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# Exploring the relationship between interface types and street centrality in Nova Zabudova (Kyiv, Ukraine)

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## ABSTRACT

The configuration of buildings' facades and, in particular, of facades located at the ground floor is fundamental for urban vibrancy and pedestrian activity at the street level. Equally important is the relationship between the configuration of such facades (e.g. transparency, opaqueness, blank) and street centrality. Suboptimal combinations (e.g. blank facades in streets with high levels of centrality and thus potential through-passage) may undermine urban vibrancy and liveliness. While there exist studies on the relationship between street centrality and density of commerce and services, systematic assessments of the relationship between the configuration of ground floors and street centrality are very limited. In this work, we propose a mixed method to, first, classify ground floor facades in types and, second, analyse the relationship between the ratios of such types and three metrics of street centrality (i.e. betweenness, closeness and straightness) through correlation analysis. This approach is applied to Nova Zabudova, a historical neighbourhood located in central Kyiv, Ukraine. More specifically, first, ground floor facades pertaining to each building are mapped according to the methodology; second, ratios of interface types and centrality metrics are computed for each street in the study area; third, relationships are assessed statistically through correlation test. Coefficients are overall weak suggesting a feeble correspondence between interface types and street centrality metrics in Nova Zabudova. However, a clear trend is visible: more active interface types correlate with all the street centrality metrics considered while inactive interface types are inversely correlated with them.

**Keywords:** ground floors, street centrality, correlation, Kyiv

## INTRODUCTION

Buildings, together with the streets and sidewalks within which they are located, provide local identity and, at the same time, influence transportation, network development, social cohesion, commercial interactions and, ultimately, democracy (Gehl, 2013; Orhan, 2018; Hassan et al., 2019; United Nations, 2022). In this regard, the ensemble of a ground floor and its pertinence space (usually a footpath) are extremely important as they constitute the main area of exchange between people, buildings and the nearby space (Gehl et al., 2006; Gehl, 2013). In fact, it can be considered as a transitional zone between architectural forms and the public space as they connect indoor and outdoor areas, where social and economic activities take place (Özyörük, 1995; Dovey and Wood, 2015). Related to this, Gehl (1987) and Gehl et al. (2006) describe ground floor facades as "soft", when a certain degree of transparency makes them social, permeable, active, or "hard", when they are blank or impermeable and less interactive for pedestrians. Other authors highlighted the importance of the design of ground floor facades for creating dynamic and liveable public spaces. For example, their design and configuration may enrich or not the public space, affecting the perception and experiences of pedestrians, as well as activities and interactions that can happen around them (Carmona, 2003; Joyce and Guaralda, 2013).

However, the material configuration of ground floors is only one side of the coin. Street centrality, an aspect of the street network's configuration, is the other side of it. Indeed, it has been identified as a significant driver of the capacity of urban areas to promote diversity and intensity of city uses and users over time, strengthening informal surveillance and community capacity. Studies on these topics date back to the end of the 20th century with the seminal work by Hillier (1996) (Space Syntax) and later developments (Multiple Centrality Assessment) by Porta et al. (2006). While showing some technical differences, both tools mainly rely on two metrics of street centrality: closeness (integration) and betweenness (choice). The former simultaneously quantifies the level of proximity and interconnectedness of street segments. The latter measures the level of potential movement through streets. While these metrics were found to be positively correlated with density of commerce and services at the ground floors in different cities (Porta et al. 2009; Porta et al. 2012), much less is known on the relationship between the configuration of ground floors and street centrality. Remali et al. (2015), to a certain extent, did investigate such a relationship. However, only one indicator (openness), capturing the level of transparency of ground floor facades, was accounted for.

