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SPACE AFTER DARK

Measuring the impact of public lighting at night on visibility, movement, and spatial configuration in urban parks

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ABSTRACT

On 19 August 2016, Transport for London (TFL) launched their first Night Tube, which offers 24-hour service on Fridays and Saturdays. With more lines coming in autumn 2016, London follows the lead of other cities such as New York, Berlin, and Tokyo to be deemed a 24-hour city. Aside from debates concerning the energy waste, pollution, and security caused by the policy, one question is evident: *How does the city 'work' at night?*

Humans navigate through space using vision which involves cue or landmark recognition, turn angle estimation, network comprehension, and route plotting strategies (Golledge, 1995). The situation changes at night when the configuration of space is altered by the presence of artificial light. This applies predominantly to outdoor spaces where lighting designers or urban planners classify the type of luminaires according to the street hierarchy: white light is used for the 'core' areas and main roads, yellow light for secondary roads, and reddish light for residential pathways (Meier, 2015, p.251).

This study aims to explore whether or not there is a change of selected or most frequently used routes due to the impact of altered visual perception of space, and how the locus and quantity of the artificial illumination may change the perceived urban structure. It uses Dalton's (2001) research on cognition and movement, and the theory of natural movement (Hillier et al., 1993) as a base. Two parks in London were selected as the main case studies: Green Park and Clapham Common, along with a pilot project in The Meadows, Edinburgh. The parks were examined using a combination of street network analysis, detailed observations on people's movement and occupancy patterns, and survey on the existing lighting conditions. Correlations between movement, space, and lighting were analysed using 'multiple linear regression' method to discover a link between the fields of urban planning and lighting design.

The results reveal that artificial illumination at night alters the perception of the spatial configuration. These results may contribute to the development of lighting master plans in cities. The research presented here produces parallel results with a recent study by Del-Negro (2015) that reveals how the lighting situation affects people's choice of routes through a series

of experiments conducted in Lisbon and London. The correlation between Normalised Angular Choice and illuminance values suggests that these two factors are reliable predictors in an urban configuration at night, which allows us to use the illumination factor as a variable when applying Space Syntax analytical methods to predict nocturnal movement patterns.

KEYWORDS

Space syntax, lighting masterplan, natural movement, public parks, nocturnal city.

1. INTRODUCTION

The introduction of industrialised artificial lighting at the end of 19th century has turned darkness into a more controllable aspect of life (Meier et al., 2015, p152). Since then, artificial lighting has developed into an important element in the urban environment as it plays a role in public area orientation during the dark hours. This is evidenced in the study by Besecke and Hänsch (Meier et al., 2015, Urban Lighting, Light Pollution and Society, Chapter 12) in Germany, where 90% respondents select 'orientation' as the primary function in the provision of artificial lighting, followed by 'safety' (87%) and security (83%).

To navigate within the built environment, humans use vision and a cognitive process that often involve inexact measurements or distorted cognitive maps, which may produce a different result compared to the computerised algorithms (Golledge, 1995). During the dark hours, artificial illumination helps people to perceive spaces by improving visibility significantly and, in turn, increasing levels of security, safety, and orientation which is the primary purpose of artificial illumination (Meier et al., 2014, p.428). Whereas it enables orientation, at the same time artificial lighting can also create what Meier et al. (2014, p.157) call *defamiliarization* of space; a new situation and ambience at night by artificial illumination, resulting in confusion of space due to the different information perceived compared with the visual condition during the day. In relation to the safety and security, public area lighting also facilitates users with visual clarity to identify other pedestrians and anticipate or avoid potential encounter (Raynham and Mansfield, 2001). This statement is a response to Valentine's (1990) research concerning women's fear of public spaces. Through a series of interviews, Valentine found that the majority of women feel safer by the presence of others as they believe it may deter potential offenders.

Visual recognition of space also has an impact on the economic and social activities in the public realm, especially when it comes to the 24-hour business and industries in metropolitan cities (Choi et al., 2006). Hence, lighting master plans are considered crucial in urban environments; particularly in the commercial areas where people are more attracted to use the space. Choi et al. (2006, 2007) composed lighting master plans for a shopping district and residential area in Seoul, South Korea, using space syntax techniques to achieve optimised distribution of movement within the project area during dark hours. However, these studies are short of evidence when it comes to the relation between pedestrian movement and illumination, and also in the way the different distribution of light at night creates a new hierarchy of space that changes the visibility in the spatial configuration. Looking back at Hillier's theory of natural movement (Hillier et al., 1993) that *"...configuration may influence movement but movement cannot influence configuration"*, Choi et al. (2006, 2007) studies need to be approached from the opposite direction.

Configuration, as described by Hillier et al. (1987, p363) is *"...the relation between two spaces taking into account a third, and as the relations among spaces in a complex taking into account all other spaces in the complex."* Spatial configuration is an advanced understanding of spatial relations that forms the space syntax theory, and a set of techniques for the representation, quantification, and interpretation of spatial configuration in buildings and urban formation (*ibid.*). The term 'natural movement' comes from the idea that movement within a spatial system is distributed, at a basic elementary level, by the configuration of the spatial structure following the logic of the links between spaces (Hillier et al., 1993). In the origins of the space syntax technique, the potential movements in urban grids are described by the measure of 'integration' in an axial map that consists of the longest and fewest straight lines that are drawn through the spaces to cover the grids (Hillier and Hanson, 1989). It uses a series of algorithms that can be generated automatically by computer programs (Hiller et al., 1993).

So far, studies on pedestrian movement patterns and route choices using space syntax techniques have only been conducted for the day time scenario (Hillier et al., 1993; Dalton, 2001; Javadi et al., 2017), whereas the way pedestrians use the space at night might change compared to the day due to the unequal presence of artificial lights. This study tries to answer in detail the following questions: *"To what extent the artificial illumination impacts the pedestrian movement patterns at night?"* and *"Is there a chance to predict night time movements by correlating the lighting hierarchy with space syntax measurements?"*

2. DATASETS AND METHODS

Space syntax establishes analytical methods to scrutinise spatial layouts and their configuration in a spatial system or settlement (Hillier, 1996). By considering the relations between each spatial element, it measures the degree of structure in urban space either convexly or axially, distributed or undistributed, and symmetric or asymmetric (Hillier and Hanson, 1989). This study uses 'Integration' and Choice' measures to capture the relation between spatial structures and natural movement patterns (Hillier & Iida, 2005). The degree of integration represents the potential for a space to serve as a destination within a system because it measures the distance from each spatial element to all other elements. 'Choice' measures the potential of a space to be used as a passing-through route when considering the shortest and simplest routes from one space to all other spaces in a spatial network (Hillier, Yang, Turner, 2012).

