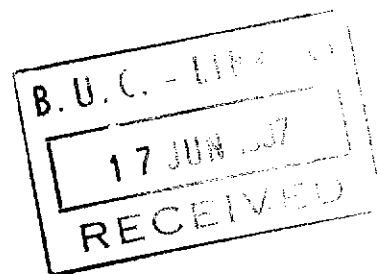


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# Public Schools Regrouping Decision Support System



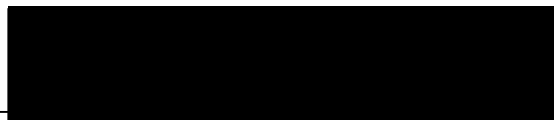
By

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**Project**

Submitted in partial fulfillment of the requirements for the degree of  
**Master of Science in Computer Science**  
at the Lebanese American University  
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## Abstract

The Public Schools Regrouping project is a project initiated by the Ministry of Education. It involves managing and planning (such as regrouping) of schools distribution in Lebanon with the aim of satisfying educational, economical and national criteria. In this work, we have developed a software tool referred to as the Schools Regrouping Decision Support System (SRDSS), that consists of four components: (a) Schools database that contains information about students, teachers, and schools, (b) Towns Database that contains information about the town's population and geographical location, (c) Schools Regrouping Algorithm, and (d) Geographical Information System that help in visualizing data and the algorithm's results.

The original contributions of this work are: (a) the formulation of the schools regrouping problem as a weighted graph problem, and (b) the application of the  $p$ -centers schools regrouping algorithm to determine how the current schools, in a user-defined region, can be regrouped to a smaller user-defined number,  $p$ , of schools such that user-defined criteria are satisfied.

The experimental application of the algorithm to the Aley Caza shows the flexibility of the algorithm in supporting regrouping decisions and gives good results that are clearly consistent with the stated criteria.

## **Acknowledgments**

I would like to start by a very special thank you to Dr. Nashat Mansour, my advisor, for all the assistance, constructive comments, and encouragement he provided me. He helped me in every aspect that made my project come to a success.

I am very grateful to Dr. Issam Moghrabi, the second reader. I also thank Khatib and Alami for their support. I thank the Ministry of Education, especially Ms. Najwa Fuliehan. I also thank Mr. Mohammed Oueidat for his assistance in the preparation of my defense presentation. Last and not least, a very big thanks to the data entry group, particularly Mr. Raed Azzam.

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## **Chapter 1**

### **Introduction**

---

In 1975, the Ministry of Education initiated the Public Schools Regrouping Project (SRP) [Ministry of Education 1983]. The goals of this project were:

1. Enhance the level of education available for the Lebanese students which was deteriorating due to the increase in number of public schools.
2. Enhance the distribution of schools so that the number of students with respect to the number of instructors increases.
3. Reduce the amount of money spent on school buildings rental
4. Increase occupancy in the public schools with competitive tuition fees
5. Compete with private and semi-private schools
6. Study the class timing to ensure better student coverage (AM shift - PM shift)

In 1995, CDR performed a manual study aiming at delivering a new public schools distribution plan satisfying the SRP objectives. These objectives are satisfied by grouping small schools (low number of students); thus, leading to enhancement of the number of students per school, an increase in training sessions, a reduction in the number of instructors, and finally building new, and healthier schools to cover all the levels of education.

As years are passing, the CDR study is losing its value due to a lot of changes occurred and consequently, criteria upon which the regrouping was based is no longer satisfying its intended objectives.

In this work, we are going to present a developed tool referred to as Public Schools Regrouping Decision Support System(SRDSS). The objective of this tool is to provide the Ministry of Education with a flexible planning utility. This utility consists of:

1. A database of the available schools with their associated parameter information. Thus, when a new school is added or deleted, it can be traced through the database (name, place, type, number of students, and number of instructors)
2. A towns database to manipulate the parameters related to towns, in addition to distances between consecutive towns.
3. A reporting module to produce statistics and reports about the towns and schools database. This module is part of both databases.
4. A Public Schools Regrouping(SR) algorithm. This algorithm is based on a graph problem formulation and a number of realistic parameters.
5. A geographical information system to visualize the information about the schools and their geographical location. In addition, the GIS gives the users the ability to query the geographical data and plot the corresponding produced maps.

This organization of the SRDSS enables the decision makers and planners at the Ministry of Education to take a decision for regrouping a set of schools in a user-defined casa or region and under user-defined criteria; thus, overcoming the limitation of the CDR manual study.

Experimental work shows good results and that although the application of the SDRSS is restricted to Mount Lebanon district and casa Aley, the components of this system are applicable to any other Lebanese area.

The rest of this project report is organized as follows. Chapter 2 defines the project objectives. Chapter 3 describes the organization of SRDSS. Chapter 4

describes the public school database in details, in addition to database design. Chapter 5 describes the towns database. Chapter 6 presents the public schools regrouping problem formulation and algorithm. Chapter 7 discusses the GIS design and implementaion. Chapter 8 states the experimental results. Finally, conclusion and remarks are presented in Chapter 9.



---

## **Chapter 2**

### **Project Objectives**

---

The objective of the Public Schools Regrouping Decision Support System (SRDSS) is to provide a flexible software tool to automate, monitor, and plan the public schools regrouping process. This tool is composed of two parts:

Part 1. Public schools and Towns databases containing all needed data about schools, geography, human resources available in the schools, etc. ...

Part 2. Regrouping algorithm that regroup schools once given necessary schools data and parameters.

#### **2.1. Public Schools and Towns databases**

The objectives for the public schools and towns databases are:

- Provide the Ministry of Education a flexible platform to manipulate the data affecting the schools regrouping process
- Associate with every school a set of parameters whose values are defined by the Ministry of Education administrators
- Determine whether a town should contain a school or rely on schools in nearby towns based on a mathematically generated factor(weight)

- Create statistical reports about the current distribution of schools, students, and instructors. This gives the administrators at the Ministry of Education the ability to evaluate and foresee future trends.
- Favor multi-sectarian schools
- Favor well-equipped schools

The reports that might be generated from the public schools database are:

- Schools with no contracted instructors (أساتذة متعاقدين)
- Schools with contracted instructors (أساتذة متعاقدين)
- French vs. English schools distribution
- Ratios of contracted vs. non-contracted Instructors.
- Ratio of instructors to students:
- French vs. English Schools
- Secondary vs. Intermediate Schools
- Ratio of population to students (Secondary, Intermediate, and Elementary): Pie chart, and report
- Ratio of students in Private-free schools (الخاص المجاني) to Public schools students
- Finding locations for possible new schools

## **2.2. Public Schools Regrouping**

The objectives of the automated public schools regrouping algorithm are defined as follows:

- Optimize the number of public schools that are rented
- Optimize the number of public schools near towns with a large number of population
- Optimize the number of instructors in public schools where the ratio of instructors to students is deemed illogical

The regrouping algorithm takes into account the following factors:

- Population
- School distance to main road
- Instructors to students ratio in a school
- Building condition of a school
- Building legal status of a school building
- Sectarian distribution in a school

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## **Chapter 3**

### **SRDSS Organization**

---

The Public Schools Regrouping Decision Support System is organized in four subsystems. These subsystems are:

Subsystem 1. Public Schools Database

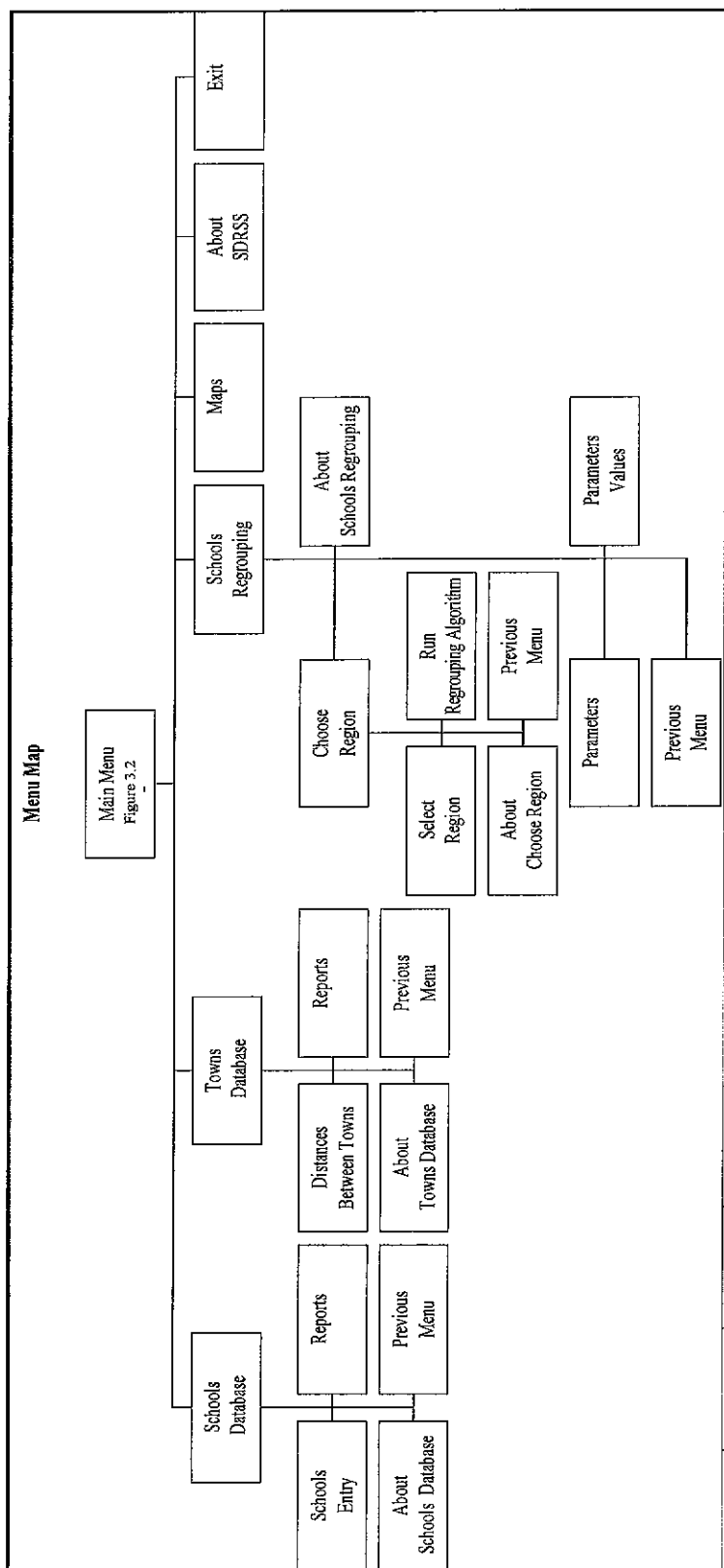
Subsystem 2. Towns Database

Subsystem 3. Schools Regrouping

Subsystem 4. Geographical Information System

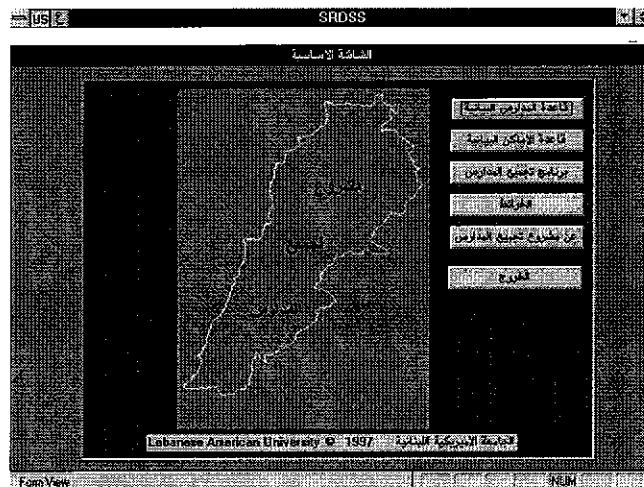
#### **3.1. SRDSS General Organization**

Each of these subsystems has several functions available for its users. The general organization of these subsystems and their respective functions is shown in Figure 3.1. A user of the SRDSS can access all of these subsystems and consequently their functions from the Main Menu which is shown as the root of the SRDSS organization chart. Each horizontal level in the SRDSS organization chart constitutes a new level of functions that can be reached from the level above it.



