4%	21.6%
1/1/0-back	0.0%	0.0%	0.0%	0.0%	0.0%
1/1/1-front	0.0%	10.0%	0.0%	0.0%	0.9%
1/open-front	67.3%	50.0%	71.0%	56.5%	64.7%

Table 4.14 - Frequency and relative frequency distributions of street-buildings interface types in the estates of detached houses based on proximity, physical and visual permeability, and social context.

Figure 4.20 - Three identified streetscapes in the estates of semi-detached house: (a) a front street with a 1/open-front street-buildings interface on each side of the street, (b) a front-side street with a 1/open-front interface on one side and a 1/0/0-side interface on the other side, and (c) a side street with a 1/0/0-side interface on each side (Photographs by Author, taken on 28.09.2019).

4.5.3. The impact of detached houses on the street activity

In the previous section 5 street-buildings interface types were identified:

(1) a distant and impermeable back interface (1/0/0-back)

(2) a distant and impermeable side interface (1/0/0-side)

(3) a distant and physically permeable back interface (1/1/0-back)

(4) a direct, physically and visually permeable front interface (1/1/1-front)

(5) a distant and open front interface (1/open)

In order to determine the impact of the micro-scale of the detached house on the street activity, these street-buildings interface types are cross-tabulated with the metric and topological properties of the street networks, and compiled in Table 4.15. The analysis evaluates street-buildings interface types in terms of how active or passive they are in supporting life on the streets (see Figure 4.21).

Based on the cross-tabulation between the metric and topological properties of the streets and street-buildings interface types, it can be concluded that there is a visible pattern in the relationship between both variables. The shorter, less connected streets with very low to medium movement tend to be defined by the distant and open front interfaces (1/open). On the other hand, the long, highly connected streets with high and very high movement potential are almost exclusively defined by distant impermeable side or back interfaces. The streets defined by distant open front interfaces are likely to be positioned internally, while the back and side interfaces are situated on the perimeter of the estate (see Figure 4.21). The only outlier can be seen in the case of the 1/1/1-front interface type in the estate D3, which is positioned on the perimeter, quite possibly to relate to the existing semi-detached houses on the other side of the street. Overall, there is a strong relationship between the streets with high importance and passive interfaces, and streets with low importance and active interfaces. As mentioned previously, the main aim of the design of the estates of detached houses was to isolate them from outside influences and treat them as enclaves catered to a specific community (in principal this is similar to gated

Cross-tabulation	back	side	back	front	front
	1/0/0	1/0/0	1/1/0	1/1/1	1/open
Total number	13	25	2	1	75
Length - frequency distribution					
0-100 metres	4	16	2	0	59
100-200 metres	5	6	0	0	14
200-350 metres	0	0	0	0	2
350-600 metres	3	2	0	1	0
600 metres and above	1	1	0	0	0
Length - relative frequency distribution					
0-100 metres	4.9%	19.8%	2.5%	0.0%	72.8%
100-200 metres	20.0%	24.0%	0.0%	0.0%	56.0%
200-350 metres	0.0%	0.0%	0.0%	0.0%	100.0%
350-600 metres	50.0%	33.3%	0.0%	16.7%	0.0%
600 metres and above	50.0%	50.0%	0.0%	0.0%	0.0%
Connectivity - frequency distribution					
Dead-ends (1)	0	5	2	0	17
Low connectivity (2)	1	8	0	0	32
Medium connectivity (3-4)	6	7	0	0	23
High connectivity (5-6)	2	2	0	0	1
Very high connectivity (7+)	4	3	0	1	2
Connectivity - relative frequency distribution					
Dead-ends (1)	0.0%	20.8%	8.3%	0.0%	70.8%
Low connectivity (2)	2.4%	19.5%	0.0%	0.0%	78.0%
Medium connectivity (3-4)	16.7%	19.4%	0.0%	0.0%	63.9%
High connectivity (5-6)	40.0%	40.0%	0.0%	0.0%	20.0%
Very high connectivity (7+)	40.0%	30.0%	0.0%	10.0%	20.0%
Combined integration and choice R3 - frequency distribution					
Very low (<63)	4	17	2	0	61
Low (63-203)	5	5	0	0	12
Medium (203-515)	0	0	0	1	2
High (515-1152)	3	2	0	0	0
Very high (10%) (>1152)	1	1	0	0	0
Combined integration and choice R3 - relative frequency distribution					
Very low (<63)	4.8%	20.2%	2.4%	0.0%	72.6%
Low (63-203)	22.7%	22.7%	0.0%	0.0%	54.5%
Medium (203-515)	0.0%	0.0%	0.0%	33.3%	66.7%
High (515-1152)	60.0%	40.0%	0.0%	0.0%	0.0%
Very high (10%) (>1152)	50.0%	50.0%	0.0%	0.0%	0.0%

Table 4.15 - Cross-tabulation between the informed types of street-buildings interfaces and metric and topological characteristics of the streets in the estates of detached houses.

communities). However, such an isolating design practice is not beneficial for the street life on the perimeter of those estates. The side and back interfaces were not designed to generate, encourage or promote longer duration activities along the streets, but solely to isolate the house. Such a negative impact on the street life would not have been so pronounced if those interfaces linked with shorter streets with low movement potential, however, in the analysed cases, the distant and impermeable street-buildings interfaces define the most important streets in Gosforth.

4.6. Summary and conclusion

In this chapter the relationship between streets and adjacent houses was explored using space syntax methods and the concept of the interface map. The aim of this chapter was to determine whether the design of the interface between the streets and the houses had an

Figure 4.21 - Activity levels on the streets of four detached estates in Gosforth (D1-D4) - determined through the analysis of street-buildings interfaces (source data can be found in Appendix A.13).

effect on the activity on the streets.

In the first part of the analysis the metric and topological properties of the street networks were investigated in order to determine the hierarchy and importance of the streets in each estate, based on metric length, connectivity and combined local integration and choice (movement potential). The relative frequency tables of each variable in each estate type (terraced, semi-detached and detached) are summarised in Table 4.16. Across all of the estate types, it can be observed that the majority of streets are shorter than 100 metres with a very low movement potential. The relative percentage of the shorter more segregated streets increases over time, from approximately 50% of streets in the estates of terraced houses to approximately 70% of cases in the estates of detached houses. The relative distribution of the connectivity in each estate type is similar with the exception of a significantly higher percentage of dead-ends and cul-de-sacs in the estates of detached houses. In other words, the overall structure of the estates of detached houses changed when compared to the estates of terraced and semi-detached houses. The estates of detached houses consisted of many shorter, more disconnected streets, which is reflected in the higher density of streets per hectare in Table 4.16.

The second part of the analysis was concerned with the study of the relationship between the streets and the adjacent buildings through the analysis of building-street interfaces, which later were aggregated into street-buildings interfaces in order to allow for cross-tabulation with the axial lines. It can be concluded that the interface can be grouped into two categories based on their origin, with interfaces that stemmed from the internal organisation of the houses, and the interfaces that were a by-product of the urban design of the estate. In terraced houses, two such interfaces can be observed: a distant, physically and visually permeable front interface (1/1/1-front) and a distant physically permeable back interface (1/1/0-back). Both interfaces originated as a result of the functional need to connect to the street network through two fundamentally different interfaces in order to separate the formal and representative front and the everyday informal back, where 'dirty' household tasks were accommodated, such as coal storage, or livestock. With technological advancements and changes in the design of the kitchen, the functional need for a back interface was not necessary anymore, thus semi-detached houses required only one interface with the street network - a distant physically and visually permeable front interface (1/1/1-front). A similar relationship can be observed between the detached house and the street network, where the organisation of the house required only one interface with the street network, through a distant open front interface (1/open-front).

However, when the interface types were cross-tabulated with the metric and topological

Summary	terraced	semi-detached	detached
Average estate area (ha)	11.4	12.6	4.5
Average number of axial lines per estate	36	21	20
Density (axial lines/ha)	3	2	4
Length - relative frequency distribution			
0-100 metres	44.3%	55.1%	68.4%
100-200 metres	27.1%	20.9%	21.5%
200-350 metres	19.0%	15.8%	1.3%
350-600 metres	6.2%	6.1%	6.3%
600 metres and above	3.3%	2.0%	2.5%
Connectivity - relative frequency distribution			
Dead-ends (1)	5.7%	6.6%	16.5%
Low connectivity (2)	36.7%	35.2%	35.4%
Medium connectivity (3-4)	32.9%	35.2%	31.6%
High connectivity (5-6)	10.5%	12.2%	6.3%
Very high connectivity (7+)	14.3%	10.7%	10.1%
Combined integration and choice R3 - relative frequency distribution			
Very low (<63)	51.4%	55.1%	70.9%
Low (63-203)	29.0%	26.5%	19.0%
Medium (203-515)	11.9%	9.2%	0.0%
High (515-1152)	5.2%	8.2%	7.6%
Very high (10%) (>1152)	2.4%	1.0%	2.5%
Activity levels - relative frequency distribution			
Active	31.5%	72.1%	45.9%
Visually passive but accessible	52.2%	7.9%	1.4%
One side active - one side passive	2.2%	6.1%	13.5%
Passive	14.1%	13.9%	39.2%

Table 4.16 - Summary of characteristics of the streets across three house types: terraced, semi-detached and detached.

properties of the streets, an interesting change in the treatment of the street lined with front interfaces was observed. The representative and formal front interfaces in terraced houses defined the most important (with regard to connectivity and movement potential) streets. On the other hand, the front interfaces in detached houses faced the community-orientated streets with very low movement potential that prioritised the relationship between inhabitants of the enclave while discouraging any interaction between inhabitants and strangers.

The interfaces that stemmed from the decisions made on the urban scale such as the geometry of the urban block or the overall layout of the estate were, in the majority of cases, morphologically similar - both physically and visually impermeable side or back interfaces. When those interfaces were cross-tabulated with the characteristics of the streets an interesting trend was observed. The importance of the streets defined by the side interfaces changed. In the estates of terraced and semi-detached houses, those interfaces defined mostly streets with lesser importance, that is shorter with low movement potential, while in the estates of detached houses the side interface faced the most topologically important streets in the estates. This was a design decision made in order to allow for each front façade in the estate to face exclusively the internal quieter streets, at the detriment of the existing urban tissue.

One of the metrics considered in this chapter was the activity level of the street based on the types of the adjacent interface. An interesting trend was observed when the distribution of the streets with different activity levels across the three estate types (terraced, semi-detached and detached) was compared. A significant increase in the number of passive streets can be observed in the estates of detached houses, which was largely influenced by the introverted design of the layout of the estate discussed above. In conclusion, this chapter has demonstrated how the treatment of the interface can affect the character and activity on the streets. It has illustrated how the undesirable passive interfaces are often a by-product of the urban design of the estates. Given that a significant increase of passive interfaces is observed in the detached estates, a growing mismatch between the architectural and urban scale can be seen through the analysis of the development of English suburban house types.

Chapter 5

The morphology of houses in Newcastle: the interface between a house and the street network

5.1. Introduction: contextualising architectural form

Buildings and their internal layouts, although distinct and significantly different in comparison to the open space between them, should be investigated in context to their immediate surroundings. As discussed in the literature review in Chapter 2, buildings and the open space are polar forms, however, they are also highly interdependent and influenced by each other. Fundamentally, buildings would not be 'usable' if there was no connection, no point of access to the outside open space. However, in morphological studies it is common to analyse buildings in isolation or with their context simplified to a point of reference.

In space syntax, the immediate context is acknowledged in the gamma-analysis, but it is simplified to a point - a cross-hair node (Hillier and Hanson, 1984, p.148) (see Figure 5.1a). Therefore, it is difficult to determine whether the analysed building is directly connected to the open space or through an elaborate set of semi-private and public in-between spaces. In graph-theoretic studies the relationship between the internal layout and its context was explored in more detail and its importance has been acknowledged (Krüger, 1979; Steadman, 1983, pp.65-66) (see Figure 5.1b and c). Various types of interfaces between buildings and their immediate context were explored by Krüger (1979), who defined multiple types of interfaces: between buildings and other directly adjacent buildings ('graph of type 1'), between buildings and plots ('graph of type 2'), and between buildings and adjacent streets ('graph of type 3')[1] (Krüger, 1979). However, there are very few configurational studies of the relationship between the internal layout of the house and its context.

This chapter discusses the development of a graph-theoretic method that allows for the systematic categorisation and analysis of internal floor plans which retains information on

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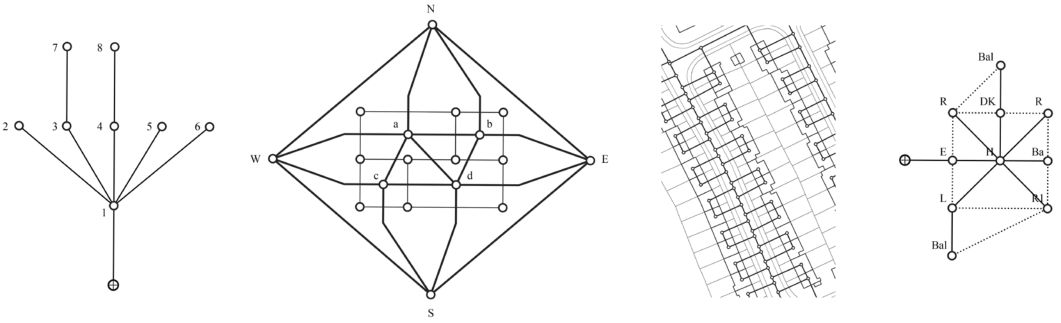
[1] Krüger also discussed graphs that illustrate relationships on urban scale: between roads ('graph of type 4'), and between urban blocks ('graph of type 5') (Krüger, 1979).

their immediate surroundings. Through the analysis of the building-network interfaces, this chapter addresses the second question of this thesis: *does the way in which a house interfaces with streets affect its internal configuration and how does it do this?*

5.2. Graph-theoretic method

The method used to analyse the internal layouts of English houses in this chapter is based on the combination of the graph-theoretic methods proposed by Seo (2003, pp.108-111; 2007; 2016), Krüger (1979), and Steadman (1983, pp.65-66) (see Figure 5.1). The aim of this method is to propose a graph representation that not only illustrates topological relationships but also helps us to understand the relationship between a building and its immediate surroundings. As the main emphasis is on the topological relationship between the house and its context, the analysis is concerned only with the ground floor plan.

Seo (2003, pp.108-111) developed a method that allowed for the analysis of the topological relationships of domestic spaces in relation to the geometric frame of the building (see Figure 5.1d). As discussed in the previous section, Krüger (1979) proposed different methods to analyse the relationship between a building and its context. Steadman argued



(a) (b) (c) (d)

Figure 5.1 - Four methods of graph representations of built form. (a) In space syntax building layouts were converted into justified access graphs that showed depth of rooms in relation to the base node. (b) Plan graph (thin lines) with its augmented dual adjacency graph (thick lines) was introduced by Steadman (1983, pp.65-66) in order to illustrate the way that the immediate surroundings of a building can be incorporated into the graph. (c) Graphs of types 1, 3 and 4, proposed by Krüger (1979) to describe interfaces between various elements. (d) Graph representation developed by Seo (2003, pp. 108-111) that combines information on the topological relationships between rooms in relation to the simplified outline of a building.

that the information on the relationship between internal spaces and the external regions can be incorporated into a graph (Steadman, 1983, pp.65-66).

The proposed method consists of three parts:

(1) The internal layouts of houses are converted into graphs based on Seo's method (2003, pp.108-111; 2007; 2016). The graphs are classified and the typology of the internal graphs is proposed based on the structure of the graphs.

(2) The relationship between the house, its plot and adjacent streets is represented as a graph based on Krüger's method (1979) and referred in this thesis as a building-network interface graph. Those graphs are then categorised into types, and the typology of the building-network interfaces is proposed.

(3) Lastly, both graph representations are combined into one graph. The information on nodes and links is stored in GIS, as points and lines respectively. The morphological characteristics of the internal graph types are then cross-tabulated with the data on the building-network interfaces and the impact of the relationship between the two is assessed.

The process of converting a floor plan into a graph is illustrated in Figure 5.2. The first step is to simplify the floor plan into a diagram that consists of a set of rectangles (Figure 5.2b). Each rectangle corresponds to a convex space with an identifiable function[2]. Most of the buildings and plots are roughly rectangular in shape, therefore, it is easy to conceptualise them as so[3]. The buildings, however, are never perfectly rectangular and in many cases the

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[2] Small convex spaces like cupboards, closets or wall indents are ignored. Adjacency between rooms that are divided by a wall shorter than a possible opening are also omitted.

[3] As Steadman discusses in the book *Architectural Morphology* (1983), the shape of most of the houses tends to be rectangular and non-rectangular designs are very uncommon. Steadman cites the work of Bemis (1936) who surveyed houses in Boston, US and found that 88.5% of houses were rectangular, and the work of Krüger who found that 98% of houses in Reading, UK were rectangular in shape (Steadman, 1983).

outline is indented. Therefore, sometimes it is necessary to include external convex spaces (called by Seo (2016) 'dummy cells') in order to preserve the rectangular shape. However, there is a drawback that is pointed out by Steadman (1983, p.14) that some of those spaces might not have any social or functional significance.

In order to topologically compare the floor plans, relative dimensional differences are removed in order to achieve a 'dimensionless representation' (Steadman, 1983, p.11) (Figure 5.2c)[4]. This allows the focus to be shifted from the metric to topological properties of the room, such as the relative position of the rooms in the house. Each rectangle is represented by a node positioned in the centre of each space (Figure 5.2c). Two types of nodes are distinguished: an internal node (white) - which represents internal spaces within the house, and an external node (black) - which represents external open spaces within the boundaries of the plot. The links between the nodes signify direct adjacency between two spaces.

In the next step, following Seo's method (2003, p.110), the graph is aligned to the outline

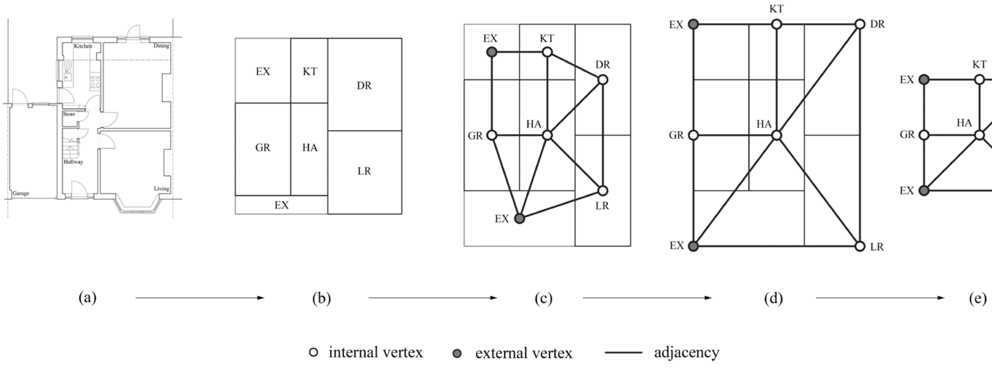

Figure 5.2 - Method used to convert floor plan into a graph. The floor plan (a) is converted into a set of rectangles (b). Next, the relative metric differences are removed to achieve a 'dimensionless representation' (c). Then, each room is represented by a node and the adjacency-based relationship between the rooms is illustrated by a link (c). The graph is aligned to the outline of the building (d) and modulated to a square format (e).

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[4] There are other methods to achieve a 'dimensionless representation'. For example a method that utilises a binary code of 0s and 1s to describe the voids and solids in the floor plans (Shayesteh and Steadman, 2015).

of the building[5] (see Figure 5.2d). To assure consistency, each dimensionless rectangle is modulated and overlaid onto a X-Y axis, where the node in the bottom left corner of the graph has coordinates (0,0), in the bottom right corner - (8,0), in the top left corner - (0,8), and in the top right corner - (8,8). The other nodes are positioned in relation to the corner nodes. The 8x8 unit axis was chosen as eight was the highest number of grid lines, in both X and Y direction, observed in the sample. Lastly, as shown in Figure 5.1e, graphs are modulated into a square format which allows for the comparison of not only topological relationships but also the relative positions of the rooms in relation to the building. In the end, the graph combines information on the adjacency-based relationships between rooms and the relative position of the rooms in relation to the outline of the building. Based on this representation, the classification of internal graphs is proposed and graph types are categorised using a descriptor defined in Figure 5.3a. Additionally, information on the

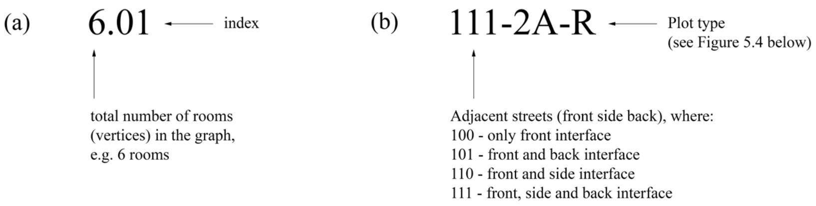
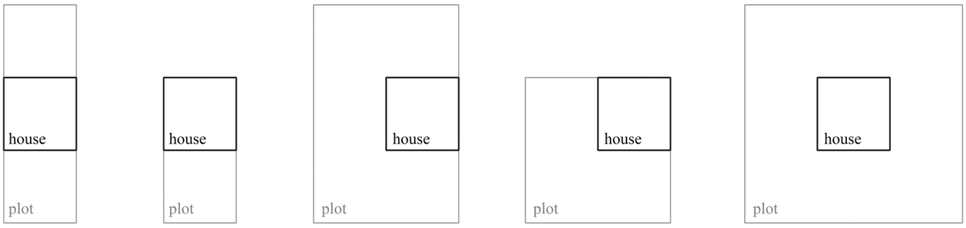


Figure 5.3 - Two types of descriptors used to classify internal graph types (a) and building-network interface types (b).



1A 1B 2A 2B 3A

Figure 5.4 - Plot types observed in the sample.

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[5] If a space takes the whole width of the graph the node representing it is positioned in the centre of the outline.

function of the room and the physical and visual permeability of the links between the rooms is added, in order to allow for a detailed analysis. However, the additional data increased the variety of the internal graph types, therefore the classification is based solely on the adjacency-based graphs.

The next step is based on Krüger's method (1979). The relationship between the house, its plot and adjacent streets is represented as a graph, where nodes illustrate regions and links depict direct adjacencies between those regions. In this representation the house is simplified to a node. Based on this method, the classification of the building-network interfaces is proposed and the interface types are classified using a descriptor defined in Figure 5.3b. The data on the internal graph types is then cross-tabulated with the information on the building-network interface types in order to assess the relationship between the two elements.

Lastly, the internal graph representation proposed by Seo (2003, pp.108-111; 2007; 2016) is extended to include information on the building-network interface of each house. External nodes (black) and outside nodes (cross-hair) - which represents the open space outside of the boundaries of plot, are added to the graph. The outline of the plot is added to allow for the representation of the relationship between the building and the plot. In order to standardise the process, all graphs are flipped or rotated in order to assure that the front of the house is at the bottom and the hallway is on the left side of the graph.

As discussed in Chapter 3, English speculative housing is intertwined with the development of three single-family house types: byelaw terraced, semi-detached and detached. The popularity of those types corresponds to different periods between the late nineteenth century and early twenty-first century (described in detail in Chapter 3). Therefore, the structure of this analysis chapter follows the chronological development in English single-family housing: starting with terraced houses, through semi-detached and ending with detached houses.

The floor plans analysed in the thesis were selected based on availability and a set of requirements. The floor plans were collected from three public access sources: Newcastle City Council planning applications database, and two online property websites: Zoopla and Rightmove[6]. The floor plans were collected between October and November 2017, however, not all of them were used in the analysis, as they had to meet the following requirements:

1. The building has to be exclusively residential, mixed developments are not included in this analysis.
2. The house has to consist of only one dwelling, in other words it has to accommodate only one household.
3. The house has to be two storeys high, in order to maintain similarity in the availability of the space to accommodate rooms.
4. The house had to be developed in the main phases of the estate development. Any further additions to the estate are not included in the analysis.

In the 18 analysed estates, 3903 buildings (82%) meet the requirements. Based on those predetermined requirements and the availability of the floor plans, 613 houses were selected. In the following sections, the floor plans of 254 terraced, 309 semi-detached and 50 detached houses are analysed using the graph-theoretic method described in this section.

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[6] Newcastle City Council planning applications database was accessed between October and November 2017 through the website: https://www.newcastle.gov.uk/services/planning-building-and-development/search-view-and-comment-planning-applications.
Property databases were accessed between October and November 2017 through Zoopla: https://www.zoopla.co.uk/ and Rightmove: https://www.rightmove.co.uk/.

[7] All 48 internal graph types can be found in the Appendix A.14.

5.3. Analysis of terraced house plans

254 floor plans were converted into adjacency graphs which resulted in 48 unique internal graph types[7], averaging 5.3 floor plans per type. Some graphs occur more frequently than the others, and the four most common types correspond with more than half of analysed floor plans (52.3%) (see Figure 5.5b).

5.3.1. Shared morphologies in terraced house plans

When compared, interesting similarities and differences were identified in the common graph types shown in Figure 5.5. The main distinction between the types is in the number

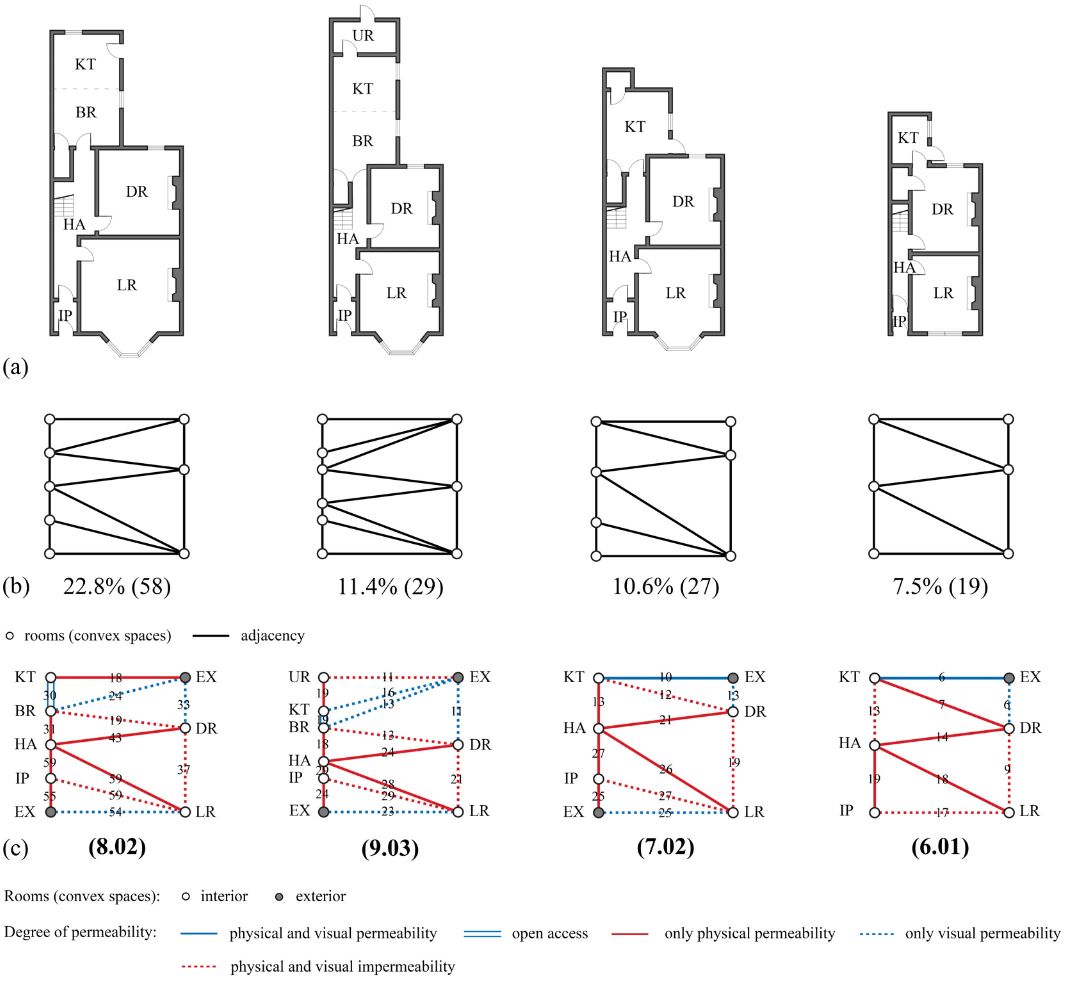


Figure 5.5 - Four common internal graph types with corresponding floor plans (a), adjacency graphs (b) and permeability graphs (c). In (c) the number on each link describes the number of occurrences of a specific relationship between the specific rooms. Key: BR - breakfast room, DR - dining room, EX - external space, HA - hall, IP - internal porch, KT - kitchen, LR - living room, UR - utility room.

of nodes and links. As shown in Table 5.1, the number of rooms in the sampled houses ranges between 4 and 11. However, the majority of terraced houses (92.9%) consist of 6 to 9 rooms, with the most common number of rooms being 8.