Parks are an interesting case study regarding pedestrian movement, whereby the configuration of space and lighting do not constantly follow those of the surrounding urban grids. Parks are also found to accommodate three types of outdoor activities, as suggested by Gehl (2011): the *necessary activities* which are more or less compulsory (going to school or work, shopping, waiting for a bus, etc.), optional activities (taking a walk, exercising, or sunbathing), and *social activities* (conversations, children playing, communal activities or encountering people on the streets). London, in particular, is an excellent case study as it denotes one of the world's mega-cities with 24-hour activity, while the city also represents the largest urban forest with 47% of its area covered in green spaces (Usborne, 2014).

Green Park and Clapham Common in London were selected based on their opening hours, character, and location. Green Park, which opens between 05:00-00:00, is located in the West End area that is a famous destination for tourism due to its proximity to the Buckingham Palace, St James's Park, and Hyde Park. On the other hand, Clapham Common is a less central area, with the park surrounded by mostly residential buildings and some educational or commercial edifices. It remains open for 24-hours, with well-connected transport links to the city centre through underground, overground, national rail services, and buses. Aside from their distinct characters, the two parks also present different situations at night where almost all pathways are lit in Clapham Common—a contrast condition to the more selective light distribution in Green Park.

The Meadows in Edinburgh was added as a pilot study to assess the applicability of the research method, as it represents the first UK city that has developed a lighting master plan (Scottish Executive, 2007), while the park is openly accessed for 24 hours and located in the heart of the city. The measures of 'Integration' and 'Choice' are used to calculate the relation between the spatial structure and the generative natural movement patterns (Hillier & Iida, 2005). The maximum/global catchment area is limited 5 km radius (approximately 60-minute walking), and the study focuses on the pedestrian movement. Following these stages, the measures are 'normalised' (using Normalised Angular Integration and Normalised Angular Choice for street segment analysis) to compare spatial systems of different sizes (Hillier, Yang, Turner, 2012). For the local scale analysis, several radii will be tested to determine the optimum distance covered by walking, which is around 400 – 1600 m radius (5 – 25 minutes walk). The values from space syntax calculations are finally compared with the observation results to look for correlations between movement and space.

The observation data are collected through the 'gate-counting' method which allows researchers to collect various kinds of data that can be represented graphically and statistically (Grajewski and Vaughan, 2001). It takes place on weekdays and weekends during three periods of time: lunch time (12:00-14:00 GMT), rush hour/early evening (17:00-19:00 GMT), and night time (19:00-21:00 GMT). Pedestrians passing the imaginary lines on each gate are counted for the duration of five minutes, and the recorded number is multiplied to get the average hourly rates (*ibid.*). The next step is to find the relation between space, movement, and illumination by correlating the data from Normalised Angular Integration (NAIN) and Normalised Angular Choice (NACH) on the appointed radii, observation, and lighting measurement.

To get the exact measurement for lighting, the illumination level is measured in horizontal (on the ground) and vertical (eye level height) position. In the Society of Light and Lighting (SLL) Lighting Guidelines (2012) for the UK, the horizontal illuminance is describe as assistance for people to see obstacles on the ground, while the vertical illuminance helps people to recognise their surroundings. The light metre tool Konica Minolta T-10 is used to measure the highest and lowest illuminance level on every segment of the park's pathways to get the average value, which is needed to analyse with other data using multiple linear regression. The correlation determines if the artificial illumination creates a spatial configuration and pathway hierarchy that may influence the movement pattern at night.

3. RESULTS

3.1 SPACE AND MOVEMENT

The aim of the pilot project in Edinburgh was to distinguish the movement pattern observed during the day and night time, and use the results to assess the research and analytical method, before correlating it with the lighting measurements. A public park located in the heart of Edinburgh, The Meadows provides connections from the residential area to the city's centre of activities. The observation of people's movement in the park, which takes place on early February (with the local sunset time is recorded to be between 17:16-17:21 GMT), reveals a distinct difference between the weekday and weekend pattern of movement.

Figure 1 demonstrates that Gate 1 leads with the highest amount of passers-by on the weekday but clearly loses significance in the weekend lunch time. A similar pattern shows in Gate 8 where, within the same period, the number of users drops by 79% compared to the weekday. Every other gates follow the pattern, with the exception of Gate 4 that increases by 50% at night. This finding may suggest that most of the pathways are used for regular activities during the working days, yet similarly quite active in the weekend.

The relation between spatial configuration and movement can be seen by comparing the 'gate-

