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THE IMPACT OF HOUSE-STREET INTERFACES ON THE MORPHOLOGY OF DOMESTIC FLOOR PLANS

Abstract: *A house requires access to a more complex street network to provide inhabitants with functions not obtainable inside their own dwelling. Spatially, this requirement manifests itself in a geometric adjacency between a house and a street – referred to in this paper as a house-street interface (following the naming convention in Palaiologou et al, 2016). The functional one to one interface between a house and a street network does not exclude, however, the possibility of more adjacency-based connections. In this paper, we explore the impact that the number of interfaces has on the morphology of domestic floor plans in Gosforth, a district of Newcastle upon Tyne, England. An empirical analysis was conducted based on a sample of 1096 floor plans distributed between three major British housing typologies – terraced, semi-detached and detached houses. The topological structure of floor plans with a single house-street interface is compared to those with multiple interfaces using syntactic measures. We observed two approaches in the morphology of houses with more than one interface. Either the configuration of the floor plan was adjusted to accommodate the additional interface or, in 63% of cases, the floor plan followed the morphology common to the housing type without addressing additional interfaces. However, the majority of houses that did not accommodate additional interface(s) in their floor plan had to introduce further measures to mitigate the impact of multiple interfaces, such as erecting a high boundary to separate the house from the additional street. We found that some of the measures introduced while improving the condition of the plot had a negative impact on the street. Our conclusions suggest that the number of interfaces between two urban domains has an impact on either their morphology or state. Not addressing the interface is more likely to deteriorate the condition of one or both spaces.*
Keywords: *house-street interface, domestic floor plans, housing typology, urban morphology, graph theory.*

Introduction

The city can be understood as a spatial system of aggregated enclosed elements situated in an open continuous carrier (Hillier and Hanson, 1984). Each element (e.g. building) is placed in relation to: the other buildings and to the open space – a combination of streets, squares and other public spaces in between. The relationships can have a different nature; however, in this paper we focus exclusively on the spatial relation of adjacency and accessibility between the elements. The importance of adjacency stems from the way the buildings are organised in space. The process of placing boundaries in the open continuous space, in order to enclose it and take control over parts of it, establishes the adjacency-based relationship between the created buildings and the outside. Cities are an aggregation of many such buildings, which result in a complex patchwork of two types of adjacencies: between buildings, and between buildings and the open space. The nature of the buildings and the open space differs fundamentally. The continuous open space is a dynamic domain of movement, probabilistic encounters and interaction, while buildings are static elements focused on cultural and social knowledge and control of the encounters, rather than their generation (Hillier and Hanson, 1984). This differentiation is important to the organisation of the city. While the buildings can relate to each other based on adjacency only, the relationship between a building and the outside has to be permeable in at least one point. Without the access between the enclosed spaces and the carrier, the buildings could not be inhabited or used. On the other hand, without the constant flow of the people from one building to the other, through the open space, the streets would lose their main purpose – transportation of people and goods. Therefore, the simplest relationship between a house and the street system consists of one permeable interface. The interface describes a space[1] where a house and a street meet and where a possibility exists for an access point enabling transition between those domains. In a more general way, the interface between a house and the street can be defined as a space where the private domestic domain and the public street meet with a possibility to interact. Despite the importance of the relationship between a house and the street network, the quantitative methods to analyse and represent architectural layouts rarely include comprehensive information on the relationship of the house to the plot or to the outside world. In some graph-theoretic representations, the external space is simplified to just one vertex which in some cases describes a combination of immediate outdoor spaces and multiple street segments adjacent to the building. While in some cases only sketching out the relationship between a house and the outside can be beneficial to the analysis, it omits information that might be important to our full understanding of the way the morphology of a house is shaped and changes.

In this paper we aim to introduce the typical and atypical relationships between a house and the street system in every major British housing typology and to provide a categorisation based on the number of house-street interfaces. This categorisation is then used to explore the impact of the number of interfaces on the morphology of the domestic floor plan. The structure of the paper is as follows. Firstly, we describe the typical and atypical relationship between a house and street system in each British major housing type in speculative housing estates in Gosforth, a district of Newcastle upon Tyne. Secondly, using graph-theoretic methods we compare the morphology of the floor plans of houses with typical and atypical number of the interfaces. Lastly, based on the observational study we discuss the impact of the treatment of the atypical to each housing type interfaces on the characteristics of the street, the plot and the house.

