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ENHANCING CITY URBAN PLANNING PROCESS THROUGH INTEGRATING GIS WITH SPACE SYNTAX SIMULATION TOOL

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ABSTRACT

Planning models and simulations support tools are considered to be an awareness-raising process in the strategic planning and design, as the aid of spatial models that integrate urban form with Soci-economic data, can open up a bright spectrum of opportunities and insights that were not evident before. Emphasizing on the relationship between space and the spatial structure that are considered to be the fundamental concept of urbanism. This paper is concerned by discussing, and evaluating the design proposal of Airport Lake (El Matter lake) in Alexandria, Egypt, with the aid of an evidence based model. This adopted methodology integrates Geographic Information Systems (GIS) and Space Syntax into a single model. The model is based on analysing current land use densities, distribution, socio economic variables and network spatial configuration analysis of city, in order to predict the likely outcomes of the proposal on Alexandria's urban life.

The model is tested on Airport lake area, using information collected from census data and General organization of physical planning. It is considered to be one of important areas in Alexandria city, due to its location adjacency to Alexandria city centre and also, it is characterized with multiple attracting elements that play main and important role in the urban and economic development in the strategic development scheme. Based on the development strategy of airport lake area and its surroundings in order to make good use of the area, whether on a touristic and residential aspects and to organize and control urban development. The adopted methodology will test the proposed design to achieve compatibility between the detailed plan as on the level of strategic design, and on general outline of the city as a higher level.

Thus, the developed model will bring together all the current available data into one practical, mappable, measurable and quantitative data produced by GIS, combined with qualitative analysis of the spatial configuration of the proposed area with the city as a whole produced by space syntax, then using Geographically weighted regression (GWR) to correlate different layers to each other. The model revealed important challenges whether on the local level of proposed area or on the level of Alexandria city development that could be used by stakeholders and the local authorities in decision making process, and assisting the quality of design, evaluating the possible policies and interventions in the light of the goals set out in Alexandria's comprehensive city plan.

KEYWORDS

Strategic Design, Urban Form, Soci-Economic Variables, Geographic Information System, Spatial Configuration Analysis.

1. INTRODUCTION

Planning models and simulations support an awareness-raising process, as Carrying out strategic planning and design with the support of spatial models that could integrate urban form with soci -economic data, can open up a bright spectrum of opportunities and insights that were not evident before. The research aims to fill in the gap and provide a framework to inform the limited physical interventions by relating different layers of analysis and design, to enhance urban design process of the city. Thus, the general approach in this study follows a process that includes four major elements:

- A detailed spatial analysis method to select, refine the urban design structure of the city
- Supporting model that studies and analyses the existing and possible situations
- A review of the overarching proposed guidelines and strategies
- Provide urban design development recommendations.

In this context, a hypothesis was proposed that integrate GIS based approaches with Space Syntax, to allow the creation of a composite model that integrate different layer for analysis, that enrich the results whether on the local level, or on the analysis of spatial configuration of city network. In order to, base the design on more layers of evidence model that describes and interprets the relationship between socio-economic variables and spatial characterizations of the urban agglomerations. a multi-criterion GIS method has been developed which takes into consideration different spatial factors and a set of socio-economic data. then using Geographically weighted regression(GWR) to correlate different layers to each other, it is a baseline guide for decision making and assisting the process of design. Moreover, The GIS tool can provide analysis of individual quantitative attributes of a selected layer, mapping the values using simplified symbology settings, displaying essential descriptive statistics, and plotting basic interactive charts, moreover can compare between different layers together. While, the Space syntax theory addresses the relationship between physical elements of a city known as, configuration, its social activity and the pattern of utilization. This method is based on analyzing the current land use densities, distribution, socio economic variables and network spatial configuration analysis of city, taking into consideration the cause and effect between spatial and socio-economic factors, as it considers space and the spatial structure as the fundamental concept of urbanism.

To enhance city planning, the needs of city must be fulfilled and achieved through highlighting the main problems, successful analysis for existing situation, and the examining the proposed strategic plan. First, stating problem during the last few decades, Egyptian cities underwent through several significant transformations regarding their sizes, population densities, mobility and land use distribution. Due to the lack of a spatial decentralization policy, most of those cities experienced an exponential population growth and, therefore, are faced with serious problems. Those problems range from the lack of infrastructure, inadequate transportation networks connecting the cities with their hinterlands, illegal or even chaotic expansion, increasing densities, congestion at the center and including dramatic changes of land use. Highlighting the specific issues entailed with the Egypt's second capital and second metropolitan national agglomeration: Alexandria city. The research adopted strategy takes into consideration the dynamics and requirements of urban growth and attempts to deal with the existing problems of the city towards two aspects: population growth/urban development aspect, and networking/ transportation aspect. Accordingly, to the strategic development strategies prepared by General organization of physical planning for airport lake area, as it is considered to be an extension for the city center for Alexandria city it will be taken as a case study to test the proposed conceptual plan.

