The Nodal Method of Collision Location

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The development of accurate and efficient accident location systems is of prime importance to the highway and traffic engineer. During the past two years the Maine State Highway Commission had developed a location system that is based on network principles widely used in the highway planning field. This paper describes the development of the systems, beginning with a review of alternative methods available and ending with an evaluation of the initial results as applied to the 4,600 miles of federal-aid and state highways. In brief, this initial experience with the node-link method of accident location suggests that it is an economical and flexible tool that has greatly enhanced the capability of the engineering staff to utilize factual data in the safety program.

•ACCURATE accident data, properly located and related to the highway environment, are essential to the work of the traffic engineer. Reviewing hazardous highway locations only after the accident problem has reached such proportions that the general public reacts is not a satisfactory operating procedure to the professional engineer. Therefore, current accident location data that enable the engineer to determine quickly those locations at which accidents are occurring or increasing must be made available as an everyday working tool. These data not only enable the engineer to determine high accident locations susceptible to correction, but also relate accident patterns to highway characteristics and thus provide the basis for corrective measures. Further, a properly established accident records system will provide the engineer with the basic data necessary to evaluate changes in highway design and operating policies that can lead to a reduction of accidents on a systemwide basis.

Accident location data are also of utmost importance to enforcement agencies. Selective enforcement programs, to be effective, must be aimed at those locations where changes in driving habits will lead to accident reduction. Accident rates and causes, when related to the type of enforcement activity, will allow evaluation of the enforcement program. Also, those involved in the public relations aspects of highway safety may make effective use of accident location and other data to provide a well-oriented service to the motoring public.

The first step in the process of developing an accident location system was a review of the extent and nature of the highway systems in the state. As given in Table 1, there are slightly more than 21,000 miles of highways in Maine.

State systems are described as state highways and state-aid highways. The State Highway Commission is responsible for construction and maintenance activi-

TABLE 1

HIGHWAY MILEAGES

Category	State (mi)	Includes F. A. P. (mi)	Includes F. A. S. (mi)
State highway	3,859	1,876	1,724
State-aid highway	7,628	–	779
Townways and miscellaneous	9,785	58	–
Total	21,272	1,934	2,503

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ties on the state highway system, whereas on the state-aid system these responsibilities are shared with the local municipality. More than 3,800 miles are designated as state highways, and some 7,600 miles are included as state-aid facilities. All but 259 miles of state highways are also designated on one of the federal systems, while only 779 miles of the 7,628-mile state-aid system are federally designated. A summary of the federal-aid and state highway system in miles is shown below:

System	F.A.I.	F.A.P.	F.A.S.	N.F.A.	Total
State highway	220	1,656	1,724	259	3,589
State-aid			779		779
					4,638

In total, there are some 4,600 miles of the more important federal-aid and state highways in Maine. Although this represents only 22 percent of the total mileage, 55 to 60 percent of the accidents are reported on these systems. In an effort to insure the rapid implementation of an effective system, a decision was made to initially limit the location system to the 4,600-mile federal-aid and state highway systems, while maintaining the flexibility for future additions.

With a total population of approximately one million and an average density of 31 persons per square mile, most of the highway system is distinctly rural in nature. Even though only 6 percent of the highway mileage is classified as urban, it was assumed that the absolute number of collisions occurring on these urban facilities was substantial, and thus flexibility of the location system to meet urban and rural needs became a design goal. Subsequent summaries of resulting data have shown that 40 to 50 percent of all the accidents reported occur in urban environments.

EVALUATION OF ALTERNATIVES

Objectives

There has been considerable discussion in recent years on the subject of collision location. Much of the published work has been concerned with the details of the physical portion of the location system—namely, the field reference markers. The decision by the Maine State Highway Commission to emphasize the improvement of the collision location process as a beginning step in improving the whole records system led to a review of previously used methods and a statement of the objectives for the accident location process.