The typical and atypical relationship between a house and the street system

The case study is based on seven speculative housing estates[2] in Gosforth, a suburban district of Newcastle upon Tyne, UK. In Gosforth, the majority of the housing stock was built between 1880 and 2015 and follows the general British housing typology with three major types: terraced, semi-detached and detached houses. The terraced houses were built in Gosforth as speculative estates between the 1880s and the 1940s to provide accommodation for working-class miners in the nearby collieries and mines. The houses were organised in rows, where each house (apart from the end terrace) is adjacent to two neighbouring units and two street segments. The house has two permeable interfaces, a front façade connected to the residential street and the back façade to the back alley. Those two polar interfaces correspond with a social division between the front and the back. The front emphasised the public side of the family, presenting their social status and position in society through the neatly kept front gardens and the lounge (or parlour), the best room in the house where the visitors were received (Hanson, 1998, Ozaki, 2003). The back was dedicated to everyday functions with the kitchen connected through the back yard to the back alley. The permeable interface with a back alley allowed for more service-orientated activities. Nowadays, the social division between the front and back is not as pronounced in the floor plan that has been adapted over the years (Hanson, 1998). However, the service focused role of the back alley is evident with bins lined up for collection. The semi-detached speculative estates can be dated to the time period between the 1940s and the 1980s, which coincides with the decline in the mining industry and emergence of the middle class. The main morphological difference between the terraced and the semi-detached houses lies in the spatial aggregation

[1] It can be a line if the house directly meets the street or a polygon if there is a secondary space between the domains e.g. front garden or yard.
[2] The sample size in this study was 1096 houses spread between seven housing estates with houses ranging from 60 to 254 per estate, with 503 terraced houses in two estates, 305 semi-detached houses in two estates, and 288 detached houses in three estates.

of houses and, as a result, the position of the house on the plot. While the terraced houses were arranged as a continuous row of houses, the semi-detached were designed as a pair which shared only one wall with the neighbouring unit. Therefore, the house accommodated only a part of the width of the plot, leaving a space on the side of the house that allowed for a direct connection between the front and the back yard. In the majority of cases, however, the house was further extended to the side to occupy the whole width of the plot. The external space providing a direct connection between the front and back yard was converted into a garage. The semi-detached houses were spatially organised to have each house (apart from the end property) adjacent to three neighbouring units and one street segment. Therefore, the typical relation between a semi-detached house and the street system consists of one permeable interface. The polar division between the front and back, emphasised in the terraced interfaces, disappeared in the semi-detached house. All the functions, previously split between the front and the back, were meant to be performed at the front of the house. The back yard changed from a service-orientated space into a private external room dedicated to leisure. The detached houses are currently the most popular typology in speculative housing in England with estates built since the 1980s. The detached house, as the name suggests, is ‘detached’ from any neighbouring buildings and is positioned in the middle of the plot with a space on each side. The width of the side yards varies and it is not unusual for the spaces to be too narrow to expand and just wide enough to allow for pedestrian access between the front and the back. Similarly to the semi-detached house, a typical detached house is adjacent to three neighbouring units and one street segment. The typical relationship between a detached house and the street system consists of one permeable interface.

