THE EFFECT OF STREET ORIENTATION AND SURROUNDING BUILDING HEIGHTS ON SOLAR ACCESSIBILITY IN WINTER SEASON IN AMMAN, JORDAN

Wael Al-Azhari, Myrna Haddadin, Rund Hiyasat
University of Jordan, Amman, Jordan

Abstract

Solar access in public space, including streets, is an essential aspect that affects human comfort. However, it is affected by the street orientation and the surrounding building heights. In this research, the objective is to examine quantitatively the effect of the orientation of a street and the surrounding buildings’ heights to allow maximum solar accessibility in Amman, Jordan.

The results of this research provide precise calculations of the exact buildings’ heights needed for a certain street orientation that benefits both outdoor and indoor solar conditions; providing maximum solar access to the residential building’s façades in winter season. It does so by analyzing the influence of different urban and architectural parameters: street orientation, surrounding buildings’ heights, and solar envelope. Hence, guidelines will be provided for the Municipality of Amman that aims towards optimizing solar accessibility in residential streets of Dahiat Al Rasheed area in Amman, Jordan.

Keywords: Solar access, urban canyon, street orientation, building heights, residential area

ВЛИЯНИЕ ОРИЕНТАЦИИ УЛИЦ И ВЫСОТЫ ОКРУЖАЮЩЕЙ ЗАСТРОЙКИ НА ИНСОЛЯЦИЮ УЛИЧНОГО ПРОСТРАНСТВА В ЗИМНИЙ ПЕРИОД В АММАНЕ, ИОРДАНИЯ

Wael Al-Azhari, Myrna Haddadin, Rund Hiyasat
Иорданский Университет, Амман, Иордания

Аннотация

Солнечное освещение в окружающем человека пространстве, в том числе уличном, является важным фактором, влияющем на человеческий комфорт. Инсоляция улиц зависит от их ориентации по сторонам света и формирующих их высот сооружений. Целью этого исследования, является изучение количественных характеристик солнечной освещенности уличных пространств в зависимости от ориентации и высоты зданий в Аммане, Иордании.

Результаты этого исследования обеспечивают точные расчеты высот зданий, необходимые при определенной ориентации улиц, обеспечивая при этом максимальный солнечный доступ к фасадам жилых зданий в зимний период. Полученные расчеты и выводы исследования, будут предоставляться в муниципалитет Аммана, работа которого направлена на оптимизацию инсоляции жилых улиц в районе Даят Аль Рашид в Аммане, Иордания.

Ключевые слова: инсоляция, уличная ориентация, высота здания, жилой район

1. Introduction

The sun is essential for all forms of life. It is the source of vision, warmth, energy, and the rhythm of human activities. Without the solar access – which is a term specifically meant for direct sunlight for solar energy systems – there will be no optimal use of the sun energy. Its movements inform the perceptions of time and space and our scale in the universe. Thus, solar access is seen as: a right to sunlight upon certain building facades regardless of the presence of active or passive solar energy systems. (Knowels, 1999)

Studying solar accessibility is of a great essential in Urban Planning for several reasons. Proper amounts of solar access in a certain space can play a big role in achieving human thermal comfort despite the fact that clothing, body shape, and psychological aspects make a difference in thermal comfort from person to person, and from season to season (Nikolopuolou, et al., 2006). Furthermore, in residential buildings, direct heat gain is the most common use of the solar access to reach the thermal comfort zone needed in cold seasons. Hence, the goal of using solar access in urban planning is to create well-designed urban districts that assure exposure of buildings' elevations and public spaces to the sun during a desired period of the year. Urban areas that do not consider solar access may cause discomfort inside buildings and on the street, as well as increase energy consumption for lighting and heating, due to the lack of passive solar energy.

In line of previous reasoning on solar access importance, several factors influence solar accessibility such as street widths, building heights and street orientation. The street width to building height ratio determines the altitude up to which solar access can be cut off. Similarly, the street orientation determines the azimuth up to which solar access can be eliminated. As a result they can be used very effectively to minimize or maximize heat gain. The amount of direct radiation received on the urban canyon is determined by the street width and buildings' height ratio. The orientation affects the time of the day when the radiation is received. So modulating the street width and orientation can very effectively control solar accessibility.