This chosen area is responding to the debates on the importance of polycentrism in contrast to the mono-centric development of cities; sociologists, economists, and geographers have developed several models, explaining where different types of people and businesses tend to exist within the urban settings. Various theories focusing on the distribution of densities within cities have also emerged: in 1945, Harris and Ullman (1945) introduced a polycentric model,

described as a more effective generalization of urban land uses, where large cities do not grow around one CBD, but are formed by the progressive integration of a number of separate nuclei in the urban pattern. While Space syntax describes the logic of society through its manifestation in spatial systems: how spaces are put together or the configuration of space relates directly with how people perceive, move through and use spatial systems of all kind, ranging from small domestic spaces to large-scale urban settlements (Karimi, 2012). The core concepts of space syntax can be explained through two fundamental propositions. The first proposition is that space is intrinsic to human activity, not a background to it. Space is shaped in ways that reflects the direct interaction between space and people, and through this the space is created, and the built environment, become humanized. The second core proposition of space syntax is that space is fundamentally a configurational entity (Hillier and Hanson, 1984; Hillier and Penn, 1991; Hillier, 1996; Hillier, 2008). Configuration, simply defined as simultaneously existing relations, is about the composition of the built form from the parts that are in a unique relationship with each other. Marcus (2007) defines the space syntax theory in a very understandable way, that the main variable of urban form that is analyzed within space syntax is accessibility and how the accessibility between spaces varies according to the changes in the configuration of urban form. Karimi (1997) adds that space syntax theory focuses on creating a platform for society and space, to give a spatial nature to society as well as a social dimension to space. The main important issue in enhancing polycentrism is through defining centers, sub-centers (centrality) and accessibility within the city.

The research will start by introducing a brief background on Alexandria city growth and development challenges, importance of study area, and moves to the implementation of the model. Finally, implementation of model should end with recommendations to the proposed conceptual plan for the area.

2. HISTORICAL BACKGROUND

Alexandria city occupies an area of about 300 km² and has a ten-fold increase in population of 4 million, with a density exceeding 1,200 per km² (Shouk, 2000). Population is expected to reach 5.4 million by 2015 (United Nations, 2008). This enormous urban growth requires precise detection with good management, prediction and planning. The city development and growth direction for Alexandria City Since 19th and 20th, the following were observed: The discrepancy between the population growth and spatial accessibility has increased recently. According to that, GOPP vision had a new vision for development for Airport lake, as it is considered to be one of Alexandria's waterfront areas. Its location adjacency to Alexandria city centre, which may be developed as another center. In addition to that, it is characterized with multiple attracting elements that play main and important role in the urban and economic development in the strategic development scheme on the level of city such as; El Nozha Airport, (Airport Lake) it is part of lake Mariout and represent an area of 1375 feddan, Aviation club and Rowing club, existing range of urban agglomerations. In addition to that, that the study area is located at a site mediating the city entrances whether from the desert road and agricultural road. It is connected with the city by a group of regional and main roads that makes area easily connected to the whole city, as well as surrounding areas.

To summarize the importance of area on the level of connectivity and accessibility, as follows:

Strategic location in Alexandria's main entrance, located near desert road, northern edge is surrounded by Agricultural road, from southern edge by the international coastal road, as shown in (figure 1), that illustrates the important road network connecting the site with surroundings and existing important features.

In the light, of the above-mentioned challenges facing the future development and growth of Alexandria city, an adopted methodology will be used to examine the proposed plan for the Lake Airport lake as a new center in Alexandria, this methodology is based on integration of space syntax into GIS, this would stimulate a research oriented toward the analysis of urban system at different levels of abstraction. Starting by analysing the existing centers in Alexandria, using GIS quantitatively using cluster method, moving to spatial configuration of city using space



Figure 1 - Airport lake and its surroundings

syntax theories. thus, GIS provides on one hand a rich set of spatial data integration, analysis and visualization capabilities that support urban studies. On the other hand, the principles that underlie space syntax theory can extend the modelling capabilities of GIS, particularly in terms of the dissemination of recent advance and experimentation throughout the analysis of urban system. The space syntax could be considered both as alternative model of space at the cognitive level, and as a practical computational method for the analysis of urban structures and patterns (Claramant C., Klarquist B., Jiang B., 2002). the starting point will be based on analyzing the current spatial pattern and the centers and sub centers . Alexandria is divided into seven administrative districts, the study will focus on five districts in Alexandria: Al Montaza, East (sharq), Central (wassat), Gommrok, West (Gharb) districts , other districts like Al Amria and Borg Arab are not included in the analysis due to difficulty to get their data as mentioned before, but it should be implemented in the model as future study. Then analyzing the conceptual plan for a developing area like Airport lake as it could be considered as another center adjacent to the main city center.

3. DATASETS AND METHODS

The research main aim is to fill in the gab and provide a framework to inform the limited physical interventions by relating different layers of analysis and design, to enhance urban design process of the city. Thus, to examine the proposed master plan for Airport lake as a new nucleus for Alexandria, it is important to first analyze the existing successful centers and sub centers to be able to have criteria for the (centrality) and accessibility. There are different approaches to analyze centers and sub-centers, the adopted methodology, designed to use GIS Based approach using cluster method to provide quantitative figures for the identified problem, and integrating it with Space Syntax approach. Enabling an evident base method to be more precious in the solutions given and to help decision makers in urban design and planning process. Therefore, the analysis will be carried out through Four main steps illustrated in figure (2), the results of each step will be used in the following step to accomplish a composite model mentioned as follows;

- City level: Step One: Defining the Sub-centers
Using Geographic information system (GIS) for identification of existing centers and sub centers.
- City level: Step Two: Existing centers formation
Using Space Syntax methodology to investigate the spatial characteristic of city, and spatial and socio-economic characteristics of centers and sub centers
- Local level: Step Three: Enhancing polycentric development
Overlaying the results from both stages to enrich the analysis and get recommendations for the planning process and decision making.
- Local level: Step Four: Testing proposed conceptual design
Examining the proposed conceptual plan for airport lake per the findings of the previous analysis of three steps.

