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Space, Time, and Natural Movement in Old Doha

The Morphological Case of Souq Waqif

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ABSTRACT

The traditional marketplace of Souq Waqif in old Doha is the most important heritage district in the State of Qatar today. It is also one of Qatar's most documented, studied urban areas. This material serves as the background for research bringing the observational and configurational modelling techniques of space syntax to Souq Waqif. The purpose was to deepen our understanding of its morphological, spatial, and functional attributes. The aim is to develop detailed information about the spatial layout and urban functioning, including pedestrian movement patterns and key distribution points from underground infrastructure, stationary occupation of space, land-use patterns, and the spatial structure of Souq Waqif as an urban place at various scales of the urban environment. Space syntax researchers at Qatar University compiled data about the functional attributes of Souq Waqif. It included ground-level land uses, building heights, active/inactive frontages, and direct 'passive' observations – supplemented with video counts – of ~37,000 people and ~16,000 vehicles during the weekend evenings from 6-10 pm over three winter months in 2020. The result is one of the most comprehensive studies about Souq Waqif ever, including critical findings on its morphological logic, spatial structure, building constitution, and adaptation to large-scale urban growth patterns in Metropolitan Doha over time.

KEYWORDS

land use, markets, morphology, space use, urban studies

1 INTRODUCTION

The traditional marketplace of Souq Waqif in old Doha is the most important heritage district in the State of Qatar today. Qatar's terrain is generally flat along the coastline of the Persian Gulf. It

was not the case in the past as the banks of Wadi Musheireb connected inland. Merchants used these banks to sell their goods while standing, giving the traditional marketplace the name of Souq Waqif, which literary translates to 'standing market' (Radoine, 2010). Souq (or Souk in UK English) is a term from the Arabic "sūq," meaning market, marketplace, or bazaar. Souq Waqif marks the location for the original founding for the capital city of Doha (Radoine, 2010; Alraouf, 2012; Fletcher and Carter, 2017). Dating from the 18th century, Souq Waqif originally included private homes, usually single-story traditional courtyard houses (Jaidah & Bourennane, 2010; Al-Mohannadi et al., 2019). The souq became a weekly market constructed by the local Bedouins to sell and trade goods and freshly caught fish and pearls. With its strategic location and Doha's gradual development, the souq became an attractive, permanent market. Over time, owner-merchants transformed homes in the area into a commercial marketplace selling various retail and wholesale goods (Tannous, 2020). Souq Waqif's organization consisted of three main parts: storage areas, craft shops, and open-air stalls. The items sold in the souq included goods imported from the Arabian Peninsula, India, Persia, and East Africa. A synthesis of contemporary and traditional urban fabric now characterizes the historic 'heart' of this city centre in Doha.

Figure 1: Street views of (left) northern segment of the main spine and (right) southern route to Ali Bin Abdullah Street towards the Doha Metro from the main spine of Souq Waqif in Doha (Source: Authors).

In the late 20th century, Souq Waqif began to deteriorate as Qataris abandoned the old city centre for contemporary villas in new suburban residential peripheries served by large modern shopping malls. After a fire destroyed several buildings in Souq Waqif in the early 21st century, the Qatari royal family acknowledged its cultural importance and funded a 2004-2008 restoration project (Salama and Wiedmann, 2013). The project included preservation efforts for the oldest buildings, demolition of all buildings constructed after 1950, and elimination of most surface parking with replacement by underground parking garages (Tannous, 2020; Major & Tannous, 2020; Khan et al., 2021). Newly constructed buildings adhere to or modernize the local Qatari architectural style. Many include traditional construction methods of the late 19th and early 20th centuries to reflect Doha's cultural origins as a fishing and pearling village. It includes thick masonry walls, mangrove roofs, natural stone, and bamboo poles, collectively acting as insulation against the hot desert climate. The restored souq also features low-rise building elevations, usually 2-3 stories in height, though there are 4-story boutique hotels in some locations (Figure 1). A series of pedestrian routes separate these buildings, including narrow passageways (Tannous, 2020). Underground parking garages serve Souq Waqif with the main one having a capacity of ~2,000 spaces (Aguilar, 2015). There is also underground parking available in adjacent areas under Souq Waqif Park to the north and Msheireb Downtown Doha to the

west, all within a five-minute walk. Surface parking is available on the opposite side of Banks Street in the Al Souq area to the east at the time of this study (Khan et al., 2021) (Figure 2).

Figure 2: (top) Location of Souq Waqif within Metropolitan Doha (Source: UREP25-002-5-001/Google/MME) with (insert) satellite view of 1 km^2 area around Souq Waqif (outlined in white) in 2021 (Source: UREP25-002-5-001/Google Earth/Maxar Technologies) and (bottom) aerial view of Souq Waqif looking east circa 2006 before completion of the 2004-2008 Restoration Project (Source: Jodidio & Halbe, 2015).

Souq Waqif is also one of the most documented, studied urban areas in Qatar (Jaidah & Bourennane, 2010; Alraouf, 2012; Salama & Wiedmann, 2013; Nafi et al., 2015; Major et al., 2019; Tannous, 2020; Tannous & Major, 2020; Mark & Tannous, 2020; Khan et al., 2021). It includes but not limited to: historical photographic documentation from the early 20th century to the present day, which is freely available from the Qatari governmental ministries, Qatar National Library, Qatar Museums, and various online and non-digital sources; studies of land use and urban planning commissioned by the State of Qatar, which eventually led to the 2004-2008 urban regeneration efforts in the area during the early 21st century such as the Doha Inner City Redevelopment Old and New Souk Action Area Plan by Dar Al-Handash Consultants/Shaire & Partners (1985-86) available in the Qatar University (QU) Main Library; and, multiple architectural research studies tending to focus on historical heritage and architecture preservation features of the oldest areas of Doha – often in combination with the adjacent Msheireb neighborhood or discussions about rapid urbanisation and globalisation in Metropolitan Doha – in an explicit search for the architectural identity of Qatar (Nafi, et al., 2015; Jaidah & Bourennane, 2010; Jodidio & Halbe, 2015; Major, et al., 2019)

This material serves as the background for a research project bringing the observational and configurational modelling techniques of space syntax to Souq Waqif. The purpose was to deepen our understanding of its morphological, spatial, and functional attributes. The aim is to develop detailed information about its spatial layout and urban functioning, including pedestrian movement patterns and key distribution points including from underground infrastructure, stationary occupation of space, detailed land-use patterns, and the spatial structure of Souq Waqif as an urban place at various scales of the urban environment in Doha. Space syntax researchers at Qatar University compiled data about the functional attributes of Souq Waqif. It included ground-level land uses, building heights, active and inactive frontages, and direct 'passive' observations – supplemented with video counts – of ~37,000 people and ~16,000 vehicles during the weekend evenings from 6-10 pm over three winter months in 2020. The result is one of the most comprehensive studies about Souq Waqif ever, including critical findings of its morphological logic, spatial structure, building constitution, and its adaptation to large-scale urban growth patterns in Metropolitan Doha over time.

