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CAPTURING URBAN INTENSITY

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Abstract. While the methods for capturing negative effects of density (e.g. congestion, friction) are widely understood and operationalized, capturing positive effects of density (e.g. vibrancy, walkability) remain poorly explored. This research focuses on the latter, proposing a novel spatial analysis and mapping approach that can be used to capture the intensity of urban environments. We distinguish between urban density and intensity. Whereas density refers to the amount of people or elements of urban form (e.g. dwelling units, floor area) per unit area of land, intensity refers to the concentration of commercial and service activities on the ground floors along city streets. Bridging morphological mapping techniques with recent network analysis in GIS, ten metrics that capture specific attributes of the built environment influential to intensity are introduced and implemented using data collected from detailed field surveys in two comparative sites within the Bugis district in Singapore. A discussion of the efficacy of these metrics for urban design concludes the paper.

Keywords. Urban intensity; density; built environment modelling; urban design; surveying.

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1. Introduction

“The charged void” describes “architecture’s capacity to charge the space around it with energy, which can join up with other energies, define the nature of things that might come, anticipate happenings... a capacity we can feel and act on, but cannot necessarily describe or record”. (Smithson and Smithson, 2005)

What Allison and Peter Smithson called the “charge” of urban spaces summarizes a set of place qualities that shape the activities and happenings that occur, or have a potential to occur, between a city’s buildings. The Smithson’s “charged void” refers to complex relationships that link the physical configuration of urban space to both the activity patterns and opinions of its users – qualities that are of great importance to any city.

The authors go on to argue, however, that these relationships can be felt and acted on by experienced practitioners, but not captured analytically. Any particular interaction between form and use in a place is likely to be neither unique nor deterministic. Instead, the relationship can take many forms and depend on a range of additional factors that affect people’s use of space beyond spatial form. Vigilant against ‘spatial determinism, a number of urban sociologists have drawn a similar warning, alerting urban designers to remain wary of what Webber (1963) has called “some deep-seated doctrine that seeks order in some simple mappable patterns, when it is really hiding in extremely complex social organization instead”.

While it is now generally accepted that spatial configuration is not the dominant — nor by any means the only — force affecting the life between buildings, its effect on the quality of a place cannot be ignored. Spatial analysis techniques have come a long way and offer a unique opportunity to revisit the challenges of describing and analysing the “charged void” empirically. The need for an empirical understanding of the environmental factors that affect, and desirably benefit, the nature and distribution of human activities on streets is further compelled by the rapid construction and redevelopment of cities, whose significant physical transformations could result in as significant social transformations.

It is well known that denser city environments tend to generate higher levels of interaction between people, establishments, and institutions than sparser city environments (Avent, 2011; Salmon, 2012). Density increases both planned and chance encounters, allowing the users of an area to get more done in less time and with lower transportation costs. This convenience is typically valued with higher real-estate prices and rents. But density alone is insufficient to warrant desirable interactions for living, working and recreation. It is often the subtle differences in the quality, not quantity, of interactions, which make one city or neighbourhood more attractive than

another (Larice, 2006). The choice of amenities and the quality of interactions that a built environment offers are not simply achieved through higher plot ratios and residential densities. The quality of streets depends as much on the gross quantities of people, jobs and business establishments around them as it does on the planimetric arrangement of built form that mitigates access between these actors. The configuration of paths between buildings determines the conditions of adjacency and proximity between the tenants of an area and its public spaces, setting them up to be encountered by many or to be hidden from movement and view (Hillier and Hanson, 1984; Porta, 2009; Anonymous, 2010). Furthermore, the quality of a street as a host to different activities is also shaped by the configuration of building floors that align it (Figure 1). The capacity of ground floors – the immediate interface between outdoor public space and indoor space that Anderson (1978) has called “occupiable” – to accommodate a wide range of activities and to generate inviting entrances towards passers-by directly influences the character of a street (Jacobs, 1993; Gehl, 2010). The ground floors and their perimeters not only affect the operations of activities that they currently accommodate, but also set the approximate limits to what activities could come to occupy them in the future (Aylward, 1969; Habraken, 1999). A number of scholars have searched vigorously for measurable propositions that link spatial form with the qualities of urban environments prior to our research (Southworth 2003; Clemente, Ewing et al, 2005a,b; Talen & Duany 2006a,b; Forsyth, Jacobson et al. 2010).