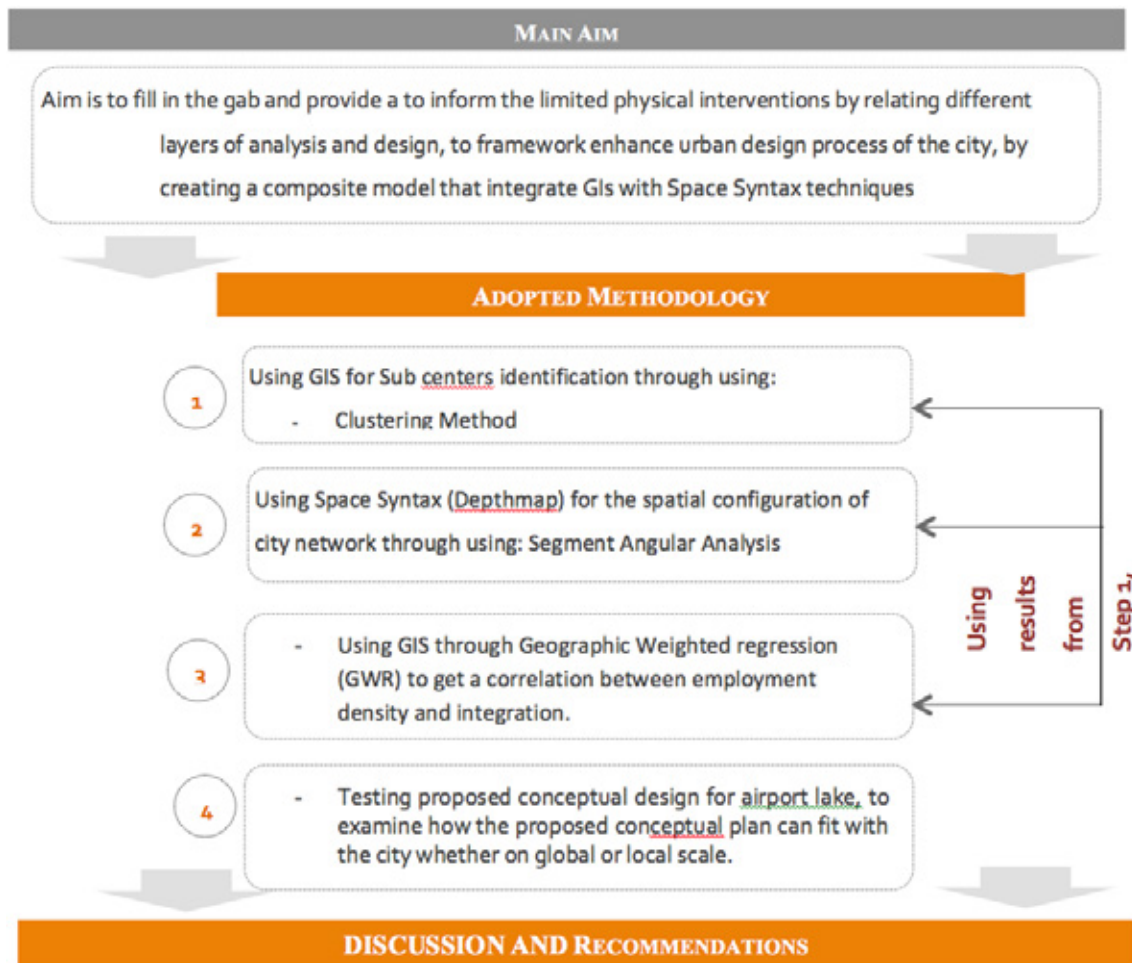


Figure 2 - Adopted methodology, integrating GIS based Approach with Space Syntax techniques to achieve the main aim

3.1 STEP ONE: USING (GIS) FOR CENTERS AND SUB-CENTERS IDENTIFICATION.

This section presents an empirical analysis of employment and population patterns of sub-centers in Alexandria; using GIS: 1- to identify employment sub centers using suitable method; 2- to apply it to data available in the region; 3- to analyze the functions and distributions of centers and their associated commuting flows. Thus, the Clustering method is used, it is one the most popular methodology for identifying employment center is based on employment density and

size, an approach developed by Giuliano and her colleagues (Giuliano and Small 1991; Giuliano et al. 2005). In the implementation of the model all data were provided from CAPMAS 2006 and an Origin Destination Matrix for peak hours for Alexandria 2010 produced by the Department of Transportation Civil Engineering, Alexandria University. The clustering method indicated 16 sub center as shown in (Figure3), it was observed that the number and size of employment centers are not only sensitive to the thresholds (D and E) but also to the transportation modes, major arterials and commercial activities. In addition to that, employment and activity sub-centers embody not only current opportunities for jobs and recreation, but also represents a criterion for formation of new centers as a future opportunity for development.