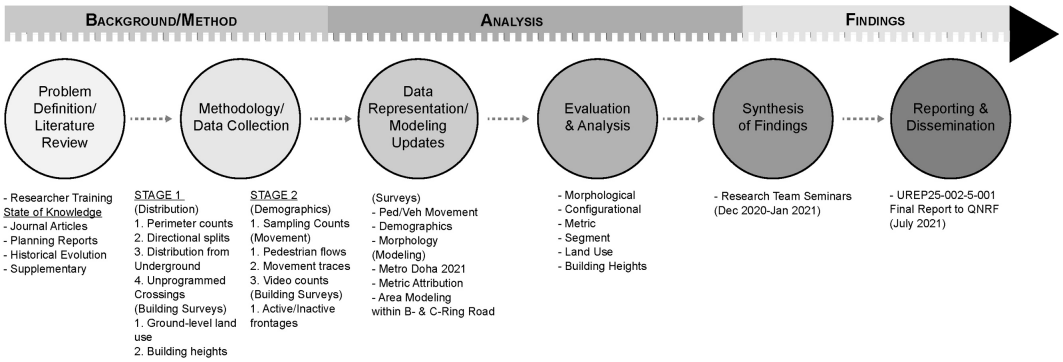

Figure 3: Research design and methodology for the STAND research project (Source: UREP25-002-5-001).

2 RESEARCH DESIGN AND METHODOLOGY

The research project's design and methodology were to develop a detailed understanding of Souq Waqif's spatial layout and urban functioning (Figure 3). Researchers compiled data bout Souq Waqif using 'passive' observations, photographic and video documentation, and visual surveys about the built environment before the global pandemic. Passive observations meant researchers did not interact or interfere with people's use of the area. The data collection is the basis for hard data representations about the reality of use on the ground in Souq Waqif. The study focuses on the period of the highest intensity in Souq Waqif, i.e., 6-10 pm on the weekend during the winter period (December-February 2020), to generate a dataset about space use and movement in the area.

There were paradigmatic, climatic/cultural, and practical reasons for this decision. Practically, the undergraduate researchers on the project had a full-time class schedule during the week, so weekend observations were more feasible. Climatically and culturally, people in the Gulf Cooperation Council (GCC) Region tend to dramatically increase their use of public space after sunset, especially on the weekends, for obvious reasons, i.e., thermal comfort and more leisure

time with family and friends[1]. Paradigmatically, researchers thought building a picture of movement and space use in the public spaces of Souq Waqif during its period of highest intensity would offer a more accurate representation of its importance in Doha as a place and Qatari public life in general. During daytime hours, people tend to retreat indoors and not linger in many public spaces because of the harsh climatic conditions in the region.

The study also includes detailed computer modelling and data visualization based on the quantitative techniques of space syntax to understand the pattern of natural movement in the area, i.e., generated by the urban spatial network itself at various scales of the built environment (Hillier et al., 1993; Penn et al., 1998). It allows us to isolate better and define the added-value benefits of attraction of commercial and retail land uses in the souq.

Data collection and modelling occurred in concurrent phases during the lifetime of the research project. Every movement observation occurred for two-minute sample counts twice every hour (once in the first half-hour and the other in the second half-hour) from 6 pm to 10 pm during the weekend evenings. The first phase involved sample counts of pedestrian movement flows focusing on the perimeter access points into Souq Waqif, such as street corners and dispersion at ground level from the underground parking garages. It included directional split observations at 10 locations accounting for the number and direction (e.g., left, right, straight) of pedestrians, 13 distribution points from underground infrastructure, simple pedestrian and vehicular flow counts at 23 locations along the perimeter streets, and a count at the main vehicular drop-off area next to Souq Waqif Mosque in the geometric centre of the souq. Researchers directly counted 7,257 pedestrians and 15,781 vehicles at a total of 47 locations over three weekends during this first phase.

The second phase involved movement flow counts at 22 interior locations of the souq and video documentation from 11 elevated locations (i.e., enabling a more expansive view) focusing on the busiest movement corridors of the souq. Since video documentation helps greater accuracy for sample counts because researchers can review the video multiple times, recordings occurred for one minute twice every hour (once in the first half-hour and the other in the second half-hour) from 6 pm to 10 pm. Based on video documentation, researchers were able to compile movement flow counts at an additional 21 locations for a total of 43 movement flow counts within the interior spaces of Souq Waqif. Researchers directly counted 5,631 pedestrians over two weekends and another 5,899 pedestrians based on video counts for a total of 11,530 users. It also involved tracking the path of a typical 200 people from 18 locations during the first 10 minutes of their visit or until they reached a destination (whichever occurred first), calibrated for the distribution counts from the perimeter collected during the first phase of fieldwork. Researchers also noted that any unprogrammed street crossings occurring on the Souq's perimeter streets

[1] The Gulf Cooperation Council (GCC) consists of six countries including Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE).

throughout this phase. An unprogrammed street crossing occurs whenever someone crosses the road without using the designated crosswalks. We did not initially set out to observe this pedestrian behavior. However, researchers noted the importance of the phenomenon during the first phase of fieldwork. We then looked to quantify it for data visualization purposes. During the fieldwork, we directly observed 443 unprogrammed street crossings along all perimeter streets of the souq.

Detailed survey work about the built environment of Souq Waqif, including building heights (i.e., number of stories), ground-level land uses updating Tannous' (2020) mapping, and surveying active and inactive frontages in Souq Waqif occurred over the two stages. Some follow-up fieldwork also occurred in 2021 after the lifting of restrictions due to the global pandemic with Souq Waqif operating at 100% capacity. We define an active frontage as any façade including doors and windows (including shop windows) where an opportunity exists for potential interaction between people in the exterior spaces and building interiors of the souq, even if it is only visual awareness. Researchers also conducted demographic counts at random locations in the souq over three days, verified against counts using video documentation from the second phase. These demographic counts distinguish as best as possible based on age (elderly above 70, children under 18, and adults between 18-69 years old), gender (male and female), and nationality (Qatari and non-Qatari) using clothing and other visual indicators.[2] We observed 6,220 users based on age, gender, and nationality, verified against 5,631 users for age distinctions in video counts for a total demographic sample size of 11,581 people.

