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Investigating what connectivity means to different social groups in a fast-growing city - The case of Abu Dhabi

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ABSTRACT

With fast flow of capital resulting from excavation of oil reserves in Persian Gulf region, countries and cities in this region have had to adopt quick solutions to cope with demands of the growing economy. Justified by the availability of inexpensive fuel as well as harsh climatic condition the countries in this region soon began to invest in massive vehicular based development plans. This resulted in settlements merged to shape cities and connected through a network of highways. While this rigid network of roads and highways provide access to every part of the city, in lack of consistent public transport system, connectivity may be different for different areas of the city and social groups. Implementation of the car-driven development logic divides the city fabric between segments of various functions and land uses, which might be well connected through high-speed vehicular routes but are not necessarily well accessible.
This paper uses space syntax method to model the urban configuration and accessibility of Abu Dhabi and examines whether the spatial network developed through vehicular-based development provides inclusive access for all city dwellers. It uses a typology as well as demographic datasets that reflect the socio-economic condition of each of various urban blocks that are planned and built in between the grid cells, and measures how different types and classes are connected to centres of activity.

Using the measures of centrality and clustering analysis, this paper argues that the result of car-driven development strategy implemented in Abu Dhabi has benefited higher Emiratis rather than the foreign workers, and the patterns of growth in Abu Dhabi have resulted in low density urban sprawl. We argue that with the focus on car development, the access to centres of activity in the city is not equal to all residents of Abu Dhabi. The results show that the urban configuration of the city has evolved in a way that provides better access for those living mansion types in suburbs, relying on personal car use rather than those who live in apartment blocks.

KEYWORDS

Road network, Spatial configuration, Space Syntax, Housing typology

1 INTRODUCTION

With the discovery of abundant fossil fuel reserves in Persian Gulf, an influx of capital investment surged the region in a way that the face of the whole area and socio-political landscape in the region was immensely impacted and changed forever. While before this discovery the lifestyle was determined by the availability of scarce water resources and the harsh weather, the amount of money that poured in the region after the excavation of the oil reserves, not only changed the face of the cities and the built environment but also changed the manner and lifestyle as well as the order of the social structure in the region.

This massive and relatively sudden change has had a very fundamental impact on the way that cities are planned and grown in recent decades. Having to accommodate the political agenda of the new leaders and dealing with the growth of population brought about a radically new approach towards developing the cities. In the years leading to the 21st century the cities of the GCC countries all adopted a similar approach of outsourcing the planning and strategic development of the cities to the firms that followed a similar idea at their core.

The idea to engage with the global economy and removing the trade barriers and allowing for freedom of interaction (Lim, 2005) lead to the introduction of large corporations in the region that defined the priorities of the development agenda in these cities. Mainly concerned with quick establishment of infrastructure that would facilitate the booming oil industry, the new developments in these cities were planned in a way to quickly respond to these demands rather than a long-term sustainable way.

In this respect vehicular development came to be the key element in responding to necessary movement in the harsh weather, where the fuel price is not an issue. While the surging growth of establishments involved with global trade and economic development required more frequent movement, the planning rationale was based on private car movement. This primary mode of movement in these cities then becomes the central element of how the functions and certain socio-economic synergies develop. In this respect, the growth of the city and the growth of the population would become reciprocal and understanding one can explain the other. Reading through how the population is accommodated in the city can become a way to understand the evolution of the city. More specifically, the dispersion of the population in the city can be used to assess the evolution of the built environment and hence the planning acts.

In the specific case of the Abu Dhabi, where there was an immense political will to shape a city with a global panache while being able to respond to context, this assessment could be dealt with

in different ways. While the city is home to major political institutions and economic establishments, there is also a significant growing industrial sector that would require its own labour force with attributes such as housing and transport.

As a part of a bigger research, this paper examines how the urban growth of Abu Dhabi, in response to the heavy development of the vehicular-based infrastructure has resulted in an environment where the accessibility and availability of service and resources has happened in a non-equitable manner.

In this paper we argue that through examining the urban configuration of Abu Dhabi, and correlating it with the socio-economic datasets, we can conclude that movement structure and the roads network does not facilitate an equitable access to services and opportunities for residents in the city. While the evidence in this research shows that the roads infrastructure does reach out to all parts of the city, in absence of broad public transport system, the roads network functions in favour of those who are better off economically. This is specifically apparent in the case of those residing in the mansion type housing in the suburbs of Abu Dhabi as opposed to those living in labour camps or apartment blocks close to the planned city centre.

2 THEORY

Understanding the underlying causes for the growth and development in cities through evidence-based research is not always an easy task. With lack of spatio-temporal datasets that explain the growth of built environment, it would be rather difficult to explore how the development of the any settlement has happened. Significantly if this has happened in a rather fast way, and with contrast to the historic background, the motives and drivers of change are even harder to understand. However, through decades of research that looked into these issues, methods have been developed that help gain an insight into how through interaction between planning rationale and social incentives cities are shaped, and this helps to somehow interpret the underlying drivers that could have impacted this.

Reading through the historic development timeline of Abu Dhabi and setting it against the evidentiary reading of its physical fabric, a lot can be explained about the evolution and its functionality. In this specific research, spatial network is used as the medium to examine the efficacy of evolved urban configuration and measure its functionality. Therefore, we here review its historic development and will approach the physical layout of the city as evidence of its evolution and examine how the dynamics of growth have resulted in its status quo.

2.1 The historic background to Abu Dhabi's growth

Quick expansion of oil industries in Persian Gulf put the countries in this region on a path to fast transition to modernization. While established practices of inward, local-oriented responses (Saleh Al-Mohannadi & Furlan, 2018) to growth in the cities would have had little success addressing the scope of envisioned growth, approaches based on a justification of rapid city planning focused on connectivity and attracting flows was adopted among the cities of the region. Heavily depending on international planning firms, and their imported ideas regarding sustainability and growth, (Saleh Al-Mohannadi & Furlan, 2018) the planning and development in these cities are generally characterized by mega projects and car-centred infrastructure developments.

Like most of the cities in the region, the same strategy was adopted at the core of planning in Abu Dhabi, where the availability of cheap oil, harsh weather, and a tendency for creating a global city resulted in rapid sprawl facilitated by highways and multiple-lane roads. This dependency on cars has been described and justified as to be pertaining to lack of other possible modes of transport (Saleh Al-Mohannadi & Furlan, 2018) which has pushed the sprawl in this context to the extreme.

