ISBN 978-93-84422-50-9
Proceedings of 2015 International Conference on Green Buildings, Civil and Architecture Engineering (ICGBCAE'15)
Dubai, Dec. 25-26, 2015 pp. 98-104

Spatial Digraph of 'Danna' Slum Area in Alexandria, Egypt

Ali Essam El Shazly

Associate Professor, Department of Architecture, Faculty of Engineering, Fayoum University, Egypt
(Mobile: +2 01228202822, E-mail: alielshazly@hotmail.com)

***Abstract*:** *The digraph with distance ranking of survey rooms in 'Danna' slum area at Alexandria clarifies the social logic of spatial interface in extended conception of space syntax. The irreflexive functional relationships among the room set interchanges the 'visitor' domain with the 'inhabitant' structure at different levels of spatial resolutions. From the global structure of deep 'inhabitant' and shallow 'visitor' interface, the local spatial system reverses the process of social logic. The essence of one 'bedroom' alternates the sign of covariance with the multiple room structure to cause a dynamic digraph networking between the 'visitor-inhabitant' domains. Meanwhile, the 'living' of more 'inhabitant' networks negatively covariate with the 'kitchen' to change to a 'visitor' space and vise versa. The common 'staircase' covariate with the layout rooms to filter 'inhabitant' from 'visitor' domains, except the unique 'kitchen' that covariate with 'inhabitant' as 'visitor' or the inverse as well. The weighted digraph further clarifies the interactive ranks of dense networking of 'kitchen, living & bedroom-I' compared to other rooms, while the shared facilities of 'toilet & staircase' have more stable network distribution.*

Keywords: *Alexandria, Danna Slum, Room Survey, Digraph, Spatial Structure*

1. Introduction

Poor building slums of developing countries represent a major challenge to resolve. In addition to the health and safety hazards, the social dimension is spatially interrelated for the slum clearance strategies. The social criteria explore various interdisciplinary approaches with the exchange of experiences for the massive redevelopment of slums worldwide. The slum areas are largely found in Egypt without enforcement of the building codes or public infrastructures [14 & 15]. The Egyptian slums suffer the social mobility from rural to urban migration, but seldom in the direction from urban to rural [6 & 7]. This study continues the social evaluation of building slums through their spatial structure. Objectively, the determination of social space clarifies the human program of slum renewal for a better technical and social environment in the future. Among the populous slums which are selected in Egypt for a detailed building survey is 'Danna' area in Alexandria. The area accommodates rural migrants form the adjacent 'Behera' rural province. Beyond the social logic of space syntax methodology [4 & 8], the interdisciplinary Graph Theory of numerous algorithms enriches the spatial measurements with statistical processing [for example 5, 9, 12 & 13]. In one algorithm, the geometrical digraph of spatial distances overcomes the space syntax limitation of topological networking. Therefore, the method of this study initiates the diagraph measure on the survey of sample buildings in 'Danna' slum area for an extended social logic of space. This survey is one of several

