GIS location-allocation models in improving accessibility to primary schools in Mansura city-Egypt

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Abstract Egypt governmental reports shows non-optimal geographical distribution of educational facilities and the difficulty in reaching school locations leads to high rates of early school drop-out. Reports showed that 2.75% of school dropout in Mansura city-Egypt (the case study) was due to spatial factors related to the difficulty of reaching school. Urban Planning Authority's report endorse that, the primary school location and the residential building must range between 500–750 m. However, such recommendations failed to take into attention or abided by a developing country like Egypt. The study goes through two Scenarios: (i) Scenario No. 1. Evaluating current school locations and (ii) Scenario No. 2. Analyzing proposed school locations and assess accessibility effectiveness after the process of schools' geographical redistribution, it was carried out using GIS environment. The study objectives are about examined the role of spatial modeling and location analysis for improving the accessibility to public primary schools in Egypt: The specific aim of the study (i) Showing geographic distribution of public primary Schools in Mansura city. (ii) Examining the accessibility to Public Primary Schools in Mansura city and (iii) Using GIS tools to propose optimum locations where future public primary schools ought to be located. The study manipulated location-allocation models in GIS being one of the location analyses tools. It supports the process of spatial decision-making through several models and various scenarios. These provides varied options and great flexibility during planning. For analyzing the current situation of primary schools' distribution, GIS spatial analysis tools were used such as: Average Nearest Neighbor, Hotspot analysis and Grouping analysis. Study results concluded that number of demand points exceeds the distance of arrival at the optimal standard was about 54.96%. Schools concentration ratio in the city was 71.74% fell to 19.77% after the process of geographical redistribution of school locations. The proposed map of primary school locations in Mansura city can give a clear view for the decision maker on what location-allocation models can contribute for improving accessibility to educational facilities through applying the reliable standards.

Keywords Spatial modeling · Spatial accessibility · Location-allocation · Optimal locations · Minimize impedance model · P-Median problem · School dropouts · Mansura city-Egypt

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Introduction

Education is still a critical issue in developing countries. However, it is suffering from serious problems; including continuing school dropouts. In its quest for growth, these countries are working to achieve a minimum level of education for their population. Appropriate spatial distribution of school locations and highly efficient accessibility boost the improvement of the educational process. To get satisfactory results in this respect, GIS location-allocation models are important tools theoretically and practically.

Elementary education in Egypt is mandatory. Public schools are vital service guaranteed by the state to citizens. Are those schools being located based on the ease of reaching (Accessibility)? Are there other considerations applying by state in choosing school locations? In order to answer this question and put the research problem within its historical context, it is useful to refer to the time context that led to the emergence of this problem. As UPA was established by Republican Decree No. 1093 of 1973, the authority is responsible for setting the state's general policies in urban planning, Sustainable development and setting standards that give local authorities the ability to carry out planning and implementation. The Higher Committee for Planning for Greater Cairo (No. 2102 of 1965) was the first nucleus for the establishment of the UPA. The role of the committee was limited to setting structural planning for Greater Cairo ignoring other regions of the country. Since 1973, the role of the UPA has extended to include the development of general policies for planning at the country level. Prior to that date, there was no concrete evidence of the existence of any planning standards used when selecting public primary school locations in the country.

In fact, despite the appearance of planning standards for the locations of primary schools later, in reality, they are more indicative than mandatory. As Rushton (1984) decided, improving the accessibility to basic services is a goal for most governments in developing countries. However, formal methods for optimal locations (location-allocation models) are rarely used to assist in decision making. As mentioned in the report of the pre-university education strategic plan (The Ministry of Education 2014), one of the main education problems in Egypt relates to the opportunity to provide land for the establishment of

the school, without calling of the criteria for accessibility or optimal location standards to these schools. The process of selecting school locations are subject to economic factors related to the appropriate prices and land area etc. Personal considerations may also interfere in the process of selecting the school locations, for example, a land may be donated by people themselves, regardless the appropriate location. This behavior is common in Egypt.

This problem is exacerbated by the fact that service planning in developing countries occurs within short time, also the future considerations are rarely seen when planning such vital services. In summary; the optimal location problem for schools in Egypt has a historical background related to the absence of legislations during certain periods of time, the misapplication of laws by local authorities, the economic aspect that relates to provide financial resources for choosing the most appropriate location for the educational services and personal considerations.

Theoretically, public schools are subject to a set of location requirements. As indicated by UPA report, the optimal distance between the primary school location and the residential building must range between 500–750 m (Ministry of Housing 2014). But is this distance considered and abided by a developing country like Egypt? Where 25.82% of its population are illiterate and 5.19% dropouts (6–20 years) (Central Agency for Public Mobilization and Statistics 2017) because of the difficulty of reaching school. In 2017, 13.16% did not join a school in the city (4 years upward). School dropout in the primary stage was 30.31% (6–20 years) (Central Agency for Public Mobilization and Statistics 2017). In 2017, the Central Agency for Public Mobilization and Statistics (CAPMAS 2017) report showed that: 2.75% of the school dropout in Mansura city was due to spatial factors related to the difficulty of reaching school locations.

The study based on the hypothesis that students or their parents -logically- prefer going to nearby schools. This hypothesis is supported by the fact that they are at an early age. Especially all public schools have the same variables (curriculums and human resources). Highly efficient accessibility is what matters to the population, especially with a lack of competitiveness for schools. Therefore, the distance is the outweighing cost. This hypothesis, which takes the time and costs as a reference is a basis on which some

of the classical theories dealing with spatial and functional relationships.

Literature review

The study of optimal locations in geography revived with the development of linear programming. Garrison 1959 published one of the first studies on optimization problems in geography, which was followed by many studies: Scott 1971, Beaumont 1982 and Church 2001 (Tong and Murray 2012). According to Church (2002) location analysis in GIS started in 1970 with the efforts of Kiefer, Robbins, Durfee, Voelker and Dobson. After that, it develops to include: public health (Harper et al. 2005; Bennett 1981; Shariff et al. 2012; Mestre et al. 2015; Daskin and Dean 2004), civil defense (Murray 2013) and emergency management (Mirzapour et al. 2013; Liperda et al. 2019; Burcu et al. 2008). Ghanim study (1988): linear programming and optimal exploitation of economic resources using mathematical models. It represents the only egyptian geographic study that addressed the subject. After that, no more researches were conducted on this subject!

Alaa (2001) endorse that, education planning is one of the topics that had no much attention from Arab geographers. Despite the early beginnings of studying this type of service, which began with the study of Hassan in 1977 on the geography of primary education in Iraq. In the last decades of the twentieth century, the number of papers dealing with the geography of education in Egypt has increased. Such as, Al-Bakir study (1990) on the educational geography of Al-Buhaira governorate, addressed the stages of education in the governorate, its geographical distribution and efficiency. Al-Baghdadi study (1992) on education and health in Ismailia governorate, concerned with studying the geographical distribution of schools in various educational levels, the quantitative and spatial distribution of health and educational services. Alaa study (2001) on the geography of primary education in Egypt, it dealt with the geographical distribution of basic education schools, measuring their efficiency and absorption rates.