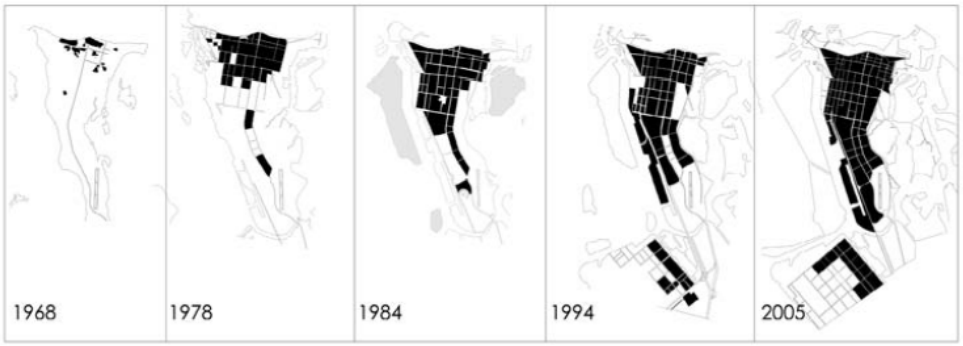

Figure 1 Abu Dhabi's changing urban morphology from 1968 to 2005 (Elsheshtawy, 2008)

This quick approach has affected the fundamental functionality of the city in many ways, that in turn would not fit the initial descriptions of a global city as well. While having the worst carbon footprint and highest greenhouse emissions per capita (Crot, 2013; Davidson, 2005; WWF, 2008) and a lifestyle trait that forces all the planning policy to facilitate it (Crot, 2013) the city has also received a large number of immigrants who take part in the everyday dynamics of change and growth in the city.

While the population growth rate has decreased substantially from 4% in 2007 to 1.49 in 2020 (IndexMundi, 2021) there is a major divide in the ethnic diversity with most of the dwellers in Abu Dhabi coming from South Asia, India and Pakistan (Ibrahim, et al., 2016; IndexMundi, 2022) this has also reflected in the way the city has grown before 2007. Evident in the way that the city has grown substantially to accommodate this growing population, this growth does not happen in the same way for all the social classes that have emerged as a result, and the urban

sprawl, enabled by the car driven planning strategies and the road infrastructure has not resulted in an equitable development in the city.

The variety of housing types generated in response to the demand and accommodating the growing population would also show that there are generally two separate housing markets in the city based on the population's ethnicity and income groups: houses of the high-income groups (mainly nationals) and houses of the middle and low income groups (mainly expatriates) (Ibrahim, et al., 2016). This disparity and gap in the housing market, is not only evident in the housing typology but in the way each of the types have been distributed in the city.

With most of the population depending on private vehicular movement, the idea and the implementation of the road network have shaped the city in favour of those with better access to cars. The impact of the road network in the generation of functional urban space, has been less subject of scrutiny and thus, quantitatively assessing its functionality and how it has been shaping the social structure is the subject of the next section.

2.2 Spatial network as a medium for examining the city functionality

While the idea of planning settlements may suggest that the outcome can be completely pre-designed and determined, the natural evolution of new cities would imply otherwise. With a relatively considerable history, what is now known as Abu Dhabi today has been the product of hugely investing in a city that corresponds to an image of a global city and planning for quickly transforming a fishing village into the capital city of a wealthy nation. This process of planning for the city which relied heavily on car-centred infrastructure has produced a city with a multitude of layers of road and highway networks to facilitate the demands for global economy and trade. While the distribution of certain land-use and functions in the city and the economic turn-over would imply the efficiency of this network, the social and political impacts of this network as civil construct may prove otherwise.

Given that this spatial network is the only material that has captured all the changes through the various periods of time when the new Abu Dhabi was being built, it can be used to study its efficiency in addressing an equitable development. And with the recent studies in the relationship between the social construct and the spatial configuration, this road network can be directly used as the medium to account for the emerging city.

This investigation would be based on the extensive body of research known as space syntax that would study activity and space in relation to each other and that suggests that the human communities are essentially spatial phenomena (Hillier & Hanson, 1984, p. 26) and that space both arranges itself (by means of buildings, boundaries, paths, markers, zones and so on) and people in it (in relation to each other and in space) (Hillier & Hanson, 1984, p. 27). Thus, the evolution of societies and the space they occupy are also captured in this spatial phenomenon and

through understanding the space and the relations embedded in it, one could also understand the relation in the social structure as well. This is where space syntax appears in this research as a set of tools and theories that were developed to illustrate these relations as well the correlation they may have with the economic, social and political processes in the built environment.

While most theories in this stratum of research focus on the function and utilization of space to explain the social relations, space syntax suggests that the urban grid i.e., natural movement corridors (Hillier, et al., 1993) is what governs growth, development and change in the physical form of the city and hence modelling the social relations in it. In this respect the extent to which segments of urban grid is central to the rest of the overall *configuration* influences the functionality of space and how the occupying society would react to it.

The central element to this rather elaborate idea is the way movement takes place in the built environment, and the influence movement has on the long-term evolution of the urban surface (Hillier, 2000). According to Hillier movement has an impact on spatial relations on two scales, where on the global level the movement generates pattern of centrality through which a degree of integration is appropriated with respect to the settlement as whole, while on the local level the degree of centrality is dependent on the local grid condition (Hillier, 2000).

This becomes important as one begins to look at the spatial network as a set of local and global relations and can understand that there is a way to decompose the network segments and categorize them in terms of their centrality and their degree of integration in the network. According to the space syntax theory this degree of integration is comparable to the spatial economic, and social processes that take place in the city and therefore this configuration can identify the location where it is more likely that people tend to confront, interact and a societal exchange is possible.

It has been shown through research that the locations with higher integration value are more likely to be where new economic synergies emerge and accordingly is more likely to accommodate the destinations where the public might aim for. As this can be shown through correlation between the land-use, function and spatial network analysis, the scale to which this is calculated shows the degree to which the *anticipated centre* is relative to possible outreach distance. In other words, the centrality measures calculated through space syntax i.e., closeness centrality (Sabidussi, 1966) and betweenness centrality (Freeman, 1977) would identify the relative centres relative to the scale of analysis and could be attributed to local or global rules. The significance of this analysis in this research is to assess the spatial network which is primarily planned through imposed vehicular-based logic and identify the centres relative to local or global relations. The degree to which these centres of encounter, activity, and exchange – which are governed by the planned configuration – are spatially distributed can be assessed and measured against the spatial dispersity of different social groups. Given that accessibility in the

city of Abu Dhabi is categorically car-dependent, this assessment would identify whether the planned road network serves the same function for different social classes or not.

3 DATASETS AND METHODS

To explore the above-mentioned idea, this paper employs open-source data and data collected from previous studies on the area (Rode, et al., 2017), as well as tools and methods to model and implement analysis on the urban configuration of Abu Dhabi in its current status. It uses space syntax road segment analysis, through different radii to explain the functionality of the urban configuration as the generator of movement and activities. This model is set against a dataset of housing typologies which serves for this purpose, and in the absent of data, as a proxy to socio-economic conditions of different communities living in the city. The following, explains these along with the methods of analysis, in this research:

3.1 Road-centre line segment model

The main component of the dataset in this analysis would be the road network which shows the lines of movement and accessibility in Abu Dhabi. This dataset in its primal form represents the axis as well as the lanes through which vehicular movement is possible and frequent. And given the method through which this data has been generated, it is an accurate representation of the purposely built and autonomously grown paths through which the public moves in the city of Abu Dhabi. This representation of the movement, encounter and activity shapes the core argument in modelling the road network in this research and is based on the logic that informs the generation of places and establishment (Hillier, 1996).