Fig. 1: Location of Danna

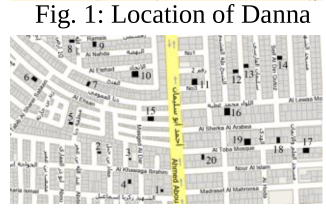

Fig. 2: Sample Buildings

Fig.3:Passage Fig.5:Kitchen

Fig.4:Heights Fig.6:Living

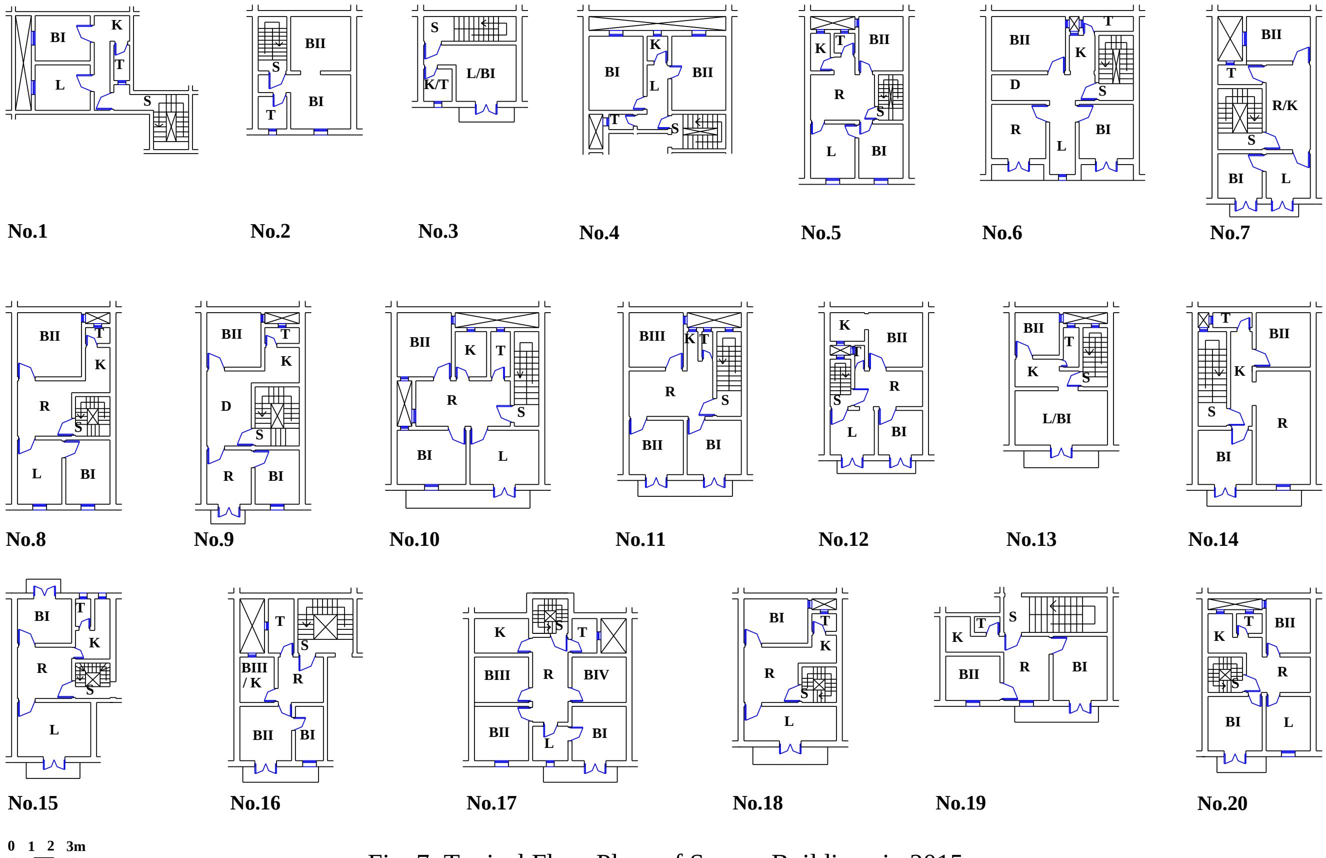

Fig. 7: Typical Floor Plans of Survey Buildings in 2015

in row, which draws twenty-sample buildings per each slum area for room details as built. The absence of shop-drawings or building consent in the sprawling Egyptian slums required a first-hand household survey in order to stratify the samples of migration buildings "Figs.1-7". The micro-level surveys of Egyptian slums blend with the other previous studies in extended scope of analysis [for example 1, 2, 11 & 16], while address the lack of social consideration in the long-term comprehensive plan strategy of redeveloping slum areas in Alexandria [3].

2. Digraph Analysis

The digraph network measures the distances from every room to all others of a layout such as the illustrated sample no.13 "Fig.8". The measured distances are ranked in order with the first rank for the nearest distance, which results in a digraph matrix defining the strength of functional relationships by distance "Table 1". The statistical processing of ranks per layout and in aggregate identifies the patterns of spatial integration in digraph flow. Unlike the yes/no permeability of space syntax conception, the spatial depth of digraph considers the nearer permeable space as of the shallower rank in functional order. Suppose two spaces are permeable to each other, their depth may not be symmetric with respect to an off-centered third permeable space. This issue has long been argued in the space syntax symposia [for example 10]. Specifically, the argument of permeability reviews the space syntax analytical conception, which states: *"....these are the notion of distance; and the notion of location. It is crucial to our approach that neither of these concepts – in spite of their manifest usefulness for the purposes for which they have been applied – appears in the foundations of 'space syntax'. This is initially distance free, and for the concept of location is substituted the concept of morphology, by which we imply a concern with a whole*