The Bugis district in Singapore offers an exemplary case for such empirical study. As the area currently undergoes another redevelopment cycle, it becomes important to understand how redevelopment is likely to affect the quality of the area’s streets and the life they host. We chose two typological samples of urban fabric in the Bugis area, both considered to be intense urban places in Singapore context, which embody contrasting traces of built form and densification strategies from different eras of Singapore’s urban development (Figure 4). While one reflects the urban patterns of pre-1960s with its predominantly old, low-rise shop house typology, the other contains densely spaced larger commercial buildings, with several floors of complex indoor shopping networks present in each. The latter is indicative of the direction in which contemporary practice of urban design and planning is moving in the Bugis area, as well as other former shop-house districts in central Singapore, where land is valuable. Thus, the main reason to compare these two samples of urban tissue is to show not only how each of them generate different levels of intensity, but also to anticipate the spatial qualities that present and future urban development is likely to bring to this area. The study could illuminate how urban design and redevelopment might

affect the spatial qualities and activity patterns of other analogous places in Singapore.

We first explore how to measure the vibrancy of both sites – the “charge” they contain – using a network-based accessibility metric that estimates walking to surrounding commercial destinations in a given access radius. We subsequently discuss how the configuration of urban form and building fronts around the sites affect the availability of destinations and the quality of walking routes that lead to them. The study is a work in progress, which aims to test new analysis methods that could be potentially used to investigate qualities of urban space in other parts of Singapore and beyond.



Figure 1. Left: Albert Centre ground floor perimeter along Rochor Street. Right: Bussorah Street looking at the Sultan's Mosque near Haji Lane.

2. Capturing Intensity

We distinguish between urban density and intensity. Whereas density refers to the amount of people or elements of urban form (e.g. dwelling units, floor area) per unit area of land, intensity refers to the concentration of commercial and service activities on the ground floors along city streets. We call this ground floor quality intensity, since it describes the interface of the urban environment that people sense most directly and encounter on a daily basis. Our definition of urban intensity refers to the volume of spatial interactions that the ground floor of a district has to offer – street networks that accommodate higher concentrations of activities are considered more intense.

By activities along streets we refer to both economic establishments and individual actors that conduct business on the area's streets. Economic establishments contain retailers, service establishments, restaurants and

drinking places, which offer their goods and services on a regular basis. Individual agents, on the other hand, denote vendors, street performers, and service providers (e.g. food kiosks) that do not have a permanent shelter for their activity and typically operate from mobile counters. The latter are rather typical in Asian cities, as well as this part of Singapore.

We capture the concentration of activities around a particular location using an accessibility metric. There are a number of accessibility metrics that could be employed for this purpose (Bhat and Handy, 2000; Sevtsuk & Mekonnen 2012). By using the Urban Network Analysis toolbox, operating in the ArcGIS environment, we can measure accessibility and centrality along pedestrian circulation paths observed in each area. The UNA toolbox allows one to quantify how many and what types of amenities are reachable on foot from a particular location on the network, as well as to capture the spatial qualities of the routes that lead to these amenities.

The *Reach* accessibility of a location describes the number of specified destinations that can be accessed from a particular location within a given access range. The reach centrality $Reach^r[i]$ of a location i in a network G at a search radius r , describes the number of destinations in G that are reachable from i on a shortest path distance of at most r . It is defined as follows:

$$Reach^r[i] = \sum_{j \in G - \{i\}; d[i,j] \leq r} W[j] \quad (1)$$

,where $d[i,j]$ is the shortest path distance between location i and destination j in network G , and $W[j]$ is the weight of a destination j (Sevtsuk and Mekonnen, 2010). The weights can represent any numeric attribute of the destinations – their size, the number of employees they contain, their attraction level etc.

We set the destinations j in the *Reach* index can be specified to capture only economic establishments and mobile vendors around each location, ignoring other uses like offices. The network radius r can be set to a distance that captures the accessibility to destinations within a desired intensity measurement range. We are interested in capturing accessibility in an immediate 3-minute walking range around both study locations, and therefore use a radius of 200 meters in our estimates that follow (Figure 2).