Previous researchers examined the effect of surrounding building heights and street orientation on solar access on the building's facades. Researchers have provided recommendations concerning the optimum building heights on north-east and south-west oriented streets in order to optimize solar access during the cold season on the building facades. (Coluccia, et al., 2012)

Also, street widths and orientation as well as surrounding building design parameters and their affect the solar accessibility was studied. The authors provided guidelines for urban designers as well as architects for favorable solar access in outdoor and indoor spaces and concluded that in order to limit excessive heating of the canyon in summer; one might orient the design towards narrow streets. (van Esch, et al., 2012)

Knowles (1999) examined the street grid's influence on the solar envelope, and found that the solar envelope regulates development within imaginary boundaries derived from the sun's relative motion. The author analyzed two projects: “Bunker Hill Envelope and Mixed Use” and “Library (designed by Anthomy Reiter)” to suggest rhythm as a design strategy to allow maximum sun light through the urban area along with new aesthetic possibilities for architecture and urban design.

In this research, the objective is to examine quantitatively the effect of the orientation of a street the surrounding buildings' heights around a 12 m wide street to allow maximum solar accessibility in Amman, Jordan. The results of this research provide precise calculations of the exact buildings' heights needed for a certain street width in a certain orientation that benefits both outdoor and indoor solar conditions; providing maximum solar access to the residential building's façades in winter season. It does so by analyzing the influence of different urban and architectural parameters: street width, street orientation and solar envelope. Hence, guidelines will be provided for the Municipality of Amman that aims towards optimizing solar accessibility in residential streets of Dahiat Al Rasheed area in Amman, Jordan.

2. Literature Review

Numerous studies have been made on the solar accessibility and thermal comfort in public spaces in different areas of the world, thus setting recommendations and guidelines for designers and urban planners in the attempt of designing comfortable urban spaces. For instance, in the article "Making Toronto Solar Ready: Proposing Urban Forms for the Integration of Solar Strategies", Colucci, et al. (2012) studied the building sizes, and heights, and their effect on insolation among north-south and east-west oriented streets. Results showed that in residential buildings with height of 10 m, very minimum increase in insolation is achieved along the north-south oriented streets. Likewise, less increase in insolation showed on the east-west oriented streets. The authors justify those results by referring to the building sized and plan dimensions in the morphology used (4.5 m x15.25 m). In another area, the authors conducted the same study on mixed-used buildings. The height of the northern buildings was assumed to be 30 m, and whose width was 15 m, and length was 30 m, while they were faced with 15 m high buildings. Results of this experiment have shown slight increase in insolation as to opposed to results of maintaining a 30 m high southern buildings. (Coluccia, et al., 2012)

"Influence of Urban Geometry on Outdoor Thermal Comfort in a Hot Dry Climate: A study in Fez, Morocco", Johansson (2006) has studied the Influence of urban geometry on thermal comfort in outdoor spaces in a hot dry climate through a comparison between deep street canyon and a shallow one in the city of Fez in Morocco; taking into consideration the ratio of the building heights (H) to the distances between the buildings (W) as factors that affect incoming and outgoing solar radiation, as well as wind speed. Johansson has concluded that the deep canyon (with H/W ratio approximate to 10) was cooler than the shallow one during a summer day. In winter, on the other hand, the shallow canyon (H/W ratio = 0.6) allows more solar access into the urban space. Therefore a compact deep canyon has a good protection from solar radiation during summer, thus allowing lower temperatures. While a disperse urban form lacks comfortable areas in the summer season. While in winter, the opposite is true. Furthermore, in hot climates where cold seasons are possible, the optimum urban design should include some wide streets or open spaces or both. However, those open spaces require solar protection for pedestrians, because, even though, they act as sun spots during winter and cause thermal comfort, they would allow more solar access during summer than narrow, compact canyons, and thus, cause lack of thermal comfort during summer. (Johansson, 2006)