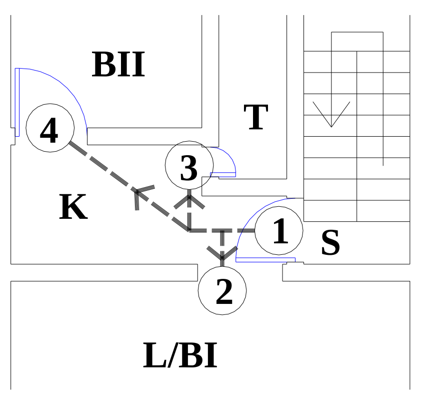

Fig. 8: Sample Diagraph of No.13

set of simultaneously existing relations." [4, p. xii]. Accordingly, the spatial measure of diagraph symmetry is defined with respect to the rank of distance among all permeable spaces at different levels of distances for the connected layout. In this process, each space queues-up the room-set of a layout in digraph depths. Nevertheless, the spatial rank of any depth may be shared if it is equidistant from the root space. In the meantime, and due to irreflexive digraph ranks of room-pairs, the total score measured 'from' and 'to' each room indicates some variance. For example, the aggregated diagraph measure of the 'kitchen' to all other room-set along the twenty-sample layouts records '310' in comparison to '279' points in the backflow. Only the 'living' space aggregates equal '215' points in both digraphs, but still of irreflexive relationship with each individual room. In this manner, the resulted ranks of distances in the digraph matrix encapsulate a certain classification of spatial interface for collective and individual layouts of the global discrete system with social interpretations.

TABLE 1: Digraph Ranks

Rm.	S	R	L	D	K	T	BI	BII	BIII	Sum
S01			1		3	4	2			10
S02						1	2	3		6
S03			2		1	1	2			6
S04			1		5	2	3	4		15
S05		1	3		5	6	2	4		21
S06		4	2	1	2	5	3	2		19
S07		1	2		1	4	3	5		16
S08		1	2		4	6	5	3		21
S09		2		1	5	6	4	3		21
S10		1	2		5	4	3	6		21
S11		1			4	3	2	5	6	21
S12		1	1		5	3	2	4		16
S13				1		2	3	1	4	11
S14		3			1	5	2	4		15
S15		1	2		3	5	4			15
S16		1			3	2	5	4	3	18
S17		1	7		3	2	8	6	5	36
S18		1	2		3	5	4			15
S19		1			2	3	4	5		15
S20		1	3		4	6	2	5		21
∑S	0	21	30	3	59	75	65	64	18	339
R05	1		1		2	3	1	1		9
R06	4		1	2	6	7	3	5		28
R07	1		1		1	1	2	1		7
R08	1		1		2	4	3	1		12
R09	2			1	4	5	1	3		16
R10	1		1		1	1	1	1		6
R11	1				1	1	1	1	1	6
R12	1		1		2	1	1	1		7
R14	3				1	5	4	2		15
R15	1		1		1	2	1			6
R16	1				1	1	2	1	1	7
R17	1		1		1	1	2	1	1	9
R18	1		1		2	3	1			8
R19	1				1	2	1	1		6
R20	1		1		1	2	1	1		7
∑R	21	0	10	3	27	39	25	20	3	149
L01	1				3	4	2			10
L03	3				2	2	1			8
L04	1				1	2	1	1		6
L05	2	1			4	5	1	3		16
L06	3	1		2	5	6	1	4		22
L07	2	1			1	4	1	3		12
L08	2	1			4	5	1	3		16
L10	3	1			5	4	2	6		21
L12	1	1			5	3	2	4		16
L13	2				2	3	1	4		12
L15	2	1			4	5	3			15
L17	5	1			4	6	1	2	3	25
L18	2	1			4	5	3			15
L20	3	1			5	6	2	4		21
∑L	32	10	0	2	49	60	22	34	3	215
D06	1	2	1		1	4	3	1		13
D09	1	1			2	3	4	1		12
∑D	2	3	1	0	3	7	7	2	0	25
K01	4		3			1	2			10
K03	2		3			1	3			9
K04	4		1			5	3	2		15
K05	6	1	4			2	5	3		21
K06	3	7	5	2		1	6	4		28
K07	1	1	1			1	2	1		7
K08	3	2	5			1	6	4		21
K09	4	5		2		1	6	3		21
K10	6	1	5			3	4	2		21
K11	4	1				2	5	6	3	21
K12	6	2	5			3	4	1		21
K13	3		2			1	2	1		9
K14	1	1				1	1	1		5
K15	2	1	4			1	3			11
K16	5	1				4	3	2	1	16
K17	2	1	7			3	8	6	4	36
K18	2	1	4			1	3			11
K19	2	1				1	3	4		11
K20	3	1	5			1	4	2		16
∑K	63	27	54	4	0	34	73	42	8	310
T01	4		3		1		2			10
T02	1						2	3		6
T03	2		3		1		3			9
T04	2		1		5		3	4		15
T05	6	2	4		1		5	3		21
T06	4	7	5	2	1		6	3		28
T07	3	1	4		1		5	2		16
T08	3	2	5		1		6	4		21
T09	4	5		2	1		6	3		21
T10	2	1	4		3		6	5		21
T11	4	1			2		5	6	3	21
T12	3	1	4		6		5	2		21
T13	4		2		1		2	3		12
T14	4	3			1		5	2		15
T15	3	2	5		1	4				15
T16	2	1			3		5	4	3	18
T17	2	1	6			3	8	7	5	36
T18	3	2	5		1		4			15
T19	3	2			1		4	5		15
T20	4	2	6		1		5	3		21
∑T	63	33	57	4	32	7	87	59	11	357
BI01	4		3		1	2				10
BI02	3					2		1		6
BI03	3		1		2	2				8
BI04	3		1		5	2		4		15
BI05	2	1	1		4	5		3		16
BI06	4	3	1	2	5	7		6		28
BI07	3	2	1		2	5		4		17
BI08	3	2	1		5	6				17
BI09	3	1		2	5	6		4		21
BI10	3	1	2		4	6				16
BI11	2	1			4	5		3	6	21
BI12	3	1	2		6	5		4		21
BI13	2		1		2	3		4		12
BI14	2	3			1	5		4		15
BI15	4	1	3		2	5				15
BI16	5	2			3	4		1	3	18
BI17	6	2	1		5	7		3	4	32
BI18	4	1	3		2	5				15
BI19	2	1			3	5		4		15
BI20	2	1	3		4	6		5		21
∑BI	63	23	24	4	65	93	0	50	13	339
BII02	3					2	1			6
BII04	4		1		2	5	3			15
BII05	4	1	6		2	3	5			21
BII06	4	5	3	1	2	7	6			28
BII07	4	1	3		1	2	5			16
BII08	4	1	3		2	5	6			21
BII09	4	3		1	2	5	6			21
BII10	6	1	5		2	3	4			21
BII11	4	1			5	6	2		3	21
BII12	5	1	4		1	2	3			16
BII13	4		3		1	2	3			13
BII14	4	2			1	3	5			15
BII15										0
BII16	4	1			2	3	1		2	13
BII17	7	1	3		6	8	5		2	36
∑BII	61	18	31	2	29	56	55	0	7	263
BIII11	6	1			2	3	5	4		21
BIII16	5	1			1	4	3	2		16
BIII17	6	1	4		5	8	7	2		36
∑BIII	17	3	4	0	8	15	15	8	0	73
BIV17	6	1	4		7	5	8	3	2	36
∑BIV	6	1	4	0	7	5	8	3	2	36
∑S~B	328	139	215	22	279	391	357	282	65	2106