Existing literature suggests that specific configurations of ground floor facades are associated with more pedestrian interactions, flow, and use. However, systematic studies assessing such a relationship are missing, except for the one study mentioned above which, however, only tested one specific aspect (i.e. transparency). The aim of this study is to systematically assess whether the configuration of ground floor facades (called interfaces from hereon) correspond to different levels of pedestrian activity. To do so, we propose a mixed qualitative/quantitative methodology that, first, defines a taxonomy based on 5 intuitive interface types (i.e. inactive, dull, in-between, friendly, and active) which simplifies a previous categorisation attempt (Dovey and Wood, 2015), affording better replicability. Second, it uses free software to map interface types in a study area. Third, it assesses the relationship between ratios of interface types at the street level and three metrics of street centrality (i.e. betweenness, closeness and straightness), through correlation analysis. The mixed methodology was tested on Nova Zabudova, a historical neighbourhood close to the city centre of Kyiv (Ukraine).

## METHODOLOGY

### A taxonomy of interface types

As previously mentioned, Dovey and Wood (2015) provided a categorisation of interfaces in Australian cities (Brisbane, Sydney and Melbourne) based on five primary types articulated in accordance with the criteria of transparency, access and setback: impermeable/blank, direct/opaque, direct/transparent, pedestrian setback, and car setback. This indeed provides a systematic way to categorise urban interfaces, however, accessibility and presence/absence of setbacks may not be that straightforward to assess. For example, facade recesses may be small at times (1 or 2m), making the classification dubious. Furthermore, the complexity of such a categorisation might hamper its replicability in other contexts and use by people with different backgrounds and education levels. We thus propose a novel taxonomy of interface types which is inspired by the work mentioned above but that, at the same time, tries to bridge the gap between technical jargon and everyday language. By doing so, the proposed taxonomy aims to empower ordinary individuals to participate in discussions about their city and foster a broader dialogue about urban planning and design. We propose the following five interface types:

- Inactive interface (Figure 1, A): inactive interfaces are typically unresponsive to the surrounding urban context. They lack visual or physical interactions with the street and pedestrians. Buildings with inactive interfaces may have solid walls or barriers without any windows or doors. Inactive interfaces can create a sense of detachment and disconnection, leading to less vibrant and dynamic urban spaces.
- Dull interface (Figure 1, B): dull interfaces are characterised by lack of visual interest or architectural detailing. These interfaces may have windows and doors, however, often appear monotonous, repetitive or uninspiring. Dull interfaces can create a sense of monotony and may contribute to a less engaging urban environment.
- In-between interface (Figure 1, C): in-between interfaces are a balance between active and inactive interfaces. They may possess some visual interest and engage with the urban environment but not as vigorously as active and friendly interfaces. In-between interfaces can include a mix of window sizes and architectural elements while maintaining a reserved or restrained appearance.
- Friendly interface (Figure 1, D): friendly interfaces are designed to be visually appealing and welcoming to pedestrians, however, they tend not to be particularly transparent. These interfaces often incorporate elements that engage people and create a sense of human scale. They may feature varied textures, colours, materials, and architectural details like balconies, awnings or ornamentation. Friendly interfaces contribute to a positive urban experience and may encourage social interaction.
- Active interface (Figure 1, E): active interfaces are highly engaging for pedestrians. They create a strong connection between buildings and public space. They often have large windows, transparent or permeable surfaces and storefronts that allow to see from the outside to the inside and vice versa. They may incorporate public amenities such as seating areas, art or greenery. Active interfaces contribute to a vibrant street life and encourage pedestrian activity.

**Data collection and processing**

Data on interface types is collected through NextGIS (https://nextgis.com), i.e. an app that allows gathering different types of georeferenced geometries (e.g. points, lines and polygons) on top of a geolocalized background map, together with photos and comments. During field work, interfaces are mapped through lines representing portions of ground floors with stylistic continuity. When such a continuity is interrupted (for example, due to a changing facade composition), a new line representing the next interface is created. Further information, such as the photo of the interface and the label of the type, should also be added as attributes for later use. Then, the data is exported in GeoJSON format and imported in QGIS software (https://qgis.org/en/site/), where interface types are mapped by categorising the field with labels of interface types added during the field work.

