THE EFFECT OF SPATIAL PLANNING PATTERNS ON DISTRIBUTION OF PEDESTRIANS IN PUBLIC SPACES OF RESIDENTIAL NEIGHBOURHOODS IN THE CITY OF NAIROBI

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Abstract

This study focuses on public spaces of residential neighbourhoods in the City of Nairobi. It establishes various spatial characteristics, hence patterns, that have a bearing on the distribution of pedestrians therein. A higher encounter rate of pedestrians is a desirable public space quality given that the higher degree of surveillance accorded to space has the attendant benefit of deterring crime. Whereas the public spaces are intended to be a physical setting for people to socialize, move from one place to another, engage in business or recreational activities, some spaces are devoid of or have sub-optimal encounter rates of pedestrians due to weaknesses in spatial planning of the settlements. Such spaces have consequently failed to fulfill the roles ascribed to them and instead have become neglected and unsafe to operate in. Space syntax and structured observation have been used to collect data. Multiple regression analysis establishes that nine public space variables significantly predict the distribution of pedestrians in public space. The significant public space variables are grouped into the following four public space planning patterns that thus explain human distribution in public space: integration, constitutedness, land use planning and connectivity. The patterns inform generation of spatial planning policies whose utilization in layout of residential neighbourhoods results in desirable distribution of pedestrians in public space environments.

Key words: Public space, pedestrian, space syntax, spatial planning, residential neighbourhoods.

1.0 Introduction

Spatial planning is concerned with how space is created and arranged, in essence, how it works. In the layout of a settlement, it is the function of planning to define a network of public spaces, in relation to buildings and other activities, which in turn contributes to the settlement's spatial form. According to Hillier and Hanson (1984), a settlement's spatial structure presents patterns which carry social information and content. Spatial planning thus, in giving shape and form to the physical world, structures the system of space in which people live and move. In doing so, it has a direct relation to social life. It sets the conditions for patterns of movement, encounter and avoidance, not only of people but also social outcomes of their use of space. The people and the social outcomes of a spatial plan are fundamentally environmental and can make a public space in a settlement either suitable or unsuitable to live in.

Presently, as Magalhaes and Carmona (2009) points out, the focus of urban policy on issues of sustainability, social exclusion, economic competitiveness, place image and culture reveals an increasing awareness of the multidimensional nature of the challenges facing cities, their managers and inhabitants. This permeates our understanding of the roles of the built environment in general and public spaces in particular, partly explaining the renewed global policy interest in the quality of public spaces. The wider understanding of public space and its urban policy role has led to a closer attention to the processes through which its quality and its ability to fulfill all those functions are created and maintained, and through which rights and obligations are established.

The quality of public spaces of residential neighbourhoods in the developed and developing worlds differs markedly. In the former, frameworks for public space environmental management are in place and see effective participation of the state, private sector and users. The resulting quality of public space is good and according to Towers (2005), it has been realized and sustained partly by effective institutional capacity development and management efforts for enforcement of necessary controls for environmental management. Conversely, in the developing world, the quality of public space is characterized by environmental decline and particularly in this study, lack of or poor distribution of pedestrians.

Previous studies on the built environment have underscored the important role played by presence of people in public space. Jacobs (1961), Alexander et al (1977), Hillier (1988) and Moirongo (2011) in this regard unravel human encounter patterns and associated social behaviour as being a consequence of spatial plan structures. The setting of this study is in the planned residential neighbourhoods of the City of Nairobi. The city is characterized by rapid population growth and yet public spaces of residential neighbourhoods do not evenly distribute their pedestrian population and therefore require investigation. The contribution of spatial planning, in the context of configuration, to promotion or suppression of distribution of pedestrians in public spaces of the residential neighbourhoods has not been explored.

1.1 Objectives

The broad objective of this study is to evolve spatial planning patterns whose application to layout of residential neighbourhoods results in improved distribution of pedestrians in public spaces. Specific objectives include:

1. To establish the extent of the relationship between spatial planning and distribution of pedestrians in public spaces of residential neighbourhoods in the City of Nairobi.
2. To establish how spatial planning has failed in regard to distribution of pedestrians in public spaces of residential neighbourhoods in the City of Nairobi.
3. To infer how spatial planning can be made effective as a tool for promoting distribution of pedestrians in public spaces of residential neighbourhoods in the City of Nairobi.

1.2 Statement of Hypothesis

This paper conjectures that failure to incorporate appropriate spatial planning in layout of residential neighbourhoods in the City of Nairobi could be the reason why distribution of pedestrians in public space is poor. In this regard, the alternative and null hypotheses are:

H_A: There exists a relationship between spatial planning and distribution of pedestrians in public spaces of residential neighbourhoods in the City of Nairobi.