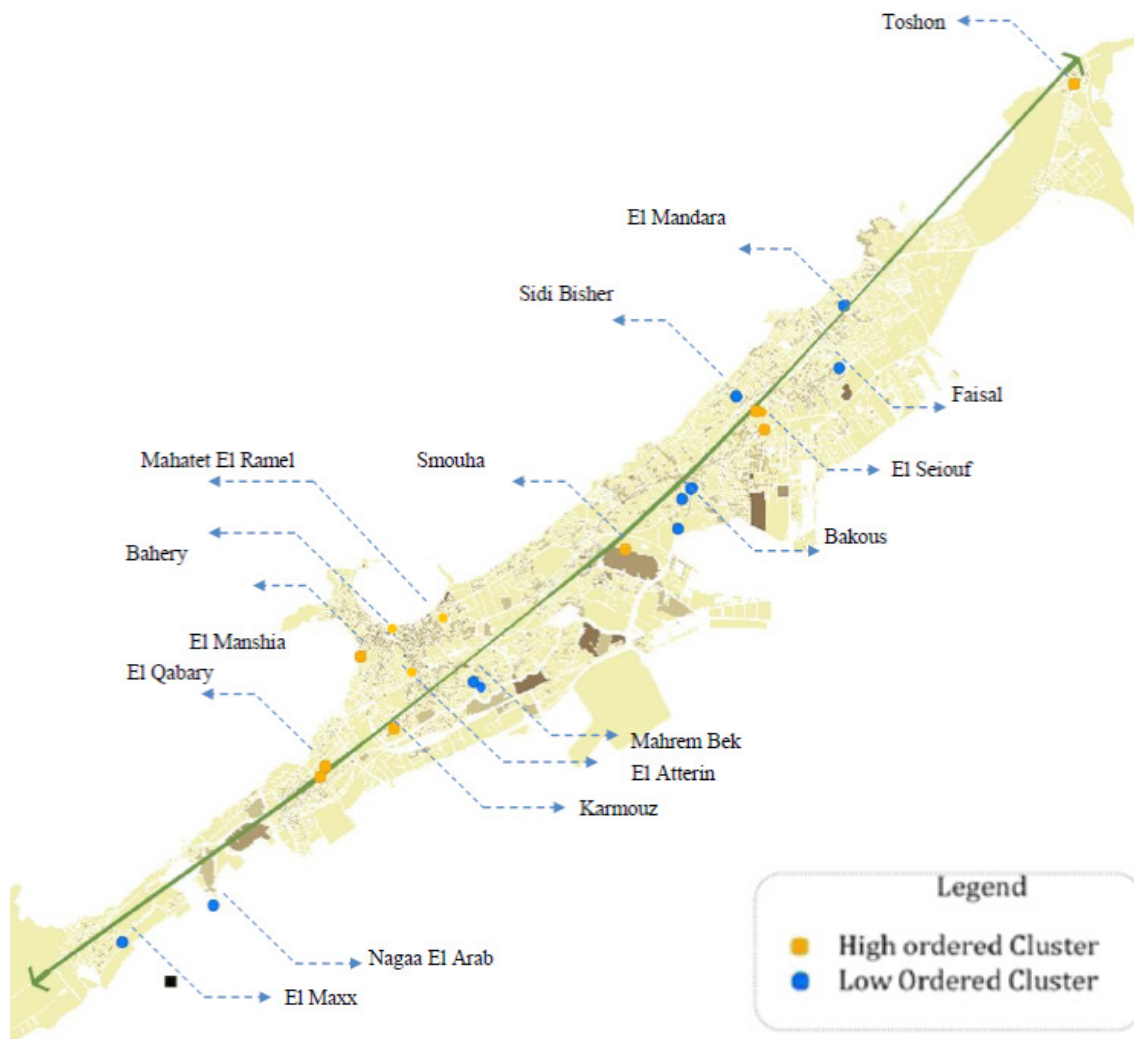


Figure 3 - Identified employment Centers and sub centers using clustering method in Alexandria city, D= 20 job/ Feddan and E=15000 which will be used in step two of analysis.

3.2 STEP TWO:

USING SPACE SYNTAX TECHNIQUES IN ANALYSING SPATIAL NETWORK OF CITY

This part contributes to the knowledge of urban spatial structure and dynamics, by the study of the functional movement of urban fabric of Alexandria city, Egypt through using the Space syntax, as it is capable of analysing the spatial network of the city how it can be described, how it effects on pattern of movement, land use and density can be measured. Thus, by understanding spatial networks, this could rebalance the planning of cities to achieve a better

harmony between global and local accessibility. Angular segment analysis is performed through node count analysis and integration analysis illustrated in figure (4), as they are considered to be best indicator of vehicular movement at different radii. Starting from global at radius 10 000 m, intermediate scale at 5000 and local scale at radii 2000 and 800. Global integration identifies the main street network of the city and the main centers, while local integration defines sub-center. The results achieved from step two at local scale radius 800 m will be overlaid with the results achieved from step one where Density $D = 20$ job/Feddin and Employment = 15,000 which will be used in part three of analysis. To compare between the sub-center and the network analysis and spatial configuration of sub centers, then moving to step three to analyse in depth some of selected centers and sub-centers. This measure helps to determine existing and potential local centers as these small radii also to identify the central destination zones for the neighbourhoods that attract potential pedestrian to-movement. This multi-centered structure reflects the actual characteristics of Alexandria, the figures show a remarkably true-to-life functional picture of the metropolitan city.

