economically, possibly by way of video digitizing; and (d) display results graphically and statistically in a variety of formats.

For public presentations, color displays are most effective. They appear "familiar" to lay people and can illustrate points vividly without appearing "automated". A substantial segment of the population appears to view computer-generated products as subject to manipulation. Color display products appear to partially allay such fears.

The successful application of GMAPS-GCARS to the Southern Tier Expressway case points to the increased importance of such systems in future planning for all modes of transportation. This prediction of increased importance and acceptance is based on current trends, namely

1. The availability of good-quality, computer-processable data banks;
2. The development of "companion" computer programs to handle other aspects of transportation planning and design;
3. The increased availability of interactive computer systems;
4. The widespread installation of time-sharing computer networks supported by minicomputers; and
5. The availability of newer, cheaper, and yet more powerful units that are capable of producing color and black-and-white products suitable for projection or printing via offset printing techniques.

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Improved Highway Safety Through Interactive Graphics

David A. Green, New York State Department of Transportation, Albany

The Centralized Local Accident Surveillance System (CLASS), which is being developed by the Traffic and Safety Division of the New York State Department of Transportation to meet federal requirements and to improve highway safety for New York motorists, is described. CLASS includes information about each of the almost 600 000 accidents that occur annually on the 172 000 km (107 000 miles) of public roads in New York and is primarily geared toward meeting the needs of local safety officials, who have responsibility for 148 000 of these kilometers (92 000 miles). The major elements of CLASS are (a) an accident-site-location map produced by interactive graphics techniques and a "link-node" coding scheme, (b) a data base that contains highway information and accident data oriented to the link-node system, and (c) a software system that allows data base information to be accessed, summarized, and analyzed and permits communication between the graphic and nongraphic files. The advantage of a highway safety program based on the concept of interactive graphics is demonstrated.

The New York State Department of Transportation (NYSDOT) is actively involved in aiding local governments to carry out their safety responsibilities on the highways under their jurisdiction. This involvement begins with the provision of the accident data and analytic techniques that are necessary to identify where safety efforts should be aimed. The Centralized Local Accident Surveillance System (CLASS) will provide this local support.

CLASS is a computerized tool that provides three primary types of information to local officials: safety, highway inventory, and map. Each type of information will be discussed in more detail later in this paper. In brief, CLASS is a versatile system designed to meet local needs and provide current information.

In implementing this project, New York will be the first state to provide and analyze accident information for every public road within its boundaries. The project is also unique in that it uses direct computer interface between graphics and data files. The CLASS project, totally funded under the Section 402 Highway Safety Grant Program (Title 2, Surface Transportation Assistance Act of 1966, as amended), will provide a focal point from which a consistent, statewide highway safety improvement program can be implemented.

PROJECT BACKGROUND

Each year, almost 600 000 accidents occur along the 172 000 km (107 000 miles) of public roads in New York State; approximately 75 percent of these accidents occur on non-state-controlled facilities. For more than 10 years, accident analysis techniques have been used successfully to evaluate the 24 000-km (15 000-mile) state highway network. During that time, however, little effort has been expended on other public roads. The CLASS project was developed to fill this gap and to supply local safety officials with the necessary data to carry out their assigned duties.

To many people, Centralized Local Accident Surveillance System suggests a conflict of purpose—i.e., centralized versus local. The fear raised is the long-standing one of the "big brother" or "ivory tower" concept often associated (and many times rightly so) with government bureaucracy. More than a year was spent in dealing with this question by involving a representative sample of local safety officials in the development phase of the project. Existing local systems were reviewed to determine their strengths and weaknesses as perceived by the users. Safety groups from each county and major municipality were queried to determine the need for the proposed system as well as to identify problems foreseen in the management of the system by the state.

The justification for the approach taken and the basic interface with local safety officials can best be explained by examining the wording of the project title.