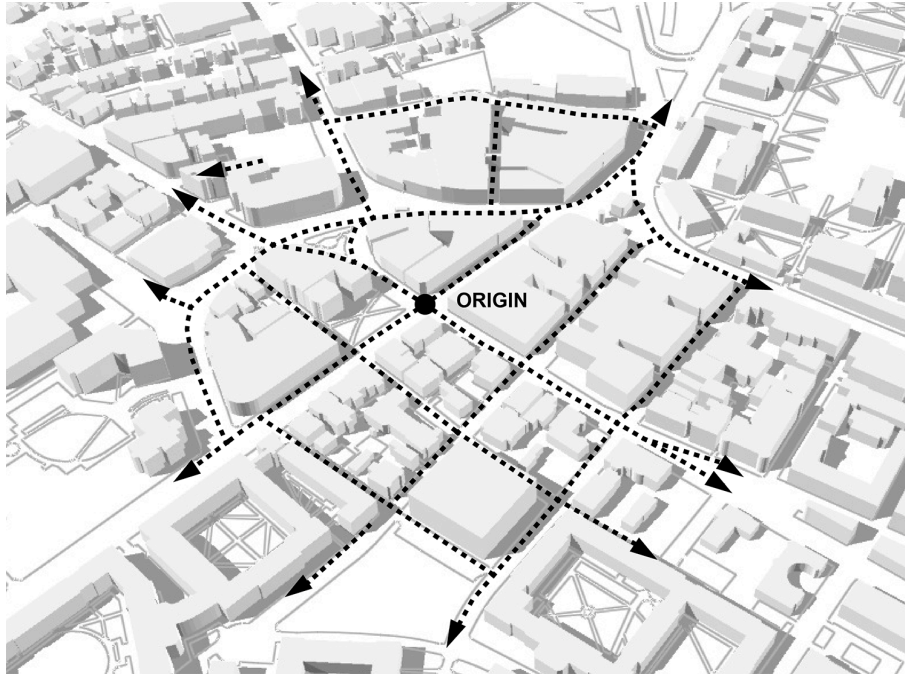


Figure 2. The extent of a 200m network radius around an origin location.

The *Reach* accessibility to commercial establishments can be affected by three distinct qualities of urban form. First, the measure can increase if the destination buildings that the index is computed to are larger in volume and accommodate more establishments. If neighbouring buildings in a two-minute walking range around a location of interest are larger in size and each contain more destinations, keeping spacing of buildings and the geometry of the street network constant, then the *Reach* measure of the location increases. Second, if the number of neighbouring buildings rises, that is, if we observe a denser spacing between buildings per linear length of street segments, keeping building sizes and the geometry of the street network constant, then *Reach* to destinations can also rise. And third, if we keep the spacing of buildings and the sizes of destinations constant, then the *Reach* measure can also increase if the origin is located at a more connected juncture of a street network, where more streets span out. Corner parcels, for instance, tend to reach a longer extent of surrounding street networks than middle parcels, all else equal. We test these three hypotheses in our case studies at Bugis, measuring the *surrounding floor area*, the *spacing*, and the *network reach* of a location in both study sites within a 200m network-based walking radius (Figure 3).

Surrounding Floor Area describes the total amount of gross floor area that is accessible around a location within a given walking radius. *Spacing* denotes the average distance between whole buildings within the given access range. It is found by dividing the total outdoor pedestrian network length (which can include multiple parallel paths) by the number of buildings. Our spacing measure therefore does not describe the true distances between adjacent buildings, but rather the length of pedestrian paths per building. *Network Reach* captures the cumulative total network length available to a pedestrian in a 200m-access radius around a place (Figure 3). The metric can distinguish between the indoor (public circulation networks inside public buildings, malls) and outdoor extent of the pedestrian network around a place (sidewalks, pedestrian crossings, arcaded paths). Together, these network paths can connect from the ground-floor plane to the basement level of an MRT station or a public roof garden on a building.

Beyond these three urban form variables, we are also interested in the spatial qualities of the areas' streets. We analyse seven characteristics of street edges that affect the experience of intensity via individual building frontages. The following provides a brief description of each of these factors and their measurement methods.