**Figure 3.1. SRDSS General Organization Chart**

Each entity in the chart of Figure 3.1, is translated to a button on the actual screens of the system. For example, the Main Menu entity has five entities under it each of which is represented as a button in Figure 3.2.



**Figure 3.2.** SRDSS Main Menu

Consequently, as one of the buttons in the Main Menu screen of the SRDSS is pressed the next level of functions available under the function representing the pressed button are made available to the user.

This logical grouping of related functions limits the number of choices the user has to do at a time and thus, helps him concentrate on specific functions he wants to perform.

In the next four chapters, we are going to discuss each of the four subsystems in details.

### **3.2. SRDSS Workflow**

The normal scenario of the workflow in the SRDSS is divided into seven stages (See Figure 3.3):

Stage 1. Gather schools and maps data sheets available in manual files (such as documents or maps)

Stage 2. End users enter data available in the gathered data sheets into the schools and towns database

Stage 3. Choose the region in which the schools regrouping has to be performed

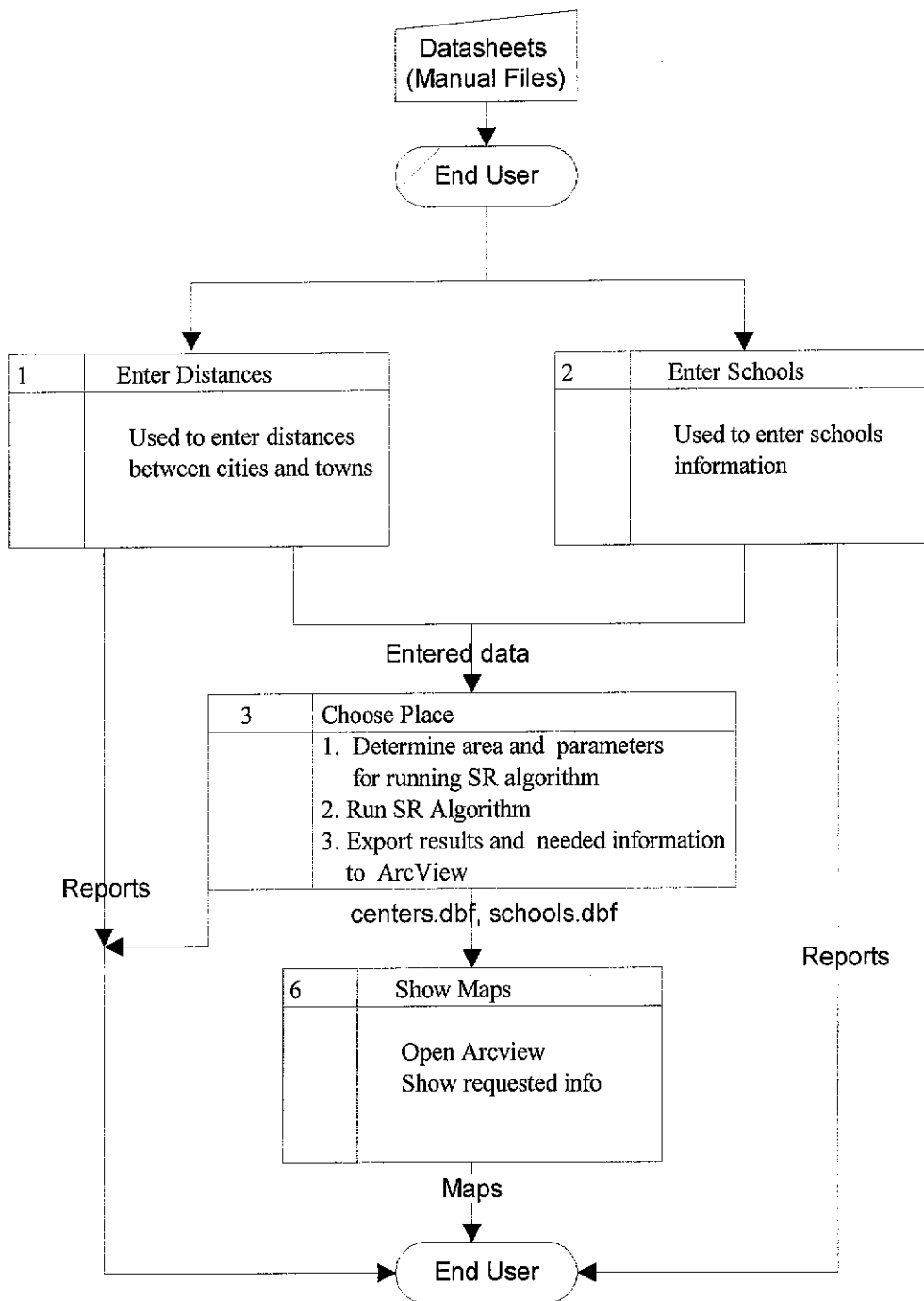
Stage 4. Determine the towns weight determinants

Stage 5. Run the Schools Regrouping (SR) algorithm

Stage 6. View the results in the GIS

Stage 7. Generate statistical and listing reports

The results of the seven stages is provided to the user for decision making or predicting future trends.



**Figure 3.3. SRDSS Workflow**



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## **Chapter 4**

### **Schools Database Design and Implementation**

---

The Public Schools Database is a relational database management system. It has predefined data structures and relationships. The data structures are designed to store entered data and relationships for ensuring and enforcing proper relationship between them. In addition, the Public Schools Database management system has a graphical user interface allowing user friendly interaction.

#### **4.1. Schools Database**

The information about schools is kept in four tables and handled through one screen. The four tables are structured in such a way to logically group related data. For example, the information about students in a school are placed in one table, information about instructors is placed in another table, and so on.

## 4.2. Schools Database Design

As mentioned in Section 4.1., the schools database is composed of four permanent tables with One-to-One relationships. These relations are in 3NF[1]. The schemes of these relationships are divided as such in order to facilitate querying and optimize data access time. The Entity Relationship diagram of the schools database is represented in Figure 4.1.

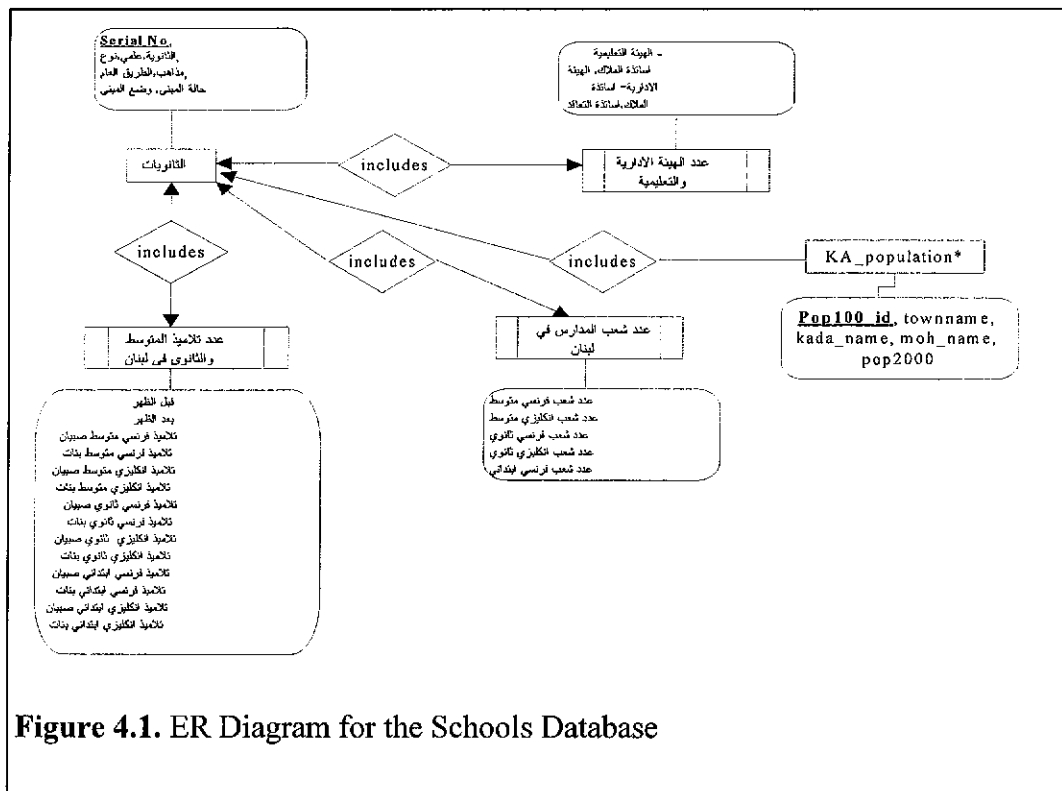
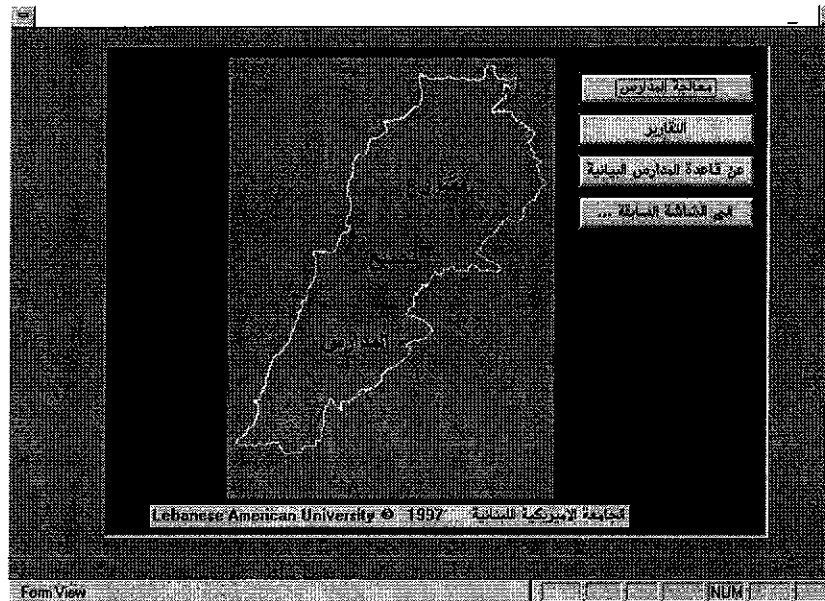


Figure 4.1. ER Diagram for the Schools Database

The charts describing the schools data processing are included in Appendix A.

## 4.3. Schools Database Manipulation Screens

The data manipulation of schools is handled through one screen while the reporting is handled through another. See Figures 4. 2, 4. 3 and 4.4.