Despite this fundamental difference, some shared characteristics can be observed. Firstly, the number of rooms situated along the right side of the graph is consistently 3. When the overall number of nodes increases, the increase can be observed on the left side of the graph. Secondly, as shown in the corresponding permeability graphs in the Figure 5.5c, the consistency on the right side of the graph can be also observed in the types of rooms. Living rooms are positioned in the bottom right part of the graphs, the dining rooms at the centre right, and the external yards at the top right. Although the main difference in

Terraced houses with:	Houses		Graphs	
	Number	%	Number	H/G*
4 rooms	2	0.8%	1	2.0
5 rooms	3	1.2%	1	3.0
6 rooms	29	11.4%	5	5.8
7 rooms	55	21.7%	8	6.9
8 rooms	95	37.4%	15	6.3
9 rooms	57	22.4%	10	5.7
10 rooms	12	4.7%	7	1.7
11 rooms	1	0.4%	1	1.0
All houses	254	100.0%	48	5.3

Table 5.1 - Internal graph types in terraced houses with a varying number of rooms (nodes). H/G* describes the house to graph type ratio.

Terraced houses with:	Parts of the graph		
	Left side	Middle	Right side
4 rooms	2	0	2
5 rooms	2	0	3
6 rooms	3	0	3
7 rooms	4	0	3
8 rooms	5	0	3
9 rooms	5	0	3
10 rooms	6	1	4
11 rooms	6	0	5
All houses	5	0	3

Table 5.2 - The position of rooms (nodes) in relation to the outline of the house in terraced houses with a varying number of rooms (nodes).

the number and function of the rooms can be observed along the left side of the graph, some recurring patterns can be identified. In all four graphs there is an entrance area in the bottom left part of the graph that consists of either 2 or 3 nodes that correspond to spaces such as: porches, hallways and doorsteps. While the number of nodes in the top left part of the graph varies between 1 and 3, the use of those rooms is consistent. Those nodes are either a kitchen or a room that supports the kitchen, e.g.: a breakfast room, or a utility room. Moreover, as shown in Figure 5.5a, those rooms tend to be located in the back projection. Therefore, the variation in the configuration of the house is more likely to be observed in the projection rather than in the core of the house.

Similar patterns can be observed in all sampled terraced houses. As shown in Table 5.2, the average number of nodes along the middle and right side of the graph is more uniform when compared to the left side of the graph. The average number of nodes along the left, middle and right side in all terraced houses corresponds to the number of nodes observed in the four common graph types in Figure 5.5.

In order to investigate whether the consistency in the position of specific types of rooms recurs in all of the sampled terraced houses, data on the position of seven types of rooms

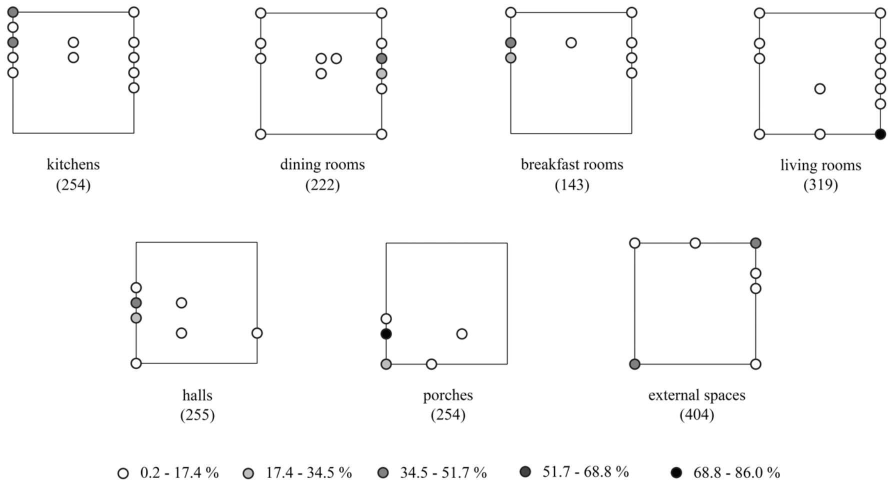


Figure 5.6 - The positions of the seven room types within the graph. The darker the node the higher the occurrence of the room in the specific position. The number under the name of each room indicates the number of occurrences of each type of room in the sample of 254 terraced houses (see Appendix A.15 for details).

(kitchens, dining rooms, breakfast rooms, living rooms, hallways, porches, and exterior spaces) was compiled in Figure 5.6. The patterns in the location of rooms are discussed and the occurrence of each type of room per house is investigated. A kitchen, a hallway and a porch can be observed in every terraced house in the sample. A dining room is present in approximately 90% of the houses, while a breakfast room appears in approximately 60%. In many houses, there are one or more living rooms and external spaces (within the outline of the graph). As shown in Figure 5.6, the position of the types of rooms across the whole sample varies, however, the majority of rooms in each room type are located in similar parts of the graph, regardless of its structure. Kitchens and breakfast rooms are more likely to be positioned in the top left part of the graph, at the back of the house. Dining rooms tend to be situated in the centre right part of the graph, and living rooms in the bottom right part of the graph - towards the front of the house. The position of the living room is interesting, because living spaces are nowadays perceived as accommodating private everyday life, thus, it would be expected for them to be positioned towards the back of the house. However, as terraced houses were mostly built at the end of the nineteenth century, the relationship between the ‘living’ room and family life was different. The front living room, also called a sitting room, or a parlour, and was used for more formal, rather than everyday, aspects of family life (Hanson, 1998).

Based on the distribution of the types of rooms in the whole sample and the analysis of the common graphs (shown in Figure 5.6 and Figure 5.5 respectively), it can be concluded that the position of the types of rooms in terraced houses is consistent regardless of the number of nodes and the graph type.

Further similarities can be observed in the configuration of the links in the common internal graphs in Figure 5.5. The movement (shown as continuous lines) through the house is accommodated along the left side of the graph. Interestingly, the rooms situated on the right side of the graph, the living and dining room, are segregated from the rest of the house and can only be accessed from the hallway. The reason for this isolation might be related to the social perception of those rooms. The living and dining rooms were reserved for formal occasions (such as family gatherings or Sunday dinners), which mostly involved receiving visitors, rather than private affairs. An exception to this pattern can be observed in graph type 6.01 in Figure 5.5, where the movement through the house leads only partially along the left side of the graph. Instead of direct access from hallway to kitchen, the kitchen can be entered through the dining room. The living room remains segregated from the rest of the house. The reason for this change is difficult to pinpoint, but might be connected with the geometric constraints of the plot. Direct access from the hallway to the kitchen would require a wider space, which might not have been possible if both living and dining room were comfortably sized.

Based on the analysis of the common graph types in Figure 5.5, it can be observed that some pairs of rooms are more likely to be linked in a certain way regardless of the structure of the graph. In order to test this hypothesis on the whole sample, data on all the links between pairs of rooms was compiled. The total number of unique links between rooms was 51 (the entire table can be found in the Appendix A.16). Table 5.3 lists the pairs of rooms (13) which can be observed in more than half of the sampled terraced houses.

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
Hall - Living room	310	0.0%	96.1%	0.0%	3.5%	0.3%
Hall - Internal porch	228	0.0%	100.0%	0.0%	0.0%	0.0%
Internal porch - Living room	226	0.0%	0.0%	1.3%	98.7%	0.0%
Dining room - Living room	217	1.4%	8.3%	0.0%	72.4%	18.0%
External space - Living room	216	6.9%	0.5%	89.4%	3.2%	0.0%
External space - Kitchen	204	29.4%	12.3%	53.4%	4.9%	0.0%
Dining room - Hall	196	0.5%	92.3%	0.0%	6.6%	0.5%
Dining room - External space	170	35.9%	0.6%	61.8%	1.8%	0.0%
External space - Internal porch	163	0.6%	99.4%	0.0%	0.0%	0.0%
Breakfast room - Kitchen	147	0.0%	3.4%	0.0%	0.0%	96.6%
Hall - Kitchen	147	0.0%	55.1%	0.0%	44.9%	0.0%
Dining room - Kitchen	145	0.0%	26.9%	0.7%	37.2%	35.2%
Breakfast room - External space	116	27.6%	6.9%	51.7%	13.8%	0.0%

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open plan

Table 5.3 - Most common pairs of rooms (links) in terraced houses (see Appendix A.16 for details).

While it is interesting to note which pairs of rooms are more likely to be directly adjacent, it is also curious which links are less likely to be observed. For example, it is less likely for a kitchen to be adjacent to a living room, and a hallway to be directly adjacent to an external space. Interestingly, 90% of sampled houses share a similar configuration of the front of the house, which consist of three pairs of rooms: porch and hall, hall and living room, porch and living room. While this observation is interesting it is not surprising if we consider the social implications. The front of the house was designed to exhibit social status of the household, not only through the façade but also through the rooms where visitors were received, such as porches, hallways and formal living rooms (parlours).

The difference in the links at the front and back of the house is even more pronounced when we consider the degree of permeability between the rooms. Out of all the links shown in the Table 5.3, 8 exhibit a consistent degree of permeability across most of the sampled houses. The majority of those links are situated at the front of the house. On the other hand, at the back of the house a higher variety in the degree of permeability within each pair of rooms can be observed. These observations coincide with the perception of the back of the houses as a space where individual expression and personalisation is more important than social norms.

Based on statistical analysis of the links between pairs of rooms and the analysis of the most common graph types (Table 5.3 and Figure 5.5 respectively), it can be concluded that there are certain pairs of rooms that are more likely to be directly adjacent, and some pairs of rooms are often linked in a similar way. Those rooms tend to be located at the front of the house, where the common social norms are prioritised, rather than at the back where individual taste is more important.

To summarise, in both the analysis of the internal configuration of the most common internal graph types and the statistical analysis of nodes and links, a strong bi-polarity in the configuration of the terraced floor plan can be observed between the formal rooms at the front of the house and everyday activities at the back. The habitable rooms at the front tend to be directly disconnected from the habitable rooms at the back, and accessible only through the entrance zone.

5.3.2. The interface between a terraced house and the street network

The analysis of the internal configuration sheds light on the logic and organisation of the space in terraced houses. However, as with all buildings, terraced houses are part of a larger system. Their topological structure does not end within the geometrical constraints of the house. Therefore, the next step of the analysis is concerned with determining the types of ways a terraced house connects to the street network, through the analysis of the building-network interfaces. In Figure 5.7, a typical interface between a house and street network is illustrated, which consists of two individual building-street interfaces - one between the front of the house and a street, and simultaneously, the second interface between the back of the house and a back alley. As shown in Figure 5.7, a typical terraced house is set back from the streets both at the front and back. In all of the cases the front interface is physically permeable. In most houses (69.2%) the front interface also allows

Figure 5.7 - The typical building-network interface in terraced houses (101-1A) which consists of two polar building-street interfaces: at the front and at the back.

passers-by to look into the front yard, view the front façade of the house, and, if allowed by the inhabitants, look into the house through a bay window. The back interface exhibits entirely different properties. It accommodates movement between the rooms at the back of the house and the back alley, however, in 98.5% of cases, the interface is visually impermeable with a tall wall on the edge of the plot. This provides privacy to the spaces at the back of the house, however, it results in a corridor-like streetscape of the back alleys. While the origin of this unique relationship is unclear, based on the internal configuration of the floor plans we can conclude that the reason for the introduction of two interfaces could be a combination of social and functional factors. The kitchens and privies required an outdoor space with direct access to the street network to receive and store coal and ash. The social factors were connected with the bi-polar division between formal front, and the everyday back. Each requiring their own access to the street network.

79.1% of sampled houses interface with the street network in the typical manner described above. However, those are not the only types of building-network interfaces. In Figure 5.8, every observed building-network interface in the sample is compiled, resulting in nine unique arrangements. There are two factors that influence the way a terraced house interfaces with a street network: the position of a house on the plot, and the number of streets that a house is concurrently adjacent to. Typically, a terraced house is positioned in the middle of the plot, occupying the whole width with a setback at the front and the back of the house (79.1%). However, as shown in Figure 5.8, those factors can vary. In 13.4% of cases, the house expanded at the back and thus became directly adjacent to the back alley (see Figure 5.8 - 101-1B). In 7.1% of cases, a terraced house is concurrently adjacent to 3 streets instead of 2, which introduces an additional building-street interface. Those arrangements are a result of the urban design of the housing estate and, fundamentally, of the organisation of terraced houses into rows. The consequence of the linear arrangement is that two terraced houses (referred to as end terraces) in each row are adjacent to 3 rather than 2 streets at a time. This results in new relationships between the house and the

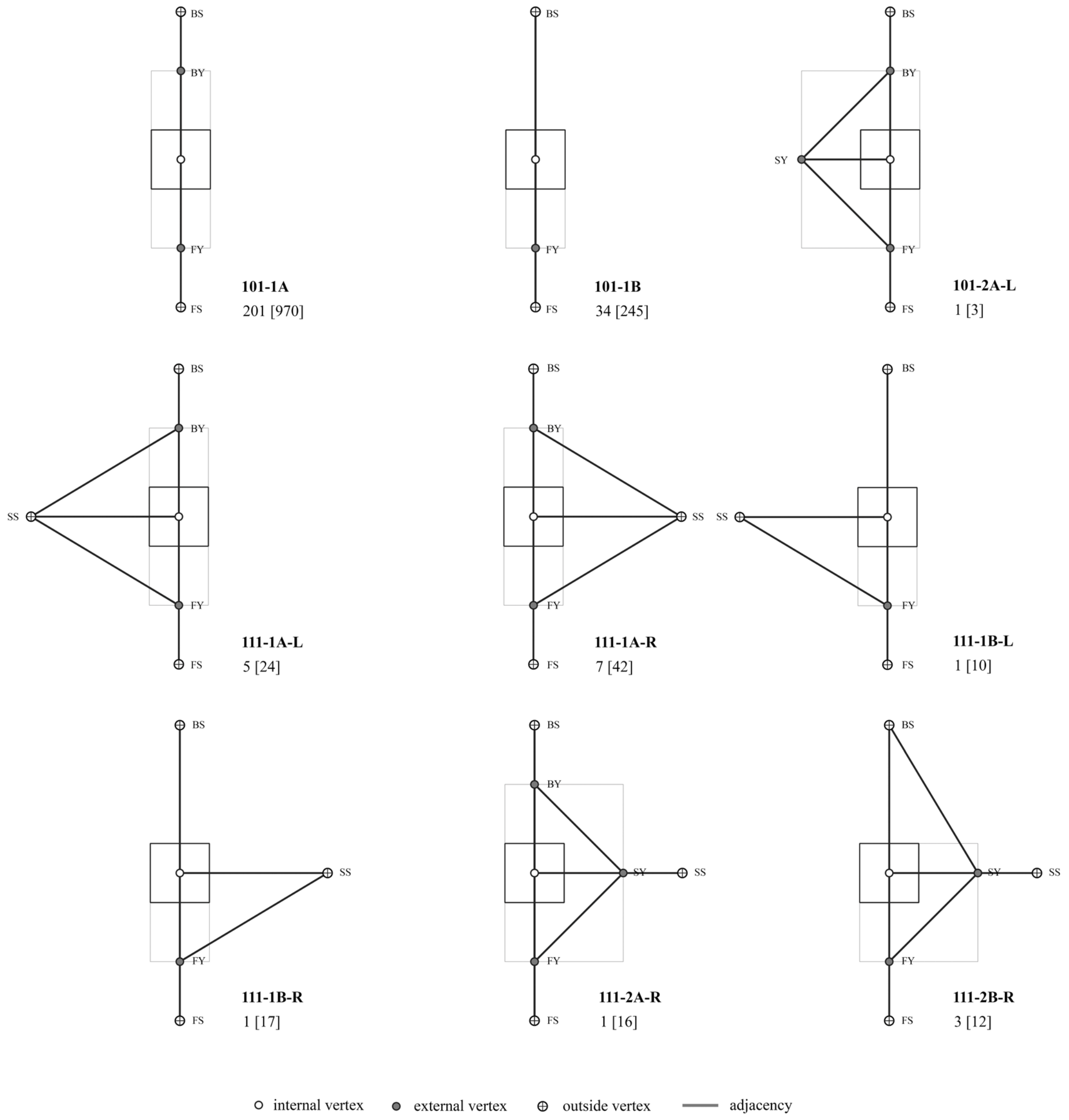


Figure 5.8 - Classification of building-network interface types in the sampled terraced houses. The type 101-1A represents a typical relationship between a terraced house and the street network.

Interface types	101-1A	101-1B	101-2A-L	111-1A-L	111-1A-R	111-1B-L	111-1B-R	111-2A-R	111-2B-R	Total
Number of houses in the sample	201	34	1	5	7	1	1	1	3	254
	79.1%	13.4%	0.4%	2.0%	2.8%	0.4%	0.4%	0.4%	1.2%	-
Number of houses in Gosforth	970	245	3	24	42	10	17	16	12	1339
	72.4%	18.3%	0.2%	1.8%	3.1%	0.7%	1.3%	1.2%	0.9%	-

Table 5.4 - Distribution of all building-network interface types (illustrated in Figure 5.8) in the sampled terraced houses and in all terraced houses in Gosforth.

street network that were not accounted for when designing a typical terraced house. In the sample as well as across all terraced houses in Gosforth, approximately 1 in 10 terraced houses is an end terrace (see Table 5.4). Even though, the majority of houses interface with the street network in a typical manner, the atypical types of building-network interfaces will be present as long as the urban organisation of estates of terraced houses does not change. Thus, it is worth investigating and understanding the impact of different types of building-network interfaces on the internal configuration of the terraced house.

5.3.3. The impact of the interfaces on the configuration of the terraced house

The impact of the relationship between internal graph types and building-network interface types is assessed based on the comparison between the characteristics of the internal layout and the properties of the interfaces. The characteristics of the internal graph types taken into consideration were: the number of nodes and links, the position of the nodes, the degree of permeability of the links.

After cross-tabulating internal graph types with the building-network interface types, as shown in Table 5.5, it can be observed that half of the graph types have a single typical building-network interface type. However, those internal graph types correspond to only 18.5% of sampled houses. 15 internal graph types (78.0% of sampled houses) have multiple building-network interface types, with one being typical and the others being atypical. Lastly, 9 internal graph types (and only 3.5% of houses) have a single atypical building-network interface type. Based on this cross-tabulation, it can be observed that it is very likely for a single internal graph type to have multiple different building-network interfaces; or in other words, for the same internal configuration to interface with the street network in many different ways. This means that even though, the internal configuration and the characteristics of the internal graph types do not change, their context does. In most cases, it results in additional links being established between internal rooms and the external spaces and streets. Those links are in the majority of cases (82.1%) both physically and visually impermeable. This means that the main aim of the design of those additional links between the rooms and the streets was to isolate the two elements (see Figure 5.9). It can be assumed that the additional side interface was not acknowledge on

Graph type	Num	%	101-1A	101-1B	101-2A-L	111-1A-L	111-1A-R	111-1B-L	111-1B-R	111-2A-R	111-2B-R
4.01	2	0.8%	2	0	0	0	0	0	0	0	0
5.01	3	1.2%	2	1	0	0	0	0	0	0	0
6.01	19	7.5%	17	0	0	2	0	0	0	0	0
6.02	1	0.4%	1	0	0	0	0	0	0	0	0
6.03	4	1.6%	3	0	0	0	1	0	0	0	0
6.04	3	1.2%	3	0	0	0	0	0	0	0	0
6.05	2	0.8%	2	0	0	0	0	0	0	0	0
7.01	15	5.9%	12	3	0	0	0	0	0	0	0
7.02	27	10.6%	23	1	0	2	0	0	0	1	0
7.03	5	2.0%	5	0	0	0	0	0	0	0	0
7.04	1	0.4%	1	0	0	0	0	0	0	0	0
7.05	1	0.4%	0	0	0	1	0	0	0	0	0
7.06	2	0.8%	2	0	0	0	0	0	0	0	0
7.07	3	1.2%	3	0	0	0	0	0	0	0	0
7.08	1	0.4%	1	0	0	0	0	0	0	0	0
8.01	2	0.8%	2	0	0	0	0	0	0	0	0
8.02	58	22.8%	53	4	0	0	1	0	0	0	0
8.03	4	1.6%	3	1	0	0	0	0	0	0	0
8.04	2	0.8%	2	0	0	0	0	0	0	0	0
8.05	1	0.4%	0	0	1	0	0	0	0	0	0
8.06	1	0.4%	1	0	0	0	0	0	0	0	0
8.07	8	3.1%	6	2	0	0	0	0	0	0	0
8.08	4	1.6%	3	0	0	0	1	0	0	0	0
8.09	2	0.8%	2	0	0	0	0	0	0	0	0
8.10	1	0.4%	1	0	0	0	0	0	0	0	0
8.11	4	1.6%	4	0	0	0	0	0	0	0	0
8.12	5	2.0%	5	0	0	0	0	0	0	0	0
8.13	1	0.4%	1	0	0	0	0	0	0	0	0
8.14	1	0.4%	0	0	0	0	0	0	0	0	1
8.15	1	0.4%	1	0	0	0	0	0	0	0	0
9.01	1	0.4%	1	0	0	0	0	0	0	0	0
9.02	2	0.8%	2	0	0	0	0	0	0	0	0
9.03	29	11.4%	15	13	0	0	0	0	1	0	0
9.04	7	2.8%	4	3	0	0	0	0	0	0	0
9.05	1	0.4%	0	0	0	0	0	0	0	0	1
9.06	2	0.8%	1	0	0	0	1	0	0	0	0
9.07	12	4.7%	9	3	0	0	0	0	0	0	0
9.08	1	0.4%	1	0	0	0	0	0	0	0	0
9.09	1	0.4%	0	0	0	0	0	1	0	0	0
9.10	1	0.4%	1	0	0	0	0	0	0	0	0
10.01	1	0.4%	0	0	0	0	1	0	0	0	0
10.02	3	1.2%	2	1	0	0	0	0	0	0	0
10.03	2	0.8%	2	0	0	0	0	0	0	0	0
10.04	1	0.4%	0	0	0	0	0	0	0	0	1
10.05	3	1.2%	1	1	0	0	1	0	0	0	0
10.06	1	0.4%	0	1	0	0	0	0	0	0	0
10.07	1	0.4%	0	0	0	0	1	0	0	0	0
11.01	1	0.4%	1	0	0	0	0	0	0	0	0
Total	254	100.0%	201	34	1	5	7	1	1	1	3

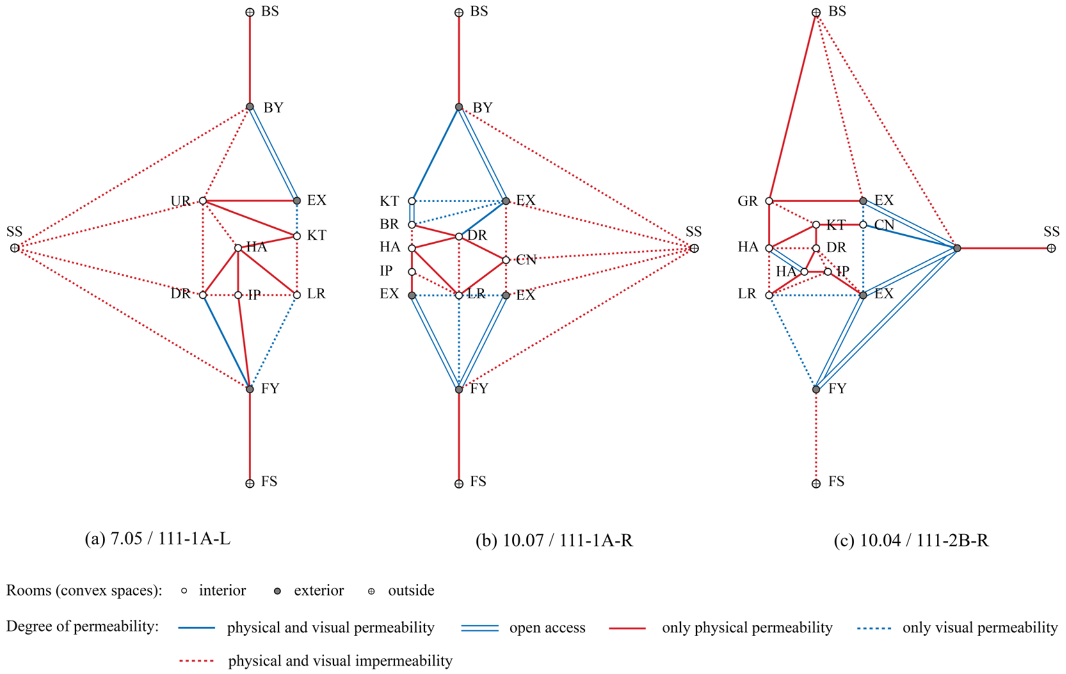
Table 5.5 - Cross-tabulation of the internal graph types with the building-network interface types in terraced houses.

purpose in order to avoid the need to design a special layout for the end terrace, which might have had an effect on the cost and time of the development. The negative of that design decision is that the end terrace might potentially be adjacent to a busy side street, which in turn might affect the use of the rooms or external spaces. Curiously, in 70% of the houses (12 in the sample and 86 in Gosforth) the street is adjacent to the right side of the graph where living rooms, dining rooms, and back yards are located. Only in 30% of cases the end terrace is adjacent to the street on the left side of the graph. It is an interesting design decision as the usability of the two habitable rooms and a private back yard could be affected if the house was adjacent to a busy street. Moreover, links between the rooms and the street adjacent to the side of the house tend to be physically and visually impermeable. While lack of physical permeability between the rooms and the street can be understood, it is rather surprising that an additional interface was not utilised as an opportunity to add more windows and provide more light to those rooms. As discussed in detail in Chapter 4, the aggregation of blank impermeable façades along one street has a negative impact on the streetscape and is likely to diminish any possibility for co-presence and encounter

Figure 5.9 - Both physically and visually impermeable side interface between the end terrace and the street on Ashburton Road in Newcastle (Photograph by Author, taken on 28.09.2019).

(see Figure 5.9). Based on the analysed data we conclude that in most of the houses that interface with the street network in an atypical way, the opportunity to enhance both the internal private and the outside public space was not considered in order to streamline the building process.

Only 9 graph types (9 houses) in the sample have a single atypical building-network interface type (see Figure 5.10). In other words, the internal configuration of those houses interfaces with the street network solely in an atypical manner. All of those houses interface concurrently with three streets, however, the way they are connected to the network varies. When compared to internal graph types that interface with the street network in a typical way, those graph types have a higher average number of nodes and links, with 9 nodes and 14 links. The reason for this increase becomes clear when we investigate their internal layouts, illustrated in Figure 5.10. Instead of being arranged along two vertical axes, nodes are organised along three: left, middle and right. This is most likely a result of an extension of the house into the side yard, where additional rooms were built to expand the size of the house and utilise the unused external space. In most cases this expansion included the



(a) 7.05 / 111-1A-L

(b) 10.07 / 111-1A-R

(c) 10.04 / 111-2B-R

Figure 5.10 - Examples of internal graph types with a single atypical building-network interface.

erection of a conservatory. If the house was adjacent to a street on the right side of the graph we can observe a shift in the position of the living and dining rooms from the right side of the graph to the middle. If the house was adjacent to the street on the left side we can observe a change in position of the entrance rooms and kitchens from the left to the middle of the graph.