Table 1: Demographic data collected in Souq Waqif in Winter 2020 (Source: UREP25-002-5-001).

Type	Male	Female	Totals	%
Elderly (above 70)	86	18	104	**2%**
Qatari Adults (18-69)	398	376	774	**12%**
Non-Qatari Adults (18-69)	3183	1496	4679	**75%**
Children (under 18)	300	250	550	**9%**
Other	113	0	113	**2%**
Totals	4080	2140	6220	
Percentage	**66%**	**34%**		

The total population in the State of Qatar is 2,799,202, with 73% males (2,064,276) and 27% females (734,926). In 2019, Qatari citizens composed 12% of the population, with non-Qatari expatriates the other 88% (Sources: Statistica/Wikipedia/Priya Dsouza Communications). Based on the demographic sampling in Souq Waqif, 66% of users are male, and 34% are female (Table 1). Females frequent Souq Waqif on the weekend evening 26% above their general population share. Twelve percent (12%) of the users in Souq Waqif are Qatari adults, which is consistent with the percentage of Qatari citizens in the general population. When distinguishing between only Qatari and non-Qatari visitors

[2] Any person indicated as “Other" in the demographic sampling means that the field observer could not distinguish their age or nationality.

(excluding age distinctions), the percentage of Qatari citizens rises to 16.5%, suggesting that Qatari citizens frequent Souq Waqif on the weekends during winter at a higher rate (+37.5%) than their share of the general population in Qatar.

According to available data, 14% of the population in Qatar is elderly above 70 years of age (Source: World Data Atlas). We counted only 2% of the users of Souq Waqif were elderly. At first glance, it appears elderly use of the souq is well below their share of the general population. However, it is also possible this is a statistical artifact of our data collection technique. For the random sample counts of demographics, we focused on people at locations with high-volume movement flows to gather as much information as possible in the briefest time. Most spaces of the souq are pedestrian-only, requiring a significant amount of walking during visits. However, there could be more elderly present, i.e., they come to the souq, find a place to sit (such as a restaurant or public bench), and stay there for a longer time. It is likely. We did not sample static people for the demographic counts. There is also a margin of error for field workers distinguishing people's age a few years below and above 70 years old based on visual appearance only. Qatar's estimated number of children under 18 years of age is ~490,700 or 16.8% of the total population in 2021 (Source: World Population Review). The percentage of children under 18 years old observed in Souq Waqif for this study is more consistent with the general population ratio in Qatar for children between the ages of 9-to-18 years old. It is also compatible with the impression of field workers that older children visiting the souq is a more familiar experience than younger ones.

Figure 4: Pattern of local integration (radius=3) in the detailed space syntax model of all routes in Souq Waqif (outlined in white) based on the most extended, fewest lines of sight and access within the B-Ring Road in Doha (Source: UREP25-002-5-001).

Finally, a modelling phase occurred simultaneously during the fieldwork. It involved updating the space syntax model of Metropolitan Doha from 2018 to 2020 in conjunction with another research grant (QUCG-CENG-20/21-1) studying three urban areas of old Doha, including Souq Waqif. Researchers modelled Souq Waqif at various scales of the urban environment using space

syntax, including 1) principal routes only of Souq Waqif within Metropolitan Doha, 2) detailed modelling of all available routes within Souq Waqif within the urban context of the B-Ring Road, and 3) a calibrated model defining the catchment contour map of Souq Waqif within Metropolitan Doha up to three changes of directions away from all internal routes of the souq. All three models produced informative results. However, the statistical correlation of space syntax measures with various functional attributes such as pedestrian movement flows in this study relies on the model of the detailed layout of Souq Waqif within the B-Ring Road. It encompasses ~6.5 km^2 of metric area (excluding water bodies such as Doha Bay) focused on the city centre of old Doha. (Figure 4).

It consists of 744 spatial routes represented as axial lines. The pattern of local integration in old Doha highlights all the perimeter routes of Souq Waqif, composing part of the contemporary super grid (reds and oranges) in old Doha due to modern transportation planning. Banks Street has the highest levels of connectivity (29) and local integration (3.84). It is 5½ times more connected than mean connectivity (5.2) and 75% above the entire area's mean local integration (2.2). Mean depth from Banks Street is 3.5, meaning everywhere else on average is only 3½ changes of direction away within the B-Ring Road.

The longest street is the long north-south stretch of the B-Ring Road (1,567m) at the eastern edge of the model, which is 7½ times longer than the mean line length (211.4m) for the entire area. The part of Salwa Road within the B-Ring Road is not its longest, straightest stretch (like within the Metropolitan Doha model) as there is a slight deviation in its alignment between the B- and C-Ring Roads. Finally, mean step-depth from all internal routes of Souq Waqif (excluding perimeter streets) is only 2.42. On average, this means that everywhere within the B-Ring Road is only 2½ changes of direction away from Souq Waqif. Street density within the B-Ring Road in Doha is 114.5/km^2 or almost the same as the mean for European city centres (114.1/ km^2) in Major's (2015) previous comparison of twenty American and European city centres. The street density in old Doha is most like The Hague (112.8/km^2) and Amsterdam (118.1/km^2) in The Netherlands. Street density in Doha is over three times denser than the mean for 20 city centres in Major's (2018) earlier study of American cities. It is almost exactly twice as dense as Philadelphia, Pennsylvania (55.6/km^2), which was the densest American city centre for street density in that study (Major, 2018).

There is a consistent relationship between local integration and connectivity (R^2=0.59) within the B-Ring Road of Doha, in line with past findings elsewhere in the world (Hillier & Hanson, 1986; Major, 2018). There is a consistent relationship between connectivity and street length (R^2=0.45), though it is weaker than in American and European cities (Major, 2015 and 2018). There is also a robust, consistent relationship between global and local integration (R^2=0.77) within the B-Ring Road of Doha. However, the scatter of Souq Waqif within this model spreads across the entire correlation, unlike its correlation within the more extensive Metropolitan Doha

urban spatial network. It shows that the spatial structure of this traditional marketplace 'mimics the space syntax' of the larger area of old Doha within the B-Ring Road, or *vice versa*.

