# COMPUTERIZED SCHOOL BUS ROUTING

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ABSTRACT In 1980 and 1981, Roger Creighton Associates Incorporated (RCAI) completed two studies of computerized school bus planning systems for the State of New York. The primary goal of this study was to demonstrate the energy and financial savings which would result from the automation of the school bus routing task. As a result of this research, in 1982 and 1983, RCAI engaged in an intensive, company funded, research program which resulted in the development of the School Bus Routing System (SBRS). As a logical offshoot of the extensive graphic mapping capabilities of SBRS, RCAI introduced its School Redistricting System (SRS) in 1989.

The SBRS/SRS system is designed around an electronic map, student data file, school building file, and vehicle inventory file. Students are located automatically on the electronic map through an address matching feature and assigned to various school building sites. School bus routes are built through a graphic interface which groups students for bus loading and constructs routes over minimum travel impedance routes. Schedules are built and various impact measures such as total cost are calculated to test various routing schemes.

## HISTORY OF RCAI

Roger Creighton Associates Incorporated was founded in 1965 as a professional services firm in the field of urban and statewide multi-modal transportation planning. The firm has varied in size over the years between 4 and 25 employees and has conducted hundreds of traffic impact studies, corridor plans, signal design studies and other regional planning activities. Roger Creighton was the director of a landmark regional transportation study conducted in Chicago in the late fifties which was the most ambitious of its type at the time and the first to make significant use of computers. He then went on to form the New York State Department of Transportation into an organization the structure of which still exists. As the result of a study done in early 1980 a new department was formed at RCAI dedicated to the development of software aimed at the solution of transportation problems. Many computer programs have been written by RCAI for use internally, and others are commercially marketed. One such program is the School Bus Routing System (SBRS). This system, initially developed in the early eighties, has been installed and used in over 80 school districts nationwide.

## GENESIS & HISTORY OF SBRS

In 1980 RCAI conducted a study jointly funded by the New York State Energy Research and Development Authority and RCAI to determine the state of the art of school bus route planning and suggest various policy changes which would result in money savings (specifically through fuel use reduction).

Various policy changes were suggested including:

- Increasing walk-to-stop distances
- Varying vehicle fleet mix
- Staggering bell times
- Increasing allowable ride times

During this study RCAI saw potential advantages of using computer models to allow transportation supervisors to get fast answers to some of these questions. Designed around fundamental parameters developed by the New York State Department of Education, RCAI began the development of the system in 1982 and it was released in January of 1984.

The system was originally written in Pascal under the UCSD p-system. This allowed object code to be ported to a number of different platforms without re-compilation. The system was entirely text based and the roadway network was not based on a cartesian coordinate system, but was a pure link-node network implementation similar to that used in the Chicago Area Transportation Study of the late 1950's.

That version of the system was sold and successfully implemented in two districts and it became apparent that this would be a going concern. Improvements to the system closely followed hardware trends:

- Apple, Radio Shack and the p-system were abandoned in favor of IBM and MS-DOS.
- Increased disk storage allowed implementation by larger school districts.
- The advent of affordable color graphics hardware allowed the development of modules to display and manipulate the map on the screen.
- Numerous GIS-like facilities have been added such as: boundary analysis, precision distance calculation, storage of data in layers, and data conversion from third party sources.

Since 1986 RCAI has had a full time programming staff ranging in size from three to five, and as the client base has grown we have added a full time production and technical support staff as well.

### Overview of the process

At its core school bus routing is essentially a four step process (see Figure 1):

- ♠ Geocode students to be transported & assign to bus stops
- ① Aggregate students into groups or "trade territories"
- ② Build optimum routes through these groups to individual schools
- ③ Schedule these routes in time and assign to vehicles

NYSDOE required in their original parameters that steps ① and ② be automatic procedures for computerized school bus routing systems. RCAI's grouping algorithm is basically a minimum path traversing procedure which identifies points beyond which specified population thresholds reside. RCAI's routing algorithm is a highly constrained model of the classic traveling salesman problem.