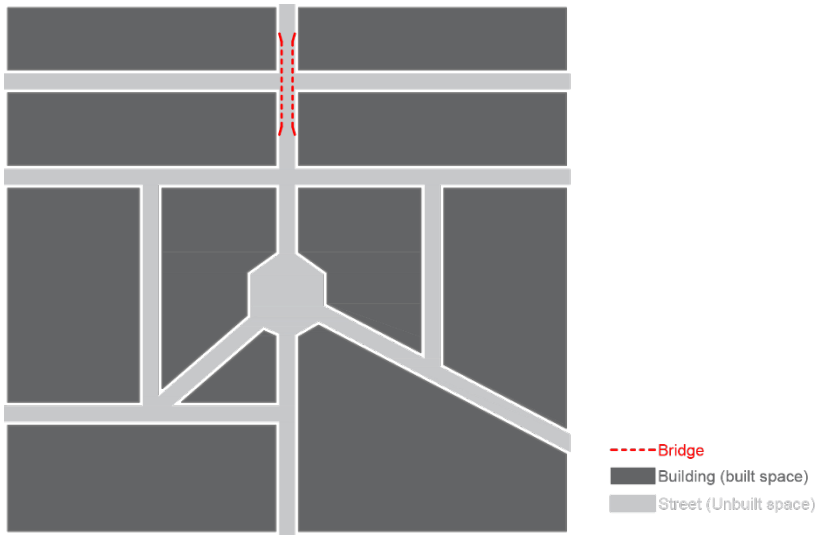

Figure 2 A hypothetical scenario for representing urban space

Therefore, the general configuration of the built environment could to some extent reflect the way in which social behaviour was shaped and created in it. As Hillier points out human-built environments can be seen as stocks of buildings linked by space and infrastructure and functionally, they support economic, social, cultural, and environmental processes (Hillier,

1996). Thus, an analysis of the network could reveal the capacity and potentials of the roads as well as the functions and activities they accommodate.

Given the availability of spatial data produced in relation to the frequent movement of people, this dataset has an accurate representation in detail (fig 3) and update frequently with both autonomous cellular data as well as user edits. The datasets used in this project is derived from the available resources of *OpenStreetMap* movement lanes which are frequently updated and categorized into different dataset via the *Geofabrik* geodata base. (OpenStreetMap, 2020)
This movement data which represents the lines of movements in detail is cleaned in a way that each access line is reduced and represented through one single line that is limited between junctions. In this model each road is comprised of multiple co-continuous lines between sections and represent possible movement that is not obstructed. These lines ideally represent the geometric centre of the public rights of way network, a transportation network of all paths on which the public have a legally protected right to pass and re-pass (Krenz, 2017). This categorical dataset then goes through a cleaning and simplification process (fig 4). The resulting model which represents all the possible move-through spaces through single lines and therefore each segment carries all the possible analysis values and not have it divided between unnecessary parallel or intersecting lines.

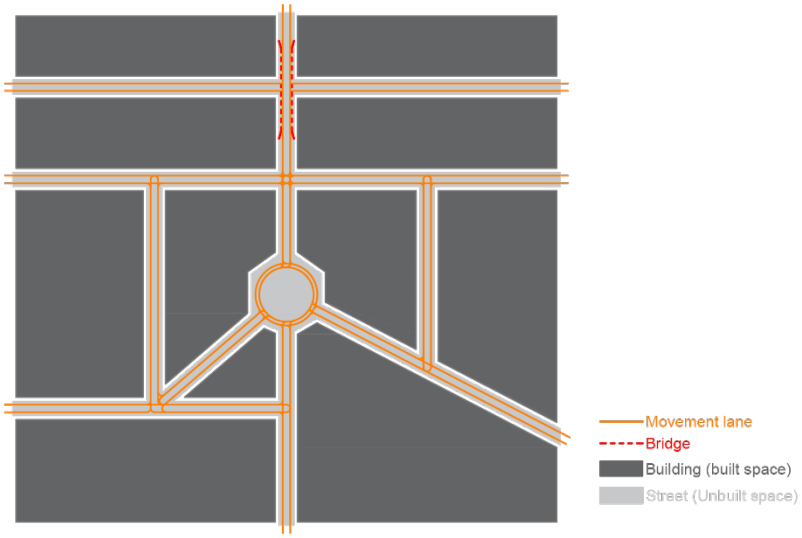

Figure 3 Movement data showing parallel paths of movement in roads

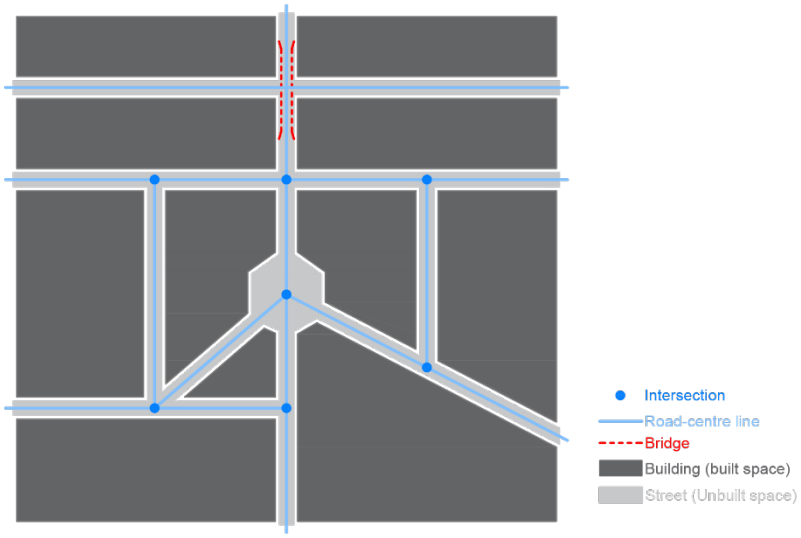

Figure 4 Road-centre line model, created from movement lines, and broken at intersections

The model selection and defining the extent of the model is based on the official municipal and administrative boundaries of Abu Dhabi (Rode, et al., 2017). Given that the expansion of this region has happened in a quick manner, this study tends to explore where the movement and accessibility impacted the development of the built environment, and how the road network and the configuration of the system in translated into connectivity. On the other hand, it can also show whether the road network provides a consistent accessibility for all the various zones, functions, and types in the city, and whether the road network does act as a barrier for certain parts of the network.