In most examples the introduction of the additional node into the graph affected the movement through the house and resulted in a ring-like structure of the layout, rather than a typical (for a terraced house) tree-like structure. On very rare occasions the movement through the house was redirected. Instead of accessing the house through the front interface, those houses are accessed through the side interface, rendering the front

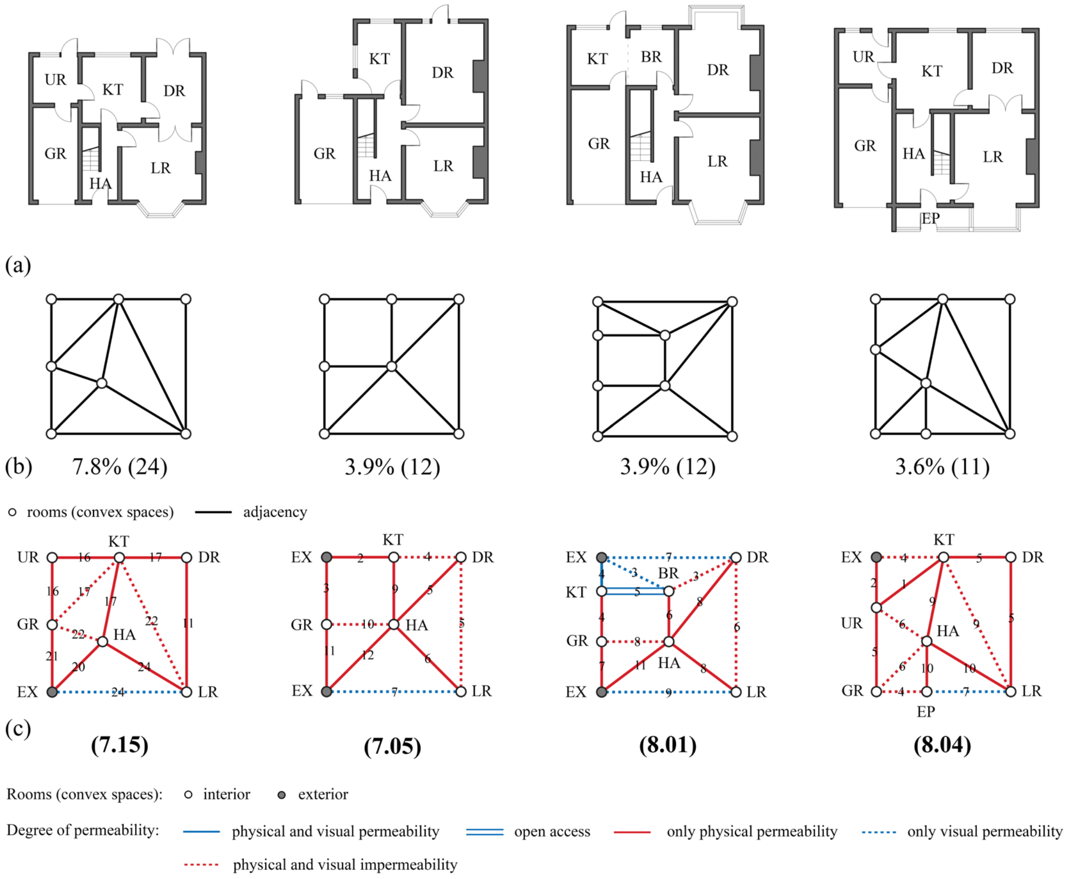


Figure 5.11 - Four common internal graph types with corresponding floor plans (a), adjacency graphs (b) and permeability graphs (c). In (c) the number on each link describes the number of occurrences of a specific relationship between the specific rooms. Key: BR - breakfast room, DR - dining room, EP - external porch, EX - external space, GR - garage, HA - hall, KT - kitchen, LR - living room, UR - utility room.

interface topologically redundant. From a social standpoint it is difficult to understand such a design choice, especially considering the strong social bi-polarity in the layout and the importance of the formal front. As seen in the Figure 5.10c, the front yard is both physically and visually disconnected from the street and physically impermeable from the house. Thus, the socially important front becomes superfluous and the cues regarding status of the household were transferred to the side façade.

Topologically, the impact of the atypical building-network interface on the internal configuration can be observed only in a small percentage of houses. In the majority of houses the atypicality of the interface is difficult to see based solely on the internal configuration of the floor plan. This, however, does not mean that the rooms in the house are not affected by the changes in the way the house interacts with its context. Most notably, the usability of the rooms might be affected by the direct adjacency to a potentially busy street.

5.4. Analysis of semi-detached house plans

309 floor plans of semi-detached houses were converted into adjacency graphs resulting in 142 unique graph types[8]. Although on average there are 2.2 floor plans per graph type, some types can be observed more often than the others. The four most common graph types coincide with a fifth of analysed floor plans (19.2%) (see Figure 5.11b). Interestingly, most of the graph types correspond to only one (85) or two (28) floor plans.

5.4.1. Shared morphologies in semi-detached house plans

In this section, the main similarities and differences between the most common internal graph types, shown in Figure 5.11, are discussed, and the patterns observed in those types are related to all of the sampled semi-detached houses. The most noticeable difference between the graph types is in the number of nodes and links, as shown in Table 5.6. The

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[8] All 142 internal graph types can be found in the Appendix A.17.

Semi-detached with:	Houses		Graphs	
	Number	%	Number	H/G*
4 rooms	1	0.3%	1	1.0
5 rooms	14	4.5%	3	4.7
6 rooms	14	4.5%	6	2.3
7 rooms	77	24.9%	17	4.5
8 rooms	71	23.0%	31	2.3
9 rooms	63	20.4%	29	2.2
10 rooms	41	13.3%	31	1.3
11 rooms	16	5.2%	13	1.2
12 rooms	7	2.3%	6	1.2
13 rooms	5	1.6%	5	1.0
All houses	309	100.0%	142	2.2

Table 5.6 - Internal graph types in semi-detached houses with a varying number of rooms (nodes). H/G* describes the house to graph type ratio.

number of nodes per house can vary between 4 and 13, with an average of 8 rooms per house. The majority of semi-detached houses (81.6%) are comprised of 6 to 9 nodes.

Despite the significant difference in the number of nodes, some morphological characteristics common to all types can be observed. In all of the common types, the number of nodes along the right side of the graph is 2. Based just on the analysis of common graphs it is difficult to assess in which part of the graph it is most likely for the number of nodes to increase when the total number of rooms increases. It becomes more apparent when we investigate the distribution of the nodes in all sampled semi-detached houses (see Table

Semi-detached with:	Parts of the graph		
	Left side	Middle	Right side
4 rooms	2	0	2
5 rooms	3	0	2
6 rooms	3	0	3
7 rooms	3	2	2
8 rooms	3	2	2
9 rooms	3	3	3
10 rooms	4	3	3
11 rooms	4	4	3
12 rooms	4	5	3
13 rooms	4	5	3
All houses	3	2	3

Table 5.7 - The position of rooms (nodes) in relation to the outline of the house in semi-detached houses with a varying number of rooms (nodes).

5.7). When the total number of nodes increase, the number of nodes is most likely to increase along the central axis of the graph, as demonstrated in Table 5.7.

As illustrated in the permeability graphs in Figure 5.11c, the distribution of types of rooms is very similar in all four graph types. The main variations can be observed at the front of the house where the number and position of nodes can vary depending on the position of the garage in relation to the house and whether an external porch is added. Therefore, the variation in the configuration of the house is more likely to occur in the entrance area at the front. In order to assess whether similar patterns can be observed in all sampled semi-detached houses, data on the position of common rooms (kitchens, dining rooms, living rooms, hallways, porches, external spaces, garages and utility rooms) was compiled in Figure 5.12. The frequency of occurrences of each type of room varies. In every house in the sample there is a kitchen, a hallway, and a living room. In 90% of houses a dining room is present, 70% of houses have a garage, and 60% of houses have a porch and a utility room. In most of the sampled houses there are two external spaces within the outline of the graph. The majority of rooms types are positioned consistently in a similar part of the graph, even if there is some variation in the exact position (see Figure 5.12). Kitchens are

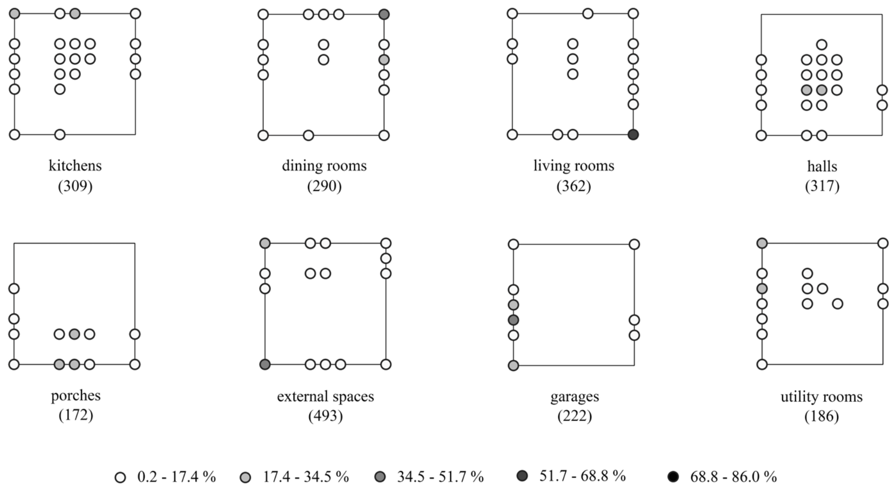


Figure 5.12 - The positions of the eight room types within the graph. The darker the node the higher the occurrence of the room in the specific position. The number under the name of each room indicates the number of occurrences of each type of room in the sample of 309 semi-detached houses (see Appendix A.18 for details).

more likely to be situated at the top left and centre of the graph, towards the back garden. Garages, porches and halls are positioned towards the bottom of the graph, and the front of the house where the main entrance to the house is located. Living rooms are more likely to be located in the bottom right part of the graph, while dining rooms in the top right part. As it was discussed in Section 5.3, the position of the living room is curious, as living rooms tend to be perceived as private spaces accommodating everyday life. Therefore, it would be expected for a living room to be situated at the back of the house, rather than at the front. It is likely that the social connotations between a living room and formal activities continued from terraced to semi-detached houses.

The analysis of the most common graph types and the statistical distribution of the types of rooms allow us to conclude that the position of the types of rooms is consistent regardless of the topological structure of the graph or the number of rooms per house. Therefore, the position of the rooms in relation to the outline of the house and its context was an important aspect in the design process of the floor plans.

Similarities are also visible in the configuration of the links and in the organisation of the movement through the house in the common internal graph types in Figure 5.11. In most of the common graph types, the movement through the house is led along the left and middle part of the graph. Along the left side of the graph an inhabitant can move from the doorstep through the garage into the utility room and either into the rest of the house or the back garden. Along the centre of the graph, the movement is directed from the doorstep, through the hallway into the kitchen. Therefore, the structure of the movement in the semi-detached house is more ring-like rather than tree-like. Interestingly, the organisation of the movement along the right side of the graph follows two scenarios. Similar to the patterns observed in terraced houses, in the graph types 7.05 and 8.01 in Figure 5.11, the living room and dining room are segregated and isolated from the rest of the house and can only be accessed from the hallway. In the second case, as seen in the graph types 7.15 and

8.04, another loop is introduced and the movement is directed from the hallway, through the living room, dining room and into the kitchen. Which means that dining room is not directly accessible from the hallway. This curious difference might illustrate a change in the perception of the formality of certain rooms and shift in the relationship between the inhabitants and visitors, from very formal to more casual. Therefore, the need for an isolated status room, such as a parlour or formal dining room, slowly diminished with the development of the semi-detached house.

Regardless of the variation in the relationship between the living and dining room, and the rest of the house, based on the analysis of the links in the common graphs, it can be concluded that most of the pairs of rooms are linked in a similar way. In order to investigate this claim in all of the sampled semi-detached houses, data on the links between pairs of rooms was compiled, resulting in 66 unique pairings. In Table 5.8, pairs of rooms (13) that can be found in at least half of the sampled houses were listed (the whole table of unique pairings can be found in the Appendix). Interestingly, most of the pairs of rooms listed (10) have a consistent degree of permeability, and 7 of those pairs are linked in a way that allows for direct access. The only significant variation in the degree of permeability within a pair of rooms can be observed in two cases: the link between dining room and

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
Hall - Living room	350	0.0%	90.6%	0.0%	7.4%	2.0%
Dining room - Living room	287	0.7%	21.6%	0.3%	44.3%	33.1%
Hall - Kitchen	245	0.0%	81.6%	0.0%	18.4%	0.0%
External space - Living room	225	10.2%	0.4%	85.3%	4.0%	0.0%
Dining room - Kitchen	215	0.5%	30.2%	0.0%	32.6%	36.7%
External space - Garage	211	4.3%	84.4%	0.0%	10.4%	0.9%
Garage - Hall	210	0.0%	3.8%	0.0%	96.2%	0.0%
External space - Kitchen	191	9.4%	6.3%	56.0%	27.2%	1.0%
Kitchen - Living room	185	0.0%	5.4%	0.0%	87.6%	7.0%
Kitchen - Utility room	158	0.0%	82.9%	0.0%	11.4%	5.7%
Dining room - Hall	157	0.0%	80.3%	0.0%	19.7%	0.0%
External space - Hall	139	2.2%	91.4%	0.0%	6.5%	0.0%
Garage - Utility room	139	0.0%	93.5%	0.0%	5.8%	0.7%

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open plan

Table 5.8 - Most common pairs of rooms (links) in semi-detached houses (see Appendix A.19 for details).

living room, and between dining room and kitchen. This observation coincides with the conclusion based on the analysis of the common internal graph types, that there was a change in the use of the living and dining rooms and relationship between those rooms and the rest of the house.

To sum up, both analyses arrived at a similar conclusion. Types of rooms in semi-detached houses are socially tied to locations in relation to the outline of the house and its context, regardless of the topological structure of the internal configuration. Moreover, the majority of pairs of rooms tend to be linked in a similar manner, in most cases allowing for direct physical permeability. However, there is a significant difference between the characteristics of the links between the dining and living room and kitchen and dining room, which is most likely related to changing customs in regards to receiving visitors and less need for a formal status room.

5.4.2. The interface between a semi-detached house and the street network

The analysis of the internal configuration revealed some shared morphologies that can be recognised in the majority of semi-detached houses in the sample. In the previous section,

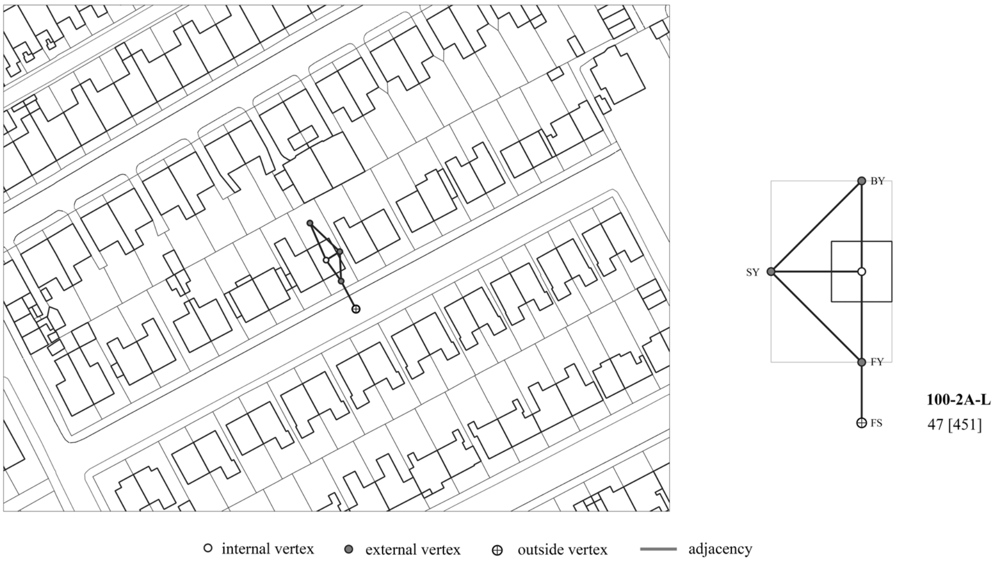


Figure 5.13 - The typical building-network interface in the inter-war semi-detached houses (100-2A-L) which consists of one building-street interface at the front of the house.

it was concluded that there is an important relationship between the rooms and the outline of the house and its context. Therefore, the next step of the analysis is to describe the ways in which the semi-detached house can interface with the street network. There are two building-network interfaces that are typical to the semi-detached house. Both consist of one building-street interface at the front of the house, however, the position of the house on the plot varies. In the early inter-war semi-detached houses, as shown in Figure 5.13, the house does not accommodate the entire width of the plot, hence, there is a space to the side of the house that allows for direct access between the front yard and the back garden. The houses in semi-detached developments built after the Second World War occupied the whole width of the plot and followed the arrangement illustrated in Figure 5.14. Regardless of the position of the house on the plot, the majority of semi-detached houses are adjacent to only one street through the front interface. In all of the cases (100%) this interface provides a setback from the street and is both physically and visually permeable, which allows for access to the house and inter-visibility between the front yard or drive and the street. The change in the position of the house on the plot and the expansion of the house was mostly related to the mass popularisation of the private car after the Second World War. The space to the side of the semi-detached house was wide enough to build a

Figure 5.14 - The typical building-network interface in the post-war semi-detached houses (100-1A) which consists of one building-street interface at the front of the house.

covered car port where the private car was stored. Nowadays, the size of cars has increased which means that in many cases the post-war garages are not capable of storing new cars and either they are used for storage, or converted into a habitable room, such as a study.

86.4% of the sampled semi-detached houses interface with the street network in one of the typical ways described above (see Table 5.9 for more details). In Figure 5.15, seven building-network interface types are illustrated, all were observed in the sample. The typical two were already described above, the remainder of the building-network interfaces differ based on two factors: the number of adjacent streets and the position of the house on the plot. In 5.8% of cases houses are adjacent to 2 streets at a time, one at the front and one at the back of the house. In 7.8% of cases houses are also adjacent to two streets at a time, however, one is located at the front of the house, while the other on the side. Similarly to the terraced houses, the additional interfaces are a consequence of the layout of the housing estate and the arrangement of urban blocks. Four semi-detached houses (end properties) per block are situated at the corners of the rectangular urban block which results in an additional side interface. The additional back interface is a result of a direct adjacency between newly built estates of semi-detached houses and existing estates of terraced houses. The back alleys were an existing element that new built semi-detached houses had to relate to, and in the majority of cases the layout of the street network imposed by the earlier housing developments was followed.

5.4.3. The impact of the interfaces on the configuration of the semi-detached house

In the sample approximately 1 in 10 houses interface with the street network in an atypical way. While it is not a large number of occurrences, the atypical building-network interfaces will exist as long as the design of the urban blocks and estates of semi-detached houses does not change. Therefore, it is important to understand the impact of the interfaces on the internal configuration of semi-detached houses, which is the topic of this sub-section.

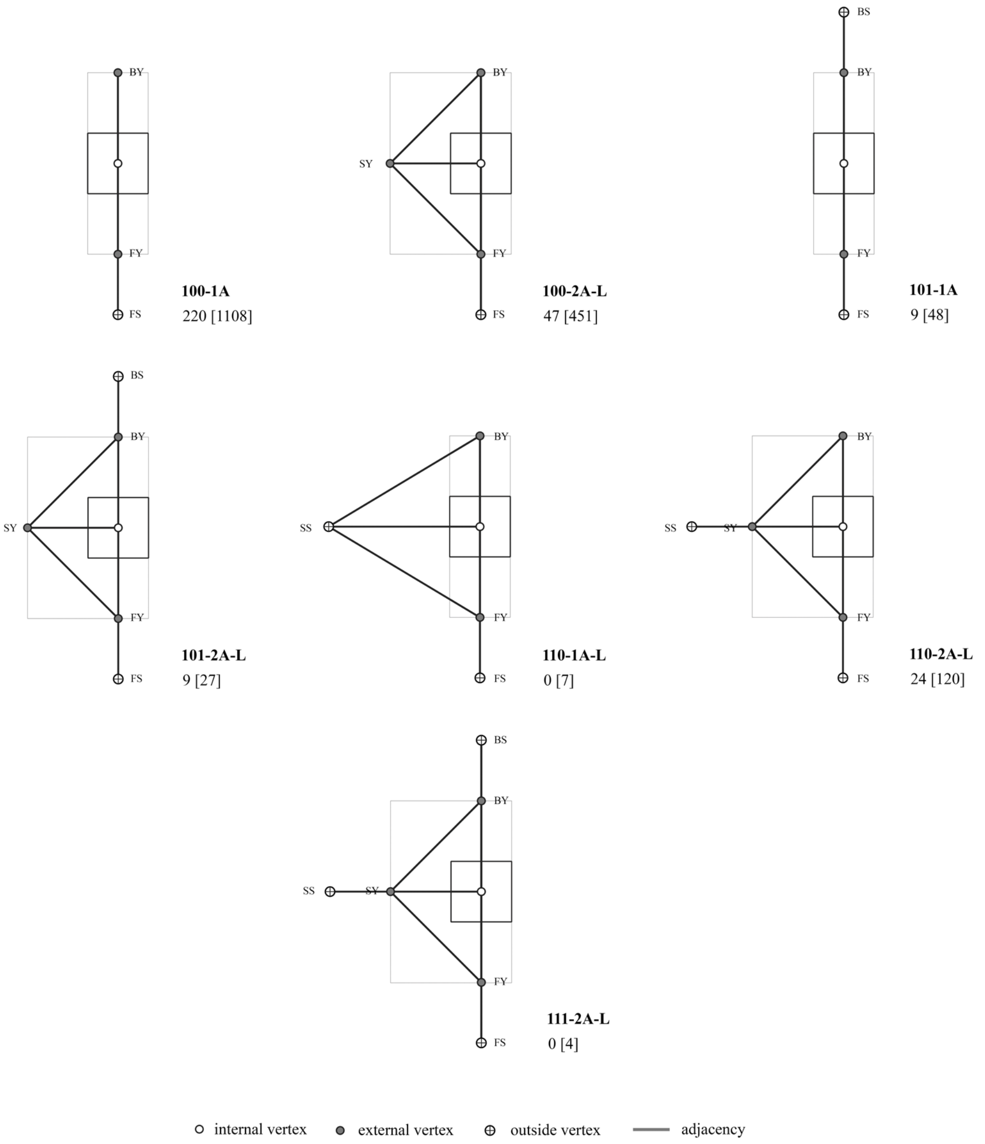


Figure 5.15 - Classification of building-network interface types in the sampled semi-detached houses. The types 100-1A and 100-2A-L represent two typical relationships between a semi-detached house and the street network.

Interface types	100-1A	100-2A-L	101-1A	101-2A-L	110-1A-L	110-2A-L	111-2A-L	Total
Number of houses in the sample	220	47	9	9	0	24	0	309
	71.2%	15.2%	2.9%	2.9%	0.0%	7.8%	0.0%	-
Number of houses in Gosforth	1108	451	48	27	7	120	4	1765
	62.8%	25.6%	2.7%	1.5%	0.4%	6.8%	0.2%	-

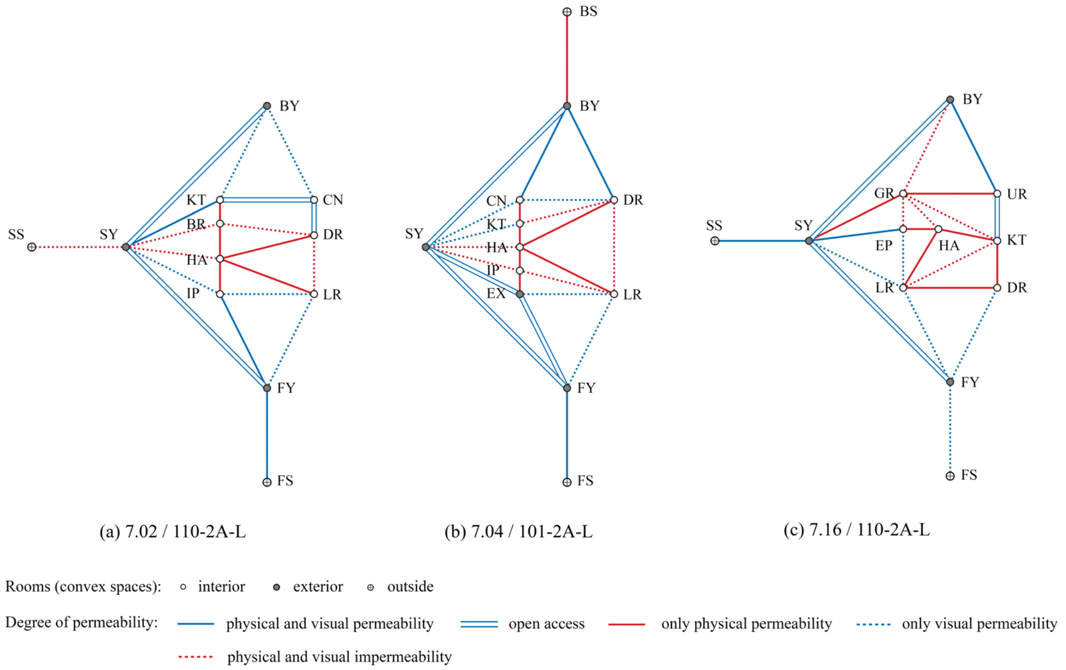
Table 5.9 - Distribution of all building-network interface types (illustrated in Figure 5.15) in the sampled semi-detached houses and in all semi-detached houses in Gosforth.

Internal graph types were cross-tabulated with the types of building-network interfaces in order to determine the relationship between both elements (see Table 5.10 for part of the table, the entire table can be found in the Appendix). 112 internal graph types (53.1% of houses) have a single typical building-network interface. 20 internal graph types, which correspond to 40.8% of houses, have multiple building-network interface types, with one being typical. Lastly, 10 internal graph types (6.5% of houses) have a single atypical building-network interface type. It is, therefore, very likely for houses with the same internal configuration to interface with the street network in multiple ways. In other words, in approximately half of the sampled houses the internal configuration remains the same, yet, their context is likely to change from one example to the other. In most cases, the additional interface is introduced between a side façade and the street. Those additional interfaces are, in the majority of cases, visually impermeable with either a brick wall or, more likely, a tall hedge blocking the view into the property (see Figure 5.16). However, those interfaces are likely to be permeable, and tend to allow for vehicular access onto the property. The main pedestrian access is, in most cases, still directed through the front interface. In all the sampled cases where the semi-detached has two concurrent interfaces

Figure 5.16 - Visually impermeable side interface between the end semi-detached house and the street on Thornfield Road in Newcastle (Photograph by Author, taken on 28.09.2019).

Graph type	Num	%	100-1A	100-2A-L	101-1A	101-2A-L	110-2A-L
5.01	3	1.0%	0	1	0	1	1
5.02	9	2.9%	0	7	0	0	2
5.03	2	0.6%	0	2	0	0	0
5.01	3	1.0%	0	1	0	1	1
6.03	3	1.0%	3	0	0	0	0
6.04	2	0.6%	0	0	0	2	0
6.05	4	1.3%	0	4	0	0	0
7.01	2	0.6%	0	0	2	0	0
7.02	4	1.3%	0	0	0	2	2
7.05	12	3.9%	11	1	0	0	0
7.06	11	3.6%	9	1	0	0	1
7.07	3	1.0%	0	2	0	0	1
7.13	3	1.0%	0	3	0	0	0
7.14	4	1.3%	4	0	0	0	0
7.15	24	7.8%	23	1	0	0	0
7.16	6	1.9%	0	0	0	0	6
8.01	12	3.9%	9	1	0	1	1
8.02	3	1.0%	2	0	1	0	0
8.03	2	0.6%	2	0	0	0	0
8.04	11	3.6%	9	0	0	0	2
8.05	3	1.0%	1	0	2	0	0
8.07	2	0.6%	2	0	0	0	0
8.08	2	0.6%	2	0	0	0	0
8.10	2	0.6%	2	0	0	0	0
8.13	2	0.6%	2	0	0	0	0
8.15	3	1.0%	2	0	1	0	0
8.17	2	0.6%	2	0	0	0	0
8.20	2	0.6%	2	0	0	0	0
8.22	3	1.0%	2	0	0	0	1
8.24	2	0.6%	2	0	0	0	0
8.26	3	1.0%	2	1	0	0	0
8.30	2	0.6%	0	2	0	0	0
9.01	4	1.3%	4	0	0	0	0
9.02	3	1.0%	3	0	0	0	0
9.04	5	1.6%	3	1	0	0	1
9.05	4	1.3%	2	1	1	0	0
9.08	5	1.6%	4	0	1	0	0
9.09	3	1.0%	3	0	0	0	0
9.10	2	0.6%	2	0	0	0	0
9.12	2	0.6%	2	0	0	0	0
9.13	2	0.6%	2	0	0	0	0
9.17	2	0.6%	2	0	0	0	0
9.19	11	3.6%	11	0	0	0	0
9.20	2	0.6%	2	0	0	0	0
9.23	2	0.6%	1	0	0	0	1
10.02	2	0.6%	2	0	0	0	0
10.04	2	0.6%	2	0	0	0	0
10.06	2	0.6%	0	2	0	0	0
10.07	2	0.6%	2	0	0	0	0
10.11	3	1.0%	2	0	0	0	1
11.07	3	1.0%	2	1	0	0	0
Total	151	48.9%	93	27	6	7	18

Table 5.10 - Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses. Houses with less than 2 floor plans per house are not shown. For the complete table see Appendix A.20.