**Figure 4.2.** Main Menu For Schools Database

Figure 4.2 shows the Schools Database main menu that allows its users to do one of the following four functions:

- (a) Manipulate schools data (See Figure 4.3): this function allows its users to add, update or delete information about a school

ملف تحرير

## شاشة المعلومات الأساسية عن المدارس الرسمية

☐ دوام ب.ظ. ☒ دوام ق.ظ. تاريخ: 05/05/06

المدينة:

حالة المبنى:

لغة التدريس:

البنات				البنين			
الابتدائي	متوسط	الثانوي	الثانوي	الابتدائي	متوسط	الثانوي	الثانوي
0	0	0	0	0	0	9	14
0	0	0	0	0	0	14	18

البنات			البنين		
الابتدائي	متوسط	الثانوي	الابتدائي	متوسط	الثانوي
0	0	0	2	3	0

اساتذة التعاقد: 13

الهيئة التدريسية - اساتذة المواد: 0

Record 1 of 19

Form View

**Figure 4.3.** Schools Data Manipulation Screen

- (b) Generate reports about the schools data (See Figure 4.4): this function gives its users the facility to view data available about schools in the form of statistical reports(pie, or bar charts) or as listings

التقارير

المدارس والاساتذة المتعاقدون

المدارس ونسبة الاساتذة للتلاميذ

رؤية تيار المتابعة

طباعة

إغلاق

**Figure 4.4.** Schools Report Menu

- (c) Know more about the Schools Database

(d) Return to the SRDSS Main Menu screen discussed in Section 3.1. This function allows its users to go one level up the SRDSS chart.

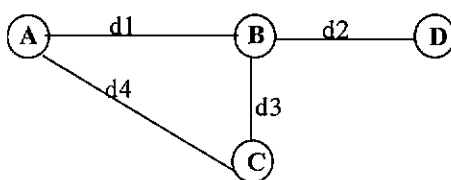
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## Chapter 5

### Towns Database Design and Implementation

---

This database is used to process information about distances between towns. The measured distances are between one town and all the adjacent towns. For example, distances between town A and B and town A and C, in Figure 5.1, are measured; however, distance between town A and D is not measured but calculated by summing up the intermediate distances. (See Figure 5.1)



**Figure 5.1.** A,B,C and D are town whereas d1, d2, d3 and d4 are distances

Based on the graph in Figure 5.1, the following distances should be entered:

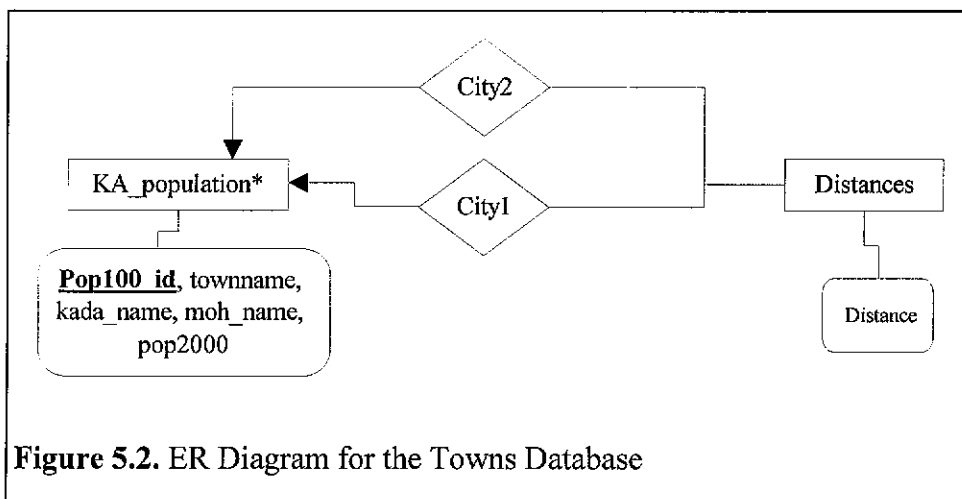
Towns and Distances		
A	B	d1
A	C	d4
B	C	d3
B	D	d2

**Table 5.1.** Distances that should be entered

The information currently available in the database is entered manually after calculating the distances from a road map of Lebanon [Geoprojects; 1993]. This information is utilized in the SR algorithm which will be discussed in Chapter 5.

## 5.1. Towns Database Design

The towns database is composed of one permanent tables related to the geographical data about towns through two One-to-Many relationships. The schemes representing these relations are in BCNF[Korth, 1991]. The Entity Relationship diagram of the Towns database is represented in Figure 5-2.



The charts describing the distances data processing are included in Appendix B.

## 5.2. Towns Database Manipulation Screens

The data manipulation of distances between adjacent towns is handled through one screen while the reporting is handled through another. See Figures 5.3, 5.4, and 5.5.

Figure 5.2 shows the Towns Database main menu that allows its users to do one of the following four functions:

- (a) Manipulate schools data (See Figure 5.3): this function allows its users to add, update or delete information about a distances between towns.

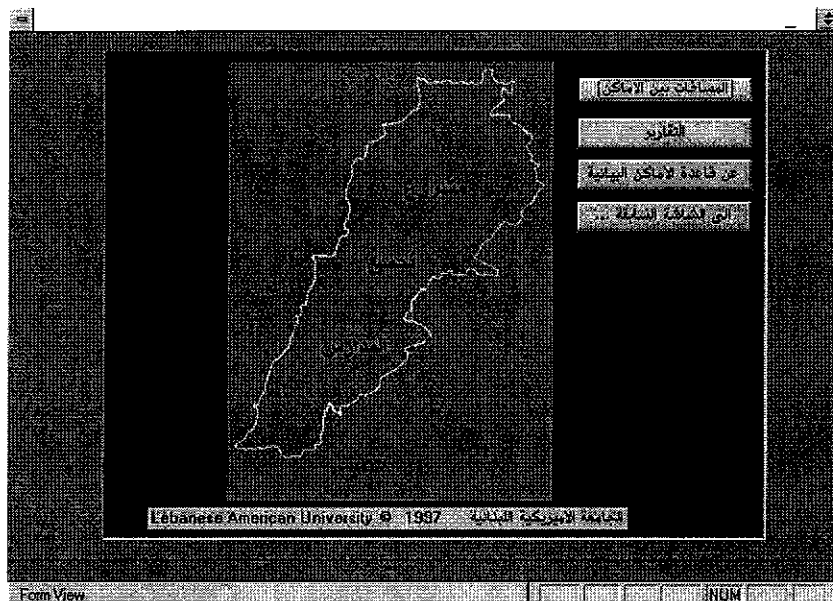


Figure 5.3. Main Menu for Towns Database

ملف تحرير

المسافات

المسافات بين الأماكن

المسافة	منطقة 2	منطقة 1
5.20	Ainab	Aabey
5.70	Bnaiye	Aabey
1.40	Kfar Malta	Aabey
6.80	Aabey	Aaramoun
5.30	Bnaiye	Aaramoun
6.40	Choufete	Ain Anoub
6.60	Kalfoun	Ain Anoub
5.80	Qmaliye	Ain Anoub

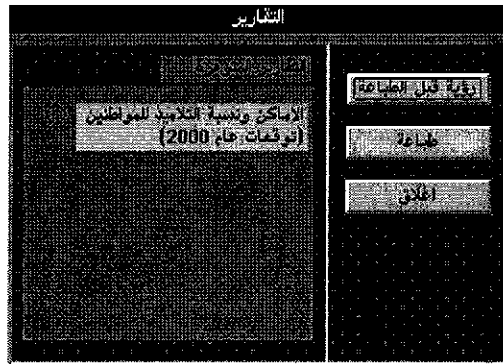
Form View

CAPS NUM

Figure 5.4. Distances Between Towns Manipulation Screen



- (b) Generate reports about the towns data (See Figure 5.5): this function gives its users the facility to view data available about towns in the form of statistical reports (pie, or bar charts) or as listings



**Figure 5.5.** Towns Database Reports Screen

- (c) Know more about the Towns Database
- (d) Return to the SRDSS Main Menu screen discussed in Section 3.1. This function allows its users to go one level up the SRDSS chart.

---

## Chapter 6

### Public Schools Regrouping

---

This chapter presents a weighted-graph formulation of the public schools regrouping problem and a p-centers algorithm that regroups schools in a user-defined region into a smaller number of schools such that a number of criteria are satisfied.

#### 6.1. Problem Definition

Given  $n$  towns with  $m$  schools. Let  $p$  ( $p < n$ ) be the maximum number of towns (i.e. centers) to be selected from the given  $n$  towns where schools will be regrouped and kept, and let  $C$  be a set of user-defined constraints. The Public Schools Regrouping Problem can be stated as follows:

Find the “best” number of towns/centers, which is less than or equal to  $p$ , where schools should be placed such that the distance from the location of a school to a “maximum” number of nearby towns is minimized, subject to  $C$ . Such a problem is usually called *minimax location problems*. [Christofides, 1975]

#### 6.2. Weighted Graph Problem Formulation

Let  $G = \langle V, E \rangle$  be a regions graph, where  $v_i \in V$  represents a town with  $m$  ( $m \geq 0$ ) schools,  $|V| = n$ , and  $(v_i, v_j) \in E$  is an edge with weight  $e_{ij}$  representing the length of the road between  $v_i$  and  $v_j$  (in kilometers).

Let  $W$  be a set of weights such that  $w_i$  is the weight associated with vertex  $v_i$ . These weights are computed as explained in Subsection 6.2.1. below.

The Public Schools Regrouping problem would be solved by finding a set of vertices  $V' \subset V$ , that satisfy the set of constraints  $C$  and the condition that the furthest vertex on the graph reaches at least one vertex  $v_i$ ,  $v_i \in V'$ .  $V'$  is called the set of “centers” whose cardinality,  $|V'|$ , should be less than or equal to  $p$ .

### 6.2.1. Town/Vertex Weight Calculation

The weights of each town/vertex depends on two variables: the population weight and the schools weights. These weights are determined by the factors listed in Table 6.1, which also shows the acronyms are some user-defined default percentages.

Factor	Acronym	Percentage (%)
Population Component	POC	30
Instructors to Students ratio	ISR	20
Distance to Main Road	DMR	15
Building Condition	BC	15
Building Status	BS	10
Sectarian Component	SEC	10

**Table 6.1.** Table of factors used to determine town/vertex weight

These percentages reflect the importance of each factor relative to the others, such that  $POC + ISR + DMR + BC + BS + SEC = 100$ .

The town/vertex weight is given by

$$\alpha_1 * \text{POC} + \sum_{\substack{\text{schools} \\ \text{in a town}}} (\alpha_2 * \text{ISR} + \alpha_3 * \text{DMR} + \alpha_4 * \text{BC} + \alpha_5 * \text{BS} + \alpha_6 * \text{SEC}) \dots (6.1)$$

where  $\alpha_1 - \alpha_6$  are user-defined coefficients. The value of a coefficient  $\alpha_i$  is meant to give a higher weight to the better values of the determining factors listed in Table 6.1. An example of these user-defined values are shown in Tables 6.2 - 6.7. Note that  $0 \leq \alpha_i \leq 100$  for  $i = 1, 2, \dots, 6$ .