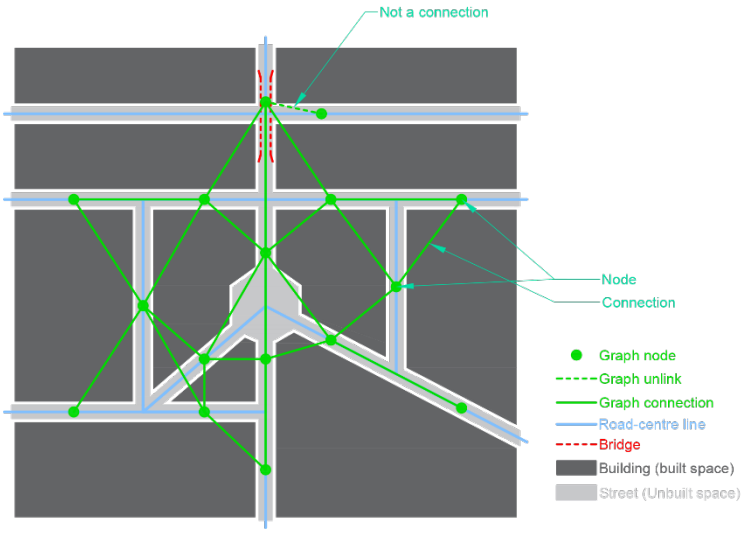

Figure 5 Dual graph created from the road-centre line model

This model is then run through space syntax analysis software *DeptmapX* (Turner, et al., n.d.). The software takes the simplified geometry of the urban configuration and uses each road segment as a node in a dual graph (Thulasiraman & Swamy, 1992; Volchenkov & Blanchard, 2007) that fundamentally shows how each segment is connected to other segments (fig 5). This is the graph representation of the space in a way that each road segment is a node in the graph and each connection that the node has would be a vertex in the graph. Later analysis is derived from

this basic understanding the road segment model and how this representation shows the direct relationship between spatial configuration and human activities or functions (Karimi, 2012).

3.2 Housing typology dataset

To assess the relation between the urban configuration of the city, the road-centre line model that is used to explain the spatial qualities of space in relation to movement and aggregate human activity is set against a dataset that classifies the urban blocks in Abu Dhabi according to their typology, use and physical condition. Based on previous that suggests that the class divide in the GCC and specifically in Abu Dhabi is reflected in the housing typology (Ibrahim, et al., 2016), this assessment uses this typology dataset to analyse the distance and accessibility of different social classes to possible centres of local or global activities.

This dataset was produced and used as a part of research project *Resource Urbanisms* of LSE Cities, at the London School of Economics and Political Sciences (LSE) (Rode, et al., 2017) and categorizes the housing typologies in terms of their physical type, as well as their distribution, era of construction and their proximity to certain natural, or built features of the city such as waterfront, suburb, etc,. While according to the laws and regulations in the UAE the land could not be sold to non-Emirati citizens until 2004, with the change in political agenda of the governors of the city the land as well as housing can now be appropriated by the foreigners and expatriates, and the socio-economic divide in the city has created two housing markets in the city, based on population ethnicity and income class. (Ibrahim, et al., 2016). The disparity of these housing typologies and social classes within the city, facilitated by the roads network is assessed in this research.

3.3 Space Syntax analysis

The cleaned and simplified road-centre line model that is run through DepthmapX to generate a dataset of centrality measures for each of the segments across various measures and radii. These centrality measures specify how each segment functions within a wider context in terms of accommodating movement to, or movement through it. In this study the centrality measures *closeness centrality* and *betweenness centrality* (Freeman, 1977; Sabidussi, 1966). This analysis shows that how each segment is facilitating movement and activity and therefore how it relates to other segments. On the other hand, as the analysis calculates the centrality measures for each segment, the result can be used to compare different segments.

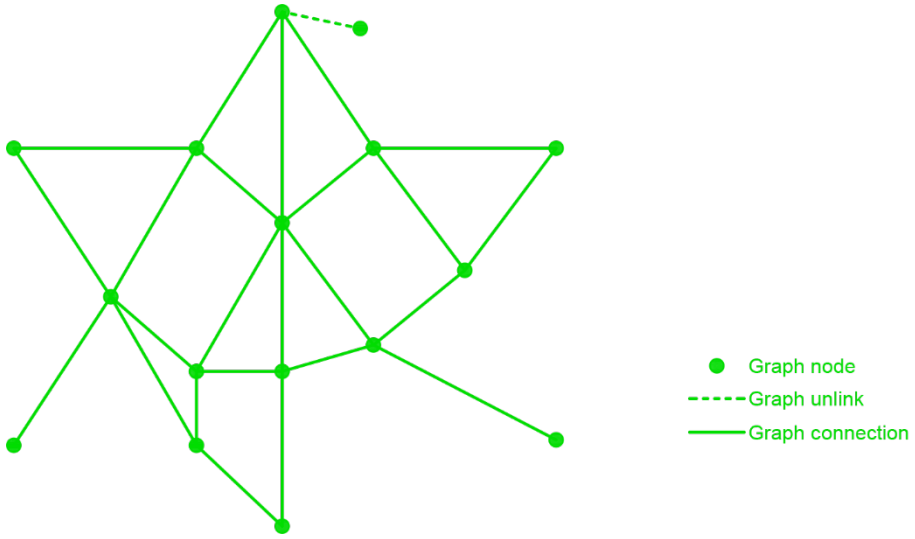

Figure 6 Dual graph representation of a spatial network that Space syntax's analysis is based on

This analysis in a single system can explain how each segment is functioning within overall system, while through the initial outcome of analysis for each radii the comparison is possible within the same system. Therefore, any cross-system comparison would require normalization. In this regard the space syntax analysis in this study uses unnormalized form of the analysis results as only one system of the study has been used and any comparison between parts is done on the same analysis outcome.

Given the nature of the study that explores multi-dimensionality of built space and uses the cross-scale characteristics of the built environment shaped by aggregate behaviour of citizens, reviewing, and performing single measure comparison will not explain these characteristics. Thus, the dataset formed of various measures and through micro to macro radii centrality analysis then becomes a basis for further investigation that investigates compiling measures. The significance of this part of the analysis is to identify, which part of the system would perform similarly through different scales while being apart.

This is achieved through using the space syntax measures and database as a foundation to explore the clustering index and see how unsupervised machine learning algorithms would associate these single measure characteristics.

3.4 K-means Clustering algorithm

The K-Means algorithm (MacQueen, 1967) used in this study to identify clusters that can be construed as urban types, is a popular data clustering method with variety of applications. The basic idea of the K-means clustering is that given an initial but not optimal clustering, relocate each point to its new nearest centre, update the clustering centres by calculating the mean of the member points and repeat the relocating-and-updating process until converge criteria are satisfied (Sammut & Webb, 2017). This algorithm can be scripted as:

$$\arg\min \sum_{i=1}^{k} \sum_{x \in S_i} \| x - \mu_i \|^2$$

Given a set of data points (x_1, x_2,…,x_n) where each of these data points have d-dimensions (in this segments are the datapoints and the centrality measures are the dimensions), the algorithm aims to partition the set of data points into k ($\leq n$) clusters ($\mathbf{S} = \{S_1, S_2, \ldots S_k\}$) in a way that within each cluster the sum squares (variance) is minimized. Here μ_i is the average points in the S_i and the formula repeats until the variance is minimized.