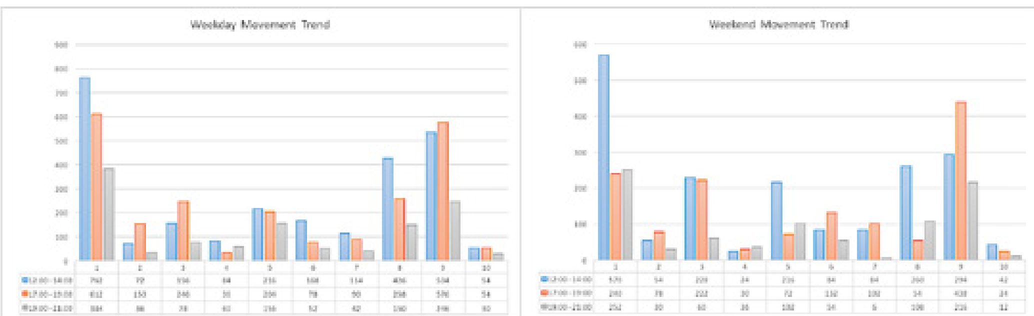
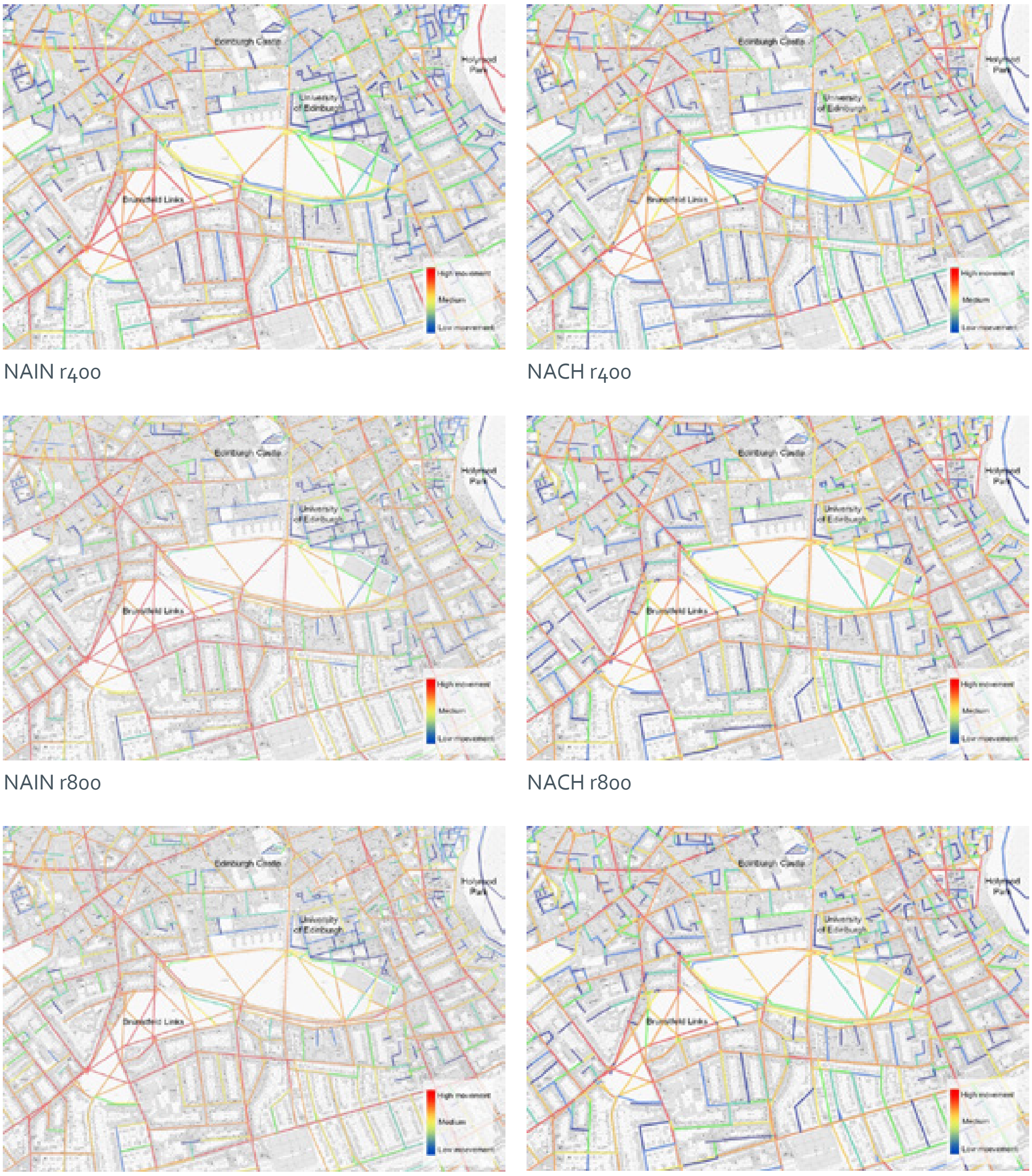


Figure 1 - Diagram showing the pedestrian flow in The Meadows within three observed periods during the weekday (left) and weekend (right). The vertical axis indicates the movement per hour captured during the observation while the horizontal axis represents the gates.

counting' observation data with the value from space syntax measurements. Several radii are tested using the Depthmap software to determine which measurements of Integration and Choice perform better in predicting movement (Hillier & Iida, 2005). This is the point of assessment to seek whether the proposed method can be used to distinguish the night time spatial configuration. Figure 2 illustrates how the segments in The Meadows start to give higher values of both NAIN and NACH in 800 m radius, meaning that the park performs well as a destination and route choice in this scale. However, the results from NAIN measurement show how the park is less dominant compared to its neighbour, Bruntsfeld Links, which suggests that it works better as a through-movement, but not as a destination.



NAIN r400

NACH r400

NAIN r800

NACH r800

NAIN r1200

NACH r1200

Figure 2 - Analysis of NAIN and NACH measurements using the Depthmap software. Source: EDINA Digimap (background) and Space Syntax Limited (segment map).

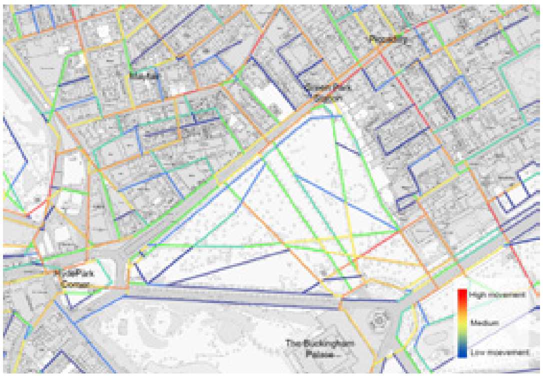
The next step is to associate the observed movement with the analysed segment map to see whether the two are relevant to each other. The R-squared values show more relevant results between NACH and observed movements in the park, with only some discrepancies at the particular period on the weekend (17:00-19:00). It may be an impact of the weekend activities that are more spontaneous, in contrast to the regular movements on the weekday. This finding signifies that people use the pathways inside the park as part of their daily routes, which corresponds with Dalton's (2001) research that suggests how people tend to retrace the preferable routes, given the opportunity to return to their destination origin. This situation suggests that the regular movements in The Meadows are not disrupted by the change of time, which is probably due to the maintained visibility during the dark. To attest the verdict, the relationship between spatial configuration and movement pattern at night needs to be analysed with the support of illuminance data. While the data were not gathered in the pilot study, they are collected and analysed in relation to the spatial configuration for the studied parks in London. The illuminance data will then be associated with the movement and NACH values to see the impact of the night time visibility to the spatial configuration. Meanwhile, NAIN values are omitted due to the irregularities in the movement data correlation (Table 1).

Measures	Weekday Movement			Weekend Movement		
	12:00 – 14:00	17:00 – 19:00	19:00 – 21:00	12:00 – 14:00	17:00 – 19:00	00
NAIN	0.53492	0.38601	0.41026	0.44580	0.13634	0.44867
NACH	0.71817	0.80261	0.78861	0.86411	0.35626	0.69955

Table 1 - R-squared values from the linear regression analysis, showing the correlation between space syntax measurements and observed movements during the appointed three periods of the day, both in weekday and weekend.