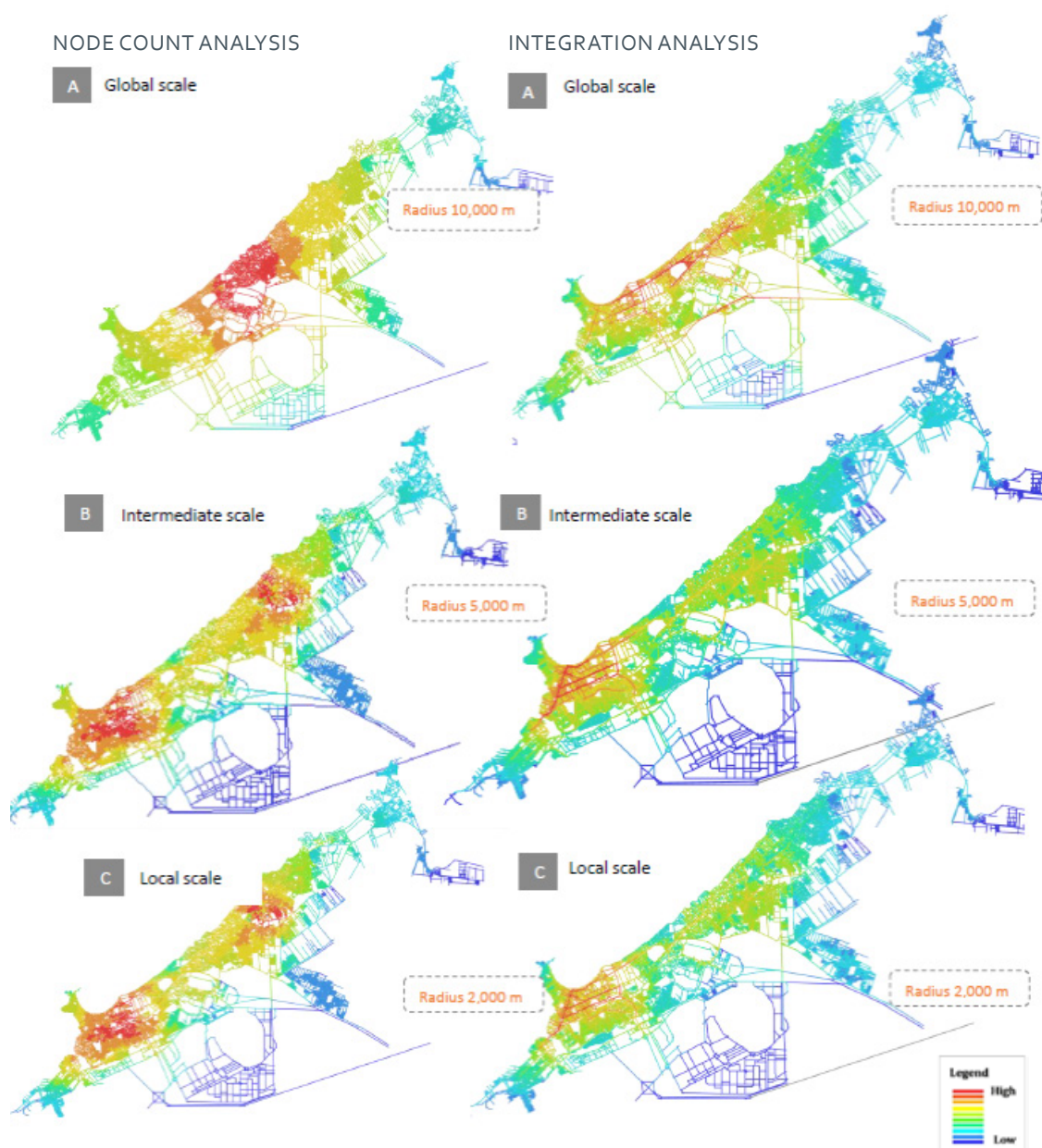


Figure 4 - Integration analysis and node count analysis at different radii for Alexandria city

4. RESULTS

To compare between the centers and sub-center identified and the network analysis, the result from step one will be overlaid with segment integration analysis at local level of radius 800. As the spatial analysis, can give a true-to-life functional picture due to the powerful influence that natural movement has on the evolution of the urban pattern. This was proved in figure (5), where it is obvious that the street network analysis corresponded to the location of sub centers identified. Then Following this stage, two areas will be selected, one of them is the Central business district (CBD) and other area is a sub centers. These two areas are adjacent to the airport lake area that will be examined later. Also, the integration analysis of these two areas highlights high values, and corresponds with centers and sub-center identified from step two. The results of these areas will be analysed to get a correlation between accessibility and other factors like employment density and population density.