H_o: There is no relationship between spatial planning and distribution of pedestrians in public spaces of residential neighbourhoods in the City of Nairobi.

2.0 Materials and Methods

This study seeks to generalize its findings to the entire frame of public spaces of planned residential neighbourhoods in the City of Nairobi. Public space is the residential street and to permit systematic inquiry, the street space is broken down into spatial units referred to as axial spaces. An axial space then as a unit of public space forms the specimen of inquiry. In order to arrive at a representative sample of public spaces, multi-stage sampling from the level of residential neighbourhood to axial spaces becomes necessary.

The study makes use of both secondary and primary data. Secondary data is collected through review of relevant literature. Primary data is collected from axial spaces of the public space system of residential neighbourhoods.

2.1 Sampling of Residential Neighbourhoods

Planned residential neighbourhoods in the city are stratified into high-income, middle-income and low-income (Table 1).

Table 1: Sampling frame of planned neighbourhoods in the City of Nairobi

income category	01 high income	02 middle income	03 low income (planned)
neighbourhoods	Westlands, Groganville, Muthaiga, Kitisuru, Lavington, Spring Valley, Kileleshwa, Kilimani, Kibarage, Barton, Mitini, Parklands, Bernard, Kyuna, Thompsom, Loresho, Milimani	Golf Course, Sunview, Magiwa, Southlands, Ngei, Otiende, Nairobi Dam, Pangani, Outerring Road, Buru Buru I-V, Nairobi South 'C', Nairobi South 'B', Woodley, Tena, Doonholm, Savannah, Nairobi West	Ofafa Maringo, Lumumba, Makadara, Ofafa Jericho, Kimathi, Kaloleni, Pumwani, Starehe, Ziwani, Kariokor, Shauri Moyo, Umoja II, Uhuru, Harambee, Umoja I, Madaraka, Mbotela, Huruma, New Mathare, Kariobangi North, Dandora, Kariobangi South, Makongeni, Bahati

Within each stratum, further stratified sampling is done using public space structure as the criterion. For the high-income group, four neighbourhoods are grid-like whereas twelve are irregular (Table 2). Application of simple random sampling resulted in selection of Parklands neighbouhood in the grid-like category and Mitini and Lavington in the irregular category.

Table 2: Stratification of High Income Neighbourhoods Based on their Internal Street structures

Grid-like Structure	Irregular Structure
1. Parklands	i. Milimani ii. Thompson iii. Mitini
2. Groganville	iv. Kileleshwa v. Lavington vi. Muthaiga
3. Westlands	vii. Spring Valley viii. Loresho ix. Kibarage
4. Kilimani	x. Kitisuru xi. Barton xii. Kyuna

For the middle-income group, 17 neighbourhoods are predominantly of intersecting streets whereas 4 are predominantly of non-intersecting streets (Table 3).

Table 3: Stratification of Middle Income Neighbourhoods Based on their Street Structures

Neighbourhoods with intersecting streets	Neighbourhoods without intersecting streets
Doonholm, Outerring Road, Buru Buru I, Tena, Savannah, Umoja I, Pangani, Southlands, Ngei, Otiende, Sunview, Golf Course, Magiwa, Woodley, Nairobi South B, Nairobi South C, Nairobi Dam	Buru Buru III, Buru Buru V, Buru Buru II, Buru Buru IV

Application of simple random sampling resulted in selection of Tena, Pangani and Otiende neighbourhoods from the predominantly intersecting street category. Buru Buru V neighbourhood was selected from the predominantly non-intersecting street category.

For the low-income group, all the neighbourhoods have irregular internal street structures and as such, building typology is used as the stratifying criterion (Table 4). In this regard, 15 neighbourhoods are in the category of a mix of single and double storey row housing, 3 neighbourhoods in the category of walk-up flats, and 4 neighbourhoods in the category of a mix of single storey and walk-up flats. Application of simple random sampling to select a neighbourhood from each of the categories resulted in selection of Ofafa Maringo, Madaraka and Umoja II neighbourhoods.

Table 4: Stratification of Low Income Neighbourhoods Based on Building Typologies

A Mix of Single and Double Storey Row Housing	Walk-up flats	A Mix of Single Storey and Walk-up Flats
Lumumba; Makadara; Ofafa Maringo; Ofafa Jericho; Kimathi; Harambee; Kaloleni; Starehe; Mbotela; Ziwani; Kariokor; Shauri Moyo; Kariobangi North; Makongeni; Bahati.	Kariobangi South; Madaraka; Huruma.	Dandora; Pumwani; Umoja II; Eastleigh.