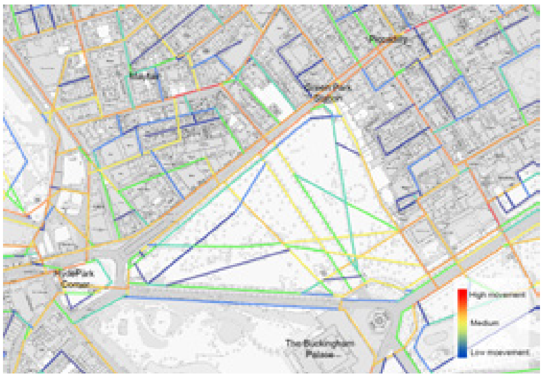
3.2 SPACE, MOVEMENT, AND LIGHT

Following results from the pilot project in Edinburgh, a similar method is then applied to the parks in London, starting up with finding the most appropriate scale for the NACH measurement (Figure 3). The analysis in NACH confirms higher values in almost every pathway inside Green Park from 800 m radius onwards. Analysis for a catchment area of 400 m radius only shows small parts of the park showing high NACH value while r1200 show similar results with r800. Hence, the preferred radius is set in 800 m. Clapham Common, on the other hand, works best as through movements in radius 1200 m with almost equal values in all segments. In this manner, each of them will be measured using two different radii, as a result of the different size of the parks.



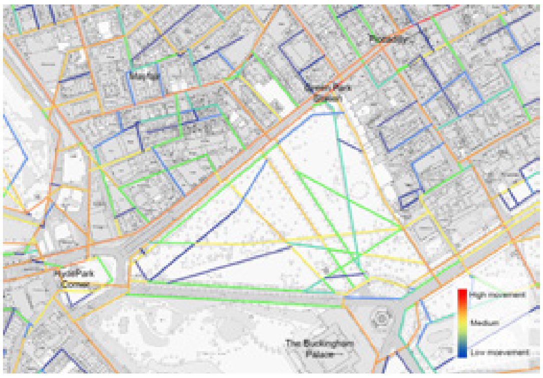
Green Park NACH r400

Clapham Common NACH r400



Green Park NACH r800

Clapham Common NACH r800

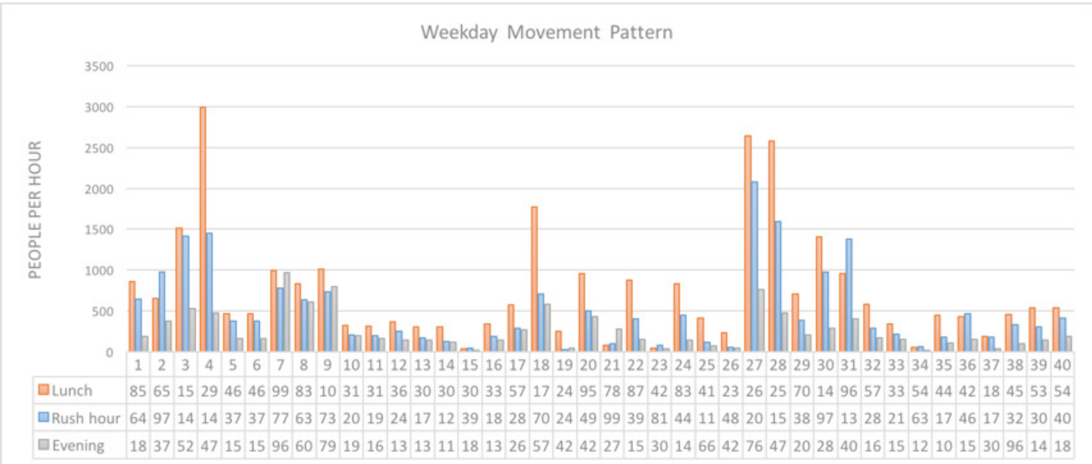


Green Park NACH r800

Clapham Common NACH r800

Figure 3- Analysis of NACH measurements on London parks using the Depthmap software.
Source: EDINA Digimap (background) and Space Syntax Limited (segment map).

Forty gates were observed in Green Park and thirty-three in Clapham Common, based on the highest values in the NACH measurement. Morning rush hour period (07:00-09:00) were also added to neutralise the change of movement pattern during the early evening (17:00-19:00) where the data may become biased due to the commuting activity within this period. Both morning and early evening period are then combined as 'rush hour', as they demonstrate similar situations (Figure 4 and 5).