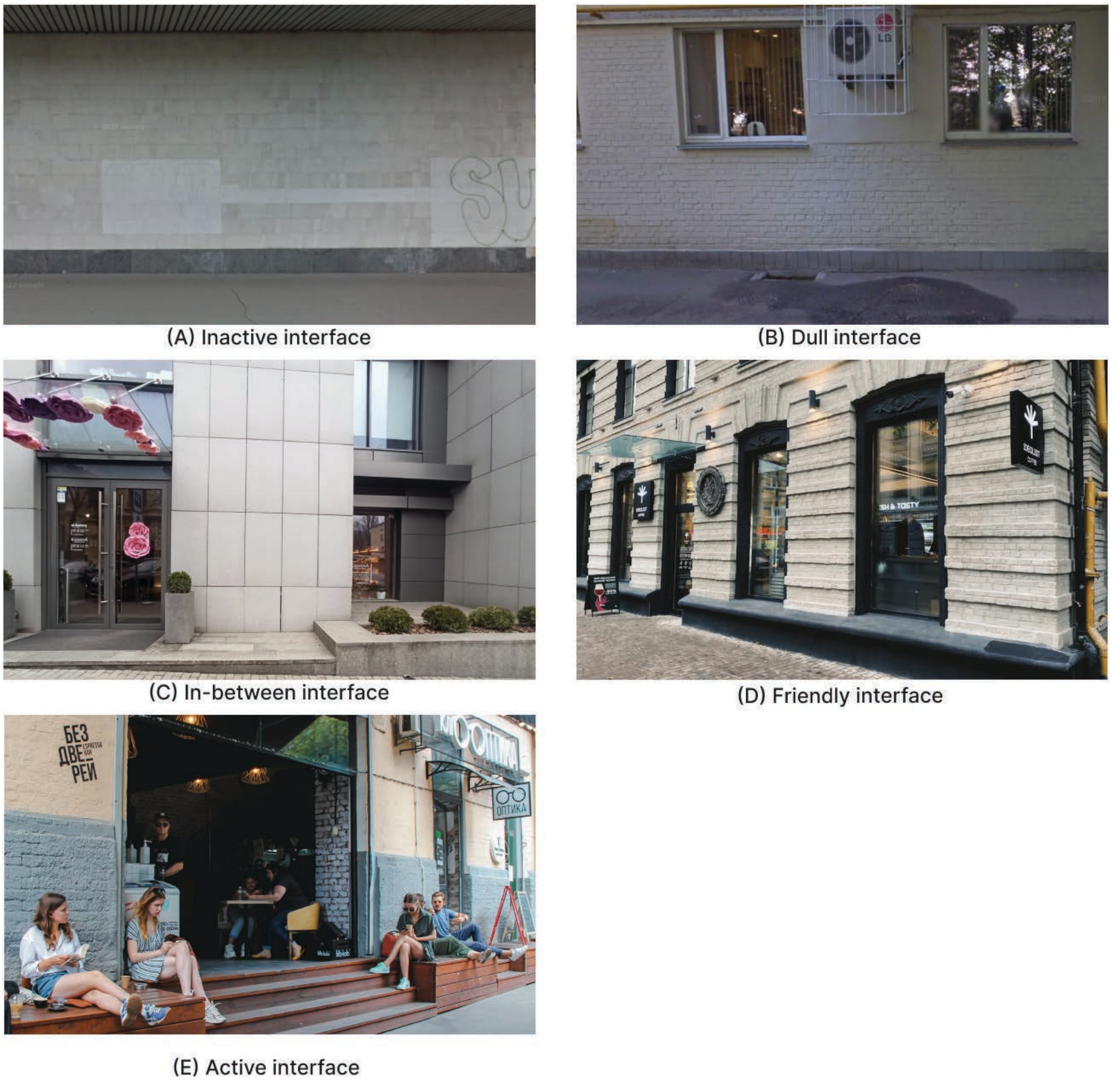


***Figure 1.*** *(A) Inactive interface. Source: Google Street View. (B) Dull interface. Source: Google Street View. (C) In-between interface. Source: Petro Kvartsianyi. (D) Friendly interface. Source: blackfield.coffee. (E) Active interface. Source: coffee shop's Facebook page*