2.2 Establishment of the Parent Population of Public Spaces

Preparation of neighbourhood axial maps is a pre-requisite to establishment of the parent population of axial spaces in the neighbourhoods. This is done by first finding the longest straight line that can be drawn within a street space and drawing it on an overlaid tracing paper, then the second longest, and so on until the entire street space is covered and all axial lines that can be linked to other axial lines without repetition are so linked. An axial line defines the axial space. An axial space is therefore a unit of a continuous street space which extends in one dimension and is linked to one or more other units in the street space system of the settlement. Initially, an accurate axial map of each neighbourhood is drawn based on maps obtained from Survey of Kenya and City Council of Nairobi. This is followed by a reconnaissance survey of each neighbourhood to identify any omitted spaces for the purpose of including them in the respective axial maps. The updated axial maps present the universe of public spaces, hence the study population. Figure 1 below, the axial map of Mitini, illustrates how this study operationalised public space.

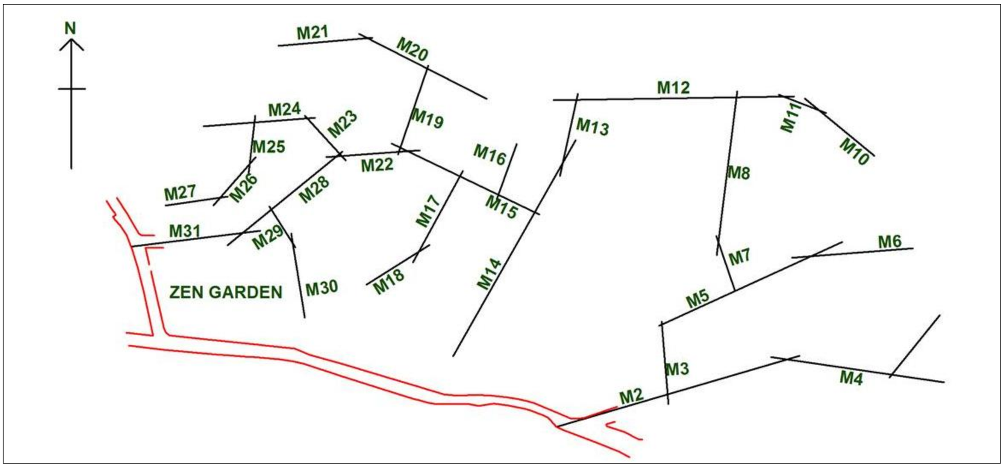

Fig. 1: Axial map for Mitini neighbourhood

The same process is done for all the sample neighbourhoods to determine the parent population of public spaces. In total, there were 369 public spaces in the sampled neighbourhoods (Table 5).

2.3 Sampling of Public Spaces

To facilitate sampling of public spaces for inclusion in the study, each public space in the respective neighbourhood axial map is coded uniquely as for example illustrated in Figure 1. The spaces are then sampled in a two-stage process. In the first stage, a public space survey is conducted in which all the spaces in each neighbourhood are systematically observed to establish the status of distribution of pedestrians in each space. The distribution status is scored using a five-point scale. In this scoring, the best status is given score of five (5) whereas the worst status is given score one (1). This preliminary assessment is done on neighbourhood basis in order to make possible selection of a sample that is representative of the parent population of public spaces. Purposive sampling is then applied in selection of spaces from each category of scores and this is carried out on neighbourhood basis. Geographical spread of each category of spaces is used as the primary criterion informing purposive sampling. In total, 120 axial spaces were sampled (Table 5).

Table 5: Sample size for public spaces in the ten residential neighbourhoods

S/No.	Neighbourhood	Study Population	Sample Size
1.	Pangani	45	18
2.	Buru Buru V	41	12
3.	Otiende	49	21
4.	Tena	35	9
5.	Umoja II	41	12
6.	Madaraka	22	9
7.	Ofafa Maringo	37	12
8.	Lavington	43	12
9.	Parklands	27	9
10	Mitini	29	6
TOTAL		**369**	**120**

Largely though, the sampling criterion is hinged on three considerations. Firstly, the quantity of spaces has to be at least thirty for findings to be generalized to the parent population which is the universe of public spaces in the ten neighbourhoods (Kazmier, 1976). The sampling distribution of the mean is assumed to be approximately normal whenever the sample size is at least thirty (Ibid). Secondly, the spaces have to reflect variation with regard to the distribution of pedestrians. Thirdly, the geographical spread of the sampled spaces has to be representative of all the spaces in each neighbourhood.

2.4 Primary Data Collection

Axial alpha-analysis and structured observation are used as the main methods of primary data collection. Axial alpha-analysis, a space syntax method of assessing exterior space of a settlement plan, is used to generate data from the axial maps of the residential neighbourhoods under inquiry. A brief introduction of the space syntax method is done in Section 2.4.1. Syntactic variables whose data is generated through axial alpha-analysis fall under the patterns of integration, and connectivity of public space. These variables are explained in the discussion section of this paper.