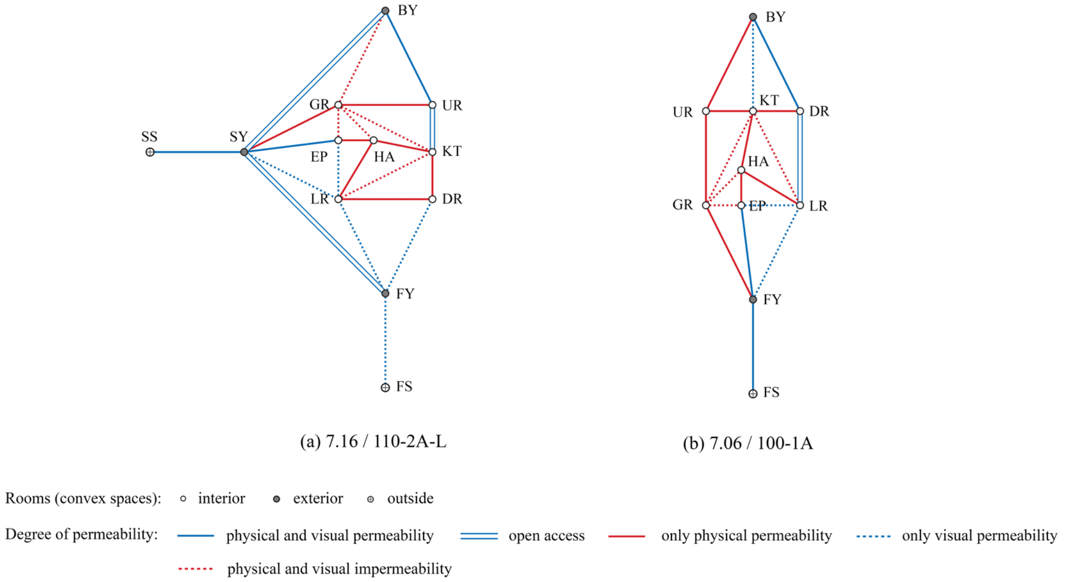


(a) 7.02 / 110-2A-L

(b) 7.04 / 101-2A-L

(c) 7.16 / 110-2A-L

Figure 5.17 - Examples of internal graph types with a single atypical building-network interface.



(a) 7.16 / 110-2A-L

(b) 7.06 / 100-1A

Figure 5.18 - Two identical internal graph types with significantly different interfaces with the street network.

with one being a side interface, the additional interface is situated on the left side of the graph. Which means rooms such as hallways, porches, or kitchens are exposed to the street. While it is unlikely that is going to affect the use of those spaces, as shown in Chapter 4, the aggregation of visually impermeable interfaces might negatively affect the activity on the street and create an unattractive corridor-like streetscape.

10 graph types (20 houses) interface with the street network in an atypical way (examples are shown in Figure 5.17), however, the way they relate to the network varies. The internal graph types with a single atypical building-network interface type tend to have, on average, a lower number of nodes and links, with 7 nodes and 14 links. The decrease in the number of nodes becomes clear when we look at the structure of the graph types in Figure 5.17. The internal configuration of those types is more similar to the configuration of terraced houses and very early semi-detached houses. It is a result of the different arrangement of vehicular access. In a semi-detached house with a typical building-network interface type the garage had to be incorporated into the front façade. However, houses with atypical building-network interface types had a choice to direct the vehicular access through the side interface rather than the front. Therefore the main difference in the internal configuration is the location of the garage, which instead of being situated at the front and incorporated into the floor plan of the house, is detached from the house and placed in the back garden. The internal configuration of the graph 7.16 is unusual and can be found only in the estate S7 built after the Second World War. The configuration of the graph 7.16 is a version of the graph 7.06 (see Figure 5.18) rotated by 90 degrees. It is very likely that streetscape in this estate was of key importance to the designers and therefore they tried to avoid creating any impermeable and blank corridor-like streetscapes. However, this design decision might have negatively affected the design of the house, as because of the unusual position of the house on the plot, the kitchen and dining room lost their usual connection to the back garden. Moreover, the front façade lost any social and topological significance as the entrance was moved to the side façade.

The impact of the atypical building-network interface types on the internal configuration can be observed in a small number of houses. In many of those houses the change is not unusual for the type, but rather preserves the early inter-war design by not introducing the garage to the front façade. The rectangular shape of the block allows for more flexibility in the arrangement of the plots, when compared to the linear blocks of terraced houses. Thus designers were able to organise the houses to avoid the aggregation of impermeable interfaces alongside one street. However, as seen in Chapter 4, there were many cases where the context of the streetscape was not considered, therefore, it is important to

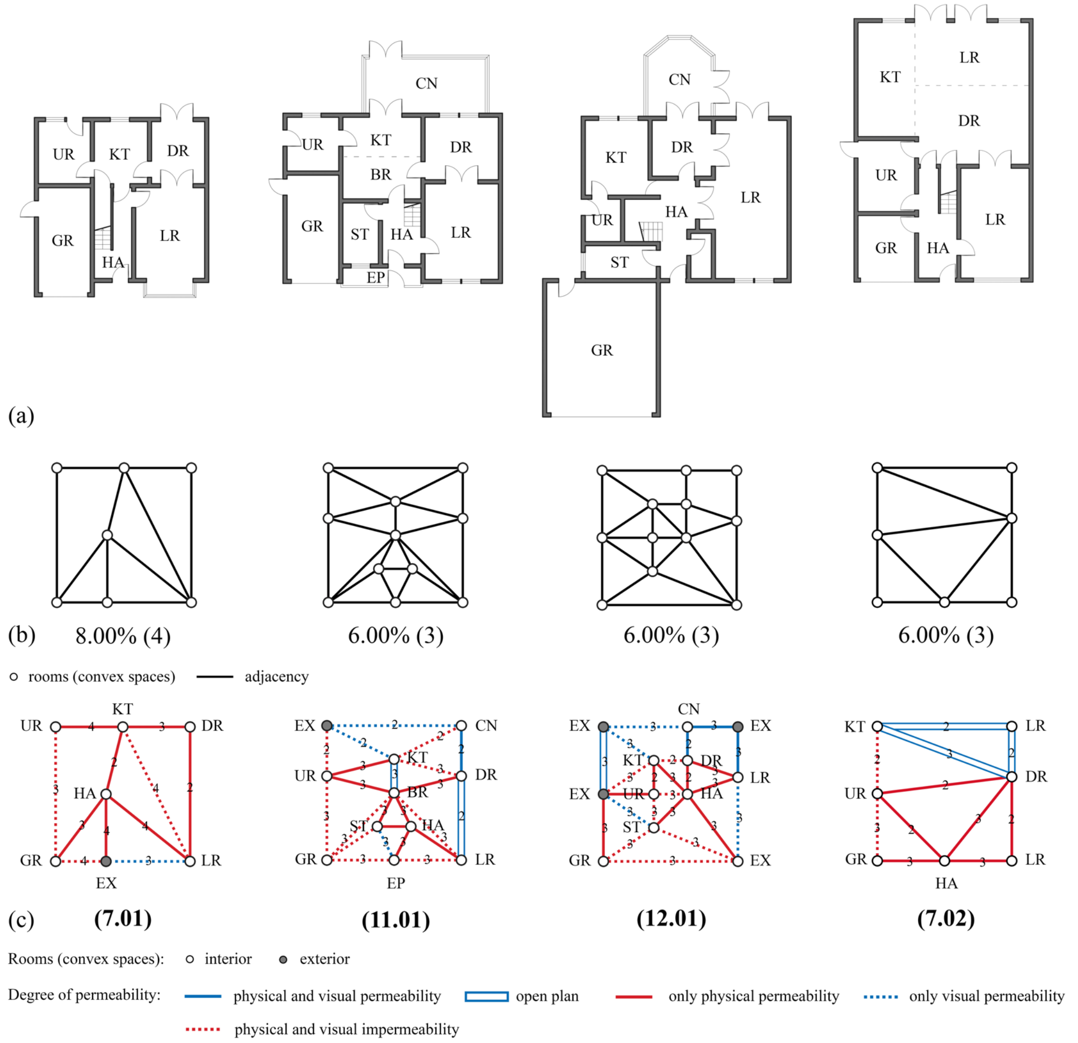


Figure 5.19 - Four common internal graph types with corresponding floor plans (a), adjacency graphs (b) and permeability graphs (c). In (c) the number on each link describes the number of occurrences of a specific relationship between the specific rooms. Key: BR - breakfast room, CN - conservatory, DR - dining room, EP - external porch, EX - external space, GR - garage, HA - hall, KT - kitchen, LR - living room, ST - study, UR - utility room.

emphasise that the design decisions made on the architectural scale affect the urban scale.

5.5. Analysis of detached house plans

50 floor plans of detached houses were converted into adjacency graphs which resulted in 40 unique graph types[9], with, on average, 1.3 floor plans per type. While it seems like every detached house analysed has a unique configuration of the floor plan, there are some graphs that appear more frequently than the others. The reason for the high individualisation in the configuration of the floor plan is most likely to be complex, however, it might be related to the increasing involvement of architectural companies in the residential development. The four most common graph types correspond to a fourth of the analysed plans (24.0%), and are shown in Figure 5.19.

5.5.1. Shared morphology in detached house plans

Although there are nearly as many unique graph types as sampled detached houses, morphological similarities and differences can still be identified in the four most common types, shown in Figure 5.19. As shown in the Table 5.11, the total number of rooms in detached houses ranges between 7 and 14. The majority of houses, however, comprise of 7 to 12 rooms, with an average of 10 rooms per house.

While the difference in the number of nodes and links results in a high variability in the configuration of the graphs, some shared morphologies can still be observed. Firstly, the number of rooms situated along the left and right sides of the graph is similar across most of the common graph types, with 3 nodes along the left and 3 along the right side. The graph type 7.01 is an exception to that pattern with a lower number of nodes on both sides. This is a result of a lack of a conservatory at the back of the house. When the total number of rooms per house increases, the increase is most likely to happen along

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[9] All 40 internal graph types can be found in the Appendix A.21.

Detached houses with:	Houses		Graphs	
	Number	%	Number	H/G*
7 rooms	10	20.0%	5	2.0
8 rooms	7	14.0%	7	1.0
9 rooms	7	14.0%	6	1.2
10 rooms	12	24.0%	12	1.0
11 rooms	4	8.0%	2	2.0
12 rooms	7	14.0%	5	1.4
13 rooms	2	4.0%	2	1.0
14 rooms	1	2.0%	1	1.0
All houses	50	100.0%	40	1.3

Table 5.11 - Internal graph types in detached houses with a varying number of rooms (nodes). H/G* describes the house to graph type ratio.

the central vertical axis. As shown in Figure 5.19, in the graph type 7.02 there is 1 node along the central bay, while in the graph type 12.01, 6 nodes can be observed along the central vertical axis. Similar patterns can be observed in all sampled detached houses, as presented in Table 5.12, where the most significant increase in the number of nodes can be observed along the central axis.

Secondly, when the corresponding permeability graphs are considered the position of many types of rooms is similar across the most common graphs. The living room is likely to be positioned in the bottom right part of the graph, towards the front of the house. The dining room tends to be situated either in the middle right or top right part of the graph, depending on whether there is a conservatory. Room types such as: garages and utility rooms are more

Detached houses with:	Parts of the graph		
	Left side	Middle	Right side
7 rooms	3	2	2
8 rooms	3	2	3
9 rooms	3	3	3
10 rooms	3	3	3
11 rooms	4	5	3
12 rooms	4	5	3
13 rooms	4	5	4
14 rooms	4	7	3
All houses	3	3	3

Table 5.12 - The position of rooms (nodes) in relation to the outline of the house in detached houses with a varying number of rooms (nodes).

likely to be situated along the left side of the graph. Lastly, entrance rooms can be observed in the lower central part of the graph, while kitchens can be seen in the top central part, towards the back garden. In order to test whether the consistency in the position of types of rooms can be observed in all sampled detached houses, data on the position of 8 common room types (kitchens, dining rooms, living rooms, conservatories, halls, external spaces, garages, and utility rooms) was compiled in Figure 5.20. In every sampled detached house there is a kitchen, a dining room and a hallway. In 90% of houses a garage was observed, while in 70% of houses a conservatory and a utility room were present. In the majority of houses, there are on average two living rooms and two external spaces within the outline of the internal graph. As shown in Figure 5.20, the position of each room type varies, however, in most cases the majority of rooms in each type are positioned in a similar part of the graph. For example, kitchens are more likely to be situated along the central axis of the graph, towards the back garden (top of the graph). Living rooms, dining rooms and conservatories tend to be located along the right side of the graph in the bottom, middle and top part, respectively. Therefore, along the right side of the graph a leisure-orientated zone can be distinguished. Garages, utility rooms and external spaces are more likely to be found along the left side of the graph. Utility rooms, kitchens and dining rooms tend to be

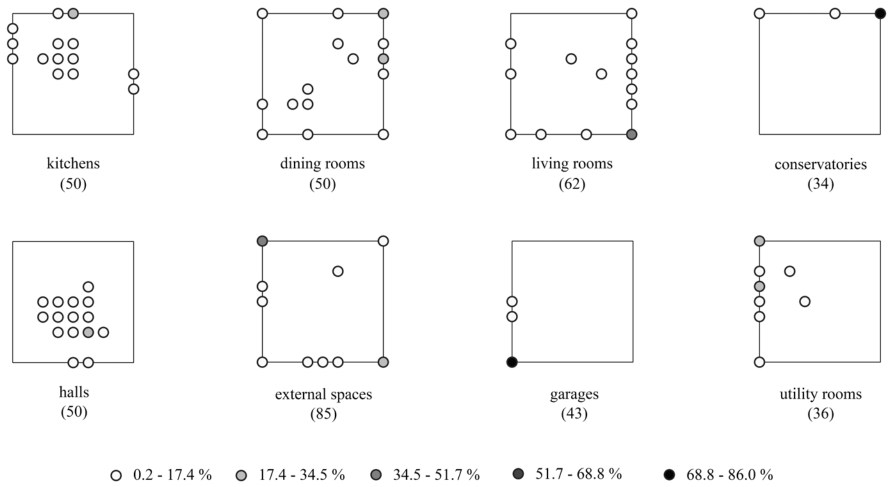


Figure 5.20 - The positions of the eight room types within the graph. The darker the node the higher the occurrence of the room in the specific position. The number under the name of each room indicates the number of occurrences of each type of room in the sample of 50 detached houses (see Appendix A.22 for details).

horizontally aligned along the middle/top part of the graph, which exhibits a strong spatial relationship between food storage, preparation and consumption. The organisation of the rooms in relation to the outline of the house can be described as two intersecting axes of habitable space: the everyday food-orientated horizontal axis in the middle/top part and an everyday leisure-orientated vertical axis along the right side of the graph. Those patterns coincide with the findings of the analysis of the internal common graphs in Figure 5.19, and allows us to conclude that the position of room types in detached houses is consistent regardless of the topological structure and number of nodes.

Shared characteristics can also be observed in the configuration of the movement through the common internal graph types. In all cases the configuration of the through-movement (represented as a continuous link) is ring-like and can be observed along the middle and right side of the graphs. The movement is organised as a loop that goes through hall, living room, dining room, and kitchen, which allows for a choice in the way inhabitants move around the house to access different rooms. In the majority of examples, garages are situated within the outline of the house, however, they are entirely isolated from the rest of the house and cannot be accessed from any other internal rooms. Similar patterns can be observed when we investigate all sampled detached houses. Data on all the links

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
Hall - Living room	57	0.0%	91.2%	0.0%	8.8%	0.0%
Dining room - Living room	45	2.2%	66.7%	0.0%	8.9%	22.2%
Dining room - Kitchen	42	0.0%	42.9%	2.4%	26.2%	28.6%
External space - Living room	40	10.0%	0.0%	75.0%	15.0%	0.0%
Conservatory - External space	37	45.9%	0.0%	54.1%	0.0%	0.0%
Kitchen - Living room	36	0.0%	13.9%	0.0%	72.2%	13.9%
Hall - Kitchen	35	0.0%	71.4%	0.0%	28.6%	0.0%
External space - Kitchen	34	0.0%	2.9%	67.6%	29.4%	0.0%
Kitchen - Utility room	33	0.0%	84.8%	0.0%	15.2%	0.0%
External space - Garage	27	0.0%	44.4%	0.0%	55.6%	0.0%
Conservatory - Dining room	25	32.0%	40.0%	0.0%	4.0%	24.0%
Garage - Hall	25	0.0%	16.0%	0.0%	84.0%	0.0%
Garage - Utility room	25	0.0%	36.0%	0.0%	64.0%	0.0%

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open access

Table 5.13 - Most common pairs of rooms (links) in detached houses (see Appendix A.23 for details).

between pairs of rooms was aggregated (see Appendix A.23) and resulted in 55 unique room pairings. In Table 5.13, a list of pairs of rooms (13) that can be observed in more than half of the sampled houses were compiled. In 90% of detached houses links can be found between: halls and living rooms, dining and living rooms, and dining rooms and kitchens. Interestingly, similar to semi-detached houses the dining room is very unlikely to be linked with the hallway. Therefore the dining room cannot be accessed directly from the hallway but rather through the kitchen or through the living room. As shown in Table 5.13, the degree of permeability is consistent in most pairs of rooms, with exception of the link between dining room and kitchen, dining room and conservatory, and links between a few internal and external rooms. The difference in the relationship between the dining room and the conservatory depends on the degree of visual permeability between the two. In most cases the conservatory is not visually permeable from the dining room, however, in a third of cases those two rooms are visually connected. What is more, in 24.0% of cases those two rooms form an open plan arrangement. The main difference in the link between the kitchen and the dining room is whether those rooms are separated by a wall and accessed through a set of doors, or if the kitchen and dining room are designed as an open plan arrangement.

Based on the analysis of common internal graphs in Figure 5.19 and the statistical distribution of unique links between pairs of rooms, it can be concluded that some types of rooms are more likely to be directly adjacent. Moreover, type of the relationship between those pairs of rooms is in most cases similar across most of the detached houses.

To summarise, the typological analysis of the most common graphs and the statistical analysis of nodes and links show that the core rooms - hall, kitchen, sitting room, dining room and garage - are configured in a similar manner across the majority of the detached houses. The individuality in the layout of the floor plan is mostly observed in the centre of the graph with the increase of the number of rooms and addition of less popular room types such as study or breakfast room. The links between the core rooms accommodate most of the through-movement in the detached houses. In the majority of houses we can observe a loop (hall-kitchen-dining room-living room-hall) that accommodates two main routes through the house.

5.5.2. The interface between a detached house and the street network

The analysis of the internal configuration of detached houses in the sample revealed shared morphological characteristics in their layouts. However, the entire analysis lacked any information about the immediate context. As with every building, a detached house is a part of a larger network and its topological structure is not contained within the outline of the house. Therefore, the next step of the analysis is to determine the types of ways a detached house interfaces with the street network, through the classification of building-network interfaces. A typical interface between a detached house and the street network is illustrated in Figure 5.21. Detached houses are typically adjacent to neighbouring units from three sides and connected to the street through the front interface. The front interface is in all of the sampled houses both physically and visually permeable. Interestingly, in

Figure 5.21 - The typical building-network interface in detached houses (100-3A) which consists of one building-street interface at the front of the house.

96% of cases there is no physical boundary between the front yard and the street, and the difference between those two spaces is indicated only through the change in paving. It can be assumed the lack of a physical border on the boundary between the private and public spaces aims to create a perception of a shared communal lawn, where, for example, children from the neighbouring houses could play, rather than clearly defined aggregation of small private gardens.

In the sample six unique building-network interface types were discovered, as shown in the Figure 5.22. There are two aspects that impact the structure of the building-network

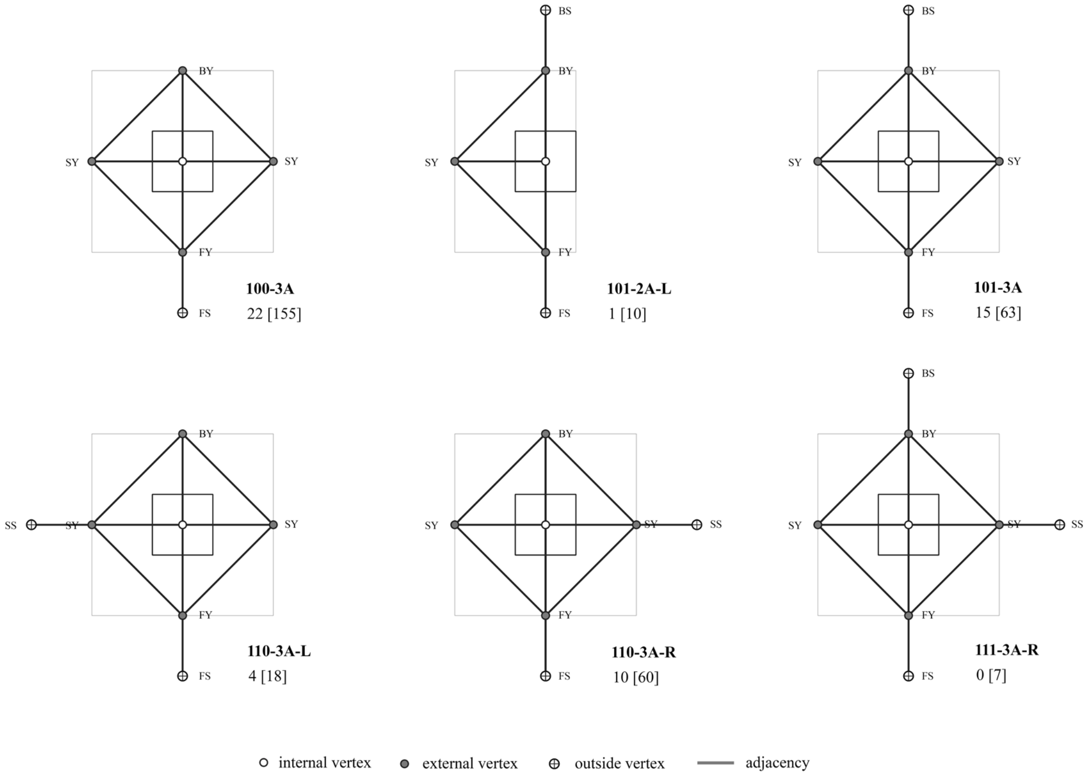


Figure 5.22 - Classification of building-network interface types in the sampled detached houses. The type 100-3A represents a typical relationship between a detached house and the street network.

Interface types	100-3A	101-2A-L	101-3A	110-3A-L	110-3A-R	111-3A-R	Total
Number of houses in the sample	22	1	13	4	10	0	50
	44.0%	2.0%	26.0%	8.0%	20.0%	0.0%	-
Number of houses in Gosforth	155	10	63	18	60	7	313
	49.5%	3.2%	20.1%	5.8%	19.2%	2.2%	-

Table 5.14 - Distribution of all building-network interface types (illustrated in Figure 5.22) in the sampled detached houses and in all detached houses in Gosforth.

interface: the position of a house on the plot, and the number of streets that a house is concurrently adjacent to. Typically, a detached house is positioned in the middle of the plot with a setback between each external wall and plot boundary. This results in four external spaces: front, back and two side setbacks. Theoretically, this allows for uninterrupted movement around the house without the need to enter the house. However, in most of the analysed houses (74.0%) the access from the front yard to the back is allowed only through one of the side yards. There is only 1 house in the sample and 10 houses in Gosforth that have only one side yard, thus one of the side external walls is directly adjacent to the plot boundary line. The rest of the houses are positioned on the plot in a typical way. The biggest variation in the way a detached house can interface with a street network stems from the design of the estate in relation to the existing urban tissue. The introverted privacy-orientated urban design resulted in a high number of houses concurrently adjacent to more than one street, as shown in Table 5.14. As a result of the urban design of the estates, 56.0% of houses in the sample and 50.5% of detached houses in Gosforth interface with the street network in an atypical manner. As seen in Table 5.14, approximately a quarter of houses interface with the street network through the front and side façades, and another quarter of houses interface through the front and back façades. It is quite surprising that less than 50 per cent of detached houses interface with the street network in a typical manner.

The disconnected and isolating design of the housing estates resulted in a significant change in the way most of the detached houses interface with the street networks. In most cases, the houses were exposed to additional streets. It is likely that this factor was not considered during the design process or that it was seen as a sacrifice worth taking in order to assure privacy and isolation of the streets within the estate. In the next sub-section the impact of different types of building-network interfaces on the internal configuration of the detached house is investigated.

Graph type	Num	%	100-3A	101-2A-L	101-3A	110-3A-L	110-3A-R
7.01	4	8.0%	1	0	1	0	2
7.02	3	6.0%	3	0	0	0	0
7.03	1	2.0%	1	0	0	0	0
7.04	1	2.0%	0	0	1	0	0
7.05	1	2.0%	0	0	1	0	0
8.01	1	2.0%	1	0	0	0	0
8.02	1	2.0%	1	0	0	0	0
8.03	1	2.0%	0	0	0	1	0
8.04	1	2.0%	1	0	0	0	0
8.05	1	2.0%	1	0	0	0	0
8.06	1	2.0%	0	0	1	0	0
8.07	1	2.0%	0	0	1	0	0
9.01	2	4.0%	2	0	0	0	0
9.02	1	2.0%	1	0	0	0	0
9.03	1	2.0%	0	0	0	0	1
9.04	1	2.0%	0	0	1	0	0
9.05	1	2.0%	1	0	0	0	0
9.06	1	2.0%	0	0	0	0	1
10.01	1	2.0%	1	0	0	0	0
10.02	1	2.0%	1	0	0	0	0
10.03	1	2.0%	0	0	0	0	1
10.04	1	2.0%	0	0	0	0	1
10.05	1	2.0%	1	0	0	0	0
10.06	1	2.0%	0	0	0	1	0
10.07	1	2.0%	1	0	0	0	0
10.08	1	2.0%	1	0	0	0	0
10.09	1	2.0%	0	0	1	0	0
10.10	1	2.0%	0	0	0	0	1
10.11	1	2.0%	0	1	0	0	0
10.12	1	2.0%	0	0	0	0	1
11.01	3	6.0%	2	0	1	0	0
11.02	1	2.0%	0	0	1	0	0
12.01	3	6.0%	1	0	1	0	1
12.02	1	2.0%	0	0	1	0	0
12.03	1	2.0%	0	0	0	1	0
12.04	1	2.0%	0	0	1	0	0
12.05	1	2.0%	0	0	0	0	1
13.01	1	2.0%	1	0	0	0	0
13.02	1	2.0%	0	0	1	0	0
14.01	1	2.0%	0	0	0	1	0
Total	50	100.0%	22	1	13	4	10

Table 5.15 - Cross-tabulation of the internal graph types with the building-network interface types in detached houses.