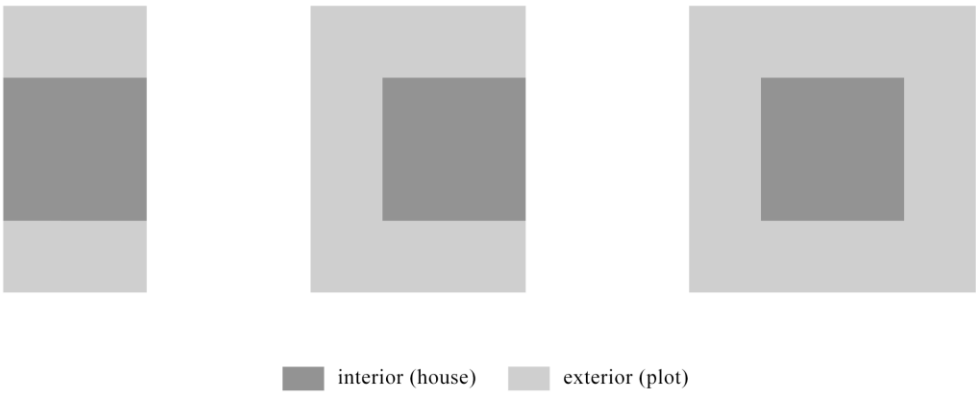

Figure 1. The diagrams represent different types of relationship between a house and the plot. On the left, the house occupies the whole width of the plot – terraced house. In the middle, the house occupies only a part of the width of the plot. The space to the side of the house allows for a direct connection between front and back – semi-detached house. On the right, the house is situated in the middle of the plot – detached house

A typical relationship between a house and the street system is not achievable in all scenarios. In Gosforth, 80 per cent of all houses have a typical relationship while the remaining 20 per cent establish an atypical relationship, which involves an additional interface(s) (see Figure 2). The reason for the atypical relationship stems from the spatial organisation of the whole estate. The position within the urban block determines how many interfaces the house can establish with the surrounding street system. In terraced and semi-detached the percentage of houses with an atypical relationship to the street system is 11 per cent. This is wholly due to the position of the house within the block. Because of this inherently urban reason, the end property establishes an additional interface with the street system which in the case of the terrace house results in three interfaces, instead of two, and in semi-detached house two interface, instead of one. The case of the detached houses is curious. On average 45 per cent of all houses establish an atypical relationship with the street system. In comparison to the other housing typologies the number of atypical relationships quadrupled. The main reason for this increase is a change in the design of the estate as a whole. While terraced and semi-detached estates were designed to integrate with and extend the existing urban structure, the detached estates were designed as an introverted islands with an emphasis on the separation from the surrounding system. Even though, the detached estate emphasised privacy and separation, the houses on the edges of the estates ended up with additional interfaces. Although the interfaces are impermeable and accentuated with a tall opaque wall on the plot boundary, they are still adjacent to, in most cases busy and noisy, streets.

Housing types	Number of houses	Typical relationship	Atypical relationship
Terraced houses	503 (1.00)	448 (0.89)	55 (0.11)
Estate 1	254 (1.00)	225 (0.89)	29 (0.11)
Estate 2	249 (1.00)	223 (0.90)	26 (0.10)
Semi-detached houses	305 (1.00)	270 (0.89)	35 (0.11)
Estate 3	135 (1.00)	124 (0.92)	11 (0.08)
Estate 4	170 (1.00)	146 (0.86)	24 (0.14)
Detached houses	288 (1.00)	159 (0.55)	129 (0.45)
Estate 5	165 (1.00)	92 (0.56)	73 (0.44)
Estate 6	63 (1.00)	30 (0.48)	33 (0.52)
Estate 7	60 (1.00)	37 (0.62)	23 (0.38)

Figure 2. The distribution of the typical and atypical relationships between a house and the street system in three major British housing typology. Each housing typology has a typical relationship between a house and a street: terraced – two house-street interfaces, semi-detached – one, and detached – one

Graph-theoretic analysis of the floor plan

In this paper, the focus lies on the topological relationships of adjacency and accessibility between internal rooms in the house, external spaces and adjacent street segments. In the analyses of topological relationships in architectural studies a well-known and heavily utilised method is graph theory. Graphs are used as an abstract representation of a set of relationships between given elements. In the case of a floor plan, those relationships are mainly spatial, but they do not have to be (Steadman, 1983). Every graph consists of set of vertices which are connected if a certain relationship between two vertices is met. The connection is represented by a line and called an edge. In the analysis of the building floor plan, the most common use of graphs is to represent and analyse the relationship between rooms. When it comes to the graph representation of the building floor plan, there are two comprehensive approaches: adjacency graphs widely discussed by Philip Steadman in his book Architectural Morphology (Steadman, 1983) and justified access graphs introduced by Hillier and Hanson in the book The Social Logic of Space (Hillier and Hanson, 1984). The main difference between those two approaches is in the definition of the edges. In Steadman’s work the edges represent adjacencies between the rooms. The vertices are connected when the requirement for adjacency between two rooms is met. Hillier and Hanson emphasise permeability between the rooms, in order to determine which room is the most and least integrated. Both approaches utilize graph theory in order to determine if a certain relationship between two rooms exists or not, because the graphs are by definition dimensionless it allows for comparison between houses that might differ in dimension but not in a topological structure. As graphs are an abstract and dimensionless representation of the floor plan, they do not have to retain information on the form and geometry of the plan.