According to Menesez and Pizzolate (2014) the study of Tiwari and Jena in 1987 is one of the earliest studies dealt with school locations, followed by several studies amongst: Viegas in 1987, Molinero in 1988, Beguin in 1989, Pizolate and Silva in 1997,

Barcelos in 2004, Tiexiera and Antunes in 2008. Location-allocation models added a further dimension in the development of the studies related to selecting public facilities locations. It benefitted from the application of advanced algorithms, amongst these studies are: Shamsul Arifin (2011), Naharudin (2014) and Menezesk and Pizzolato (2014).

On the other hand, other researchers follow a different direction relying on a study of accessibility measures to assess the efficiency of educational facilities, for example: a study of Gao et al. (2016) that dealt with an imbalance in access to primary and secondary schools in China, based on determining the shortest travel distance between the population and schools. A study of Bulti et al. (2019) which examined spatial distribution analysis and access to primary schools in Bishoftu; Ethiopia, the study concluded that more than 23.9% of the population are expected to travel twice the maximum standard distance and the study of Tang et al. (2017) on accessibility analysis for primary schools in China; Xiantao City, indicated that accessibility analysis is an important indicator for assessing the effectiveness of educational facilities.

Spatial decision-making support

Localization decision is a vital issue; upon which the continuity of facility, abandonment, or relocation depends. The localization decision becomes more difficult if some points are taken into consideration, some of which were mentioned by Sugumaran and Degroote (2010): (i) which software is the best in the decision-making support? (ii) Which spatial model is the best? (iii) How a user-friendly interface is being developed? (iv) How outputs are evaluated? (v) How to make sure of their authenticity? (vi) What are the suitable techniques? and (vii) To which extent resources are adequate?

The optimal location term is behaviorally difficult to define since a location can be suitable from a viewpoint and unsuitable from another viewpoint. Also, programmatically, the available mathematical algorithms do not guarantee this within Heuristic Solutions, the personal considerations make it more complex, lobbying groups, it's branching into sub-groups in solution style (Deterministic, Heuristic), problem type (Private, Public) and size (Small, Medium, Big). Lee and Hidgart (2014) added to the previous points; a different attitude of the decision-

maker to the problem nature and the style of its solution. Because of various scientific backgrounds, it may be considered a transportation problem or location-allocation problem.

Optimal locations attract the interest of various sciences: regional sciences, economics and operations research etc. So that, the matter is not related to geography only, but other sciences share the same interest. This add more variation and complication to this type of study. In the context of spatial optimization, within the literature on optimal locations, there are four techniques for solving facility location problems (Lee 1992): (i) Approximate solutions. (ii) Spatial suitability maps. (iii) Linear programming and (iv) Heuristic algorithms. The first and second techniques are used for small location problems. The third technique is used for complicated location problems. The fourth technique is marked by its simplicity and mathematical efficiency.

Optimization problems in geography are divided into two techniques: (i) location-allocation models and (ii) spatial suitability maps (Murray 2010; Xiao 2005). Both of them follows a different path: The first technique deals with it as a mathematical problem that passes through several stages to find suitable algorithms. The second technique selects a number of potential locations depending on predefined spatial criteria. Both techniques can't measure non-spatial factors like: demographic conditions for example (workers, characteristics and skills), political decisions and public opinion tendencies. Xiao (2005) states that the negligence of such techniques to influence the previous factors—it is difficult to formulate mathematically if not impossible—may make its solutions completely non-optimal. The first technique is difficult to use by non-specialists (Lindeskov 2002). Whereas, the second technique can't answer the number of required facilities. So that, the population can utilize the required facility within the standard criteria.

The differences between the two techniques are not contradictory. But, integrated. Both can be combined by selecting the most appropriate one of all the probable locations through location-allocation models which provide different algorithms by which the interaction between the model elements can be tested and different scenario outcomes can be evaluated. In its presentation. The study focused on location-allocation models, as it addresses the accessibility in an interactive context within mathematical models and various scenarios that fulfill the objectives of each facility in a timely and interactive manner.

Location-allocation models

Location-allocation models aim to locate the optimal location for each facility. Allocating a number of people for each facility, according to the inputs of each model. How to find a point (school) among three points (people) at which the least distance between it and such points can be achieved? That was the historical dilemma formulated by The French mathematician Fermat to The Italian physicist Torricelli (seventeenth century), through whom Weber in 1909 developed his views on industrial locations.

Hoover (1948) see that public facilities locations are being selected on the transportation network to facilitate population accessibility. Owen and Daskin (1998) state that the average time for an individual's journey is a significant measure to determine location effectiveness, especially in public facilities. Their relationship is inverse; the greater the average distance, the less efficient the facility. The fault of accessibility measures is that it allows the evaluation of facilities' performance, but it is not able to suggest the allocation or redistribution of such facilities (Acosta et al. 2015).

Location-allocation models may be useful in the localization of some public facilities such as: hospitals, schools and libraries. Highly efficient accessibility is the dominating element. But location-allocation models are not sufficient in locating nuclear power plants as there are other factors participating in their localization such as: cooling water, hydrological conditions, soil resistance, political decision, fuel and transportation costs (1993). Also, environmentalist have a growing powerful influence on government decisions for the neutralization of its attitudes concerning anti-environmental activities.

Optimal location problems and location-allocation models are varying accordingly. Each model is concerned to solve a particular problem. Each facility has a convenient model. Rushton (1979) Church and ReVelle (1974) see that solving optimization problems for public facilities locations are more complicated because of the overlapping of varied considerations, whereas the private facilities are less complicated because of the harmony of their goals

(cost reduction and profit maximization). The first looks for spatial justice and the second is concerned with spatial efficiency (Gustavo 2013).

Literature (Farahani et al. 2009) refers to three spatial space techniques in location-allocation models: (i) The continuous model: any point on the surface represents a potential location even is unsuitable. (ii) The discrete model: depends on a number of regular points and (iii) The network model: in which potential locations are connected with existing nodes in the transportation network.

GIS technology provides a good incubator for location-allocation models, avoiding users the necessity of understanding complicated mathematical algorithms. It provides a convenient environment for displaying data, analysis and modeling. So that, the matter turned from abstract numbers into an interactive display on the map. This provide a convenient framework for geographers to use these models in a spatial environment that simulating the real world away from the complications of such algorithms which some like Rahman and Smith (2000) see the difficulty of using them in developing countries because of their complexity.

Integration between the two systems does not prevent some shortcomings which were determined by Church and Sorensen (1994). (i) The difference in structural data composition which does not let GIS software to directly handle such algorithms, but through intermediate stages and (ii) Variation in the accuracy of the suggested location due to the difference in the aggregation level of demand points.

Location-allocation models in GIS are divided into seven main problems, those can be simplified into three subgroups: (i) P-Median problems. (ii) Coverage problems and (iii) Competition problems. Tong and Murray (2017) added a fourth group relating to Centre Problems, but it is not available in ArcGIS software. Esri technology depend on the network analyst extension for modeling optimal locations through several variables: Demand points, Facility points, Transportation Network, Cutoff distance etc.

According to Esri the network analyst extension handles location-allocation problems using Teiz and Part heuristic algorithm to identify the best available solutions. Church and Medrano (2018) see that the solutions provided by the previous algorithm

are often better if not optimal. Church (1999) points out that most of the coverage models are part of the P-Median problems. On determining the optimal distance, P-Median models turn into the maximize coverage model. The two models lie within the classification of Non-Deterministic Problems (NP-hard). So that, it is difficult -even impossible- to solve their problems optimally for reasons due to computer resources.