Over the years various methods have been used to identify the locations of different design and operating characteristics and other events on state highway systems. Collisions, then, were only one item among many pieces of an inventory puzzle and were considered in that perspective. Although all of these programs present basically the same goal of inventorying a specific item on a massive highway network, the details of the inventory routine have not in the past been identical or even compatible. For this reason, the formulation of objectives for the collision location method assumed considerable importance. These objectives were summarized as follows:

1. The method should be sensitive enough to accurately identify high-frequency accident locations, and permit basic research on the relationship of design and operating elements to accident production.
2. The method should be simple enough to permit accurate use by the average policeman in the field.
3. The method should have maximum potential for use as a general road inventory procedure.
4. The method should have potential for uses other than collision (motorist information and guidance, traffic planning, etc.).

5. The cost of the system should be minimal.

The problem of inventorying collisions, design features, or any other descriptive element or event on a large highway system initially assumes substantial dimensions, but the use of high-speed computers with large storage capacities and easy access have reduced the problem considerably. The task of the state highway engineer in designing and carrying out this inventory may be compared to the inventory control problem frequently encountered in private industry.

The first requirement—that the method be accurate enough to identify high-frequency locations—was, of course, the basic reason for the program, since the requirement has seldom been met. Some of the specific accuracy problems that had plagued Maine's Planning and Traffic Division are discussed in a later section.

Because the police investigator was to remain the principal source of data collection in the foreseeable future, the method chosen for improving the location process must be simple, concise, and not involve cumbersome or time-consuming procedures in the field. A stated goal of the entire records system improvement had been the reduction of effort on the part of the police investigator.

High-speed computers offer a good opportunity to improve the highway and traffic engineer's ability to recall descriptive information useful in his design and operations' tasks. At the same time, the unification of all inventory and descriptive procedures was identified as a major goal. Keeping road inventory information on one location basis, traffic volume information on another, and bridge inventories on a third was to be avoided if possible. It was initially felt that all these inventories should be placed on an identical location basis, rather than correlating different location procedures with lengthy computer routines.

The ability to use the accident location method for non-safety purposes could be considered a fringe benefit. Motorist information and guidance is frequently mentioned as another use for the accident location system with specific recognition of the reference markers in the field. This is possible at several different levels of sophistication. For example, the mere installation of an understandable series of signs along the road has obvious use to the motorist. In more sophisticated terms, there should be some consideration of the relationship between the future development of automated vehicle guidance and control systems and collision location procedures. Substantial research and development work has been undertaken in this area by the Bureau of Public Roads' Office of Research and Development. In the highway planning field there would be considerable advantage in a collision location method that would have some compatibility with existing traffic assignment procedures, since this could simplify areawide or statewide traffic assignments.

Although the ability to accurately locate collisions is of basic importance, it is only a tool to be used in reducing collisions, and the resources committed to developing the tool should be reasonable. The maintenance and operation of the whole location process in future years was considered an important part of the total cost, which had to be balanced with the initial investment. Thus, a procedure that might eliminate the need for reference markers in the field would be desirable only if the subsequent cost of the office coding of locations was less than the cost of the markers.

Existing Method of Collision Location

For several years in Maine, some excellent work in accident data collection has been accomplished, especially by the state enforcement agency, the Maine State Police. In this state, collisions are reportable if a personal injury results or if total property damage exceeds $100. The state statutes require that the police agencies investigating accidents file standard report forms with the State Police Headquarters and that drivers file similar reports. For the most part, driver reports are not used by the State Highway Commission. The Maine State Police have had the responsibility for processing the basic information. In 1966, a total of 21,000 accident reports were filed with State Police Headquarters. The level of reporting is considered to be reasonably good, although specific areas of underreporting have become clear as the accumulated data in the new system have become available.

Prior to the development of the new location procedures, the accident report form, which is standardized and used by all state and local police departments, contained the following location information: (a) city or town name, (b) county name, (c) name or number of street or highway, and (d) distance and direction in miles and tenths to a landmark.