**Ratios of interface types and street centrality metrics**

Since the centrality metrics are computed for street segments, interface types are aggregated for these spatial units by adding the lengths of each interface type on both sides of each street and dividing this value by the length of the street they face, ultimately resulting in a ratio. In terms of street centrality analysis, the first step consists in gathering the georeferenced street network for the case study under examination and a buffer area of 800m around it to avoid edge effects in the computation of the centrality metrics. Such data can nowadays be easily retrieved from multiple open sources, for example, Geofabrik (http://download.geofabrik.de/), or the data hub of official mapping agencies, for example, from the UK Ordnance Survey (https://osdatahub.os.uk/downloads/open/OpenRoads).

Once this data is obtained, the Multiple Centrality Assessment (MCA) (Porta et al., 2006) (http://docs.momepy.org/en/stable/user_guide/graph/centrality.html), a set of Python scripts that measure centrality in street networks, is applied to the street network of the case study under examination. More specifically, 3 centrality metrics are considered:

- *Betweenness*, which is based on the concept that a node (street intersection) is central if it lies on many of the shortest paths linking couple of nodes in a street network.
- *Closeness*, which quantifies to what degree a node is near to all the other nodes in a network along the shortest paths.
- *Straightness*, which is based on the concept that being central means to be more directly reachable by all other nodes in the street network.

Closeness centrality is computed for 3 different radii, i.e. 200m, 400m and 800m, corresponding to a submultiple (200m) and a multiple (800m) of the edge of the "sanctuary area" (400m), an urban sub-space usually made up of few blocks surrounded by main streets, typical of walkable urban fabrics (Mehaffy et al., 2010). Since this approach focuses on the relationship between interface types and street centrality in sub-spaces within a city, the radii used in the computation of closeness do not go beyond 800m, i.e. a measure widely adopted for the neighbourhood scale (e.g. in New Urbanist schemes).

### Correlation analysis

Both ratios of interface types and centrality metrics tend to be skewed. For example, it is possible that a specific interface type is rare in a study area, thus only few streets will have a value while the remaining ones will be 0. Centrality metrics tend also to be skewed, especially betweenness centrality (Barthelemy, 2004; Jiang, 2009). For this reason, Spearman correlation (Corder and Foreman, 2014) is preferred to Pearson correlation since the former, by assessing a monotonic relationship based on ranks rather than continuous values, is better suited and more robust in case of skewed distributions. The outputs of the Spearman correlation test are a coefficient ($r_s$) varying between −1 (i.e. perfect negative relationship) and 1 (i.e. perfect positive relationship) and a p-value providing information on the statistical validity of the tested correlation.

## ANALYSING INTERFACE TYPES IN NOVA ZABUDOVA

### The case study

Nova Zabudova (Нова Забудова), is a neighbourhood of Kyiv, Ukraine (Figure 2). It is situated in the central part of the city and holds significance in terms of history, urban development and socioeconomic composition. Nova Zabudova originated in the 1830s and 1840s when it was designated as a settlement area for residents displaced from the Pechersk neighbourhood due to the construction of the New Pechersk Fortress (Figure 3, bottom right). In the late 19th and early 20th centuries, Nova Zabudova witnessed notable urban expansion, both in terms of ordinary buildings, such as tenement blocks (Figure 3, top right), and special ones, such as the Saint Nicholas Roman Catholic Church (Figure 3, left). As a centrally located neighbourhood, it attracts diverse population, including residents from different social and economic backgrounds. The area has a mix of residential, commercial, and institutional spaces, contributing to a vibrant urban environment. Overall, Nova Zabudova stands as a historically significant neighbourhood that has undergone several development phases over time. Its location in the city centre and historical context makes it an intriguing area with cultural, architectural, and socioeconomic diversity.