Van Esch et al. (2012) also studied the effects of urban design parameters (including street width and orientation) and building design parameters (including roof shape and building envelope design) on solar access to the urban canopy and on the viability of passive solar heating strategies in residential buildings. In this research, trigonometric equations were used to calculate the solar access in reference to the sun position in the sky and the geometry of the canyon. Results showed that streets running in an east–west direction with a width of at least 20m with single-pitched roofed dwellings facing south, crossed by narrow streets of around 10m running north-south provide indoor solar gain and outdoor thermal comfort. Therefore, deciduous trees might be used on the north side of an eastwest- oriented street in order to prevent overheating in summer, and allow solar access during winter. The researchers also suggested introducing a moving water element to the east-west-running-street to provide evaporative cooling during summer season. As for wide north-south-oriented-streets, small trees can be placed on the east side of the street in order to provide shadow on the west-facing facade, while overhangs or shading elements can be placed on the façades of the buildings. (van Esch, et al., 2012)

Ahmed, in multiple researches, has studied Thermal comfort in urban spaces. In the research "Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments" Ahmed has concluded that the effects of some environmental factors on urban spaces can be influenced by building geometry and orientation, as well as material of construction and water bodies in humid tropical climates. (Ahmed, 2003)

Moreover, in "A comparative analysis of the outdoor thermal environment of the urban vernacular and the contemporary development: case studies in Dhaka" Ahmed's results showed that in hot humid climates, the maximum daily temperature decreases by an average of 4.5K when H/W ration increased from 0.3 to 2.8. (A Comparative Analysis of the Outdoor Thermal Environment of the Urban Vernacular and the Contemporary Development: Case Studies in Dhaka, 1994)

3. Methodology

In order to study the orientation effect on the urban canyon parameters, a residential area was chosen that is classified as class B according to GAM Regulations (front and side setbacks of 4 m and rear setback of 6m) with a maximum building height of 15 m. The area's average street width was 12 m.

Our approach for estimating solar accessibility was based on varying street orientation (four orientations), as well as varying the surrounding building height combinations on the sides of the street between 9m, 12 m, and 15 m, on the average street width: 12 m, on three dates (21st of December, 21st of January, and 21st of February) at 7 different peak hours of the day for each facade. These days represent the cold seasons as mean minimum temperature is the lowest throughout the year, hence, the solar access demand is at its highest.

The orientations that are considered in this study were: North – south streets, east – west streets, northeast – southwest streets, and northwest – southeast streets. The buildings' heights varied between 9 m, 12 m, and the maximum allowed building height of 15 m, for class B residential buildings according to Greater Amman Municipality (GAM) regulations, resulting on the following combinations of building heights on both sides of the streets: 9 m - 9 m, 9 m - 12 m, 9 m – 15 m, 12 m – 9 m, 12 m – 12 m, 12 m – 15 m, 15 m – 9 m, 15 m – 12 m, and 15 m – 15 m.

1512 images were generated with the aid of Autodesk Ecotect Analysis software, representing shadow and solar exposure on the facades of each side of the street, at the mentioned 7 peak hours of a winter day on Dec 21st, Jan 21st, and Feb 21st. Solar access was measured by calculating the shaded area in each of the images produced in the different cases of the study then the average percentage of the solar access according to each building height combination was found.

Table 1. Temperature in Amman in 2008

Temperature 2008 (Amman, University of Jordan) °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extreme Max	24.0	25.1	26.3	33.0	39.0	38.3	39.0	41.5	39.0	34.6	28.0	24.8
Mean Max	10.1	11.5	15.0	20.2	25.2	28.1	29.5	29.6	28.3	25.1	18.2	12.4
Mean	6.4	7.4	10.2	14.6	18.9	21.9	23.6	23.6	22.2	19.0	13.1	8.4
Mean Min	2.7	3.2	5.4	8.9	12.5	15.7	17.7	17.6	16.0	12.8	8.0	4.3
Extreme Min	-8.3	-4.5	-6.5	-1.5	1.4	4.5	8.5	8.8	4.5	3.4	-2.0	-4.8

Table 2. GAM Regulations of Residential Areas

Required building setbacks in GAM regulations for residential zones. (Source: Greater Amman Municipality, GAM, 2006).