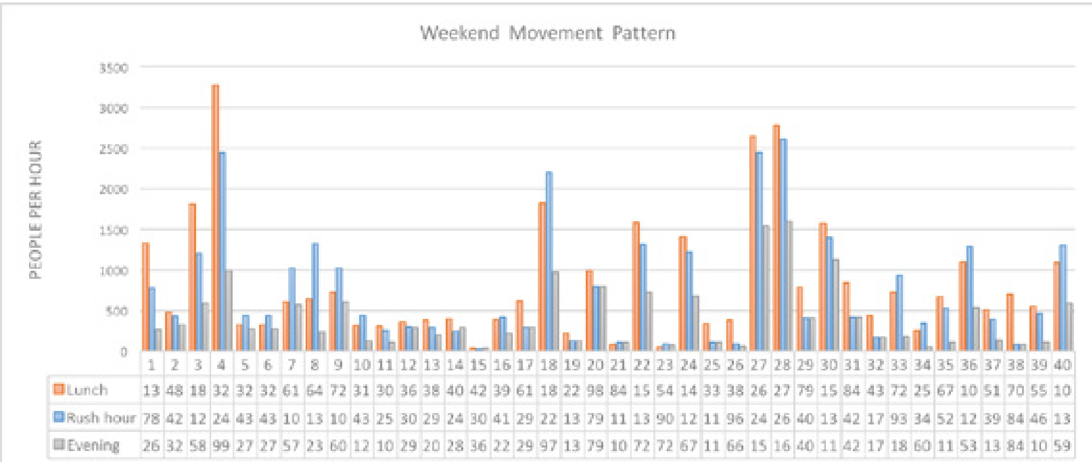
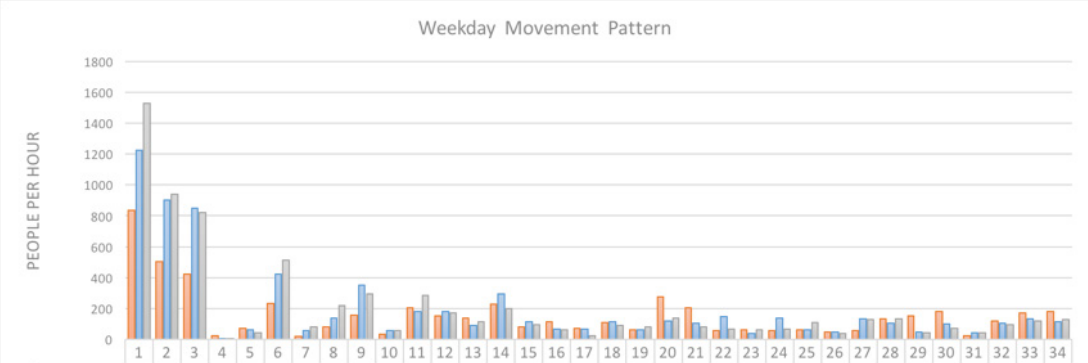
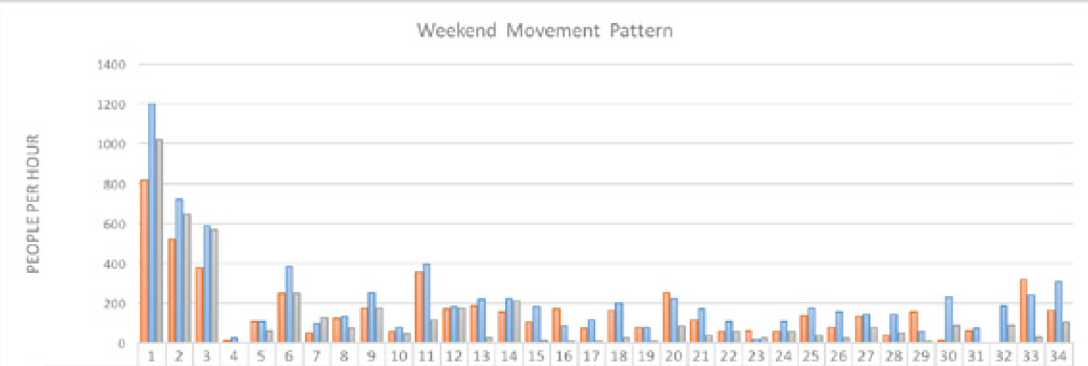


Figure 4 - Recorded movement pattern in Green Park within three periods of a day.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Lunch	834	504	420	24	72	234	18	78	156	30	204	150	138	228	78	114	72	108	60	276	204	54	60	54	60	48	54	132	150	180	24	120	168	180
Rush hour	122	903	849	6	63	420	57	135	351	57	180	180	87	294	114	66	66	114	63	120	105	144	36	135	60	48	132	102	48	99	42	105	132	111
Evening	153	942	822	6	42	510	78	216	294	54	282	168	114	198	96	60	24	90	78	138	78	66	60	66	108	36	126	132	42	72	42	96	120	126



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Lunch	816	522	378	12	108	246	48	120	174	54	354	168	186	156	102	168	72	162	78	252	114	54	60	54	138	78	132	36	156	12	60	0	318	162
Rush hour	120	720	588	24	108	384	96	132	252	78	396	180	216	222	180	84	114	198	78	222	168	108	18	108	174	156	144	144	54	228	72	186	240	306
Evening	102	648	564	0	60	246	126	72	174	42	114	174	24	210	12	6	6	24	6	84	36	54	24	54	36	24	78	48	6	90	0	90	30	102

Figure 5 - Recorded movement pattern in Clapham Common within three periods of a day.

Looking at the trend in the above figures, it is evident that more movements are captured at the gates located near the attraction points that Hillier (1993) refers to 'multipliers'. In Green Park, Gate 4 connects the park to the underground station with a straight route to Buckingham Palace, while Gate 27 and 28 heads directly to the Palace. Clapham Common has fewer attractions than Green Park, with only the first five gates lead to the underground station. The recorded pattern indicates how the 'multipliers' work in an extreme manner, as they multiply the number of movements in the urban structure. In this sense, the space syntax measurements need to be adjusted by adding these multipliers into the segment map before correlating them with the observation data to get more relevant results. Using the logic that segments with more proximity to the attraction points should have higher values, Metric Step Depth is added to the measurements as it calculates the distance from an assigned point to other segments. Thus, the following formula is used:

$$Weighted\ NACH = NACH\ value\ x\left(\frac{1}{M1+M2+M3}\right)$$

M1 = Metric step depth from multiplier 1 (Underground station)
M2 = Metric step depth from multiplier 2 (The Buckingham Palace)
M3 = Metric step depth from multiplier 3 (Hyde Park Corner)

By adding the Metric Step Depth into NACH measurement, the highest values are shifted to the nearby attraction points. As they now share more resemblance with the observed movement patterns, it becomes possible to correlate the two data using the linear regression method (Table 2). The correlation result suggests that the two parks have a different situation regarding the recorded movement trends. Despite the high number of movement recorded between 12:00-14:00 in Green Park, the movement only corresponds better with the NACH value on the weekday early evening, while Clapham Common demonstrates relatively consistent patterns in all time periods. It clearly illustrates how tourism activities bring high impact to the configuration, since it creates unsystematic patterns of movement due to the indistinct destinations. The issue with tourists is that they are trying to meander through space instead of navigating [1] through the network (Hillier and Iida, 2005). This presumption is supported by the lower R-squared values in the Green Park's weekend correlation which shows how the irregular movements from the tourists, who use the space rather freely, dominate the space.

Parks	NACH – Weekday Movement			NACH – Weekend Movement		
	12:00 – 14:00	17:00 – 19:00	19:00 – 21:00	12:00 – 14:00	17:00 – 19:00	19:00 – 21:00
Green Park	0.35969	0.47759	0.23790	0.27323	0.17952	0.15196
Clapham Common	0.43682	0.64064	0.65608	0.44969	0.52186	0.63481

Table 2 - R-squared values from the linear regression analysis in Green Park and Clapham Common, showing different results between movement and the weighted NACH in each appointed radius.