4.1 STEP THREE:

OVERLAYING THE RESULTS OF GIS AND SPACE SYNTAX APPROACHES USING GEOGRAPHICALLY REGRESSION WEIGHTED APPROACH

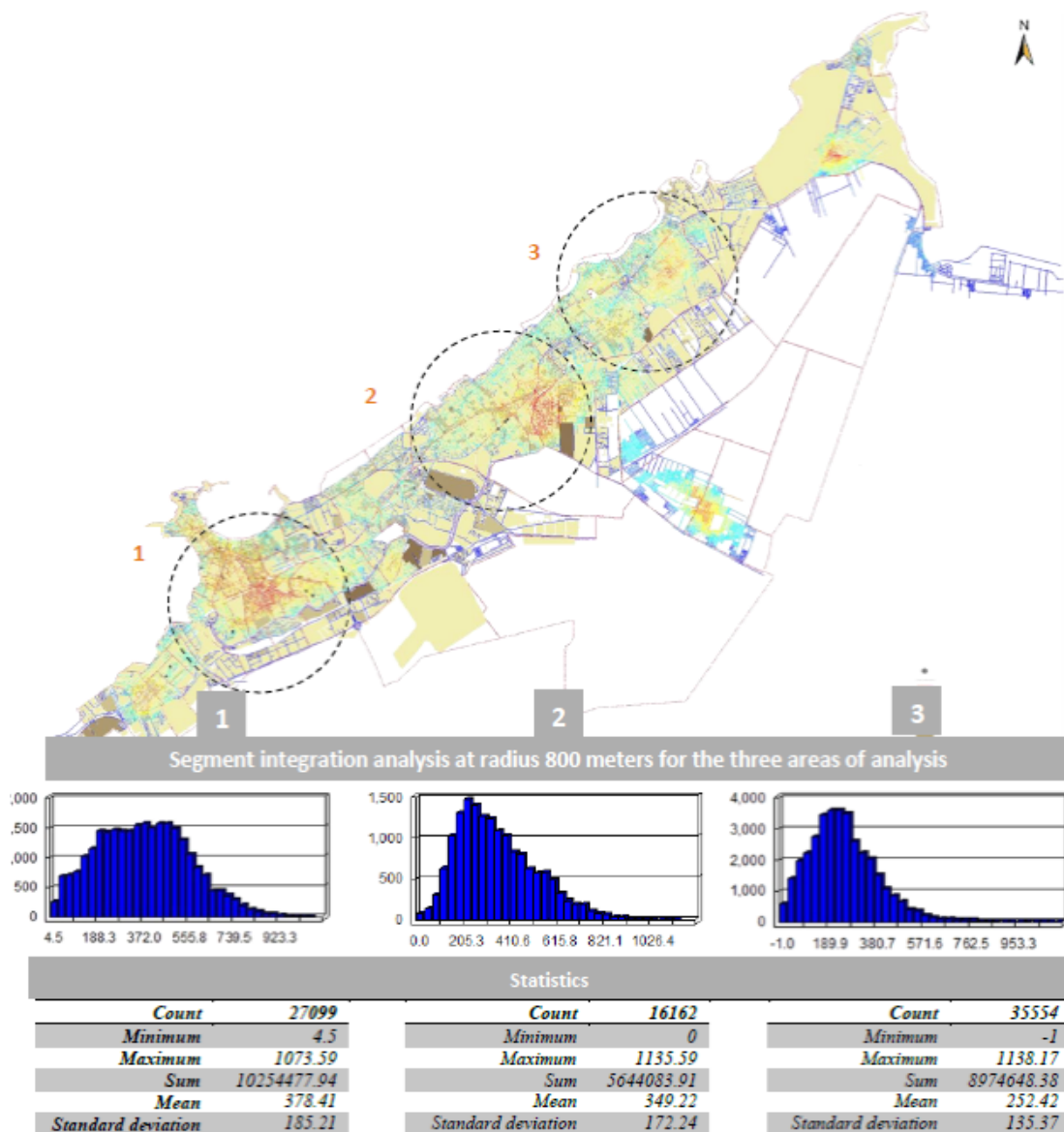


Figure 5 - Segment integration analyses overlaid with sub centers identified of three areas

From an experiential point of view, it can be argued that what matters is the degree of accessibility to density, which is achieved by the design of urban fabric of streets and buildings. This relation will be analysed using Geographically Weighted Regression (GWR), as the regression analyses attempt to demonstrate the degree to which one or more variables potentially promote positive or negative change in another variable. In addition to that, spatially auto correlated (features near each other are more similar than those further away) and features behave differently based on their location/regional variation. This will be applied to the two areas to be able to extract the coefficient correlation (R^2) between the degree of integration and employment density; the following results were found, the first area $R^2 = 0.68$, where the dark colour shows the areas where this relationship is significant and high. The high correlation value corresponds with the identified sub-centers and high integration value as shown in the scatterplot graph and figure (6).

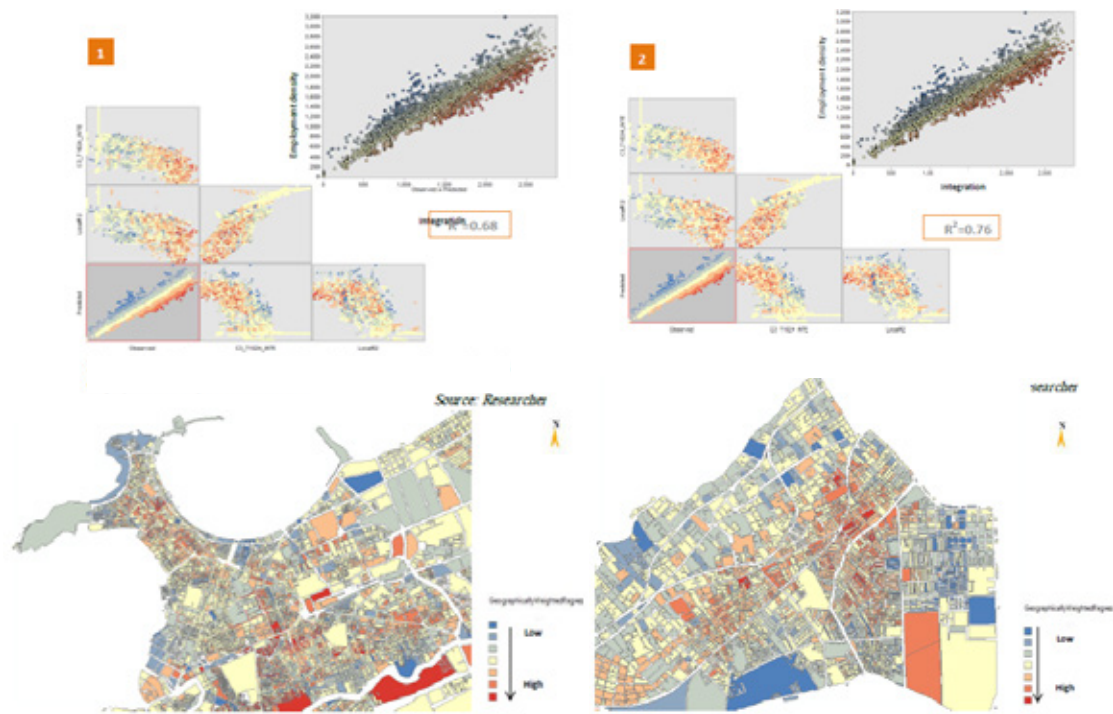


Figure 6 - Scatterplot graph showing relation between integration and employment density, where $R^2 = 0.68, 0.76$ in two areas. Dark colours show high significant relation between employment center and integration.

Therefore, by comparing the results from selected areas shown in table (1), studied a correlation between accessible nodes showed strong relation with average employment density by 76% ($R^2 = 0.76$) and 68% ($R^2 = 0.68$). According to observed results, it is crucial to have a strong correlation between accessibility and employment density to have a successful sub center.

Selected Areas	R^2 Correlation Between node count & integration	Average Employment Density Job/Feddan	Average Employment Density Person/Feddan	Average Integration $r=800$	R^2 Correlation Between integration & employment density
Area 1	0.76	120	450	375	0.68
Area 2	0.78	100	400	349	0.76

Table 1 - Comparison between selected areas

4.2 STEP FOUR:

EXAMINING THE PROPOSED CONCEPTUAL PLAN FOR AIRPORT LAKE AREA.