Setbacks in GAM regulations for residential zones

	Residential zone	Frontal setback (m)	Side setback (m)	Rear setback (m)	Allowable block height	Allowable built area[a]
1	Class (A)	5	5	7	15 (m)	36%
2	Class (B)	4	4	6	15 (m)	42%
3	Class (C)	4	3	4	15 (m)	51%
4	Class (D)	3	2.5	2.5	15 (m)	52%

[a] The maximum allowable built area is given as a percentage of the total plot area.

4. Analysis

Data was subjected to Autodesk Ecotect Analysis on Latitude 32°N, holding constant the street width at 12m, and varying the building height combination on both sides of the street between 9m, 12m, and 15m high. The produced images of shade and shadow area were used in calculating the shaded area on the facades facing the sides of the street.

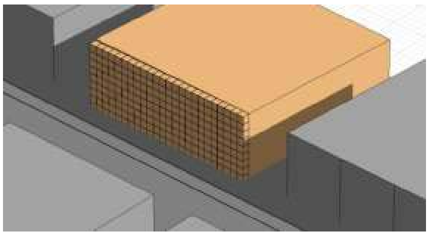
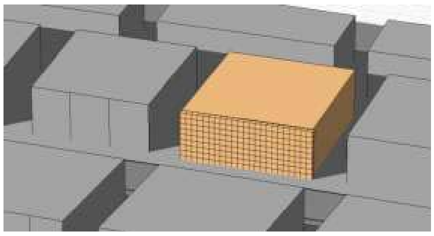
Analysis showed that solar accessibility is influenced by street orientation and the surrounding building heights. When considering East-West oriented streets, varying the street's northern building's height while holding constant the height of the street's southern building have no effect on the solar access on the south facing facades. On the other hand, varying the heights of the southern buildings is inversely proportional to the solar access, in other words, as the building height increases the solar access decreases.

Similarly, north-south oriented streets were studied. Observations showed no significant difference when altering the heights of buildings on either sides of the street in the solar access.

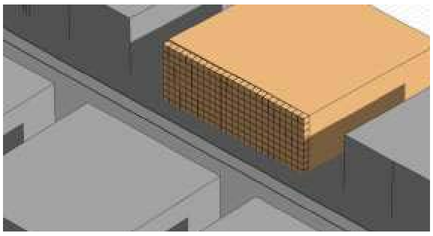
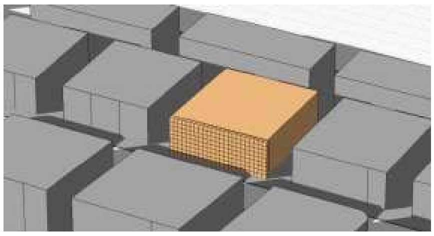
Furthermore, northeast-southwest orientation was also analyzed. However, Northwest facing facades showed no effect in reference to building height, as they appeared to be shaded most of the day, where they are exposed to sunlight for one hour a day. Similarly, the southeast facing facades showed no significant effect of the opposite buildings height, as they exposed to sunlight almost all day long.

Finally, northwest-southeast orientations were studied, and results showed that northeast facing facades were entirely shaded except at a single hour (9:00 am) on February 21st, otherwise, the façade was not significantly affected by the opposite building's height. While the southwest facing facades, and although were almost entirely exposed to sunlight, the shaded area in the afternoon hours showed an increase as the opposing building height increased.

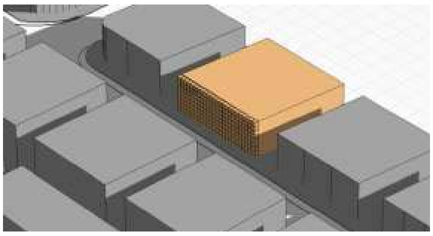
Detailed Analysis is provided in Appendices A through D, attached with this research.

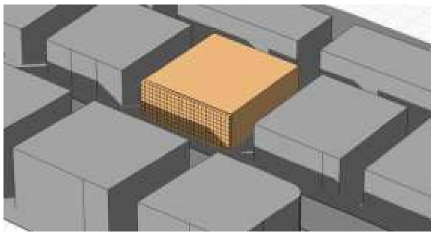



Picture (i) – Image produced by Autodesk Ecotect Analysis for an E-W oriented street of a 9m, north-facing elevation, opposed by a 9 m high building on January 21st at 15:00 pm on latitude of 32°N.	Picture (ii) – Image produced by Autodesk Ecotect Analysis for an E-W oriented street of a 9 m, south-facing elevation, opposed by a 9m high building on January 21st at 15:00 pm on latitude of 32°N.