To interpret the findings of location-allocation models, it is necessary to understand their solutions nature: i) The first is exact solution algorithms in which all mathematically possible solutions are tested, these solutions are subject to the computational complexity- theory that is interested in measuring the time required to solve certain problems based on computer resources availability and ii) The second is heuristic solution algorithms -because of the infinite number of mathematical possibilities within Exact solution algorithms- don't guarantee the optimal solution, but gives better results. According to Esri to solve a small problem of selecting 10 optimal locations out of 100, the number of statistical possibilities to solve this problem is 17 trillion, according to Eq. (1):

$$\begin{pmatrix} 100 \\ 10 \end{pmatrix} = \frac{100!}{10! \times (100 - 10)!} = 17,310,309,456,440 \tag{1}$$

The study attempted to examined the strength of location-allocation models in modeling, analyzing the current geographical distribution of primary school locations in Mansura city and proposed new optimal locations for them. Consequently, some measures of accessibility (Total network lengths and Average distance) were used to assess the locations of these schools before and after the spatial modeling process. The study objectives are: (i) Modeling and analyzing current primary school locations. (ii) Proposed new optimal locations for primary schools and (iii) finding out whether or not the geographical redistribution of primary school locations has improved the efficiency of accessibility? As no such method has been addressed in studying the optimal locations for schools in egyptian geographical studies, it could be the start of such kind of studies in the future.

Methodology

Study area

The city of Mansura is located in Dakahleya governorate (Fig. 1), on the eastern bank of The Nile river (Damietta branch) away 124 km from Cairo, the capital of Egypt. The total area is 28.49 sq.km and consists of 12 residential districts, the average area of each district (2.37 km^2), the Standard Deviation (2.67 km^2) and Coefficient of Variation (117.75%). The biggest district is Sandoub (9.09 km^2) and the smallest is Siam district (0.15 km^2). The Population of the city is 543,581 (Central Agency for Public Mobilization and Statistics 2017), representing about 8.37% of the governorate's population and approximately 46.70% of the region's population. The average inhabitants of each district (45,298), the standard deviation (37,420) and Coefficient of Variation (86.28%). The Coefficient of Variation indicate a degree of consistency in population distribution against area of the districts.

Number of families in the city is (140,782). It has 18 slum areas inhabited by 2895 families (Ministry of Housing 2014), constituting a burden on the educational facilities, as it often not included in the national or local development plans. According to the CAPMAS (2017) the highest percentage of Mansura city population (19.08%) works in the services sector, while the lowest percentage (0.4%) works in water supply, sewerage and waste management and remediation activities.

Spatial data analysis process

This section presents the spatial statistic analysis process ("Appendix 1") that has been used to address the spatial variations of school locations and population concentration related to demand points in the city through ArcGIS toolset such as; analyzing Patterns,
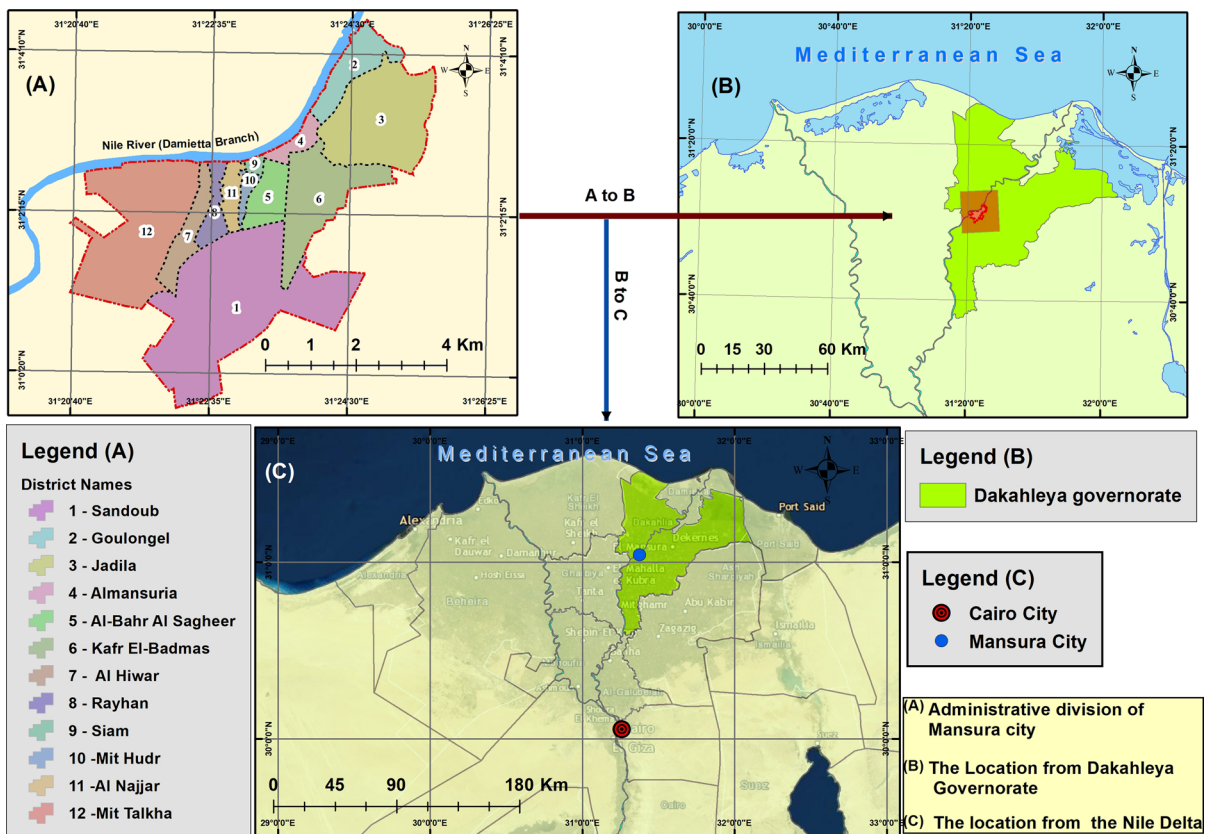

Fig. 1 The location of Mansura city

Mapping Clusters and Measuring Geographic Distributions as following:

- The average nearest neighbor (ANN) was used to measure the variance pattern of school locations and population density in the city from clustered to dispersed. Also, standard distance, directional distribution and hotspot analysis.
- The central feature of residential blocks was used to divide the city into five zones of 1000 m distance to determine the number of schools and population concentration in each zone.
- The city was divided into two groups by using GIS grouping analysis. And to point out the number of effective districts group "Kalinski & Harabasz" standard was used. Referring to Pseudo F-Statistic (Fig. 2) the ideal number of groups was 11. Such number is approximately the same number of residential districts. Hence, it is not suitable to be applied. The choice of the two groups is the best between the range of two up to five groups.
- Study variables were modeled by Ordinary Least Squares regression to interpret the change in the dependent variable (schools), using a number of independent variables: illiterate people, population, area of residential districts, street lengths,

buildings, land slop, employees in the sectors of services, commerce, agriculture, industry, transportation and hospitality.

Spatial data modeling process

The Minimize Impedance model (P-Median) was used to analyze the overall performance of schools' system in the city (38 Schools), the optimal coverage (Cutoff 750 m) was measured by the Maximize Coverage model, the issue of Minimum Facilities was addressed by the Minimize Facilities model. Competing models were excluded because of the similarity of educational variables in public primary schools and the absence of competitiveness. The study excluded the school capacity variable due to the incapability of providing the number of classes and students in each school.