Centralization

The Highway Safety Act of 1966 requires each state to monitor accident experience on every public road to determine which highway segments warrant improvement. This process, entitled accident identification and surveillance, is also the name of Highway Safety Standard 9 of the 1966 Act. During the past 10 years, several local governments have made an effort to develop their own systems, with varying results. When a state highway accident surveillance system was successfully implemented, the value of a centralized system that would cover other public roads became evident. The factors that led to this decision included the following:

1. Decreased development costs—Analysis of large quantities of data can be handled most efficiently by using a computer, but development of computer software can be expensive. So, instead of each safety group expending the necessary resources to develop their own computer systems, centralization means that development costs occur only once and the resulting system can be used by all.
2. More complete data base—The systems that were being developed by each safety group had access only to police-reported accident data. Approximately 60 percent of all reported accidents are investigated by the police; the remaining 40 percent that are reported only by the motorists involved could not, therefore, be used in these local safety analyses. The centralized system uses the New York Department of Motor Vehicles (DMV) accident data base, which contains information about all accidents reported, regardless of the reporting source.
3. Increased computer capability—Most local governments could not justify the level of sophistication in computer capability that a centralized system can provide. In fact, many local groups could not justify any computer capability, and thus the centralized service is a real advantage to them.
4. More stable staffing conditions—Year-to-year budgeting conditions are more stable in the environment of the centralized state-operated system because of the uncertainty associated with local governments' ability to ensure continued financial support. This is especially true with respect to the accident coding process, which the state DMV is already mandated to perform.

Local Interface

Local interface comes in two forms: assistance and access. State assistance is designed to help local governments implement effective safety improvement programs (SIPs). The SIP includes all necessary functions, beginning with individual accident information and ending with implementation of effective remedial actions.

Assistance specifically relates to four areas:

1. Where to look—The primary product of CLASS is data on accident location; this is accomplished through an analytic technique called "accident surveillance", which is discussed in detail later in this paper.
2. How to look—Standard traffic engineering principles must be applied to each location identified in the first step. Short traffic engineering courses developed by NYSDOT are taught by qualified instructors at sites throughout the state. These courses cover data requirements, factors to be considered, and evaluation techniques. The primary attendees are local safety officials.
3. How to improve—Consistent accident patterns usually define the choices of remedial actions, the best being determined by a cost analysis of expected accident reduction. Accident patterns are determined by reviewing the data supplied by CLASS, and cost analysis is performed by following procedures developed by NYSDOT for use on the state highway system.
4. How to fund—The biggest problem for local officials is funding. The federal government has established several funding programs that are aimed at improving the safety of local roads but require accident data. CLASS provides the data, and the Community Assistance Section of NYSDOT helps the local government apply for the funds.

A combination of several state-sponsored programs provides assistance to local areas in implementing effective safety programs; CLASS provides the basic information without which no safety program can be effective.

Local access to information contained in or related to CLASS is the key to satisfying local needs. This access covers five primary areas:

1. Regional computer terminals—Most inquiries by local safety officials pertain to recent accident experience at a particular intersection or along a given stretch of highway. Each regional office of NYSDOT has a computer terminal from which local officials may obtain this information within 15 min.
2. Local computer terminals—Several larger counties may generate enough requests to warrant their own terminals. Local governments will have to pay for the terminal and communication costs.
3. Periodic reports—Many listing, summary, and analytic programs produce output that is too voluminous to transmit via telecommunications. These reports will be produced on a high-speed printer and transmitted by mail.
4. Updates—Updates of highway characteristics are primarily based on information from local offices. These updates can be transmitted via telecommunications but will probably be screened at NYSDOT before being entered into the data base. Updates can be either interactively entered or batch-processed into the data base. If local needs result in the identification of additional items to be included in the data base, consideration will be given such requests. The current content of the data base was greatly influenced by the local perception of needs.
5. Retrieval of accident reports—During some safety investigations, computer-generated accident reports may not provide all needed information. In that case, local safety officials can request a paper copy of the original accident report(s) submitted to the DMV.

This variety of access provides needed information, as required, and at no cost to the local community for the output.

Accident Surveillance

Accident surveillance is the monitoring and analyzing of reported accident data to determine locations that have an unexpectedly high rate of accident occurrence. Surveillance techniques can be as simple as sticking pins in a map or as complicated as the sophisticated computer analysis of CLASS. Simple techniques can only compare locations based on the number of accidents, which usually indicates only high traffic volume. Expected accident frequency, however, is different for different types of highways. By using the computer, one can make the calculations necessary to analyze accident experience more accurately.