It is obvious from the analysis carried for Alexandria city that Airport lake area is close to the main city center (Area 1) and sub centers (Area 2) in Alexandria, thus it is important to study how the proposed network (figure 7 (a)) and proposed land use (figure 7 (b)) will influence the whole city. This will be achieved by analyzing the spatial configuration at global and local scales at radius of 10,000, 5000, 2000 and 800 m, where spatial configuration at radius 800m will be studied with two near centers illustrated in figure (8), also a segment integration analysis is analyzed to the proposed area with adjacent centers, illustrated in figure (9) and a scatter-plot between the integration and node count is performed in figure (10)



Figure 7 - a) Proposed road network for Airport Lake area and b) proposed Land use

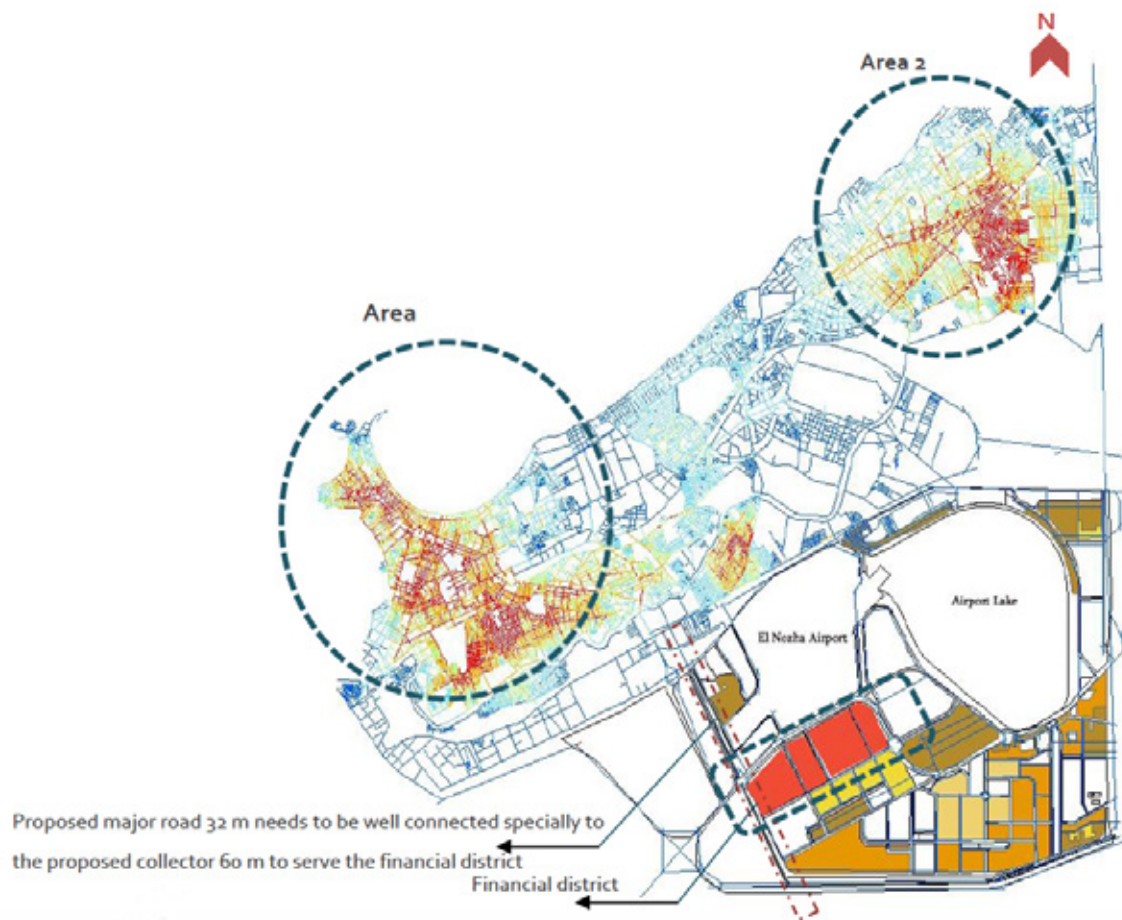


Figure 8 - integrati on analysis overlaid with proposed land use for airport lake area at radius of 800 m

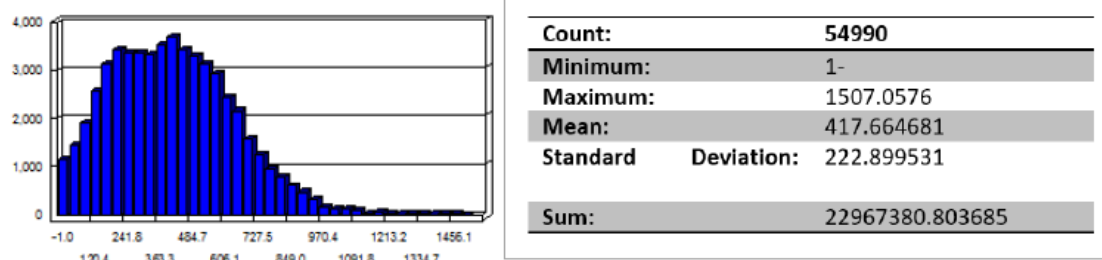


Figure 9 - Segment integration analysis for the proposed area with the surroundings centers