The study dealt with its authentic objective through two Scenarios: (i) Scenario No. 1. Evaluating current school locations and (ii) Scenario No. 2. Analyzing proposed school locations and assess accessibility effectiveness after the process of schools' geographical redistribution. There was a comparison between statistical indicators of both scenarios through network total lengths and average distance to the educational
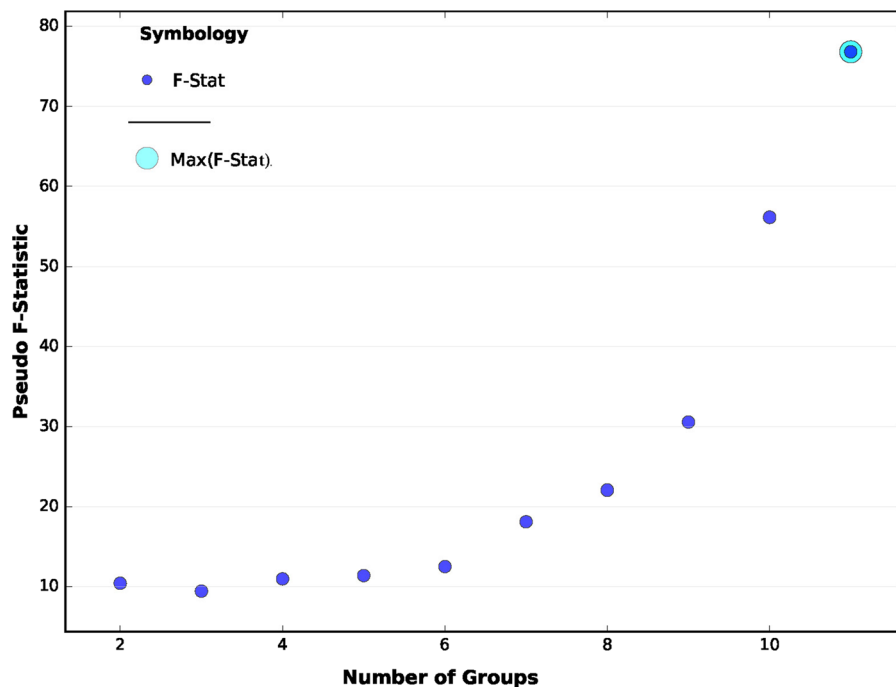

Fig. 2 Pseudo F-Statistic graphic

Table 1 The summary of study datasets

Dataset	Data source	Data type	Data purpose
Location map	Central agency for public mobilization and statistics	Esri shape file (Polygon layer)	Showing the administrative division of the city
School locations	The Egyptian general authority for educational buildings	Esri shape file (point layer)	Selecting the geographical location of primary schools
Residential blocks	Generated from arial imagery	Esri Shape file (polygon layer)	Defining residential areas in the city, through which the demand points layer was created
Demand points	Generated from residential blocks (centroid)	Esri shape file (point layer)	Was used as one of the parameters in the location-allocation models
Transportation network	Open street map (OSM)	Esri shape file (line layer)	For activating location- allocation models

facility. The spatial statistical analysis tools were used in modeling and analyzing school locations. Therefore, a geographical database (Esri File Geodatabase 10.6) was built, it included school locations, transportation network, city administrative boundary, demand points and residential blocks (Table 1).

The aggregation of demand points is important; the different levels of aggregation may result in varying accuracy of results. At first, it was planned to rely on the actual residential blocks (1223) as demand points (Fig. 3a), but that was ignored for two reasons; the first is a variation of the area of these blocks: mean (2.27 km^2) and a standard deviation (12.9 km^2), the second is the variation in the spatial density of demand

points, this resulted in its concentration in the northern parts of the city because of the small area of residential blocks, and their few numbers in other areas because of the big area of residential blocks. So that, the city was divided into a grid of equal cells (100 × 100 sqm), whose number amounted to 2999 cells, from which 1578 cells were excluded as they were not residential. 1421 cells were kept up (Fig. 3b) and were used for analyzing the current locations of schools as demand points and studying the suggested locations as schools and demand points at the same time, whereas using the actual residential blocks was limited to spatial statistical analysis. The study used discrete model (grid cells) and transportation network. The

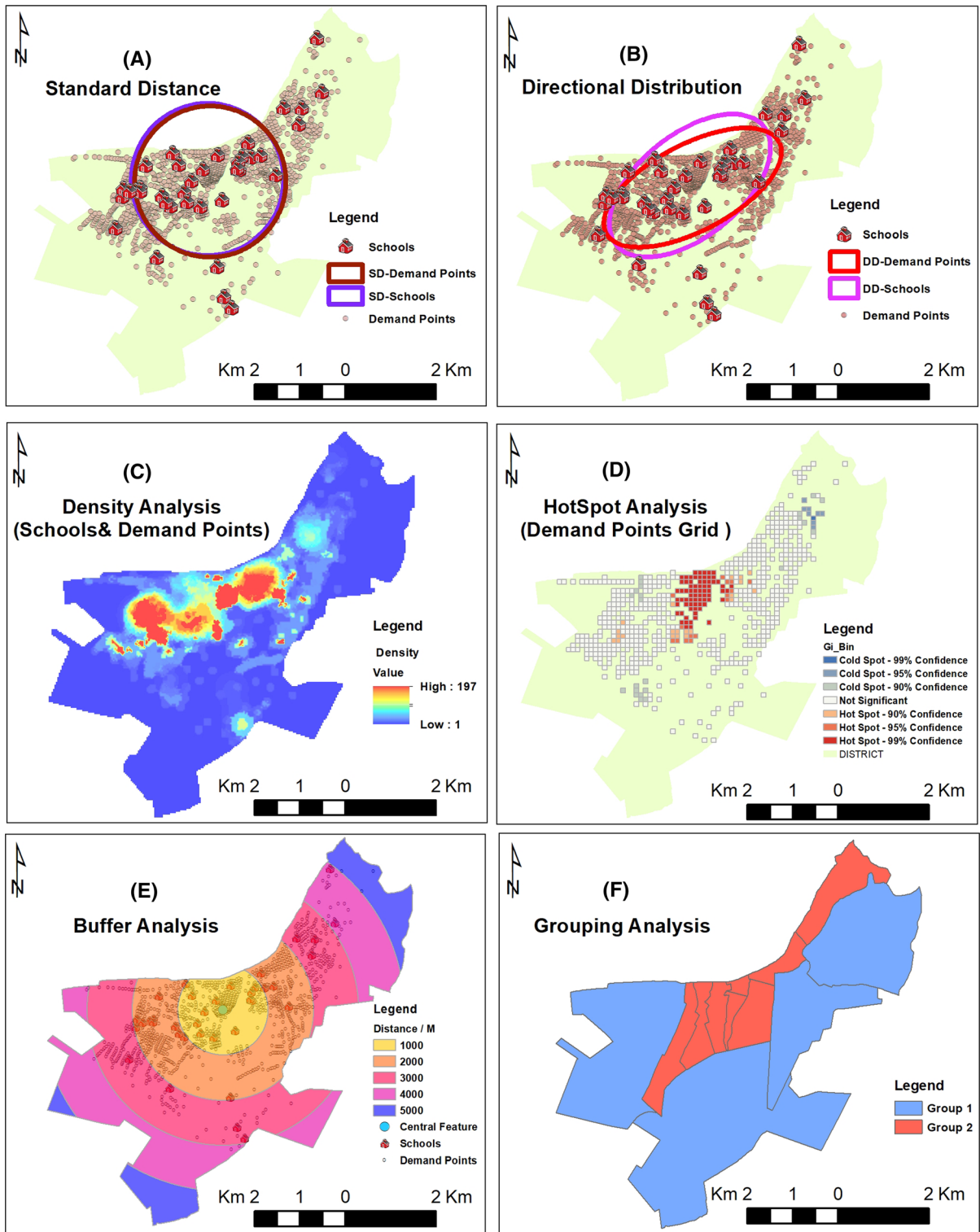**Fig. 3** The actual residential bocks and grid cells for Mansura city