Given this specific study, the method is used to cluster nodes of activity that are geographically relevant to each other, and through this determine the polls of active centres in the city.
This happens through an iterative process, through which the centroid of the top 10% of the segments with high closeness centrality values are grouped together to determine the optimum number of the clusters. Each cluster of these points would then shape a convex hull that would be interpreted as one whole activity centre. Later the distance from the various types of urban blocks to these centres are measured to assess how far different types of blocks are from the activity centres.

4 RESULTS

Processing the RCL model through space syntax analysis, the model is clearly showing a rigid network of roads and highways that facilitate the movement in the city (fig7), based on a model depending on cars. Given the car-centric nature of the roads and highways, along with the planning logic and climatic limitations that do not address the harsh warm and humid weather, cycling and walking along and/or across this network is simply not a favourable option. Thus,

driving is the obvious choice for those who can afford to drive.

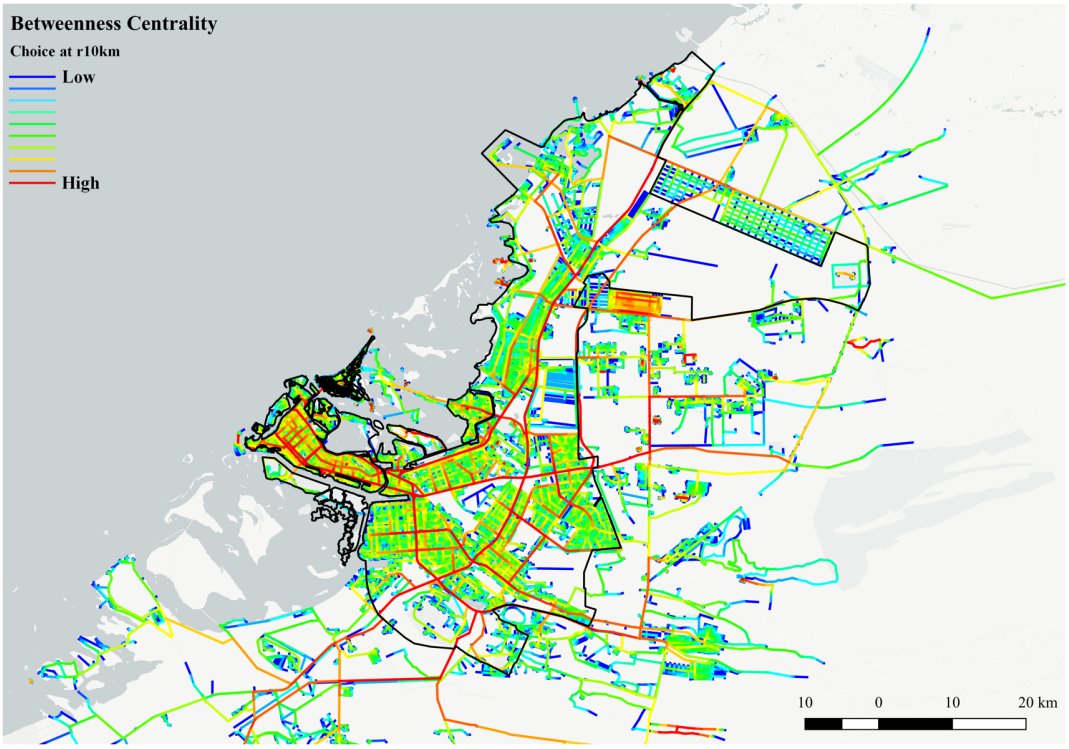

Figure 7 Betweenness centrality map of Abu Dhabi Rn, showing a rigid planned network of highways that have created islands of city blocks that are not accessible by any mean other than cars

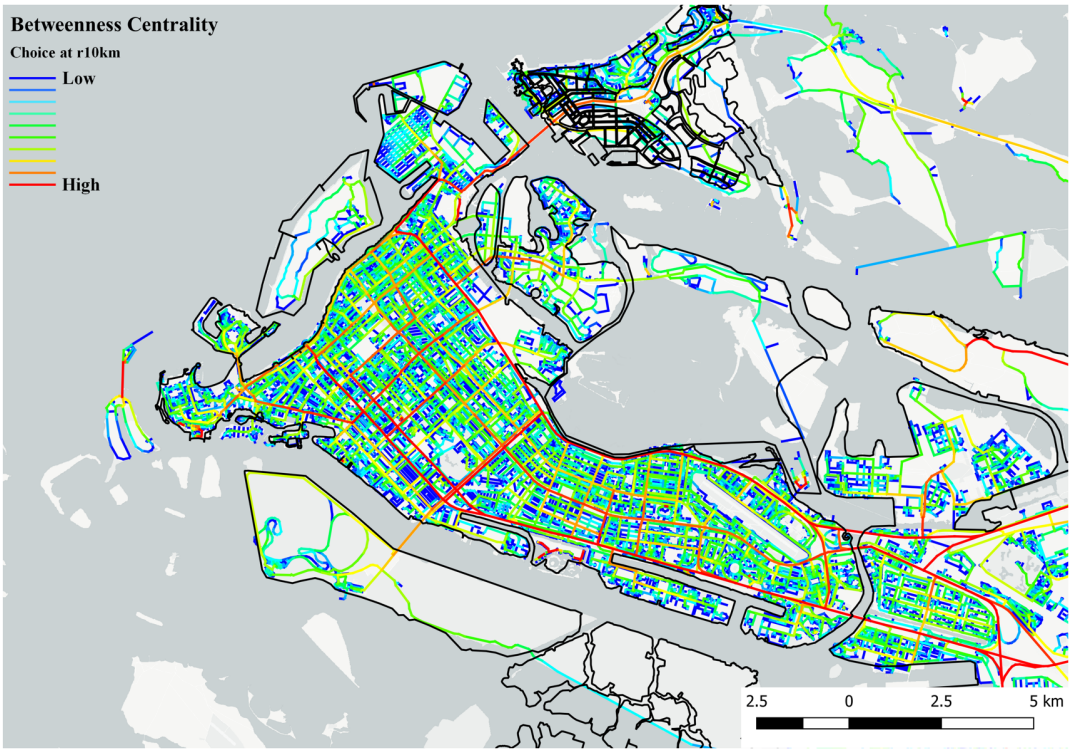

Figure 8 The main island, where it used to be the old city of Abu Dhabi is replaced with a rigid grid of road and highways to accommodate the growing business profile of the city

As this rigid grid of highways and road networks was planned to facilitate the ambitious image of a global city, major centres of activity and business have been planned along this network, which can be observed through the closeness centrality analysis maps of the city. In this respect the old city of Abu Dhabi has been replaced by a dense grid of roads, which would serve the global flow of businesses as well as the royalties that have been historically settled in the main island.