***Figure 2***. *Left map: Nova Zabudova and the city limits of Kyiv. Right map: zoom in Nova Zabudova and immediate surroundings. Source of basemap: Google Satellite*

***Figure 3***. *Left St. Nicholas Roman Catholic Church. Top right: Tenement block building. Bottom right: New Pechersk Fortress. Source: Wikipedia*

**Mapping interface types**

The distribution of the interface types in Nova Zabudova reveals intriguing disparities. Remarkably, the proportion of active and friendly interfaces stands at a mere 5.54% and 5.58%, respectively, while percentages of in-between, inactive, and dull interface types are 9.96%, 31.47%, and 47.19%, respectively (Figure 4). This contrast emphasises the prevalent presence of dull interfaces throughout the neighbourhood, followed by inactive facades – a juxtaposition that seems somewhat incoherent for a central neighbourhood. However, upon a more meticulous analysis, the preponderance of dull interfaces becomes more comprehensible since a significant portion is located in secondary and tertiary streets mainly characterised by residential and/or institutional functions. Inactive interfaces are notably prevalent along Korolensivska St, as well as on Fitzcultury St and Antonovycha St, particularly within the western sector of the neighbourhood. These streets are marked by an amalgamation of former industrial sites, underutilised land and construction sites. Furthermore, a concentration of inactive interfaces is evident in the eastern side of the Olympic Stadium and on some primary streets. In-between, friendly and active interfaces are evenly distributed throughout the neighbourhood. However, the latter two also distinctly cluster in the area of Velyka Vasylkivska St., i.e. a central hub of Kyiv, characterised by the intersection of two metro lines and several main landmarks, including the Pinchuk Art Center, the Basarabian Market, and the Sportyvna Square.


*Figure 4. Interfaces of Nova Zabudova colour coded according to the 5 types considered in this study.*

**Street centrality analysis**

The street network of Nova Zabudova and a buffer area of 800m is downloaded from Geofabrik and consists of 8,530 street segments, subdivided in 17 categories of streets (such as, primary, secondary, tertiary, cycleway, track). Since the MCA focuses on the configuration of the main structure of street networks, only key street categories (i.e. primary, secondary, service, tertiary, residential) are kept in the analysis, resulting in a dataset of 4,252 main street segments. The 5 centrality metrics presented in the Methodology are computed for such data and displayed in Figure 5. The outputs of the computations of each centrality metric are discussed next.

*Betweenness centrality*

The study area is traversed by one main N-S axis (Velyka Vasylkivska St) with very high levels of betweenness centrality (Figure 5, top left). Secondary axes with medium to high levels of betweenness, connecting with Velyka Vasylkivska St, are located south (in E-W direction, Ivana Fedorova St and, in NE-SW direction, Vasylia Tiutiunnyka St) and north of the study area (in E-W direction, Lva Tolstoho St). Two further axes with medium to high levels of betweenness are located at the eastern and western edges of the study area (Lesi Ukrainky Blvd and Korolenkivska St, respectively). Nova Zabudova shows the configuration of traditional/bottom-up neighbourhoods (Strano et al., 2012) with a main backbone traversing its centre, several secondary streets connected to it and several less connected streets, mainly tertiary roads and cul-de-sac.

*Straightness centrality*

In terms of straightness centrality (Figure 5, top right), Nova Zabudova does not present high levels in its core but, mainly, N and S of it, at the interface with nearby neighbourhoods. Streets with medium to high levels of straightness centrality are Lva Tolstoho St in the north and Yevhena Konovaltsia St and Ivana Fedorova St in the south. This is likely because nearby neighbourhoods present more continuous grid layouts, typically characterised by 4 main parallel streets going roughly in N-S direction and several secondary streets crossing them at right angles. Conversely, the study area has only 2 main parallel streets due the presence of large infrastructures (e.g. the National Sports Complex "Olympiyskiy") and the slightly curved nature of the site.