The average ranking points per room compare their structure. The average outflow of 'staircase' measures 17-points per layout, compared to the inflow of 16.5-points. The core 'reception' scores only 10-points of outflow, while reduces to 9.3-points in the opposite direction. The following 'living & kitchen' ranks tie together by 15-16-points of outflow respectively. Their reversed flow, however, increases to 15.5-points for the 'living' and decreases to 14.7-points for the 'kitchen' room. The distant 'toilet' maximizes up to 18-points for reaching other rooms, and also 19.5-points to be reached. The two main 'bedroom' spaces closely tie by 17-17.5-points of average outflow, with respective 18-19-points for the way back. The overview of ranking points structures the 'visitor' domain by outflow of deeper interface with the 'inhabitant' domain than the inverse. In corollary, deepest 'inhabitant' spaces outflow in shallower interface with the 'visitor' domain than the way back. This spatial logic enforces the irreflexive social structure of 'visitor-inhabitant' interface with dynamic flow between rooms. Meanwhile, the analogical 'living & kitchen' spaces suppose their independent structure for the former to be toned as 'inhabitant' space through the increase of inward flow, while the latter proves more 'visitor' by the increase of outward flow distances.

On the individual room distribution, 75% of the 'staircase' outflow ranges from second to fourth rank towards the 'inhabitant' reach. Over 70% of the 'reception' encounters, nevertheless, sustain the first-rank across rooms. The couple spaces of 'living & kitchen' share one-third of their total flow by rank-one, while swap another one-third between second and third ranks, with the 'kitchen' in shorter links. Their remaining third extends up to fifth-rank with a variety of ranks. In the 'toilet' case, distances stretch up to the sixth-rank in balanced percentages among the various ranks. However, the twin 'bedroom' spaces flow differently, where the ranks of shorter distances are concentrated in one case more than the other, especially at the second and fourth ranks. Overview of individual ranks observes the highest probability of rank-one for the 'visitor' domain. Thus, the collective and individual flows of 'visitor-inhabitant' interface contrast with each other, where the individual ranks have ‘reception’ nearness to the ‘inhabitant’ domain but longer counterparts. Accordingly, the irreflexive depth ranking supposes the different functional relationships of the same domain in ‘Danna’ area at different levels of room resolutions from the discrete spatial system down to the generation of alternative layouts.

