THE OASIS EFFECT CONCEPT IN HOT DESERT CLIMATE CITIES: DENSIFYING AND COMPACTING AROUND METRO STATIONS TO ENHANCE PEDESTRIAN COMFORT

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Abstract

Nowadays, the cities in which we are living are complex, energy-consuming, and polluting systems. Radical changes since the last century have happened as a result of the automobile introduction and the oil boom. Moreover, one of the essential factors that influence microclimate is urban morphology. Streets, as they are a substantial part of urban open space, play a significant role in creating the urban microclimate. Street geometry and orientation affect the amount of solar radiation received by street surfaces. Outdoor thermal comfort in hot desert-climate cities depends on solar radiation. Under low latitude conditions, the minimization of solar radiation within the urban environment may often be a desirable principle in urban design, and the urban fabric of old compact Islamic cities reflects that. Jeddah is a city located in the western part of Saudi Arabia, at latitude 21° 32' north. The city is expected to start constructing a subway in 2020. Therefore, that is likely to change the behaviors of its inhabitants drastically.

This study aims to extract concepts from the old compact area to develop an outstanding future strategic compact morphology that would facilitate the dynamic development of the city. Considering the main stations of the future metro as nodes creating more densely inhabited fabric around them would provide transitional spaces for pedestrian activities. The concept is to provide an 'oasis effect,' mainly attributed to shading. Microclimate generated in and around these activity nodes must be mainly well designed to encourage residents and visitors to reclaim a pedestrian life that was noticeable in the old city, but has virtually disappeared in newer neighborhoods, entirely devoted to automobile transport. Services and facilities around metro nodes should become the transitional thermal comfort areas of the metro station exits.

The paper provides an overview of the old Islamic cities' morphology located at low altitudes. It evaluates the characteristics of the old urban fabric of Jeddah city through graphical analysis of the street geometry, orientations, and calculating the built-up density. Four different density indicators have been calculated (FSI), (GSI), (L), and (OSR). Furthermore, simulations that are used to assess the incident solar radiation in the old urban layout by the software "Heliodon 2" (direct shortwave, Sky View Factor) "Heliodon plus" (climatic data), describe the quantitative distribution of incident radiation on the canyon and facades enabling us to identify specific aspects.

The findings illustrate the implications of the old layout. It shows that the existing morphology significantly undermines the intensity of solar energy and solar access time interval in summer and winter on the horizontal surfaces (canyons) and vertical surfaces (walls). The results provide some helpful insights for the planning of a high density and compact 'Oasis effect' around the metro nodes.

Keywords: Urban morphology; pedestrian comfort; oasis effect concept; hot climate cities

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1. Background

City making is a process whereby social, economic, political, and physical urban components interact with each other. Urban forms are more or less a result of urban experiences, which are the key to human settlements, culture, and society. Elements of urban form tend to mediate physically and spatially with its social, economic, and environmental setting (Chapman and Lynch, 1962). Therefore, any city is a result of a complicated relationship between its socioeconomic, spatiotemporal, and environmental processes and practices.

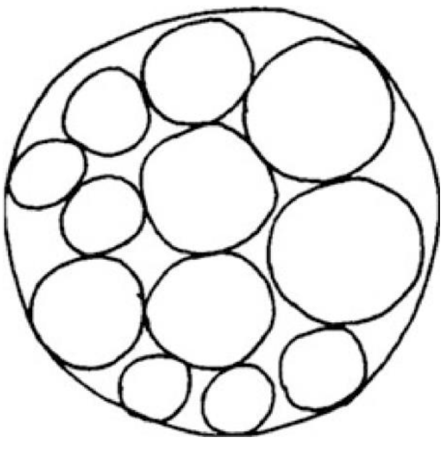
The continents of the earth have their geographical conditions, and the countries in them have different urban developments. The urban forms of Arabian cities necessarily differed from North American cities, European cities, and East Asian cities. Cities in Arabian countries can have similarities, but they can also have different urban patterns due to their historical development, natural and human-made determinants. One of the strongest influences, Islam, emerged in a desert region and later occupied the large belt of hot and arid zones reaching from North Africa to India. These areas always marked by a strong nomadic hinterland and prevailing tribal structure. The natural living conditions encouraged specific environmental, urban, and architectural responses, which had an impact on Islamic architecture and urban design, as did the nomadic background (Bianca, 2000).

Islamic cities grouped based on their origin. There are three types, the first two of which were those existing urban settlements, which have either experienced organic growth, exemplified by Erbil (ancient Arbela)**.**

On the other hand, those of Greek and Roman origins, which have been planned, exemplified by Damascus, the Muslims took these as their empire expanded. The third type of city founded on lands conquered by the Muslim armies, of which Tunis provides an example (Morris-1994).

In general, in Islamic territories, the city is considered as a collection of homogenous and integrated neighborhoods Figure 1. Over the centuries, there have been incremental changes in traditional society. Integrated neighborhoods were bound together by ties of climate, culture, customs, beliefs, and art. While historical Islamic cities show a variety of origins and growth patterns, they were nonetheless established by a standard set of social, geographic and religious factors leading to similar morphological principles, developing the urban fabric (Ben-Hamouche, 2009; Hakim, 1986; Bianca, 2000; Lapidus, 1969; Saqqaf, 1987).

Figure1. **The Muslim city as a collection of homogenous areas**



Source: The Moslem city as a collection of homogenous areas (Rapoport 1977). Source: book, Urban Structure in Islamic Territories, Chapter 4.

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Besides, it is quite possible to understand how this type of pattern came to be universally adopted by the people of the region. Anybody living in, or experiencing, the severe climate of the desert naturally seeks shade, which is incorporated into the city by narrowing and orientating the streets to avoid the hot desert solar radiation and the hot winds, which can be achieved by making these streets winding in shape, with closed vistas (Fathy, 1973) He points out the winding shape of roads, and, by contrast, attempts to confirm the advantages of the shape of the streets. He declares that the typical layout of the 'Islamic city' was characterized by "narrow winding streets with a similar arrangement of housing plots," which are the result of the best answer to the climate.

The transformation of the Islamic city up to the end of the 20th century can be summarized by a gradual shift from an urban texture of pedestrian scale and formal homogeneity of the physical environment into a fabric of vehicular scale and formal fragmentation of the physical environment, thus, from a social order based on total harmony and integration into a social order based on economic & technological dominance and social segregation & disintegration (Cetin, 2010).