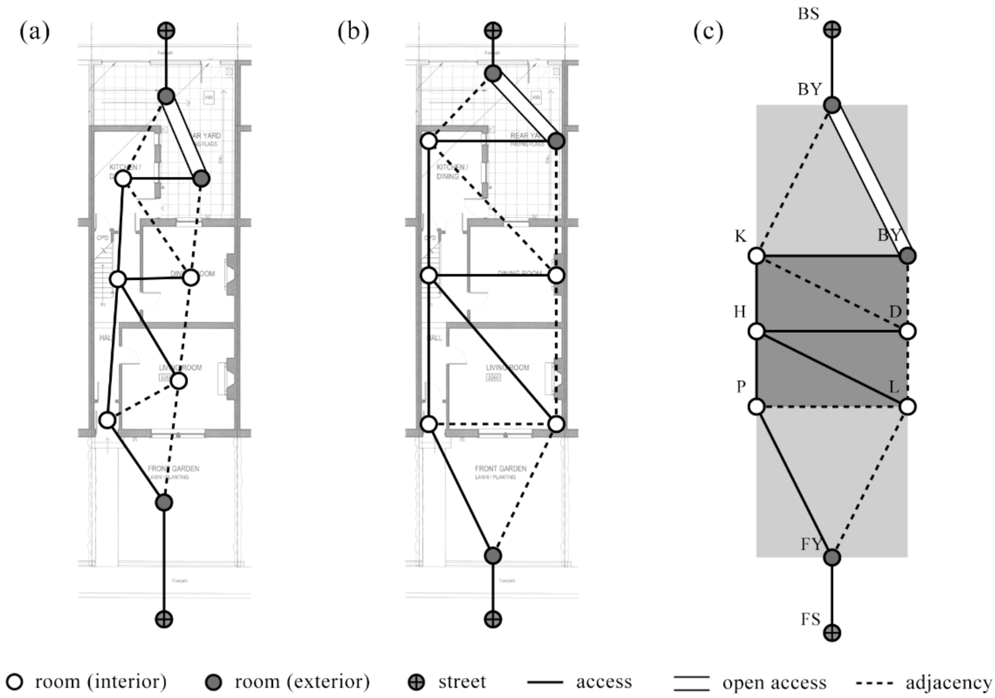

Figure 3. The transformation of the access-adjacency graph into a dimensionless representation with preserved information on the simplified outline of the building and the plot. In (a) the vertices are placed in the centre of each room. In (b) the vertices are aligned to the outline of the building and the plot. In (c) the graph is converted into a dimensionless representation. (FS – front street, FY – front yard, P – porch, L – lounge or living room, H – hallway, D – dining room, K – kitchen, BY – back yard, and BS – back street or back alley)

The dichotomy between topology and shape is acceptable in research, however, as Boast (1987) stresses the architectural floor plan in the real life scenario and in the design process should be understood as an integration of both approaches. Seo (2007) tackled this dichotomy between space and form and introduced a graph representation that presents the topological relationships while still retaining the information on the outline of the building. Similar representation was discussed by Steadman (1983), four external regions, north, east, south and west were introduced as an indication of the situation of the building in relation to the cardinal directions. Additionally, Seo combined the information on adjacency and permeability by varying the line type of the edge, with the solid black line representing access, solid white line representing open access and the dotted line – adjacency. Open access is a special case of permeability between two rooms which are not separated by a physical boundary (e.g. a wall) but they are functionally different. In the end, the graph contains not only information on the relationship between rooms in terms of adjacency and access but also preserves the simplified outline of the geometry of the house.