The next step is to see if the artificial illumination brings a direct impact to the visibility of the spatial configuration. This can be assessed using the multiple linear regression method by correlating both movement and space configuration with the measured illuminance in the network structure. Horizontal illuminance that represents the amount of light received on each pathway may be used to evaluate, as it has direct relation with the street segment and can be measured technically. Hence, it is possible to associate the horizontal illuminance with values from movement and space configuration. The value itself can be obtained by summing up the highest and lowest horizontal illuminance between two light sources, and dividing the aggregate value with the distance (Figure 6). The average illuminance is then divided by the length of its street segment to get a quantitative value for lighting. Using this measurement technique, it is now possible to correlate illumination level with both space syntax values and observed movement data to see how the artificial lighting creates a different spatial hierarchy at night.

The on-site lighting measurement shows a contrasting situation in the two parks. Green Park, which is dominated by the use of the Victorian gas lamps, does not follow the minimum requirements from Lighting Guide 6 (SLL, 2012) and requires to be manually lit each night[2]. The lamps only contribute the maximum value of 20lux (horizontal) and 2lux (vertical), while most of the pathways only have 3lux (horizontal) and 1,5lux (vertical). This condition generates a contrast situation between the park and its surrounding streets, with the average illuminance in Piccadilly Street between 14-38lux (horizontal) and 17-29lux (vertical).

1 According to a study of human cognition (Golledge and Gärling, 2002), there is a distinct meaning between navigation (a certain knowledge on the routes is assumed) and way-finding (no predetermined criteria is defined which cause to involve search and exploration through space).

2 As reported by Maev Kennedy in an article posted in The Guardian online on 25 December 2015 (https://www.theguardian.com/culture/2015/dec/25/londons-last-gas-street-lamps).

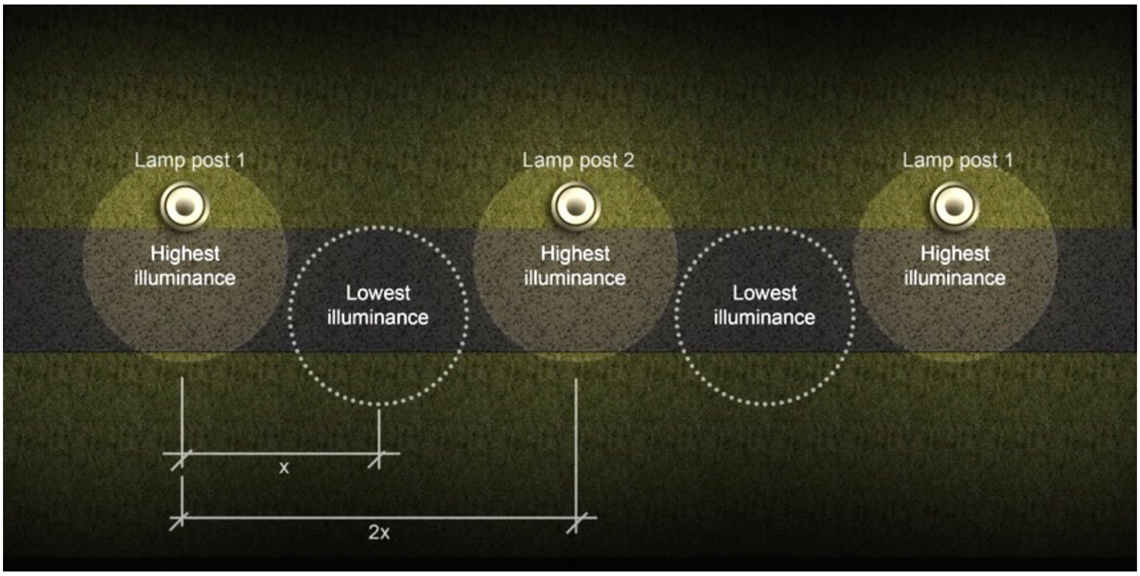


Figure 6 - The measurement technique to get the value representing the lighting intensity in the segment analysis. The highest and lowest illuminance generated by each lamp post are summed and divided by the total distance covered by them.

A different situation is recorded in Clapham Common, where the light is almost evenly distributed on the pathways using metal halide and sodium lamps. On average, the metal halide post lamps generate 13-36lux (horizontal) and 11-35lux (vertical), while the sodium lamps range between 4-25lux (horizontal) and 3-25lux (vertical). These illumination levels are slightly lower than the surrounding areas from LED post lamps that provide uniform illuminance with 40-45lux on the ground and 34-36lux vertical. However, the level drops quite significantly on the Southern side of the park, with the average illuminance 3-19lux (horizontal) and 1-8lux (vertical). This situation creates an early presumption that the configuration of space may change in areas with the poor visual recognition at night.

To support this premise, linear regression analyses between NACH and illuminance values in the two parks are performed separately. As expected, Green Park shows relatively low R-squared value compared with Clapham Common that indicates the higher correlation between illuminance and space measurement with R2 = 0.48504 on the weekday and 0.47748 on the weekend. This finding signifies a relation between space-movement and space-illuminance, with the higher value on the space-movement being linear to the space-illuminance, as shown in Table 3. It may indicate a prediction that higher correlations on space and illumination might generate more movements. Further evaluation of the relationship between the three measurements is performed in the final process using the multiple linear regression method. It uses the Stepwise method in the SPSS statistic software that calculates each independent variable to the dependent, as well as both independents to the dependent.

Parks	Weekday			NACH & Illuminance (Eh)
	Lunch	Rush hour	Evening	
Green Park	0.35969	0.47759	**0.2379**	**0.14292**
Clapham Common	0.43682	0.64064	**0.65608**	**0.48504**

Parks	Weekday			NACH & Illuminance (Eh)
	Lunch	Dusk	Evening	
Green Park	0.27323	0.17952	**0.15196**	**0.02245**
Clapham Common	0.44969	0.52186	**0.63481**	**0.47748**

Table 3 - Comparison between R-squared value from the first linear regression with the correlation between NACH and average horizontal illuminance.

The independent variables are the defining factors that are reliable for the dependent value. In this sense, movement is placed as the dependent variable, while NACH and illuminance values are calculated as the independent variables, since movement may become the outcome of the spatial configuration shaped by the spatial configuration and lighting hierarchy. This is in line with Hillier et al.'s observation (1993), that *"...configuration may influence movement but movement cannot influence configuration".* In this sense, the values from space syntax measurements and illumination may define the number of movements as they shape the spatial configuration and hierarchy, either during the day or night time.