Picture (iii) – Image produced by Autodesk Ecotect Analysis for an E-W oriented street of a 9 m, north-facing elevation, opposed by a 12 m high building on January 21st at 15:00 pm on latitude of 32°N.	Picture (iv) – Image produced by Autodesk Ecotect Analysis for an E-W oriented street of a 9 m, south-facing elevation, opposed by a 12 m high building on January 21st at 15:00 pm on latitude of 32°N.





Picture (v) – Image produced by Autodesk Ecotect Analysis for an E-W oriented street of a 9 m, north-facing elevation, opposed by a 15 m high building on January 21st at 15:00 pm on latitude of 32°N.	Picture (vi) – Image produced by Autodesk Ecotect Analysis for an E-W oriented street of a 9 m, south-facing elevation, opposed by a 15 m high building on January 21st at 15:00 pm on latitude of 32°N.

5. Discussion

The objective of this research is to examine the effect of street orientation and surrounding building heights on the solar access. Data obtained from Autodesk Ecotect Analysis supported the prediction that the solar accessibility varies with street orientation and surrounding building heights, as observed in the east-west oriented streets, which showed clear correlation between the variables under study, in contrast to the north-south oriented streets, which have shown the least correlation.

This result is supported by the extant literature on the topic. For example: Johansson (2006) found that for north-south street direction, solar access change is insignificant throughout the season, while for east-west oriented streets, the situation is more complex. On the other hand, our results extend the current literature that found solar access is a function of orientation, as our research took into consideration four different street orientations, rather than two, and 18 different building height combinations, which, in turn, produced significant insights and knowledge that was missing in the current literature.

Depending on the analysis results of the east-west orientated streets, altering the northern building's height would not affect the solar access while altering the southern building's height shows a significant effect. It was observed that there was no significant difference when altering the southern building's height between 9m and 12 m, the significant difference, however, was found when the southern building's height was set to be 15 m. As a result, the best height recommended on east-west oriented streets is 12 m, in order take advantage of an additional floor level on the southern building. Furthermore, as the northern building's height showed no effect on solar access, it is recommended that its height reaches the maximum allowed height in the GAM regulations of 15 m.

When addressing the north-south oriented streets, results show that since altering the buildings' heights has no significant difference on the solar access, it is safe, from solar access point of view, to recommend a 15 m high buildings on both sides of the streets. Moreover, proposals of increasing the heights to 18 m on both sides can be taken into consideration.

In the northwest-southeast street orientation, results show that since the southeast facing facades do not have any effect on the northwest-facing facades, it is recommended that southeast-facing buildings heights to be 15m. Furthermore, since results show zero correlation between building height and solar access, further research can be conducted to study the effect of even higher buildings such as 18 m on solar access. In contrast, and according to the results, since the southeast-facing facades are slightly affected by the opposite buildings, thus, 15 m heights are recommended for preferable solar access in addition to sufficient number of floors in the northwest-facing buildings.

Finally in studying northwest-southeast street orientations, southwest-facing facades have no effect on the opposite northeast facing buildings, thus, 15 m are the recommended height, in addition to the possibility of building higher than 15 m. While, there is a relatively significant effect of the northeast-facing facades on the opposite buildings between the 12 m and the 15 m high buildings, it is, therefore, recommended that buildings facing northeast do not exceed the limit of 12 m high.

In conclusion, this research provided recommended building's heights enclosing a 12 m width street at different orientations. However, the back sides of these buildings would make a good target for further research, in order to provide further recommendations concerning setback regulations. Results may include the addition of green parks, as well as thermally comfortable open public spaces.

References

A Comparative Analysis of the Outdoor Thermal Environment of the Urban Vernacular and the Contemporary Development: Case Studies in Dhaka. **Ahmed, Khandaker Shabbir. 1994.** [ed.] et al Etzion Y. Dead Sea, Israel: s.n., 1994. 11th PLEA conference (Architecture of the Extremes). pp. 341 - 348.