### Benefits to Users

For those districts who seriously use the system in an attempt to streamline their transportation operation it almost always pays for itself in the first year by taking at least one bus off the road. (An average annual cost of about $30,000)

However, it is not always possible to use the system as it was originally designed mostly because of the inertia of history. This marketplace adheres strongly to the adage "If it ain't broke don't fix it." The political and personal nature of school bus transportation results in the system being used in a variety of ways:

- Some users simply use it to replicate the transportation system currently on the ground
- Others start with the current system and slowly optimize over time
- A few have completely tossed tradition and used SBRS to redesign their transportation from the ground up
- Finally, some use it to just print mailing labels

### Development of SRS

As RCAI gained more experience in the school district marketplace other problems arose which could be solved using many of the same tools developed to address the school bus routing problem. The realities of school district politics led us to develop the School Redistricting System in response to such issues as: magnet schools, controlled choice and ethnic balancing. Boundary analysis tools are most helpful to school administrators attempting to meet the specific policies set forth by the school board. Pockets of students can be identified and assigned to particular schools until the proper balance is struck.

## Conclusion

RCAI's School Bus Routing System and School Redistricting System have grown over the past ten years into what we call a job-specific Geographic Information System. While existing commercial GIS products could be adapted to address the same issues certain speed and processing efficiencies are acheived by having a dedicated product.

## Case Study - Dayton Ohio

Each installation of SBRS highlights the unique needs of the individual school district. RCAI's work in Dayton, Ohio in 1990 culminated in attempted solutions, through the use of SBRS and SRS, of very sensitive problems in the central business district. The following is a summary of these problems and a description of the use of RCAI's software to provide data for solutions.

As Dayton Public Schools neared completion of their School Bus Routing program, they came to us with a separate but related problem. Their existing transportation system was causing large numbers of students (80 or more at a time) to wait at bus stops in the Central Business District of Dayton, causing major disruptions.

There were several factors which contributed to this situation:

- Secondary students are not transported by Dayton Public Schools, but instead they are issued passes for the public transportation system (the Miami Valley Regional Transit Authority) to travel to and from school.
- The Regional Transit Authority is a radial system, (See Figure 2) and all the routes converge on the Central Business District where there are only a few tranfer sites.
- The passes issued to the students allowed a two hour ride window, both morning and afternoon.
- Dayton Public Schools had implemented an open enrollment policy, with magnet schools, which allowed any student to attend any school in the district. Magnet schools allow specialization of curricula and increase the possibility of voluntary desegragation, however this system increases the number of students traveling long distances to school.

These factors had a negative impact on the Central Business District area. The students who transferred in the CBD spent more time traveling to and from school, because of thetime spent waiting at the transfer stop. There were also some very serious hazards encountered by the students because of the large crowds congregating at bus stops, such as drug dealing, fights (occasionally with knives and even guns involved), and the frequently unpredictable crowd behavior.

Local merchants, workers and shoppers were inconvenienced and sometimes intimidated by the large crowds of students, leading to the perception that the Central Business District was a dangerous place to work or shop. Central Business Districts have been under seige for decades, with the exodus to the suburbs of businesses and shopping malls. The Dayton business community and city officials could not afford to ignore this problem.

Security had been increased in an attempt to control the situation. Dayton Police had assigned ten additional officers to the CBD in the afternoon, when the largest concentrations of students occurred. Dayton Public Schools sent security personnel, and additional security was hired by the local merchants.

At this point Roger Creighton Associates were consulted by the Dayton Public Schools to help find a solution. The City of Dayton, the Dayton Business Committee, and the Miami Valley Regional Transit Authority joined with the Dayton Public Schools to create a Policy Committee. The goals were determined to be:

- Minimize travel time and risks for the students
- Minimize direct and indirect impacts on the downtown businesses
- Minimize transportation costs

The Solution:

Using our School Bus Routing System, all students home locations were assigned and distance to school was calculated. The students who lived within walking distance of their school were eliminated from the study, leaving 5500 students.

All secondary schools were located on the map, and using this sector map, (See Figure 3) it could then be determined how many students had to travel through the Central Business District to reach their school. Of the 2600 students who potentially needed to travel through the CBD, 1100 attended a school within the CBD, and the remaining 1500 attended four separate high schools.

These figures were compared with current available loads on existing buses, including the regular Regional Transit Authority buses and the Limited Service buses provided by the RTA, which follow regular RTA routes, but do not stop in the CBD for transfers.

Alternative plans were developed and tested. It was determined early in the study that middle school students would receive one color passes, while high school students would receive another color pass, each with a one hour non-overlapping time for transfers. This was possible because the arrival and dismissal times differed by an hour for the middle and high schools. This would reduce the potential for concentration of students at bus stops by 25%.

Midway through the study, it was determined that 13 routes should be built by Dayton Public School personnel to transport 9th grade students at Patterson Co-op, the school located in the downtown area. When these buses were found to be lightly loaded, 10th grade students were also assigned to these buses. There was an observable reduction in numbers of students at the downtown bus stops after these routes were built.