Sheltered Walkways describe the amount of outdoor network that is sheltered as opposed to exposed to an open sky (Figure 3). This is an important aspect of pedestrian paths in tropical cities like Singapore with hot and rainy climate conditions. The cumulative sheltered network length is expressed as the percentage of covered paths among the total outdoor pedestrian network within a given 200m-walking radius.

Entrance Count captures the total number of outside doors that enter the streets within a given network radius (Figure 3). Building entrances work as both origins and destinations of pedestrian traffic on city streets – streets with more entrances, everything else being equal, tend to channel more people.

The *Ground-Floor Heights* capture the amount of buildings whose ground floors are at least four feet above or below the street level. Sightlines between the street and the interiors of ground floor spaces get interrupted with significant height differences. We capture the ground-floor height metric as the percentage of building entrances accessible along the outdoor network above and below the assumed ground floor within a given 200m radius.

The *Setbacks* measure the average distance between building entrances and the nearest outdoor pedestrian path for all building entrances within a given radius. Buildings with wider setback, too, increase the effort for access and decrease the visibility for bypassers (Figure 3).

Age Diversity quantifies the age distribution of buildings within the same access radius. Variations in building age may contribute to the perceived intensity of urban spaces. Buildings from different eras display a body of knowledge of their time, which can stimulate associations and meanings that intensify the cognitive experience of a street. To capture the variation between building ages, we group buildings into age groups that get shorter in time as group is nearer to the present (e.g. 1800-1900; 1990-1950; 1950-1975) and calculate age diversity as an entropy index (Limtankool, 2009). The index examines how uniformly building ages are distributed throughout the study sites. It is defined as:

$$E = - \sum_{i=1}^L z_i \cdot \ln(z_i) / \ln(L) \quad (2)$$

,where E is the entropy index, Z_i the ratio of buildings in a given age group to the total number of buildings in the area, and L is the number of age groups. E is constrained between 0 and 1. It is 0 if all buildings in the study area involve only one age group, and 1 if buildings are equally distributed among all age groups.

Edge Permeability captures the amount of non-structural walls on the ground floor facades within the buffer area (Figure 3). Permeable facades increase the visibility of the building contents, and increase the opportunities for interaction. Our perimeter permeability metric measures the proportion of non-structural facade length to the load-bearing facade length in the study area.

Finally, our *Transience* indicator captures the amount of mobile vendors that are found around a place. Vendors using pushcarts on wheels tend to be highly visible to pedestrians as they can quickly locate to areas of high pedestrian traffic. We capture the availability of mobile vendors by simply counting them around each site, in the same 200m walking radius as the rest of the metrics.