(A)

(B)
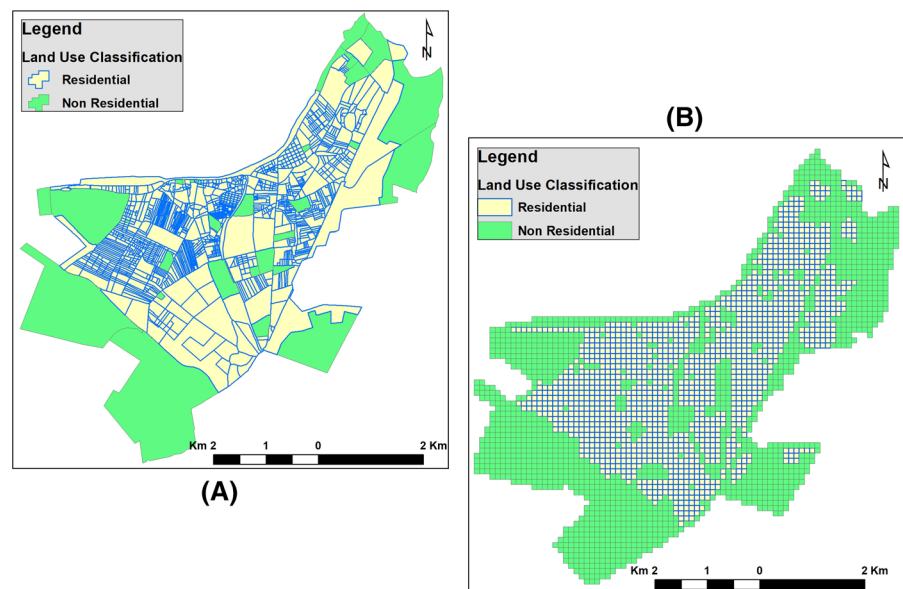
Fig. 4 Spatial analysis for primary schools' distribution in Mansura city

latter is considered more appropriate for educational facilities since student's reach schools through a transportation network whether the paved or non-paved roads. Unsuitable areas: water streams and agriculture lands were excluded.

Results and discussion

The average nearest neighbor in the primary schools is clustered (0.746, Z-Score: − 2.99, P value: 0.0027) and the residential blocks (0.731, Z-Score: − 17.93, P value: 0.000). 65.79% of schools concentrated in an area of 24.77%, 60.51% of the residential blocks in an area of 24.99% (Fig. 4a). The directional distribution was northern east (Fig. 4b). The spatial concentration for both were noticed in the city core (Fig. 4c). That cluster is considered a one of the characteristics of public facilities planning in developing countries, where planners are often used to overcome some obstacles that faces them during planning. This goes hand in hand with Rushton (1979) who stated that the weakness of the transportation network in the developing countries leads to a high degree of facility concentration. According to the hotspot analysis, such cluster was statistically proved for residential blocks (GiZScore 2.30:10.03, GiPValue 0.02: 0.00), (Fig. 4d). Statistically significant hotspot clusters for school locations were not pointed out.

- According to (Fig. 4e) the highest number of schools and residential blocks were 13 schools and 376 blocks for the first zone, and 16 schools and 540 blocks for the second zone respectively; this is because such areas represent the city core from beginning. Also, the static planning of the public facilities in the developing countries to be carried out in a specific period, ignoring the variables that may occurs in population locations; because of immigration factors or geographical redistribution process.
- Referring to (Figs. 4f and 5) the city was divided into two groups; group one: included four residential districts in the south of the city, all variables were greater than the mean. Group two: included eight residential districts in the rest of the city, all variables were smaller than the mean.
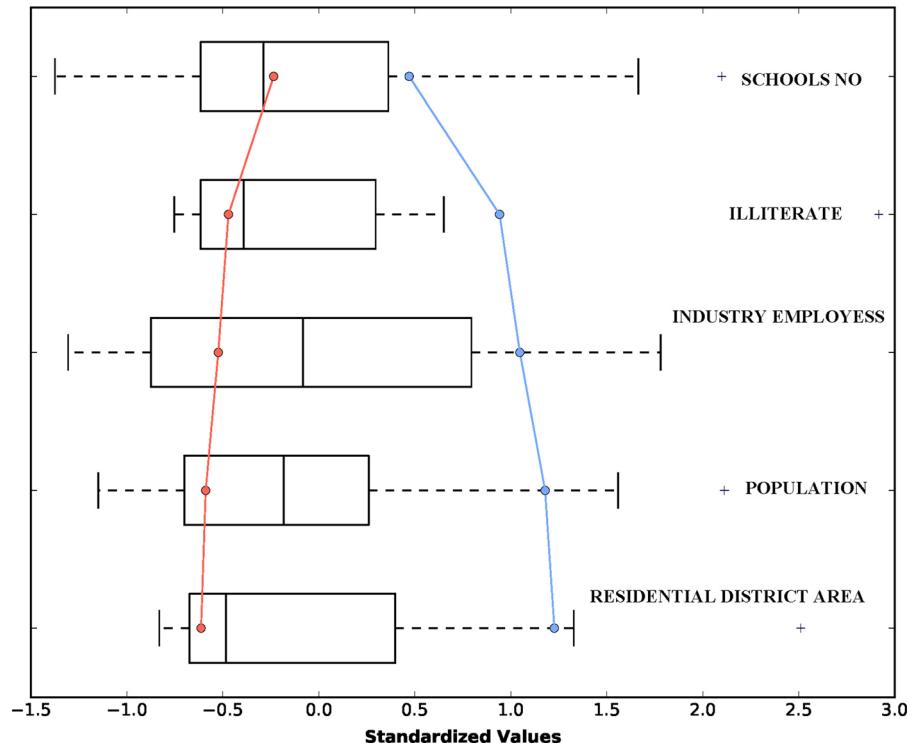

Fig. 5 Parallel box plot for study variables in Mansura city

- Only two models were passing by the Exploratory Regression analysis. The first included: illiterate people, employees in the industry sector, population, area of residential districts. The Adjusted R-squared value was 0.742, AIC indicator value was 67.99. The second included: employees in the sectors of industry and services, population, area of residential districts. The Adjusted R-squared value was 0.608, AIC indicator value was 66.19.