The final component of the plan was to:

- Expand the Limited Service routes of the RTA, which did not allow transfers downtown, and use separate passes that would be accepted only on LS routes.
- Several additional routes were built and operated by the Dayton Public Schools.
- The few remaining widely scattered students that could not be transported in a cost effective manner were assigned to the RTA regular routes.

The costs associated with the additional routes were calculated and found to be less than the current costs of the extra security. Once a consensus had been reached Dayton Public Schools were able to use our School Bus Routing System to quickly and efficiently build new routes to relieve the congestion at the bus stops in the Central Business District. This allowed the student travel time and exposure to risk to be minimized, and reduced the impacts on the downtown community.

**Figure 1**

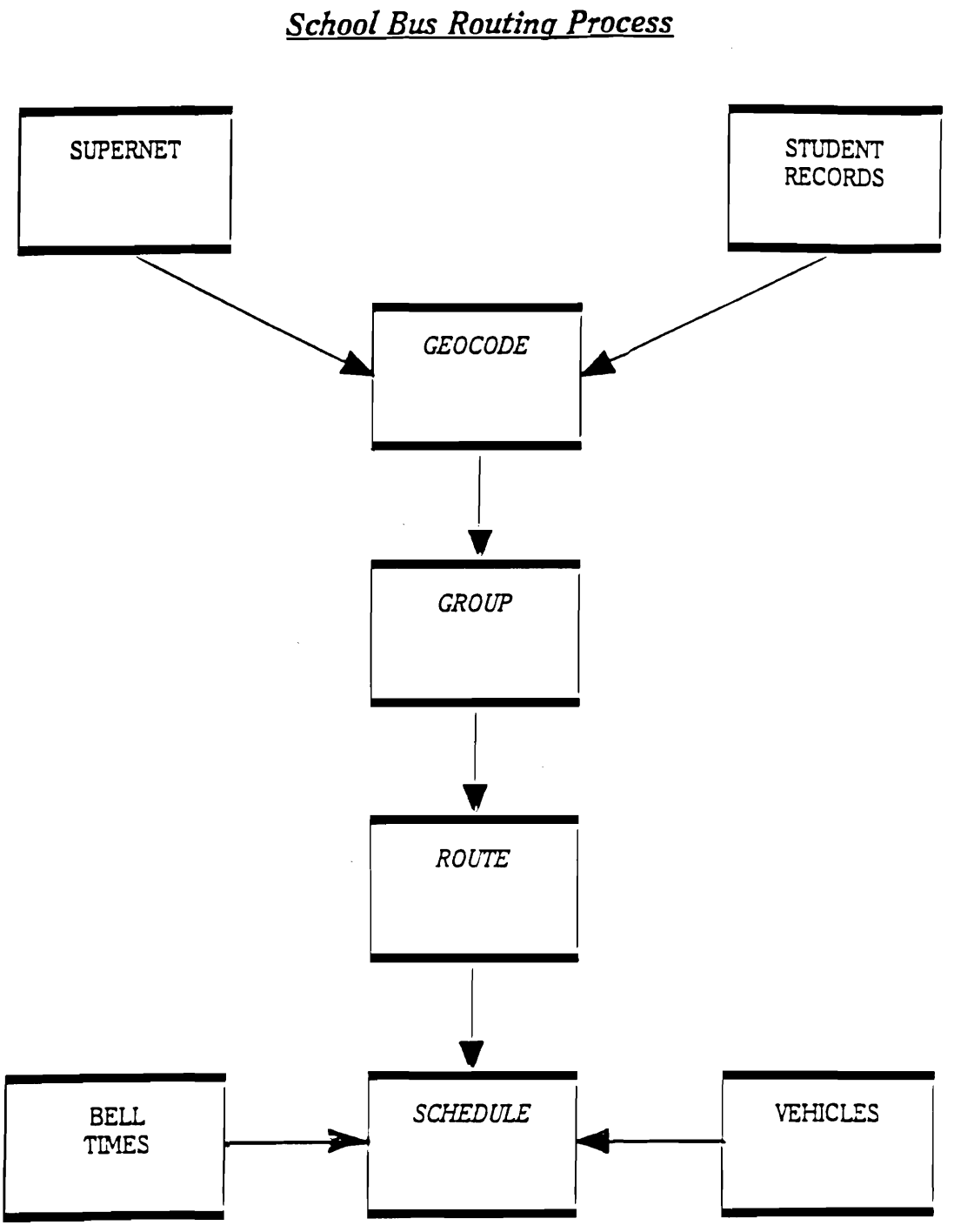
School Bus Routing Process
SUPERNET
STUDENT RECORDS
GEOCODE
GROUP
ROUTE
BELL TIMES
SCHEDULE
VEHICLES