Police were instructed to measure the distance from a landmark to the collision site using the vehicle odometer and also indicating the appropriate direction. They were encouraged to use intersections of US- and state-numbered highways as "landmarks." Experience in using the data had defined the following kinds of problems:

1. Locations based on the name of a business or residence.
2. Locations based on a street or highway name that does not appear on available maps.
3. Locations referenced by utility pole numbers.
4. Locations that were long distances from the reference landmark.
5. Errors in the direction from the landmark to the collision site.
6. Vague or incomplete data.
7. Estimates of distance rather than measurements.

In short, the location data, as available, did not provide the necessary accuracy or adaptability to machine processing to accommodate the expanding needs of the Maine State Highway Commission and other state agencies. For that reason, early in 1967 the State Highway Commission decided to establish an interim records system that would staisfy the needs of the Department until such time as proposed modifications to the existing records system were completed. As a beginning process, copies of all 1966 source documents (police reports only) were obtained, and those accidents that could be located on the federal-aid and state highway systems (approximately 4,600 miles) were processed onto punch cards for environmental analyses.

This work provided the opportunity to test some of the recommendations made in an earlier study of the entire accident records system, and these are described in a later section.

Comparison of Alternative Methods

The first step in selection of the accident location method was to review the procedures that have been developed in other states. A review of the literature and personal contacts with some of the state highway departments revealed four basic different methods of accident location then in use or under development, as follows: (a) route number and accumulated mileage (reference markers at regular intervals), (b) route number and accumulated mileage (reference markers at irregular intervals), (c) route number and accumulated mileage (no reference markers), and (d) coordinates.

The most commonly considered method of accident location was based on route numbers and accumulated mileage, with signs posted at specific intervals (usually one mile). In its usual form the signs showed the mileage for a particular route beginning at the state line and accumulating throughout its entire length within the state. To indicate the location of a collision, the police investigator must observe the mileage signs on either side of the site, or otherwise must be aware of their sequencing, and then measure the distance to one of these sign locations. He adds the distance measured (usually to the nearest one-tenth mile) to the lowest signpost number and records it in this fashion. Measurements are commonly done with vehicle odometers reading in one-tenth mile increments.

Several problems were apparent in the application of this procedure in Maine. The first of these concerns the difficulties that are encountered with overlapping route numbers. A considerable portion of the state highway system carries more than one route number. In order to retain the ability to easily recall data for a particular route, it would have been necessary to provide for considerable manipulative ability, which would have reduced the ease of data handling. Changes in the route locations would, of course, create some reporting problems on the local level, but the entire mileage of routed highways, which is changed from one location to another, is usually quite small in any particular year. Changes in the length of a particular route because of reconstruction or relocation would, however, have a significant effect on the procedure. It would require the repositioning of a substantial number of signs in the field to maintain the continuity of the system or as an alternate solution the use of additional equations. In urban areas, the reporting of accident locations on the basis of route number and accumulated mileage would be inadequate and further information would be required. It was realized that the accident problem is urban oriented to a significant degree, even in the rural State of Maine. The last and perhaps the most serious disadvantage of the regular mileposting procedure is that the locations that are referenced in the field have little or no significance in terms of changes in the environment. The locations are strictly controlled by the posting interval and are thus not the place where traffic volumes or highway design and operating elements change. Obviously, if the locations that are referenced by signs in the field have some significance in terms of a change in the environment, then the future data processing costs will be reduced. The best example of this is the problem of recalling a particular intersection or group of intersections. This is a task that Maine's Planning and Traffic Division is most frequently required to accomplish. Under the milepost procedures, efficient recall of accident data at specific intersections would require the preparation of a comprehensive listing that showed the mileage location of each and every intersection. The cost of this correlation would be significant, and it is not clear that adequate results could be obtained for complex intersection configurations. It would be necessary to search at least two, and possibly three, different route numbers and accumulative mileage figures to be sure that all accidents are recalled for the specific location.