In this analysis, the significant factor is determined by finding the calculated probability[3] (P values) of each element. For this reason, NAIN is excluded due to the inadequate Significance (P value ≥ 0.05). Both case studies are then assessed using an identical method, although the illuminance factor is excluded in Green Park due to the high P-value, that is 0.084 on weekday and 0.811 on weekend (P-value ≥ 0.05). The analysis implies that the movement value only corresponds with NACH r800, although it does not show high R-squared value, with only 0.238 on weekday and 0.152 on weekend (Table 4). On the contrary, Clapham Common shows positive results when the illumination factor is included to the analysis, while the Significance value is recorded to be 0.000 in both weekday and weekend data. Two models are calculated: first, using NACH r800 as the only independent; second, using both NACH r800 and illuminance value as predictors which simulates the multiple linear regression analysis. The result shows higher R-squared value in the second model, compared to the first one (Table 5). This finding shows how the illuminance value becomes a reliable predictor for movement once it has the higher correlation with the NACH measurement. It may suggest that the illumination factor only works when there is a strong correlation between space and movement, as shown previously in Table 3 where the Green Park's R-squared values cannot exceed 0.5.

3 Standard scientific practice, which is entirely arbitrary, usually deems a P value of less than 1 in 20 (expressed as P < 0.05, and equivalent to a betting odds of 20 to 1) as "statistically significant" and a P value of less than 1 in 100 (P < 0.01) as "statistically highly significant" (Greenhalgh, 1997, p.423).

Weekday Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.488[a]	.238	.218	203.900	0.001[a]

a. Predictors: (Constant), Weighted NACh R800

Weekend Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.390[a]	.152	.130	364.461	0.013[a]

a. Predictors: (Constant), Weighted NACh R800

Table 4 - Data summary of multiple regression analyses in the Green Park using weekday and weekend night time movement data as the dependent variable and NACH as the independent, excluding illuminance due to the P value (Sig.) ≥ 0.05.

Weekday Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.797[a]	.635	.623	130.714	.000[a]
2	.855[b]	.731	.714	113.971	.000[b]

a. Predictors: (Constant), Weighted NACH R1200
b. Predictors: (Constant), Weighted NACH R1200, Eh/m

Weekend Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.797[a]	.635	.623	130.714	.000[a]
2	.855[b]	.731	.714	113.971	.000[b]

a. Predictors: (Constant), Weighted NACH R1200
b. Predictors: (Constant), Weighted NACH R1200, Eh/m

Table 5 - Data summary of multiple regression analyses in Clapham Common using weekday and weekend night time movement data as the dependent variable, NACH and average illuminance as the independent, which results higher R2 value in the second model.

3.3 CORRELATION PATTERNS

For a better understanding of the change of visibility in the spatial configuration, the results from multiple linear regression analysis are then plotted on top of the segment maps (Figure 7 and 8). This procedure helps to see how the R-Squared values from space and movement correlations create several clusters that indicate different characters on each segment. The red lines resemble high NACH value with high movement, while the green lines indicate the lowest values on both. Two periods of time are compared to identify the change of the visible spatial configuration during the day and night time in each park.

The plotted maps demonstrate how Clapham Common maintains the same spatial hierarchy in both day and night time, while in Green Park the visible structure is shifted at night as the high movements do not follow the high NACH values. This situation can be attributed to the scattered movement of tourists who dominate the park. The lack of correspondence between movement and space configuration is shown in grey colour, indicating the weak relation between movement and NACH value. This finding suggests that the change of visibility, as the result of the presence of artificial illumination, may generate different movement patterns at night. Accordingly, equal distribution of light may help to maintain similar visibility levels to the ones during day time across the park's spatial configuration.