Data collected through structured observation is both for non-syntactic spatial plan variables and distribution of people in public space. Non-syntactic variables relate to the physical, social and economic characteristics of space. Distribution of pedestrians is measured as frequency, which is the number of recorded counts per metre of space. Observation of distribution of people in space is done on week days between 9.00 a.m. and 4.00 p.m., a time frame that is outside the peak hours when people are going to or coming from work. This time limit is necessary for consistence purposes.

Variables to be observed and the style of recording the observations are defined in an observation schedule. Data collected through structured observation is measured either qualitatively using a five-point scale ranging from score 1 for the worst quality to score 5 for the best quality, or with the aid of precision instruments which include a measuring wheel, tape and tally counter. A measuring wheel is used for measuring horizontal and long distances whereas a 5-metre long measuring tape is used for measuring short distances, both horizontal and vertical. A hand-operated tally counter is used in counting of pedestrians. Standardization of data, where necessary, is done in order to allow for comparison among spaces of different sizes.

2.4.1 Space Syntax

Space syntax is a method of structuring a settlement plan system in a manner that permits quantitative measurement of its spatial relations. It has its root in the space syntax theory conceived by Bill Hillier and Julienne Hanson at the University College London (Hillier and Hanson, 1984). According to Wang *et al*., (2007), an understanding of spatial relationships, as in space syntax, is important considering that it informs the approach to evolution of desirable spatial forms in the physical environment. Once the relational quantities have been obtained, an explanation of the status of environmental occurrences in space is explained through correlation and regression studies. Hillier (1998) points out that space syntax research is an answer to the challenge of describing the physical complexity of a settlement with sufficient rigour and consistency to permit it to be controlled as a variable in research. This implies that space syntax, besides bringing to light the underlying patterns and structure of a settlement, provides a platform for understanding occurrences in space such as distribution of pedestrians. This implies that with an understanding of the relation between and among spaces in a settlement and how this explains pedestrian distribution, minimization of crime in public space is possible and this results in better environments in which to live and operate. In this regard, space syntax is a method that informs layout of space and as Southworth et al (2012) points out, space plays a powerful role in shaping social behaviour.

2.5 Data Analysis and Interpretation

Statistical Package for Social Scientists (SPSS) is used to aid analysis of data and generation of outputs for interpretation. Initially, all independent variables in the study are assessed for multicollinearity. For any two multicollinear variables, one of them is omitted. Independent variables are the syntactic variables and those linked to the physical, social and economic characteristics of space. Distribution of pedestrians in public space comprises the dependent variable. Multiple regression using the stepwise method is applied to establish independent variables that significantly predict distribution of pedestrians in public space. Analysis of variance at 99 percent confidence level is used to test the significance of the relationship.

3.0 Results and Discussion

Establishment of independent variables that significantly predict distribution of pedestrians in public space is carried out at two levels. Firstly, axial alpha-variables are regressed against the dependent variable to establish the extent to which they explain the distribution. Secondly, all independent variables are regressed against the dependent variable in order to present a comprehensive picture of the prediction. Outputs from the SPSS for the two scenarios are illustrated in Tables 6 and 7 below.

Table 6: Model 1. Distribution of pedestrians in space using axial alpha-variables as predictors

Variable	Uns. B	SE B	β
N9	-.018	.004	-.365
N3	.426	.112	.313

Constant=0.114; R= 0.463; R^2= 0.215; Adjusted R^2= 0.201; S_e = 0.075; df= 2,117; F= 15.978; Sig. =0.000

Table 7: Model 2. Frequency of pedestrians in space using all independent variables as predictors

Variable	Uns. B	SE B	β
D42	-.058	.016	-.259
F4	1.546	.357	.283
F17	.517	.165	.225
F9	34.638	7.610	.264
D46	.182	.059	.189
C3	1.552	.470	.212
N9	-.008	.003	-.164
D1	.000	.000	.131

Constant=0.086; R= 0.889; R^2= 0.791; Adjusted R^2= 0.765; S_e = 0.041; df= 8, 66; F= 31.175; Sig. =0.000

For Tables 6 and 7, R= Multiple correlation coefficient; R^2= Coefficient of determination; S_e= Standard error of the estimate; Uns. B= Unstandardised coefficient; SE B= Standard error of B; β= Standardized coefficient; df= degrees of freedom of the model; F= Analysis of Variance coefficient; Sig. = Significance (p) value of the model. N_9= Depth from "Y", the carrier space; N_3= Adjacency and permeability per metre of space; D_{42}= Proportion of number of buildings with setbacks; F_4= Frequency of retail shops; F_{17}= Frequency of informal business activities; F_9= Frequency of bookshops; D_{46}= Proportion of buildings with social places; C_3= Frequency of intersections within the space; D_1= Percentage of space length fronted with fronts of buildings.