The posting of route mileages at existing landmarks occurring at irregular intervals would eliminate some of the disadvantages of the regular interval posting. Several states, which are using this procedure, post accumulated route mileages on signs, bridges, utility poles, and at intersections. Thus, it is theoretically possible to choose the locations for the field reference markers that have environmental significance. The freedom of choice, however, is reduced considerably in rural locations. Considerable use has to be made of traffic signs as locations for field referencing. Since these signs tend to cluster rather than occur uniformly over a given stretch of highway, and since signs are not permanent in nature, it was felt that the method had serious drawbacks for use in the state, even though reference marker costs are lower. A complete sign inventory is not available to the Planning and Traffic Division, and thus design of the locations would have had to be accomplished in the field. Such a procedure would also be somewhat more difficult for the policeman to use in the field, but this was not a major consideration.

The third possibility for an accident location procedure was to use a route-number and accumulated-mileage system, which is based on very detailed straight-line diagrams of the entire highway system. Several states are using this procedure with apparent success. In one case, the accidents are coded in the field by the police officer, which requires distribution of maps to all accident investigators. In another case, the location coding is done in the office based on the usual data reported by the police authorities. In both instances reference markers in the field are not a part of the system. The procedures would have been difficult to apply in Maine, due to the lack of sufficiently detailed straight-line diagrams. In addition, the original problems of data handling with the mileposting procedure are still in evidence. From a long-term cost standpoint it was felt that the cost of installing and maintaining field reference markers would be less than the cost of coding all accident locations in the office.

The last concept, which was under consideration by several states, is based on the use of coordinates in stating collision locations. A major advantage of this procedure is that it is readily adaptable to mechanical plotting. Two basic possibilities exist for using the method. The first would involve preparation of a series of maps with coordinate grids superimposed on a considerable amount of topographic and cultural detail. These maps would then be distributed to the investigators who would determine and report the coordinates of the collision locations. An alternate procedure would involve the coding of the locations in the office using the same maps. The former approach was ruled out, since many problems had been encountered with the data on locations as currently reported by the police investigators, and it was felt that major innovations in the reporting process would be required. The first approach, involving the distribution of maps to the police investigators, was thought to be too cumbersome and complicated for the average investigator. In addition, the correlation of accidents with highway design and operating elements would require a complete digitizing of the highway system, a long and costly process. Development times for either of the two approaches were considerable and would have meant substantial delays in this portion of the traffic safety program.

In an effort to combine some of the advantages offered by the different alternates, the Planning and Traffic Division decided to evaluate a proposal that accidents be located on the highway system according to a simple nodal principle. The proposal called for numbering and posting in the field of all major intersections on the highway system, as well as city-town lines, urban lines, railroad grade crossings, and major bridge structures. The concept was adapted from the highway planning process that simulates highway networks on a nodal basis for traffic assignment purposes. Under the procedures proposed, the policeman would indicate the accident location by one of two processes, depending on the location. If the accident occurred at an intersection, then the number of the intersection is all that needs to be recorded. If the accident occurred between intersections, then the police officer is instructed to record the intersection numbers on either side of the location and measure the distance to one of the two intersections.

For the policeman, the concept of accident location as presented by this method is very similar to the concept now used; that is, he is locating the accident site by referencing it from a known landmark. However, since the frequency of these landmarks was to be greatly increased, the distance that has to be measured is considerably decreased, with more accurate results. The confusion concerning the direction from the landmark to the accident site is completely eliminated by the provision for recording intersection numbers on both sides of the accident site. The method is adaptable to rural and urban locations, and is particularly valuable on limited-access facilities, where individual ramps can be posted according to the same basic principles as other roads. The processing of the data using the method entails a minimum amount of work. In the first place, location of the accident is reported in numerical form, which is computer oriented. Only keypunching and a minimum amount of editing is required to put the data in computer format. Second, the ease in handling the data would be considerably enhanced. It becomes an easy matter, for example, to recall accidents at any particular intersection or group of similar intersections. By the same token, accidents can be easily recalled for routes, combinations of routes, areas, or highway systems. The adaptability of this accident location procedure to the highway planning process is evident. The procedure is also adaptable to some of the more sophisticated proposals for route identification and guidance. Work now in progress by the Federal Highway Administration indicates that such systems will be based on the identification of decision points (intersections) on the highway networks.

