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DEVELOPING NEW EDUCATIONAL FACILITIES IN CITIES OR LARGE MUNICIPALITIES USING GIS: A CASE STUDY IN THESSALONIKI, GREECE

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This study presents the modeling of the system of educational facilities included in a large city or a municipality, to facilitate a decision regarding the optimum location of a new educational facility. As will be shown, the allocation of a new school is a multidimensional one and for this reason, a particularly complex decision will have to be made, based on examining a large number of variables, relating both to the deficiencies in areas shown per each educational level, as well as the available land for erecting schools located within the urban area of study. The complexity of this decision necessarily leads to the modeling of the educational system and its management, using GIS. Specifically, the analysis data, which needs to be integrated into the GIS, is presented along with the process of analysis, interpretation and the conclusion drawing relating to the problems of the existing situation in conjunction with the methodology of finding those critical spatial entities, where the construction of a new, and of a particular level, educational installation, is more urgent. For the application of the methodology, the educational system of Thessaloniki, Greece, will be used as a case study.

Keywords: Planning, Education facilities, GIS, Model.

INTRODUCTION: EDUCATIONAL FACILITIES PLANNING AND THE USE OF GEOGRAPHICAL INFORMATION SYSTEMS

Urban planning has a complex relationship with Geographic Information Systems (GIS). The process of urban intervention has mainly two phases: a) the analysis phase, in which the existing urban space is recorded and interpreted and b) the proposal phase, in which the future features of the urban space are planned and designed. During the analysis phase, GIS are used by planners as a tool for mapping and analysis of urban space. During the proposal phase, GIS retain their role as a tool (e.g., for cartographic production), while they enhance it as decision support systems. In this case, the modeling of spatial information in GIS, namely the organization of thematic layers, the organization of attribute data that accompanies each thematic level and their cartographic presentation are not only issues related to the technique of GIS, but also results of a given urban planning logic. Moreover, the design of thematic layers and their cartographic presentation can guide, or even manipulate, political decisions.

This paper focuses on the planning of educational facilities, using as a case study the educational facilities in the municipality of Thessaloniki in Greece. Specifically, the interest relates to the modeling of the system of educational establishments, but, primarily, to the methodology, which is used to find the optimal location of a planned school. It is important to note that this application has taken into account the specificities of both the Greek education system and the Greek urban planning system, which may differ more or less in relation to those of other countries.

THE EDUCATIONAL SYSTEM AND THE PLANNING OF EDUCATIONAL FACILITIES IN GREECE

The educational system of Greece is divided into three tiers: primary, secondary and higher education. The first tier includes only the elementary schools, to which children aged 6 to 12 are admitted, while the second tier includes lower-secondary and upper-secondary schools, which accept children aged 12 to 15 and adolescents between 15 and 18 respectively. Attendance in elementary and lower-secondary schools is mandatory, as opposed to upper-secondary schools which is optional. Concerning the institutional status of the provider of educational services, in the 2007-8 school year, 94% of students enrolled in public schools, which offer free education (Eyrydice 2009: 1-2), while the rest 6% of the students enrolled in private schools. The operation of public schools in elementary and secondary education is the responsibility of each municipality in which these schools are located. This study is focused on the planning of new public educational facilities of these two tiers (elementary and secondary education).

Regarding the urban planning system, planning of public facilities in Greece is carried out through the establishment of *Structure Plans*. Structure Plans are made for each municipality separately and, inter alia, are responsible for the planning of elementary and secondary education facilities. This planning leads to the designation of certain land as sites on which erection of educational facilities is allowed. Each municipality is required to expropriate these lands, compensating financially the land owners, so as to bring the land into its possession and make it available for future construction of schools. Failing to pay the proposed compensation to the owners of the land, the latter have the right to sue for removal of expropriation, reclassification of the land as an area of education and restoring the previous land use status, which usually allows the construction of residential and commercial uses.