3.1 Modelling Distribution of People in Public Space

Multiple regression analysis between axial alpha variables and distribution of people in public space reveals that 21.5 percent of the variance in the dependent variable is significantly explained by depth from *Y* and adjacency and permeability per metre of space (Equation 1). The relationship is significant at 99 percent confidence level.

Distribution of pedestrians in public space $= 0.114 - 0.018N_9 + 0.426N_3 +/- 0.075S_e$ ……………………………………………. (1)

In this prediction, depth from *Y* has an inverse relationship with the dependent variable. This suggests that an increase in depth from *Y*, while holding all other predictor variables constant, results in a decrease in the frequency of people in public space. Unlike in shallower spaces where there are more people and a higher level of investment in small scale retail shops and informal activities, deeper spaces are marked with lower levels of activity. This public space environment is not desirable because of its characteristic lower surveillance from public space users and therefore a lower sense of safety (Jacobs, 1961). Hillier (1988) adds that public spaces with fewer people have higher burglary rates. Adjacency and permeability per metre of space, on the other hand, indexes the constitutedness property of public space which, in this model, relates directly with the dependent variable. This implies that an increase in constitutedness, while holding all other independent variables constant, leads to a corresponding increase in the frequency of people in public space. The spatial environment characterized with this pattern is desirable because of its associated benefit of crime prevention (Jacobs, 1961; Alexander, 1977). Hillier (1988) empirically establishes a positive correlation between constitutedness and encounter rate of pedestrians, a scenario that concurs with the findings of the present study. In effect, these findings add to the doubt already cast on the concept of defensible space as advocated for by Newman (1972) and Coleman (1985), at least in so far as one of its main conjectures behind it is that the elimination of natural movement and encounter within housing estates increases safety. In disagreeing with this view, Hillier (1988) points out that advocates of defensible space seem to believe that criminals are part of the passing crowd, and that strangers are therefore in principle dangerous.

Multiple regressions between distribution of people in space and all independent variables show that 79.1 percent of the variance in the dependent variable is significantly explained by eight independent variables (Equation 2). The relationship is significant at 99 percent confidence level.

Distribution of pedestrians in space $= 0.086 - 0.058D_{42} + 1.546F_4 + 0.517F_{17} + 34.638F_9 + 0.182D_{46} + 1.552C_3 - 0.008N_9 + 0.000D_1 +/- 0.041S_e$ ………………………………………………………………… (2)

Two of these predictor variables have an inverse relationship and include proportion of number of buildings with setbacks and depth from *Y* space. This suggests that an increase in any of the variables, while holding all other variables constant, results in a decrease in the frequency of people in space. Building setback refers to the distance by which the building is removed from the edge of the public space. For the sample public spaces examined in this study, building setback ranges from zero (0) to six (6) metres. When a building setback is greater than zero, the building wall ceases being the property boundary and instead a fence of some kind serves this role. This is a feature of low density settlements in which there is a clear definition of public and private environments within the outdoor space system. Inasmuch as there is constitutedness in this spatial layout, removal of a building off the edge of a public space has the effect of reducing pedestrian flow due to reduced social intercourse between the residents and stranger in the public space. In regard to the variable of depth of a public space from *Y*, the manner in which it leads to a decrease in the frequency of people in public space has already been discussed under Equation 1.

The remaining six independent variables have a direct relationship with the dependent variable and include frequency of retail shops, frequency of informal business activities, frequency of bookshops, proportion of buildings with social places, frequency of intersections within the space, and percentage of space length fronted with fronts of buildings. This suggests that an increase in any one of them, while holding all other independent variables constant, results in an increase in the frequency of people in public space. The first four in this category of variables are activity magnets that pull people into the public space fabric of the residential settlement and the more there are in a public space, the higher the frequency of people. A public space with a high frequency of intersections is a high connectivity space and according to Min (1993), is associated with a high encounter rate of people. Such a public space is also of high control (Hillier and Hanson, 1984) and positively correlates with encounter rate (Hillier, 1988). Fronts of buildings defining a public space are permeable to it and thus are an index of the property of constitutedness. The influence of constitutedness on frequency of people in public space has been discussed under Equation 1.

3.2 Hypothesis Testing

In this paper, establishing whether there exists a significant relationship between spatial planning and distribution of pedestrians in public space is done by assessing the statistical significance of each prediction equation. ANOVA at 99 percent confidence level aids in determining the statistical significance of the results in each equation. As Pallant (2005) points out, this tests the null hypothesis that the multiple correlation coefficient, R, in a prediction equation, equals zero (0). Table 8 below illustrates that, for each of the equations, there exists a significant relationship between spatial planning variables and the distribution of pedestrians in public space hence implying that the null hypothesis is rejected. This communicates that there is a relationship between spatial planning and the distribution of pedestrians in public space. It further suggests that spatial planning, depending on how it is applied, can either minimize or maximize distribution of pedestrians in the public spaces of residential neighbourhoods.