Ahmed, Khandaker Shabbir. 2003. Comfort in Urban Spaces: Defining the Boundaries of Outdoor Thermal Comfort for the Tropical Urban Environments. *Energy and Buildings.* 2003, Vol. 35, pp. 103 - 110.

Architecture, CLEAR: Comfortable Low Energy. Street Orientation. *CLEAR: Comfortable Low Energy Architecture.* [Online] http://www.new-learn.info/packages/clear/visual/buildings/site/orientation.html

Coluccia, Andrew and Horvata, Miljana. 2012. Making Toronto Solar Ready: Proposing Urban Forms for the Integration of Solar Strategies. *Energy Procedia.* 2012, Vol. 30, pp. 1090 - 1098.

Johansson, Erik. 2006. Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. *Building and Environment.* 2006, Vol. 41.

Knowels, Ralph L. 1999. The Solar Envelope. 1999.

Nikolopuolou, Marialena and Lykoudis, Spyros. 2006. Thermal Comfort in Outdoor Urban Spaces: Analysis across different Europian Countries. *Building and Environment.* 2006, Vol. 41, 11, pp. 1455 - 1470.

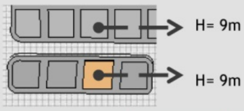
Van Esch, M. M.E., Loomana, R.H.J. and de Bruin-Hordijka, G.J. 2012. The effects of Urban and Building Design Parameters on Solar Access to the Urban Canyon and the Potential for Direct Passive Solar Heating Strategies. *Energy and Buildings.* 2012, Vol. 47.

DATA ABOUT THE AUTHORS

Wael Al-Azhari,
Myrna Haddadin,
Rund Hiyasat
Department of Architecture, the University of Jordan, Amman, Jordan
e-mail: w.alazhari@ju.edu.jo

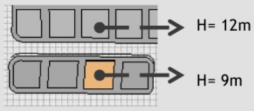
Appendix A –Shaded Areas (sqm) on E-W Oriented Streets Tables

Street Direct: E-W



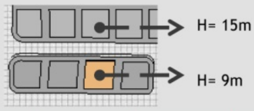
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: E-W



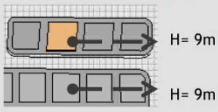
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: E-W



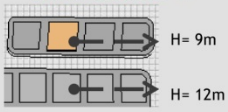
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: E-W



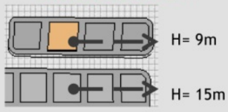
Time	21-Jan	21-Feb	21-Dec
9:00	0	0	0
10:00	0	0	0
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	0	0	20

Street Direct: E-W



Time	21-Jan	21-Feb	21-Dec
9:00	0	0	38.3
10:00	0	0	0
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	0	0	28
15:00	35	0	91

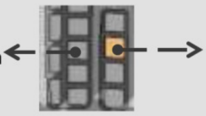
Street Direct: E-W



Time	21-Jan	21-Feb	21-Dec
9:00	80.75	0	109.8
10:00	38	0	69.1
11:00	22	0	59.5
12:00	0	0	51.8
13:00	23.8	0	66.3
14:00	48	0	97.1
15:00	108.2	0	161.7

Appendix B –Shaded Areas (sqm) on N-S Oriented Streets Tables

Street Direct: N-S

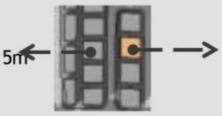


Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	0	0	29.32

Street Direct: N-S

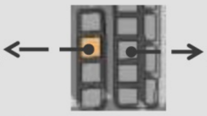
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	43.78	0	98.2

Street Direct: N-S



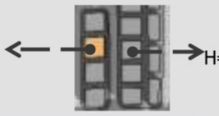
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	100.98	36.3	158.64

Street Direct: N-S



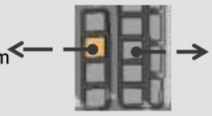
Time	21-Jan	21-Feb	21-Dec
9:00	9	0	0
10:00	0	0	0
11:00	0	0	0
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: N-S



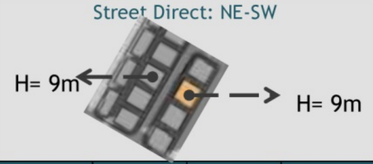
Time	21-Jan	21-Feb	21-Dec
9:00	0	0	0
10:00	0	0	0
11:00	0	0	0
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: N-S