Moreover, the Middle East urban growth determined by financial resources. Countries like Saudi Arabia, Iran, and the Gulf states have generated their developments from oil revenues. Oil has been responsible for the rapid industrialization of the predominantly rural Asia, the Middle East, and North Africa (Antonio Erias 2016).

Furthermore, the introduction of transportation systems during the Industrial Revolution brought a complete disengagement between energy sources and urban center locations. The subsequent expansion of transportation flexibility allowed for new urban structures, morphologies, and typologies (Mackett and Edwards, 1998). Cities around the world and in the Middle East began a process of transformation related to horizontal and expanded urban growth, bringing with it the rise of the phenomenon "urban sprawl". Car and road networks brought low-density structures with a lack of public space and social centers. This urban morphology not only influenced the city structure from a social aspect but has also generated critical consequences for the environment today (Lefèvre, 2009).

The rapid and uncontrolled expansion of contemporary cities has brought about environmental and social costs that have become unsustainable, and it is now widely recognized that a large-scale approach to this problem and a new urban model are required. It is agreed that urban concentration, in contrast to dispersal, is a feature that makes the urban form more sustainable and resilient, as it reduces travel distances and, consequently, environmental impact. The "energy revolutions" have, therefore, profoundly changed the characteristics of traditional architecture and the morphology of urban settlement (Frediani et al., 2008).

2. Literature review

The worldwide movement towards rapid urbanization imposes a threat on urban climate; which leaves the urban population extremely vulnerable to a number of hazards such as decreased thermal comfort (Emmanuel, 2012, 2016; Jauregui and Romales, 1996; Johansson, 2017, 2008; Oke, 1988, Rosenfeld et al., 1995).

Many studies in warm countries report that climate issues are not sufficiently considered in contemporary urban design and planning. Aynsley and Gulson 1999 interpret the lack of climate consciousness in urban planning and design; "urban climate is often a largely unplanned outcome of the interaction of several urban planning activities, an outcome for which no

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authority and no profession take responsibility”. De Schiller and Evans 1998 and Soufiane *et al.* 2015 emphasize that incorrect decisions at the urban planning level are normally impossible to correct at a later stage. Ainsley and Gulson as well argue that outdoor thermal comfort should be a routine aspect of urban development and that climatic aspects should be included in urban development codes and guidelines at different planning levels.

Furthermore, shading is one of the counteracting measures to thermal stress in hot climate cities since it reduces the convective heat transfer from sunlight to building and ground surfaces, it also reduces direct shortwave radiation reaching buildings and ground surfaces as well as humans (Spronken-Smith and Oke, 1999). The street orientation and canyon geometry generally determine the level of the effect of shading in terms of sky view factor and height-to-width (H/W) ratio (Johansson and Emmanuel, 2006; Oliveira *et al.*, 2011; Shashua-Bar *et al.*, 2012). In previous studies, it was found that daytime maximum physiological equivalent temperature decreases with increasing H/W ratio (Johansson, 2006; Ali-Toudert and Mayer, 2006; Abreu-Harbich *et al.*, 2014). In terms of mean radiant temperature (*Tmrt*), it can be up to 30° C higher in sunlit places than the areas under shade (Mayer and Höppe, 1987; Thorsson *et al.*, 2011). These studies confirmed that shading is effective in alleviating thermal discomfort in an urban environment.

The impact of each variation from the basic configuration of a street canyon on the outdoor thermal environment has been studied intensely in recent decades. As reviewed in Jamei et al. 2016, the impacts of street canyon design for pedestrian thermal comfort could be categorized into two groups: urban geometry and green infrastructure. The main variations in urban geometry include canyon aspect ratio (H/W) and orientation, as mentioned previously. There is no doubt that higher H/W ratio values led to less radiation and better thermal comfort in the summer season (Oke 1988, Jihad A.S 2016). Meanwhile, the street canyon orientation plays an important role in creating favorable environments for pedestrians since it is associated with solar access (Herrmann, J 2012). The conclusions of these studies are similar: north-south (N-S) -oriented streets mitigate thermal stress in the summer, while east-west (E-W) oriented streets suffer from heavier heat stress (Ali-Toudert, F., Mayer, H 2006).

In addition to the impact of urban geometry and greenery, building-level shading strategies (e.g., Galleries, overhanging facades, and extruded windows (Rewashing)), which extruded windows (Rawashin) are common in Jeddah old town, are valuable in areas with hot climates. In terms of the impact of galleries on outdoor thermal comfort, (Ali-Toudert and Mayer 2007) examined a deep street canyon and found that the physiological equivalent temperature (PET) in galleries was notes expected. The PET minimum (PET min) under the galleries was the same as that outside and PET maximum (PET max) was 4 °C higher under the gallery than outside.

However, the relation between H/W ratio and gallery in a single orientation on pedestrian thermal comfort was studied in previous research by the authors’ (Yin, S.; Xiao, Y 2016). Nevertheless, the previous research on the impact of arcade on pedestrian thermal comfort is insufficient, such as the relation between the aspect ratio of an arcade with the solar access, and the correlation between arcade and other configurations in a street canyon. Regardless of the realization of the previous studies, it is still challenging to use this knowledge to achieve transformation in practice. Urban planning and design are a complicated process, requiring the designer to deal with a combination of parameters at multiple levels As Erell 2008 mentioned. The capacity for improving thermal stress and the outdoor environment are helpful for designers dealing with geometric manipulation to balance the outdoor thermal comfort. Lee et al compared the shading effect of buildings, umbrellas, and trees in an open area. In a warm, summer desert climate. The measurement results confirmed that the measurement findings and

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results confirm that trees shading strategy has a less effective ability for cooling performance than buildings shading strategy since the buildings have a strong ability to block shortwave radiation. Although, the gap concerning the correlation between shading strategies and street morphology and thermal comfort still exists. Yin and Lang investigated the impact of shading strategies and configurations in Traditional shophouse neighborhoods on outdoor thermal comfort. Three street canyons with different shading strategies were selected. Results revealed that the canyon axis orientation significantly influenced the pedestrian thermal comfort level only in alleys and arcade streets. Moreover, findings showed the pedestrian thermal stress, increase dramatically; the H/W ratio was lower than 1.5 in allys and boulevards 0.78 while the higher an H/W ratio than 1 indicates a remarkable reduction of the PET for arcades pedestrian.