The CLASS surveillance procedure begins by defining hundreds of different highway types and intersections by using such factors as type of geographic area, number of lanes, control of access, functional classification (travel purpose), intersection configuration, and type of traffic control. The accident data are then accumulated for each category, and mean accident rates are calculated. The actual accident experience for each segment of highway or each intersection is then compared with the appropriate mean rate based on category type by using a standard "upper control limit" statistical formula. Locations for which the actual accident rate is significantly higher than the mean rate (e. g. , three standard deviations) warrant a safety investigation to determine what remedial action should be taken.

Traffic volumes are the best exposure base (rate basis) to use in the process of accident surveillance. But, in developing a system to monitor all public roads, data on traffic volume are not always available. CLASS techniques have therefore been programmed to operate with or without information on traffic volume.

THE BASIC SYSTEM

CLASS is based on an interactive graphics system developed by M&S Computing, Inc. The system consists primarily of standard computer hardware linked together by software developed by M&S Computing. The basic components of CLASS are described below.

Hardware

The major hardware components of CLASS are three digitizing units comprised of Tektronix screens and Altek digitizing boards; a fourth interactive station, which also uses Tektronix screens; a Digital Equipment Corporation PDP 11/70 computer with 256K words of core; four 300-mb Ampex disk drives, two Kennedy 9100 tape drives, a high-speed Data Products line printer, and a Kongsberg flatbed plotter.

Software

Three operating systems are used in CLASS:

1. The RSX 11-M operating system of the PDP 11/70, which controls general systems operation, provides file control and administration, directs communications, and supports the general utility tasks available to the user;
2. The interactive graphics design system IGDS 7.2, the graphics operating system that controls all graphical tasks; and
3. The data management retrieval system (DMRS), the data base operating system that controls the definition of the data base structure and the ability to inquire and report on information contained in the data base.

Costs

The total cost of development will be about $2 million, of which the hardware-software-maintenance contract represents $750 000. The other $1.25 million is primarily personal service funds required to enter the graphical and highway inventory data and to produce the outputs for the first two years of operation. These costs are about the same as the estimated costs of preparing these products by using standard cartographic procedures for the reference maps. Nevertheless, as I will explain later, the advantages of interactive graphics justified the selected approach.

Staff

Sixteen state employees are assigned to the CLASS project. This staff is divided into three primary groups, and a technical coordinator manages the project. The cartographic staff of five is responsible for the digitizing and map production functions. The data preparation staff of seven is responsible for highlighting map features to make the digitizing process more efficient and coding the data on highway characteristics. Three data-processing personnel run the computer and plotter and perform other typical data-processing functions. This level of staffing is to be maintained for the three-year development-creation phase.

SELECTION OF INTERACTIVE GRAPHICS TECHNIQUE

Interactive graphics was selected as the medium on which the CLASS project would be based because of its updating advantages, display capabilities, accurate mileage calculations, more efficient technique for coding accident location, and other applications that could be implemented by NYSDOT. The M&S Computing system was selected because of its unique graphics capabilities and its ability to "marry" a large data base and graphical files by means of computer software.

The key to a reliable system of accident analysis is accurate, current map information. The interactive graphics concept is the most efficient means of accomplishing this goal. The primary advantages of interactive graphics in the updating process are the ease with which changes can be made and the increased frequency at which changes to maps can be implemented. Because of the direct link between the graphics and the data base, highway inventory updates can be made interactively to the graphics files by using the road elements as visual keys to aid in making the correct change and then programmatically unloading the information to the data base files.

The old saying, "A picture is worth a thousand words," can certainly be applied to the use of interactive graphics in CLASS. Any item contained in the data base can be displayed graphically. The two primary applications will be in safety and cartography. When the accident surveillance programs identify "hazardous" locations, this information can be relayed to the graphics file in such a way that the computer plotter can produce a map that shows these suspicious highway segments in red and all other segments in black. This will give safety officials a clear visual perspective of their problem areas. In cartography, thematic (special-purpose) mapping is much in demand; it is also very time consuming. In CLASS, maps that show, for example, the federal-aid or functional classifications of highways can be directly produced on the computer plotter by interfacing these elements in the data base with their respective elements in the graphics.