3 FINDINGS

3.1 Morphology and Land Use

The urban morphology of Souq Waqif emphasizes compactness in its shape, which is square-ish and covers a metric area of only 0.19 km^2. When accounting for the open plazas in Souq Waqif to the northeast and associated with the old cemetery/Al Koot Fort in the west-central area, the net metric area of Souq Waqif is ~0.15 km^2 (Khan et al., 2021). Tannous (2020) already characterized the evolution of the main and secondary spines of Souq Waqif over time (Tannous & Major, 2020; Khan et al., 2021). The main spine forms an open angle 'L' alignment established before 1952, with one arm of this spine later extending northward due to land reclamation for the construction of Al Corniche (Figure 5). By 1966, the alignment of the contemporary spine was present.

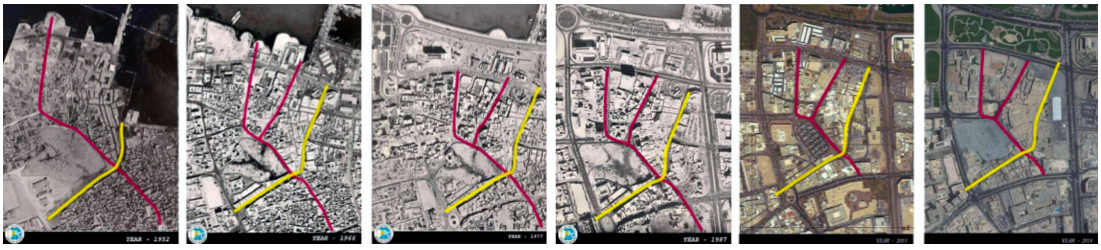

Figure 5: Aerial views of route evolution in the Souq Waqif illustrating major route consistency (with secondary spine routes in red and the primary spine ones in yellow) from (left-to-right) 1952, 1966, 1977, 1987, 2003, and 2018 (Source: Tannous, 2020).

The same was true for a secondary spine, forming a modified 'F' alignment for cross-circulation purposes at the scale of the entire souq. Souq Waqif Mosque lies at the centre of this secondary spine near the geometric centre of the souq itself. It defines near-right-angle connections at its principal intersections with a route running northwest-to-southeast, which also becomes straighter over time. The route connected directly into a southern residential area before urban renewal for the contemporary Gold Souq sometime between 1987 and 2003. Construction of the north-south Banks Street in the 1980s also made this historic connection redundant. Three segments of the main and secondary spines are routes parallel to each other and running perpendicular to the modified coastline. The macro-scale grid logic of Souq Waqif has been remarkably consistent since the mid-20th century, even as interstitial and peripheral areas of the urban fabric underwent significant redevelopment (Khan et al., 2021).

A pedestrian shed provides a simple walkability measure 'as the crow flies' based on metric distance from the geometric centre of an urban area, allowing for adjustment of specific radii for different climatic conditions. In Qatar, QU researchers typically use a pedestrian shed radius of 300-400 meters (m), or a 3-to-5-minute walk, due to the harsh, hot climate during most months of the year. In Souq Waqif, the geometric centre is the drop-off zone next to the Souq Waqif Mosque at an intersection composing the secondary spine. A figure-ground representation showing all blocks in white and space

in black serves as the basis for the pedestrian shed. The pedestrian shed shows that Souq Waqif is very walkable, with every location being easily accessible within a radius of 300 m from the geometric centre, except for the south-eastern facades of the buildings at the intersection of Banks Street and Ali Bin Abdullah Street (Tannous, 2020; Khan et al., 2021) (Figure 6).

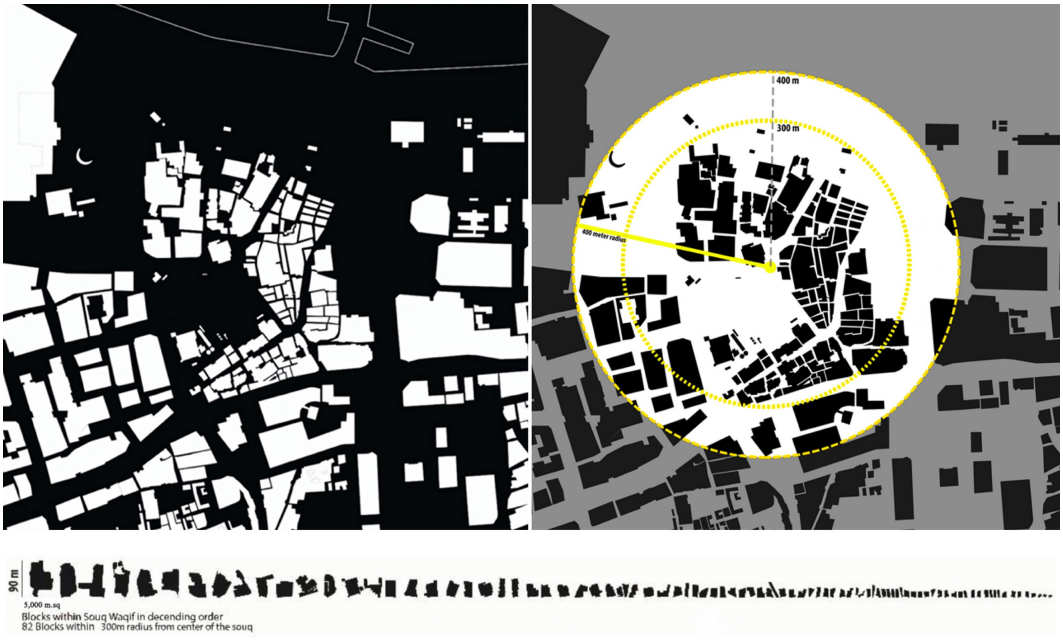

Figure 6: (left) Figure-ground representation of Souq Waqif and the surrounding context within 1 km^2 area, (right) pedestrian shed of a 3-to-5-minute walk (300-400 meters) from the geometric centre of Souq Waqif, and (bottom) rank ordering of all urban blocks and free-standing buildings within 300 m set to a standard scale in descending order (from largest to smallest) in Souq Waqif (Source: UREP25-002-5-001/Tannous, 2020/Khan et al., 2021).