3. Methodology and used data

The urban scientific field needs to reinforce and merge the link between theoretical research and practical actions in existing and future urban settlements. This type of approach cannot be done without a direct and profound knowledge of the old urban realities and the constrictions and peculiarities that inevitably affect and characterize it. Therefore, to carry out the present investigation relating it directly to an existing urban case, and not with ideal archetypes. Therefore, four different density indicators have been calculated to evaluate the old urban fabric, (FSI), (GSI), (L), and (OSR) which quantify the amount of floor space in relation to the gross land area and spaciousness (Pont, MB., Haupt, P. 2012)

The researchers created a 3D digital mock-up using the cadastral information available. Moreover, in the field of development of the City Geographic Markup Language (CityGML), an open data system for the storage and exchange of the information associated with Virtual urban models, the Open Geospatial Consortium (OGC) defined five levels of detail (LoD - level of detail) (Verdie, Y., Lafarge, F. And Alliez, P.2015) for the representation in three dimensions of physical environments. The two levels of detail (LoD2 and LoD3) are adapted to an appropriate representation of the urban fabric and its essential elements the blocks, and this classification can then be considered a useful reference to define the level of detail and characterize the morphological models according to their approach to reality, by means of some objective parameters.

Also, the research establishes an evaluation and analysis by utilizing Heliodon2, simulation software, which provides possible data about the cumulative distribution of solar energy from the streets and the building envelopes (facades) (Beckers, B., Masset, L 2009). Computations complete with the Heliodon Plus tool (Nahon 2016), which allows taking into account the climatic data. Heliodon2 is a program that simulates the sun's path at a specific geographic site and provides graphical and numerical information about the evolution and the distribution of solar radiation, taking into account the shadows cast by neighboring obstructions.

Jeddah's old urban layout sample was evaluated on the 21st of June (summer solstice) and 21st of December (winter solstice). The information provided was the following: the solar time interval, Sky View Factor (%), and the solar flux (kWh/m^2/day) describing the quantitative distribution of incident radiation and enabling us to identify specific aspects.

The simulation of the model was done in two phases Figure 2:

1. First phase: simulating the canyon surface and facades using the LoD 2 (level of details) to test the effect of the urban morphology in relation to the amount of receiving direct solar radiation.

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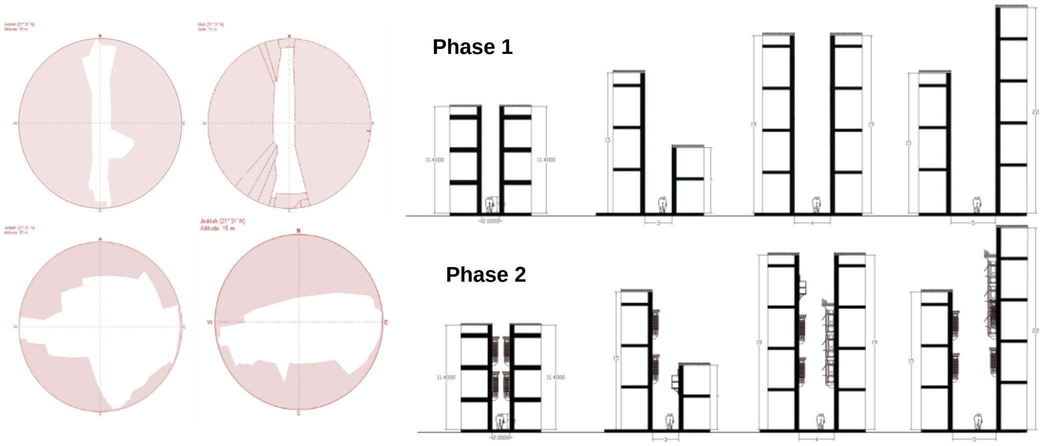
2. The second phase: simulating the canyon surface, creating a model of LoD 2 and LoD 3, adding extruded windows (Roshan) with a hypothetical size of 60 cm to the entire model.

Figure 2. **On the left is the old Jeddah layout SVF & on the right are sections of some of the canyons demonstrating Phase 1 & phase 2**



Source: The SVF was graphed with Heliodon 2.7 and with the author elaboration

1.1 Case study description

Jeddah city is located on the western part of Saudi Arabia, where it overlooks the east coast of the Red Sea. With 3.9 million inhabitants, Jeddah is considered the second-largest city in Saudi Arabia in terms of population after Riyadh. Jeddah is the most important seaport of Saudi Arabia on the Red Sea. The city is at latitude 21° 32' North, and longitude 39° 10' East. It has a hot climate, an arid subtropical climate (BWh) under Koppen's climate classification**.** With an average Low/High temperature typically varying between 18°C and 39°C, and rarely going below 16°C or above 41°C.

Skies are almost always clear, with cloud cover varying between 2 % and 18 %. The relative humidity varies between 30 % and 73 %, so the air is mostly humid. Rainfall in Jeddah is generally sparse and usually occurs in small amounts in November and December. Jeddah is very close to the Tropic of Cancer; the sun almost reaches the zenith at close to the summer solstice, reaching 45° at the winter solstice. The difference in day length between the two solstices is two hours and forty minutes. Solar height is up to 40° between 10:30 and 13:30 during the entire year, and the direct radiation is then up to 800 W/m2 in sunny hours, reaching 1000 W/m2 in the summertime (Masoud B, Beckers B, Coch H 2016).

1.2 Jeddah old layout description

The historical town of Jeddah covered an area of 1.5 square km Figure 3 and comprised of four original quarters, bounded by the city wall. The street system in old Jeddah, an essential component of its form, displayed a clear hierarchy Figure 4. First were citywide roads connecting the city's main gates to its core, housing, the souk (market), and the Great Mosque. These routes formed a fundamental part of the network connecting distant localities to the city, and their minimum width was determined by the functional requirement to allow two fully loaded camels to pass without hindrance.