In another dimension, the frequency of distance ranks defines the room integration from global to local resolutions. The total of 725-frequencies divides into eight-scale ranking of '213, 136, 122, 104, 85, 47, 12 & 6' in order. Meanwhile, the gradual decrease of global integration measures three intervals of optimum 'rank-one', moderate 'second to fourth ranks', and disintegrated 'fifth to eighth ranks' in sequence. Nevertheless, the unequal distribution maximizes the room integration of the moderate interval by doubled frequencies in comparison to the shortest and longest intervals. The local 'rank-1' unbalances between the 'reception' of 61-frequency against the other rooms of one-third frequency ratio. In this regard, the irreflexive integration of rank-one dissolves the 'visitor' centrality by the digraph of alternative 'inhabitant' choices. The next moderate ranking maximizes the integration of the ‘inhabitant’ domain with distributed frequencies among rooms. Further disintegrated interval ranking concentrates in the 'staircase, bedroom & utility' rooms. Therefore, the local integration compensates the central control of 'visitor' domain through the extended bypass of moderate integration in the 'inhabitant' domain. The particular division of rank-one integration in the 'inhabitant' domain matches the 'bedroom' spaces with 'living or kitchen' integration. Meanwhile, the sanitation of 'utility' rooms attaches the ‘toilet’ to the two-sided 'kitchen' interface. The second and third ranks of the moderate interval integrate the 'staircase' with 'living, kitchen & bedroom' in alternation. The further two ranks integrate the 'living & kitchen' to the 'bedroom & toilet'. Overview of digraph frequency balances the 'visitor' global integration with clusters of local 'inhabitant' structure.

The statistical cross-tabulation expands the spatial structure in a wider scope of digraph correlation. In this processing, the distances among multiple rooms identify zones of functional relationships interactively. The frequency of irreflexive rank of distances observes the covariance of either positive or negative relationships in scatterplot with the overall box-plot weighing “Figs. 9 & 10”. The stable 'reception' of shortest ranking preserves the one-sided positive covariance across the room correlations. However, the ‘staircase’ observes a wider variety of scatterplot among rooms. From the 'staircase & reception' rooms, a dense (2,1) respective ranks correlate in the 'living' room to form one functional zone. The same correlation extends to other spaces such as the 'bedrooms' with longer ranks correlating in the 'kitchen' room. The plot of 'staircase & living' has (1,1) direct correlation that meets only in the 'reception' to form a 'visitor' zone. The longer ranks, however, zone-up at 'utility & bedroom' spaces with mutual 'inhabitant' correlation. The positive covariance of 'staircase & living' is reversed by a negative relationship towards the 'kitchen' zoning. Comparable covariance observes the 'staircase & kitchen' of positive 'visitor' and negative 'bedroom' relationships. Also the plot of 'staircase & toilet' covariates negatively among the room set, except with the 'reception' zone. The plots of 'staircase & bedrooms' swap their covariance with the 'kitchen & living' alternatingly. Overview of the 'staircase' networks concentrates the 'visitor' domain in one zone, while expands the 'inhabitant' domain such as 'bedrooms' in more than one zoning relations.