A rank ordering of all urban blocks and free-standing buildings based on size and shape further illustrates the walkability characteristics of Souq Waqif. There are 82 urban blocks and free-standing structures accessible within 300 m of the geometric centre of Souq Waqif, with the most extended length of the largest urban block being only 90 m in length. It translates into an average block size of 2,317 square meters (m^2) – or 48 m x 48 m if square in shape – in Souq Waqif. This calculation is merely illustrative and does not account for the metric area available for circulation spaces nor the metric area of the large open plazas in the west-central and north-eastern areas of the Souq (Khan et al. 2021). Based on the space syntax model of the most extended and fewest lines of sight and movement (refer to Figure 4), there are 141 distinct spatial routes available in Souq Waqif. The longest interior route of Souq Waqif – i.e., not connecting from the souq to a surrounding area such as Al Rayyan Road, of which only 30% of its length is internal to Souq Waif – is the Market/Al Souq Street route. It forms part of the secondary spine around the Souq Waqif Mosque. It is ~405 m in length. It connects from Abdullah Bin Jassim Street/Souq Waqif Park at the northern perimeter through the geometric centre of the souq and large western plaza to terminate on the eastern façade of the Al Koot Fort. It is over 3 ½ times longer than the average route length (112.6 m) in the souq. Based on this, street density is about 741 streets per km^2. This street density is incredibly compact and dense (Major, 2015 and 2018). Of course, it is apparent in the figure-ground representation that block sizes scale upward significantly in the surrounding areas of old Doha. On average, it means that users will typically have access to two urban blocks and three cross-circulation routes, each with a

pavement width between 4-8 m, along the length of routes in Souq Waif.

Field observers updated Tannous' (2020) ground-level land use survey, including completing the dataset for the north-eastern area of Souq Waqif (Figure 7, left). The ground-level land use map shows the substantial number of small retail units in the oldest areas of Souq Waqif near/next to the central and northern spine routes. The larger footprints and intensity of restaurant land uses available along the southern spine are also clear, which Tannous (2020) already noted as a meaningful change in land use from the Souq's historical role after the 2004-2008 Regeneration Project (Dar Al-Handash Consultants/Shaire & Partners, 1985-86). The largest building footprints in Souq Waqif are the boutique hotels (all next to vehicular streets), Perfume/Cosmetics Souq building (the former Gold Souq) next to Banks Street, the Al Rayyan TV office space, and the Falcon Souq in the north-western area.

Figure 7: (left) Ground-level land uses, (centre) active and inactive frontages, and (right) building height survey based on the number of stories in Souq Waqif in 2020-21 (Source: Tannous, 2020/UREP25-002-5-001).

We also surveyed active and inactive frontages (Figure 7, centre). While we do not know the exact age of specific urban blocks, outward-facing blocks strongly characterize the oldest areas of Souq Waqif near/next to the central and northern portions of the main spine. Two-sided urban blocks characterize the southerly parts, emphasizing the frontage on the south spine and facing the large west plaza or Wadi Mshereib Street/Al Asmakh Street except nearest to the street intersection with Banks Street. Most inactive frontages in this part of the souq involve service alleyways and passageways, especially for restaurant land uses. In contrast, inactive frontages characterize sizable areas north of Souq Waqif Mosque and the Falcon Souq itself. However, active frontages in this area tend to involve two-sided blocks, especially in the Falcon Souq, typically opening inward towards the geometric centre of the sub-area and outward to principal surrounding routes.

Finally, we surveyed building heights (Figure 7, right). Two-story buildings primarily characterize the area intermixed with a series of one-story buildings (often the oldest ones) and 14 three- and four-story buildings, mostly boutique hotels. We attributed building height data to the axial lines with pedestrian movement flows to evaluate building heights as a factor for forecasting pedestrian movement flows in Souq Waqif. There is no statistical relationship

between building height and any other metric, spatial, or use variables. It is unsurprising since Souq Waqif has been a historical district regulating height restrictions since the 2004-2008 Regeneration Project (Tannous, 2020). The average building height along the length of all routes where we attributed pedestrian movement flow counts in the spatial database is almost precisely 2-stories (1.98), proving the effectiveness of these height restrictions. Generally, it means pedestrians' impression in movement through Souq Waqif is of a two-story urban environment.

3.2 Movement

There is an attractor effect on the main spine of the souq due to the concentration of retail and restaurant land uses. However, this attractor effect begins at the north-eastern end of the north spine with Abdullah Bin Jassim Street/Banks Street intersection. The number of people distributing from underground infrastructure at this location is significantly higher than any other in the souq that there is logarithmic distribution even when including the Doha Metro underground distribution point on the south perimeter next to Ali Bin Abdullah Street. During the fieldwork, the Doha Metro was open and working at 100% capacity before the lockdowns associated with COVID-19. The Doha Metro is the second most-used distribution point from underground infrastructure. It is also consistent with the directional split counts at the Banks Street/Ali Bin Abdullah Street intersection, where there are 1,300 pedestrians/hour. People are heading either towards the cross-circulation route accessing the south spine of Souq Waqif or further along Wadi Mshereib Street to the west.

The high use of the north-eastern underground distribution point is due to immediate access to underground parking garages under both Souq Waqif and Souq Waqif Park and the nearness of their vehicular entry/exit points to Al Corniche. However, the attractor effect is not merely an effect of the underground parking garages, as shown by the high number of pedestrians (1,334 pedestrians/hour) moving diagonally to the north spine from the crosswalk at the Banks Street/Abdullah Bin Jassim Street intersection. We discerned that the most significant distribution occurs from the eastern perimeter, emphasizing the northeast and southeast corners of the souq due to the Banks Street intersections. However, most pedestrian distribution from underground infrastructure tends to skew towards the main spine of Souq Waqif and away from the north-western areas such as the Falcon Souq.

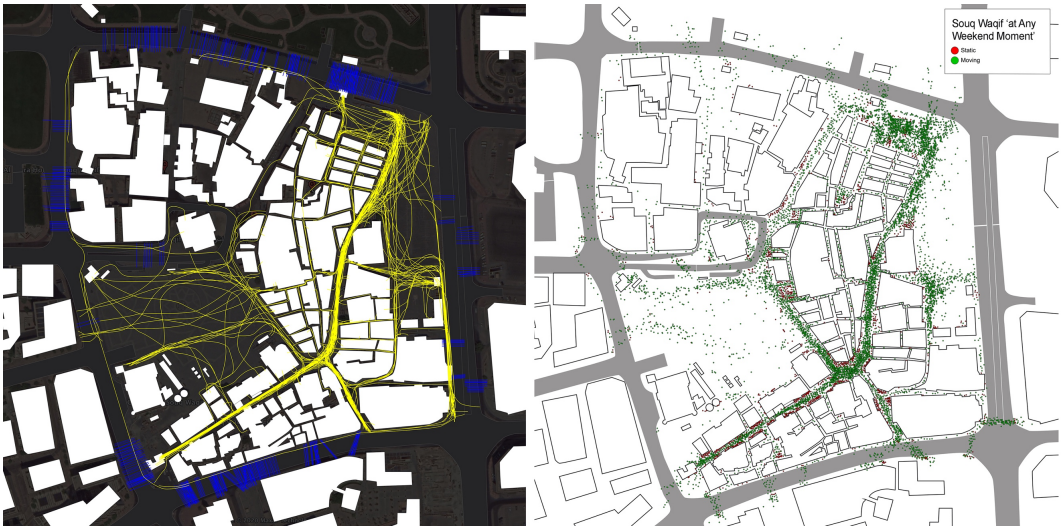

Figure 8: (left) Movement patterns of a typical 200 people from perimeter streets and underground infrastructure during the first 10 minutes of their visit or until they reached their initial destination, whichever came first (in yellow) and all unprogrammed street crossings of perimeter streets (in blue) observed during all fieldwork, and (right) qualitative snapshot 'at any moment' of the functioning for pedestrian movement (green dots) and static occupation (red dots) in Souq Waqif during the weekend evenings from 6 pm to 10 pm (Source: UREP25-002-5-001).