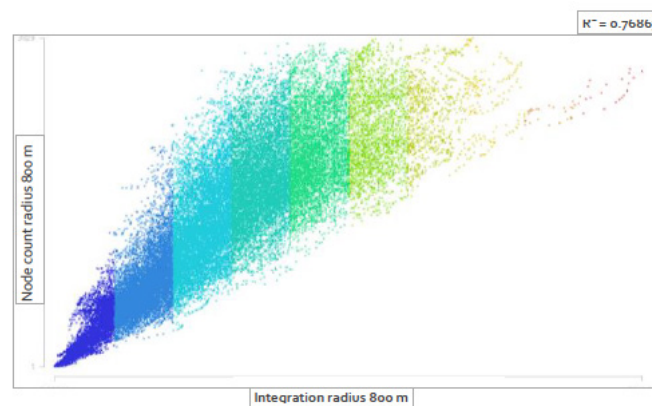


Figure 10 - Coefficient correlation between node count and integration at radius 800 m

The Analysis at global scale and intermediate scale shows that the proposed road network is connected with major road thus, linking the proposed area with the surroundings especially the city center and smouha sub center, but at a local scale the integration value is low. Therefore, the proposed road network succeeded in connecting the area with surroundings but still needs to be improved on the local scale, also it is important to consider the criteria for a successful urban center extracted from step one where $D=20$ job/Feddan and $E=15000$, Also correlation between accessible routes that correlated with average accessible population density by 72% ($R^2=0.726$).

5. DISCUSSION AND REFLECTION ON BENEFITS OF APPLICATION

The adopted model was designed to test a proposed plan for the Lake Airport lake as a new center in Alexandria, thus it was important to identify existing centers and sub-centers, then analysing the spatial configuration of the city. This was fulfilled through four steps as follows:

1. Using GIS-based approach for identification of the centers and sub-centers using the clustering method. Three scenarios were tested with the clustering method, and the results were compared to the results of the layer based socio-economic analyses. The scenario with " $D=20$ jobs/feddan & total employment (E)= 15000 " was selected, as it was the one that achieves the nearest match between the outputs from the existing situation.
2. Using Space Syntax approach for analysing spatial configuration of city depending on Angular Segment Integration (ASI) analysis. ASI were analysed from global to local levels at different radii starting from 10 000 meters (for global) till 800 meters (for local). At each radius, different numbers of centers are identified per the scale of analysis. The resulted integration maps at radius 800 meters was selected, as it has produced results that corresponds with the identified centers and sub-centers from step one.

3. Integrating GIS and Space Syntax approaches, through the overlay of the resulted maps from the integration analysis and identified centers and sub-centers together. It was found that the areas that were identified as sub-centers completely match with the Angular Segment Integration analysis. Nevertheless, there were also other areas that have high integration values but do not match with the results from the clustering method. This is mainly due to the lack of complete GIS data in those areas. In Addition, Geographically Weighted Regression analysis (GWR) was used to measure the correlation between the accessibility and employment density. The results were illustrated in the scatter plots in figures (6). The resulted R^2 is generally high and indicates high correlations between the two variables.

Through integrating space syntax and GIS-based approaches, this research emphasized how movement patterns and flows in cities are powerfully shaped by the street network; this relation shapes the evolution of the centers and sub-centers that affects the well-being of people in the city. The space syntax approach was used to analyse the road network accessibility quantitatively. The use of GIS allowed for the integration of additional data layers (such as socio-economic data) to improve the quality of analyses and findings. Space syntax proved to be a powerful tool that can deal with micro to macro scales, and therefore could be used in early stages to assist decision makers in evaluating different design and planning solutions. For a successful planning designs the proposed plans should be tested and examined for better scenarios and enhancing quality of life in city.

6. CONCLUSIONS

Enhancing polycentric development can be achieved through vitalizing existing center, sub-center by improving their density patterns, as well as connecting the existing centers with the newly proposed ones by means of accessible routes. The vitalization of centers and sub-centers requires that each center to be self-dependent, while enhancing the means of cooperation with other centers through adequate and accessible routes. GIS-based approaches, such as the clustering method, are powerful tools for the delineation and identification of existing centers and sub-centers within the urban environment. Setting appropriate criteria for the selection of the adequate analytical tools is vital to achieve efficiency in the outputs and analyses.

In this research, the spatial and socio-economic relationship was acknowledged through using configuration analytical methods in urban planning and design process. The social and physical theories of city and finally the spatial configuration related theories were introduced, and the following was concluded; There are several types of analytical tools, as previously mentioned. To fulfill the research needs, several criteria have been set (e.g. presence of spatial dimensions, could link space with people and users, dealing with different scales, and investigating system as a whole). Those criteria conform to the space syntax approach that will be used in the analysis of spatial pattern of city.

By examining the introduced theories, it was found that testing centrality and measuring accessibility could be a good determinant for enhancing polycentric development. Using Space Syntax approach requires studying the theory foundation, methodologies, parameters and new developments. It is concluded that; Angular Segment Analysis produces better correlation with observed vehicular flow than axial analysis. Thus, it will be used in the analysis of network configuration of city. Thus, using Space Syntax approach through Depthmap software and Geographic Information system (GIS) would give the best results. Using both approaches could integrate different layers to analysis and create a composite model.

The adoption of the proposed methodology and model on the selected application has led to the following conclusions; The research sets a new approach to understand the physical pattern of city, based on the cause and effect of spatial- socio-economic relationships. This

approach is applied through using the clustering method and Space Syntax tool and then integrating both tools together. The research introduced quantitative data about the existing centers and sub-centers with the employment density ratio, thus this would help to create liveable successful sub-center.

The research highlighted the significant correlation between accessible routes that correlated with average accessible population density by 72% ($R^2=0.726$) in the livable sub-center and it identified the actual routes in real life. This could be used further in create livable successful sub-centers. The investigation model could assist decision maker in developing their action planes for interventions within the city.

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