In this paper, we build on the graph representation proposed by Seo (2016). When searching for the shaping rules of the building in context to its plot and the outside, we found that preserving the outline of the building in the graph representation was particularly helpful. As the majority of the floor plans and plots of speculatively built houses can be simplified to a rectangle, the alignment of the graph to the rectangular outline helps to emphasise the difference between four sides. In our analysis, this property allows for a clear representation of the interface (or lack of). Moreover, the combined representation of adjacency and permeability allows for a comprehensive description of the relationship that a house can have with an adjacent street segment. Focusing the analysis on the permeable interfaces, as in the justified access graphs, omits information on the impermeable interfaces which might be of the same importance to the structure and use of the house. In his work, Seo (2007, 2016) studied modern multi-unit housing in South Korea and Malaysia with a focus on internal configuration of apartment units. The situation of the flat in a bigger context was only indicated by the rectangular outline of the graph. There is no additional information in the graph that helps us understand how each flat is connected to a bigger network. One of the aims of this paper is to extend Seo's graph representation to include information on the configuration of the internal and external spaces of the building in relation to the street network.

As in the traditional graph-theoretic representation of the architectural layout, the vertices are symbols of each room in the layout (cupboards and closets are omitted). We distinguished two types of rooms, internal and external, with the solid white points describing internal rooms and the solid black external rooms (see Figure 3). As we are interested in the relationship of the rooms to the possible adjacent streets, we introduced a third type of a vertex. A grey point with a cross inside, which in a traditional representation describes the 'outside world', is used to represent every street adjacent to the house. The vertices are connected when a relationship of either adjacency or permeability is met. In this analysis we were only interested in the relationships between rooms and between rooms and the adjacent streets, the information on the connectivity between street segments was purposefully omitted, as it diverts from the purpose of the graph. In the figure 3(a) the vertices were situated in the centre of each (internal and external) room with additional vertices indicating adjacent street segments. In the figure 3(b) the internal vertices were aligned to the rectangular outline of the building and the external vertices were aligned to the outline of the plot. In the last step (figure 3(c)) the graph was converted into a dimensionless representation and colour was introduced to indicate the difference between internal and external rooms, with interior indicated as a dark grey and exterior as a light grey square.

The relationship between the morphology of the floor plan and the house-street interface(s)

In order to compare similarities and differences in the morphology of the floor plans between houses with typical and atypical relationship with a street system, we drew graphs based on 243 floor plans, evenly distributed between all speculative estates and building typologies. In each housing typology we determined the most common graph of a floor plan with a typical relationship with a street system and compared it to the graphs of floor plans with atypical relationships (see Figure 4). The typical floor plan in the terraced house can be described as bi-polar. There is a strong hierarchy and a social difference between front and back of the house, which is visible in the configuration of the floor plan. The rooms at the front of the house, e.g. front yard, porch, and lounge, have a more 'public' character and are facing the front residential street. The rooms at the back of the house, e.g. kitchen, dining room and back yard, are service-orientated and connected to the back alley. The terraced houses with atypical relationship to the street system, in most cases end terraces, were designed in three different fashions. In the first and most popular approach, the layout of the end terrace was structured in the same way as the typical terraced floor plan (see Figure 4(A1)). The hierarchy and social division between front and back were still dominant and the additional side interface was not acknowledged in the design. As Muthesius mentioned during the construction of the speculative terraced houses the builders did not know how to address the blank wall of the end terrace (Muthesius, 1982). However, even though the side street was omitted during the design, the house retained the adjacency to the street. The lounge and dining room were adjacent to the street segment and although not permeable or visible, the rooms were exposed. On the other hand, the street segment was adjacent to a blank impermeable wall which did not generate any possibility for encounter or co-presence. The second approach was similar to the first, in the way the additional interface with a side street was not acknowledged (see Figure 4(A2). However, in these cases designers introduced a side yard which separated the house from the street. As the side yard was accessible only from the front and largely disconnected from the house itself, the main use was as a lawn with small trees and shrubbery. The potential of the space between a house and the street was reduced to a more 'visually pleasant' blank wall. The last approach to the atypical interface was to adjust the configuration of the floor plan to integrate the additional interface (see Figure 4(A3). When we look at the internal configuration only, there was not much change in the structure of the floor plan. The position of the porch (P) changed to address the entrance from the side, rather than the front. However, if we include the plot and adjacent street in the analysis, we can observe a fundamental change to the configuration. The internal configuration is disconnected from the front yard and the front residential street. Additionally, the hierarchical structure of the layout, that emphasised transition from the public front to the private back changed to a more interconnected and ring-like configuration.