Table 8: Results of hypothesis testing

Equation	**R**	**R^2**	**Degrees of freedom (df)**	**Variance Ratio - F**	**Sig. (p-value)**	**Testing of null hypothesis at 99% confidence level**
1	0.463	0.215	2,117	15.978	0.000	Rejected
2	0.889	0.791	8,66	31.175	0.000	Rejected

3.3 Discussion

Four public space planning patterns emerge from the predictor variables in equations 1 and 2. Each pattern consists of one or more related independent variables (Table 9). The patterns, include integration, constitutedness, land use planning and connectivity of public space.

Table 9: Emerging Public space planning patterns and variables that build them up

Pattern	**Integration**	**Constitutedness**	**Land use Planning**	**Connectivity**
Variable(s)	Depth from 'Y'	-Degree of adjacency and permeability -Percentage of space length fronted with fronts of buildings	1. Mix of activities -Frequency of informal businesses -Frequency of bookshops -Proportion of buildings with social places 2. Density of settlement -Proportion of buildings with setbacks	Frequency of intersections within the space

3.3.1 Integration

Integration of public space has to do with the degree of symmetry-asymmetry. Two axial spaces are said to relate symmetrically when there is no intermediate space in between them. On the other hand, the relationship is asymmetric if one has to pass through an intermediate space to move from one space to another (Hillier and Hanson, 1984). It is succinct then to put it that in a residential settlement with a series of axial spaces, unless one is considering the relationship between two adjacent axial spaces, the relationship that is of central focus is that of asymmetry. In this study, the degree of asymmetry of an axial space is looked at in terms of how deep it is from the carrier space. In this respect, the variable that addresses the pattern of integration is depth from 'Y'. Depth from 'Y' refers to the number of steps a public space is from 'Y' in an axial map (Ibid.). 'Y' is the carrier space and is given the value 0. In a neighbourhood, the peripheral road system is used as the carrier space. The space intersecting the carrier space is given the value 1, the next one given the value 2 and the process goes on until all the spaces are allocated their respective values. Using the public space system of Mitini (Figure 1) as an example, Table 10 illustrates Depth from 'Y' values for sample spaces investigated in this study.

Table 10: Depth from 'Y' values for sample spaces in Mitini residential neighbourhood (Figure 1)

Public Space	**M2**	**M7**	**M24**	**M20**	**M14**	**M10**
Depth from 'Y' value	1	4	4	5	5	7

In a settlement layout, the more descriptions are symmetric, then the more there will be a tendency to the integration of social categories, such as the categories of inhabitant and stranger. Conversely, the more they are asymmetric then the more there will be a tendency to the segregation of social categories. Prior to getting to understand how depth from the carrier space contributes to integration and segregation of public space, it is important to first shed light on the concepts of integration and segregation. Segregation, as Moirongo (2011) points out, is to a greater extent associated with homogeneity or specialization. It implies a separation of functions and groups that differ from one another. In this regard, residential settlements in the City of Nairobi are segregated on the basis of income level into low-income, middle-income and high-income. On the other hand, integration is associated more with generalization and diversity or heterogeneity. According to Gehl (1996), integration implies that various activities and categories of people are permitted to function together or side by side. This implies that integration of space in a settlement is enhanced by diversity, mixing of activities and emphasis on pedestrian dominance in space. Conversely, mono-functionalism promotes segregation.

As this study establishes, an axial space that is shallow in relation to the 'Y' space has a higher degree of symmetry whereas a remarkably deep one is asymmetric. In the latter case, we talk of the structure being tree-like, or nondistributed as movement occurs from the carrier space into the settlement. This suggests that a space closer to the carrier space is more integrating whereas a remarkably deep space is segregating. A higher degree of integration in public space is desirable as it is associated with a higher encounter rate of pedestrians and therefore an improved sense of safety. Integrating spaces are naturally inviting, are easily accessible and by virtue of their higher degree of activity mix, motivate people to move into and through the spaces. On the other hand, segregating spaces, with their mono-functional nature, are repulsive. Their location in the layout does not encourage people to move into them. In layout of residential settlements therefore, public space should not be over-hierarchised as this results in segregation.

Results of this study are similar to what other studies have established in regard to the contribution of the integration property of public space to distribution of pedestrians. Baran *et al.,* (2008) establishes that streets with greater integration exhibit more walking behaviour. Min (1993) realizes that integration of neighbourhood layouts correlates positively with encounter rate of pedestrians.