**Population Component (30 %)**

Parameter / Range	$\alpha_1$
< 10000	25
10000 - 12000	50
> 12000	100

**Table 6.2.** Weight distribution for the “population” factor

**Instructors to Students ratio (20 %)**

Parameter / Range	$\alpha_2$
0-10%	100
11- 50 %	50
> 50 %	25

**Table 6.3.** Weight distribution for the “Instructors to Students” factor

**Main Road (15 %)**

Parameter / Range	$\alpha_3$
$\leq 2$ km	100
3 -5 km	50
> 5 km	25

**Table 6.4.** Weight distribution for the “main road” factor

**Building Condition (15 %)**

Parameter / Range	$\alpha_4$
Excellent Condition	100
Good Condition	50
Bad Condition	25

**Table 6.5.** Weight distribution for the “building condition” factor

**Building Status (10 %)**

Parameter / Range	$\alpha_5$
Rented	25
Owned	100

**Table 6.6.** Weight distribution for the “building status” factor**Sectarian Component (10 %)**

Parameter / Range	$\alpha_6$
One Religion and same sect	25
One Religion but different Sects	50
Different Religions and different sects	100

**Table 6.7.** Weight distribution for the “sectarian” factor

### 6.3. Algorithm

Consider each pair  $\langle v_i, w_i \rangle \in \langle V, W \rangle$  separately, and “penetrate” along all possible routes leading from  $v_i$  up to a distance  $\delta_i$ ; where  $\delta_i = \lambda/w_i$  and  $\lambda$  is a number which is called the “*penetration*”.

Let  $Q_\lambda(v_i)$  be the set of all vertices  $y \in V$  from which  $v_i$  is reachable within a distance  $\delta_i$  and let the region  $\phi_\lambda$  be the set of vertices  $v_k \in V$  all of which can reach the same set of vertices of  $G$  within the distance  $\delta_k$  for a given value of  $\lambda$ .

In general,  $Q_\lambda$  can be calculated from a matrix of minimum distances between vertices. This matrix can be calculated using Floyd’s algorithm [Brassard and Bratly, 1988].

$\phi_\lambda$  can be calculated from the reachable sets  $Q_\lambda$  as follows:

$$\phi_\lambda(0) = \{y|y \text{ on } G\} - \bigcup_i Q_\lambda(v_i)$$

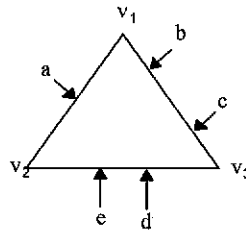
where  $\phi_\lambda(0)$  is the set of vertices that can reach no vertex other than itself. The regions that can reach the  $t$  vertices  $v_{i_1}, v_{i_2}, v_{i_3}, \dots, v_{i_t}$  (for any  $t = 1, 2, \dots, n$ ) and no other vertex are given by:

$$\phi_{\lambda}(v_{i_1}, v_{i_2}, v_{i_3}, \dots, v_{i_t}) = \bigcap_{q=1}^t Q(v_{i_q}) - [\bigcap_{q=1}^t Q(v_{i_q})] \cap [\bigcup_{q=t+1}^n Q_{\lambda}(v_{i_q})]$$

where the second term excludes the regions that can reach other vertices in addition to  $v_{i_1}, v_{i_2}, v_{i_3}, \dots, v_{i_t}$ .

**Example:**

Consider the following graph shown in Figure 6.1.



**Figure 6.1.** Example Graph

Let  $\lambda = 2$  and the weights for every  $v_i$  is 1. This implies that  $\delta_i = 2$  for all  $i$ .

The regions are:

*Region 1:* point  $a$  is the only point that can reach  $v_1$  and  $v_2$  in a distance of 2 units.

*Region 2:* The section of  $(v_1, v_3)$  lying between points  $b$  and  $c$

*Region 3:* Composed of the edges  $(a, v_1)$  and  $(v_1, a)$

*Region 4:* Composed of the edges  $(a, v_2)$  and  $(v_2, e)$

*Region 5:* Composed of the edges  $(c, v_3)$  and  $(v_3, d)$

*Region 6:* The section of  $(v_2, v_3)$  lying between points  $e$  and  $d$  (This region can't reach any vertex)

### 6.3.1. Outline of the SR p-center Algorithm

Given  $p$ , where  $p$  is the maximum number of centers requested, an outline of the algorithm to find the  $p$ -centers of a graph  $G = (V, E)$  is shown in Figure 6.2.

**Step1.** Form Graph  $G$  distances matrix

**Step2.** Calculate the minimum distances matrix of  $G$  using Floyd's algorithm

**Step3.** Calculate the weight of each vertex  $v_i \in V$

**Step4.** Set  $\lambda = 0$ .

**Step5.** Set  $\Delta\lambda = 0.5$

**Step6.** Increase  $\lambda$  by  $\Delta\lambda$ .

**Step7.** Find the sets  $Q_\lambda(v_i)$  for all  $v_i \in V_n$  and calculate the vertices  $\phi_\lambda$ .

**Step8.** Form the bipartite graph  $G' = (V' \cup V, E')$  where  $V'$  is a set of vertices each representing a potential center, and  $E'$  is a set of edges so that an edge between a potential center and vertex  $v_i$  exists if and only if  $v_i$  can be reached from that center.

**Step9.** Find the minimum dominating set of  $G'$

If the number of vertices in the above minimum dominating set of  $G'$  is greater than  $p$  return to step 6; otherwise stop. The vertices in this set then form the  $p$ -center of the original graph  $G$ . The vertices that can be served by each center found by the algorithm can be determined from the matrix representing  $\phi$ .

**Figure 6.2.** SR  $p$ -center algorithm

The SR  $p$ -center algorithm has a time complexity of  $O(n^3)$ .

### 6.3.2. Determining Minimum Dominating Sets

For a given value of  $\lambda$ , the distances  $\delta_i = \lambda/w_i$  are calculated for every  $v_i \in V$ . Then, each vertex is either reachable or not within a distance  $\delta_i$  from a vertex  $v_i$ . This makes the graph divided into sections, each defined by a vertex. Consequently, each vertex  $v_i$  can be represented by a binary vector  $(j_1, j_2, \dots, j_n)$  of length  $n$  (the number of vertices), where  $j_k = 1$  if the vertex  $v_k$  is reachable within  $\delta_i$  from  $v_i$  and  $j_k = 0$  otherwise.

The vertices with the same binary vector form a region and hence the regions  $\phi_\lambda$  can be determined. Since a region can be reached from a set of vertices for which  $j_k = 1$  and from no other vertex, these binary vectors will hereforth be referred to as *strict intersection*(SI).

**THEOREM 1:** [Christofides; 1975] For a given  $\lambda$ , a minimal dominating set of  $G'$  can be found by excluding from the set of vertices  $X'$  those vertices which correspond to SI's dominated by other SI's in  $X'$ . We say that  $(SI)_1$  dominates  $(SI)_2$  if

$$(SI)_1 \otimes (SI)_2 = (SI)_2, \text{ where } \otimes \text{ signifies a Boolean product.}$$

### 6.3.3. Algorithm Adaptation and Implementation

The p-centers algorithm discussed in Section 6.3.1. is adapted to fit the problem of grouping public schools. The adaptations are listed in Table 6.8.



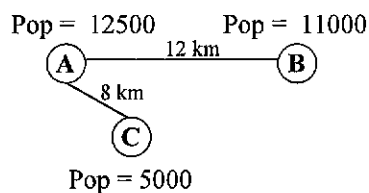
Graph	Realistic Representation
G	Caza Mount Lebanon, District Aley
v (vertices)	Towns in District Aley
e (edges)	Roads (Distances) between towns
w (weights)	Weight of each town
Center	A town that is <i>chosen</i> by the algorithm to be the location of a group schools that will replace schools in nearby <i>non-chosen</i> towns

**Table 6.8.** Adapting the p-center algorithm to fit the public schools regrouping problem

Originally, the p-centers algorithm uses Dijkstra's algorithm to find  $Q_\lambda(v_i)$  for every  $v_i$ . After adapting this algorithm to form the SR p-center algorithm, the  $Q_\lambda$  are found for all  $v_i$  using Floyd's algorithm [Brassard and Bratelly; 1988].

#### 6.3.4. Numerical Example

Consider the graph shown in Figure 6.3 .



**Figure 6.3.** Numerical Example Graph

Let POC = 100, and ISR = DMR = BC = BS = SEC = 0.

Let p=1.

**Step 1.** Form distances matrix

$$\begin{bmatrix} 0 & 12 & 8 \\ 12 & 0 & - \\ 8 & - & 12 \end{bmatrix}$$

**Step 2.** Form minimum distances matrix

$$\begin{bmatrix} 0 & 12 & 8 \\ 12 & 0 & 20 \\ 8 & 20 & 12 \end{bmatrix}$$

**Step 3.** Calculate the weight of each vertex using Table 6.2 and Equation 6.1.

$$\begin{matrix} A \\ B \\ C \end{matrix} \begin{bmatrix} 1 \\ 0.5 \\ 0.25 \end{bmatrix}$$

**Step 4.** Set  $\lambda = 0$ . and increment it by  $\Delta\lambda = 0.5$

**Step 5.**

$$Q = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\phi_{0.5} = \{ A, B, C \} \quad 3 > p$$

**Step 6.** Iterate until  $\lambda = 8$

$$Q = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \end{bmatrix}$$

$$\phi_{0.5} = \{ A \} \quad 1 \leq p$$

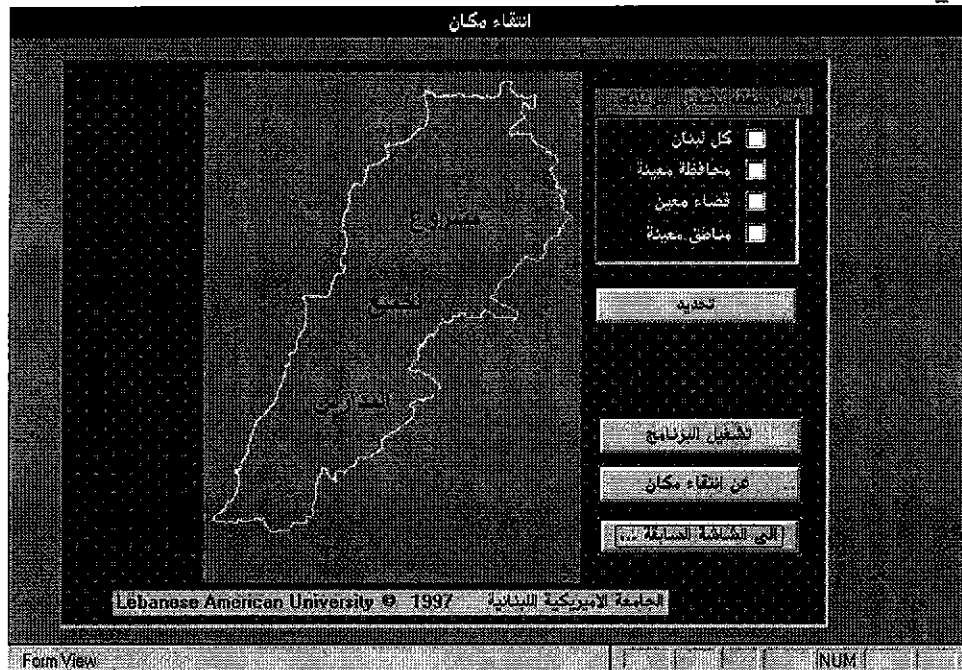
**Step 7.** Report “A” as a center

## 6.4. SR algorithm Execution

Before viewing centers of towns on a map, there are three main steps that need to be executed, namely:

1. Choose the area for which the centers need to be determined for
2. Enter corresponding parameters needed to calculate the weights for the chosen area
3. Execute the SR algorithm

Each of the above steps can be executed from the “Choose place main menu”.  
(See Figure 6.3).