Because of the high price of urban land and the economic difficulties often faced by municipalities in Greece, the latter cannot expropriate all the land that the Structure Plan assignes for educational facilities construction, due to inability to pay the required compensation. As a consequence of the aforementioned inability, the municipalities expropriate these lands in stages, giving priority to those located in areas where the most significant weaknesses for an adequate supply of education services appear. Specifically, the municipalities plan only their next immediate action, when they can financially afford it and when it is required by the seriousness of the difficulties the educational system is facing. The success of such an approach to programming as an ongoing or, more correctly, as a fragmented procedure, relies on the early diagnosis of the most critical problems concerning the organization of educational facilities. Therefore, it is obvious that the modeling of the educational facilities system in GIS helps the municipality to monitor the current state of the education system and plays a key role in the process of taking action in the current Greek urban practice.

THE PROBLEM OF PROVIDING ADEQUATE EDUCATIONAL SERVICES

According to the Constitution of Greece, the provision of education is an obligation of the state to all citizens and is compulsory for at least nine years (Article 9, paragraph 1 and 3). Also, according to the *Code of Municipalities and Communities*, which defines the responsibilities of local government, the expropriation of land for the construction of schools, the construction of these schools, their operation and maintenance is decentralized from the central state and is, henceforth, responsibility of municipalities (GGG 114/08/06.2006, paragraph 1 and 15). As is clear from the above, educational facilities included in a municipality are required to meet all the educational needs of their citizens. This requirement means that schools must register and provide educational services to all students of the municipality who choose to attend them. However, for lack of a sufficient number and/or size of educational facilities to serve the educational needs of the citizens inevitably leads to one of the following two options.

The first option is the deterioration of the educational services offered, by registering a greater number of students from that which corresponds to the building capacity of each school. Such deterioration can be calculated by measuring the ratio between the build area of the school and the number of students attending them (this ratio is called *occupancy ratio*) and comparing this ratio with the corresponding planning standard. Such standards exist in almost every developed country[1] (in Greece are provided in GGG 285/D/5.3.2004). For example, if a primary school has a 1.000sq.m. built area and serves 200 students, this means that the occupancy ratio is 5sq.m. per student. This ratio is then compared to the corresponding standard, which for Greece is set to 6 sq.m. of built area per student. As it is understood, comparison of the current occupancy ratio to the planning standard suggests that this primary school does not provide adequate educational services and has more students than it should (or, otherwise, this particular number of students is housed in a building smaller than as it should be).

The second option is to operate the school in two shifts, so as half school population will attend school in the morning and the other half in the afternoon. Of course, the operation of schools in two shifts constitutes an indirect degradation of educational services, as schools should be operate only during the morning hours.

THE ANALYSIS OF EDUCATIONAL FACILITIES SYSTEM USING GIS

The analysis of the educational facilities must be done in a way that leads to the identification of this area of the town which provides the least satisfactory educational services. It is obvious that if this disadvantaged area is found, the municipality can intervene by planning a new educational facility there.

This analysis could be based on the calculation of the occupancy ratio for each educational facility. These occupancy ratio values could form the basis for the construction of a continuous surface, using kernel density estimation function, available in most GIS software. High values of this surface would indicate the areas that receive good educational services, in contrast to the low ones, which would indicate areas not adequately served by existing educational facilities. One such technique of spatial analysis has been presented by M. Thurstain-Goodwin and D. Unwin (2000) for the purposes of delimitation of urban centers. However, such an approach, based on occupancy ratios of schools, is not appropriate for the Greek reality as it conceals from the analysis the fact that some schools present high values in the occupancy ratio because they operate in two shifts. For this reason, it is proposed to identify the areas that enjoy unsatisfactory education services as the remaining areas of the town after the extraction of the areas which enjoy adequate education services. As it is clear, the interest is focused on the identification of areas that provide *adequate education services*, a subject which is probed deeper in the next section.

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[1]For England see: DfEE 1996, for Italy see: Secreto interministriale, 2 Aprile 1968, No 1444, for California see: SFPD 2000 and for Hong Kong see: Planning Department 2008.

METHODOLOGY FOR DETERMINING THE INTERVENTION AREAS TO CONSTRUCT NEW EDUCATIONAL FACILITIES

Educational services offered by a school depends on a number of parameters, only some of which need to be included in a strategic analysis of the educational facilities system. For example, the age of buildings, the arrangement of individual rooms, the dimensions of classrooms, equipment included in the latter, the condition of this equipment and its utilization in the educational process, all these are just some of the factors that undoubtedly affect the quality of the educational services. Nevertheless, these parameters are too detailed for the level of analysis of the present study and, therefore, will be not included.