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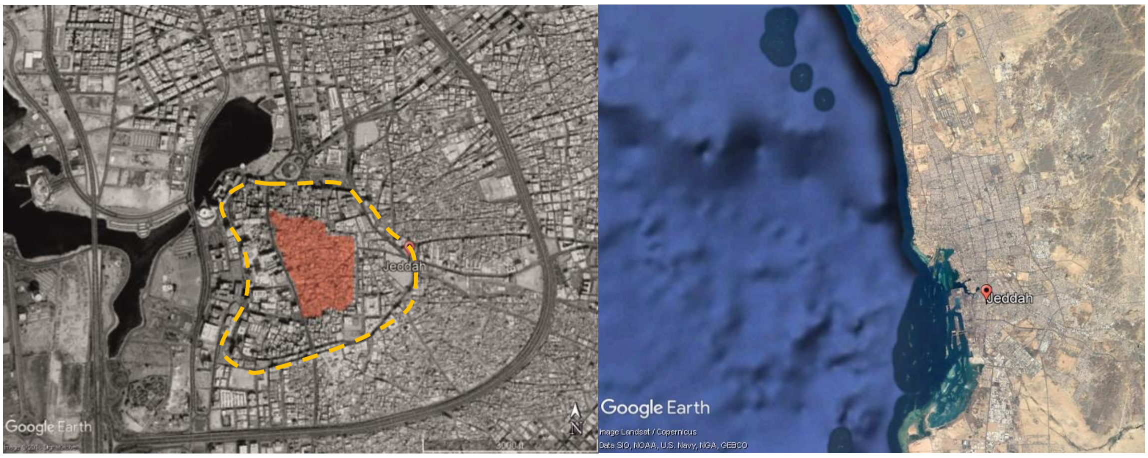
Figure 3. **Jeddah city on the right and the old town on the left**



Source: www.Googleearth.com

The second order of streets included primary streets and main access routes within and between the major quarters of the city. These streets tended to form shortcuts across the first-order streets. While main roads were designed to connect the city gates with the center of the city, secondary streets often ran east-west with some angle to the north or south, depends on the location, to connect residential areas with the city center. This design also provided maximum shade and cool air during the daytime.

Third-order streets provided access and linkage within quarters and tended to be used by people living, working, or with frequent contacts in the quarter. Finally, on the smallest scale, there was a system of cul-de-sacs referred to as *zuqaq.* This type of access was not public and belonged to adjacent or bordering residents. There was no specific pattern linking them to the larger hierarchy, and they could be connected to any of the three types mentioned above. The building heights in Albalad range from two to ten stories, Figure.5, and it's street widths vary between 2m and 5m. The district was laid out in an irregular urban form, with irregular attached buildings. The flat walls are characterized by projecting wooden windows (Rawashin). (Abu-Ghazzeh, 1994, Alharbi, 1989)

Figure 4**. Jeddah old town narrow canyons and extruded windows (Roshan)**

Source. Author elaboration.

The map on the left Figure 5 demonstrates some of the street orientations in Jeddah's old layout. The red lines represent the North-South streets-orientation axis, the blue lines represent the East-West streets orientation axis, the green is the Northwest-Southeast, and the orange is the Northeast-Southwest orientation axis. The most dominant street orientations are the Red and blue lines (North-South and East-West).

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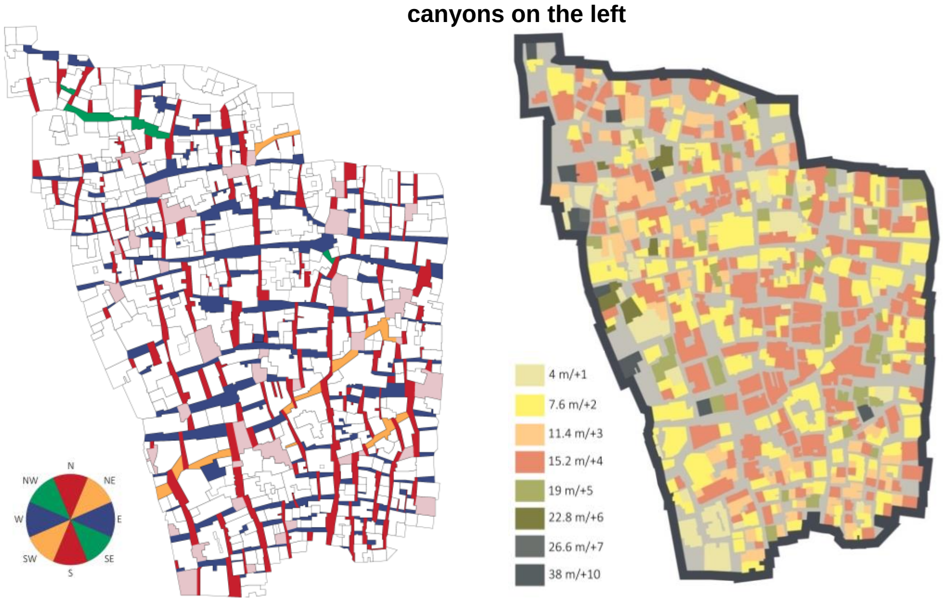
Figure 5. **Building height on the right and a map demonstrating the orientations of the canyons on the left**

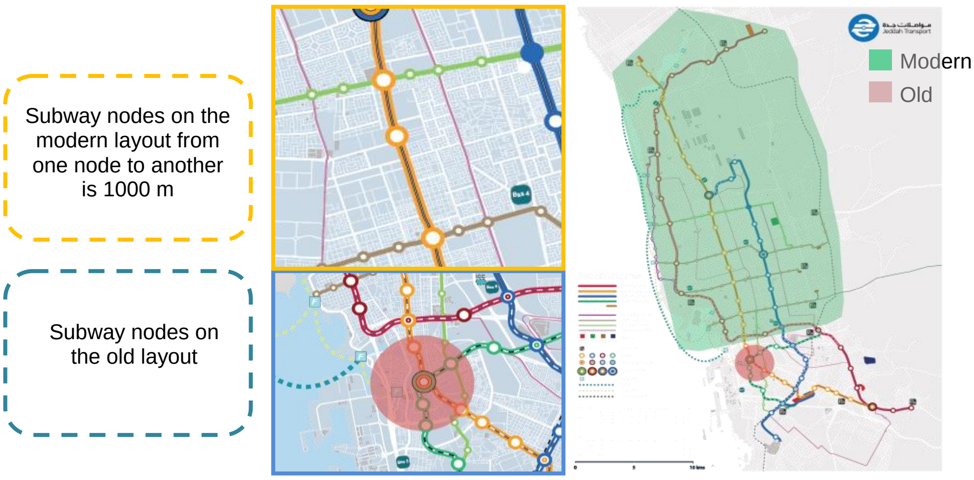


Source: The cadastral information available https://www.jeddah.gov.sa

Additionally, Jeddah city will shortly start constructing a Public transportation program (JPTP) in response to the city's needs; it is expected to change the habits of its inhabitants radically. Figure 6. With the urban sprawl city system, wide streets exposed to the solar radiation Figure 7 and the existence of low rise buildings that permit the solar radiation to penetrate easily to the streets it is difficult for the citizens to transit from one point to another under this harsh weather without being protected from solar radiation.