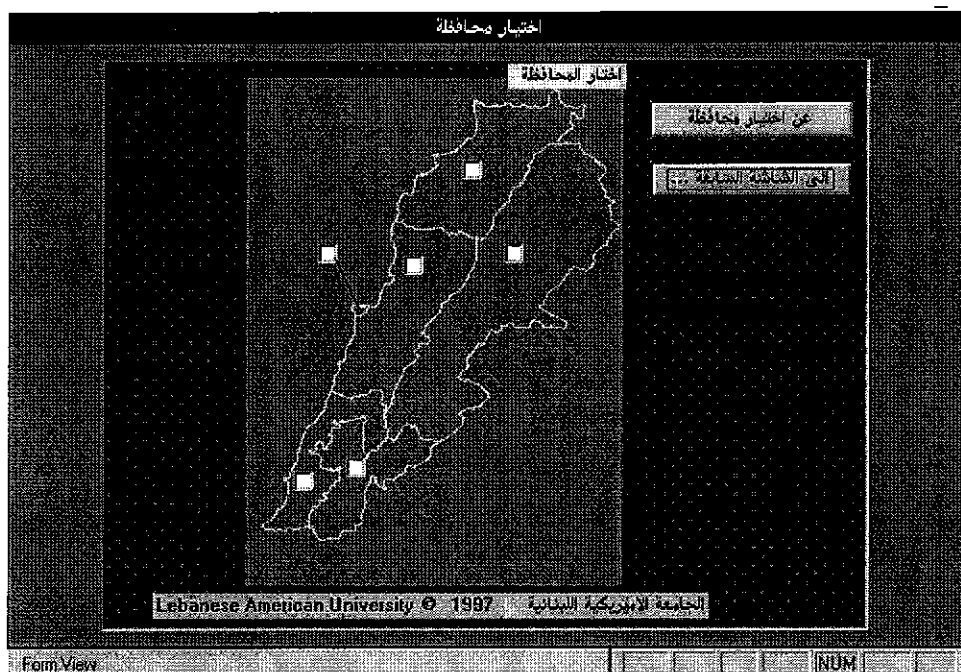


**Figure 6.3.** Choose Place Main Menu

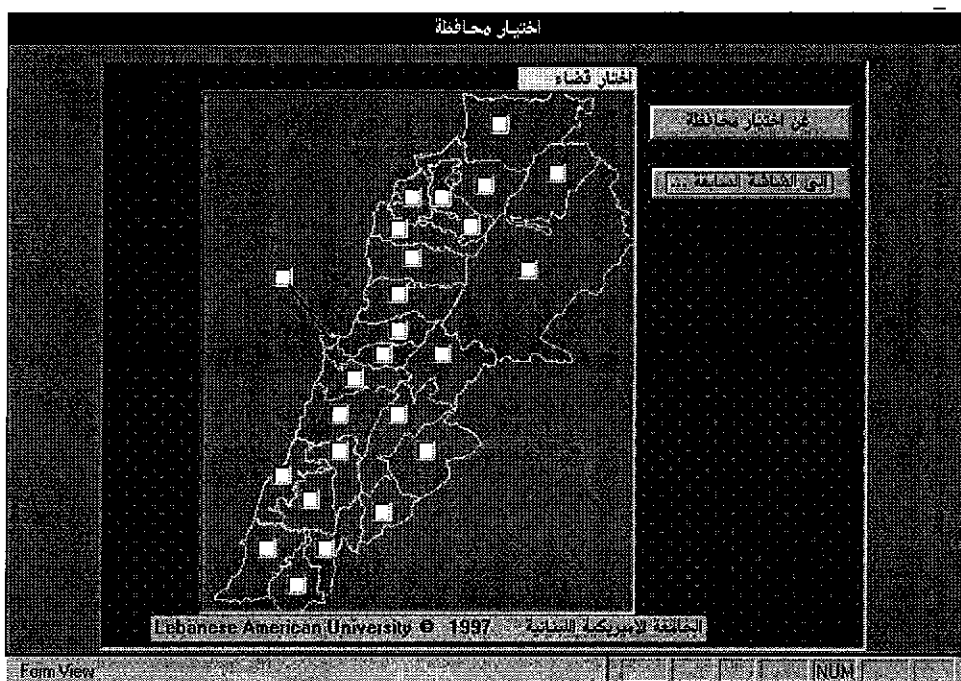
#### 6.4.1. SR Region Selection

The region for SR execution can be chosen to be “All Lebanon”, a single “Mohafaza”, a single “Caza”, or a group of selected “Towns”.

Each of these selection is determined on a separate screen except “All Lebanon”. These screens are shown in Figures 6.4 - 6.6.



**Figure 6.4.** Selecting a Mohafaza



**Figure 6.5.** Selecting a Caza

اختيار محافظة

اختار مكان		إلى الشاشة السابقة
<input type="checkbox"/>	Aaba	
<input type="checkbox"/>	Aabadlye	
<input type="checkbox"/>	Aabba	
<input type="checkbox"/>	Aabbassye	
<input type="checkbox"/>	Aabboudye	
<input type="checkbox"/>	Aabdelle	
<input type="checkbox"/>	Aabdine	
<input type="checkbox"/>	Aabeidal	
<input type="checkbox"/>	Aabey	
<input checked="" type="checkbox"/>	Aaboud	
<input type="checkbox"/>	Aabra	
<input type="checkbox"/>	Aabra	

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Form View NUM

**Figure 6.1.** Choose a Group of Towns

#### **6.4.2. Parameters Manipulation**

As stated in Section 2.2, there are six parameters existing in the SRDSS. These parameters are manipulated through two screens (See Figures 6.7 and 6.8).

Figure 6.7 shows the screen that enables its users to enter the global percentages associated with each parameter whereas the screen shown in Figure 6.9 gives the user the utility to determine the distribution of the global parameter percentage over several values(i.e. $\alpha_i$ ).

ملف

الوسائط والنسب الاحصائية

رقم الوسيط	وصف الوسيط	نسبة ثبات الوسيط
1	الطريق العام	15.00%
2	عدد المواطنين	30.00%
3	نسبة الاساتذة الى التلاميذ	20.00%
4	حالة المبني	15.00%
5	وضع المبني	10.00%
6	توزيع الطوائف	10.00%

Record: 1 of 6

Figure 6.7. Total Percentage Parameters Screen

ملف

الوسائط

اسم الوسيط:  هذه الشروط

الرمز	القيمة الاولى	القيمة الثانية	القيمة
1	10000	0	25
2	10000	12000	50
3	12000	0	100
4		0	0

Record: 1 of 3

Figure 6.8. Parameters global percentage distribution screen

### 6.4.3. Executing the SR Algorithm

Before executing the SR Algorithm, required information is exported to be used by the algorithm. These information are:

1. Basic Schools Information
2. Distances Between Towns
3. Town Weights

Each of these entities require the execution of a piece of code to calculate it and extract it the database.



---

## Chapter 7

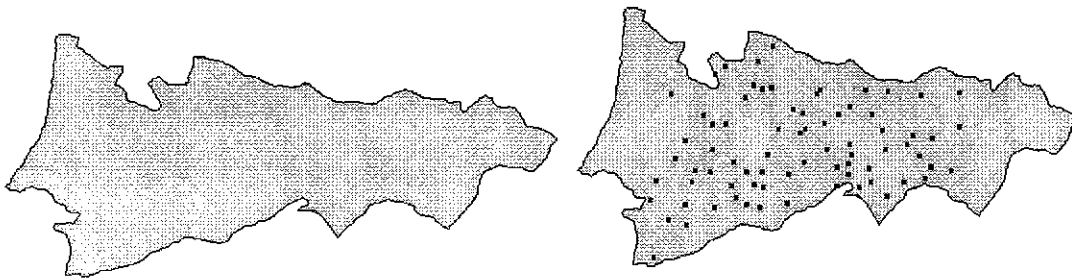
### Schools Regrouping GIS

---

The Public Schools Regrouping Geographic Information System(SRGIS) consists of two main divisions:

- (a) Coverages Digitizing
- (b) Programs

There exist two coverages that are utilized in the SRGIS, namely the Lebanese Cazas coverage and the Lebanese Towns coverage. (See Figures 7.1(a) and 7.1(b))



**Figure 7.1.** (a) Coverage 1 - Caza Aley      (b) Coverage 2 - Towns in Caza Aley

These coverages were digitized using a specialized software from ESRI called ARC/INFO[ESRI 1990].

#### 7.1 Coverages Attributes

Each coverage digitized using ARC/INFO can be associated with a set of attributes. These attributes may vary between a coverage and another. For example, the Caza coverage has three main attributes: Case id, Caza name, and Caza perimeter; while the

Lebanese Towns Coverage has five main attributes, namely Town id, Town Mohafaza, Town Caza, Town name, Expected Town Population in 2000.

## **7.2 SRGIS Utilities**

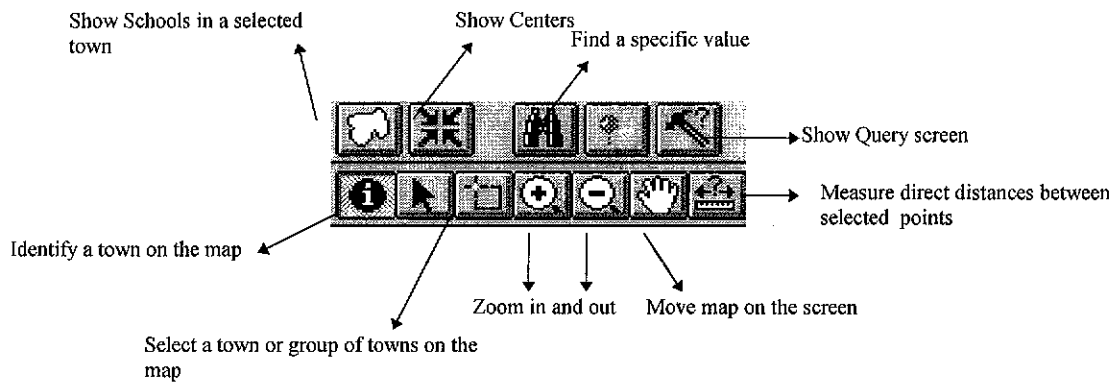
To utilize and analyze the digitized coverages, we developed a small application using two powerful software products from ESRI. These products are Arcview and Avenue. [Razavi A. 1995].

### **7.2.1. Arcview Utilities**

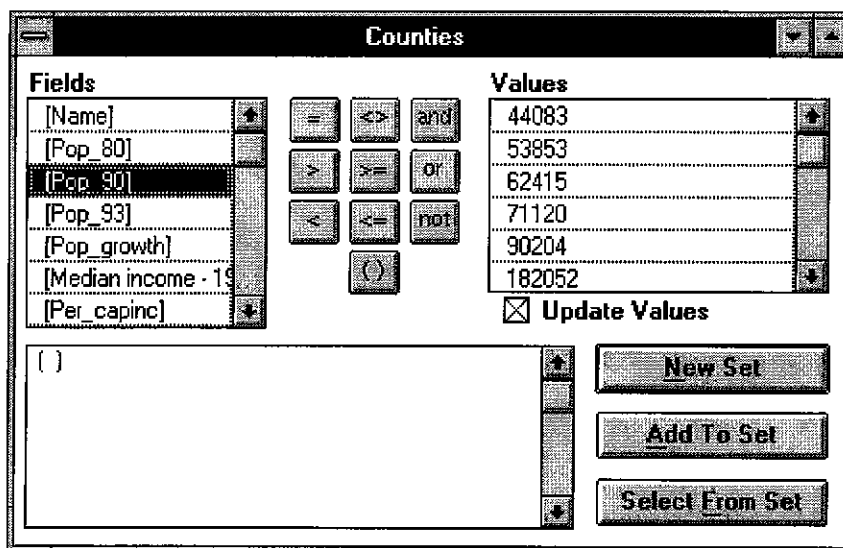
Arcview comprises a set of utilities that gives the user the facility to create customized queries that can collect data from several related geographical coverages.