In contrast, for the strategic analysis of the system of educational facilities, such as the one attempted in this study, only two parameters seem to be crucial. The first concerns the occupancy ratio and the second the school operation in shifts, whose importance to the quality of the educational services has already been commented on above. Based on these two parameters, it is possible to calculate the areas which provide adequate educational services, assuming that: a) the number of students served by the school is such that the occupancy ratio is equal to the proposed standard and b) each school operates on a single, morning shift. Based on the above assumptions and using the methodology below, the service area of a school (i.e., the area in which residents receive adequate educational services) can be determined. In this way, areas of the municipality not covered by the service area of the existing schools are the areas, in which the municipality needs to intervene by planning new school facilities.

Suppose a school with certain service area E. In this area the school provides adequate educational services. The build area of the school is a_x and it serves P students of the total population A of the area E. Population density d of the service area of the school is given by the relation:

$$d = A / E \qquad \text{(relation 1)}$$

Assuming that the service area tends to have circular shape with radius r, then the relation 1 can be written as follows:

$$d = A / \pi \cdot r^2 \quad \text{or else:} \quad A = d \cdot q \cdot r^2 \qquad \text{(relation 2)}$$

As this school provides satisfactory education services, it follows that the value of the occupancy ratio coincides with the standard set by law. Suppose the occupation ratio is O_x and is equal to the quotient of the built area of the school (a_x) for the (P) users it serves. That is:

$$O_x = a_x / P \qquad \text{(relation 3)}$$

Of the total population of the area served by the school, only a percentage u are the P students. This persentage (u) depends on the number of people who are age-wise eligible to register in the school and, obviously, this percentage varies among countries, but also among different regions of the same country. According to the most recent Census of Population (Hellenic Statistical Authority 2001), in 2001, ages 6 to 12 years accounted for 6%, ages 12 to 15 for 3.3% and those aged 15 to 18 for 3.8% of the total population. As it has already been noted, attendance at primary and secondary education is obligatory, which means that 6% and 3.3% of the total population of Greece is called to attend compulsory elementary and secondary schools respectively. However, attendance at upper-secondary schools is voluntary and only about 80%

of those in this age group enters them (see: GGG 285/D/05.03.2004). As a result, only 3% (3,8% x 80%) of the total population are upper-secondary school students. In conclusion, the value of *u* is equal to 6% for primary schools, 3.3% for secondary schools and 3% for upper-secondary schools.

Because *u* is the proportion of the population who are users of school facilities (students), then relation 3 can be written as follows:

$O_x = a_x / u \cdot A$ (relation 4)

The above relation 4, after replacement of the population with that of relation 2 becomes:

$O_x = a_x / u \cdot d \cdot q \cdot r^2$ meaning: (relation 5)

$r^2 = \dfrac{\alpha_x}{\pi \cdot \mathrm{u} \cdot \mathrm{d} \cdot \mathrm{O_x}}$ or, otherwise: $r = \sqrt{\dfrac{a_x}{\pi \cdot u \cdot \mathrm{d} \cdot \mathrm{O_x}}}$ (relation 6)

According to the above relation 6, the square of the radius of service area is proportional to the built area of the school and inversely proportional to the percentage of residents served by the school, the density of the region and the occupancy ratio.

For example, suppose that, in an area with a mixed density equal to 200 persons per hectare (*d* = 0,02 p./sq.m.), the service radius of a 1.000sq.m. primary school is being sought. From the age structure of this area (or, approximately, on the basis of the data of a wider area), the percentage of *u* who are ages 6 to 12 years and are potential users of elementary school can be calculated (suppose *u* = 6%). Also, the planning standards specify that 6sq.m. built area of school per student (O_x = 6sq.m./st.) is required in order to provide adequate educational services. Thus, based on these figures and applying relation 6, it follows that the service radius of this elementary school is 210 meters. This means that the spesific school can provide adequate educational services only within a radius of 210 meters.