*Closeness centrality*

The highest levels of closeness at 200m (Figure 5, middle left) correspond to local systems characterised by a main street and several access roads connecting to it (see, for example, Shota Rustaveli St and Pushkinska St) or by short and very well-connected streets within blocks (see, for example, the small-scale local street system around the Royal Tower). In terms of closeness at 400m (Figure 5, middle right), two main centralities emerge from the analysis: one is located around L'va Tolstoho Square where the street layout changes orientation, while a second one corresponds to a dense and well-connected street system located in the western side of the case study, where Zhylianska St crosses Volodymyrska St. At the neighbourhood scale (800m) (Figure 5, bottom left), such two centralities merge, creating a larger street system characterised by well-connected streets near each other, hinting at a potential neighbourhood core.

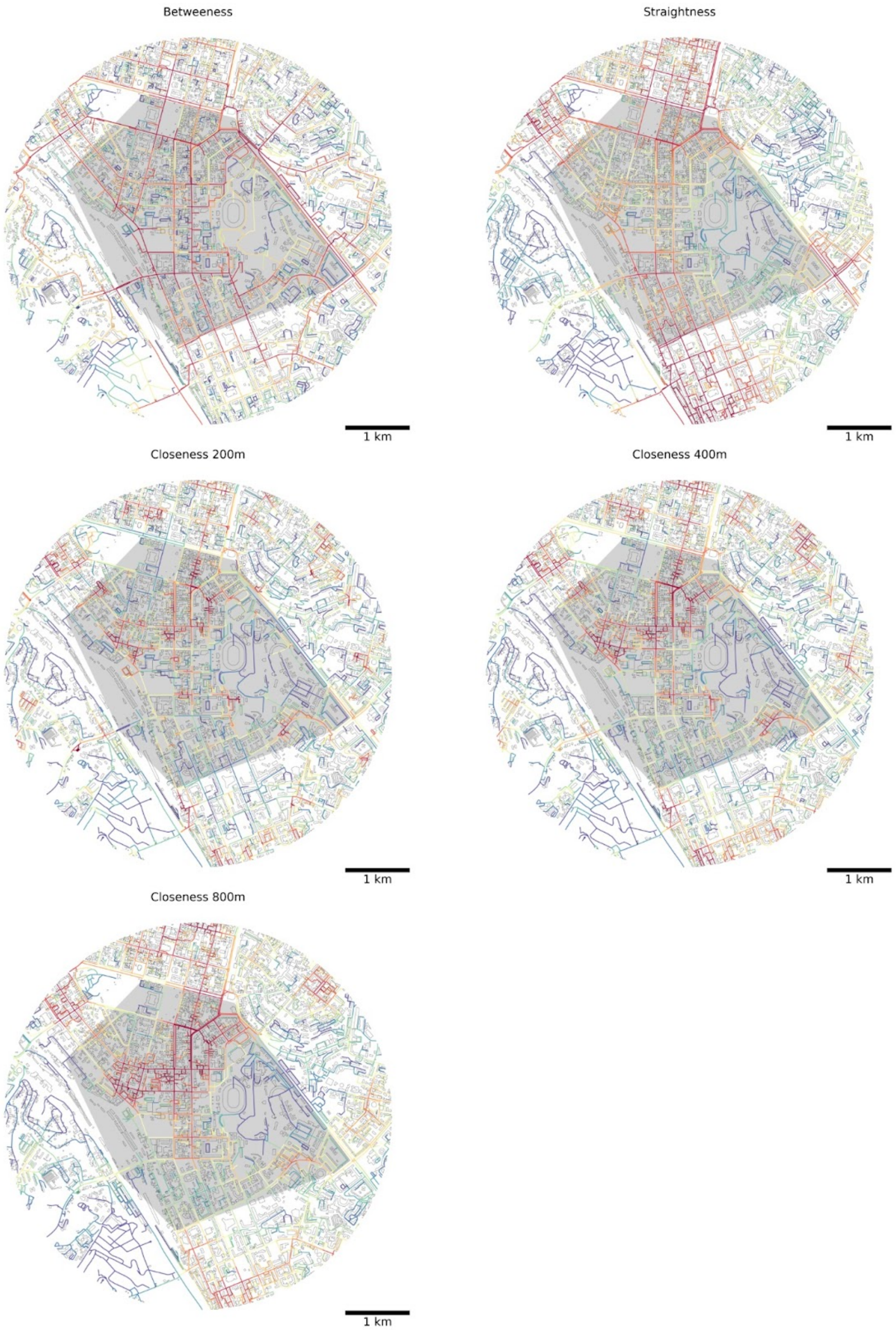


***Figure 5****. The five centrality metrics computed in Nova Zabudova (in grey) and surrounding buffer area. Red corresponds to the highest centrality. Blue corresponds to the lowest centrality.*

**Correlating ratios of interface types and street centrality**

The Spearman correlation test is applied to all pairwise combinations of ratios of interface types and centrality metrics (Figure 6). Overall, the former tends to be weakly correlated with the latter (with correlation coefficients varying between 0.09 and 0.3), indicating a feeble relationship between the configuration of ground floor facades in Nova Zabudova and the centrality metrics. In terms of ratios of active facades, these