**Figure 2: Miami Valley Regional Transit Authority Routes**

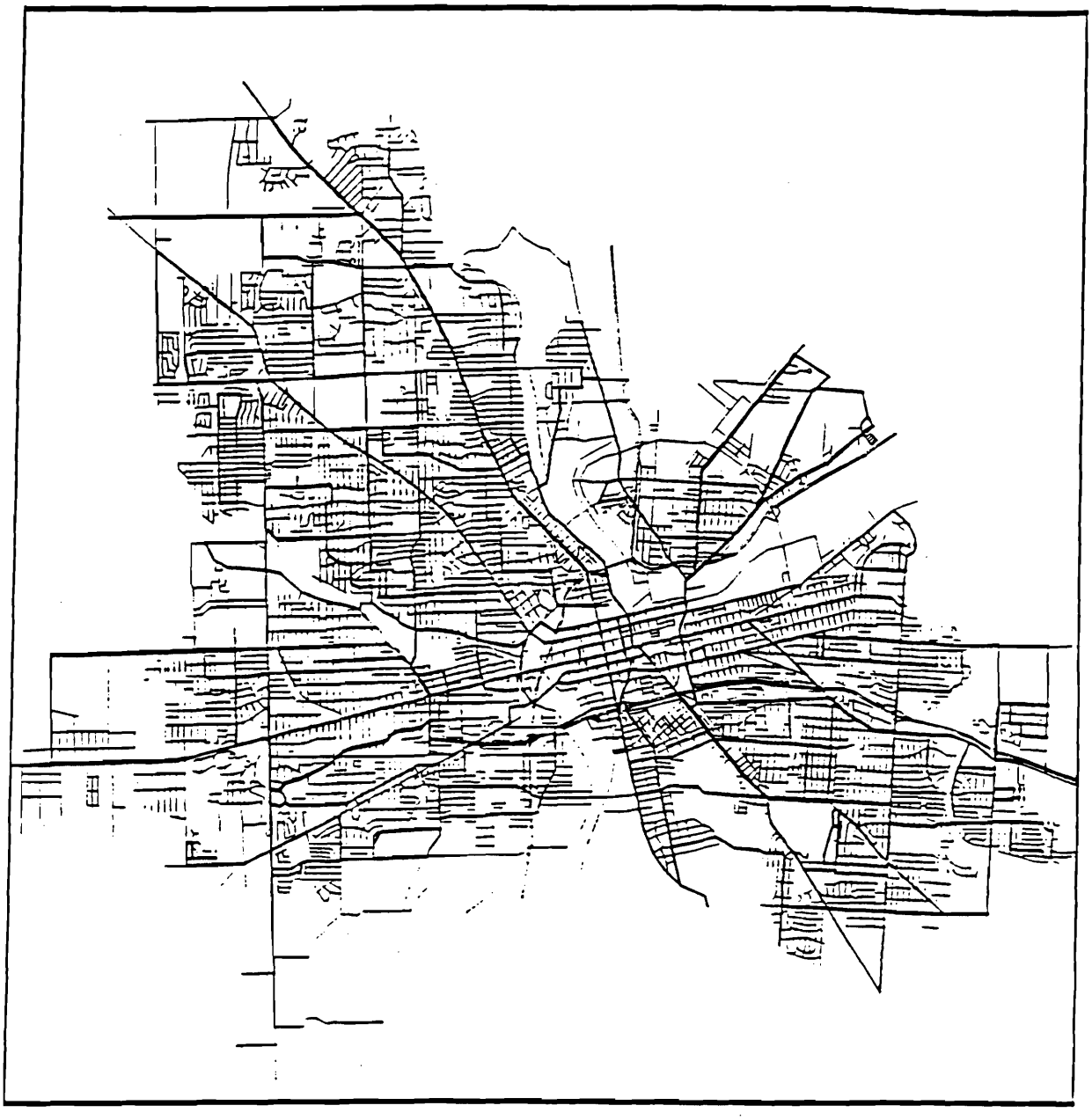

**Figure 3: Map of Sectors Used for Counting Students**