Corresponding to the previous statements, the present demand for sustainable built environments in Jeddah city in particular, and Saudi Arabia, in general, is coupled with the need to minimize the effect of the severe solar radiation condition during the summertime on users of outdoor spaces.

Figure 6. **Jeddah metro layout in the old area and the modern area**



Source: http://www.metrojeddah.com.sa/ and the author elaboration

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Figure 7. **The exposure of the streets to direct solar radiation**

Source: http://www.metrojeddah.com.sa/ and the author elaboration

4 Results and discussion: (First Phase)

4.1 Time interval on a horizontal surface (Canyons)

The results of the solar time interval in Jeddah's old urban layout (Albalad) are analyzed according to the abstractions that are redefined through the urban morphology parameters (H/W ratio and SVF). Together with canyon orientation, they perform an important role in determining the results. The results shown on the Heliodon map indicate different levels of solar access time, through the color scale shown in Figure 8, the map is composed of colors going from blue (lowest value) to red (highest value) with green, yellow and orange (which are average values). It is important to state that due to the asymmetrical canyons, height of buildings and irregularities of the canyons, the results on the surfaces are shown in the following:

Figure 8. **Canyon Time interval summer and winter Jeddah old layout**

Source: Heliodon software

The N-S orientations that have an H/W ratio between 2 to 10 show a low sun period due to the deep canyons in relation to the other canyon orientations and due, the solar angle during summer. The differences of sun period are high due to Jeddah's old urban morphological characteristics and its location and notably its latitude. In summer the N-S canyons receive an average of 2 h to 2 h 30 minutes of solar radiation, and in winter it receives almost 1 h, due to the difference of the solar angle between winter and summer and the high built-up density of the urban layout that obstructs solar radiation from penetrating, as mentioned previously. During summer, the E-W orientation canyons receive an average of 5 h to 9 h of solar radiation; at

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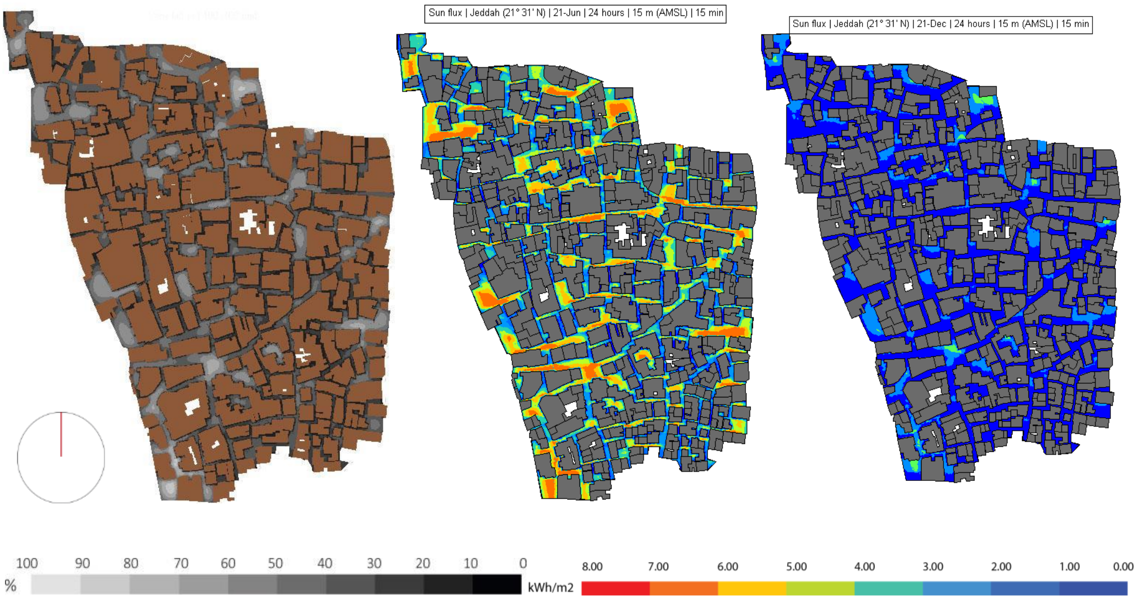
times, it can be as high as 10 hours. In winter they range between 1 h and 2h 24 minutes of solar radiation and during summer, the intermediate orientation NS-SW canyons receive an average of 1 h to 4 h, at times almost 5 h; in winter the figure is almost 0.30 minutes due its perpendicular axis in relation to the solar angle in summer and winter. For plazas, solar radiation ranges from 2 h 27 minutes to 12 h due to its higher SVF. The N-S canyons receive the least sun hours compared with other canyon orientations, and E-W canyons receive the highest sun period. This relationship between the canyon orientation in relation to the different aspect ratios and SVF shows the difference in temporal sun period, which displays the effect of the built obstructions.

4.2 The first phase, the solar flux in relation to the sky view factor

The simulation reveals that the average SVF for the whole layout of canyons generally ranges from 20% to 60% and in open spaces (Plazas) 40% 80% Figure 9. Due to the plazas' function in this urban setting, it is more exposed to a higher SVF value. Moreover, the calculation was done on the whole layout, rather than on a specific point. Therefore, the morphology evaluation and effect are conducted to check how far the urban geometry affects the direct solar radiation received, taking into consideration all the obstructions and the parameters that are affecting each canyon, rather than investigating one canyon.

Figure 9. **Sky View Factor of the horizontal surface (Canyons) Jeddah old layout**



Source: Heliodon software

The amount of direct solar radiation on the canyons, including the discomfort that it produces in the human body, was determined by analyzing and assessing the solar flux received on the canyons- using the sunshine duration and Sky View Factor. The simulation reveals that the average solar flux received on a horizontal surface (canyon) is 3 kWh/m2 per day. Given that narrow streets characterize the old layout, building blocks are obstructing the solar radiation from penetrating to the canyons. Figure 10 below shows the streets-oriented N-S with H/W ratio 3 to 7.2 and an average SVF ranging between a minimum of 20% and a maximum of 40%. This orientation amounts to an average solar flux of 1 to 2.5 kWh/m2 per day during summer, while