Fig. 7 The results of current and proposed location-allocation ▶ models for primary schools in Mansura city

- The Ordinary Least Squares model was applied to the first model data due to its significant statistical indicators. All findings of the model variables were statistically significant (99%), VIF values were less than 7.5. The model interpreted 74.24% of the variation in school numbers. The Residual values were measured. Such values should not be spatial

Table 2 Result of location-allocation models for primary schools in Mansura city

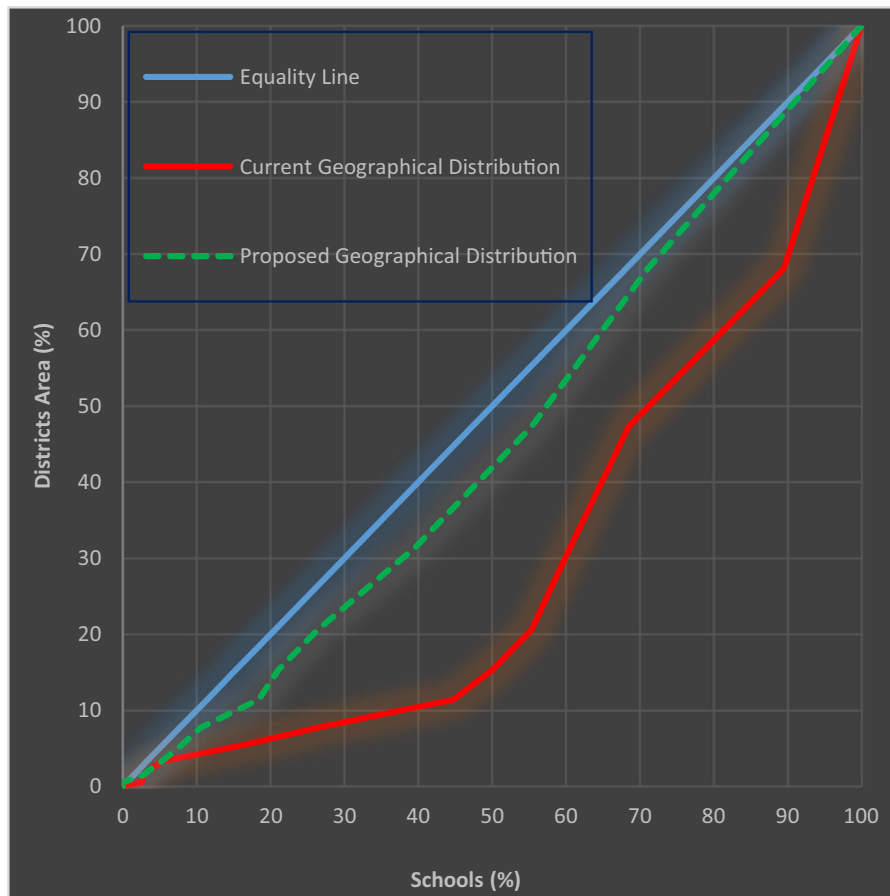| Model	Scenario No. 1			Scenario No. 2		
	No. Schools	Total network lengths/km	Average distance/m	No. Schools	Total network lengths/km	Average distance/m
Minimize Impedance	38	962.36	677.24	38	491.98	346.22
Maximize Coverage	38	383.66	406.85	38	506.29	356.29
Minimize Facilities	23	406.78	431.37	34	568.19	399.85

Fig. 6 Lorenz curve for primary schools and districts area in Mansura city
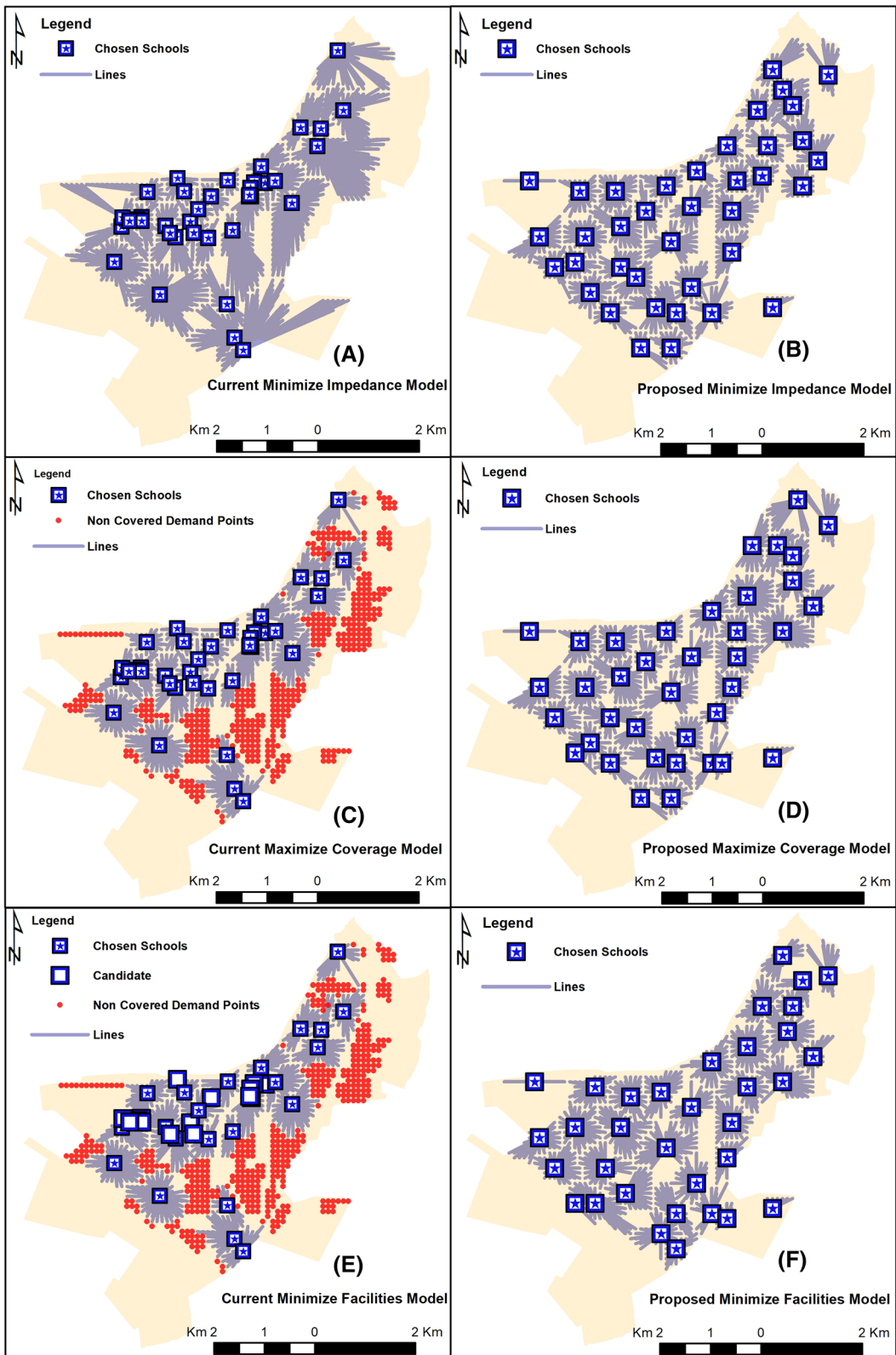
autocorrelation; this was confirmed by Moran's analysis.

The evaluation of the geographical redistribution of primary school locations in the city districts could be recognized by analyzing the proposed Minimize Impedance model where outputs (Table 2) showed an advantage compared to the other two models. The Lorenz curve analyzes the relationship between school numbers and the area of districts according to the outputs of the current and proposed model (Minimize Impedance). It is clear from (Fig. 6) there is a reduction in the area of asymmetry after the process of geographical redistribution of primary school locations compared to the current distribution. By measuring the Concentration Ratio of school locations, it was found that the Concentration Ratio decreased from 71.74% in the current geographical distribution to 19.77% in the proposed geographical distribution.