Aid to local communities is often based on the road mileage under their jurisdiction. Since the CLASS road network is an accurate digital representation of the NYSDOT base map series, the graphical files can be used to determine mileage without having to drive each highway or measure maps.

Added justification for using interactive graphics was obtained by investigating the accident location coding process performed by the DMV. Two advantages were found to exist: the efficiency of the process and the reduced rate of error. Because the interactive graphics approach main-

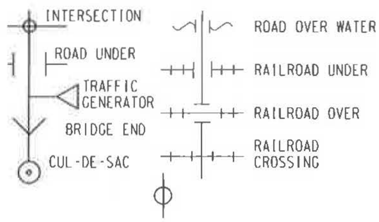


Figure 1. Accident coding of nodes

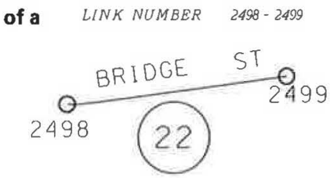


Figure 2. Description of a link.

Table 1. Interim accident summary.

Link-Node	Total Accidents	Severity: Fatal	Severity: Injury	Severity: Property Damage Only	Severity: Non-reportable	Number of Vehicles: 1	Number of Vehicles: 2	Number of Vehicles: ≥3	Accident Type: Fixed Object	Accident Type: Pedestrian	Accident Type: Wet Conditions	Accident Type: Nighttime
12	1	0	1	0	0	0	1	0	0	0	0	0
13	2	0	2	0	0	1	1	0	0	1	1	0
13-8	2	0	0	2	0	0	1	1	0	0	0	0
8	5	0	5	0	0	2	3	0	0	2	0	3
8-14	3	0	1	2	0	0	2	1	0	0	0	0
14	1	0	1	0	0	1	0	0	0	1	0	1
14-15	6	0	2	4	0	0	3	3	0	0	1	3
15	1	0	1	0	0	1	0	0	1	0	0	1

Figure 3. Verbal description listing.

Region 6 County 1 Mohegan Municipality 88 Village of Doeville Run Date 10/21/77
Link/Node Location = 14 - 15

Injury , Thu 2/19/76 03 PM, Weather-Rain, Road-Straight/Grade/Wet , No Traf Control, Lite-Oth 02 Veh, 0 Killed
Collide W/Mot Veh Overtake, On Road, 07 Injured

Veh: 01, Going Straight ,Go-E, Hit Bldg/Wall ,Front, Factor-Brakes Def ,Other (Human), ,Pub-Prop,Viol
Veh: 02, Left Turn ,Go-E, Hit Utility Pole ,L-Door, Factor-Tire Def ,Pavement Slpr. ,Viol

Case No. 6194125

tains the maps required to locate each accident as graphical files, the actual location process can be accomplished by "tagging" the appropriate graphical element for each accident. This process makes the interactive graphics approach more efficient than any alternate approach because it eliminates the need to repeatedly code and keypunch the location identifier. The second advantage—the reduction in error—is related to the elimination of these two additional steps. NYSDOT experience with state highway accident data coded by using manual techniques indicated that almost 10 percent of accident location codes were wrong because of mistakes made during these two steps. The automatic location tagging procedure will virtually eliminate these types of errors.

A final justification for using interactive graphics in CLASS is that other NYSDOT activities could ultimately benefit from this capability. Examples of such activities are (a) the automated county base map series, (b) the interactive redesign of intersections for improved safety and traffic flow, (c) network traffic assignments for planning functions, (d) other network inventories (e.g., railroad), and (e) site location needs of other state and local agencies.

SYSTEM ELEMENTS

Structure

The major elements of CLASS are a highway-site-location map, a data base that contains highway data and associated accident information, and a retrieval system that is designed to manipulate the data base to produce needed output reports. The site location map is used by the DMV to locate accidents and by NYSDOT as a basis for coding data on highway characteristics.