Same calculations are repeated for all the schools of each educational level, i.e. separately for elementary, secondary and upper-secondary schools. Once the above process is completed and, also, is completed the drawing of separate maps, which present the areas of satisfactorily services, for each tier of education, it soon becomes apparent the areas of underservicing areas, which is a key aim of the analysis. The demarcation of areas not adequately served by existing educational facilities causes the investigator to choose the area considered to be the worst in terms of providing educational services, and hence, the one where it is more necessary to build a new school.

Before dealing with the above, it is necessary to know the capabilities of a municipality regarding the planning of one or more educational facilities. The first case occurs when a municipality has the finances to build an educational facility for each separate tier of education. In this case, the investigation turns to search for the worst area, in terms of providing educational services, *separately for each educational tier*. The comparison between the different areas which have been demarcated is based on the comparison of the population living in them. Thus, an area A is deemed most suitable for locating a new educational facility in relation to an area B, if the population living in area A is larger than that of region B.

The second case, which is slightly more complex than the first, occurs when a municipality has the option to build only one new educational facility for only one educational tier. Therefore, what is needed is, on the one hand, to determine the tier to which the new educational facility will belong, while, on the other hand, its location. This case does not differ significantly from the former, as the comparison between the areas which do not provide adequate educational services is based on *the number of potential users* rather than the population size. For example, suppose two areas have been identified: area A, with a population of 2,000 inhabitants, which does not provide adequate educational services at the level of primary school and area B, with a population of 3,000 residents, which does not provide adequate education services at the level of upper-secondary school. Between the above two areas, it is imperative to construct an elementary school in region A, instead of an upper-secondary school in region B, although the latter contains a larger population. This is because in region A the potential users of elementary school students amount to 120 (u = 6%), in contrast to B, which contains only 90 potential students (u = 3%).

THE APPLICATION OF THE METHODOLOGY TO THE MUNICIPALITY OF THESSALONIKI

To implement the above methodology, two municipal districts of the municipality of Thessaloniki in Greece were selected as the study area, in which a total of 225,000 residents, 36 primary schools, 19 secondary schools and 15 upper-secondary schools are included. The study will be limited to the first two types of educational establishments, for research economy.

For the purposes of the application, the ArcGIS software of ESRI was used. The study area consists of 1,656 street blocks. Each block was classified according to its population density in one of the following five classes: from 0 to 10, from 11 to 268, from 268 to 445, from 446 to 600 and finally, more than 601 inhabitants per hectare. Next, the location of the schools was marked, as point data in a separate thematic layer, while in the attribute data of the latter, the built area of each school was introduced. Afterwards, the average population density of the street blocks surrounding each school within a radius of 300 meters was calculated and, using relation 6, the service radius of each school was also calculated. The values of the parameters used in relation 6 are for primary schools: u=6,0% and O_x=6sq.m. per student, while for secondary schools: u=3,3% and O_x=5 sq.m. per student. Finally, by implementing the buffering capability provided by the ESRI software, the service area of each school was identified. The final result is presented in the following Figures 1 and 2, which depict, separately for elementary and secondary schools, the areas that provide adequate education services.

In these maps, is now possible to define areas *not providing adequate educational services*. It is obvious that the demarcation focuses only on the largest of these, as the latter are the potential sites for planning new school facilities. This process is completed visually. For example, in Figure 1, the areas E1, E2, E3 and E4 are delineated. The latter two, although they are continuous, their shape requires separate demarcation, as its is impossible for only one school to serve the whole of this continuous area. In Figure 2, the identification of areas of unsatisfactory provision of educational services shows no such assumptions and leads to the identification of areas S1, S2, S3 and S4.

As shown in Table 1, area E3 contains the largest population and is, therefore, the most appropriate location for a new primary school. Also worthy of comment is region E4, which, despite having more than twice the surface of area E3, is inhabited by a much smaller population than the latter. Similarly, the area that is most suitable for the construction of a new lower-secondary school is site S3, which is the largest, both in population as well as spatially. In case the construction of a single educational facility is decided, irrespective of educational level, the E3 region has precedence over region S3, although the latter includes a greater number of residents. This is because the number of potential primary school students is 6% of the total population of the region, in contrast to the number of potential secondary school students who are 3.3% of the total population. As shown in the fourth column of Table 1, the number of students in region E3 is 783 users, which predominates that of 511 in region S3.