Referring to Table 2 and Fig. 7a–f, the performance of the city's transportation network system has improved after the geographical redistribution of school locations. Regarding Scenario. No 1 (Current Geographical Distribution). The Maximize Coverage model showed a preference compared to the other two models, as the total network lengths were 383.66 km,

mean was 406.85 m. But excluded 478 demand points beyond optimal coverage. Concerning Scenario. No 2 (Proposed Geographical Distribution). The Minimize Impedance model is the best as the total network lengths were 491.98 km, mean 346.22 m. Yet, it is not reliable since it treats its objectives with a holistic view -ignore the individual interest- as it disregards the optimal distance between the population -individual level- and the nearest facility.

- By analyzing the current geographical distribution of school locations (Table 3) and (Fig. 8) it is clear that three districts: Sandoub, Jadila and Kafr El-Badmas (54.96% of the demand points) in which the distance of arrival exceeds the optimal distance (814.38 m, 887.28 m and 813.57 m) respectively. These districts extend contiguously in the southern margins of the city; the reason for the low efficiency of accessibility in these districts is due to the large area (58.63%), high population of those districts (42.91%) and the small number of schools in (23.68%). While the rest of the city's districts (Nine districts) which occupy 45.04% of the demand points are within or near the optimal arrival distance, those districts extend in the northern part of the city (76.32% of schools).

Table 3 Accessibility indicators for primary schools in Mansura city districts

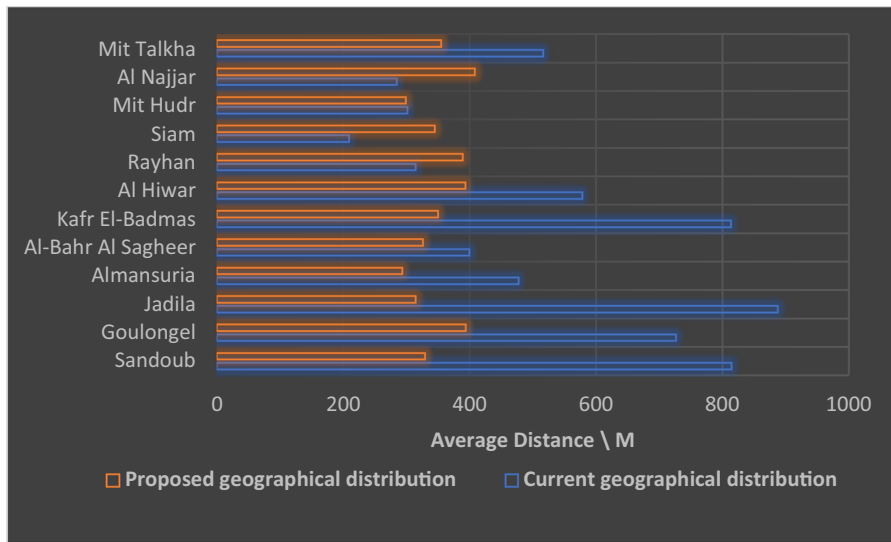| District No	District name	Minimize impedance model (current geographical distribution)					Minimize Impedance Model (Proposed geographical distribution)				
		Schools		Demand points		Average distance/m	Schools		Demand points		Average distance/m
		Count	%	Count	%		Count	%	Count	%	
1	Sandoub	4	10.53	355	24.98	814.38	11	28.95	355	24.98	329.31
2	Goulongel	2	5.26	80	5.63	726.63	2	5.26	80	5.63	393.76
3	Jadila	3	7.89	202	14.22	887.28	6	15.79	202	14.22	314.77
4	Almansuria	1	2.63	37	2.60	477.59	1	2.63	37	2.60	293.63
5	Al-Bahr Al Sagheer	7	18.42	71	5.00	399.49	3	7.89	71	5.00	325.97
6	Kafr El-Badmas	2	5.26	224	15.76	813.57	5	13.16	224	15.76	350.08
7	Al Hiwar	2	5.26	99	6.97	578.35	1	2.63	99	6.97	393.58
8	Rayhan	4	10.53	56	3.94	314.54	1	2.63	56	3.94	388.85
9	Siam	1	2.63	11	0.77	209.17	0	0.00	11	0.77	344.62
10	Mit Hudr	0	0.00	23	1.62	301.72	1	2.63	23	1.62	299.05
11	Al Najjar	4	10.53	53	3.73	284.63	1	2.63	53	3.73	408.14
12	Mit Talkha	8	21.05	210	14.78	516.26	6	15.79	210	14.78	354.86
Total	–	38	100	1421	100	–	38	100	1421	100	–

Fig. 8 Accessibility indicators of current and proposed location-allocation models for Mansura city districts

Minimize Impedance Model
Current geographical distribution

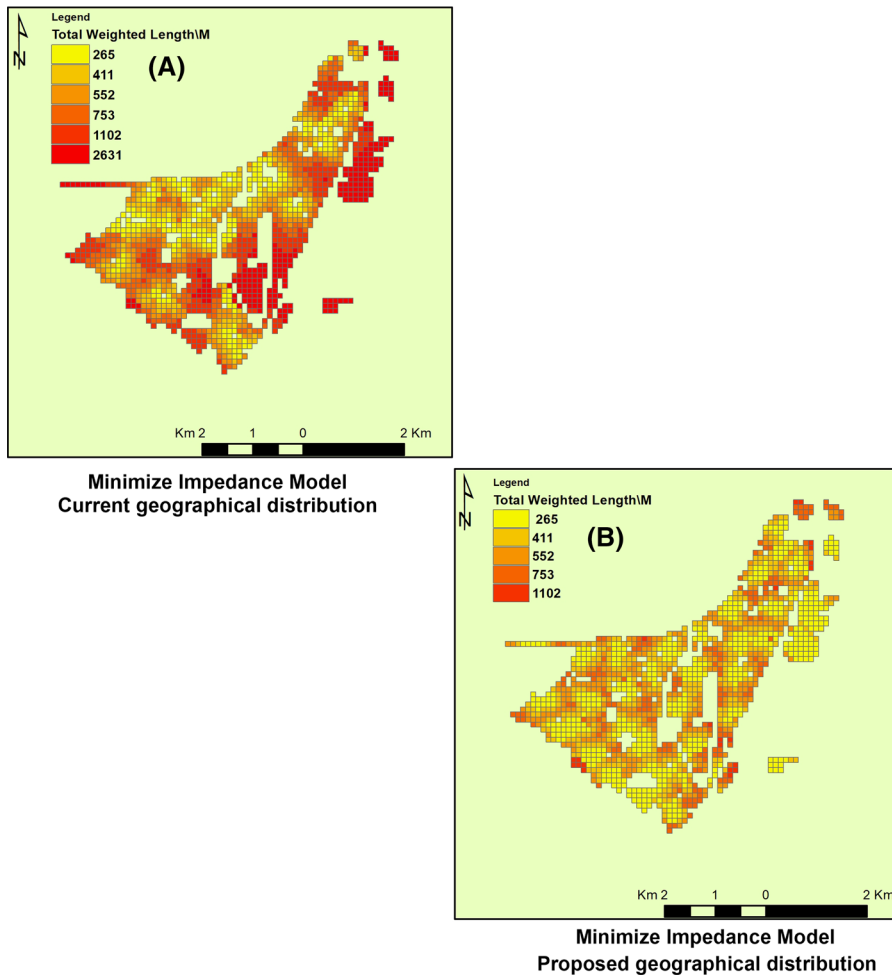**Minimize Impedance Model**
Proposed geographical distribution