The basic highway-site-location technique used in CLASS is called "link-node." A node is a point of intersection along the highway; each type of node is graphically illustrated by a unique symbol called a "cell" in the interactive graphics operating system. Types of nodes and the symbols used are shown in Figure 1. (The symbol shown at the bottom center of the figure is used to represent a group of nodes to which accidents cannot be coded: points at which a highway and a boundary or a highway and a map neatline cross, a change in highway characteristics, a mileage break to keep highway segments from becoming too long, and a dead end.)

A link is the portion of highway between two nodes. Each node is assigned a number in such a way that there are no duplicate node numbers within a municipality. The link number is simply the low-high combination of the two node numbers that define the ends of the link. An example is shown in Figure 2.

A data base will be established for each of New York's 62 counties. The 172 000 km (107 000 miles) of highway will be divided into about 750 000 links, which will result in an average link length of 0.25 km (0.15 mile). For each link, more than 25 characteristics will be contained in the data base. To define this number of links, more than 500 000 nodes (each with 10 characteristics) will also be encoded to the data base. Three years of accident data (i.e., almost 2 million accidents, each with 30 characteristics) will also be retained in the data base, which includes the following:

1. Interim accident summary—The interim accident summary provides a link-by-link, node-by-node summary of accident data for a specified time period, such as three months. An example is given in Table 1.

2. Priority investigation location—The priority investigation location listing is the key to an effective SIP. The analytic technique used to create this output determines an expected accident rate for several hundred types of roads and intersections and then determines which specific road segments and intersections experience an accident rate

Table 2. Street characteristics.

Main Street at	Node	Number of Lanes	Functional Class	Area Type	Section Length (km)	Parking
East Pearl/West Pearl	12	2	Minor arterial	Urban	0.10	Both sides
Jefferson	13	2	Minor arterial	Urban	0.10	Both sides
Madison	8	2	Local	Rural	0.18	One side
East Fassett/West Fassett	14	2	Local	Rural	0.18	One side or re-stricted

Note: 1 km = 0.62 mile.
All highway characteristics maintained could not be displayed in the available space. Others are, for example, federal-aid class, pavement width, and pavement type.

Figure 4. Creation procedure.

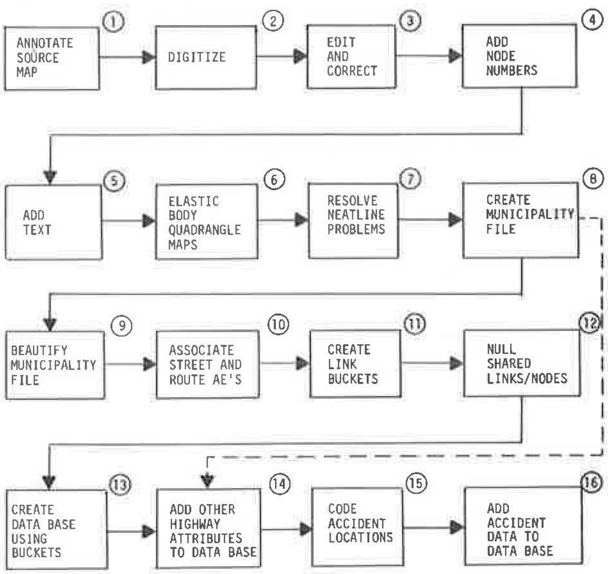
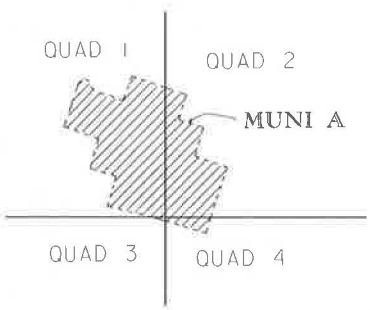


Figure 5. Elastic-body process.



significantly higher than the expected rate. Each listing includes a display of important accident data and accident rates.

3. Verbal description listing—The verbal description listing (see Figure 3) describes in abbreviated terms each accident that occurred at the given location and identifies the situations and possible causes. These listings are available to local officials through remotely located alphanumeric computer terminals that can provide quick answers to specific questions.