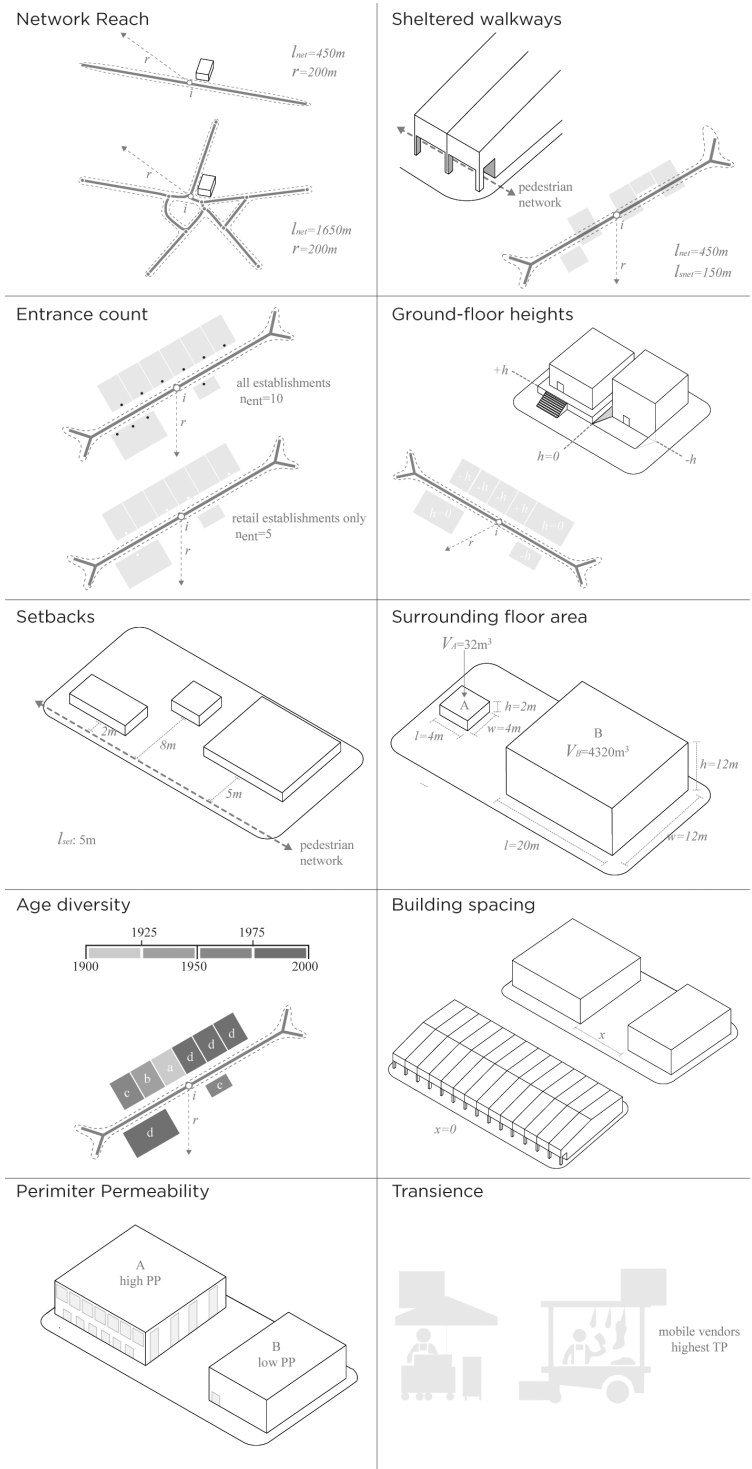


Figure 3. Illustration of the metrics used on case-study sites.

3. Bugis Case Studies

The Bugis district is located in the Rochor area of central Singapore. A high-density, relatively low-rise district, it has a diverse urban form made up of shop-houses, modest-sized malls, office towers and a few Housing Development Board (HDB) blocks. Our two case-study sites were chosen within a similar distance from the Bugis Mass Rapid Transit (MRT) station (Figure 4). One situated on the corner of the Albert Centre, the other near the northern end of Haji Lane, were chosen for their interesting differences in the surrounding urban form. The Haji Lane location illustrates a rather well preserved fabric of the 19th century shop-houses accompanied by a few modern commercial buildings. The Albert Street location used to house a similar shop-house fabric until the 1950s, but has since been entirely redeveloped with modern deep-floor-plate multi-story commercial structures. The centroids of both sites are approximately 350 meters from the nearest MRT entrance – a quality whose difference could otherwise play an important role in affecting the density of commerce around the sites. During the survey in the fall of 2012, researchers collected three layers of information on the sites: 1) the ground floor structural typology of buildings, 2) the distribution of economic establishments and mobile vendors, and 3) the outdoor and indoor pedestrian circulation networks that are accessible to the public. Combined, these data layers embody complementary functional and morphological attributes of a district that are required to estimate the above ten metrics describing the intensity of the sites. The data was digitized and entered into GIS for spatial analysis. For both sites shown in Figure 4, we analysed a 200-meter buffer around the marked origin points and computed the corresponding metrics. Table 1 presents the outcomes of these measurements.