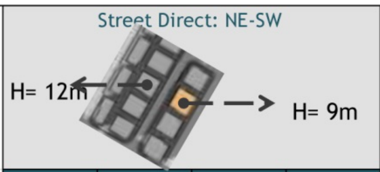


Time	21-Jan	21-Feb	21-Dec
9:00	78.85	27.75	69.75
10:00	0	0	0
11:00	0	0	0
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

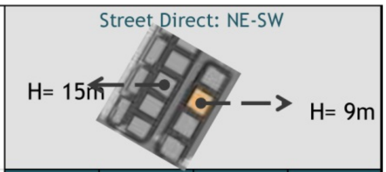
Appendix C –Shaded Areas (sqm) on NE-SW Oriented Streets Tables



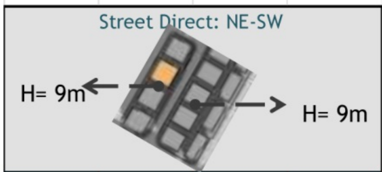
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	0	0	0



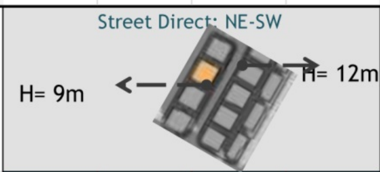
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	0	0	0



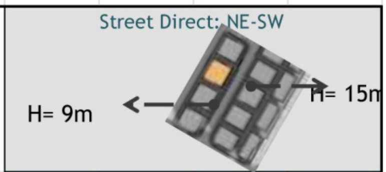
Time	21-Jan	21-Feb	21-Dec
9:00	216	216	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	0	0	0



Time	21-Jan	21-Feb	21-Dec
9:00	19	0	21.6
10:00	0	0	0
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	216	216	216



Time	21-Jan	21-Feb	21-Dec
9:00	76	27.7	78.4
10:00	0	0	18.2
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	216	216	216



Time	21-Jan	21-Feb	21-Dec
9:00	133	88	131.3
10:00	60.8	0	76
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	216	216	216

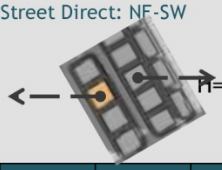
Appendix D –Shaded Areas (sqm) on NW-SE Oriented Streets Tables

Street Direct: NE-SW

H= 9m  H= 9m

Time	21-Jan	21-Feb	21-Dec
9:00	216	0	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: NE-SW

H= 9m  H= 12m

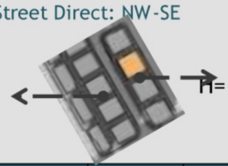
Time	21-Jan	21-Feb	21-Dec
9:00	216	0	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: NW-SE

H= 9m  H= 15m

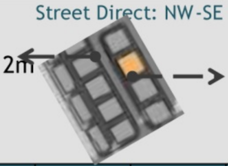
Time	21-Jan	21-Feb	21-Dec
9:00	216	0	216
10:00	216	216	216
11:00	216	216	216
12:00	216	216	216
13:00	216	216	216
14:00	216	216	216
15:00	216	216	216

Street Direct: NW-SE

H= 9m  H= 9m

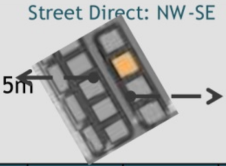
Time	21-Jan	21-Feb	21-Dec
9:00	0	216	0
10:00	0	0	0
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	0	0	0
15:00	32.5	0	65

Street Direct: NW-SE

H= 12m  H= 9m

Time	21-Jan	21-Feb	21-Dec
9:00	0	216	0
10:00	0	0	0
11:00	0	0	0
12:00	0	0	0
13:00	0	0	0
14:00	24	0	72
15:00	91	27	127

Street Direct: NW-SE

H= 15m  H= 9m

Time	21-Jan	21-Feb	21-Dec
9:00	0	216	0
10:00	0	0	0
11:00	0	0	0
12:00	0	0	0
13:00	0	0	46.9
14:00	96	0	141.6
15:00	153.75	82.4	184.8