5.5.3. The impact of the interface on the configuration of the detached houses

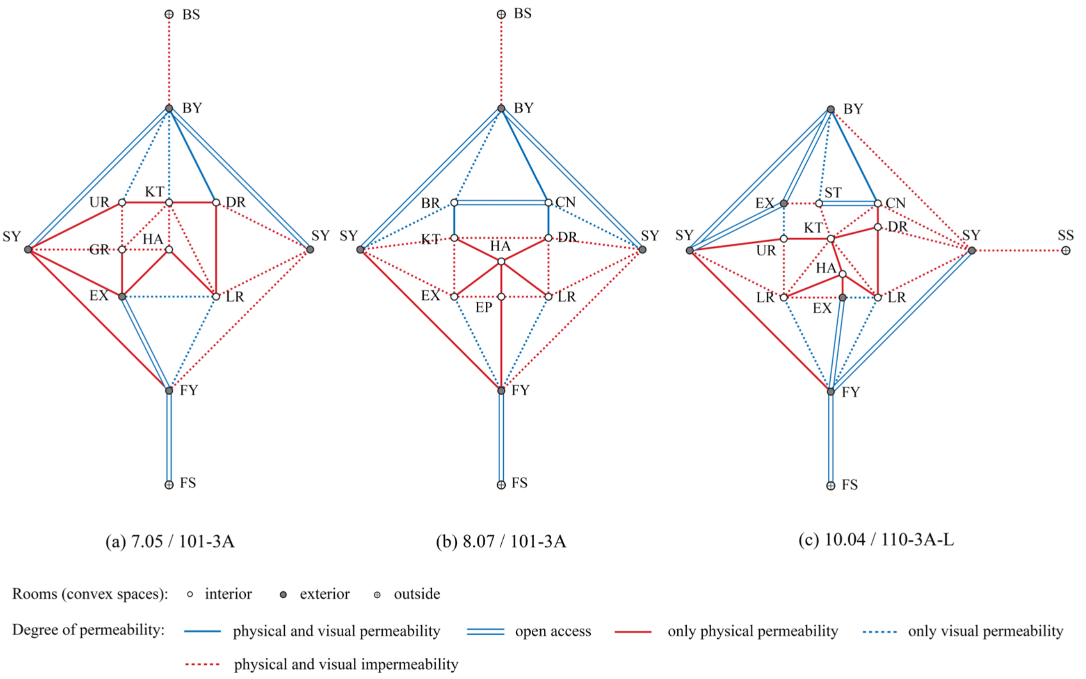
As approximately half of the analysed detached houses interface with the street network in an atypical manner, it is important to understand the impact of the interface on the internal configuration of detached houses. The impact of the relationship between building-network interface types and internal graph types is determined based on the cross-tabulation of

Figure 5.23 - An example of the layout of the estate of detached houses in Gosforth (D1). Source: OS MasterMap. Scale 1:2500. Updated: 2018, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service.

both elements (see Table 5.15), and comparison between the characteristics of the internal graph types and building-network interface types, such as: the number of nodes and links, the position of the nodes, and the degree of permeability between spaces.

It can be noted that 15 graph types (which correspond to 34.0% of houses) have a single typical building-network interface type, as seen in Figure 5.21. 4 internal graph types (24.0% of houses) have multiple building-network interface types. Which means, in other words, that the same internal configuration of the house connects to the immediate context differently. As most of the internal graph types in the sampled detached houses correspond to only one house it makes it challenging to determine if certain layouts interface with the street network exclusively in a typical way or in multiple different ways. Therefore, the next step is to analyse the internal layouts of houses that interface with the street network atypically.

21 graph types (42.0% of houses) have a single atypical building-network interface, which in most cases results in additional interface at the side or back of the house. As mentioned in the previous section, the reason for this sharp increase in the number of atypical interfaces lies in the change in the urban design of housing estates. The layout of the estates is organised as an arrangement of disconnected cul-de-sacs and dead-end streets (see Figure 5.23). In all of the sampled houses that interface with the street network atypically, the front interface is designed to provide access to the house and allow for visual connection between the street and the front garden or drive. On the other hand, the additional side and back interfaces do not seem to provide any meaningful relationship with the adjacent streets. In 78.6% of cases (11) the back interface and in all of the cases (14) the side interface is both physically and visually impermeable. This might have negative implications for both the architectural and urban scales. In the typical layout, the back of the detached house is seen as an extension of the private leisure-orientated internal rooms and is surrounded by neighbouring units thus sheltered from the busy public space. When a house interfaces with the street network atypically, the role of the back garden



(a) 7.05 / 101-3A

(b) 8.07 / 101-3A

(c) 10.04 / 110-3A-L

Figure 5.24 - Examples of internal graph types with a single atypical building-network interface.

transforms and the space is exposed to potentially busy roads. As discussed in Chapter 4 in detail, in many estates of detached houses the back of the houses are adjacent to streets with high potential for movement. Thus, there is an increased likelihood of noise-related disturbance in the private back garden.

Nearly 1 in 5 houses has an additional side interface situated on the right side of the graph. As discussed in the previous section, the rooms dedicated to everyday life and leisure are organised along the right side of the graph. In a typical scenario the side external walls and setbacks of a detached house are adjacent to neighbouring units, however, in these cases those rooms are again exposed to the street. While there is a setback between the side external wall and the street, it is on average 90 centimetres wide, which might not be enough to provide a sufficient buffer. The consequences are likely to be similar to those discussed in the case of the atypical back interface. Apart from the impact on usability of some spaces, the impact might be also economic and affect the value of the property.

In Figure 5.24 three examples of internal configurations that interface with the street network in an atypical way are illustrated. When analysed, the morphological characteristics, such

Figure 5.25 - Both physically and visually impermeable side interface between the end terrace and the street on Yetlington Drive in Newcastle (Photograph by Author, taken on 28.09.2019).

as average number of nodes and links, the position of the rooms and the frequency of occurrences and type of the links between pairs of rooms, are similar to that observed in the houses with a typical interface. There is also no apparent difference in the structure of the internal graphs in the houses with an atypical building-street interface. The spatial logic observed previously can be seen in those graphs and there are no significant outliers to those patterns. The highest variability in the graphs can still be observed along the middle vertical axis of the house. There is no change in the distribution of the main room types and their average position within the graph. There are also no significant changes in the number of occurrences in links between certain room pairs and their degree of physical and visual permeability. All in all, there is no significant change in the data that allows us to conclude that the internal configurations of those houses were in any way affected by the interface(s).

This is worrying, because the lack of change in the internal configuration does not mean that there is no change in the overall configuration of the detached house and its context. Direct adjacency to additional, atypical, streets result in new links between external private spaces and public streets that might not have been considered during the design process. The most visible negative result is the physically and visually impermeable tall wall which delimits most of the sampled estates, as pictured in Figure 5.25. In the sample, those uninterrupted blank impermeable walls are between, approximately, 75 and 329 metres long, with an average wall being 136.6 metres long. If those additional interfaces were considered during the design process, the isolating and segregating impact of a long impermeable boundary on the street was disregarded. From the perspective of the house, unaddressed exposure to the additional street might lead to change in the usability of some private external spaces, depending on the levels of noise and air pollution caused by traffic. Thus, it is important to consider at least the immediate context when analysing the configuration of the houses, because in all of the sampled detached houses it was impossible to assess how each house interfaced with the street network solely based on the internal configuration of the plan.

5.6. Summary and conclusion

This chapter discussed the impact of the relationship between houses and the street network on the internal configuration of English houses utilising a graph-theoretic method.

Summary	terraced	semi-detached	detached
Number of houses	254	309	50
Number of internal graph types	48	142	40
House/Graph type ratio	5.3	2.2	1.3
The percentage of houses that four most common graph types correspond to	52.4%	19.1%	26.0%
Rooms (nodes)			
Average number of vertices per house	8	8	9
Avg. number of nodes along the left side	5	3	3
Avg. number of nodes along the middle	0	2	3
Avg. number of nodes along the right side	3	3	3
Number of most common room types (e.g. kitchen, dining room)	7	8	8
Links between nodes			
Average number of links per house	13	14	17
Avg. number of phys. and vis. permeable links	6.3%	5.0%	6.0%
Avg. number of only phys. permeable links	40.8%	42.4%	38.5%
Avg. number of only vis. permeable links	15.7%	13.1%	14.0%
Avg. number of impermeable links	24.6%	30.3%	32.7%
Avg. number of open plan links	9.1%	9.2%	8.8%
Building-network interface			
Number of building-network interface types	9	7	6
Number of houses with a typical building-network interface	201	267	22
	79.1%	86.4%	44.0%
Number of houses with an atypical building-network interface	53	42	28
	20.9%	13.6%	56.0%
The relationship between internal graph type and building-network interface type(s)			
Number of internal graph types with a single typical building-network interface type (Corresponding percentage of houses)	24	116	15
	(18.5%)	(37.5%)	(34.0%)
Number of internal graph types with a single atypical building-network interface type (Corresponding percentage of houses)	9	10	21
	(3.5%)	(3.2%)	(42.0%)
Number of internal graph types with multiple building-network interface types (Corresponding percentage of houses)	15	16	4
	(78.0%)	(26.9%)	(24.0%)

Table 5.16 - Summary of morphological characteristics across three house types: terraced, semi-detached and detached.

The variables discussed in this chapter were summarised in Table 5.16 and are briefly concluded in this section.

In the first part of the analysis the morphology of the internal configuration of English houses was investigated in order to determine the typology of the floor plans based on their topological structure, referred to as the typology of internal graphs. It was observed that the ratio of the number of houses to the number of internal graph types decreased in time. In other words, higher standardisation of floor plans was observed in terraced houses (5.3 houses/graph) and higher individuality of layouts was found in the detached houses (1.3

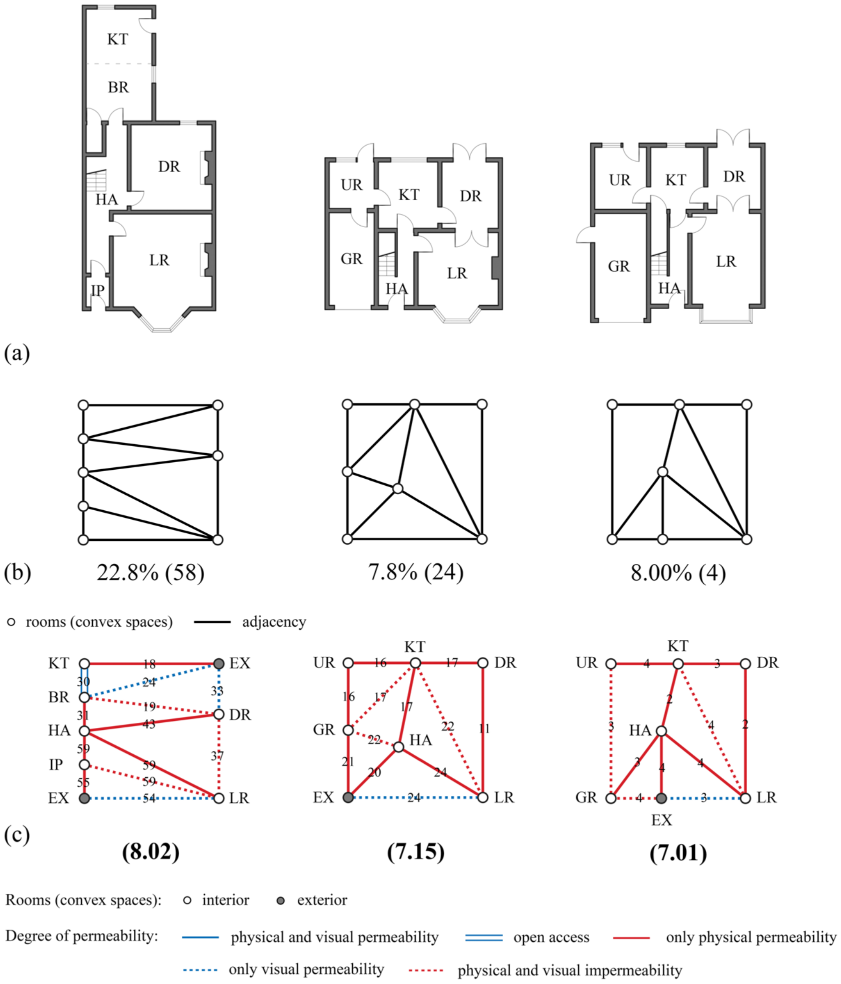
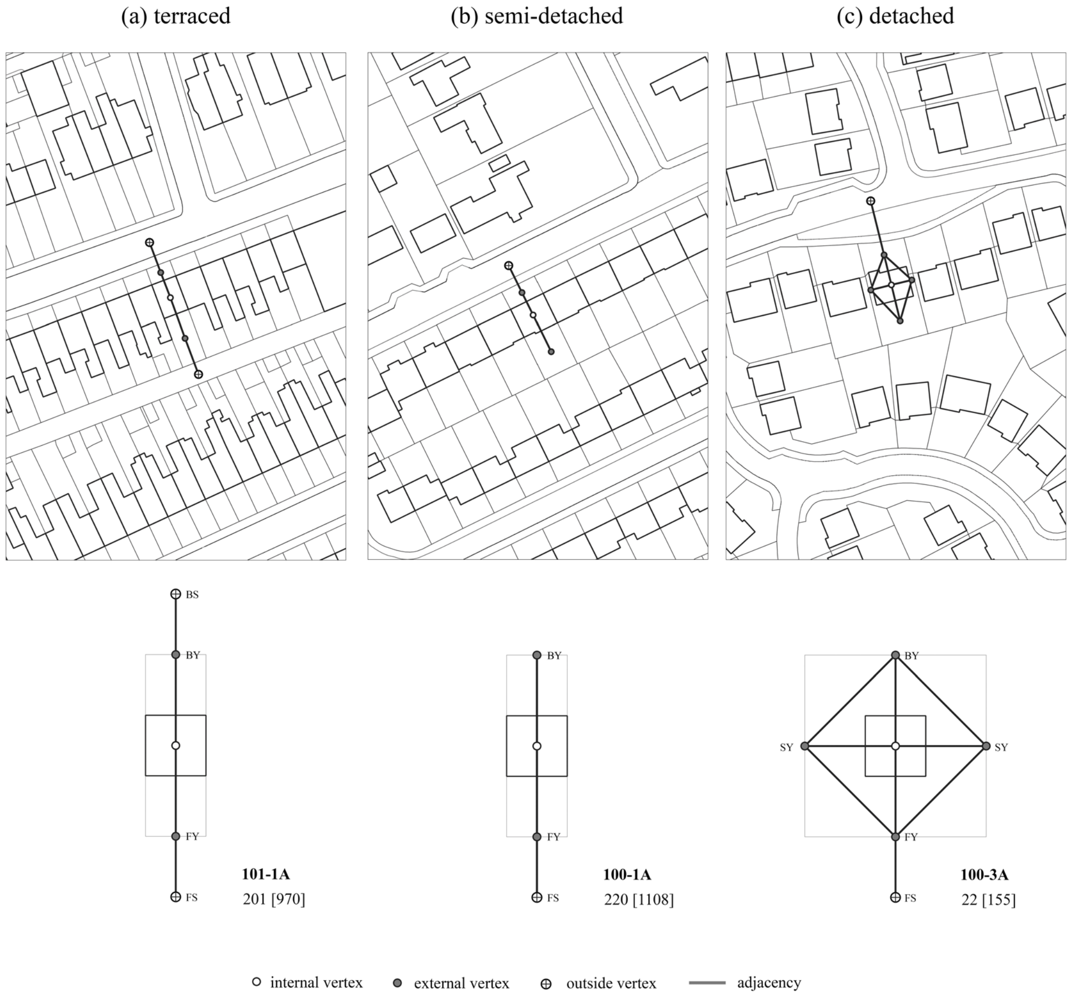


Figure 5.26 - Comparison of the most common internal graph types in terraced, semi-detached and detached houses, with corresponding floor plans (a), adjacency graphs (b) and permeability graphs (c). In (c) the number on each link describes the number of occurrences of a specific relationship between the specific rooms.

houses/graph). The reason for the increase in the individualisation of the internal layout is difficult to pinpoint precisely, however, it might be connected to the growing involvement of architectural companies in the design process of residential developments. The most common internal graph types in each house type are illustrated in Figure 5.26. In both terraced and semi-detached houses the average number of nodes is 8, while in detached houses the average number of nodes is slightly higher, at 9. When the location of the nodes in relation to the outline of the house was considered, a shift between the organisation of terraced houses in comparison to semi-detached and detached can be observed. In terraced houses the rooms tend to be organised along two vertical axes: on the left and right side of the graph. In semi-detached and detached houses, the rooms are organised along three vertical axes: on the left, in the middle and on the right side of the graph. The most common room types are very similar in all three house types. Kitchens, dining rooms, living rooms, halls and external spaces can be found in terraced, semi-detached and detached houses. However, there are some types of rooms that are more common in particular types. For example, garages and utility rooms are common in semi-detached and detached houses, but less prevalent in terraced houses. When terraced houses were constructed at the end of the nineteenth century, garages were not necessary as the wide-spread popularisation of private cars did not occur until after the Second World War.

The average number of links, which describe an adjacency-based relationship between a pair of rooms, increased over time, with the average number of links in terraced houses being 13 and 17 in detached houses. An interesting observation was found when the degree of permeability of the links was analysed. As shown in Table 5.16, the average number of links with different types of permeabilities is similar across all three house types. The distribution of the average number of links with varying degrees of permeability is comparable in all three house types and can be approximated as: 6% of links being both physically and visually permeable, 40% being only physically permeable, 15% being only visually permeable, 30% being impermeable, and 9% describing an open plan arrangement. This finding indicates that there is an underlying logic as to how some types of rooms are linked to each other that is independent of the overall topological structure of the floor plan and even the house type. Additionally, it is interesting that the percentage of physically impermeable links is so high (on average approx. 45%). Therefore, many rooms are directly adjacent with a possibility for access that is not exploited. This observation coincides with Steadman's theory that the adjacency-based relationships between rooms are 'of the greatest functional significance' (Steadman, 1983, p.62), as they provide an opportunity for access between the rooms, which does not have to be utilised.


(a) terraced

(b) semi-detached

(c) detached

Figure 5.27 - Comparison of the typical building-network interfaces in terraced (101-1A), semi-detached (100-1A), and detached houses (100-3A).

The next step in the analysis was concerned with determining the ways that each English house type interacts with the street network, through the analysis of the building-network interface. It was noted that in each house we can observe a typical (most common) building-network interface (see Figure 5.27). An exception was found in semi-detached houses where two typical building-network interfaces were found, one more common in the early inter-war developments, the second one more wide-spread after the Second World War. Moreover, it was observed that the typical interface is not the only way a house can link to the street network and many atypical interfaces can be found in each house type - 8 in terraced houses, 5 in semi-detached and detached houses. The reason for the atypicality is twofold and depends on: the number of directly adjacent streets to the house, and the position of the house on the plot. Therefore, the urban design decisions such as the layout of the estate and the structure of the urban block are very significant in the understanding of the relationship between houses and the street network. An interesting shift can be observed in the distribution of houses with typical and atypical building-network interfaces, as shown in Table 5.16. In terraced and semi-detached houses the majority of houses interface with the street network in a typical manner (79.1% and 86.4% respectively). However, that significantly changes in the case of detached houses, where only 44% of houses interface with the street network typically. As discussed in the Section 3.5, this is a result of a change in the overall design of the housing estate, from grid-like interconnected layouts to disconnected arrangements of cul-de-sacs that prioritised isolation and segregation from the existing urban structure. The detached houses were organised in a way that the front façade in each house was facing the internal streets, which meant that it was geometrically impossible for many houses to not be adjacent through either the side or back façade to the existing urban fabric. The by-product of that shift in residential design was the significant increase in the atypical relationships between houses and the street network. This mismatch between housing type and the urban design of estates was present to a smaller degree in the estates of terraced and semi-detached houses. However, it was not as prevalent as in the estates of detached houses.

The consequences of the discrepancy between the architectural and urban scales are likely multifaceted, and while they are not studied in this thesis, the method proposed might be used as a foundation for further socio-economic studies.

In the last step of the analysis the relationship between the internal graph types (discussed in the first step) and the building-network interface types (discussed in the second step) was studied. In this part of the analysis the third question of this thesis: *does the way in which a house interfaces with streets affect its internal configuration and how does it do this?* is addressed and the hypothesis that the atypical building-network interface affects the internal configuration of the floor plan is examined. The findings of this analysis are twofold.

Firstly, it was observed that there is only a small percentage of terraced and semi-detached houses that interface with street network atypically and have a significantly different internal layout from that commonly seen (3.5% and 3.2% respectively). In terraced houses, the difference in the configuration of the internal layout lay in the way the nodes are arranged in relation to the outline of the house. Instead of being situated along 2 vertical axes, the rooms are organised along 3. This change can be observed in terraced houses that most likely had a setback between the side façade and the adjacent street, therefore, the house was extended in order to occupy the unused and topologically insignificant space. In the semi-detached houses we can observe the opposite change in the organisation of the nodes. Rather than being positioned along 3 vertical axes, the rooms are situated along 2 - along the left and right side of the house. The reason for that change is in the placement of a garage in relation to the house. In typical semi-detached houses the garage had to be positioned as part of the front façade as the access to the house was only available through the front façade. With an additional interface the garage could have been detached from the house, positioned in the back yard and accessed through the side interface.

Secondly, in a high percentage of houses it was observed that a unique internal graph type can be found interfacing with the street network in multiple different ways. In other words, even though the internal configuration of the floor plan is constant, its immediate surroundings varies.

If an internal layout was designed to interface with the street network in a typical manner and it is then linked to the network atypically, it might affect the use of some rooms that were not designed to be exposed to a potentially busy street. Therefore, in most cases an impermeable blank wall is introduced to protect the inherently private spaces from the unintended adjacency to the public space. The wall itself, however, might be sufficient enough to isolate the spaces visually but not sufficient enough to block out noise and air pollution. Moreover, as discussed in Chapter 4, the quality of the street might be negatively affected if many impermeable interfaces are aggregated along one street. As discussed in Section 5.5, it is not uncommon for estates of detached houses to introduce long blank walls on the perimeter of the estate that can be between 75 and 329 metres long.

To summarise, while the impact of the relationship between a house and street network on the ‘isolated’ internal configuration might be minuscule, the impact on the configuration of the house as a part of a system is more significant, which is manifested in the increasing mismatch between the house type and the layout of the estates. In the majority of cases, this mismatch between the architectural and urban scale results in a low quality boundary between those two realms which might not only negatively affect the activity and safety on the streets, but also the use and value of the house.

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Chapter 6

Conclusion and discussion

6.1. A return to the research questions

This thesis has examined spatial interfaces between houses and streets in Newcastle upon Tyne between 1880s and 2018 with a research question: *does the spatial relationship between houses and streets affect the configuration and use of both?* This spatial relationship, referred to in this work as the *interface*, was examined using two configurational approaches: space syntax for the urban scale and graph representation for the architectural scale, which were integrated using a geographic information system (GIS). This work concluded with four main original contributions to the existing body of knowledge. Firstly, through empirical study, a mismatch between the architectural and urban scales in English housing was recognised. Secondly, it was observed that the mismatch between houses and streets is progressively growing over time. Thirdly, the thesis contributes an original dataset, amassed through direct observational study, on the interfaces between houses and streets. Finally, an original methodological framework was developed that integrates the analyses of architectural and urban forms in GIS.

The main research question was split into four in order to more easily address it, and those questions are revisited in this section:

> (1) Does the way in which a street interfaces with houses affect the activity on the street and how does it do this?
> (2) Does the way in which a house interfaces with streets affect its internal configuration and how does it do this?
> (3) By what means can the macro-scalar analysis of streets and the micro-scalar analysis of houses be integrated?
> (4) Does the interface between houses and streets differ across different morphological periods?

The first research question: *does the way in which a street interfaces with houses affect* *the activity on the street and how does it do this?* was addressed in Chapter 4 through the combination of the macro-scalar analysis of street networks with the examination of the topological characteristics of interfaces based on the proximity, physical permeability and visual permeability between streets and houses. The key aspects of the activity in the streets, as observed in the literature review in Chapter 2, are movement and sufficient space which is capable of accommodating long-duration activities. The analysis of street networks in Gosforth using space syntax allowed us to determine the potential of each street to accommodate movement. In order to determine whether the interface is active and capable of generating and supporting co-presence and probabilistic encounters, the interfaces were categorised into types based on their topological properties (proximity, physical permeability and visual permeability). The main results are as follows:

> (1) An overall increase in the number of streets with passive interfaces per estate can be observed over time, from approximately 14% of passive streets observed in the estates of terraced and semi-detached houses to 40% of cases in the estates of detached houses.
> (2) More importantly, passive interfaces became more prevalent along the locally important streets over time. In estates of terraced houses the passive interfaces were observed along the less important streets (in regards to metric length, connectivity and movement potential). In the estates of detached houses the majority of important streets are lined with passive interfaces.

Thus, it has been observed that, while the interface is not the only factor affecting the street activity, the poor quality of the interface adversely affects its capability to generate and support co-presence in the streets. The blank impermeable walls at the edge between the public and private domains are very unlikely to accommodate any longer-duration activities which are a key factor in supporting co-presences, interaction and activities.

The second research question: *does the way in which a house interfaces with streets affect their internal configuration and how does it do this?* was addressed in Chapter 5 through the combination of the micro-scalar analysis of the internal configuration using graph theoretic methods with the investigation of the types of ways a house interfaces with the street network (building-network interfaces), determined based on the number of interfaces and their topological characteristics (proximity, physical permeability and visual permeability). The main results of Chapter 5 are as follows:

> (1) The number of houses where the internal configuration changed based on the difference in the interfaces with the street network was insignificant, with approximately 3.5% of floor plans having distinctly different internal layouts.
>
> (2) An increase in the number of houses with atypical (for their housing type) ways of interfacing with the street network has been observed. In terraced houses approximately 20% of houses interface with the street network atypically (through the side façade), while in detached houses 56% of houses did (through the side and back façades).
>
> (3) In a high percentage of houses it was observed that a unique internal configuration can interface with the street network in multiple different ways. This means that, even though the configuration of the layout is constant, the way it links to the immediate surroundings varies. Thus, when a floor plan is linked to the context in an unusual way, it might affect the character and use of some rooms that were not designed to cope with certain circumstances, for example, a private back garden might be exposed to a potentially busy street.

Thus, while the effects of the difference in the immediate context might not be visible in the configuration of the floor plan, the adjacency to public space, that is not accounted for in the design process, might affect perception and use of certain rooms and spaces.

The third research question: *by what means can the macro-scalar analysis of streets and the micro-scalar analysis of houses be integrated?* was addressed in both analysis chapters. The dichotomy between the urban macro-scale and architectural micro-scale is apparent in both design and research and has been observed through empirical analysis of the spatial interfaces in Gosforth. The streets with passive interfaces and houses atypically interfacing the street networks are a result of the mismatch between the urban and architectural scale. In order to address the imbalance between the streets and buildings, a method was developed to manage the relationship between the scales with the creation of a one-to-one relationship between both elements through the adaptation and scaling of the concept of the interface.

> (1) In the street-focused Chapter 4, in order to relate the way houses link with a street, the individual building-street interfaces were amalgamated to a composite street-buildings interface that incorporated information on the buildings situated on one side of the street. This allowed for cross-tabulation of the micro-scalar characteristics with the macro-scalar properties of the streets as parts of a larger network.
>
> (2) In the building-focused Chapter 5, in order to relate the way the house interfaces with a street network, the individual building-street interfaces were amalgamated to a composite building-network interface which described the total extent of the relationship between the house and the street network. This allowed for cross-tabulation of data between those interfaces (and by proxy the macro-scalar information) with the graph-representation of the floor plans in each house.

The centralisation and automation of the process of the scalar manipulation of the interfaces was achieved in a geographic information system (GIS). The ability to store the spatial and non-spatial data as independent but cross-referenced layers in one GIS database allowed us to relate the macro-scalar and micro-scalar data through the concept of the interface.

The fourth research question: *does the interface between houses and streets differ across different morphological periods?* was addressed in both analysis chapters. It was observed that there are two ways an interface between houses and street is established, either as a direct extension of the internal organisation of the house, or as a by-product of the urban design of the estate.

> (1) The interfaces that stemmed from the internal organisation of the houses are intrinsically connected to each house type, and thus, the change can be observed mainly when the shift between those different house types occurs. The key interface in each house type is the front interface which continues to serve as the main access point to the house, as well as a spatial reflection of the social status of the household. However, the morphology of the transition between the public and private domains changed over time. In the front interfaces of terraced houses the hierarchy of the entry is pronounced with well defined transition spaces, and every step of the entrance is spatially demarcated and controlled through a set of gates and doors. In semi-detached houses, the front interface became less formal and the spatial demarcation of the in-between spaces was less pronounced. It was common not to have a physical gate between the public street and the front yard/drive but rather an opening in the fence. In detached houses there is no physical boundary between the private and public spaces. The space in front of the house blends with the public space of the communal street. Moreover, it can also be observed that technological advancements and changes in the way kitchens and bathrooms were used, led to the disappearance of the functional back interface. Modern household appliances do not require a utilitarian back yard and a direct connection to the street to function.