The dynamics of the growing city, facilitated with this network of road and movement corridors has incrementally defined an unprecedented urban/suburban neighbourhood zoning with different profiles that are reflected in the mentioned housing typologies of the city. While the impact of spatial configuration can be assessed on different parameters, such as land-use etc, in this research the housing typology have been set to be measured against the centres of activities that have been generated through the road network configuration n as the main indicator of the efficacy of the planned network.

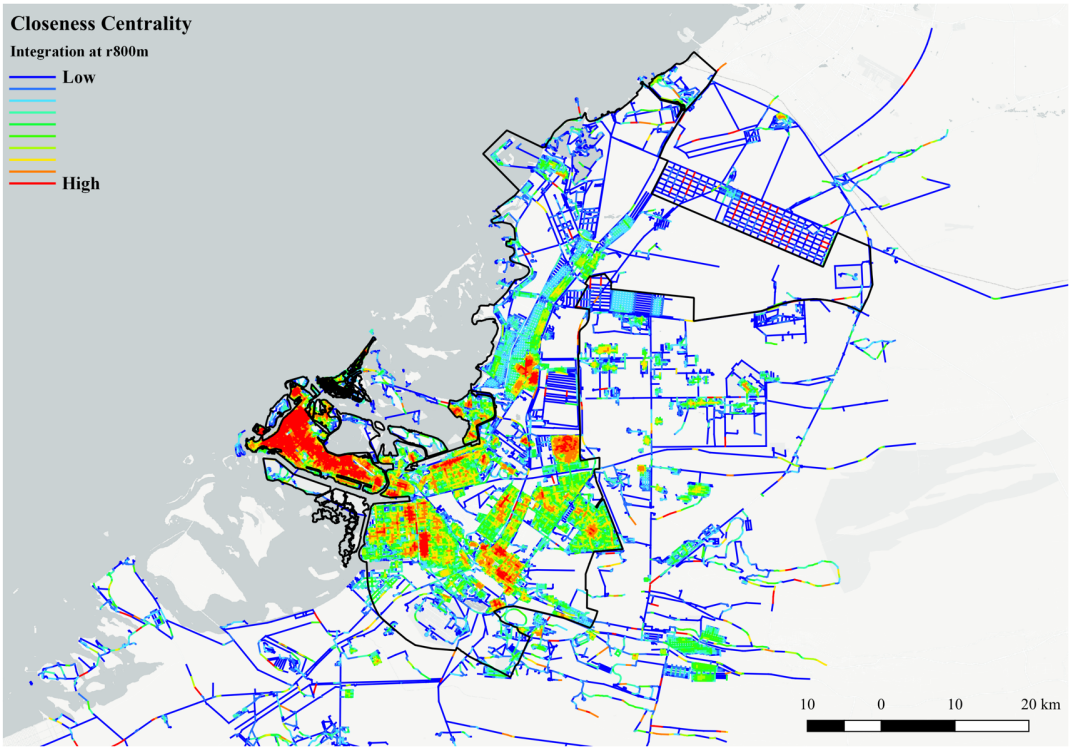

Figure 9 Network integration at r800m, showing centres of activity that have been generated through the overall network

With the majority of the active centres grown on the main island, the closeness centrality analysis at 800m radius shows that other local centres have also been generated throughout the fabric of the city. For this research the top 20% of highly integrated lines in this model i.e., the hot spots or centres of highly concentrated movement lines have been selected out of the model, and then put through a process of clustering – K-means clustering algorithm – which groups them according to their proximity to a centre point depending on the number of anticipated processes. Based on the local radius analysis (r800m), and through an iterative process, the algorithm picked 25 clusters that each create a convex hull that contains a group of highly integrated segments that

would potentially accommodate most of the activity centres, meeting points, points of interests and opportunities etc.

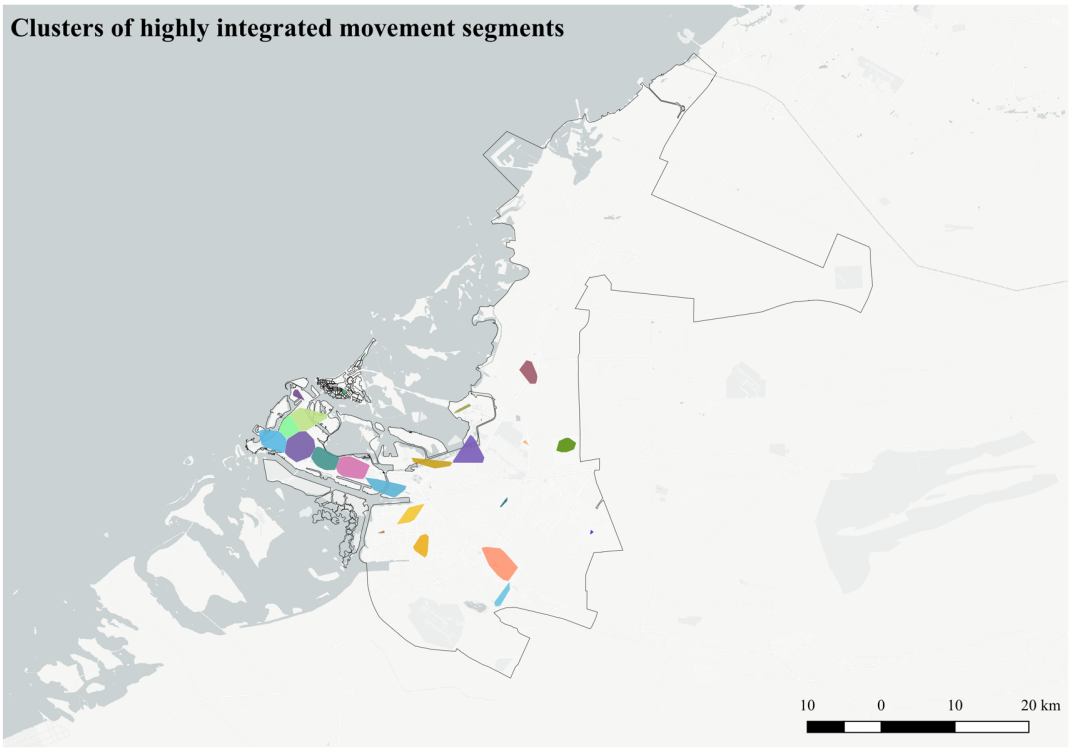

Figure 10 K-means algorithm picks the points that are within a close proximity of a centroid point and clusters them together. In this iterative process it has picked 25 clusters that each contain a group of highly integrated lines in the spatial network that have been highlighted through integration analysis at r800m and shows the local centres of possible activity and encounter that are accessible within 800m movement.

The accessibility of these active cores was measured against the centres of urban blocks with different typologies and a distance matrix was produced to measure how far each dominant block typology is in relation to the local and/or global integrated activity cores. This process was repeated for distance matrices from the block centres to local integration cores (r800m and r1200m) and global cores (r5km and r10km).