Highway Inventory

Information about highway characteristics is essential to an effective accident surveillance system and subsequent roadway analysis, facilitates the proper management of the highway network, and aids in fulfilling state and federal data requirements. The link-node system provides a simple means to collect and maintain required data about highway characteristics in a form that directly corresponds to accident data.

Several listings and summaries of this highway information are available in CLASS. Table 2 gives one example.

An aspect of the DMRS is a user-oriented report generator language. If none of the 19 preprogrammed outputs provides the analysis required by a local safety official, a special program can be designed and written. This service would probably be performed by CLASS personnel, but local officials who wished to do so could learn the language and write their own programs. Voluminous reports would still have to be produced on the high-speed printer and sent to the user by mail.

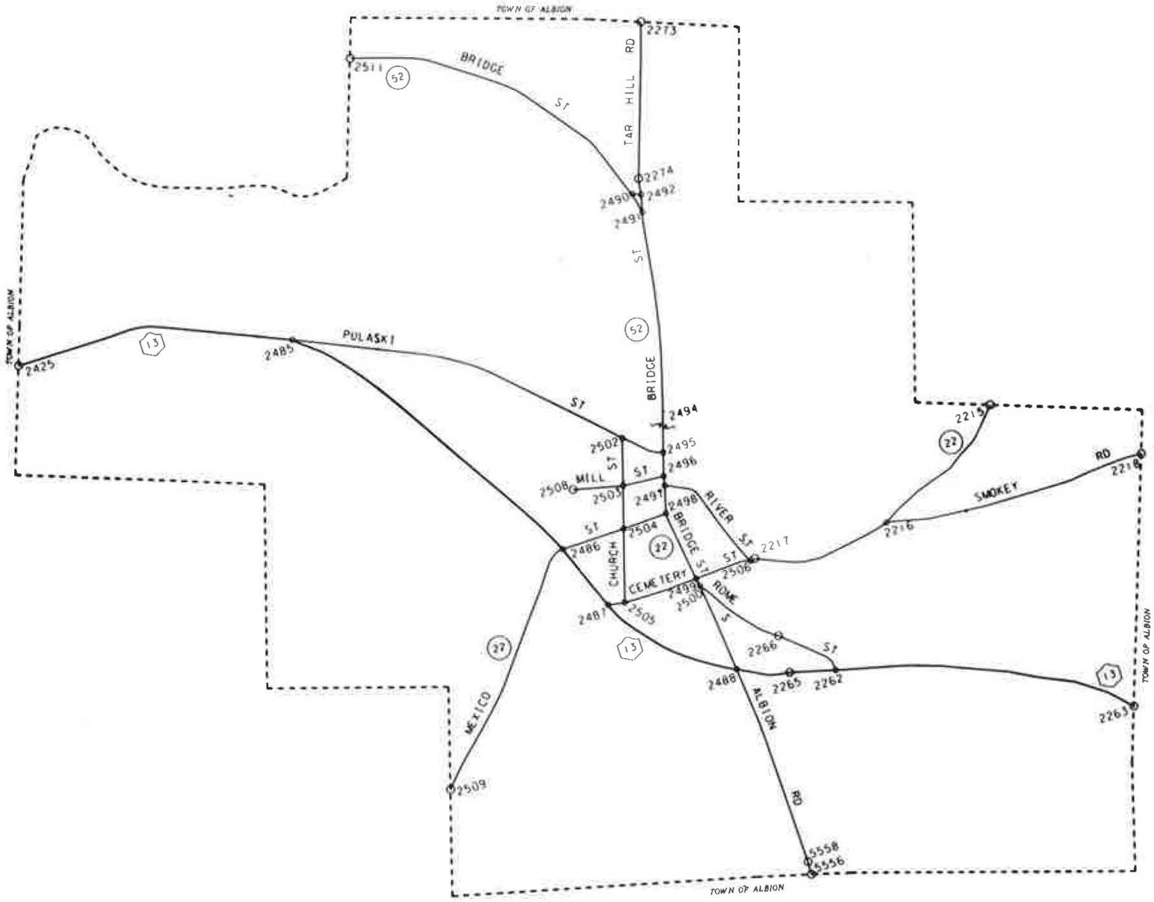
CREATION PROCEDURE

Three primary files are generated during the creation process: a graphical file that precisely replicates the road and boundary alignments of the original NYSDOT source map, a graphical file that contains information on a single municipality (i.e., a city, town, or village), and a data base file that contains the data on highway characteristics and historical accident data. These three files are integrally related to ensure that every roadway element exists and can be uniquely identified on each of the three files.