It is emphasized that the method of identifying intersections is adaptable to description by coordinates, and it is possible that the coordinates of each node will be established at a later date as the mechanical plotting process gains importance.

DESIGN OF THE ACCIDENT LOCATION SYSTEM

Map Numbering Sequence

The first element in the design of the node-link system was a careful review of the different possibilities available for numbering the field refrerence points. It was felt that the procedures developed should be readily adaptable to the entire street and highway mileage in the state, even though the first concern would be limited to the 4,600 miles of federal-aid and state highways. This decision, coupled with the desire to maintain four digits as the maximum on the field reference markers, meant that the numbering sequence would be unique on a county level. Thus, a total of 10,000 locations would be the capacity for each county. Final design and production of the necessary location maps showed that approximately 10,000 locations would be signed initially on the 4,600-mile federal-aid and state highway systems.

A total of six alternate numbering schemes were reviewed in some detail. Most of the schemes reviewed carried information identifying the highway system and the urban-rural classification. There were significant variations in the number ranges reserved in each group and the ordering of the number ranges. The scheme finally selected carries only the system designation as follows:

Highway System	Reference Marker Number Range
Maine Turnpike, non-Interstate	9700-9999
Interstate Highway System (state highway)	9000-9699
Federal-aid primary highway system (state highway)	7000-8999
Federal-aid secondary highway system (state highway)	6000-6999
Federal-aid secondary highway system (state-aid)	5000-5999
Non-federal-aid highway system (state highway)	4000-4999

The sequence as designed provides for (a) ease of sorting by highway system, (b) continuity of numbering along major routes in each county, and (c) expansion of system capacity by at least a factor of 2.

Numbering generally was done in ascending order from south to north and west to east along routed highways. The limited-access facilities have been treated as two

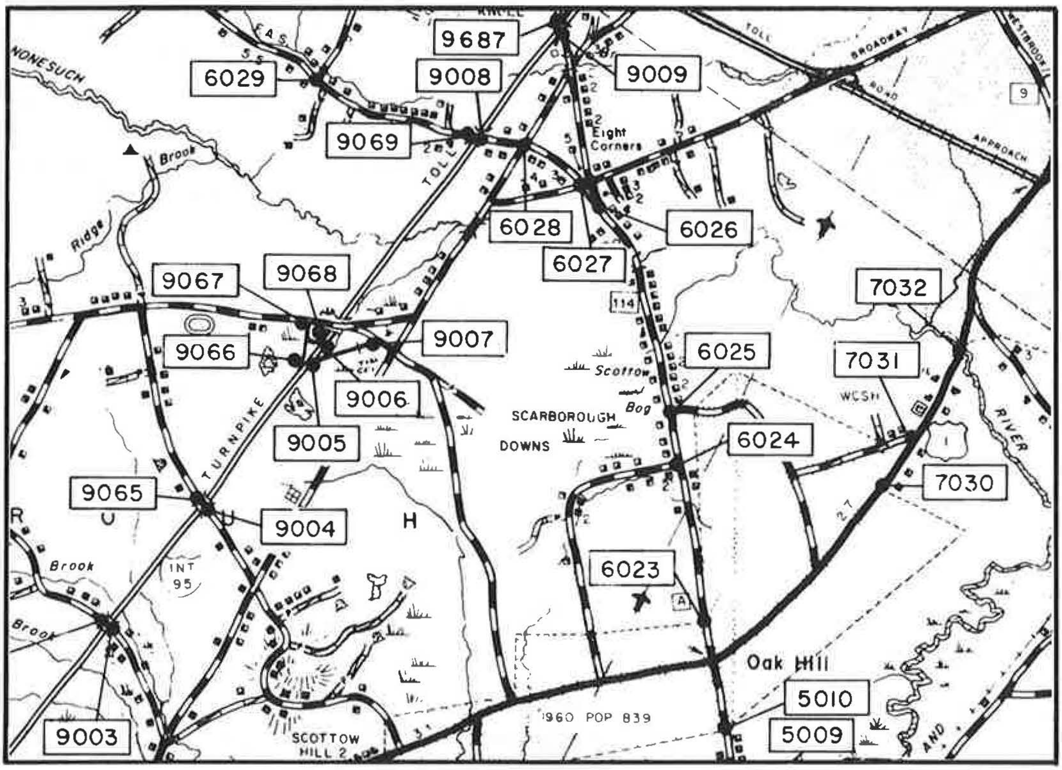

Figure 1. Typical accident location map.