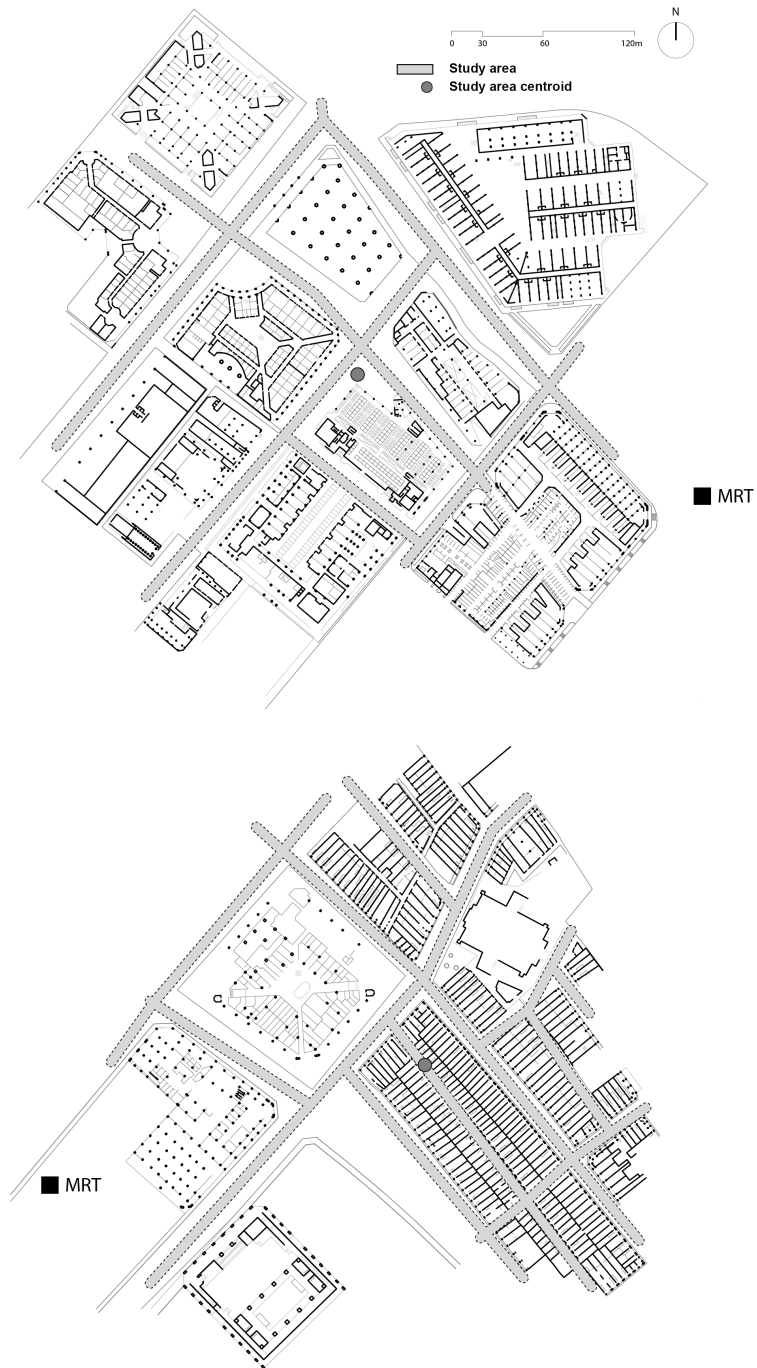


Figure 4. Case study areas. Top: 200m buffer around the Albert Centre. Bottom: 200m buffer around Haji Lane. The origin points of the study areas are marked with red dots.

Metric	Albert Centre	Haji Lane
<i>Reach</i> to commercial establishments	1015	673
Total floor area within a 200m range	603,000 m ²	181,500 m ²
Avg. Spacing between buildings	221.7m	21.5m
Network Reach	5,765m	6,127m
Sheltered outdoor walkways	2,408m	2,056m
Entrance count	230	380
Ground-floor heights (elevated)	11%	0.52%
Average Setback	4.2	2
Age Diversity	0.69	0.11
Edge Permeability	91.6%	77.8%
Transience	32	23

Table 1. Results of case study area measurements.

The total *Reach* to establishments, including both stationary stores and mobile vendors is 50% higher around the Albert Centre (1015) than Haji Lane (673), suggesting an overall higher accessibility to destinations around the former location. In other words, the Albert Centre site has 50% higher intensity according to our metric. How do we explain this difference?

The 200m buffer around Haji Lane contains a slightly longer outdoor path network (6,127m) and significantly more individual buildings (285) than the Albert Centre. (26), so the difference in the accessibility to establishments cannot be attributed to a more connected street network or a denser spacing of buildings around Albert Centre. The difference is rather explained by the considerably larger commercial floor plates around the Albert Centre, which all together contain 333% more floor area than the area at Haji Lane. A number of large buildings, such as the Sim Lim Square, contain numerous small shops on up to six floors. Consistent with the fact that many of the establishments around Albert Centre are indoors, we also observe a greater number of doors on the streets around Haji Lane (380) than Albert Centre (230).