Based on distribution of pedestrians from the perimeter streets and underground infrastructure, field observers tracked the paths of a typical 200 people during the first 10 minutes of their visit or until they reached their initial destination (whichever came first) in the souq. Researchers calibrated the number of people for field observers to pick up at key locations on the perimeter using the percentage use levels calculated for the perimeter and underground distribution counts during the first phase of the fieldwork (Figure 8, left). Field observers then tracked their route choices from a discreet distance.

Since most access occurs from the eastern perimeter of the souq, especially to the northeast and southeast intersections of Banks Street, the movement traces skew heavily towards the main parts of Souq Waqif. It includes the main spine routes as well as the secondary cross-circulation routes from the Doha Metro underground access/Ali Bin Abdullah Street/Wadi Mshereib Street to the south and Al Souq Street along the eastern edge of the large west plaza, as well as east-west across the northeast plaza to the northern spine.

Table 2: (left) Gross total of unprogrammed street crossings at various locations during all fieldwork (Source: UREP25-002-5-001).

Name	Location/Type	Number
Abdullah Bin Jassim Street	North/Perimeter	165
Wadi Mshereib Street/Ali Bin Abdullah Street	South/Perimeter	129
Banks Street	East/Perimeter	46
Al Asmakh Street	West/Perimeter	94
Underground Garage Lane (Al Asmakh)	Entry/Exit Ramp	9
Total	**All Perimeters**	**443**

During all fieldwork, observers also marked the location of any unprogrammed street crossings on the perimeter streets of Souq Waqif. We did not systematically collect this data but merely noted it when encountering this pedestrian behavior, so the visual pattern of unprogrammed street crossings is more informative than the raw numbers (Table 2). Nonetheless, we noted 94 unprogrammed street crossings on Al Asmakh Street associated with most pedestrians taking the most direct route to/from the Amiri Diwan Mosque/parking and the Falcon Souq and to/from the southern spine of Souq Waqif and Mshereib Downtown Doha near the Wadi Mshereib Street/Al Asmakh Street intersection. There were also a few unprogrammed street crossings to/from the west plaza of Souq Waqif to Msheireb Downtown Doha, which we would expect to increase as operational and residential capacities increase in Msheireb Downtown Doha.

The most unprogrammed street crossings (165) occurred on Abdullah Bin Jassim Street to/from Souq Waqif and Souq Waqif Park. Field observers noted that many unprogrammed street crossings on the northern perimeter involved females with children, including some walking down the centre median of the road after the introduction of fencing in 2021. We also noted 129 unprogrammed street crossings across Wadi Mshereib Street/Ali Bin Abdullah Street between Souq Waqif and the Gold Souq/Al Najada. Finally, we noted 46 unprogrammed street crossings along Banks Street, which is the most difficult to cross for pedestrians due to fencing running down the centre of the street. On Banks Street, everyone crossed to the central median and walked down the road centre until they could find a place to move through the fencing. In all cases, unprogrammed street crossings involve pedestrians attempting to take the most direct route across the street instead of diverting some distance away to a marked crosswalk.

Researchers compiled a substantial amount of pedestrian and vehicular movement data about Souq Waqif during the study. As part of this focus, we produced a summary data visualization. It is a qualitative snapshot of how Souq Waqif looks for pedestrian movement and static use ‘at any moment’ during the weekend evenings. Researchers compiled this qualitative representation based on the direct observations, photographic and video documentation, and the field notes of observers. It follows the earlier data representation techniques of Major et al. (2000) for crowd situations (Figure 8, right). There is a narrow purpose for this qualitative representation, i.e., to provide a simple, easy-to-understand all at once glance at the functioning of Souq Waqif during the weekend evenings in pleasant weather conditions.

For the pedestrian movement flows, we ended the fieldwork with reliable counts at 71 locations around the perimeter and within the interior spaces of Souq Waqif. Researchers attributed this data along the length of 42 spatial routes represented as axial lines in the detailed space syntax of urban layout in Souq Waqif within the B-Ring Road. The mean movement flow along all these routes is 404 pedestrians/hour.

Figure 9: View looking north at the focal point for pedestrian movement at the intersection of the main and secondary spine in Souq Waqif during Ramadan, when everything closes, in June 2018 (Source: Authors).

The highest pedestrian volumes occur on the north spine of the souq, with 1,687 pedestrians/hour. Pedestrian flows on the weekend evenings along the length of the Souq's main spine are high, ranging between 1,400-to-1,700 pedestrians/hour. There is a small decline (-17%) in volume from north to south (1,440 pedestrians/hour). However, this may change after Msheireb Downtown Doha begins operating at full capacity and completing the urban regeneration project in Al Najada to the southwest. Pedestrian volumes on the routes of the Souq's secondary spine range from 200-to-1,000 pedestrians/hour, with the highest usage occurring to the south due to the Doha Metro entry/exit point (964 pedestrians/hour) and the lowest occurring along the Al Rayyan TV/drop-off route (218 pedestrians/per hour). However, the average lowers since this line of sight also passes into the Falcon Souq. The lowest pedestrian volumes occur in the Falcon Souq. Generally, we can say that pedestrian movement decreases from north-to-south on the main spine and decreases from south-to-north on the secondary spine with the focal point at their intersection on the central portion of the main spine (Figure 9).

3.3 Spatial Modelling

Researchers modelled and analysed Souq Waqif at various scales of the urban environment using space syntax. All models were informative, but researchers used Souq Waqif's model within the B-Ring Road boundary (refer to Figure 4) for forecasting pedestrian movement flows.