The typical layout in the semi-detached house was originally similar to that of the terraced house with the addition of the space to the side of the house which directly connected the front and the back. With time, the type changed and majority of semi-detached houses were extended to include a garage and a utility room in place of the side yard. However, the 'original' layout was preserved in the majority of end semi-detached houses (see Figure 4(B1)). The end semi-detached house interfaced with two, instead of one, street segments, which meant that there was a choice to the placement of the garage. In the majority of cases, the garage was disconnected from the house and accessible from the side street, not the front.

This was not the only way to address the additional interface. Similar to the terraced house, the configuration of the house and the plot was adjusted to incorporate the additional interface; however, it is not visible if we study the internal configuration only (see Figure 4(B2)). The internal structure was preserved to follow the typical semi-detached floor plan, however, it was rotated by 90 degrees in relation to plot. That means, where previously garage and lounge were adjacent to the front yard, in the atypical example, their position changed to face the side yard. The dining room in the typical semi-detached house is adjacent and accessible from the back yard, however, in this case, the position of the dining room changed to face the front yard. The front yard, previously an important part of the configuration of the semi-detached layout, was disconnected from the house.

The typical detached house was situated in the middle of the plot to isolate the house from the neighbouring unit with one permeable front interface connected to a residential street. However, not many of the houses in the estates followed this 'ideal' layout because of the design of the estate as a whole. Estate layout designed to promote privacy, isolation and separation from the existing urban structure, generated additional interfaces between detached houses and the street network that did not follow the typical configuration. As a result of urban decisions, detached houses have the most numerous and complex relationship with the street system (see Figure 4 (C1)). However, it is not addressed in the design of the floor plan. Even though, there are three different types of a relationship that a detached house can establish with a street system, in every case the configuration of the floor plan is designed as if the house was adjacent only to one street segment. This can be problematic for both the quality of the space in house and the street. For example, in many cases the back yard, designed as the private exterior room dedicated to leisure and assumed to be adjacent only to neighbouring units, is adjacent to a busy and noisy street, which may deter from the use of the space. Additionally, the main streets which should have been adjacent to the front façades of the houses face a tall opaque wall on the back edge of the property, which may affect use and liveability of this street.