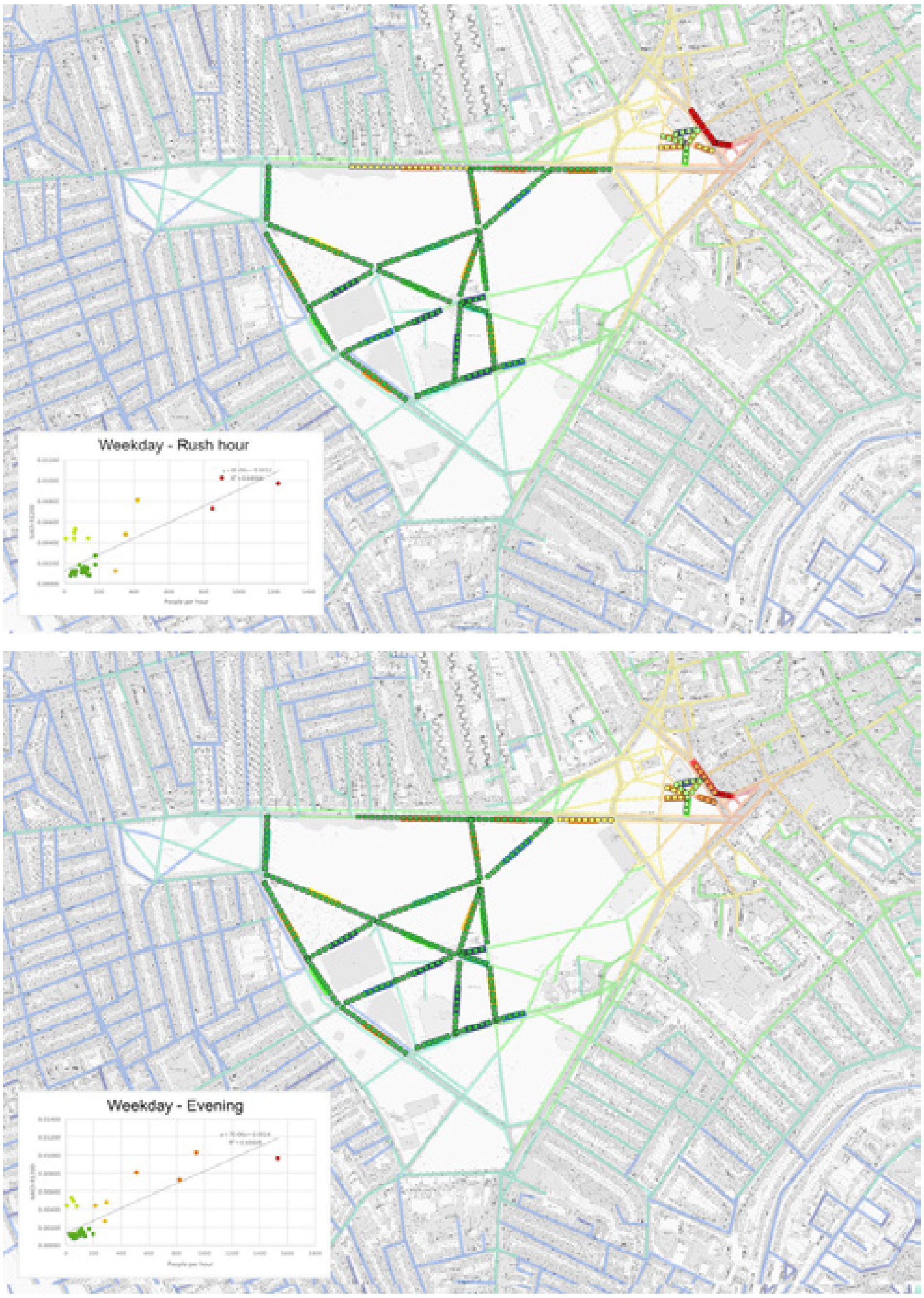


Figure 7 - The clusters in Clapham Common found in the correlation between NACH r1200 and weekday rush hour movement (top). The pattern remains at night (bottom). Source: EDINA Digimap (background) and Space Syntax Limited (segment map).

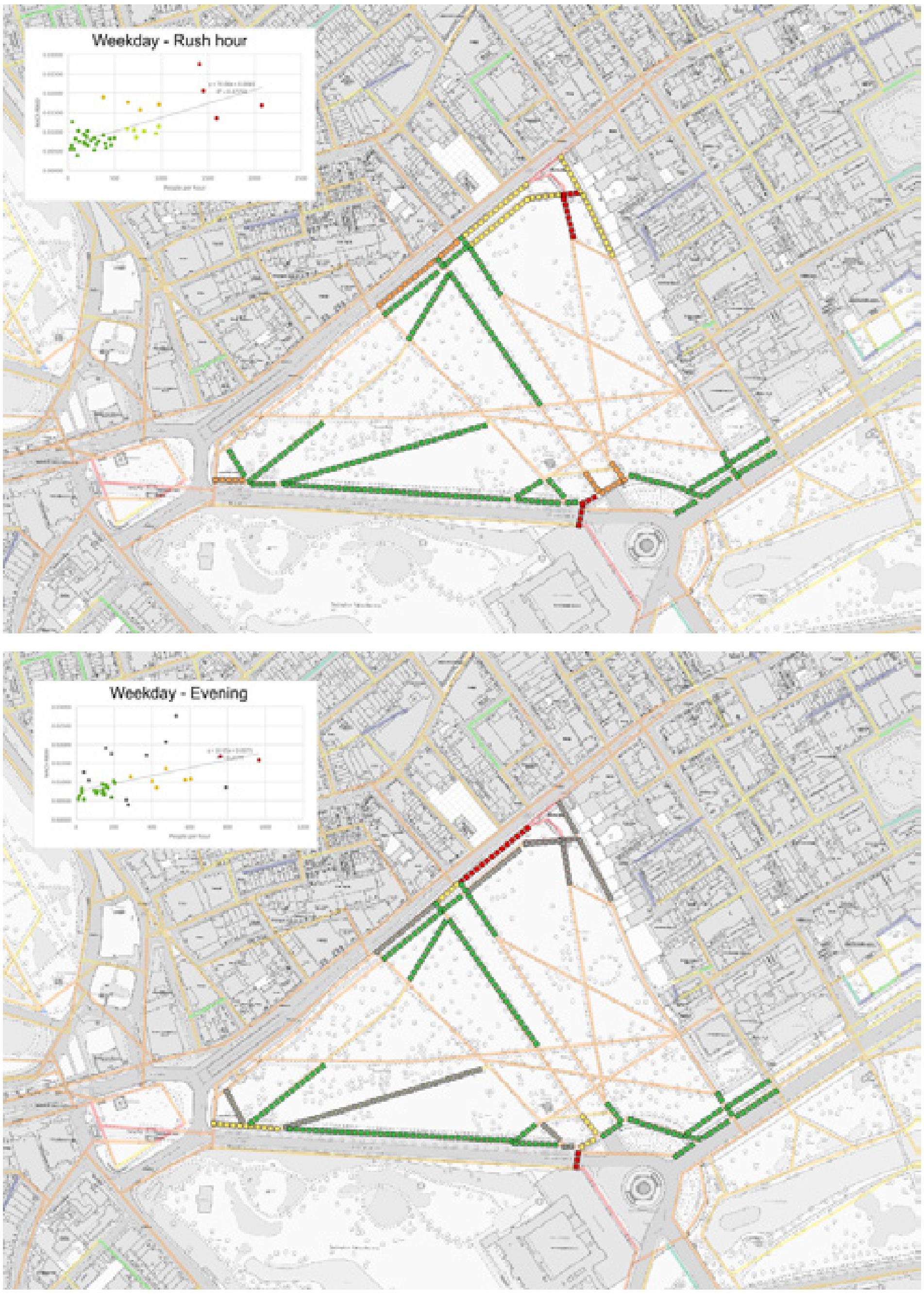


Figure 8 - The clusters in Green Park found in the correlation between NACH r800 and weekday rush hour movement (top). The pattern disappears at night following the change of spatial configuration (bottom). Source: EDINA Digimap (background) and Space Syntax Limited (segment map).

4. CONCLUSIONS

This research aims to assess whether there is a possibility to develop the night time model for predicting pedestrian movement patterns, using the space syntax analysis and quantitative lighting measurement values. The idea comes from the change of visibility at night where the artificial illumination replaces daylight. While some areas are maintained by the equal provision of light at night, unlit pathways remain dark and turn themselves into visual boundaries. Subconsciously, people move towards spaces that provide better visual recognition as an implication to safety and security issues.

This study examines the way that public area lighting in the outdoor environment influences the change of visibility in a spatial structure, which may affect the pattern of movement, as an implication of the route choice. The hypothesis is scientifically and empirically tested using technical and observation data. It reveals high correlations between movement and Normalised Angular Choice (NACH) at night when the lighting strategy follows the spatial configuration. Further research on this matter may lead to create a guidance to develop lighting master plan in urban structures; in the sense that higher illuminance may indicate higher movement, and the contrary. It also helps to improve earlier studies by Choi et al. (2006, 2007) that use Integration as a measurement to develop lighting master plans, by suggesting the use of Normalised Angular Choice (NACH) as a better predictor for natural movement at night. It suggests that Integration may be used to determine the required lighting intensity, while Choice defines the areas that may need to be lit. In the future, it might be possible to create a forecast model for the night time environment by inserting illumination factor as a new variable.

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