(2) The morphology of the interfaces that stemmed from the urban design is consistent across all the housing types and in most cases those side (or back) interfaces are physically and visually impermeable and passive. However, the types of streets lined with those interfaces changed over time. In terraced houses the passive atypical to the house interfaces mostly faced the less important streets (in regards to metric length, connectivity and movement potential). In detached houses, however, those passive interfaces are mostly adjacent to the locally important streets. This is a result of a change in perception of the relationship between the house and the street. In the late nineteenth century it was important for a terraced house to face a busy street in order to display, through the design of the façade and the front garden, the status of the household. In the semi-detached and later detached houses, the privacy of the household and a community became increasingly important.

6.2. Limitations and generalisability

A number of limitations can be seen in this work. The first limitation of this study has to do with the difference between the potential values and actual values. In the street network analysis in this thesis, movement and street activities are measured as potential rather than actual. The movement is determined by configuration and morphology of the urban form, rather than direct observational study of co-presence and encounter. While, it is likely that the potential and actual values in this thesis are not identical, as has been mentioned in the literature review, there is empirical evidence that syntactic measures determining potential movement correlate with the actual volume of movement (Bafna, 2003). This study, therefore, can be used as a foundation for a future study on the actual co-presence, encounter and activity based on direct observational methods.

The second limitation is the availability of floor plans for the analysis of the internal configuration of houses. The micro-scalar data is not as widely available as the data on urban form and street networks. Therefore, in this study we had to rely on the availability of floor plans from governmental and commercial sources. This limitation was addressed by introducing a set of requirements that had to be met in order to include an estate in the analysis. Because of the way the houses were developed at the end of the nineteenth century, differences occurred on a street by street basis. In order to assure adequate coverage each street in the estate had to be represented by at least one floor plan.

The findings in this thesis are generalisable methodologically and geographically. The development of the methodology and tools that allow for the analysis of the interface and the integrated analysis of both architectural and urban scale are generalisable as they can be applied to other datasets. Geographically, based on the historical review and similarities in English housing development, the findings of the empirical study of the interfaces between houses and street in Gosforth can be generalised to the whole of England.

6.3. Practical implications of the study

Urban and architectural studies are inherently set in the context of design. Therefore, it is interesting to discuss the practical implication of the study of the interface for developers, urban planners and architects. To address the practical implications in this work the following question was asked:

> How can this work be applied by developers, planners and architects of new housing estates in order to create better interfaces between houses and streets?

From the perspective of developers, the methods proposed in this thesis could help to improve the quality of the interfaces in the design of modern housing estates through a set of small interventions. The popular layout of estates of detached houses can still be preserved while assuring that the perimeter of the estate is not a blank impermeable boundary. For example, a mix of low-rise flats and shops could be introduced along the perimeter of the estate in between the public space and the back garden of the detached houses. Thus, the arrangement of the houses towards the centre of the estate is still preserved, while at the same time the detached houses are not directly adjacent to the potentially busy street through their back gardens. This could not only improve the quality of the streetscape on the perimeter of the estates, introduce more affordable housing options which are encouraged by the local authorities, but also might raise the value of the property. This arrangement is not novel and can be observed in the early estates of terraced houses in Gosforth, where it was not unusual for the important and busy streets to be lined with either larger terraced houses or Tyneside flats.

The methods developed in this thesis could allow planners to evaluate the places where the mismatch between the architectural and urban scale can be observed in order to either improve the quality of the existing public space or make sure that future developments do not worsen the current conditions. Moreover, the evaluation of the interfaces might prove useful during the planning application and permission process, in order to determine where the new developments should be situated in the existing urban tissue to improve the overall quality of the public spaces, or if the proposed design compliments and improves the existing context. From an architect's perspective, the methods might prove helpful in the design process, in order to visually and analytically assess the impact of the design ideas on the existing spaces, through the holistic, rather than selective, analysis of the relationships between both.

6.4. Future work

Beyond the work in this thesis, there are number of clear avenues for future work. The data gathered and methods developed in this thesis could be used as a base for a study of the social and economic implications of the mismatch between the architectural and urban forms. The effect of the design of the interface could be examined in relation to a wider set of data, such as census data, house prices, or poverty and crime rates, in order to investigate the relationship between the spatial boundaries and social issues, e.g. social segregation.

A qualitative element could be added to the dataset gathered in this thesis. This study could conduct surveys or interviews to understand whether people's perception of the interfaces correlates with their morphological characteristics. In order to understand the complex structure of the interface and transition between private and public spaces, the combination of the spatial and socio-psychological interpretation of the interface might help us understand the way the boundaries are perceived and established.

Finally, this work could be expanded to consider other housing and building types. With the current shift towards the construction of denser housing in the urban cores and inner suburbs, the understanding of the way a multi-family house interfaces with the public space and street network would allow us to create not only better domestic environments but also human-scale streets. Additionally, the study of the housing estates and neighbourhoods could be expanded to include non-residential types of buildings within those estates.

6.5. Concluding thoughts

Throughout this work the importance of understanding the spatial relationships between houses and streets has been strongly advocated. The reason for that lay in the hypothesis that if a direct adjacency between two distinct types of spaces exists, it is very likely that they affect each other to some degree. This hypothesis was investigated through the combination of macro- and micro-scalar configurational approaches: space syntax and graph representation of built form, in order to assess whether the spatial relationship between houses and streets affects their configuration and use.

The overarching observation in this empirical study of the interface between houses and streets in Gosforth is the mismatch between the architectural and urban scale that can be observed in each English house type. What is worrying, is the observation that the mismatch between those two scales is getting more significant over time as observed in the comparative analysis between the terraced, semi-detached and detached houses in this thesis. Thus, it is important to study the way different urban elements interact in order to assure that the full potential of both elements is utilised. As Madanipour (2003, p.70) aptly pointed out:

> ‘The challenge of boundary setting is to erect the boundaries between the two realms so that they combine clarity with permeability, acknowledging the interdependence of the two realms, and supporting both sides of the boundary.’

List of references

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A Pattern Language: Towns, Buildings, Construction.* Oxford University Press.

Allen, G. (1934). Building to sell. In E. Bentham (Ed.), *House Building 1934-1936* (pp. 137-154). London: Federated Employers' Press.

Al-Sayed, K. (2018). *Space Syntax methodology.* University College London, Bartlett School of Architecture.

Altman, I. (1975). *Environment and Social Behavior: Privacy, Personal Space, Territory, and Crowding.* Monterey: Brooks/Cole.

Anderson, S. (1987). *On Streets: Streets as elements of urban structure.* The MIT Press.

Appleyard, D. (1981). *Livable Streets.* University of California Press.

Arendt, H. (1958). *The Human Condition.* University of Chicago Press.

Austin, W. G. (1992). Industry in the 19th Century. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 42-43). Newcastle Libraries & Information Service.

Austin, W. G., & Buswell, R. J. (1992). Industry and Employment, 1900-1975. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 66-67). Newcastle Libraries & Information Service.

Bafna, S. (2003). Space Syntax: A Brief Introduction to Its Logic and Analytical Techniques. *Environment and Behavior, 35*(1), pp.17-29.

Barke, M., & Buswell, R. J. (1992). *Newcastle's Changing Map.* Newcastle Libraries & Information Service.

Barke, M., & Buswell, R. J. (1992). Physical Change in Newcastle's Central Area in the 1980s. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 84-85). Newcastle Libraries & Information Service.

Batty, M. (2004). A new theory of space syntax. *Centre for Advanced Spatial Analysis (CASA) Working Papers*.

Batty, M. (2013). *The New Science of Cities.* The MIT Press.

Bemis, A. F. (1936). *The Evolving House: Rational Design.* Cambridge: The Technology Press.

Bentley, I., Alcock, A., Murrain, P., McGlynn, S., & Smith, G. (1985). *Responsive environments: A manual for designers.* Routledge.

Berghauser Pont, M., Stavroulaki, G., Bobkova, E., Gil, J., Marcus, L., Olsson, J., Sun, K., Serra, M., Hausleitner, B., Dhanani, A., & Legeby, A. (2019). The spatial distribution and frequency of street, plot and building types across five European cities. *Environment and Planning B: Urban Analytics and City Science, 46*(7), pp.1226-1242.

Bobic, M. (2004). *Between the Edges: Street-building transition as urbanity interface.* Bussum: THOTH Publishers.

Brown, F. E., & Steadman, P. (1987). The Analysis and Interpretation of Small House Plans: Some Contemporary Examples. *Environment and Planning B: Urban Analytics and City Science*, pp.407-438.

Burnett, J. (1986). *A Social History of Housing, 1815-1985.* Methuen.

Buswell, R. J. (1992). Newcastle in the 16th and 17th centuries. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 19-20). Newcastle Libraries & Information Service.

Buswell, R. J. (1992). Origins of Newcastle and growth to 1600. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 15-16). Newcastle Libraries & Information Service.

Can, I., & Heath, T. (2016). In-between spaces and social interaction: a morphological analysis of Izmir using space syntax. *Journal of Housing and the Built Environment, 31*(1), pp.31-49.

Caniggia, G., & Maffei, G. L. (2001). *Architectural Composition and Building Typology.* Alinea.

Carmona, M. (2010). *Public Places Urban Spaces: The Dimensions of Urban Design.* Architectural Press.

Carr, C. M., & Whitehand, J. W. (2001). *Twentieth-Century Suburbs: A Morphological Approach.* Routledge.

Cataldi, G. (1998). Designing in Stages. Theory and design in the typological concept of the Italian School of Saverio Muratori. In A. Petruccioli (Ed.), *Typological Process and Design Theory* (pp. 35-55). Aga Khan Program for Islamic Architecture.

Chadwick, E. (1842). *Report on the Sanitary Condition of the Labouring Population of Great Britain.*

Chisolm, M. (1972). Macro- and Micro-Approaches to Urban Systems Research. *The Geographical Journal, 138*(1), pp.60-63.

Conroy Dalton, R. (2003). The Secret Is To Follow Your Nose: Route Path Selection and Angularity. *Environment and Behaviour, 35*(1), pp.107-131.

Conzen, M. R. (1960). *Alnwick, Northumberland: a study in town-plan analysis.* London: George Philip and Son.

Dovey, K., & Wood, S. (2015). Public/private urban interfaces: type, adaptation, assemblage. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 8*(1), pp.1-16.

Dyos, H. J. (1961). *Victorian suburb: a study of the growth of Camberwell.* London: Camberwell.

Edwards, A. M. (1981). *The Design of Suburbia: a critical study in environmental history.* London : Pembridge Press.

Figueiredo, L., & Amorim, L. (2005). Continuity lines in the axial system. *In Proceedings of the Fifth International Space Syntax Symposium*, pp.161-174.

Fishman, R. (1987). *Bourgeois Utopia.* New York: Basic Books.

Fox, K. (2014). *Watching the English: The Hidden Rules of English Behaviour.* Hodder & Stoughton.

France, L. (1992). Population in the 20th Century: Distribution and Density. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 58-59). Newcastle Libraries & Information Service.

France, L. (1992). Public Transport in the 20th Century. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 68-69). Newcastle Libraries & Information Service.

France, L. (1992). Transport in the 19th Century. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 44-45). Newcastle Libraries & Information Service.

Gater, G. H., & Wheeler, E. P. (1937). *Survey of London: Volume 18, St Martin-in-The-Fields II: the Strand.* London County Council.

Gauthier, P. (2005). Conceptualizing the social construction of urban and architectural forms through the typological process. *Urban Morphology, 9*(2), pp.83-93.

Gehl, J. (1977). *The Interface between Public and Private Territories in Residential Areas: A Study by Students of Architecture at Melbourne University Under the Supervision of Jan Gehl.* (F. Brack, & S. Thornton, Eds.) Department of Architecture and Building, University of Melbourne.

Gehl, J. (1986). "Soft edges" in residential streets. *Scandinavian Housing and Planning Research, 3*(2), pp.89-102.

Gehl, J. (2011). *Life Between Buildings: Using Public Space.* Island Press.

Gehl, J., Kaefer, L. J., & Reigstad, S. (2006). Close encounters with buildings. *URBAN DESIGN International, 11*, pp.29-47.

Gibberd, F. (1955). *Town Design.* London: Architectural Press.

Gil, J., Beirao, J., Montenegro, N., & Duarte, J. (2012). On the discovery of urban typologies: data mining the many dimensions of urban form. *Urban Morphology, 16*(1), pp.27-40.

Goethe, J. W. (1790/2019). *The Metamorphosis of Plants.* The MIT Press.

Gorst, T. (1995). *The Buildings Around Us.* Taylor & Francis.

Habraken, N. J. (1998). *The Structure of the Ordinary: Form and Control in the Built Environment.* MIT Press.

Hanson, J. (1998). *Decoding Homes and Houses.* Cambridge University Press.

Hanson, J. (2000). Urban transformations: a history of design ideas. *URBAN DESIGN International, 5*, 97-122.

Hanson, J., & Zako, R. (2007). How public open space shapes awareness and behaviour in residential developments. *In Proceedings of the Sixth International Space Syntax Symposium*.

Hillier, B. (1988). Against enclosure. In N. Teymur, Markus, & T. Woolley (Eds.), *Rehumanizing Housing* (pp. 63-88). Butterworth.

Hillier, B. (1996). *Space is the machine: A configurational theory of architecture.* University of Cambridge Press.

Hillier, B., & Hanson, J. (1984). *The Social Logic of Space.* Cambridge University Press.

Hillier, B., & Iida, S. (2005). Network and Psychological Effects in Urban Movement. *In Proceedings of Spatial Information Theory: International Conference (COSIT)*, pp.475-490.

Hillier, B., & Shu, S. (2000). Crime and Urban Layout: The Need for Evidence. In *Secure Foundations: Key Issues in Crime Prevention, Crime Reduction and Community Safety* (pp. 224-248). Institute of Public Policy Research.

Hillier, B., Burdett, R., Peponis, J., & Penn, A. (1987). Creating Life: Or, Does Architecture Determine Anything? *Architecture & Behaviour, 3*(3), pp.233-250.

Hillier, B., Penn, A., Hanson, J., & Xu, J. (1993). Natural movement: or, configuration and attraction in urban pedestrian movement. *Environment and Planning B: Planning and Design, 20*, pp.29-66.

Hills, J. (2007). *Ends and Means: The future roles of social housing in England.* CASEreport 34 - ESRC Research Centre for Analysis of Social Exclusion.

Horsey, M. (1985). London Speculative Housebuilding of the 1930s: Official Control and Popular Taste. *The London Journal, 11*(2), pp.147-159.

Jackson, A. A. (1973). *Semi-Detached London.* George Allen & Unwin.

Jacobs, J. (1961). *The Death and Life of Great American Cities.* New York: Vintage Books.

Jensen, F. (2007). *The English Semi-detached House.* Ovolo Publishing Ltd.

Kamalipour, H. (2016). Mapping Urban Interfaces: A Typology of Public/Private Interfaces in Informal Settlements. *Spaces and Flows: An International Journal of Urban and ExtraUrban Studies, 8*(2), pp.1-12.

Karimi, K. (2012). A configurational approach to analytical urban design: 'Space syntax' methodology. *URBAN DESIGN International, 17*(4), pp.297-318.

Kent, S. (1991). Partitioning space: Cross-cultural factors influencing domestic spatial segmentation. *Environment and Behavior, 23*(4), pp.438-473.

Kropf, K. (2001). Conceptions of change in the built environment. *Urban Morphology, 5*(1), pp.29-42.

Kropf, K. (2009). Aspects of urban form. *Urban Morphology, 13*(2), pp.105-120.

Kropf, K. (2017). *The Handbook of Urban Morphology.* John Wiley & Sons.

Krüger, M. J. (1979). An approach to built-form connectivity at an urban scale: system description and its representation. *Environment and Planning B: Urban Analytics and City Science, 6*, pp.67-88.

Larkham, P. J. (2006). The study of urban form in Great Britain. *Urban Morphology, 10*(2), pp.117-141.

Lawrence, R. J. (1981). Connotation of transition spaces outside the dwelling. *Design Studies, 2*(4), pp.203-207.

Lynch, K. (1984). *Good City Form.* The MIT Press.

Madanipour, A. (2003). *Public and Private Spaces of the specificity.* Routledge.

March, L., & Steadman, P. (1971). *The Geometry of Environment: An Introduction to Spatial Organization in Design.* RIBA Publications Limited.

Marcus, L. H., & Legeby, A. (2012). The need for co-presence in urban complexity: Measuring social capital using space syntax. *In Proceedings of the Eighth International Space Syntax Symposium*.

Marshall, S. (2009). *Cities Design & Evolution.* Routledge.

Marshall, S., & Caliskan, O. (2011). A Joint Framework for Urban Morphology and Design. *Built Environment, 37*(4), pp.409-426.

Marshall, S., Gil, J., Kropf, K., Tomko, M., & Figueiredo, L. (2018). Street Network Studies: from Networks to Models and their Representations. *Networks and Spatial Economics, 18*(3), pp.735-749.

Meen, G., Gibb, K., Goody, J., McGrath, T., & Jane, M. (2005). *Economic segregation in England: causes, consequences and policy.* Joseph Rowntree Foundation.

Mitchell, B. R. (1988). *British Historical Statistics.* Cambridge University Press.

Moudon, A. V. (1994). Getting to Know the Built Landscape: Typomorphology. In K. A. Franck, & L. H. Schneekloth (Eds.), *Ordering space: types in architecture and design* (pp. 289-314). Van Nostrand Reinhold.

Moudon, A. V. (1997). Urban morphology as an emerging interdisciplinary field. *Urban Morphology*(1), pp.3-10.

Mumford, L. (1961). *City in History: Its Origins, Its Transformations, and Its Prospects.* New York: Harcourt, Brace and World.

Muthesius, S. (1984). *The English Terraced House.* Yale University Press.

Newcastle City Council & Gateshead Council (2015). *Planning for the Future: Core Strategy and Urban Core Plan for Gateshead and Newcastle upon Tyne 2010-2030.* Newcastle City Council and Gateshead Council.

Newman, O. (1972). *Defensible Space: Crime Prevention through Urban Design.* New York: Macmillan.

NHBC (2015). *Homes through the decades: The making of modern housing.*

Nooraddin, H. (1998). Al-fina', in-between spaces as an urban design concept: making public and private places along streets in Islamic cities of the Middle East. *URBAN DESIGN International, 3*(1-2), pp.65-77.

Olsen, D. J. (1976). *The Growth of Victorian London.* New York: Holmes and Meier.

Orwell, G. (1939). *Coming Up for Air.* Victor Gollancz.

Palaiologou, G. (2015). *Between buildings and streets: a study of the micromorphology of the London terrace and the Manhattan row house 1880-2013.* Ph.D. dissertation, University College London.

Palaiologou, G., & Vaughan, L. (2014). The sociability of the street interface – revisiting West Village, Manhattan. *In Proceedings of the 21st International Seminar on Urban Form (ISUF): Our common future in Urban Morphology*, pp.88-102.

Palaiologou, G., Griffiths, S., & Vaughan, L. (2016). Reclaiming the virtual community for spatial cultures: Functional generality and cultural specificity at the interface of building and street. *The Journal of Space Syntax, 7*(1), pp.25-54.

Panerai, P., Castex, J., Depaule, J. C., & Samuels, I. (2004). *Urban Forms: The Death and Life of the Urban blocks.* Routledge.

Peck, F., & Morphet, C. S. (1992). Industry and Unemployment in the 1980s. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 82-83). Newcastle

Libraries & Information Service.

Prizeman, J. (1975). *Your House: The Outside View.* Hutchinson.

Rapoport, A. (1991). Pedestrians Street Use: Culture and Perception. In A. Moudon (Ed.), *Public Streets for Public Use* (pp. 80-92). New York: Columbia University Press.

Roberts-Hughes, R. (2011). *The Case for Space: The Size of England's New Homes.* Royal Institute of British Architects (RIBA).

Rowe, C., & Koetter, F. (1978). *Collage City.* The MIT Press.

Rudlin, D., & Falk, N. (1999). *Building the 21st Century Home: The Sustainable Urban Neighbourhood.* Architectural Press.

Seo, K. W. (2003). *Spatial Interpretation of Housing: The Role of Topological Intuition in the Evolution of the Houses in Seoul.* Ph.D. dissertation, University College London (UCL).

Seo, K. W. (2007). Space puzzle in a concrete box: finding design competence that generates the modern apartment houses in Seoul. *Environment and Planning B: Planning and Design, 34*, pp.1071-1084.

Seo, K. W. (2016). Finding Housing Genotypes by Graph Theory: an investigation into Malaysian houses. In J.-H. Lee (Ed.), *Morphological Analysis of Cultural DNA: Tools for Decoding Culture-Embedded Forms* (pp. 37-47). Springer.

Shayesteh, H., & Steadman, P. (2015). Coevolution of urban form and built form: a new typomorphological model for Tehran. *Environment and Planning B: Planning and Design, 42*, pp.1124-1147.

Sill, M. (1992). Growth of Newcastle in the 19th Century. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 28-29). Newcastle Libraries & Information Service.

Sill, M. (1992). Residential Patterns in the Late 18th and early 19th Centuries: Selected Aspects. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 26-27). Newcastle Libraries & Information Service.

Skjaeveland, O., & Garling, T. (1997). Effects of interactional space on neighbouring. *Journal of Environmental Psychology, 17*, pp.181-198.

Ståhle, A., Marcus, L., & Karlström, A. (2005). Place Syntax: Geographic accessibility with axial lines in GIS. *In Proceedings of the Fifth International Space Syntax Symposium*, pp.131-144.

Steadman, P. (1983). *Architectural Morphology: An Introduction to the Geometry of Building Plans.* Pion Ltd.

Steadman, P. (2014). *Building Types and Built Forms.* Matador.

Stern, N. (2006). *The Economics of Climate Change: The Stern Review.* Government of the United Kingdom.

Talor, C. C. (1992). Types of Housing Development: 1851-1901. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 40-41). Newcastle Libraries & Information Service.

Talor, C. C., & Buswell, R. J. (1992). The Development of Central Newcastle. In M. Barke, & R. J. Buswell (Eds.), *Newcastle's Changing Map* (pp. 30-31). Newcastle Libraries & Information Service.

Thompson, F. M. (1974). *Hampstead: Building a Borough, 1650-1964.* Routledge and Kegan Paul Books.

Thomson, R. C. (2003). Bending the axial line: smoothly continuous road centre-line segments as a basis for road network analysis. *In Proceedings of the Fourth International Space Syntax Symposium*, pp.50.1-50.10.

Turner, A. (2007). From axial to road-centre lines: a new representation for space syntax and a new model of route choice for transport network analysis. *Environment and Planning B: Planning and Design, 34*(3), pp.539-555.

URBED (2005). *Better Neighbourhoods: Making higher densities work.* Commission for Architecture & the Built Environment (CABE) and Corporation of London.

Vaughan, L. (2007). The spatial syntax of urban segregation. *Progress in Planning, 67*(4).

Vaughan, L., & Geddes, I. (2009). Urban form and deprivation: a contemporary proxy for Charles Booth's analysis of poverty. *Radical Statistics*, pp.46-73.

Vialard, A. (2014). Typological atlases of block and block-face. *In Proceedings of the 21st International Seminar on Urban Form (ISUF): Our Common Future in Urban Morphology*, pp.166-180.

Vialard, A. (2015). Defining Street Boundaries. *In Proceedings of the 22nd International Seminar on Urban Form (ISUF): City as organism: new visions for urban life*, pp.889–898.

Vialard, A. (In 2012). Measures of the fit between street network, urban blocks and building footprints. *In Proceedings of the Eighth International Space Syntax Symposium*, pp.8101:1-8101:17.

Welford, R. (1879). *A History of the Parish of Gosforth.* Walter D. Welford.

Whitehand, J. W. (2001). British urban morphology: The Conzenian tradition. *Urban Morphology, 5*(2), pp.103-109.

Whitehand, J. W., Gu, K., Conzen, M. P., & Whitehand, S. M. (2014). The typological process and the morphological period: a cross-cultural assessment. *Environment and Planning B: Planning and Design, 41*, pp.512-533.

Wong, C., & Schulze Bäing, A. (2010). *Brownfield residential redevelopment in England: What happens to the most deprived neighbourhoods?* Joseph Rowntree Foundation.

Appendices

A.1. The population growth in England between 1541 and 2011

Years	Population	Growth rate
1541	2,774,000	-
1551	3,011,000	8.5
1561	2,985,000	-0.9
1571	3,271,000	9.6
1581	3,598,000	10.0
1591	3,899,000	8.4
1601	4,110,000	5.4
1611	4,416,000	7.4
1621	4,693,000	6.3
1631	4,893,000	4.3
1641	5,092,000	4.1
1651	5,228,000	2.7
1661	5,141,000	-1.7
1671	5,067,000	-1.4
1681	4,930,000	-2.7
1691	4,931,000	0.0
1701	5,058,000	2.6
1711	5,230,000	3.4
1721	5,350,000	2.3
1731	5,263,000	-1.6
1741	5,576,000	5.9
1751	5,772,000	3.5
1761	6,147,000	6.5
1771	6,448,000	4.9
1781	7,069,000	9.6
1791	7,842,000	10.9
1801	8,287,907	5.7
1811	9,405,342	13.5
1821	11,178,050	18.8
1831	12,976,329	16.1
1841	14,847,888	14.4
1851	16,738,495	12.7
1861	18,753,390	12.0
1871	21,290,596	13.5
1881	24,396,880	14.6
1891	27,226,145	11.6
1901	30,512,831	12.1
1911	33,570,142	10.0
1921	35,230,225	4.9
1931	37,359,045	6.0
1939	38,084,321	1.9
1951	41,164,356	8.1
1961	43,460,525	5.6
1971	46,018,363	5.9
1981	46,382,051	0.8
1991	47,055,204	1.5
2001	49,138,831	4.4
2011	53,012,456	7.9

Table A.1 - The population growth in England between 1541 and 2011. Sourced from UK Censuses between 1801 and 2011 and pre-census sources in (Mitchell, 1988, p.7).