3.3.2 Constitutedness

Constitutedness of a space is said to exist when adjacent buildings and other bounded areas, such as inhabited plots, gardens and parks, are directly or indirectly permeable to it (Hillier and Hanson, 1984). Permeability in this regard refers to access between the enclosed and public space environments which can be either physical access through doors or gates, or visual access through windows or transparent perimeter wall openings. When buildings or such bounded areas are directly accessible to an axial or public space, we say that the space is constituted by the buildings, but if the space is adjacent to buildings or bounded areas to which it is not directly permeable, we say it is unconstituted. In this paper, constitutedness of a public space is measured by two variables – the degree of adjacency and permeability and percentage of space length fronted with fronts of buildings. This study established that a higher degree of adjacency and permeability and a higher percentage of space length fronted with fronts of buildings have the effect of increasing the frequency of pedestrians in public space. The degree of adjacency and permeability refers to the number of buildings or inhabited plots that are both adjacent and permeable to the space, measured per metre of space. This indicates that the measure is standardized and this allows drawing of inferences based on comparison of spaces of different lengths.

Broadly then, constitutedness is defined by the degree of permeability or accessibility, the degree of enclosure and the degree of transparency. This implies that constitutedness deals with the quality of the boundaries that define public space. The pattern of constitutedness thus has a bearing on the presence of people and surveillance in a public space, the manner of use of the space, and the resulting quality of the public space environment. In this respect, a constituted space is a better quality environment to operate in whereas an unconstituted one is dangerous owing to the compromised surveillance.

The positive correlation between constitutedness and the frequency of people in public space established in this study concurs with other studies in the built environment. In this regard, Baran *et al.,* (2008) establishes that streets which are more accessible exhibit a higher frequency of walking behaviour. Hillier (1988) finds out that encounter rate of pedestrians in public space is lower in spaces fronted with walls that have no openings. Radford and Ragland (2003) realizes that more accessible streets have a higher degree of pedestrian movement than less accessible ones.

3.3.3 Land Use Planning

Land use planning in the layout of a residential neighbourhood refers to the allocation of portions of land to various activities. Aspects of land use addressed in this paper include mix of activities and density of settlement. It emerges that higher land use mix and density of settlement are desirable for a better distribution of pedestrians in public space.

A mix of uses, if it is to be sufficiently complex to sustain a higher frequency of pedestrians, settlement safety and cross-use, needs an enormous diversity of ingredients. At the level of public space, this has a bearing on distribution of activities in the buildings constituting the space. Spatial planning has often failed to create heterogeneous settings in public space in Nairobi's residential neighbourhoods. The existing situation is mostly that of homogeneous residential use, a scenario that deprives the public space of people for a larger part of the day during working hours. However, in the endeavour to attain heterogeneity, spatial planning needs to avoid haphazard mixing of incompatible land uses as this leads to urban obsolescence. In this study, a number of variables significantly contribute to the mix of activities in public space. These include frequency of informal businesses, frequency of bookshops, frequency of retail shops and proportion of buildings with social places. A higher frequency of these activities is associated with a higher encounter rate of people in public space which, according to Jacobs (1961), is a desirable environmental quality. Findings of this study concur with that of Alfonzo et al (2008) which realizes that a higher mix of land use activities has a direct relationship with the intensity of walking. Similarly, Ozer and Kubat (2007) establishes that introduction of central functions, such as retail, in a settlement, enhances movement of people through space.

Density of settlement is another aspect of land use that can either promote or minimize distribution of pedestrians in a residential public space. This study establishes that proportion of buildings with setbacks as a variable that points to density of settlement. Low density neighbourhoods, which are characterized with a higher proportion of buildings with setbacks, have a lower encounter rate of pedestrians in public space. High density settlements, which have a lower proportion of buildings with setbacks, are however associated with a higher frequency of pedestrians in public space. This finding concurs with that of Alfonzo et al (2008) which establishes that neighbourhoods with high population density have higher encounters of walking behaviour.

3.3.4 Connectivity

Connectivity or distributedness of space in a settlement is said to exist when there is more than one route of movement from one point to another (Hillier and Hanson, 1984). Distribution of space is greater with a higher frequency of intersections. This has a bearing on the scale of convenience in space use with regard to block length. Shorter block lengths have the benefit of increasing pedestrian encounter rate in public space and thus enhance its control.

In this study, the variable of frequency of intersections within a public space brings out the pattern of connectivity. This variable has a direct relationship with the distribution of pedestrians in public space. It therefore emerges that a higher degree of connectivity is desirable as this leads to a higher encounter rate of pedestrians. This finding is consistent with that which is described in literature. In this respect, Min (1993) establishes that connectivity of public space correlates directly with the density of pedestrian movement. Similarly, Radford and Ragland (2003) realizes that streets with higher connectivity experience more pedestrian utilization than less connected ones.