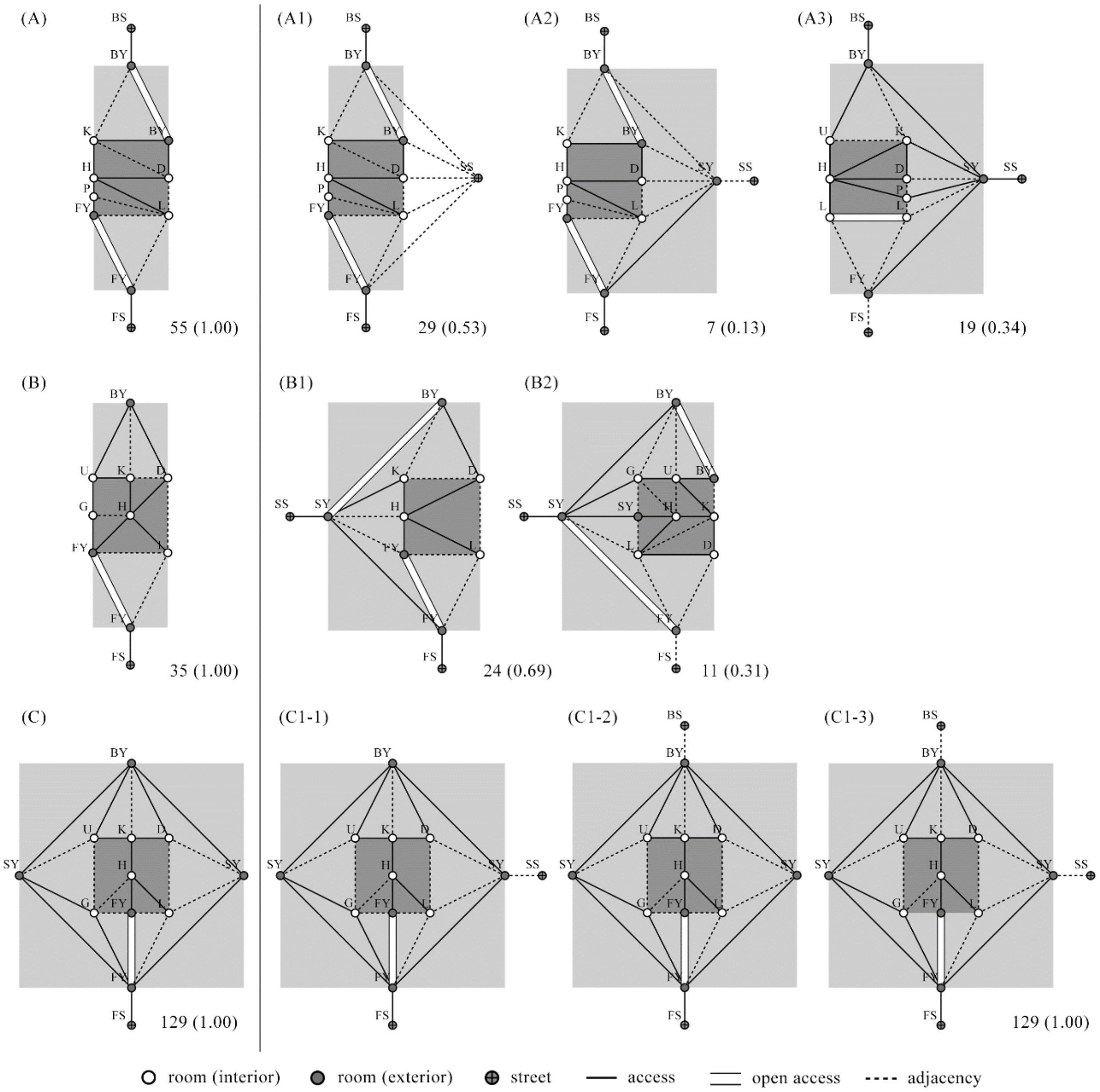

Figure 4. The morphology of the floor plans with typical (A, B, and C) and atypical relationships between a house and the street system. The first row presents the typical relationship in terraced housing (A) and three different approaches to the atypical relationship: (A1) to not integrate the additional interface in the floor plan, (A2) to acknowledge but not integrate the additional interface, and (A3) to integrate the additional interface in the floor plan. The second row illustrates the typical relationship in semi-detached houses (B) and two different approaches to the atypical relationship: (B1) to acknowledge but not integrate the additional interface, and (B2) to integrate the additional interface in the floor plan. The last row describes the typical relationship for the detached house (C) and one approach to the atypical relationship, which does not acknowledge the additional interface (C1-1 to C1-3) (FS – front street, FY – front yard, P – porch, L – lounge or living room, H – hallway, D – dining room, K – kitchen, U – utility room, SY – side yard, SS – side street, BY – back yard, and BS – back street or back alley)

Conclusion

In this work, we have examined the impact of the relationship between a house and the street system, measured by the number of house-street interfaces, on the morphology of the plan. We observed two approaches in the treatment of the morphology of houses with atypical relationship with the street system. Either the configuration of the floor plan was adjusted to accommodate the additional interface or, as in 63% of cases, the floor plan followed the morphology common to the housing type without addressing additional interfaces. When the house layout was adjusted to accommodate the additional interfaces the most important change was the disconnection of the front yard from the house, which is interesting given the importance of the front interface in each housing typology. The change in the house layout rarely affected the relationship between the internal rooms and in most cases changed the relationship between the internal and external spaces. The majority of houses that did not accommodate additional interface(s) in their floor plan had to introduce further measures to mitigate the impact of multiple interfaces, such as erecting a high boundary to separate the house from the additional street. We found that some of the measures introduced while improving the condition of the plot could had a negative impact on the liveability in the street. Our conclusions suggest that the number of interfaces between these two urban domains has an impact on either their morphology or state. Not addressing the interface during the design process is more likely to deteriorate the condition of one or both spaces.

Figure 5. An impermeable interface of the end terraced house. The impermeable blank wall could affect the liveability of the adjacent street as the interface does not generate any possibility for encounter or co-presence in this space

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