A.2. Age and type of English houses

Age and type of English houses (%)	1850-1918	1919-1944	1945-1980	1980-2015
Terraced	54.9	27.3	24.9	24.9
Semi-detached	16.6	49.3	34.2	14.2
Detached	8.2	12.0	17.2	30.7
Flats	20.4	11.4	23.7	30.1
All housing types	100.0	100.0	100.0	100.0

Table A.2 - Age and type of English houses. Source: Ministry of Housing, Communities & Local Government - *50 years of the English Housing Survey, 2017. Annex Table 2.4: Age and type of English homes, 2015.*

A.3. Distribution of English house types

Type of English houses, 2011	
Terraced	5,642,969
Semi-detached	7,076,395
Detached	5,128,552
Flats	5,095,953
All housing types	22,943,869

Type of English houses, 2011	(%)
Terraced	24.6
Semi-detached	30.8
Detached	22.4
Flats	22.2
All housing types	100.0

Table A.3 - Distribution of English house types. Source: Ministry of Housing, Communities & Local Government - *English Housing Survey, 2011. Annex Table AT1.1: Percentage of dwellings by tenure and age.*

A.4. Distribution of house types in Newcastle upon Tyne

Type of houses in Newcastle, 2011	
Terraced	32,049
Semi-detached	41,054
Detached	9,447
Flats	39,316
All housing types	121,866

Type of houses in Newcastle, 2011	(%)
Terraced	26.3
Semi-detached	33.7
Detached	7.8
Flats	32.3
All housing types	100.0

Table A.4 - Distribution of house types in Newcastle upon Tyne. Source: *UK 2011 Census, Dwellings, household spaces and accommodation type (KS401EW).*

A.5. Distribution of house types in Gosforth

Type of houses in Gosforth, 2011	
Terraced	2,537
Semi-detached	3,043
Detached	801
Flats	2,431
All housing types	8,812

Type of houses in Gosforth, 2011	(%)
Terraced	28.8
Semi-detached	34.5
Detached	9.1
Flats	27.6
All housing types	100.0

Table A.5 - Distribution of house types in Gosforth. Source: *UK 2011 Census, Dwellings, household spaces and accommodation type (KS401EW).*

A.6. Distribution of house types in each ward in Newcastle upon Tyne

Area	Terraced	Semi-detached	Detached	Flats
Benwell and Scotswood	19.6%	48.5%	5.7%	26.2%
Blakelaw	24.6%	50.3%	4.6%	20.5%
Byker	36.0%	17.8%	3.7%	42.6%
Castle	24.3%	49.1%	16.5%	10.0%
Dene	7.0%	48.6%	25.9%	18.5%
Denton	31.4%	47.4%	5.1%	16.1%
Elswick	28.3%	22.5%	4.9%	44.3%
Fawdon	23.0%	43.5%	5.9%	27.6%
Fenham	23.0%	49.8%	5.7%	21.5%
Gosforth (West and East)	28.8%	34.5%	9.1%	27.6%
Heaton (North and South)	30.2%	27.4%	2.2%	40.2%
Jesmond (North and South)	27.8%	8.9%	3.4%	59.9%
Kenton	30.2%	42.7%	4.3%	22.8%
Lemington	27.1%	47.2%	12.7%	13.0%
Newburn	26.5%	42.1%	12.4%	19.0%
Ouseburn	21.9%	3.2%	1.3%	73.6%
Parklands	12.4%	46.0%	20.3%	21.3%
Walker	46.9%	22.8%	4.2%	26.1%
Walkergate	21.2%	49.3%	4.4%	25.1%
Westerhope	15.3%	53.8%	23.7%	7.2%
Westgate	13.2%	4.1%	1.8%	80.9%
Winsgrove	30.7%	21.3%	4.8%	43.1%
Woolsington	38.1%	31.9%	11.4%	18.7%
Newcastle upon Tyne	26.3%	33.7%	7.8%	32.3%

Table A.6 - Distribution of house types in each ward in Newcastle upon Tyne. Source: *UK 2011 Census, Dwellings, household spaces and accommodation type (KS401EW).*

A.7. Population and population density in each ward in Newcastle upon Tyne

Area	Residents	Avg. household size:	Area (ha)	Pop. Density (p/ha)
Benwell and Scotswood	12,694	2	410	31
Blakelaw	11,507	2	244	47
Byker	12,206	2	299	41
Castle	10,069	2	2,185	5
Dene	9,667	2	287	34
Denton	10,500	2	228	46
Elswick	13,198	3	274	48
Fawdon	10,090	2	208	49
Fenham	10,954	2	231	47
Gosforth (West and East)	20,136	2	513	39
Heaton (North and South)	19,538	2	313	62
Jesmond (North and South)	21,662	3	393	55
Kenton	11,605	2	282	41
Lemington	10,228	2	424	24
Newburn	9,536	2	920	10
Ouseburn	11,352	3	137	83
Parklands	9,971	2	793	13
Walker	11,701	2	281	42
Walkergate	9,463	2	257	37
Westerhope	9,196	2	256	36
Westgate	10,059	2	255	39
Winsgrove	13,685	3	328	42
Woolsington	11,160	2	1,828	6
Newcastle upon Tyne	280,177	2	11,346	25

Table A.7 - Population and population density in each ward in Newcastle upon Tyne. Source: *UK 2011 Census, KS101EW Usual resident population.*

A.8. The relationship between the building-street interface type and the type of facade in terraced house

Building-street interface types	front	side	back
Direct impermeable (0/0/0)	0	92	7
Direct vis. permeable (0/0/1)	0	0	0
Direct phys. permeable (0/1/0)	0	35	247
Direct phys. and vis. permeable (0/1/1)	27	1	0
Direct open (0/open)	0	0	0
Distant impermeable (1/0/0)	27	29	19
Distant vis. permeable (1/0/1)	6	2	0
Distant phys. permeable (1/1/0)	490	50	1665
Distant phys. and vis. permeable (1/1/1)	1575	44	25
Distant open (1/open)	14	0	25
Total	2139	253	1988

Table A.8 - The relationship between the building-street interface types and the type of facade (front, side, and back) in terraced houses.

A.9. Activity levels on the streets of six terraced estates in Gosforth

	T1	T2	T3	T4	T5	T6	Total
Active street	14	7	8	5	9	15	58
Active street on one side / passive on the other	37	12	15	4	9	19	96
Constitute street but visually passive	2	2	0	0	0	0	4
Passive street	5	5	6	3	5	2	26
Non-residential	19	0	9	0	1	0	29
Total	58	26	29	12	23	36	184

	T1	T2	T3	T4	T5	T6	Total
Active street	24.1%	26.9%	27.6%	41.7%	39.1%	41.7%	31.5%
Active street on one side / passive on the other	63.8%	46.2%	51.7%	33.3%	39.1%	52.8%	52.2%
Constitute street but visually passive	3.4%	7.7%	0.0%	0.0%	0.0%	0.0%	2.2%
Passive street	8.6%	19.2%	20.7%	25.0%	21.7%	5.6%	14.1%

Table A.9 - Activity levels on the streets of six terraced estates in Gosforth.

A.10. The relationship between the building-street interface type and the type of facade in semi-detached house

Building-street interface types	front	side	back
Direct impermeable (0/0/0)	0	5	0
Direct vis. permeable (0/0/1)	0	0	0
Direct phys. permeable (0/1/0)	0	0	0
Direct phys. and vis. permeable (0/1/1)	0	0	0
Direct open (0/open)	0	0	0
Distant impermeable (1/0/0)	0	159	27
Distant vis. permeable (1/0/1)	0	0	3
Distant phys. permeable (1/1/0)	22	38	96
Distant phys. and vis. permeable (1/1/1)	2159	0	7
Distant open (1/open)	0	0	0
Total	2181	202	133

Table A.10 - The relationship between the building-street interface types and the type of facade (front, side, and back) in semi-detached houses.

A.11. Activity levels on the streets of eight semi-detached estates in Gosforth

	S1	S2	S3	S4	S5	S6	S7	S8	Total
Active street	5	8	14	13	14	30	31	4	119
Active street on one side / passive on the other	1	0	2	2	4	3	1	0	13
Constitute street but visually passive	0	2	4	0	0	0	2	2	10
Passive street	1	4	2	7	2	4	0	3	23
Non-residential	1	0	0	0	0	5	32	0	38
Total	7	14	22	22	20	37	34	9	165
	S1	S2	S3	S4	S5	S6	S7	S8	Total
Active street	71.4%	57.1%	63.6%	59.1%	70.0%	81.1%	91.2%	44.4%	72.1%
Active street on one side / passive on the other	14.3%	0.0%	9.1%	9.1%	20.0%	8.1%	2.9%	0.0%	7.9%
Constitute street but visually passive	0.0%	14.3%	18.2%	0.0%	0.0%	0.0%	5.9%	22.2%	6.1%
Passive street	14.3%	28.6%	9.1%	31.8%	10.0%	10.8%	0.0%	33.3%	13.9%

Table A.11 - Activity levels on the streets of eight semi-detached estates in Gosforth.

A.12. The relationship between the building-street interface type and the type of facade in detached house

Building-street interface types	front	side	back
Direct impermeable (0/0/0)	0	0	0
Direct vis. permeable (0/0/1)	0	0	0
Direct phys. permeable (0/1/0)	0	0	0
Direct phys. and vis. permeable (0/1/1)	0	0	0
Direct open (0/open)	0	0	0
Distant impermeable (1/0/0)	0	90	69
Distant vis. permeable (1/0/1)	0	0	0
Distant phys. permeable (1/1/0)	0	0	10
Distant phys. and vis. permeable (1/1/1)	9	0	0
Distant open (1/open)	317	0	0
Total	326	90	79

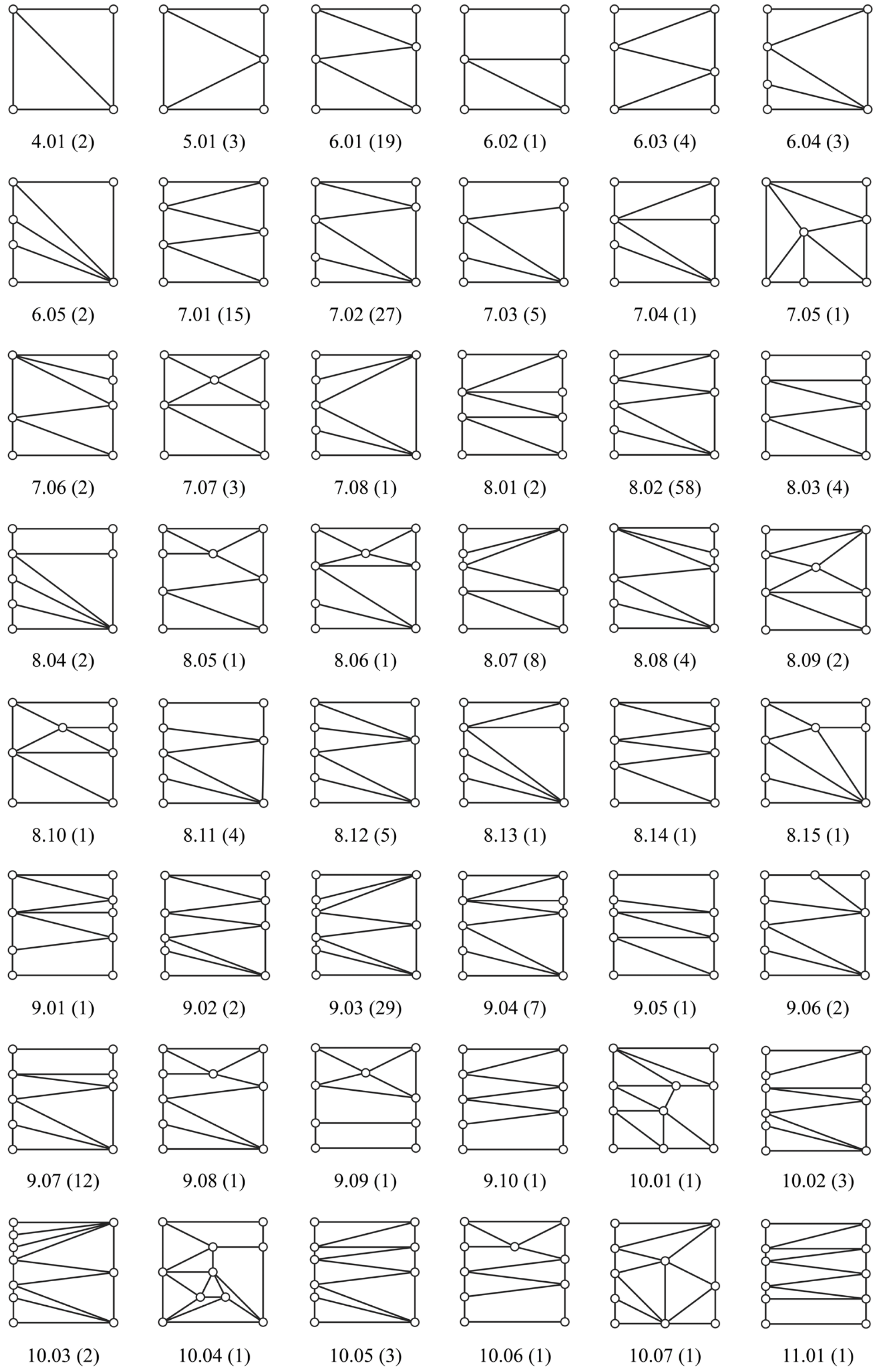
Table A.12 - The relationship between the building-street interface types and the type of facade (front, side, and back) in detached houses.

A.13. Activity levels on the streets of four detached estates in Gosforth

	D1	D2	D3	D4	Total
Active street	15	3	8	8	34
Active street on one side / passive on the other	1	0	0	0	1
Constitute street but visually passive	3	1	4	2	10
Passive street	11	2	8	8	29
Non-residential	0	0	0	7	7
Total	30	6	20	18	74
	D1	D2	D3	D4	Total
Active street	50.0%	50.0%	40.0%	44.4%	45.9%
Active street on one side / passive on the other	3.3%	0.0%	0.0%	0.0%	1.4%
Constitute street but visually passive	10.0%	16.7%	20.0%	11.1%	13.5%
Passive street	36.7%	33.3%	40.0%	44.4%	39.2%

Table A.13 - Activity levels on the streets of four detached estates in Gosforth.

A.14. Internal graph types in terraced houses



4.01 (2) 5.01 (3) 6.01 (19) 6.02 (1) 6.03 (4) 6.04 (3)

6.05 (2) 7.01 (15) 7.02 (27) 7.03 (5) 7.04 (1) 7.05 (1)

7.06 (2) 7.07 (3) 7.08 (1) 8.01 (2) 8.02 (58) 8.03 (4)

8.04 (2) 8.05 (1) 8.06 (1) 8.07 (8) 8.08 (4) 8.09 (2)

8.10 (1) 8.11 (4) 8.12 (5) 8.13 (1) 8.14 (1) 8.15 (1)

9.01 (1) 9.02 (2) 9.03 (29) 9.04 (7) 9.05 (1) 9.06 (2)

9.07 (12) 9.08 (1) 9.09 (1) 9.10 (1) 10.01 (1) 10.02 (3)

10.03 (2) 10.04 (1) 10.05 (3) 10.06 (1) 10.07 (1) 11.01 (1)

Figure A.14 - Internal graph types in terraced houses.

A.15. The positions of room types within the graph - terraced houses

XY	KT	DR	BR	LR	CN	ST	HA	IP/EP	EX	GR	UR
0,0	0	1	0	1	0	0	10	71	171	0	0
0,2	0	0	0	0	0	0	0	179	0	0	0
0,3	0	0	0	0	0	0	82	2	0	0	0
0,4	1	0	0	0	0	0	124	0	0	0	0
0,5	18	2	36	3	0	0	36	0	0	0	1
0,6	91	9	56	5	0	1	0	0	0	0	2
0,7	2	0	0	0	0	0	0	0	0	0	0
0,8	108	5	23	4	9	3	0	0	11	3	88
3,0	0	0	0	0	0	0	0	1	0	0	0
3,2	0	0	0	0	0	0	1	0	0	0	0
3,4	0	0	0	0	0	0	1	0	0	0	0
4,0	0	0	0	2	0	0	0	0	0	0	0
4,3	0	0	0	1	0	0	0	0	0	0	0
4,4	0	1	0	0	0	0	0	0	0	0	0
4,5	1	2	0	0	0	0	0	0	0	0	0
4,6	7	0	3	0	0	0	0	0	0	0	1
4,8	0	0	0	0	1	0	0	0	1	0	0
5,2	0	0	0	0	0	0	0	1	0	0	0
5,5	0	1	0	0	0	0	0	0	0	0	0
8,0	0	2	0	244	1	0	0	0	6	0	0
8,1	0	0	0	0	0	0	0	0	0	0	0
8,2	0	0	0	1	0	0	1	0	0	0	0
8,3	1	12	0	5	1	0	0	0	0	0	0
8,4	2	61	1	12	0	1	0	0	0	0	0
8,5	7	80	3	31	4	1	0	0	2	0	1
8,6	8	37	9	5	4	0	0	0	5	0	0
8,7	0	0	0	0	0	0	0	0	0	0	0
8,8	8	9	12	5	3	1	0	0	208	1	8
Total	254	222	143	319	23	7	255	254	404	4	101
Frequency	1.0	0.9	0.6	1.3	0.1	0.0	1.0	1.0	1.6	0.0	0.4

Table A.15 - The positions of room types within the graph - terraced houses.

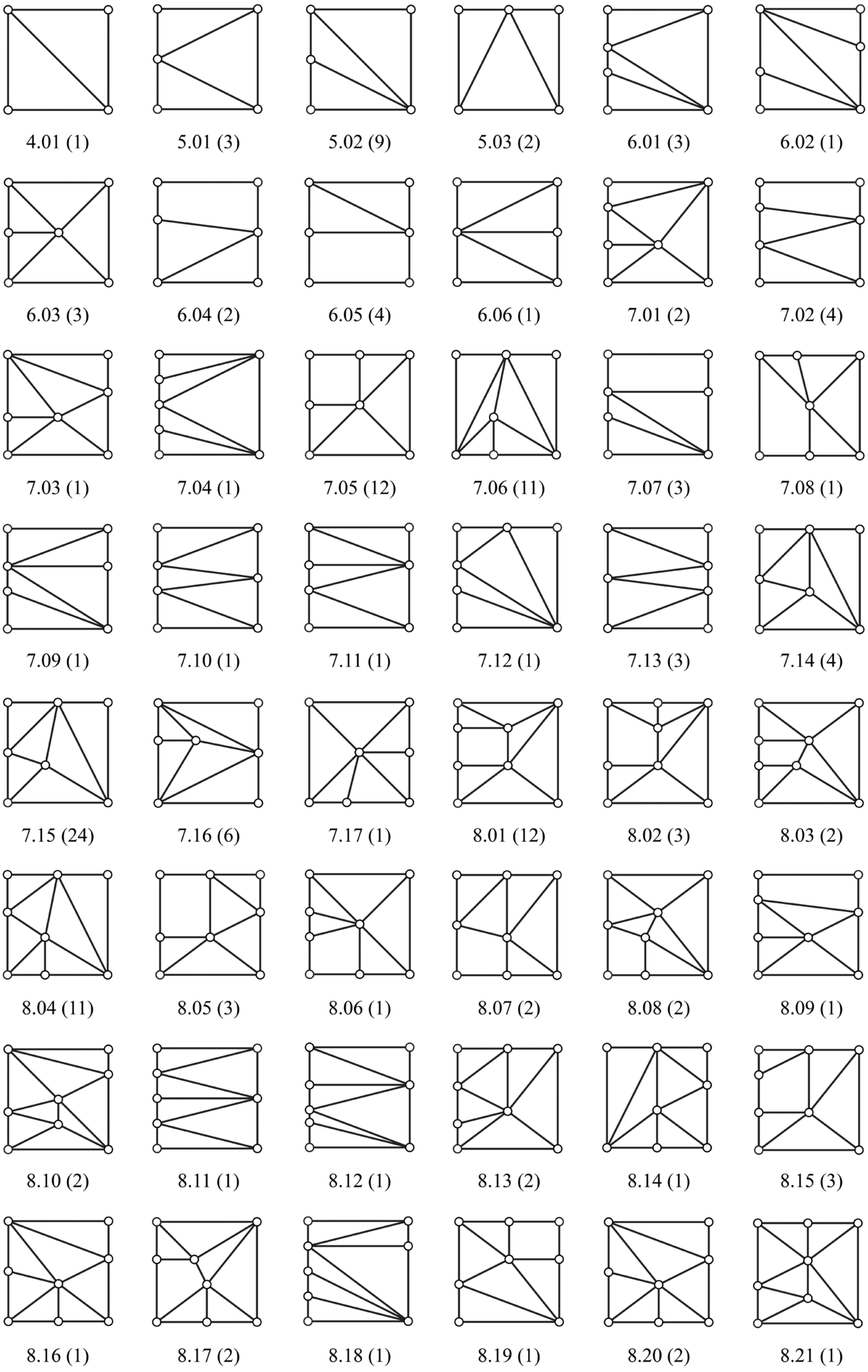
A.16. Unique pairs of rooms (links) - terraced houses

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
Hall - Living room	310	0	298	0	11	1
Hall - Internal porch	228	0	228	0	0	0
Internal porch - Living room	226	0	0	3	223	0
Dining room - Living room	217	3	18	0	157	39
External space - Living room	216	15	1	193	7	0
External space - Kitchen	204	60	25	109	10	0
Dining room - Hall	196	1	181	0	13	1
Dining room - External space	170	61	1	105	3	0
External space - Internal porch	163	1	162	0	0	0
Breakfast room - Kitchen	147	0	5	0	0	142
Hall - Kitchen	147	0	81	0	66	0
Dining room - Kitchen	145	0	39	1	54	51
Breakfast room - External space	116	32	8	60	16	0
Breakfast room - Hall	93	0	82	0	11	0
External space - Utility room	93	12	30	21	29	1
Breakfast room - Dining room	83	3	12	1	54	13
Kitchen - Utility room	79	0	70	0	8	1
Kitchen - Living room	61	0	8	0	38	15
Living room - Living room	46	0	3	0	40	3
Breakfast room - Living room	35	0	5	0	23	7
Conservatory - External space	21	9	0	8	4	0
External porch - Living room	20	0	0	10	10	0
External porch - Internal porch	18	0	18	0	0	0
Breakfast room - Utility room	16	0	15	0	1	0
Dining room - Utility room	14	0	7	0	7	0
Conservatory - Kitchen	13	0	3	0	2	8
External space - Hall	11	0	9	0	2	0
Hall - Utility room	10	0	6	0	4	0
Breakfast room - Conservatory	8	1	1	1	0	5
Conservatory - Dining room	8	4	1	0	1	2
External porch - Hall	7	0	7	0	0	0
Conservatory - Living room	6	1	1	0	2	2
External space - Study	6	2	0	2	2	0
External porch - External space	5	0	1	3	1	0
External space - External space	5	0	0	0	0	5
External space - Garage	5	0	4	0	1	0
Living room - Utility room	5	0	4	0	1	0
Dining room - Internal porch	4	0	0	0	4	0
Garage - Kitchen	4	0	3	0	1	0
Breakfast room - Study	3	0	0	0	2	1
Conservatory - Utility room	3	2	1	0	0	0
Hall - Study	3	0	3	0	0	0
Study - Utility room	3	0	3	0	0	0
Living room - Study	2	0	1	0	1	0
Conservatory - Hall	1	0	1	0	0	0
Conservatory - Study	1	0	0	0	0	1
Dining room - Study	1	0	0	0	1	0
External porch - Kitchen	1	0	0	0	1	0
Garage - Hall	1	0	1	0	0	0
Hall - Hall	1	0	0	0	0	1
Kitchen - Study	1	0	1	0	0	0

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open plan

Table A.16 - Unique pairs of rooms (links) - terraced houses.

A.17. Internal graph types in semi-detached houses



4.01 (1) 5.01 (3) 5.02 (9) 5.03 (2) 6.01 (3) 6.02 (1)

6.03 (3) 6.04 (2) 6.05 (4) 6.06 (1) 7.01 (2) 7.02 (4)

7.03 (1) 7.04 (1) 7.05 (12) 7.06 (11) 7.07 (3) 7.08 (1)

7.09 (1) 7.10 (1) 7.11 (1) 7.12 (1) 7.13 (3) 7.14 (4)

7.15 (24) 7.16 (6) 7.17 (1) 8.01 (12) 8.02 (3) 8.03 (2)

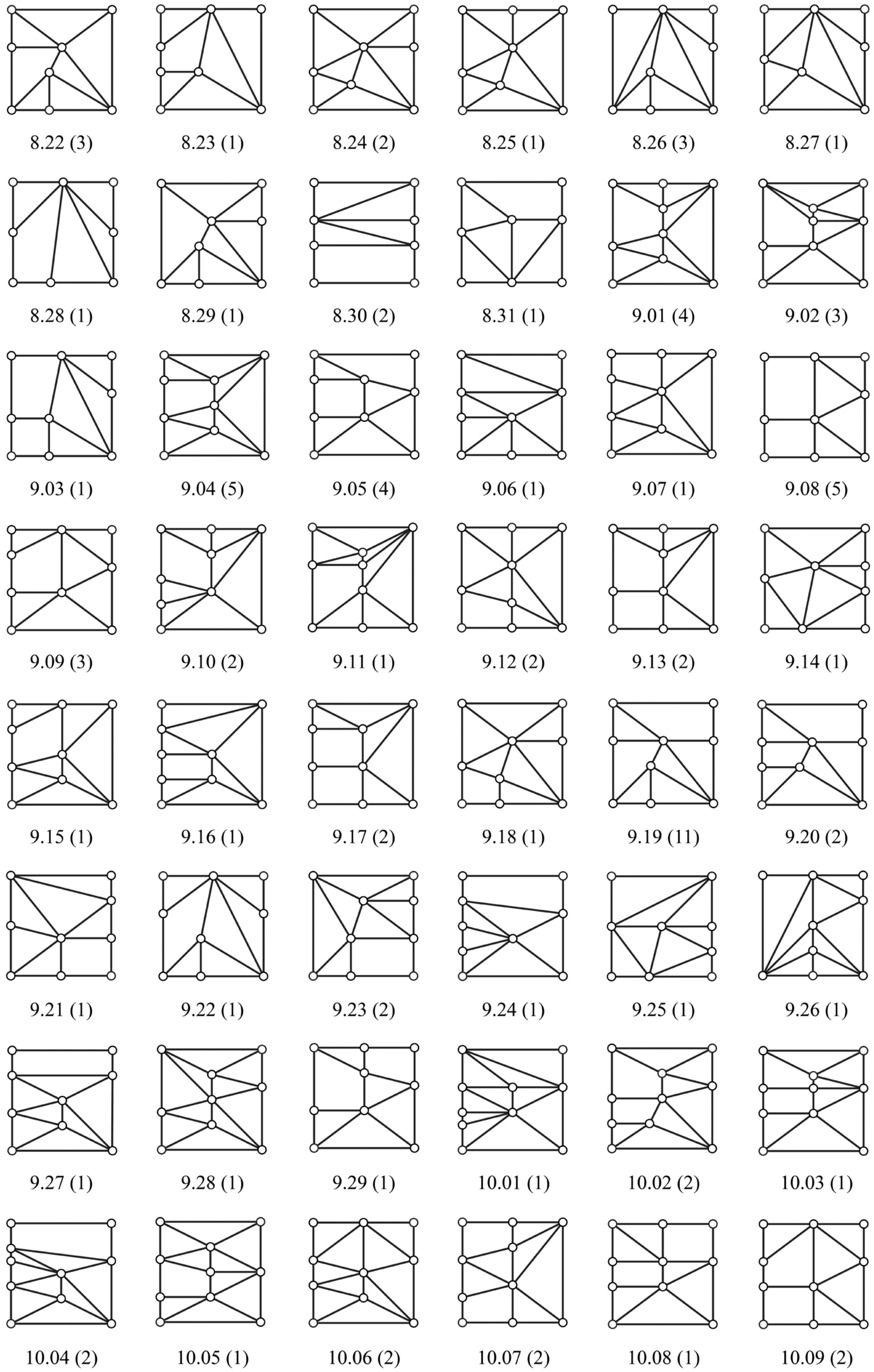
8.04 (11) 8.05 (3) 8.06 (1) 8.07 (2) 8.08 (2) 8.09 (1)

8.10 (2) 8.11 (1) 8.12 (1) 8.13 (2) 8.14 (1) 8.15 (3)

8.16 (1) 8.17 (2) 8.18 (1) 8.19 (1) 8.20 (2) 8.21 (1)

Figure A.17 - Internal graph types in semi-detached houses.

A.17. Internal graph types in semi-detached houses (cont.)