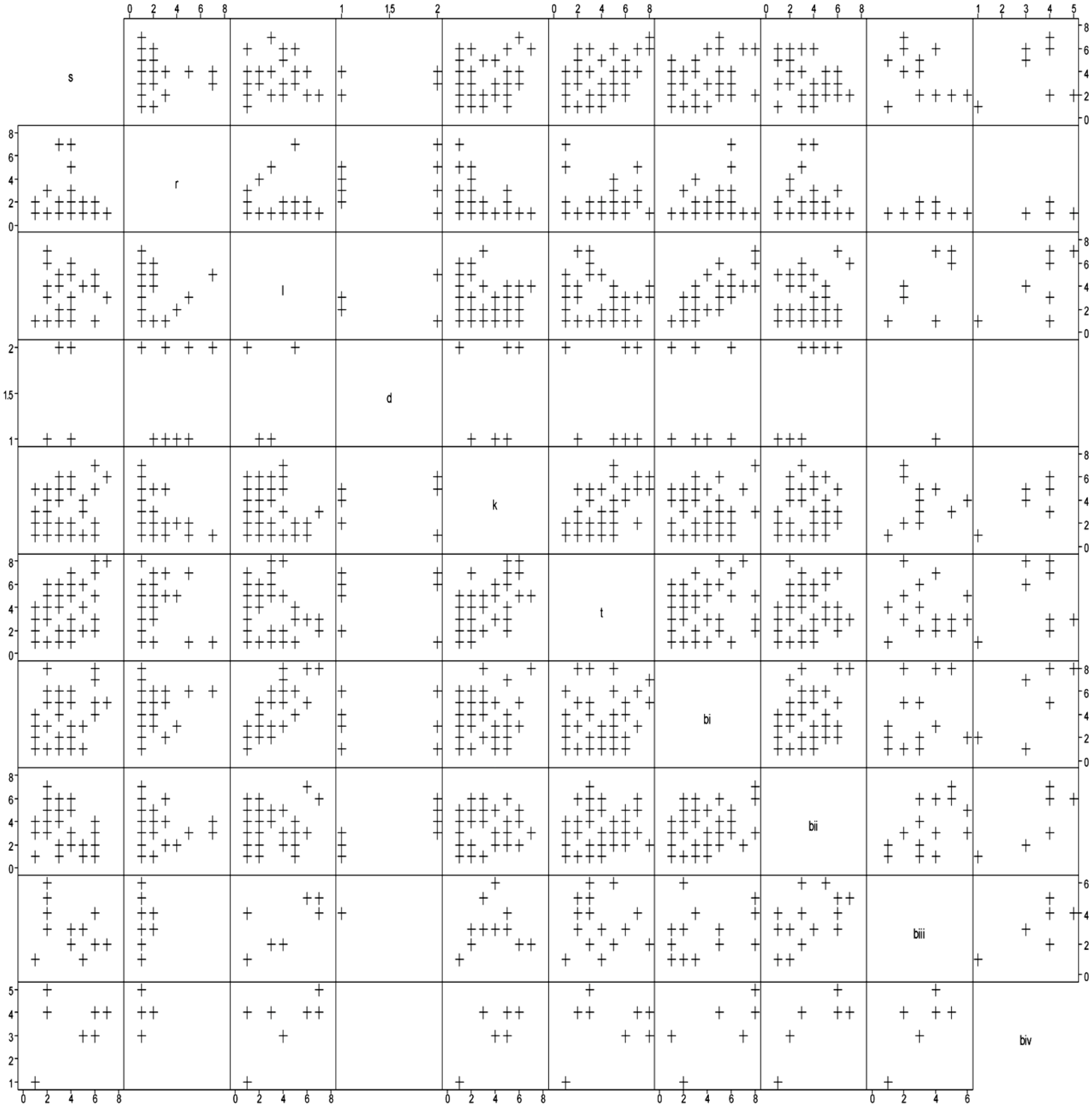

Fig. 9: Scatterplot of Digraph Rank of Distances

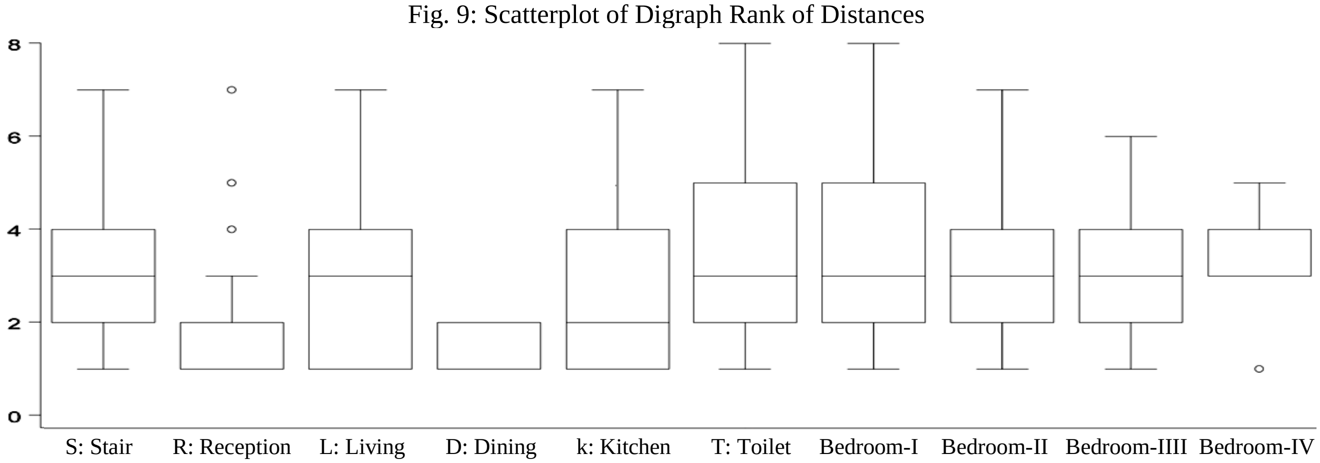

Fig. 10: Box-plot of Digraph Rank of Distances

The following 'living' plot observes a negative covariance with the 'kitchen' room. The more the 'living' is near to one 'bedroom' the far is the 'kitchen' and vise versa. The zones of 'inhabitant' domain, therefore, plan one 'bedroom' in 'living' zone, while set the other 'bedroom' near to the 'kitchen' side. The 'kitchen' scatterplot with 'living' observes the same two zones of ‘inhabitant’ domain to form a reflexive functional relationship. In the further 'living & toilet' plot, the random covariance dissolves the 'visitor-inhabitant' relationships by a dispersed zones of 4-frequency in average. Multiple 'living & bedroom' correlations, however, mix the zoning distribution. The observation of positive covariance ranges from the first up to sixth rank, with usual (1,1) correlation in the 'visitor' space, followed by the second rank correlation in the 'staircase' zone. From the third to the sixth ranks, nevertheless, the covariance with ‘bedroom-I’ alternates with positive-negative signs of correlation in 'bedroom-II & utility' zones. In this regard, the early zoned 'inhabitant' wings cross-correlate with the change of zoning. One reason observes the spaced door openings of the two rooms along one continuous wall instead of being next to each other, which measures longer than the distance to the door openings at the opposite side across the central space. So far the digraph network of 'living' space structures the 'inhabitant' zone into distant wings with respect to the 'kitchen' room, but switches to a cross-wing in 'visitor' bypass with respect to 'bedroom-I' door. In the correlation of 'living & bedroom-II', however, the 'inhabitant' wings revert into stable zones of 'living & bedroom-I' versus 'kitchen & bedroom-II' with the 'visitor' space in between. The 'staircase' is set closer to the former wing than the latter. Thus, the network of 'living & bedroom-I' holds dynamic zoning of layout domains.

The digraph observation of the 'kitchen' in correlation to the ‘two-bedrooms' clarifies the plan structure. The covariance of 'kitchen & bedroom-I' changes from one room to the other. Negative covariance observes the more correlation of either room with the ‘staircase’ whenever the other room miscorrelates. Meanwhile, the ‘living’ has more correlation with the ‘bedroom-I’ than the ‘kitchen’, while the 'reception' has equal frequencies of (1,1) correlation with both rooms. The ‘kitchen’ has two-sided correlation with the ‘toilet’ for piping and the ‘bedroom-II’ in one ‘inhabitant’ zone. The further plot of the 'kitchen-bedroom-II' observes positive covariance. Some of the 'reception' correlation deviates from the (1,1) ranking dominance by a second rank of the 'kitchen' distance. Nevertheless, the midway correlation of the 'kitchen & bedroom-II' meets in the 'bedroom-I' across the central space. Meanwhile, the flow of 'living' room correlates with closer distances to the 'bedroom-II' than the 'kitchen' room. The deep 'toilet' detaches from 'bedroom-II' with a wide ranking differences. The 'staircase' forms an average rank of alternating correlation with the 'kitchen & bedroom-II'. More negative covariance of the two 'bedrooms' alternates the shorter rank of distances to either the ‘staircase’ or ‘reception’ rooms. The 'living' has a constant correlation of high rank with the first ‘bedroom’ than the second. In contrast, the 'utility' rooms correlate with the second 'bedroom' zone away from the first. Overview of alternating zoning for the ‘inhabitant’ domain introduces dynamic spatial structure in connection to the 'visitor' centrality. This dynamics is further observed in the box-plot weighs of first to second rank of 'reception & kitchen' correlations compared to the average 'inhabitant' of up to the third rank. The quartiles enforce the overlap of the far 'inhabitant' wings with the near 'visitor' networks through the social interaction of 'bedroom-I' with the 'kitchen & living' rooming structure.

3. Conclusion

The digraph algorithm of distance measure, which is conducted on the building survey of ‘Danna’ slum area in Alexandria, determines the social logic of spatial structure as follows:

1- At the aggregated level of global discrete system, the irreflexive digraph structures the ‘visitor’ domain with deeper outflow to the ‘inhabitant’ domain than the way back. In this process, the ‘living’ of longer inflow than the outflow classifies as an ‘inhabitant’ space, while the inversed flow of the ‘kitchen’ prevails as a ‘visitor’ space. Nevertheless, the aggregated diagraph distribution of each individual room inverts the spatial structure into a shallow ‘inhabitant’ and deep ‘visitor’ domains. Meanwhile, the frequency of ranked distances compensates the central integrity of the ‘visitor’ domain with a dense network of moderate spacing integrity for the ‘inhabitant’ domain. Thus, the digraph measure of room distance reflects an interchangeable dynamics of social structure at different levels of spatial resolutions.