TABLE 2

FREQUENCY OF REFERENCE MARKERS

County	Highway System Mileage	No. of Reference Marker Locations	Locations per Mile
Androscoggin	167	600	3.6
Aroostook	724	1,074	1.5
Cumberland	359	1,352	3.8
Franklin	243	320	2.8
Hancock	264	585	2.2
Kennebec	323	843	2.6
Knox	88	256	2.9
Lincoln	129	235	1.8
Oxford	342	493	1.4
Penobscot	453	1,190	2.6
Piscataquis	145	220	1.5
Sagadahoc	99	253	2.6
Somerset	364	622	1.7
Waldo	169	325	1.9
Washington	336	534	1.6
York	321	1,217	3.8
Total	4,526	10,119	Avg. 2.2

separate roadways and numbered accordingly with reference markers also located at ramp terminals. Reference markers have also been located at the intersections of directional roadways within major channelized intersections.

Preparation of Maps

Subsequent to defining the rules for numbering reference points on the highways, the Highway Commission prepared a series of 162 maps (Fig. 1) showing the location of each reference marker. These maps were produced to assist in the field installation phase, as well as to provide a test of the location process (without benefit of reference markers in the field). The base maps for this project were existing general highway maps prepared and maintained by the Highway Commission. The rural series (scale 1 inch = 1 mile) contains a considerable amount of culture, while the urban series (scale 1 inch = 600 feet) generally presents only street names, route numbers, rivers, railroads, and major public buildings.

Table 2 summarizes the total number of field reference marker locations in each of the 16 counties as compared with the miles of highway on all of the systems considered. The frequency of reference markers is directly related to the degree of urbanization, and this is clear from the data in Table 2. Androscoggin, Cumberland, and York counties are the most urbanized counties in the state and have the highest marker frequencies. In no case was the distance between reference markers allowed to exceed 1 mile in urban areas or 2 miles in rural areas. Where this would have occurred, due to the absence of an intersection, bridge, railroad grade crossing, or city line, a dummy location was established.

Table 3 summarizes the numbers and percentages of each type of location field referenced. It is noted that intersections account for approximately 80 percent of the total.

Test of the Location Process

The next step in the development of the records system was the creation of an accident records file for the federal-aid and state highway systems using the accident location process as previously described. It was recognized that the process itself should be subjected to a thorough test prior to an investment in field reference markers. In addition, there was a pressing need to create an accident records file of data for use in current programs. Obviously, the installation of the field reference markers,

TABLE 3

SUMMARY OF REFERENCE MARKER LOCATION TYPES

Type of Location	No. of Occurrences	Percent of Total
Intersections (and urban boundaries)	8,203	81.0
Railroad grade crossings at intersections	43	0.4
Railroad grade crossings between intersections	167	1.7
Bridges	572	5.7
City, town lines	764	7.5
Dummy nodes	370	3.7
Total	10,119	100.0

Figure 2. Reference marker installation.

the changing of the accident report forms, education of the police investigators, and the accumulation of several years of accident records would be a time-consuming process. To overcome these difficulties, a decision was made to establish a records file using existing accident reports (i.e., the previous year, 1966). Photocopies of all accident reports (police) for the calendar year 1966 were obtained and processed. Locations were fixed as accurately as possible with the existing data, and those collisions occurring on the federal-aid and state highway systems were recorded on punch cards for rapid analyses. The Highway Commission has continued to receive and process copies of the original source documents during 1967 and 1968.