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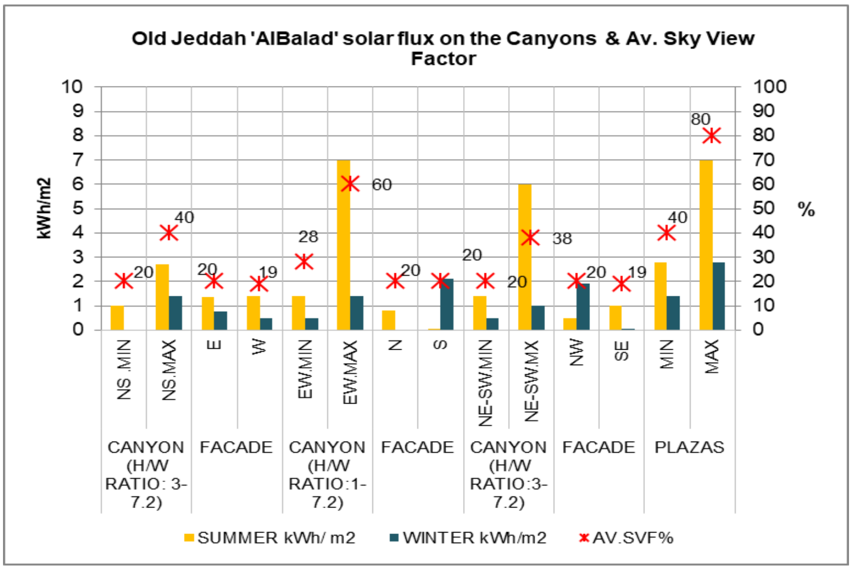
in winter, 1 kWh/m^2 per day it is due to the high H/W ratio and the low average SVF including the low solar angle.

Furthermore, in the summer on the E-W orientations with H/W ratio ranging from 1 to 7.2, an average SVF ranging between 28% and a maximum of 60%, based on an average solar flux of 1.5 to 7 kWh/m^2 per day and in winter from 0.5 to 1.5 kWh/m2 per day. Besides, the intermediate orientation NW-SE with an H/W ratio 3 to 7.2 records an average SVF ranging between 20% and 38%. In summer, an average solar flux ranging between 1.3 and 6 kWh/m2 per day is received, and in winter, it ranges between 0.5 and 1 kWh/m^2 per day. On the other hand, plazas have an average SVF ranging from 40% to 80%, receiving an average solar flux of 3 to 7 kWh/m2 per day in summer and winter 1.3 to 3 kWh/m2 per day.

Here, it should be stressed that while the E-W canyon orientations are characterized by lower average SVF than plazas, they still receive the same amount of solar flux due to canyon orientation alliance in relation to the solar movement.

Figure10. **Solar flux and SVF simulation results winter and summer (Facades and canyons)**



Source. Author elaboration.

4.3 *Solar flux in relation to Sky View Factor on vertical surfaces (Facades)*

The overall results in old Jeddah selected urban layout, the vertical surfaces (Facades) receives less incident solar radiation than the horizontal ones (Canyons). Additionally, vertical surfaces receive fluctuated solar radiation depending on the façade orientation and the solar angle. Accordingly, on the 21st June, the façade that obtains the most solar flux value is the East & West facades, receiving 1.40 kWh/m^2 per day with an average SVF of 20 % and the lowest is the north façade, which receives 0.05 kWh/m^2 per day with an average SVF of 21%. Also, the Southeast façade receives 1 kWh/m^2 per day.

On the 21st December, the South and Northwest façade obtains the highest amount of solar flux value, receiving on the South façade 2.1 kWh/m^2 per day, and the Northwest façade receives 1.90 kWh/m^2 per day. Furthermore, the North façades receive zero-incident solar energy on the winter solstice day due to the solar angle on the summer solstice is higher than it is on the winter solstice. Additionally, due to the high built-up density and compactness of the old urban layout, the average Sky View Factor is constant in all vertical surfaces (facades).

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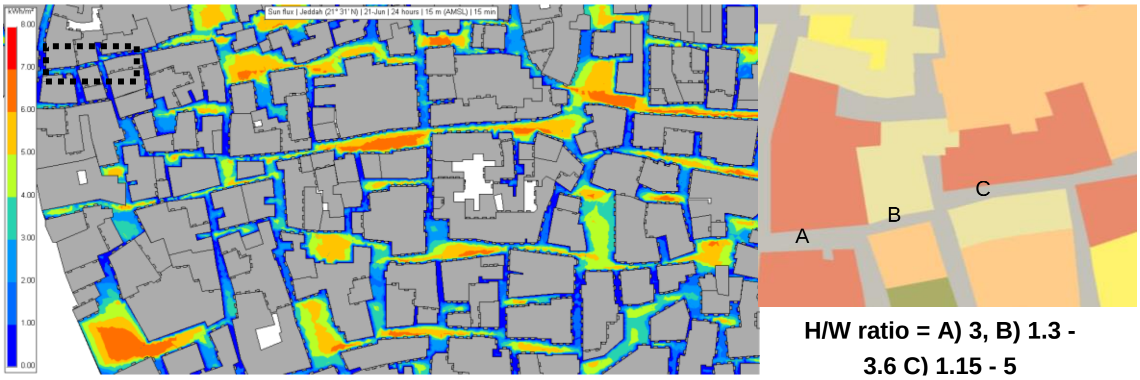
4.4 *Extended windows (Roshan) (Second phase)*

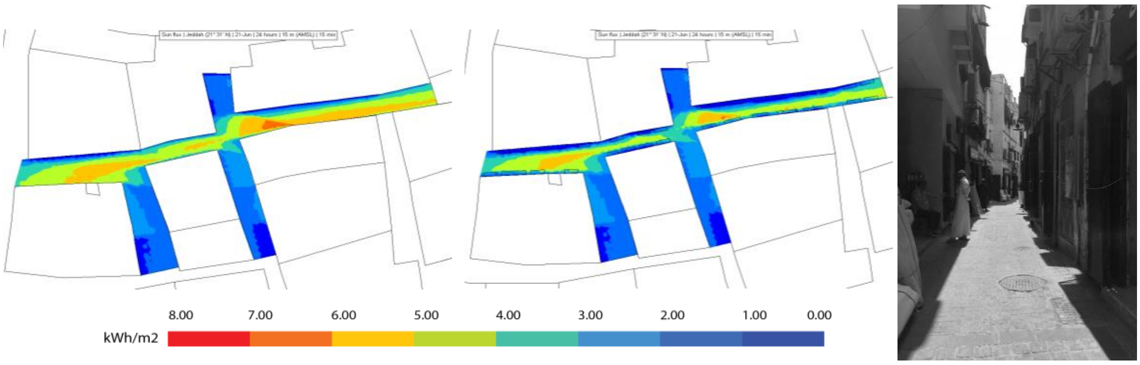
The findings revealed Figure 11 an overall reduction in the horizontal surface after applying the extruded windows (Rawashin) on the entire model of a 12.5% solar flux. Nevertheless, the results revealed that under these windows, the reduction was clearer than the overall reduction of the layout. Therefore a chosen sample canyon from the simulation is zoomed in to demonstrate the reduction of solar flux on an E-W canyon.