are positively correlated with all the tested centrality metrics and, in particular, with closeness at 800m ($r_s$=0.3), hinting at a suitable placement of such facades in the neighbourhood core. Active facades are also correlated, although to a lesser degree, to streets with more straightness centrality ($r_s$=0.2), corresponding to rectilinearly better-connected places. Finally, a very weak relationship is observed with betweenness centrality ($r_s$=0.1), indicating that the active facades of Nova Zabudova might not benefit as much from the potential pedestrian through-movement generated within the neighbourhood. In terms of ratios of dull facades, we observe a positive relationship (with $r_s$ varying between 0.1 and 0.2) with all centrality metrics except betweenness centrality (no correlation), suggesting a dubious positioning of such interfaces in the neighbourhood. Friendly facades show positive correlations, although weaker than those observed for active facades (with $r_s$ varying between 0.09 and 0.2), with most of the centrality metrics, except closeness at 200m (no correlation). In-between facades are positively associated with three out of five centrality metrics (straightness, closeness at 800m and betweenness), with $r_s$ varying between 0.1 and 0.2. Finally, in terms of inactive facade, we observe inverse correlations ($r_s$=-0.2) with all closeness centrality metrics and no correlation with straightness and betweenness, indicating that this interface type tends to be located outside local cores and, at the same time, does not show a relationship with central streets in terms of connectivity through Euclidean paths and potential through passage.