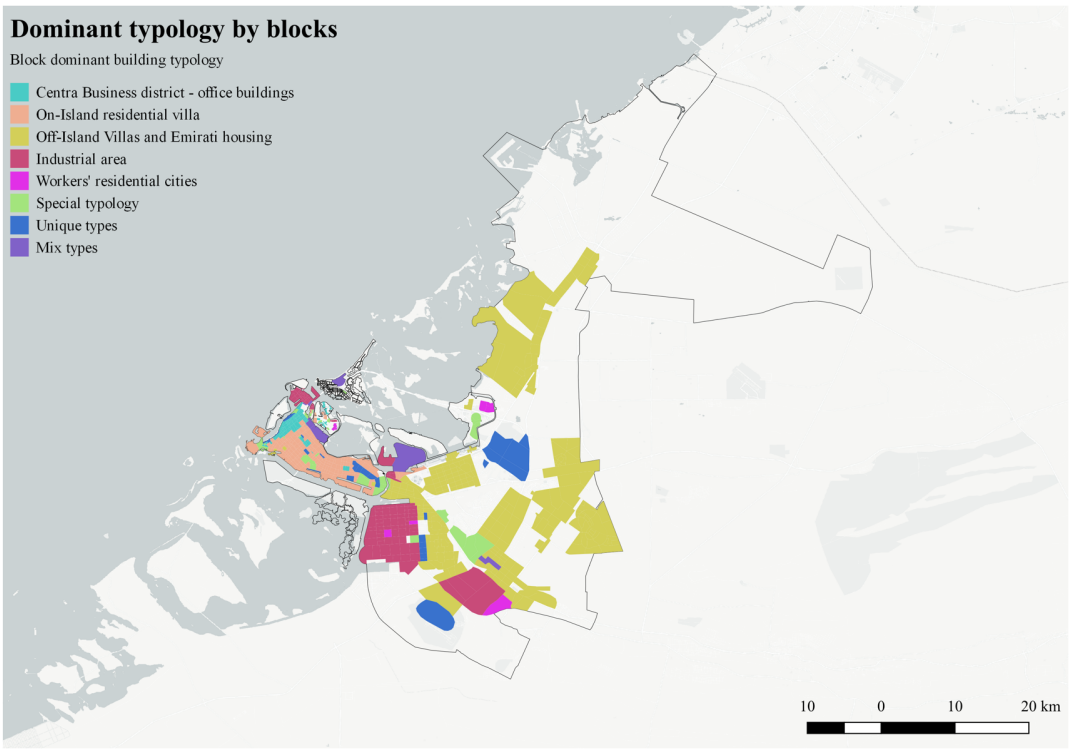

Figure 11 Categorization of urban blocks based on the dominant building type and use

The distance matrix shows that on average planned villas are further (i.e. off-island villas and Emirati housing) are further away from these integration cores. While at a local level most of the typologies seem to be similarly distanced from the evolved cores, the off-island villa type which happen to be associated to The Emiratis are further away. This is even more severe in analysing the distance to meso scale analysis (r5000m INT core) where there is a bigger gap of the average distance between this type and the rest.

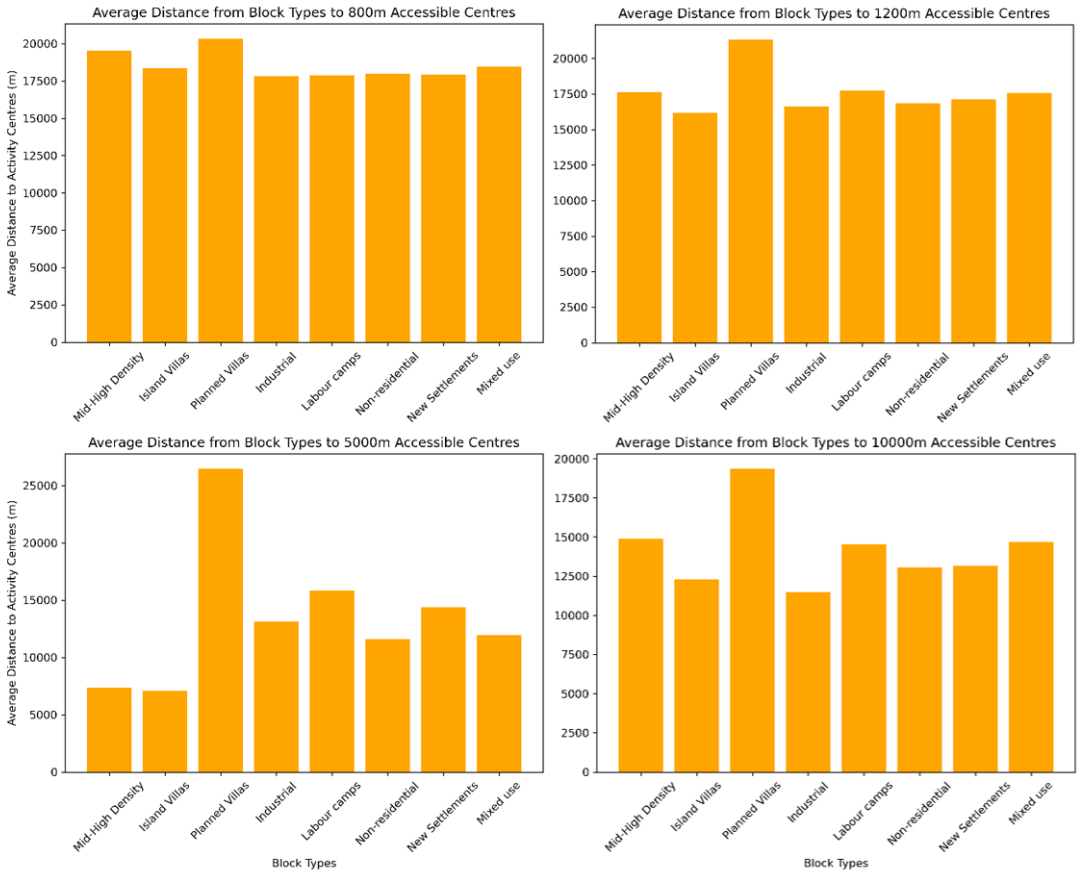

Figure 12 Average distance to the integration cores for different urban block types and different radii of movement

In-spite of the graphs that suggest that the block with typologies associated with the lower and middle economics class are closer to the integration cores in the city, one must consider that with the harsh climatic condition as well as lack of inclusive public transport, it would be unlikely that these integration cores are travelled to on foot or through public transport. This would in turn suggest that the dispersity of the upper-class Emirati housing blocks, whose settlers have access to private cars would have better access to the integration cores.