Figure11. **Solar flux on E-W canyon for Phase 1 & 2**



Source: Heliodon software

Figure12. **A comparison of an E-W Canyon solar flux from phase 1 & phase 2**



Source: Heliodon software

Each canyon is characterized by different H/W ratios and an average SVF. The demonstrated canyon has an H/W ratio ranging from 1.15 to 5 and SVF ranging from 20% to 40%. The solar flux received on the canyon without applying the windows models (Rawashin) is as follows: Figure 12 on the left, in the summer of the 21st of Jun the solar flux is fluctuated starting from the south part of the canyon reaching to the north part of the canyon ranging from 7-5 kWh/m2 per day to 2 kWh/m2 per day. It was observed that the southern part in summertime receives more solar flux than the northern part of the canyon, and in winter is the contrary the northern part of the canyon receives more solar flux than the southern part, and that’s due to the solar angle in both seasons.

Moreover; the solar flux received in the canyons with the application of extruded windows (Rewashing) is as follows: the reduction of solar flux is clear on the right Figure 12 the canyon fluctuates in summer starting from the center of the canyon reaching under the windows (Rawashin) it is going from the center 6-5 kWh/m2 per day reducing to under the extruded

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windows to 1 kWh/m2 per day. The solar flux was reduced on the Sothern part of the canyon under the windows from 7-6kWh/m2 per day to 3 kWh/m2 per day. And the northern part of the canyon under the windows from 3 kWh/m2 per day to 1-0 kWh/m2 per day. The findings revealed a reduction between 57 % and 77 % of solar flux on E-W canyons in the south part of the canyon. We can see the effect of the horizontal shading forms on the horizontal surface (canyon) is highly efficient and should be taken into consideration when designing cities in hot climate cites it is not enough to modify the morphology of the urban layout to reduce direct solar radiation.

5 Conclusions

The findings illustrate the implications of the old layout. It shows that the existing morphology characterized by high site coverage, buildings closely packed together, and open spaces are scarce. The existing morphology significantly undermines the intensity of solar energy and solar access time interval in summer and winter on the horizontal surfaces (canyons) and vertical surfaces (walls). The results provide some helpful insights for the planning of high density and compact 'Oasis effect' around the metro nodes.

One of the crucial conclusions is that the street area below the extruded windows (Rawashin) decreased the average solar flux potential on the 21st of June, summer solstice, between 57 % and in some areas 77 % on E-W canyons, compared to the E-W canyons without extruded windows. Extruded windows on the vertical morphology should be encouraged. Building regulations on building codes should be modified to provide outdoor shade from harsh sun penetration. In other words, due to the results and findings obtained in this investigation and for the necessity of shading pedestrian walkways in low latitudes, it is advised to apply horizontal shading to protect from the direct solar radiation, not only considering the modification of the urban morphology. Nevertheless, it is the recommended when designing horizontal shading devices, whether it was (extruded windows, balconies, arcades, galleries or overhanging facades) the south façade extruded element should be wider due to the penetration of direct solar radiation in summer season that is considered essential to be protected from at that time of the year to enhance pedestrian comfort. Also, always consider the aspect ratio of the streets and canyons while designing them.

Subsequently, creating an 'Oasis effect' concept, by densifying the urban fabric around the metro nodes, and applying building geometric design solutions, could be an acceptable approach to reducing the harsh solar radiation penetration on the streets and for rapid urbanization.

As the extruded windows have changed the amount of received solar flux and it was 60 cm therefore with the application of horizontal shading devices with the correct H/W ratio of streets and canyons will reduce the amount of direct solar radiation received on the horizontal surface to protect pedestrian from the direct solar radiation and will enhance their thermal comfort especially in summer. Applying the concept of the ‘ Oasis Effect ‘ through applying adequate AV.SVF on the N-S orientation % and the E-W orientation and applying on the E-W orientations horizontal shading devices around the metro station nodes where people are walking and perusing their needs will give the shading needed.

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References

Abu-Ghazzeh, T. (1994) 'Built Form and Religion: Underlying Structures of Jeddah Al Qademah', Traditional Dwellings and Settlements Review, 5(2), pp. 49–55.

Alharbi, T. H. (1989) 'The development of Housing in Jeddah, changes in built form from the traditional to the modern.', (March), p. 392.

Ali-Toudert, F., Mayer, H., (2007). Effects of asymmetry, galleries, overhanging façades and vegetation on thermal comfort in urban street canyons. Sol. Energy 81 ,

Ali-Toudert F., Mayer H., 2006: Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. Building and Environment,

Aynsley R., L. Gulson. (1999). Microclimate and urban planning in the humid tropics. Paper presented at RAPI 27th National Congress, 19–22 September, Northern Territory Dept. of Lands, Planning and Environment, Darwin, Australia.

Abreu-Harbich L.V., Labaki L.C., Matzarakis A., (2014). Thermal bioclimate in idealized urban street canyons in Campinas, Brazil. Theoretical and Applied Climatology, 115, 333-340.

Antonio Erias, Cansu Karaka, Corinna Grajetzki, James Carton, Mekalia Paulos, Pirjo Jantunen, Prajwal Baral, Samal Bex, J. M. V. (2016) 'World Energy Resources 2016', World Energy Council 2016, pp. 6–46.doi:http://www.worldenergy.org/wpcontent/uploads/2013/09/Complete_WER_2013_Survey.pdf

Beckers, B., Masset, L (2009) . Heliodon2 Software and user's guide. http://www.heliodon.net .

Nahon, R, and Muñoz, D, and Beckers, B. (2016) Heliodon Plus user manual. www.heliodon.net

Ben-Hamouche, Mustapha (2008) Climate, Cities and Sustainability in the Arabian Region: Compactness As a New Paradigm in Urban Design and Planning. Archnet-IJAR - International Journal of Architectural Research. Vol. 2, no. 2, p. 196–208. DOI 10.26687/archnet-ijar.v2i2.241.

Bianca, S. (2000) Urban form in the arab world past and present.pdf. Thames and Hudson, 500 fifth Avenue, New York 10110.