From the perspective of the ground floor morphology, the street edges around Haji Lane are more aligned with the ground plane than the street edges around the Albert Centre. Despite fewer overall destinations, the street edges leading to the available destinations around Haji Lane have better edge qualities. We only observe 2 out of 380 street entrances around Haji Lane that are elevated above the ground floor. At the Albert Centre, in contrast, 27 of the 230 entrances are raised above ground. The higher total number of buildings around Haji Lane (285 versus 26) suggests that architectural variety is wider around Haji Lane. Buildings are much closer to each other at Haji Lane and setbacks smaller. But interestingly, this variety does not imply greater permeability of the street edges around Haji Lane nor a greater age

diversity among its buildings. On the contrary, the edges of the larger buildings around Albert Centre produce a higher percentage of permeable (non-structural) perimeter walls (91%) than the smaller and more numerous shop houses around Haji Lane (78%). Most of the larger structures around Albert Centre are designed with *podiums* around the ground floors, built with open column-beam structural frames, with almost the entire street frontage open for doors, windows and non-load-bearing partition walls.

The age diversity index is lower at Haji Lane (0.11) than around the Albert Centre (0.69). This is explained by the fact that 276 buildings out of 285 around Haji Lane are shop houses from the same era. We observed roughly a similar number of mobile vendors in the 200m buffer around both areas - 32 around Albert Centre and 23 around Haji Lane, with most of the latter concentrated in front of the Sultan's mosque.

4. Discussion

Both the Albert Centre area and the Haji Lane area are relatively intense urban places in the Singapore context. Since both sites were deliberately chosen in the same Bugis commercial area and at roughly equal distances from the closest MRT entrance, we have been able to focus on how the morphological differences between both sites affect their differences in commercial accessibility.

The Albert Centre area has roughly 50% more commercial destinations in a 200m buffer than the Haji Lane area. This was explained by the considerably larger and newer structures around Albert Centre, which contain three times more commercial floor area. The segments of Waterloo and Albert Street that surround the Albert Centre are fully pedestrian and designated public places, which is likely to positively add to the commercial viability of the area's stores. But, given the predominantly low-rise typology of the Haji Lane area, a surprisingly large number of commercial establishments were also found in a 200m buffer in its vicinity (673). If we look at the number of commercial establishments per each 1,000 square meters of surrounding floor area, the Haji Lane area actually supports more activities – 3.71 establishments per 1,000 square meters of surrounding floor area versus 1.68 establishments per 1,000 square meters of surrounding floor area at the Albert Centre. This difference could, in part, be due to the larger size of individual establishments around the Albert Centre.

The qualitative differences in urban form between the two areas are rather remarkable. Despite the fact that there is over three times more total floor area around Albert Centre, its buildings generate 65% fewer doors on the street than the buildings around Haji Lane, including back entrances, emergency exits, and service doors. The doors on the street play an

important role in shaping the area's intensity. The differences in the amount of doors that the two sites produce are likely to be influenced by their contrasting building typologies – whereas the Albert Centre is surrounded by relatively large podium block structures, which contain elaborate public indoor circulation networks, the buildings around Haji Lane are small and utilize the street as their main circulation spine.

Overall, the comparison of the sites illustrates that a high density of commercial accessibility can be achieved with remarkably different building types and neighborhood configurations. The methodology we use can be automated in such a way that it could investigate not only intensity related patterns, but also various other metrics, in different contexts within Singapore and beyond. It is too early to draw any causal inference about the efficacy of different urban design solutions from the study and more research is needed to understand the social and economic effects of urban form on both sites. But the development of urban form metrics that capture important qualitative aspects of places is an important step towards developing a better empirical understanding of how good urban environments work.

The research has so far explicitly focused on urban form, but not adequately on socio-economic activities, zoning laws, incentives, or behavioural patterns that may potentially have crucial impacts on the commercial intensity of the area. Furthermore, historical trends that could be responsible for the changes in the chosen sites need to be examined closely. It would be interesting in follow-up research to gather ethnographic activity data on how the streets and public spaces between the buildings are being utilized on both sites (Gehl 2010), and to tie the behavioural evidence together with the spatial and economic patterns.

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