There is a strong relationship between global choice and line length ($R^2=0.63$, $p<0.001$), a consistent but weaker relationship between local integration and the linear length of total building frontages along routes ($R^2=0.47$, $p<0.001$), and a slightly more robust relationship between local integration and linear length of active frontages ($R^2=0.50$, $p<0.001$). It leads to some key findings in this study. First, there is a clear hierarchy of average pedestrian/hour

movement flows based on 1) perimeter streets, 2) the main spine, 3) principal cross-circulation routes connecting directly to the main spine, and 4) the secondary spine/access from the north. There is another hierarchy at the lower end of the pedestrian movement scale based on whether active or inactive frontages characterize interstitial passageways (refer to Figure 7, centre). In effect, the first, second, and third compose the principal routes generating the local area effect for Souq Waqif in the Metropolitan Doha model (Figure 10, insert). There is also a clear attractor effect on the main spine routes of the souq and principal cross-circulation routes connecting to it, especially the southern route accessing the entry/exit point to the Doha Metro. Hence, researchers use a logarithmic transformation of average pedestrians/hour data.

The pattern of local integration in the space syntax model of Souq Waqif within the B-Ring Road successfully accounts for 65% of pedestrian movement flows when weighting for the percentage of active frontages available along the length of spatial routes with movement counts. It means researchers measured the total building frontage and active frontage available along each axial line to set up a ratio from 1 (fully active) to 0 (blank walls). We then weighed local integration values based on this ratio so that a spatial route with 100% active frontages will keep its total value (x 1). In contrast, a spatial route with 75% active frontages would lose 25% of its local integration value (x 0.75), and so forth. We excluded the perimeter streets from this correlation since the frontage measurement on those routes only considers one side of the road. We also had to exclude the two cross-axis routes passing through the centre of the large west plaza. There are frontages available at either end of these routes; for example, in the Falcon Souq and the perfume areas of the main souq. However, more than 75% of their length is the plaza's open space. We also excluded four routes with a value of zero, i.e., the restaurant service passageways in the south part of the souq and a horse stable passageway in the Falcon Souq.

Interestingly, local integration and active frontages appear to operate in a mutually supportive manner in Souq Waqif, whereby each is a contributory factor for this significant relationship with pedestrian movement. There is a consistent but weak relationship between (log)pedestrians/hour with local integration ($R^2=0.34$, $P<0.001$) and active frontages ($R^2=0.23$, $p=0.005$). In effect, local integration and active frontages are 'stronger together' than either on their own, so local integration accounts for ~60% and active frontages for ~40% of this relationship. Nonetheless, this is a robust, consistent relationship. It represents a significant finding about the nature of natural movement in the city centre of a Middle Eastern/Gulf Region settlement (Hillier et al., 1993). In the context of Middle Eastern urbanism, where historical issues of privacy and gender segregation in Islamic cultures have led to a sophisticated formal and spatial logic for handling active and inactive frontages, these findings in Souq Waqif make sense.

At a large scale, the space syntax model of Metropolitan Doha in 2020 includes only the principal routes of Souq Waqif, i.e., main and secondary spine routes and other critical

connectors to the perimeter streets (Figure 10, left). The historic marketplace forms a well-defined local area effect in the scatter of synergy (statistical correlation between the space syntax measures of global integration, radius=n, and local integration, radius=3) in traditional terms as Hillier (1996) and others previously showed using space syntax (Major, 2018). The scatter of the Souq Waqif crosses over the slope of correlation for Metropolitan Doha into the higher ranges of local integration, showing a local intensification of the urban grid. It means that wherever you are and what you can see in Souq Waqif offers a good indication of your location in the more extensive metropolitan spatial network. There are two distinct, though still closely related, clustering of routes in Souq Waqif: the main part of the souq and the routes accessing the northern and northeast perimeter. The main souq forms a very tight correlation as a sub-system on its own within the metropolitan spatial network. The slight differentiation for the routes accessing the north/northeast perimeter is the possible consequence of the historical evolution of Souq Waqif. Specifically, the loss of its historical connection to the coastline due to land reclamation for construction of Al Corniche in the mid-20th century. However, the differences between the distinct parts of the souq are marginal, not indicative of any type of spatial dysfunction. Quite the opposite, it suggests an opportunity for the northward expansion of Souq Waqif to re-establish its historical relationship with the coastline as recommended by Tannous (2020).

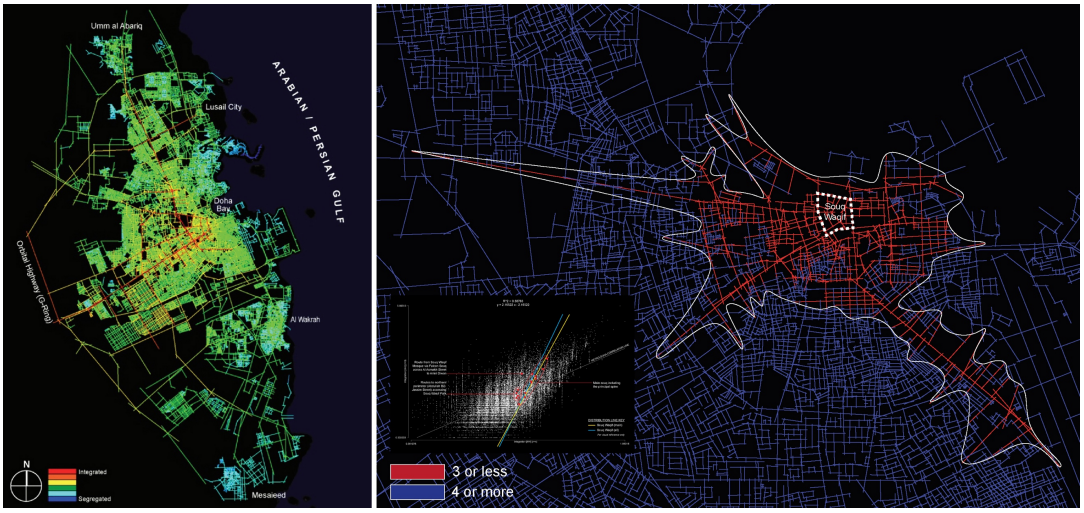

Figure 10: (left) Space syntax model of the pattern of global integration in Metropolitan Doha in 2020 and (right) catchment contour map based on all streets, represented as axial lines, within three changes of direction from the principal routes of Souq Waqif, excluding perimeter streets (Source: QUCG-CENG-20/21-1/UREP25-002-5-001) with (insert) local area effect for the principal routes of Souq Waqif within Metropolitan Doha (Source: UREP25-002-5-001).