8.22 (3) 8.23 (1) 8.24 (2) 8.25 (1) 8.26 (3) 8.27 (1)

8.28 (1) 8.29 (1) 8.30 (2) 8.31 (1) 9.01 (4) 9.02 (3)

9.03 (1) 9.04 (5) 9.05 (4) 9.06 (1) 9.07 (1) 9.08 (5)

9.09 (3) 9.10 (2) 9.11 (1) 9.12 (2) 9.13 (2) 9.14 (1)

9.15 (1) 9.16 (1) 9.17 (2) 9.18 (1) 9.19 (11) 9.20 (2)

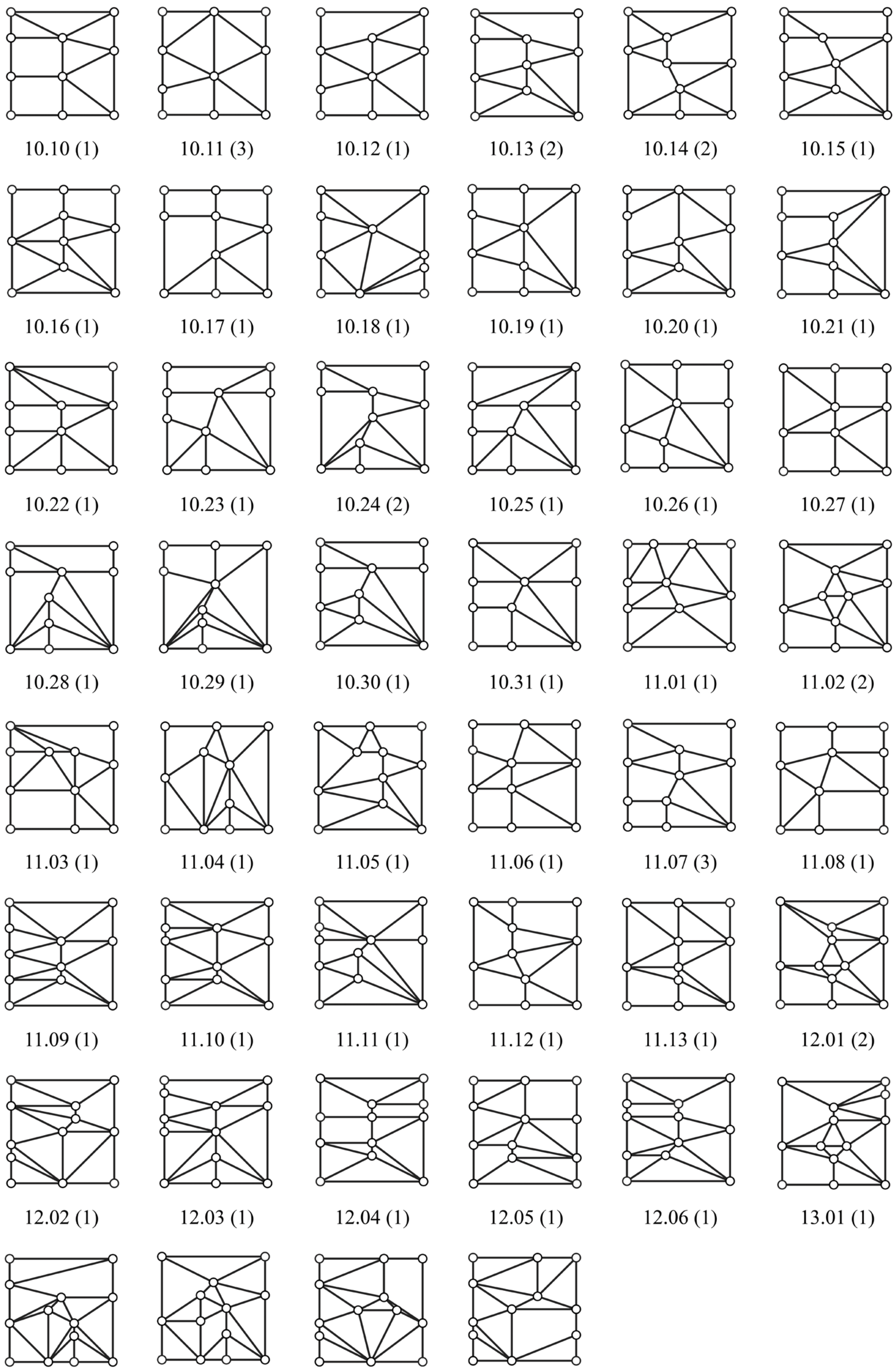
9.21 (1) 9.22 (1) 9.23 (2) 9.24 (1) 9.25 (1) 9.26 (1)

9.27 (1) 9.28 (1) 9.29 (1) 10.01 (1) 10.02 (2) 10.03 (1)

10.04 (2) 10.05 (1) 10.06 (2) 10.07 (2) 10.08 (1) 10.09 (2)

Figure A.17 - Internal graph types in semi-detached houses (cont.).

A.17. Internal graph types in semi-detached houses (cont.)



10.10 (1)
10.11 (3)
10.12 (1)
10.13 (2)
10.14 (2)
10.15 (1)
10.16 (1)
10.17 (1)
10.18 (1)
10.19 (1)
10.20 (1)
10.21 (1)
10.22 (1)
10.23 (1)
10.24 (2)
10.25 (1)
10.26 (1)
10.27 (1)
10.28 (1)
10.29 (1)
10.30 (1)
10.31 (1)
11.01 (1)
11.02 (2)
11.03 (1)
11.04 (1)
11.05 (1)
11.06 (1)
11.07 (3)
11.08 (1)
11.09 (1)
11.10 (1)
11.11 (1)
11.12 (1)
11.13 (1)
12.01 (2)
12.02 (1)
12.03 (1)
12.04 (1)
12.05 (1)
12.06 (1)
13.01 (1)
13.02 (1)
13.03 (1)
13.04 (1)
13.05 (1)

Figure A.17 - Internal graph types in semi-detached houses (cont.).

A.18. The positions of room types within the graph - semi-detached houses

XY	KT	DR	BR	LR	CN	ST	HA	IP/EP	EX	GR	UR
0,0	1	1	0	10	0	2	8	20	205	60	3
0,2	0	0	0	0	0	3	1	6	0	18	2
0,3	2	0	0	0	1	2	20	1	0	82	26
0,4	3	1	4	0	0	0	20	0	0	48	19
0,5	17	1	11	2	0	1	1	1	5	2	41
0,6	26	4	11	1	1	1	0	0	8	0	21
0,7	0	0	1	0	0	0	0	0	0	0	0
0,8	63	8	17	3	13	2	0	0	130	9	63
3,0	1	1	1	3	0	1	2	46	13	0	0
3,2	0	0	0	0	0	0	16	5	0	0	0
3,3	4	0	0	0	0	0	76	0	0	0	0
3,4	3	1	1	0	0	0	8	0	0	0	1
3,5	3	0	1	0	0	0	8	0	0	0	1
3,6	4	0	1	0	0	0	0	0	1	0	1
3,8	1	1	0	0	0	0	0	0	1	0	0
4,0	0	0	0	2	0	0	1	48	2	0	0
4,2	0	0	0	0	0	0	11	34	0	0	0
4,3	0	0	1	0	0	0	83	0	0	0	0
4,4	5	0	4	1	0	0	44	0	0	0	0
4,5	33	1	14	1	0	0	4	0	0	0	2
4,6	31	7	23	2	0	1	1	0	10	0	0
4,7	0	0	0	0	0	0	0	0	0	0	0
4,8	90	7	19	0	6	0	0	0	14	0	0
5,0	0	0	0	0	0	0	0	4	3	0	0
5,2	0	0	0	0	0	0	0	5	0	0	0
5,3	0	0	0	0	0	0	5	0	0	0	0
5,4	0	0	0	0	0	0	4	0	0	0	0
5,5	2	0	1	0	0	0	1	0	0	0	0
5,6	1	0	3	0	0	0	0	0	0	0	0
5,8	0	1	1	1	0	0	0	0	0	0	0
6,4	0	0	0	0	0	0	0	0	0	0	1
8,0	0	48	0	240	0	0	0	1	19	0	0
8,2	0	0	0	1	0	0	1	1	0	1	0
8,3	0	2	0	7	0	0	2	0	0	1	0
8,4	7	9	0	7	0	0	0	0	0	0	2
8,5	4	73	0	38	0	2	0	0	0	0	1
8,6	3	6	0	5	0	0	0	0	1	0	0
8,7	0	0	0	0	0	0	0	0	1	0	0
8,8	5	118	5	38	60	0	0	0	80	1	2
Total	309	290	120	362	81	15	317	172	493	222	186
Frequency	1.0	0.9	0.4	1.2	0.3	0.0	1.0	0.6	1.6	0.7	0.6

Table A.18 - The positions of room types within the graph - semi-detached houses.

A.19. Unique pairs of rooms (links) - semi-detached houses

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
Hall - Living room	350	0	317	0	26	7
Dining room - Living room	287	2	62	1	127	95
Hall - Kitchen	245	0	200	0	45	0
External space - Living room	225	23	1	192	9	0
Dining room - Kitchen	215	1	65	0	70	79
External space - Garage	211	9	178	0	22	2
Garage - Hall	210	0	8	0	202	0
External space - Kitchen	191	18	12	107	52	2
Kitchen - Living room	185	0	10	0	162	13
Kitchen - Utility room	158	0	131	0	18	9
Dining room - Hall	157	0	126	0	31	0
External space - Hall	139	3	127	0	9	0
Garage - Utility room	139	0	130	0	8	1
Dining room - External space	127	42	1	76	8	0
Breakfast room - Kitchen	119	0	14	0	4	101
External porch - Hall	111	0	110	0	1	0
Garage - Kitchen	98	0	34	0	64	0
External space - Utility room	93	18	51	8	15	1
External porch - Living room	92	0	1	65	26	0
Conservatory - External space	77	37	1	35	3	1
Hall - Utility room	76	0	6	0	70	0
Breakfast room - External space	72	29	2	29	12	0
Breakfast room - Hall	67	0	57	0	10	0
External porch - External space	59	6	1	35	17	0
Hall - Internal porch	53	0	53	0	0	0
Conservatory - Dining room	51	18	11	3	3	16
Breakfast room - Living room	49	0	2	2	36	9
Breakfast room - Dining room	47	0	9	1	27	10
External porch - Garage	46	0	1	1	44	0
Internal porch - Living room	46	0	0	0	46	0
External space - Internal porch	44	4	39	0	1	0
Living room - Living room	39	0	3	0	28	8
Breakfast room - Utility room	35	0	17	1	16	1
Breakfast room - Garage	32	0	22	0	10	0
Garage - Internal porch	31	0	0	0	31	0
Conservatory - Kitchen	29	1	6	2	13	7
External space - External space	23	0	0	1	0	22
Conservatory - Living room	17	3	6	0	1	7
Dining room - External porch	17	0	0	8	9	0
Dining room - Utility room	17	0	7	0	10	0
Breakfast room - Conservatory	16	4	3	2	1	6
Living room - Utility room	12	0	5	0	7	0
External space - Study	11	2	0	8	1	0
Hall - Study	11	0	9	0	2	0
Study - Utility room	10	0	5	0	5	0
Conservatory - Utility room	8	1	4	0	3	0
External porch - Internal porch	8	0	8	0	0	0
Hall - Hall	8	0	0	0	0	8
Dining room - Internal porch	7	0	0	0	7	0
Garage - Living room	6	0	1	0	5	0
Internal porch - Utility room	6	0	1	0	5	0
Dining room - Garage	5	0	2	0	3	0

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open plan

Table A.19 - Unique pairs of rooms (links) - semi-detached houses.

A.19. Unique pairs of rooms (links) - semi-detached houses (cont.)

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
External porch - Utility room	4	0	1	0	3	0
Garage - Study	4	0	3	0	1	0
Conservatory - Hall	3	0	3	0	0	0
Dining room - Study	3	0	2	0	1	0
Kitchen - Study	3	0	2	0	0	1
Living room - Study	3	0	0	0	3	0
Breakfast room - Internal porch	2	0	0	0	2	0
Conservatory - Study	2	0	1	0	0	1
External porch - Study	2	0	0	1	1	0
Internal porch - Study	2	0	0	0	2	0
Breakfast room - Study	1	0	1	0	0	0
Conservatory - Garage	1	0	1	0	0	0
External porch - Kitchen	1	0	1	0	0	0
Internal porch - Kitchen	1	0	0	0	1	0

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open plan

Table A.19 - Unique pairs of rooms (links) - semi-detached houses (cont.).

A.20. Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses

Graph type	Num	%	100-1A	100-2A-L	101-1A	101-2A-L	110-2A-L
401	1	0.3%	0	1	0	0	0
501	3	1.0%	0	1	0	1	1
502	9	2.9%	0	7	0	0	2
503	2	0.6%	0	2	0	0	0
601	3	1.0%	0	1	0	1	1
602	1	0.3%	0	1	0	0	0
603	3	1.0%	3	0	0	0	0
604	2	0.6%	0	0	0	2	0
605	4	1.3%	0	4	0	0	0
606	1	0.3%	0	1	0	0	0
701	2	0.6%	0	0	2	0	0
702	4	1.3%	0	0	0	2	2
703	1	0.3%	1	0	0	0	0
704	1	0.3%	0	0	0	1	0
705	12	3.9%	11	1	0	0	0
706	11	3.6%	9	1	0	0	1
707	3	1.0%	0	2	0	0	1
708	1	0.3%	1	0	0	0	0
709	1	0.3%	0	1	0	0	0
710	1	0.3%	0	1	0	0	0
711	1	0.3%	0	1	0	0	0
712	1	0.3%	0	0	0	0	1
713	3	1.0%	0	3	0	0	0
714	4	1.3%	4	0	0	0	0
715	24	7.8%	23	1	0	0	0
716	6	1.9%	0	0	0	0	6
717	1	0.3%	0	1	0	0	0
801	12	3.9%	9	1	0	1	1
802	3	1.0%	2	0	1	0	0
803	2	0.6%	2	0	0	0	0
804	11	3.6%	9	0	0	0	2
805	3	1.0%	1	0	2	0	0
806	1	0.3%	1	0	0	0	0
807	2	0.6%	2	0	0	0	0
808	2	0.6%	2	0	0	0	0
809	1	0.3%	0	0	1	0	0
810	2	0.6%	2	0	0	0	0
811	1	0.3%	0	1	0	0	0
812	1	0.3%	0	0	0	1	0
813	2	0.6%	2	0	0	0	0
814	1	0.3%	1	0	0	0	0
815	3	1.0%	2	0	1	0	0
816	1	0.3%	1	0	0	0	0
817	2	0.6%	2	0	0	0	0
818	1	0.3%	0	1	0	0	0
819	1	0.3%	1	0	0	0	0
820	2	0.6%	2	0	0	0	0
821	1	0.3%	1	0	0	0	0
822	3	1.0%	2	0	0	0	1
823	1	0.3%	1	0	0	0	0
824	2	0.6%	2	0	0	0	0
825	1	0.3%	1	0	0	0	0

Table A.20 - Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses. Complete table.

A.20. Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses (cont.)

Graph type	Num	%	100-1A	100-2A-L	101-1A	101-2A-L	110-2A-L
826	3	1.0%	2	1	0	0	0
827	1	0.3%	1	0	0	0	0
828	1	0.3%	0	1	0	0	0
829	1	0.3%	1	0	0	0	0
830	2	0.6%	0	2	0	0	0
831	1	0.3%	1	0	0	0	0
901	4	1.3%	4	0	0	0	0
902	3	1.0%	3	0	0	0	0
903	1	0.3%	1	0	0	0	0
904	5	1.6%	3	1	0	0	1
905	4	1.3%	2	1	1	0	0
906	1	0.3%	1	0	0	0	0
907	1	0.3%	0	1	0	0	0
908	5	1.6%	4	0	1	0	0
909	3	1.0%	3	0	0	0	0
910	2	0.6%	2	0	0	0	0
911	1	0.3%	0	1	0	0	0
912	2	0.6%	2	0	0	0	0
913	2	0.6%	2	0	0	0	0
914	1	0.3%	1	0	0	0	0
915	1	0.3%	1	0	0	0	0
916	1	0.3%	1	0	0	0	0
917	2	0.6%	2	0	0	0	0
918	1	0.3%	1	0	0	0	0
919	11	3.6%	11	0	0	0	0
920	2	0.6%	2	0	0	0	0
921	1	0.3%	1	0	0	0	0
922	1	0.3%	1	0	0	0	0
923	2	0.6%	1	0	0	0	1
924	1	0.3%	1	0	0	0	0
925	1	0.3%	1	0	0	0	0
926	1	0.3%	1	0	0	0	0
927	1	0.3%	1	0	0	0	0
928	1	0.3%	1	0	0	0	0
929	1	0.3%	1	0	0	0	0
1001	1	0.3%	1	0	0	0	0
1002	2	0.6%	2	0	0	0	0
1003	1	0.3%	1	0	0	0	0
1004	2	0.6%	2	0	0	0	0
1005	1	0.3%	1	0	0	0	0
1006	2	0.6%	0	2	0	0	0
1007	2	0.6%	2	0	0	0	0
1008	1	0.3%	1	0	0	0	0
1009	2	0.6%	2	0	0	0	0
1010	1	0.3%	1	0	0	0	0
1011	3	1.0%	2	0	0	0	1
1012	1	0.3%	1	0	0	0	0
1013	2	0.6%	2	0	0	0	0
1014	2	0.6%	2	0	0	0	0
1015	1	0.3%	1	0	0	0	0
1016	1	0.3%	1	0	0	0	0

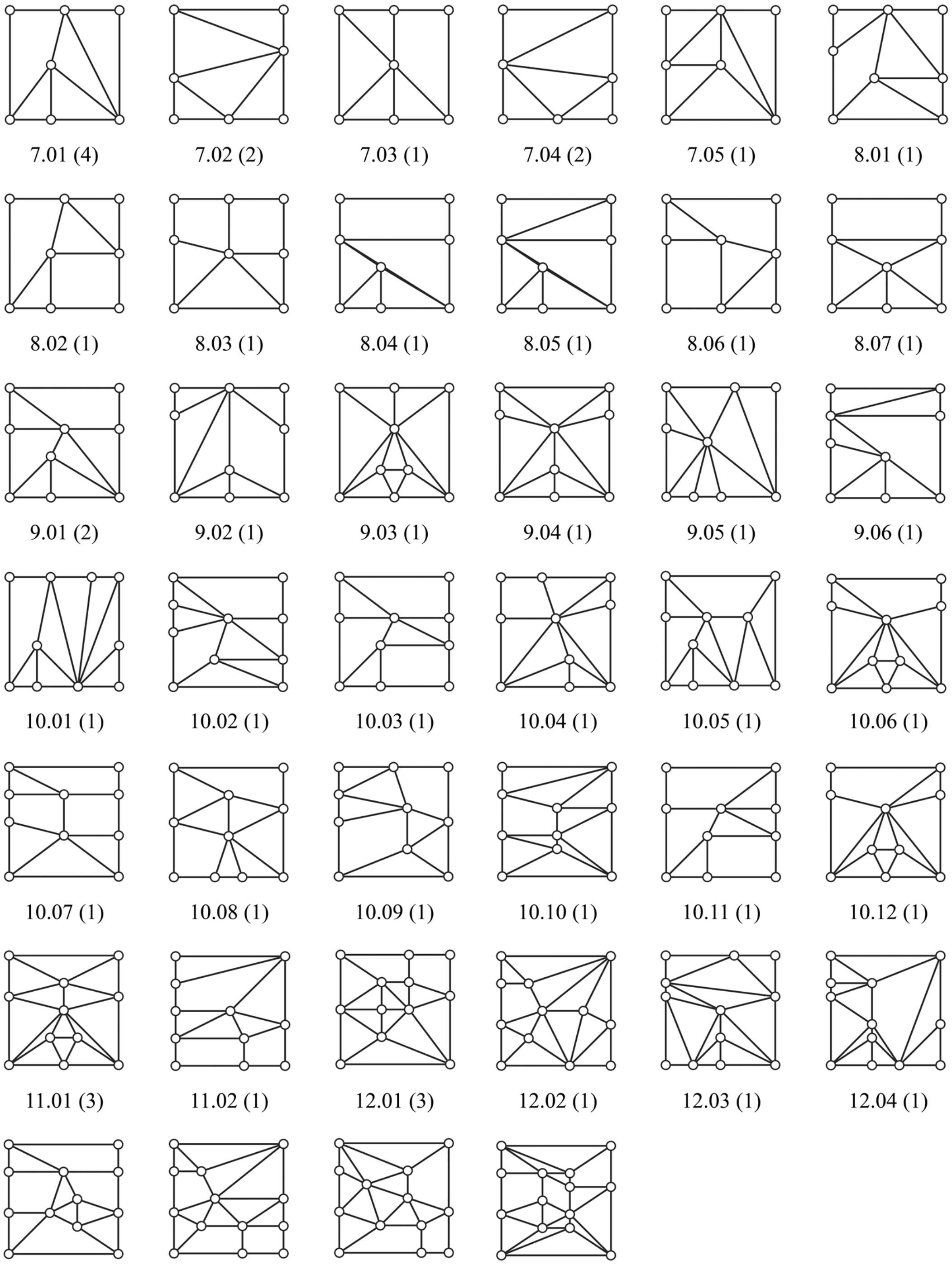
Table A.20 - Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses. Complete table (cont.).

A.20. Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses (cont.)

Graph type	Num	%	100-1A	100-2A-L	101-1A	101-2A-L	110-2A-L
1017	1	0.3%	1	0	0	0	0
1018	1	0.3%	1	0	0	0	0
1019	1	0.3%	1	0	0	0	0
1020	1	0.3%	1	0	0	0	0
1021	1	0.3%	1	0	0	0	0
1022	1	0.3%	1	0	0	0	0
1023	1	0.3%	1	0	0	0	0
1024	2	0.6%	2	0	0	0	0
1025	1	0.3%	1	0	0	0	0
1026	1	0.3%	0	0	0	0	1
1027	1	0.3%	1	0	0	0	0
1028	1	0.3%	0	1	0	0	0
1029	1	0.3%	0	1	0	0	0
1030	1	0.3%	1	0	0	0	0
1031	1	0.3%	1	0	0	0	0
1101	1	0.3%	1	0	0	0	0
1102	2	0.6%	2	0	0	0	0
1103	1	0.3%	1	0	0	0	0
1104	1	0.3%	1	0	0	0	0
1105	1	0.3%	1	0	0	0	0
1106	1	0.3%	1	0	0	0	0
1107	3	1.0%	2	1	0	0	0
1108	1	0.3%	1	0	0	0	0
1109	1	0.3%	1	0	0	0	0
1110	1	0.3%	1	0	0	0	0
1111	1	0.3%	1	0	0	0	0
1112	1	0.3%	1	0	0	0	0
1113	1	0.3%	1	0	0	0	0
1201	2	0.6%	2	0	0	0	0
1202	1	0.3%	0	0	0	0	1
1203	1	0.3%	0	1	0	0	0
1204	1	0.3%	1	0	0	0	0
1205	1	0.3%	1	0	0	0	0
1206	1	0.3%	1	0	0	0	0
1301	1	0.3%	1	0	0	0	0
1302	1	0.3%	1	0	0	0	0
1303	1	0.3%	1	0	0	0	0
1304	1	0.3%	1	0	0	0	0
1305	1	0.3%	1	0	0	0	0
Total	309	100.0%	220	47	9	9	24

Table A.20 - Cross-tabulation of the internal graph types with the building-network interface types in semi-detached houses. Complete table (cont.).

A.21. Internal graph types in detached houses



7.01 (4) 7.02 (2) 7.03 (1) 7.04 (2) 7.05 (1) 8.01 (1)

8.02 (1) 8.03 (1) 8.04 (1) 8.05 (1) 8.06 (1) 8.07 (1)

9.01 (2) 9.02 (1) 9.03 (1) 9.04 (1) 9.05 (1) 9.06 (1)

10.01 (1) 10.02 (1) 10.03 (1) 10.04 (1) 10.05 (1) 10.06 (1)

10.07 (1) 10.08 (1) 10.09 (1) 10.10 (1) 10.11 (1) 10.12 (1)

11.01 (3) 11.02 (1) 12.01 (3) 12.02 (1) 12.03 (1) 12.04 (1)

12.05 (1) 13.01 (1) 13.02 (1) 14.01 (1)

Figure A.21 - Internal graph types in detached houses.

A.22. The positions of room types within the graph - detached houses

XY	KT	DR	BR	LR	CN	ST	HA	IP/EP	EX	GR	UR
0,0	0	1	0	1	0	3	0	0	7	37	1
0,2	0	1	0	0	0	0	0	0	0	0	0
0,3	0	0	0	0	0	0	0	0	0	5	2
0,4	0	0	1	3	0	1	0	0	3	1	4
0,5	4	0	1	0	0	1	0	0	0	0	11
0,6	5	0	2	1	0	0	0	0	5	0	5
0,8	4	1	4	0	1	0	0	0	32	0	8
2,0	0	0	0	1	0	1	0	2	0	0	0
2,2	0	2	0	0	0	0	0	0	0	0	0
2,3	0	0	0	0	0	0	1	0	0	0	0
2,4	0	0	0	0	0	0	1	0	0	0	0
2,5	1	0	0	0	0	0	0	0	0	0	0
2,6	0	0	0	0	0	0	0	0	0	0	2
3,0	0	1	0	0	0	0	0	7	5	0	0
3,2	0	1	0	0	0	10	2	0	0	0	0
3,3	0	1	0	0	0	1	7	0	0	0	0
3,4	3	0	1	0	0	0	5	0	0	0	3
3,5	1	0	0	0	0	0	0	0	0	0	0
3,6	5	0	0	0	0	0	0	0	0	0	0
3,8	1	0	0	0	0	1	0	0	0	0	0
4,0	0	0	0	0	0	0	6	7	5	0	0
4,2	0	0	0	0	0	0	2	2	0	0	0
4,3	0	0	1	0	0	0	4	0	0	0	0
4,4	1	0	3	0	0	0	4	0	0	0	0
4,5	8	0	3	1	0	0	0	0	0	0	0
4,6	5	0	1	0	0	0	0	0	0	0	0
4,8	10	0	2	0	0	0	0	0	0	0	0
5,0	0	0	0	3	0	0	2	2	1	0	0
5,2	0	0	0	0	0	0	9	3	0	0	0
5,3	0	0	0	0	0	0	1	0	0	0	0
5,4	0	0	1	0	0	0	4	0	0	0	0
5,5	0	0	1	0	0	0	1	0	0	0	0
5,6	0	3	0	0	0	0	0	0	2	0	0
5,8	0	1	0	0	4	0	0	0	0	0	0
6,0	0	0	0	0	0	0	0	1	0	0	0
6,2	0	0	0	0	0	0	1	0	0	0	0
6,4	0	0	0	1	0	0	0	0	0	0	0
6,5	0	1	0	0	0	0	0	0	0	0	0
6,8	0	0	1	0	0	0	0	0	0	0	0
8,0	0	2	0	28	0	1	0	0	19	0	0
8,2	0	0	0	2	0	0	0	0	0	0	0
8,3	1	0	0	8	0	2	0	0	0	0	0
8,4	1	1	0	5	0	0	0	0	0	0	0
8,5	0	15	0	4	0	0	0	0	0	0	0
8,6	0	7	0	1	0	0	0	0	0	0	0
8,8	0	12	0	3	29	0	0	0	6	0	0
Total	50	50	22	62	34	21	50	24	85	43	36
Avg	1.0	1.0	0.4	1.2	0.7	0.4	1.0	0.5	1.7	0.9	0.7

Table A.22 - The positions of room types within the graph - detached houses.

A.23. Unique pairs of rooms (links) - detached houses

Room A - Room B	Total	1/1	1/0	0/1	0/0	open
Hall - Living room	57	0	52	0	5	0
Dining room - Living room	45	1	30	0	4	10
Dining room - Kitchen	42	0	18	1	11	12
External space - Living room	40	4	0	30	6	0
Conservatory - External space	37	17	0	20	0	0
Kitchen - Living room	36	0	5	0	26	5
Hall - Kitchen	35	0	25	0	10	0
External space - Kitchen	34	0	1	23	10	0
Kitchen - Utility room	33	0	28	0	5	0
External space - Garage	27	0	12	0	15	0
Conservatory - Dining room	25	8	10	0	1	6
Garage - Hall	25	0	4	0	21	0
Garage - Utility room	25	0	9	0	16	0
Breakfast room - Kitchen	23	2	0	0	0	21
External porch - Hall	22	0	22	0	0	0
External space - Utility room	22	3	8	7	4	0
External space - Hall	20	0	18	0	2	0
Dining room - Hall	18	0	16	0	2	0
External porch - Garage	17	0	0	0	17	0
External space - Study	17	2	0	9	6	0
Conservatory - Kitchen	16	2	4	2	7	1
Hall - Study	16	0	16	0	0	0
External porch - Living room	15	0	0	3	12	0
Garage - Study	14	0	1	0	13	0
Breakfast room - Dining room	13	0	7	0	6	0
Breakfast room - Hall	13	0	12	0	1	0
Garage - Kitchen	13	0	3	0	10	0
Conservatory - Living room	12	6	3	2	0	1
External porch - External space	12	2	1	7	2	0
External space - External space	11	0	0	0	0	11
Hall - Utility room	10	0	4	0	6	0
Breakfast room - External space	9	4	1	4	0	0
Breakfast room - Living room	9	0	1	0	7	1
Breakfast room - Utility room	9	0	3	0	6	0
Study - Utility room	9	0	0	0	9	0
Dining room - External space	8	0	0	7	1	0
Breakfast room - Garage	6	0	0	0	6	0
Garage - Living room	6	0	2	0	4	0
Living room - Living room	6	0	1	0	2	3
Breakfast room - Study	5	0	0	0	5	0
Dining room - Garage	5	0	0	0	5	0
External porch - Study	4	0	0	3	1	0
Kitchen - Study	4	0	1	0	3	0
Conservatory - Study	3	1	1	0	0	1
Dining room - Utility room	3	0	3	0	0	0
Living room - Study	3	0	0	0	3	0
Breakfast room - Conservatory	2	0	0	1	0	1
Conservatory - Utility room	2	0	1	0	1	0
External space - Internal porch	2	0	2	0	0	0
Hall - Internal porch	2	0	2	0	0	0
Internal porch - Living room	2	0	0	0	2	0
Internal porch - Study	2	0	0	0	2	0
Dining room - External porch	1	0	0	0	1	0
Dining room - Study	1	0	1	0	0	0
Living room - Utility room	1	0	0	0	1	0

1/1 - physical and visual permeability 1/0 - only physical permeability 0/1 - only visual permeability
0/0 - physical and visual impermeability open - open plan

Table A.23 - Unique pairs of rooms (links) - detached houses.