Table 1: It shows the areas of unsatisfactory provision of educational services, the population, the number of potential students and their area.

	REGION	POPULATION	STUDENTS*	AREA (ha)
ELEMENTARY EDUCATION	E1	5,792	348	34.9
	E2	9,092	546	33.6
	E3	13,047	783	31.6
	E4	4,522	271	88.8
LOWER SECONDARY EDUCATION	S1	5,607	185	50.7
	S2	12,124	400	44.4
	S3	15,485	511	55.0
	S4	11,683	386	30.9

* The number of students is 6% and 3.3% of the total population of the area for primary schools and lower-secondary schools respectively.

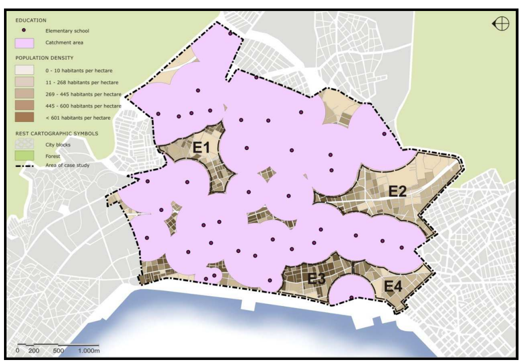

Figure 1: Here shown is the study area which is part of the municipality of Thessaloniki, the location of primary schools and the areas providing adequate educational services.

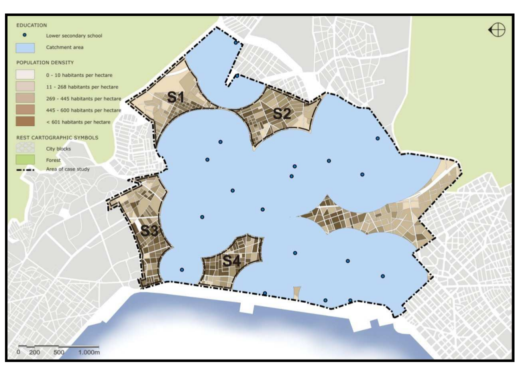

Figure 2: Here shown is the study area which is part of the municipality of Thessaloniki, the location of secondary schools and the areas providing adequate educational services.

CONCLUSIONS

The methodology of finding the most suitable location for the construction of a new educational facility fills an important gap in related literature, which focuses on the formulation of appropriate sizes which different types of educational facilities should have, but leaves in limbo the question of their location. Indeed, as it was noted at the outset, planning new schools in already built up areas is a complex issue, with planning and policy implications. The problem of determining the most appropriate location for the construction of a new educational facility is found frequently in urban practice and is usually treated empirically. In the context of the current operational planning practice on the planning of educational facilities, the methodology presented is an important step towards formulating documented planning proposals. Other significant advantage of this methodology is its accurancy, as well as its siplicity, which makes the application of the methodology accessible to most urban planners.

However, this method is not devoid of weaknesses, which should be highlighted, first of all, in order to achieve a timely preparation for dealing with them by each planner who applies it and, secondly, to be investigated for further development of the method. The first two weaknesses which, only very strictly can be regarded as such, concern the mandatory use of GIS tools for the application of the method and the availability of statistics on population per street block. Of course, we need to emphasize that the constantly expanding use of GIS and the availability of detailed spatial data in digital form seem to be the rule rather than the exception. On the basis of the above, it becomes clear that the application of the aforementioned methodology is feasible to almost all cities and by all planners.

Concerning a third weakness of the method, we should note that the demarcation of areas not adequately served by education services involves some empirical assumptions regarding their shape, which, although in the application presented, their influence was not significant, it cannot be ruled out that in another application they may not play a crucial role. Finally, as shown in the application of the method, the service areas of schools overlay each other. If this overlay could be eliminated, it would lead to the overall larger service area identification. However, this overlay does not affect the final decision on the location of new educational facilities.

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