For instance, SRGIS users can build their custom queries to retrieve, analyze and view data from the Lebanese Cazas and the Lebanese Towns coverages that are related by the Caza name. For example, the user can view towns in Aley Caza having an expected population greater than 1000.

Figure 7.3 shows the screen through which the SRGIS user can build his customized queries. This screen is built in Arcview and it can be activated from a toolbar button. (See Figure 7.2)



**Figure 7.2** SRGIS Toolbar



**Figure 7.3** Arcview built-in querying screen

### 7.2.2. Avenue Utilities

SRGIS contains data about schools and centers. This data is retrieved from the Public Schools Database and from the Schools Regrouping algorithm (See Appendix D). The schools and centers data are not digitized. Thus no geographical coverage can be generated. To be able to process the data or plot it, some coding has to be added. This

code will be written in an Object-oriented language from ESRI called Avenue[Razavi A. 1995].

The SRGIS contains two examples for such queries. The first query list schools in a town selected from the Lebanese Towns Coverage. The second query shows the centers generated from the last execution of the SR algorithm.

### **7.3 SRGIS Objectives**

The SRGIS has two objectives:

- (a) View the results of the SR algorithm
- (b) Give the Ministry of Education a powerful tool to plan and monitor Lebanese schools regrouping.

---

## Chapter 8

### Experimental Results

---

This chapter presents experimental results for five test cases used to demonstrate the operation of the SRDSS. Table 8.1 summarizes the five test.

Test Case	A	B	C	D	E
No. of towns	3	7	14	81	81
No. of requested centers	1	2	6	15	20
No. of produced centers	1	2	6	12	16
Towns and Weights Table	8.2	8.4	8.6	8.8	8.9
Towns/Centers distribution table	8.3	8.5	8.7	N/A	N/A
Map Figure Number	8.1	8.2	8.3	8.4	8.5

**Figure 8. 1.** Test cases summary table

#### 8.1 Test Case A

Table 8.2 shows towns with their corresponding weights calculated using Equation 6.1 and the default factors and coefficient values stated in Tables 6.1 - 6.7.

Towns	Town Weight
1. Chouifete	72
2. Aley	53
3. Bchamoun	45

**Table 8. 2.** the list of considered towns with their corresponding weights

The SR algorithm yields the distribution shown in Figure 8.1.



**Figure 8. 1.** Centers distribution for Test Case A. Centers are identified by circles

Table 8.3 shows which towns can be served by which center.

Center Served Towns	
Chouifete	
	Aley
	Bchamoun
	Chouifete

**Table 8. 3.** Table of towns served by each center

## 8.2 Test Case B

Table 8.4 shows towns with their corresponding weights calculated using Equation 6.1 and the default factors and coefficient values stated in Tables 6.1 - 6.7.

Towns	Town Weight
1. Chouifete	72
2. Aley	53
3. Bhamdoun	7.5
4. Ain Anoub	7.5
5. Bchamoun	45
6. Aaramoun	49
7. Aabey	7.5

**Table 8. 4.** the list of considered towns in Test Case B with their corresponding weights

The resulting centers distribution is shown in Figure 8.2.



**Figure 8. 2.** Centers map distribution for Case B

Table 8.5 shows which towns can be served by which center.

Serving Towns	
Bhamdoun	Bhamdoun
	Aley
Aramoun	Aramoun
	Chouifete
	Bchamoun
	Ain Anoub
	Aabay

**Table 8. 5.** Table of towns served by each center



### 8.3 Test Case C

Table 8.6 shows towns with their corresponding weights calculated using Equation 6.1 and the default factors and coefficient values stated in Tables 6.1 - 6.7.

Town	Town Weight
1. Kahale	12.5
2. Bsous	12.5
3. Chouifete	100
4. Aley	62.5
5. Sofar	12.5
6. Chanay	12.5
7. Ain Anoub	12.5
8. Bchamoun	62.5
9. Kaifoun	12.5
10. Aaramoun	37.5
11. Mechrefe	12.5
12. Maasraiti	12.5
13. Aabey	12.5
14. Bnaiye	12.5

**Table 8.6.** the list of considered towns in Test Case C

The resulting centers distribution is shown in Figure 8.3.



**Figure 8. 3.** Centers map distribution for Case C

Table 8.7 shows which towns can be served by which center.

Towns Served by Center	
Bnaiye	Bnaiye
	Aabay
Ain Anoub	Aramoun
	Chouifete
	Bchamoun
	Ain Anoub
Kaifoun	Kaifoun
Kahale	Aley
	Bsous
	Kahale
Chanay	Sofar
	Chanay
	Mecherfe
Maasraiti	
	Maasraiti

**Table 8. 7.** Table of towns served by each center

## 8.4 Test Case D

Table 8.8 shows towns with their corresponding weights calculated using Equation 6.1 and the default coefficient values stated in Tables 6.1 - 6.7. However, for this case the population factor (PR) percentage is set to 100 and the rest of the factors percentages are set to zero.

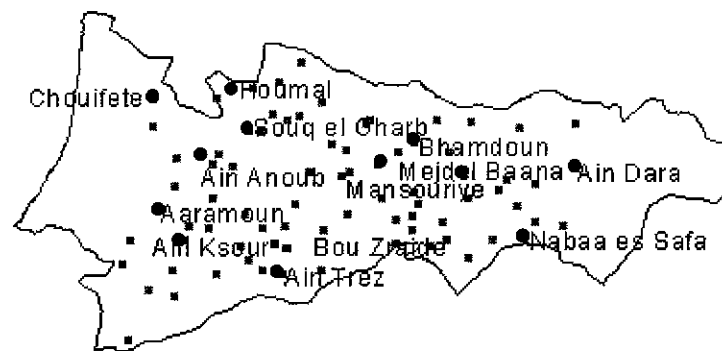
Town	Weight
Kahale	12.5
Bsous	12.5
Houmal	12.5
Bdedoun	12.5
Chouifete	100
Blaibel	12.5
Aley	62.5
Qmatiye	12.5
Ain er	12.5
Ain Jouaiq	12.5
Ain ej Jdide	12.5
Mhattet	12.5
Rouissat Sofar	12.5
Mdairej	12.5
Bkhechtay	12.5
Deir Qoubil	12.5
Sofar	12.5
Bmekkine	12.5
Souq el Gharb	12.5
Bhamdoun	12.5
Bhouara	12.5
Rejme	12.5
Btalloun	12.5
Chanay	12.5
Ain Anoub	12.5
Aitat	12.5
Bchamoun	62.5
Mansouriye	12.5
Chemlane	12.5
Kaifoun	12.5
Ain Dara	37.5
Ghboun	12.5
Taazniye	12.5
Mejdel Baana	50
Ain el Fraidis	12.5

Town	Weight
Aazzouniye	12.5
Sarahmoul	12.5
Ouata	12.5
Ain el Halzoun	12.5
Ainab	12.5
Btater	12.5
Bedghane	12.5
Kfar Aamaiy	12.5
Homset Hama	12.5
Ighmid	12.5
Aaramoun	37.5
Sibaal	12.5
Baissour	50
Habramoun	12.5
Bserrine	12.5
Mechakhti	12.5
Mechrefe	12.5
Bmahray	12.5
Fsaqine	12.5
Majdalaya	12.5
Qabr	12.5
Doueir er	12.5
Rouisset en	12.5
Mazraat en	12.5
Nabaa es	12.5
Ain Drafil	12.5
Aadaisse	12.5
Rmaile	12.5
Ain Ksour	12.5
Bou Zraide	12.5
Maasraiti	12.5
Dfoun	12.5
Ramliye	12.5
Chartoun	12.5
Charoun	12.5

Town	Weight
Mreijat	12.5
Remhala	12.5
Baaouerta	12.5
Rechmaiya	12.5
Silfaya	12.5
Aabey	12.5
Bnaiye	12.5
Ain Trez	12.5
Daqqoun	12.5
Kfar Matta	12.5
Klailiye	12.5

**Table 8. 8.** The weights corresponding to each considered town in Test Case D

The resulting centers distribution is shown in Figure 8.4.



**Figure 8. 4.** Centers map distribution for Test Case D

## 8.5 Test Case E

Table 8.9 shows towns with their corresponding weights calculated using Equation 6.1 and the default factors and coefficient values stated in Tables 6.1 - 6.7

In this case, all the towns in Mount Lebanon, Caza Aley. The number of these towns is eight one towns.

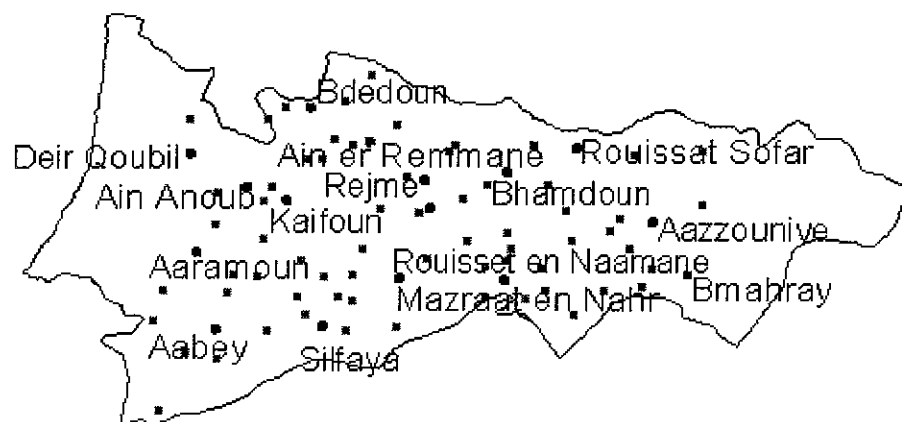
Town	Weight
Kahale	7.5
Bsous	7.5
Houmal	7.5
Bdedoun	7.5
Chouifete	7.5
Blaibel	7.5
Aley	51.5625
Qmatiye	7.5
Ain er Remmane	7.5
Ain Jouaiq	7.5
Ain ej Jdide	7.5
Mhattet Bhamdoun	7.5
Rouissat Sofar	7.5
Mdairej	7.5
Bkhechtay	7.5
Deir Qoubil	7.5
Sofar	7.5
Bmekkine	7.5
Souq el Gharb	7.5
Bhamdoun	7.5
Bhouara	7.5
Rejme	7.5
Btalloun	7.5
Chanay	7.5
Ain Anoub	7.5
Aitat	7.5
Bchamoun	45
Mansouriye	7.5
Chemlane	7.5
Kaifoun	7.5
Ain Dara	45
Ghboun	7.5
Taazniye	7.5
Mejdel Baana	43.125
Ain el Fraidis	7.5

Town	Weight
Aazzouniye	7.5
Sarahmoul	7.5
Ouata Charoun	7.5
Ain el Halzoun	7.5
Ainab	7.5
Btater	7.5
Bedghane	7.5
Kfar Aamaiy	7.5
Homset Hama	7.5
Ighmid	7.5
Aaramoun	48.75
Sibaa	7.5
Baissour	43.125
Habramoun	7.5
Bserrine	7.5
Mechakhti	7.5
Mechrefe	7.5
Bmahray	7.5
Fsaqine	7.5
Majdalaya	7.5
Qabr Chamoun	7.5
Doueir er Remmane	7.5
Rouisset en Naamane	7.5
Mazraat en Nahr	7.5
Nabaa es Safa	7.5
Ain Drafil	7.5
Aadaisse	7.5
Rmaile	7.5
Ain Ksour	7.5
Bou Zraide	7.5
Maasraiti	7.5
Dfoun	7.5
Ramliye	7.5
Chartoun	7.5
Charoun	7.5

Town	Weight
Mreijat	7.5
Remhala	7.5
Baaouerta	7.5
Rechmaiya	7.5
Silfaya	7.5
Aabey	7.5
Bnaiye	7.5
Ain Trez	7.5
Daqqoun	7.5
Kfar Matta	7.5
Klailiye	7.5

**Table 8. 9.** The weights corresponding to each considered town in Test Case E

The resulting centers distribution is shown in Figure 8.5.