2- The cross-tabulation of digraph distance defines the functional relationships of multiple rooms in correlation, where the 'staircase' has positive covariance with the 'living & reception' to form a 'visitor' zone, but covariate negatively with the 'kitchen & bedrooms' to prove different domains. In this regard, the multiple spatial system when seen from the carrier 'staircase' switches the 'living & kitchen' into the inverse domains of the previously aggregated singular viewpoints. This is further proved by the 'living & kitchen' scatterplot of mutual negative covariance against each other with respect to the room set.

3- The scatterplots of 'bedrooms' differ between one 'bedroom' of alternating positive/negative covariance with the 'visitor-inhabitant' domains, while the other is more stable towards the 'inhabitant' domain. From the 'living' standpoint, however, the first 'bedroom' covariate positively in the 'visitor' domain versus the negative second 'bedroom' to prove a different 'inhabitant' domain. The box-plot weighing of diagraph further observes the interactive 'living, kitchen & bedroom-I' networking among the social domains. Despite the unskilled architecture, the digraph reveals dynamic social structure with multiple logic of the same space.

4. Acknowledgements

Gratitude to the Japan Society for the Promotion of Sciences (JSPS) for the scholarship award, which resulted in this research.

5. References

[1] A. El Shazly, "Spatial Structure at the Room-level of Squatter Urbanism in Metropolitan Cairo," *Journal of Asian Architecture and Building Engineering*, vol. 4-2, pp. 391-398, 2005.

[2] A. El Shazly, "Spatial Cross-section at the Edge of Cairo City Using GIS," In *proceedings of the Annual International Conference of the Geographic Information Systems Association of Japan*, Osaka, 2005, pp. 7-12.

[3] Alexandria Governorate and Alexandria University, *The Comprehensive Plan Project of Alexandria*, Final Report, Cairo: El Shorouk Press, 2005.

[4] B. Hillier, and J. Hanson, *The Social Logic of Space*, Cambridge: Cambridge University Press, 1984.
http://dx.doi.org/10.1017/CBO9780511597237

[5] G. Chartrand, *Introductory Graph Theory*, New York: Dover Publications, 1985.

[6] H. Kato, E. Iwasaki, and A. El Shazly, "Internal Migration Patterns to Greater Cairo - Linking Three Kinds of Data: Census, Household Survey, and GIS," *Journal of The Mediterranean World*, Hitotsubashi Univ., Tokyo, vol. 17, 2004, pp.173-252.

[7] H. Kato, E. Iwasaki, A. El Shazly, and G. Yutaka, Regional Diversity and Residential Development on the Edge of Greater Cairo – Linking Three kinds of Data – Census, Household Survey and Geographical Data – with GIS to Greater Cairo. In *GIS-based Studies in the Humanities and Social Sciences*, A. Okabe, Ed., UK: Taylor & Francis, 2006, pp.191-210.

[8] J. Hanson, *Decoding Homes and Houses*, Cambridge: Cambridge University Press, 1998.

[9] L. Hamilton, *Statistics with STATA*, Belmont: Duxbury, 2003.

[10] M. Batty, Networks, Flows, and Geometry in Cities: A Challenge to Space Syntax, *The Journal of Space Syntax*, vol. 1-2, pp.364-366, 2010.

[11] M. Khalifa, "Redefining Slums in Egypt: Unplanned Versus Unsafe Areas," *Journal of Habitat International*, vol. 35, pp.40-49, 2011.
http://dx.doi.org/10.1016/j.habitatint.2010.03.004

[12] P. Blanchard and D. Volchenkov, *Mathematical Analysis of Urban Spatial Networks*, Berlin: Springer, 2010.

[13] R. Diestel, *Graph Theory*, 3rd ed., Berlin: Springer, 2006.

[14] Republic of Egypt, *The Law of Building Works*, 10th ed. Cairo: Ameriya Press, 1995.

[15] Republic of Egypt, *The Law of Urban Planning*, 6th ed. Cairo: Ameriya Press, 1995.

[16] The American University in Cairo, *Egypt's Strategy for Dealing with Slums*, Final Report prepared by The Center for Sustainable Development, Printed by The American University in Cairo, 2014.