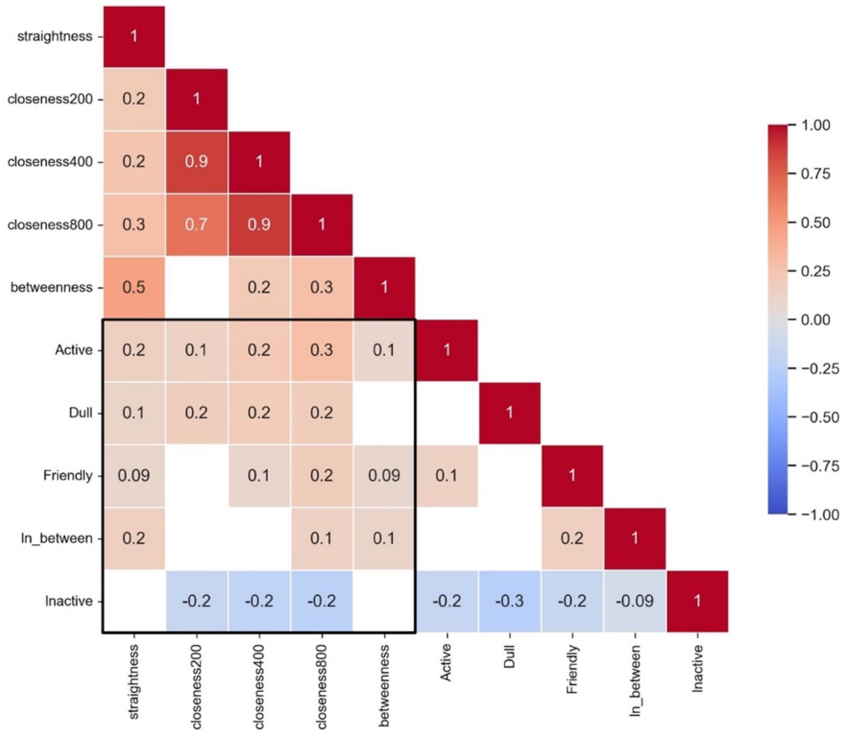


*__Figure 6__. Correlation analysis between ratios of interface types and street centrality metrics. Red corresponds to the strongest correlation. Blue corresponds to the weakest correlation. Blank squares represent non statistically valid correlations (p-value>0.05). The black outline highlights the main results of this study.*

## DISCUSSION

The correlations found in this study are overall aligned with previous qualitative theories suggesting that more active ground floor facades are associated with more pedestrian activity (Gehl et al., 2006; Gehl, 2013). This is evidenced by the correlations found for the "extreme" interface types (active and inactive). More nuanced behaviours were instead observed for friendly and in-between interfaces. This is likely because such types mix characteristics of both active and inactive facades and are thus located both on central and less central streets. Conversely, the result for dull facades was counterintuitive since they were found to correlate with all centrality metrics except betweenness, suggesting a non-optimal placement of such interfaces in the neighbourhood under examination.

The overall weak results may indicate either that previous theories are imprecise (active interfaces, pedestrian activity and street centrality go hand in hand but the landscape of ground floor facades is much more varied/heterogeneous than assumed) or the case study under examination has some design fallacies (wrong interface types are placed in streets with a high potential of through passage). Replicating the methodology proposed in this paper in different geographic contexts, eventually at the city scale, may help to address this conundrum. Nonetheless, the results of this study can still inform the decision-making process in case the interfaces and streets of Nova Zabudova will be subject to redesign.

While the taxonomy of interface types was simplified to make it more accessible and replicable, it still relies on personal observations, which are subject to potential biases. A plausible way to address this issue would be to i.) have several people mapping the interfaces of a study area separately (not to be affected by predominant opinions); ii.) bring them together to discuss the mapping exercise guided by a facilitator (who will make sure that everyone has his/her say) and iii.) propose a final mapping for the case study under examination.

Future work might investigate scaling up the methodology proposed in this paper through machine learning techniques. More specifically, a machine learning model can be, first, trained on street view pictures with manually categorised interface types and, second, used to predict types in streets where no data is present. If the model proves to perform well, the proposed methodology can be scaled up at the city level, regional level and beyond.

## CONCLUSIONS

This work enables the systemic investigation of an understudied topic in urban planning, that of the relationship between interface types and potential pedestrian activity computed through metrics of street centrality. While previous works assumed a relationship between active/transparent ground floor facades and more pedestrian activity (Gehl et al., 2006, Gehl, 2013), such an assumption has hardly been tested quantitatively. In this work, we proposed a mixed methodology consisting of an intuitive taxonomy based on 5 interface types and correlation analysis to investigate the relationship between ratios of interface types in each street and centrality metrics. The application of the methodology to Nova Zabudova, a central neighbourhood of Kyiv, outputs overall weak correlations indicating a feeble correspondence between interface types and centrality metrics. This, in turn, might be a signal of possible fallacies in the design of the ground floor facades of the neighbourhood. Nonetheless, there are several statistically valid correlations which are aligned with the results of previous studies in the urban design domain. More specifically, active interfaces are the most positively correlated with the set of centrality metrics considered, while inactive interfaces are the most inversely correlated ones. Dull interfaces, by being positively correlated with most centrality metrics, show a counterintuitive behaviour as one would expect them to be in less central places. The methodology and results presented in this work can inform the debate on how to improve existing places or design new ones that support pedestrian activity through the correspondence between specific interface types and street centrality levels.


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