**Figure 8. 5.** Centers map distribution for Test Case E

---

## **Chapter 9**

### **Conclusion**

---

In this report, we present a developed tool referred to as Public Schools Regrouping Decision Support System(SRDSS). The objective of this tool is to provide the Ministry of Education with a flexible planning utility. This utility consists of: a schools database, a towns database, a reporting module, a Public Schools Regrouping(SR) algorithm, and a geographical information system.

The organization of the SRDSS enables the decision makers and planners at the Ministry of Education to take a decision for regrouping a set of schools in a user-defined casa or region and under user-defined criteria; thus, overcoming the limitation of the CDR manual study.

The Schools Regrouping algorithm is based on a p-centers algorithm. The p-centers algorithm was adapted and modified to fit the schools regrouping problem.

Further work can be applied to find better or more optimistic algorithms that distribute schools over Lebanese towns, develop the tool interface using AVENUE and enhancing the algorithm to find the exact number of requested centers.

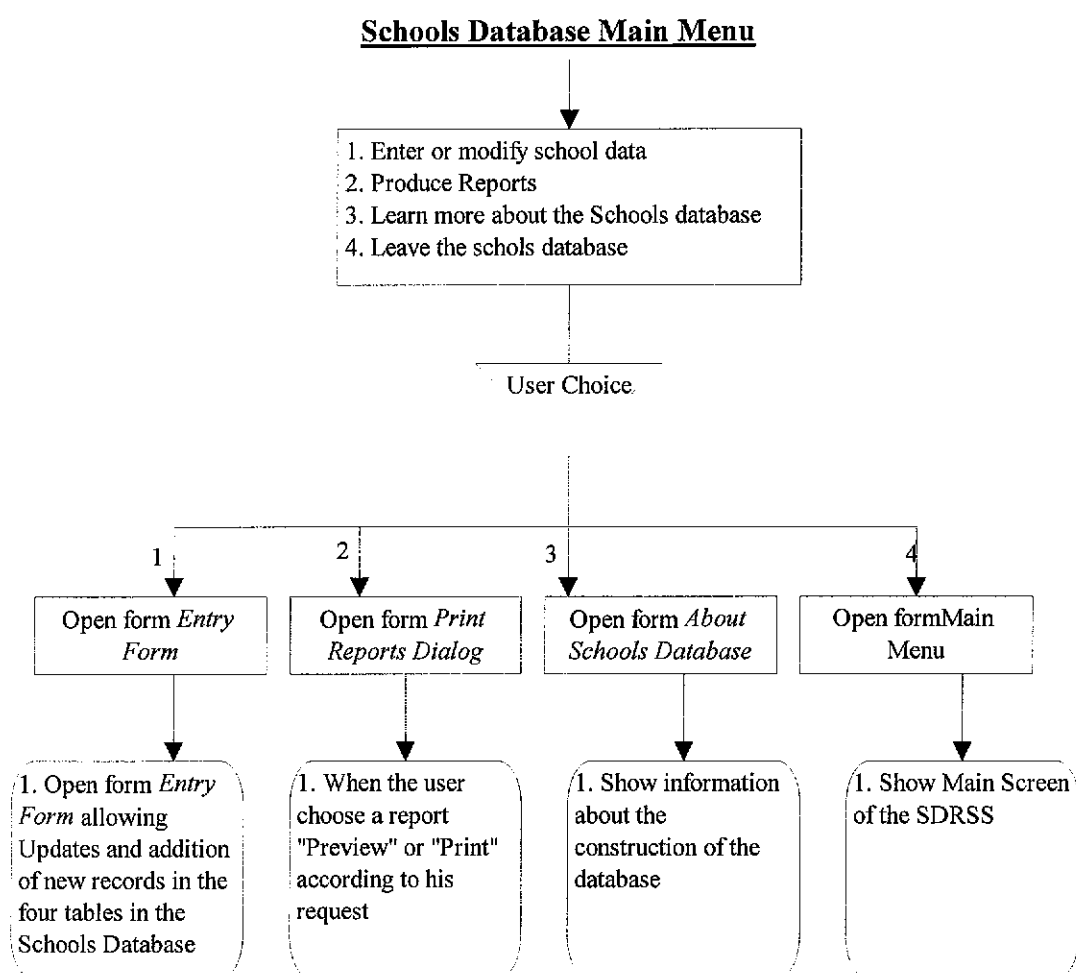
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## Appendix A

### Schools Database Flowchart

---

The following flowchart for the Schools database was drawn using ABC Flowcharter 3.0 to show how the options available in the Schools Database Main Screen are related. (See Figure A.1.)



**Figure A.1.** Schools Database Flowchart



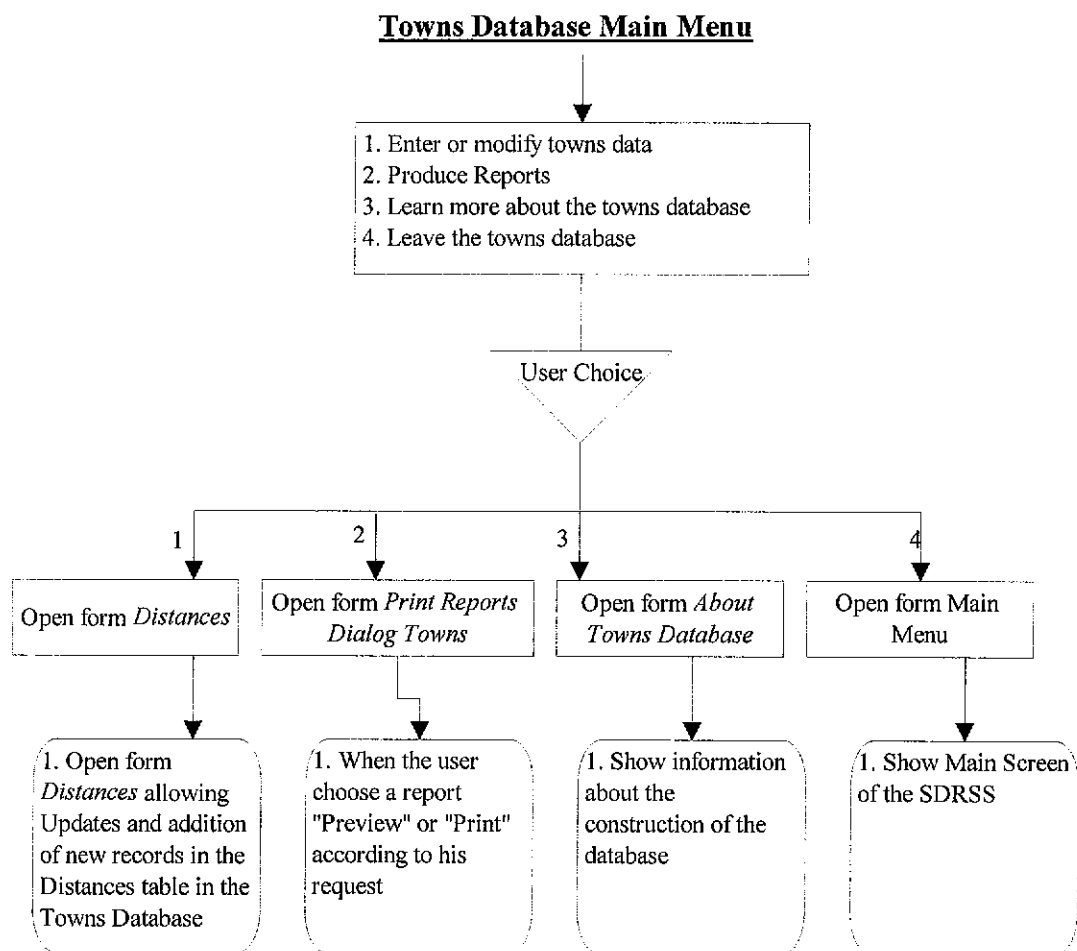
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## Appendix B

### Towns Database Flowchart

---

The following flowchart for the Towns database was drawn using ABC Flowcharter 3.0 to show how the options available in the Towns Database Main Screen are related. (See Figure B.1)



**Figure B.1.** Schools Database Flowchart

---

## Appendix C

### Implementation Issues

---

#### C.1. Software Implementation Tools

The software tools used to develop the project are listed in Table C.1.

Project Component	Tool
Schools Database	Microsoft Arabic Access version 2.0
Geographical Information System	Arcview 2.1
Public Schools Regrouping Algorithm	Turbo Pascal 7.0

**Table C.1.** Tools used to develop SRDSS

#### C.2. Turbo Pascal Limitation

The Turbo Pascal version 7.0 for PCs has a limitation. This limitation is that Turbo Pascal can allow only 65520 bytes of memory to be allocated by static data whereas 45860 bytes of memory to be allocated for dynamic data. This limitation meant that the maximum number of towns that can be considered by the SR algorithm is one hundred and eleven.

### **C.3. Dominating Sets and Set Covering**

When finding minimum dominating sets, the algorithm is actually finding the minimum number of rows to cover all columns. This is in quiet resemblance of the set covering problem.

---

## Appendix D

### Interfaces Between the Public Schools Database, Grouping Algorithm, and GIS System

---

This appendix discusses how the components of the Public Schools Regrouping Decision System interact in order to deliver the required decision system functionality.