As discussed previously the spatial configuration, and accordingly the planned road network would facilitate the evolution of change and concentration of functions and activities. In this regard it can be argued that through this process the roads network in Abu Dhabi have facilitated in a way that the access to the integration cores is just as possible for the upper class that live further away, and with lack of other means of transport, this road network is at the advantage of the upper class.

5 CONCLUSIONS

As discussed briefly here, the fast development resulting from the influx of investment in the cities of the GCC countries, along with the global ambitions of the rulers of these city-states, a set of similar planning strategies have been adopted that relied heavily on vehicular movement.

These strategies that would address the sudden flow of businesses and incoming immigrants in the quickest way possible, have shaped the current state of the cities of the Persian Gulf region. Abu Dhabi specifically have grown through using a rigid network of roads and highways that would both address the demand for vehicular transport in the harsh weather and is suitable with the available cheap oil prices.

On the other hand, with the shortage of labour in the country a significant number of worker immigrants have entered the country. Since the neighbourhoods are dominantly homogeneous in their occupation by different types of demographics (citizens, non-citizens and low-income workers), the roads by segregating neighbourhoods are segregating these demographics. This spatial segregation along with the limiting regulations which had prohibited the appropriation of land by the foreigners and expatriates, have created dispersed city fabric of urban block with different housing typologies that reflect this socio-economic divide.

Having analysed the spatial network of the city as well as the disparity of these housing blocks, it can be argued that the city planning, and the roads infrastructure, have been developed in a way that facilitates the movement for the Emiratis, but also locks them into using a car. Reading through the distance matrices that show the average distance between different housing/building types to the cores of integration where most activities and opportunities may arise, it is clear that the roads network would facilitate the access of the Emiratis, in-spite of the longer distance.
In other words, it can be argued that that considering all possible modes of movement, it is the private car owners that are benefitted from this network, and given the rather unwalkable conditions, and lack of public transport, it is the upper class that the city's road network is planned for. Accordingly, this would suggest that despite the frequent, and rigid infrastructure, the roads network does not provide equal accessibility to functions and opportunities for all social classes.

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REFERENCES

Crot, L., 2013. Planning for Sustainability in Non-democratic Polities: The Case of Masdar City. *Urban Studies,* 50(13), pp. 2809-2825.

Davidson, C. M., 2005. *The United Arab Emirates: A Study in Survival.* United Kiingdom: Lynne Rienner Publishers.

Elsheshtawy, Y., 2008. Cities of Sand and Fog: Abu Dhabi's Global Ambitions. In: Y. Elsheshtawy, ed. *The Evolving Arab City: Tradition, Modernity and Urban Development.* New York: Routledge, pp. 258-304.

Freeman, L. C., 1977. A Set of Measures of Centrality Based on Betweenness. *Sociometry,* Volume 40, pp. 35-41.

Hillier, B., 1996. Cities as movement economies. *URBAN DESIGN international,* 1(1), pp. 41-60.

Hillier, B., 1996. *Space is a Machine.* Cambridge: Cambridge University Press.

Hillier, B., 2000. Centrality as a process: accounting for attraction inequalities in deformed grids. *Urban Design International,* Volume 3/4, pp. 107-127.

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

Hillier, B., Penn, A., Hanson, J. & Grajewski, T., 1993. Natural movement: or, configuration and attraction in urban pedestrian movement. *Evironment and planning B: Planning and Design,* Volume 20, pp. 29-66.

Ibrahim, H., Salama, A. m., Wiedmann, F. & Awwad, R., 2016. A comparative assessment of housing dynamics in Abu Dhabi and Doha. *International Journal of Architectural Research,* 10(3), pp. 152-169.

IndexMundi, 2021. *Population Growth Rate in UAE.* [Online]
Available at: https://www.indexmundi.com/g/g.aspx?c=tc&v=24
[Accessed 17 11 2021].

IndexMundi, 2022. *United Arab Emirates Demographics.* [Online]
Available at: https://www.indexmundi.com/united_arab_emirates/#Demographics
[Accessed 7 1 2022].

Karimi, K., 2012. A Configurational Approach to Analytical Urban Design: 'Space Syntax' Methodology.. *URBAN DESIGN International,* 17(4), pp. 297-318.

Krenz, K., 2017. *EMPLOYING VOLUNTEERED GEOGRAPHIC INFORMATION IN SPACE SYNTAX ANALYSIS.* Lisbon, Lisbon Instituto Superior Técnico, Departamento de Engenharia Civil, Arquitetura e Georrecursos, pp. 150.1-150.26.

Lim, G., 2005. Globalization, spatial allocation of resources and spatial impacts: A conceptual framework. In: H. Richardson & C. Bae, eds. *Globalization and Urban Development. Advances in Spatial Science.* Berlin, Heidelberg: Springer.

MacQueen, J., 1967. *Some methods for classification and analysis of multivariate observations.* Berkeley, University of California Press, pp. 281-297.

Meadowcroft, J., 1997. Planning, Democracy and the Challenge of Sustainable Development. *International Political Science Review,* 18(2), pp. 167-189.

OpenStreetMap, 2020. *GCC states region data,* s.l.: Geofabrik.

Rode, P. et al., 2017. *Resource Urbanism; Asia's divergent models of Kuwait, Abu Dhabi, Singapore and Hong Kong,* London: London School of Economics and Political Sciences.

Sabidussi, G., 1966. The centrality index of a graph. *Psychometrika,* Volume 31, pp. 581-603.

Saleh Al-Mohannadi, A. & Furlan, R., 2018. THE PRACTICE OF CITY PLANNING AND DESIGN IN THE GULF REGION: THE CASE OF ABU DHABI, DOHA AND MANAMA. *International Journal of Architectural Research,* 12(2), pp. 126-145.

Sammut, C. & Webb, G. I. eds., 2017. *Encyclopedia of Machine Learning and Data Mining.* s.l.:Springer US.

Saramaki, J. et al., 2007. Generalizations of the clustering coefficient to weighted complex networks. *Phys. Rev. E,* February, 75(2), p. 027105.

Stiglitz, J. E., 2002. *Globalization and Its Discontent.* W.W. Norton, Incorporated: Stiglitz, 2002.

Thulasiraman, K. & Swamy, M., 1992. *Graphs theory and algorithms.* New York: Wiley.

Turner, A. et al., n.d. *depthmapX - multi-platform spatial network analyses software.* [Online]
Available at: https://github.com/SpaceGroupUCL/depthmapX
[Accessed 20 07 2020].

Volchenkov, D. & Blanchard, P., 2007. Discovering Important Nodes Through Graph Entropy Encoded in Urban Space Syntax.

Whitford, A. B. & Wong, K., 2009. Political and Social Foundations for Environmental Sustainability. *Political Research Quarterly,* 62(1), pp. 190-204.

WWF, 2008. *Abu Dhabi unveil plans for sustainable.* [Online]
Available at: https://wwf.panda.org/wwf_news/?121361/WWF-Abu-Dhabi-unveil-plans-for-sustainable-city
[Accessed 20 11 2021].