Figure 4 shows the steps required to create the three separate yet integrally related files. The steps (referenced by number in the figure) are as follows:

1. Annotate source map—Key map items are highlighted in color on the source documents, and confusing map features are clarified to make the digitizing process more efficient.
2. Digitize—Basic map elements, including control monuments, boundaries, exact highway alignments for all public roads, major shorelines, and location of all nodes, are digitized. The different types of data are each stored separately on one of 63 available levels.
3. Edit and correct—Plotted digitized maps are then edited for accuracy and completeness to ensure that the single-line plotted highway alignment falls entirely within the double-line representation of the highway on the source base map.
4. Add node numbers—Each node is programmatically given a four- or five-digit number, which is then placed on the graphical file with a given orientation to the node.
5. Add text—Street names and route markers are added to the graphical file.
6. Elastic-body quadrangle maps—The irregularly shaped municipality maps are "clipped" from the rectangular quadrangle maps after they have been merged (see Figure 5).
7. Resolve neatline problems—Even after the elastic-body process, locations along the neatline, where the two ends of a highway are supposed to come together, still may not align perfectly, so that further adjustment is required.
8. Create municipality file—The individual municipalities are "clipped" from the merged elastic-body file. Figure 6 shows a municipality.

Figure 6. Map of municipality (village of Altmar).



9. Beautify muni file—Several additional map features applicable only to the municipality maps are added at this time.

10. Associate street and route associated elements—An associated element (AE) is the procedure used to add textual intelligence, such as street name, to a graphical element, such as a line.

11. Create link "buckets"—Transfer of data from the graphical file to the data base file and vice versa is accomplished by using a technique called buckets. A bucket is a nongraphical element within a graphical file that has direct association with a graphical element. The key highway characteristics (attributes) are contained within the link buckets. Node buckets also exist and are established by the automatic node numbering program (step 4 above). The link-bucket creation establishes the buckets for each link and then uses the various AEs and other data base intelligence (e.g., levels) placed in the graphical file throughout this process to encode the data in the buckets.

12. Null shared links and nodes—Some political boundaries go down the middle of roads (links) and through intersections (nodes). These links and nodes belong to only one municipality but must be shown on both. This process establishes the correct municipality assignment.

13. Create data base by using buckets—Data contained in the buckets are simply transferred to the appropriate location within the data base file.

14. Add other highway attributes to data base—Other highway characteristics are manually coded, keypunched, and entered into the data base through batch processing.

15. Code accident locations—The DMV uses municipality files to location-code all accidents that occur in New York State.

16. Add accident data to data base—The accident data received from the DMV are batch-processed into the data base.

This creation procedure is both long and complex, but the resulting products are powerful, versatile data bases and multipurpose graphics files.

CONCLUSIONS

Improved highway safety requires accurate, manageable, and easily analyzed accident data. The link-node location system in CLASS provides a simple and accurate means of identifying accident locations. The interactive graphics system provides accurate, easily updated maps for use in the process of accident location.

The data base manager system provides for the storage of data on highway characteristics and accident data as well as analyzing the relation between these two elements. It can thus be concluded that the many different aspects of CLASS jointly provide the information local safety officials require to properly perform their duties.

The versatility of CLASS and the interactive graphics system on which its development was based also provide numerous "spin-off" products to NYSDOT that otherwise could not be realized.

ACKNOWLEDGMENT

I wish to thank M&S Computing, Inc., of Huntsville, Alabama, for permission to describe their interactive graphics system as it relates to the CLASS project. IGDS and DMRS are standard M&S products. The concepts and capabilities of CLASS were designed by NYSDOT staff. The descriptions in this paper are mine.