#### D.1. Interface with the Public Schools Grouping Algorithm

As the above discussion reveals, to determine the centers, the algorithm needs:

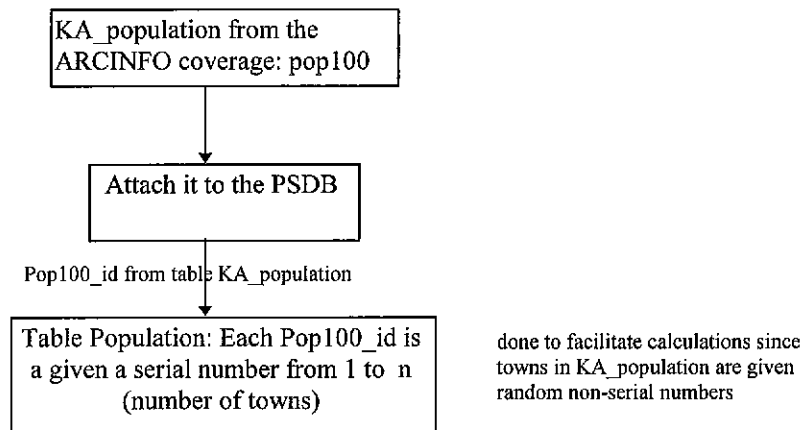
1. Towns available in Mount Lebanon
2. Distances between towns
3. Weight of each town

How are these pieces of data provided to the algorithm? (See Table D.1)

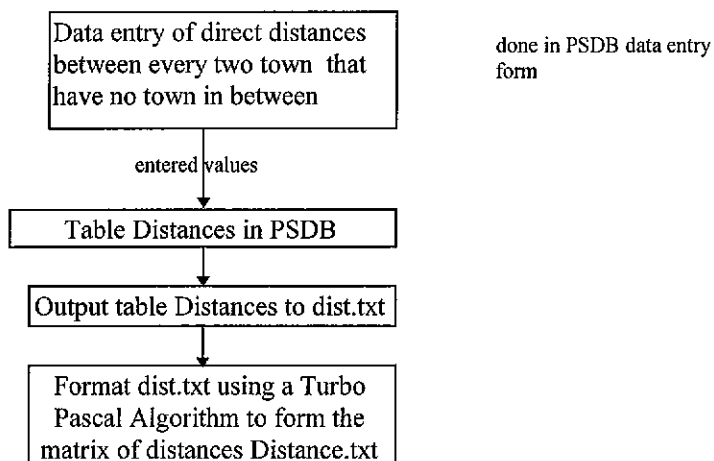
Data	Source	Location
Towns in Mount Lebanon	From the population list provided by K&A	Population in Schools Database
Distances between towns	By data entry through a screen in the SCHOOLS DATABASE	Dist.txt
Weight of each town	Running of an algorithm in SCHOOLS DATABASE	Weights.txt

**Table D.1.** Data provided to the Schools Regrouping Algorithm

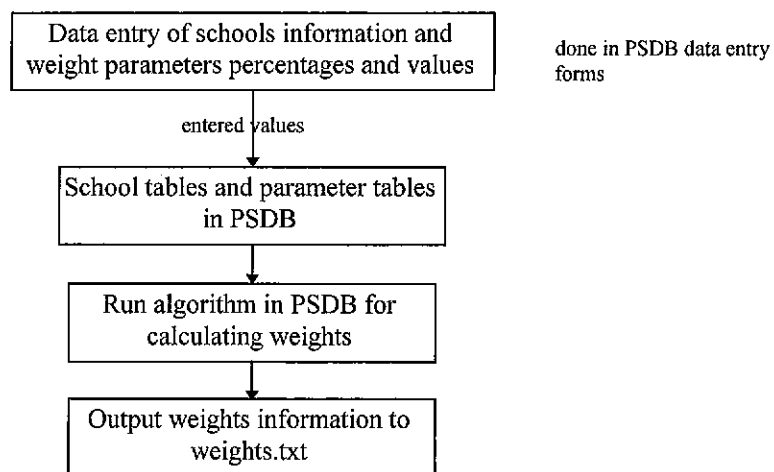
### D.1.1. Table Population



### D.1.2. File Dist.txt



### D.1.3. File Weights.txt



## D.2. Interface with the Public Schools GIS System

Item	Source	Output
List of Centers	From the Public Schools Grouping Algorithm	Centers.txt
Schools Information	SCHOOLS DATABASE	Schools.txt
Towns Code Matching	SCHOOLS DATABASE	Param.txt

**Table D.2.** Data files available for the public schools GIS

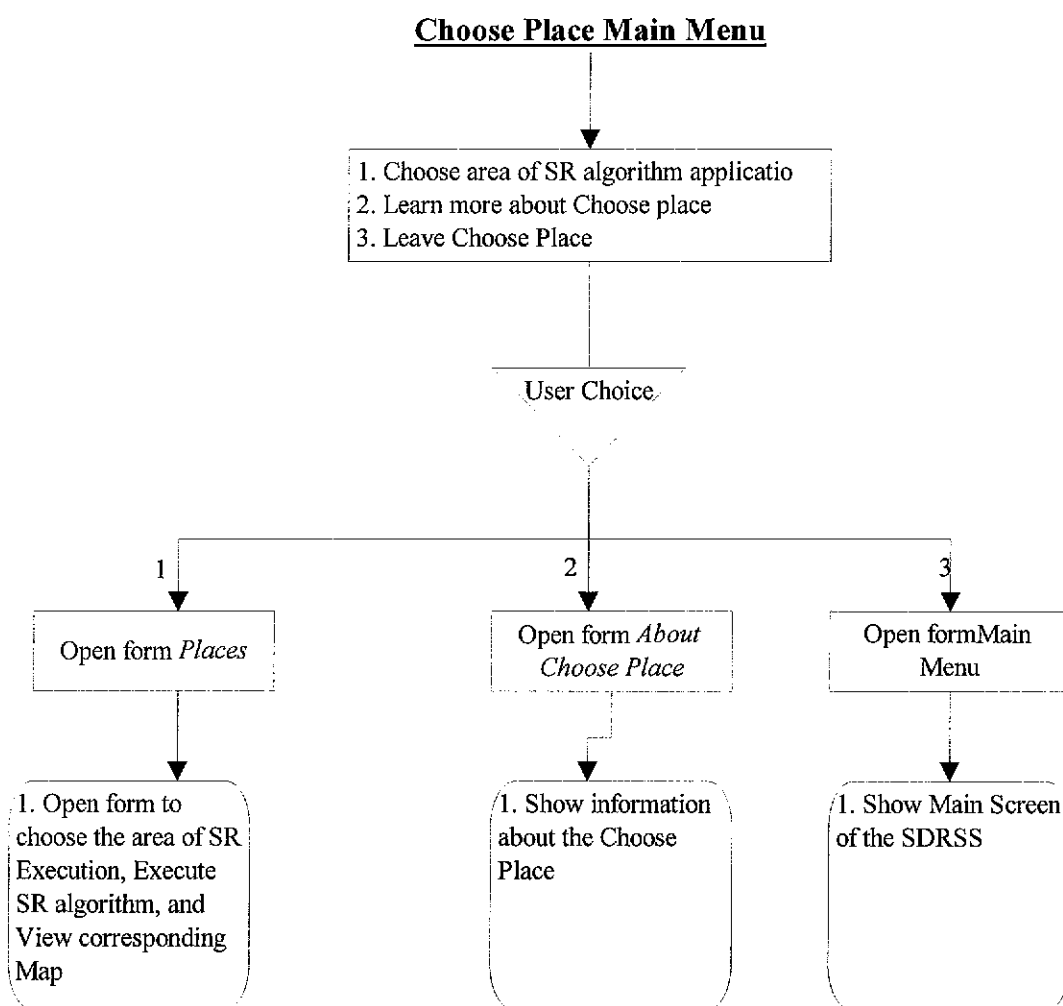
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## Appendix E

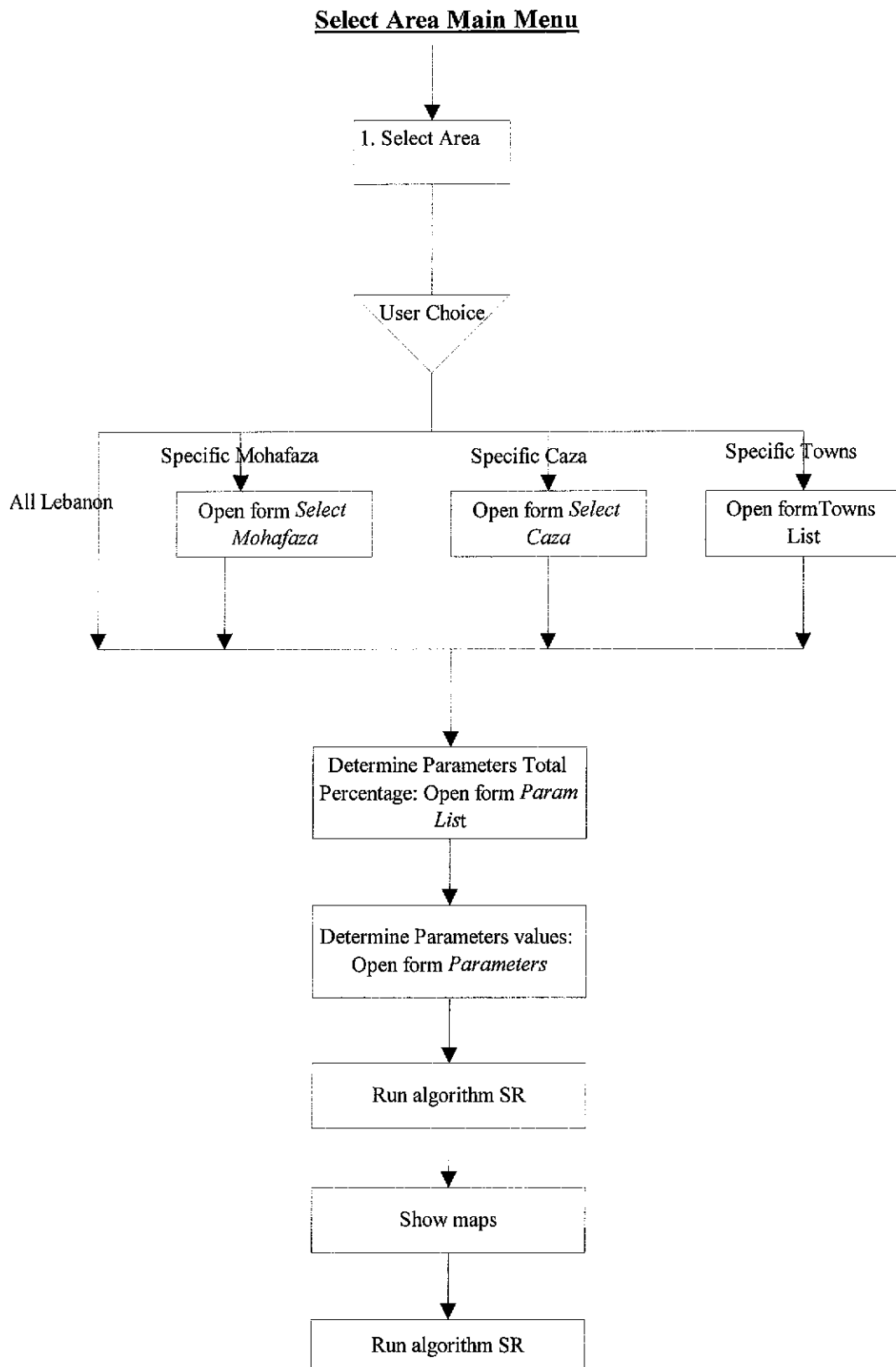
### Choosing Place Flowchart

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The following flowchart for the Towns database was drawn using ABC Flowcharter 3.0 to show how the options available in the Choose Place Main Screen are related. (See Figure E.1)



**Figure E.1.** Choosing Places Flowchart



**Figure E.2.** Selecting area of SR Execution



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## References

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**Malouf N., and Khoury E. 1983.** *تجميع المدارس* Ministry of Education - Elementary Education Administration.

**Khairallah S. and Partners. 1995.** *Projet De Regroupement Des Ecoles - Sommaire Executif.* Conseil Pour Le Developpement et la Reconstruction.

**Christofides N. 1975.** *Graph Theory - An Algorithmic Approach.* Academic Press.

**Brassard G. and Bratly P. 1988.** *Algorithmics - Theory and Practice.* Prentice-Hall International, Inc.

**Al-Rassi Ibrahim. 1993.** *الابنية المدرسية ومشروع تجميع المدارس*. Secondary Schools Association.

**Khairallah S. and Partners. 1994.** *School Regrouping Project - Lebanon.* Council of Development and Reconstruction.

**Korth H. 1986.** *Database System Concepts.* McGraw-Hill International, Inc.

**Razavi A. 1995.** *Arcview - Developer's Guide.* OnWord Press.

**ESRI 1990.** *Understanding GIS - The ARC/INFO Method.* OnWord Press.