4.0 Conclusion

This paper has demonstrated that failure to utilize an appropriate approach to spatial planning in layout of residential neighbourhoods in the City of Nairobi is a significant factor explaining the poor distribution of pedestrians in the public space system. This is evidenced in the remarkable breakup of the public space system which results in segregated spaces, unconstituted spaces which pedestrians keep away from for fear of their safety, creation of long cluster blocks that result in poor distribution of public space and reduced scale of convenience of users, and monofunctional residential land use that lacks the ingredient of diversity of mix of activities. In order to evolve sustainable public space environment with regard to better distribution of pedestrians, this study roots for four areas of activity. One, public space should be constituted by buildings that are adjacent to it. This requires that the public space boundaries are permeable, have a higher degree of transparency and a lower degree of enclosure. Two, there should be minimal break-up of the public space system by avoiding creation of public spaces that are very deep in relation to the carrier space. This ensures that the evolved public space system is integrating, has a higher frequency of people and hence a secure environment to operate in. Three, short blocks should be created during layout of residential settlements so as to improve distribution of pedestrians in public space. Four, density of settlement in residential neighbourhoods needs to be high coupled with a diverse mix of compatible activities.

References

Alexander C., Ishikawa S., Silverstein M., Jacobson M. and Angel I. F. S. (1977). *A Pattern Language*. Oxford University Press, New York.

Alfonzo M., Boarnet M. G., Day K., McMillan T. and Anderson C. L. (2008). *The Relationship of Neighbourhood Built Environment Features and Adult Parents' Walking. Journal of Urban Design*, 13 (1), pp. 29-51.

Baran P. K., Rodriguez D. A. and Khattak A. J. (2008). *Space Syntax and Walking in a New Urbanist and Suburban Neighbourhoods. Journal of Urban Design,* 13 (1), pp. 5-28.

Coleman A. (1985). *Utopia on Trial*. Hilary Shipman, London.

Gehl J. (1996). *Life Between Buildings: Using Public Space.* 3rd ed. Arkitektens Forlag, Copenhagen.

Hillier B. (1998). *The Common Language of Space,* [online]. Available at: <http://www.spacesyntax.org/publications/commonlang.html> [Accessed 1 August 2009].

Hillier B. and Hanson J. (1984). *The Social Logic of Space*. Cambridge University Press, Cambridge.

Hillier B. (1988). Against Enclosure. In Teymur N., Markus T. and Wooley T. (Eds). *Rehumanizing Housing*. Butterworth, London. Ch. 5.

Jacobs J. (1961). *The Death and Life of Great American Cities*. Random House, New York.

Kazmier L. J. (1976). *Business Statistics*. McGraw-Hill Book Company, New York.

Magalhaes C. and Carmona M. (2009). *Dimensions and Models of Contemporary Public Space Management in England. Journal of Environmental Planning and Management*, 52 (1), pp. 111-129.

Min Y. (1993). *Housing Layout and Space Use: A Study of Swedish and Chinese Neighbourhood Units*. Chalmers University of Technology, Goteborg.

Moirongo B. O. (2011). *Urban Space Design and Environmental Management for Sustainable Cities*. LAP LAMBERT Academic Publishing, Verlag.

Newman O. (1972). *Defensible Space*. The Macmillan Company, New York.

Ozer O. and Kubat A. S. (2007). *Walking Initiatives: a quantitative movement analysis,* [online]. Available at: <http://www.spacesyntaxistanbul.itu.edu.tr/papers%5Clongpapers%5C017%20-%20Ozer%20Kubat.pdf> [Accessed 4 May 2011].

Pallant J. (2005). *SPSS Survival Manual: A step by step guide to data analysis using SPSS for Windows (Version 12).* Allen & Unwin, Sydney.

Radford N. and Ragland D. R. (2003). *Space Syntax: An Innovative Pedestrian Volume Modelling Tool for Pedestrian Safety*, [online]. Available at: <http://escholarship.org/uc/item/50m064zp> [Accessed 1 September 2012].

Southworth M., Cranz G., Lindsay G. and Lusi M. (2012). *People in the Design of Urban Places. Journal of Urban Design*, 17 (4), pp. 461-465.

Towers G. (2005). *An Introduction to Urban Housing Design: At Home in the City*. Architectural Press London.

Wang J., Zhu Q. and Mao Q. (2007). *The Three Dimensional Extension of Space Syntax*,[online]. Availableat:http://www.spacesyntaxistanbul.itu.edu.tr/papers%5Clongpapers%5C048%20-%20Wang%20Zhu%20Mao.pdf > [Accessed 4 May 2011].