Cetin, M. (2010) 'Transformation and Perception of Urban Form in Arab City.', International Journal of Civil & Environmental Engineering, 10 (4), pp. 30–34. Retrieved from: http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=20771258&AN=62093450&h=kXSUoPN+vJ+8I2aGZTlfOi//Zz54FcXIMUzjVa+/IZkErrnECNQoIy59DNzrOx2HdhGuLhN00+ki+lKmT098SQ==&crl=c.

Chapman, E. H. and Lynch, K. (1962). 'The Image of the City', The Journal of Aesthetics and Art Criticism, 21(1), p. 91. doi: 10.2307/427643.

De Schiller S., Evans J. M. (1998) Sustainable urban development: design guidelines for warm humid cities. Urban Design International :3(4):165–184. doi:10.1080/135753198350299

Emmanuel, R., (2012) . An Urban Approach to Climate Sensitive Design: Strategies for the Tropics. Taylor & Francis.

ISSN e: 2604-6512

Emmanuel, R., (2016). Urban climate challenges in the tropics. In: Emmanuel, R. (Ed.), Urban Climate Challenges in the Tropics: Rethinking Planning and Design Opportunities. Imperial College Press, London, London. http://dx.doi.org/10.1142/9781783268412_0007.

Erell, E , (2008) . The Application of Urban Climate Research in the Design of Cities. Adv. Build. Energy Res. 2, 95–121.

Frediani, J. et al. (2008). 'Compact City – Sprawl City : two interacting urban forms', ISOCARP Congress, (44), pp. 1–12.

Hakim, B. S. (1986) Arabic-Is lamic Cities. 2010th edn. Taylor & Francis group , London and New York.

Jamei, E.; Rajagopalan, P. , Seyed mahmoudian, M.Y, (2016). Review on the impact of urban geometry and pedestrian level greening on outdoor thermal comfort. Renew. Sustain. Energy Rev. 54, 1002–1017.

Jendritzky, G., de Dear, R., Havenith, G., (2012) . UTCI-why another thermal index? Int. J. Biometeorol. 56, 421–428. http://dx.doi.org/10.1007/s00484-011-0513-7.

Johansson, E., (2006) . Influence of urban geometry on outdoor thermal comfort in a hot, dry climate: a study in fez, Morocco. Build. Environ. 41, 1326–1338. http://dx. doi.org/10.1016/j.buildenv.2005.05.022

Jihad, A.S.; Tahiri, M, (2016). Modeling the urban geometry influence on outdoor thermal comfort in the case of Moroccan microclimate. Urban Clim. 16, 25–42.

Johansson, E., Emmanuel, R., (2006). The influence of urban design on outdoor thermal comfort in the hot, humid city of Colombo, Sri Lanka. Int. J. Biometeorol. 51, 119–133. http://dx.doi.org/10.1007/s00484-006-0047-6.

Lindberg, F., Grimmond, C , (2010). Continuous sky view factor maps from high resolution urban digital elevation models. Clim. Res. 42 (3), 177–183.

Lee, I., Voogt, J.A., Gillespie, T.J, (2018). Analysis and Comparison of Shading Strategies to Increase Human Thermal Comfort in Urban Areas. Atmosphere , 9, 91. [CrossRef]

Lefevre, Benoit, (2009). Urban transport energy consumption: Determinants and strategies for its reduction an analysis of the literature. Sapiens. Vol. 2, no. 3.

Masoud, B., Coch, H., Crespo, I., Beckers, B, (2018). Effects of urban morphology on shading for Pedestrians Sky view factor (SVF) as an indicator of Solar Access. Passive and low energy architecture conference, Hong Kong.

Masoud, B., Coch, H., Beckers, B, (2016). Sky Access versus Shading for Pedestrian Comfort in the Hot Tropical Climate of Jeddah. First international conference on urban physics, Quito-Galapagos .

Mackett, R. L. and Edwards, M. (1998). 'The impact of new urban public transport systems: will the expectations be met?', Transportation Research Part A: Policy and Practice, 32(4), pp. 231–245. doi: 10.1016/S0965-8564(97)00041-4.

Morris, A.E.J, (1994). History of Urban Form - Before the Industrial Revolutions. 3rd Edition. Essex, U.K. & New York, USA. Longman Scientific & Technical.

Mumford, L, (1966). The City in History. Harmondsworth: Penguin.

Oke, T.R., (1988). Street design and urban canopy layer climate. Energy. Build. 11, 103–113. http://dx.doi.org/10.1016/0378-7788(88)90026-6.

Saqqaf, Abdulaziz Y, (1987) . The Middle East City. New York: Paragon House.

ISSN e: 2604-6512

Shishegar, N, (2013). Street Design and Urban Microclimate: Analyzing the Effects of Street Geometry and Orientation on Airflow and Solar Access in Urban Canyons. J. Clean Energy Technol. doi:10.7763/JOCET.2013.V1.13.

Pont, MB., Haupt, P, (2012). Spacematrix, Space, Density and Urban Form. NAi Uitgevers ISBN 10: 9056627422.

Rosenfeld, A.H., Akbari, H., Bretz, S., Fishman, B.L., Kurn, D.M., Sailor, D.J., Taha, H., (1995). Mitigation of urban heat islands: materials, utility programs, updates. Energy. Build. 22, 255–265. http://dx.doi.org/10.1016/0378-7788(95)00927-P.

Spronken-Smith, R.A., Oke T.R., (1999). Scale modeling of nocturnal cooling in urban parks. Boundary-Layer Meteorology, 93, 287–312.

Soufiane F., Said M., Atef A, (2015) . Sustainable Urban Design of Historical City Centers. Energy Procedia :74:301–307. doi:10.1016/j.egypro.2015.07.612

Hassan Fathy, (1973). ‘‘Constancy, Transposition and Change in the Arab City,’’ in Carl Brown, ed., Madina to Metropolis (Princeton, NJ: Darwin Press), pp. 319–34.

Herrmann, J.; Matzarakis, A, (2012). Mean radiant temperature in idealized urban canyons—Examples from Freiburg, Germany. Int. J. Biometeorol. 2012, 56, 199–203.

Yin, S.; Xiao, Y, (2016). Scale Study of Traditional Shophouse Street in South of China Based on Outdoor Thermal Comfort. Procedia Eng.169, 232–239. [CrossRef]

Verdie, Y., Lafarge, F. And Alliez, P, (2015) ‘LOD Generation for Urban Scenes To cite this version : LOD Generation for Urban Scenes’, Acm Transactions on Graphics, 34 (3), pp. 1–14. Available at: http://dl.acm.org/citation.cfm?id=2732527.

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