Fig. 9 Grid accessibility index for primary Schools in Mansura city districts

- According to the proposed Minimize Impedance model (Table 3), some school locations were redistributed at the level of the city's districts, as some districts (four districts) witnessed an increment in number of schools over their current status, for example, Sandoub district from 4 to 11 schools, Jadila district from 3 to 6 schools, Kafr El-Badmas district from 2 to 5 schools, Mit Hudr district from 0 to 1 school, while other districts (Six districts) witnessed a decrease in number of schools, for example, Al-Bahr Al Sagheer district from 7 to 3 schools, Al Hiwar district from 2 schools to 1 school, Rayhan district from 4 to 1 school, Siam district one school removed, Al Najjar district from 4 to 1 school and Mit Talkha district from 8 to 6 schools, while Only two districts witnessed stability in the numbers of their schools (Goulongel, Almansuria).

- As a result of the geographical redistribution of school locations among the districts of the city, indicators of accessibility improved in the districts that were suffering from a high distance to school locations. As the average distance (Table 3) and (Fig. 8) of arrival in Sandoub district decreased from 814.38 m to 329.31 m, in Jadila district from 887.28 m to 314.77 m and in Kafr El-Badmas district from 813.57 m to 350.08 m.

- In general, all indicators of accessibility to primary schools in all districts of the city have been improved comparing to the current distribution (Fig. 9). Although there are some districts (Rayhan and Siam) that have increased their distance of accessibility from the current situation (slightly increased), but they are still within the optimal distance of arrival allowed by the concerned authorities.

Conclusion

Spatial decision making goes through several levels: National, Regional, and Positional. It's a mixture of many factors such as; Spatial, Economic, Political, Social and Environmental. Despite the care shown by the state when setting planning standards for educational facilities locations, those standards are often ignored and not used. It may be disregarded in favor of other factors. Education is an authentic right that all countries care about for their citizens, especially at the early stages. Yet, that right face many restrictions,

among them: Financing, Planning and Manpower, in addition to spatial restrictions related to the difficulty of reaching the educational facility. The issue of education in Egypt is addressed from several points: Social, Economic and Political. Recently, government reports indicating the negative effect of spatial factors in increasing school dropouts. Geographical studies in Egypt that dealt with that topic within the geography of education are still biased in a specific direction that addresses issues such as: the quality of educational, the number of classes, the density of students and the geographical distribution of schools. These studies ignored vital topics that greatly affect the education quality, perhaps the most important of them is the issue of optimal locations for schools and the role of this in achieving highly efficient accessibility for students to school locations. The study attempted to combine two important related subjects by studying the current primary school locations in Mansoura city, spatial modeling of the proposed optimal school locations and the impact of this on improving accessibility to school locations. The study objectives were analyzed through GIS environment: (i) Location-Allocation Models: Minimize Impedance, Maximize Coverage, Minimize Facilities and (ii) Statistical spatial analysis: average nearest neighbor, group analysis, standard distance, directional distribution, hotspot analysis, approximate analysis and Ordinary Least Squares regression. The study results showed that developing countries should adopt spatial decision support models during the localization process, showing its role in improving the selection of public facilities locations, especially with the spread of decision support models that have become more popular with the maturity of GIS software.

Study limitation

Because of the inability to obtain reliable data on land use in the city -as well as many other relevant layers— The model of spatial suitability maps were disregarded. As a result, the modeling and analysis of school locations emerged from the greenfield analysis hypothesis. It is one of the issues facing the GIS community in the field of facility location planning. Related to the concerned algorithms designed for solving the new facility location problems (Church 2002) The Researcher hopes to coordinate the two models as an adequate framework for upcoming studies.

Compliance with ethical standards

Conflict of interest The author declare that he has no conflict of interest.

Availability of data and material The data that support the findings of this study are available from the author upon reasonable request.

Human and animal rights The author did not involve human participants or animals.

Informed consent The author did not involve the collection of any personally identifying data, nor anything that could be construed as identifying an individual, hence informed consent was not relevant.

Appendix 1 The technical report for study analysis tools.

Analysis tool	Tool inputs	Tool outputs	Tool description
Standard distance	School locations (point layer) Residential blocks (point layer) Circle Size (1_STANDARD_DEVIATION—1 standard deviation)	For measuring the compactness of primary schools and residential blocks in Mansura city	Measuring the compactness of a distribution provides a single value representing the dispersion of features around the center. The value is a distance, so the compactness of a set of features can be represented on a map by drawing a circle with the radius equal to the standard distance value. The Standard Distance tool creates a circle polygon
Directional distribution	School locations (point layer) Residential blocks (point layer) Circle size (1_STANDARD_DEVIATION—1 standard deviation)	For measuring directional trends of primary schools and residential blocks in Mansura city	Creates standard deviational ellipses to summarize the spatial characteristics of geographic features: central tendency, dispersion, and directional trends
Optimized hot spot analysis	Residential blocks (point layer)	For creates a map of statistically significant hot and cold spots for primary schools and residential district in Mansura city	Given incident points or weighted features (points or polygons), creates a map of statistically significant hot and cold spots using the Getis-Ord Gi* statistic. It evaluates the characteristics of the input feature class to produce optimal results
Buffer analysis	The central feature of residential blocks Distance [value or field]: 1000 M	For creating multiple buffers for primary schools and residential blocks in Mansura city	The feature class containing the output buffers
Grouping analysis	Mansura layer (Polygon Layer) Number of groups (2) Analysis fields (Schools No., population, Illiterates, industry employees, residential district Area.) Spatial constraints (contiguity edges only)	For dividing Mansura city to groups (residential districts) based on feature attributes	Groups features based on feature attributes and optional spatial or temporal constraints. The output feature class created containing all features, the analysis fields specified, and a field indicating to which group each feature belongs
Location–allocation models/Problem type must be in this area			
Problem type	Facilities to choose (38 Schools)		It chooses facilities such that the total sum of weighted impedances

Analysis tool	Tool inputs	Tool outputs	Tool description
	Impedance cutoff (None). Belongs to minimize impedance	For determining the effectiveness of primary schools' network in Mansura city	(demand allocated to facility multiplied the impedance to the facility) is minimized
Minimize impedance	Impedance transformation (linear).		
	Impedance (length-meters)		
	Travel from (Demand to facility).		
	Output shape type (straight line)		
Maximize coverage	Facilities to choose (38 schools).	For determining the covered and non- covered facilitate demand points in Mansura city	It chooses facilities such that all or the greatest amount of demands is within a specified impedance cutoff
	Impedance cutoff (750 m).		
	Impedance transformation (linear).		
	Impedance (length-meters)		
	Travel from (demand to facility).		
	Output shape type (straight line)		
Minimize Facilities	Facilities to choose (None).	For determining the minimum facilities for primary schools in Mansura city	It chooses the minimum number of facilities needed to cover all or the greatest amount of demand within a specified impedance cutoff
	Impedance cutoff (750).		
	Impedance transformation (linear).		
	Impedance (length-meters)		
	Travel from (demand to facility).		
	Output shape type (straight line)		

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