Based on this analysis, researchers developed a catchment contour map of Souq Waqif within the Doha metropolitan spatial network. First, we select all routes internal to Souq Waqif, excluding its perimeter streets, within the Metropolitan Doha model. We run a step-depth analysis based on simple changes of direction from these routes, limiting the colour range up to only three steps in the axial map. We then draw a contour boundary linking the furthest extend of all routes within three direction changes away, being careful to naturally curve the contour between all the points

to produce a view of Souq Waqif's contextual catchment area within the metropolitan region (Figure 10, right).

From the perimeter of Souq Waqif, the catchment area directly extends five kilometres (km) to the west and nearly 2 km to the southwest, and 'as the crow flies' a little over 4 km to the southeast. It encompasses the entirety (or almost so) of the adjacent Msheireb Downtown Doha neighborhood to the west, Amiri Diwan complex to the northwest, Al Souq to the immediate east, and Old Al Ghanim (Zone 6) to the southwest. It also incorporates large sections of Al Najada to the south, southern segments of Al Bidda Park to the northwest beyond the Amiri Diwan, Mushaireb (Zones 4 and 13) further to the west and southwest, Al Doha Al Jeeeda further south, and Al Mirqab and Al Rufaa further to the east, though none in their entirety. The catchment contour map also encompasses the whole of the A- and B-Ring Roads system. Souq Waqif encompasses 0.19 km^2 excluding perimeter streets. However, the catchment contour map within three directional changes is 22 km^2 within the Doha metropolitan region or a 116-to-1 ratio compared to the size of the souq itself. It shows is the role of urban centrality at work within the spatial network via primarily radial routes, especially to the west, southeast, and southeast, to keep the locational importance of Souq Waqif as an urban centre for spatial accessibility within the expanding city (Hillier, 1999). Using Hillier's (1999) terminology, the catchment contour map of Souq Waqif forms a large 'spikey potato' reaching outward into Metropolitan Doha.

4 DISCUSSION AND FUTURE RESEARCH

In many ways, these findings are typical of those in other cities using space syntax, especially concerning the movement economy (Hillier et al., 1993; Hillier, 1996; Hillier, 1999). There are also comparable findings with other souqs previously researched in the GCC region, including Souq Mutrah in Muscat, Oman, and Souq Al Wakra in Al Wakrah at the southern periphery of Metropolitan Doha. (Tannous, 2020; Tannous & Major, 2020; Major & Tannous, 2021; Khan et al., 2021). However, there are also subtle differences in our findings on Souq Waqif. These include the necessity for weighing local integration based on active frontages percentages to validate the natural movement pattern using space syntax in Souq Waqif. Also, the distinct active/inactive frontage strategies occurring in historic and new parts of the souq, such as along the southern spine and the Falcon Souq.

There are two possible reasons for this correlation with movement flows. First, it may be a simple modification necessary due to the extensive construction work occurring in the surrounding context. It includes Al Souq to the east, continuing construction of Mshereib Downtown Doha to the west, road works along Al Corniche to the north, and closure of the Mushaireb 4 area to the southwest for a future urban regeneration project. Second, it may reflect a cultural component of the contemporary urban environment as the calibration of active/inactive frontages has become a recognisable planning strategy to compensate for privacy and exclusivity

concerns in Islamic cities instead of more traditional approaches (Tannous, 2020). The active/inactive frontage pattern in the older areas of the souq arises from a historical evolution, i.e., outward-facing blocks. The 'front and back' pattern along the southern spine, with its many restaurant land uses, relates to the servicing of these buildings. However, the inward-facing active/inactive frontage pattern in the Falcon Souq is more reminiscent of the Souq Al Wakra's building typology, i.e., a contemporary re-creation of a traditional fishing village (Kahn et al., 2021) or the contemporary development of The Pearl-Qatar in north Doha (findings forthcoming in papers by Major & Al-Amadi).

Whatever the case, there will be more opportunities to data-mine this material as part of concluding or newly awarded research projects including "The Doha Syntax, Phase 2: Urban Movement Network Validation of Space Syntax Model of Metropolitan Doha, State of Qatar" (QUCG-CENG-20/21-1) and the "Generation and Evolution of Neighbourhoods Investigated as Urban System Localities of Configurational Inequalities (GENIUS LOCI): Using Space Syntax to Understand Urban Centrality and Neighborhood Structure in Doha" QU Collaborative Grant researching eight Doha neighbourhoods. The fact is space syntax researchers will continue to dig into this data for the next half-decade, at least.

Crucially, our findings of unprogrammed street crossings do not mean there is a need for further attempts to control pedestrian behavior. Such efforts include fencing down the central median of roads like recently introduced on Abdullah Bin Jassim Street between Souq Waqif and Souq Waqif Park. Quite the opposite, we argue these unprogrammed street crossings offer compelling evidence of a need for traffic-calming measures around the perimeter streets of Souq Waqif. It would enhance pedestrians' urban environment and connectivity to and from the souq and its surrounding neighbourhoods in promoting walkability. Abdullah Bin Jassim Street has the most urgent need for traffic-calming measures due to families crossing between Souq Waqif and Souq Waqif Park in fair weather conditions. It could provide the 'seed' for beginning to re-establish the historical relationship of Souq Waqif to the coastline, as recommended by Tannous (2020) (Major & Tannous, 2020).

The STAND study significantly contributes to our knowledge about Souq Waqif and pedestrian movement patterns in a historically important area of Doha, specifically, and Middle Eastern cities, in general. The weighing of local integration for active frontages provides a critical tool for accounting for the cultural distinctiveness of Islamic settlements with their historical emphasis on privacy concerns realized in the built environment.

5 CONCLUSIONS

The traditional marketplace of Souq Waqif in old Doha has been one of the most documented, studied urban areas in Qatar. This documentation served as the background for a study bringing the observational and survey methodologies and configurational modelling techniques of space

syntax to bear on Souq Waqif. The purpose was to deepen our understanding of its spatial layout and urban functioning with data about demographics, pedestrian movement flows, static occupation of space, land-use patterns, and urban morphology. QU researchers generated a wealth of data, either directly or via video counts, with a sample size of 37,000 pedestrians the 0.19 km^2 area of Souq Waqif. Researchers linked this data to space syntax modelling of Souq Waqif within the urban context of the B-Ring Road to investigate the relationship between the urban spatial network and higher-level cultural, economic, and social outcomes. There were notable findings in the study about the spatial structure and urban functioning of Souq Waqif at various scales of the urban environment. One of the most important was a discernible attractor effect in the souq and the measure of local integration, weighted for active frontages, reliably accounted for 65% of the movement patterns in Souq Waqif.

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