In general, the coding project was a success, even though it was clear that the absence of field reference markers reduced the accuracy of the location process for the 1966 and 1967 data. The feasibility of the process has been established, and a workable file of accident records was then available. Prior to installation of the field reference markers, the location coding utilized business and city directories, commercial maps, and even telephone calls to local agencies, in addition to the routine data on the report form.

Installation of Reference Markers

Once the "map test" of the methodology was successfully completed, the Commission adopted the process and decided to install the field reference markers on the entire 4,600 miles of federal-aid and state highways. A total of 20,000 markers were fabricated in the state sign shop utilizing 3-inch numerals (silver) on a 5 by 10-inch sign blank (green). Each field installation consisted of two markers on a single support. Erection of the markers was accomplished during the winter months of 1967-68 by state crews attached to the Planning and Traffic Division (Fig. 2). Existing sign structures were utilized in approximately 60 to 70 percent of the installations. This phase of the program cost a total of $57,000 and was partially funded by the National Highway Safety Bureau.

TABLE 4

STATEWIDE ACCIDENT DISTRIBUTION, 1966

No. of Accidents	Number of Locations					
	Nodes			Links		
	Urban	Rural	All	Urban	Rural	All
1	717	369	1,086	991	1,571	2,262
2	249	112	361	309	563	872
3	119	34	153	104	235	339
4	73	18	91	55	124	179
5	45	4	49	27	55	82
6	26	2	28	12	22	34
7	21	1	22	10	12	22
8	14	–	14	5	6	11
9	9	–	9	1	3	4
10+	44	–	44	6	4	10

Initial Experience

During the period of field installation of the reference markers, the Maine State Police, which serves as the central records agency, modified the standard report form to provide for direct reporting of accident locations by node-link identification. At the same time, additional changes in the report form were made and a series of regional training sessions scheduled to instruct state and local police officers in the use of the new form. Initial results with the system have varied. Few problems have been noted where the system is used, but some of the local police agencies had not been consistently reporting locations using the node-link identification. The State Police, who account for approximately 50 percent of the accident reports, are using the system consistently and with no apparent problems. Additional training and orientation sessions with individual local police departments have been held to encourage use of the node-link system and thereby further reduce the office coding burden to a minimum. These efforts have been most encouraging. In addition to location-to-location data, 49 columns of other information are coded on the keypunch form. Of the total of 21,281 accidents reported to the central agency in 1966, 11,948 or 56 percent were located on the 4,600-mile federal-aid and state highway systems (22 percent of the total mileage). All coding, punching, and editing of the 12,000 reports that are processed by the Commission's Planning and Traffic Division consume 1½ man-years of effort annually. Coding of the data makes up most of this total, and a significant part of the coding task involves the manual checking of location data and a comprehensive classification scheme. In summary, the initial experience with the process has been good, and the small cost of data processing suggests a high level of operational efficiency.

Use of Accident Data

Prior to the development of the data described, all principal accident studies done by the Commission's engineering staff required the use of the original report form document and involved large investments in searching and processing of the data. This problem, combined with the inaccuracies of the then existing location methods, severely limited the use of accident records. The availability of computerized accident information accurately located on a systemwide basis has effectively removed these restraints.

Early work with the collision data involved summaries of accident frequencies by highway system and type of environment. One of these summaries appears in Table 4 and consists of a distribution chart for urban and rural nodes and links for the year 1966. A total of 11,000 accidents are represented by these data, with 64 percent occurring on links and 36 percent at nodes. It is interesting to note that this preliminary information shows a much greater dispersion of link collisions as compared to those that occur at nodes. Approximately 18 percent of all nodes had one or more collisions in 1966, as opposed to 40 percent of all the links. It seems clear from these data that more than one year's information is necessary to satisfactorily identify high-frequency locations, particularly in the case of nonintersection locations.

In the short time since they became available, the data have been used for a wide variety of projects. The following represents a partial list of completed projects:

1. Comprehensive listing of high-accident links and nodes based on travel volumes followed by field reviews.

2. A study of bridge accidents.
3. A study of fixed-object collisions.
4. A study of collisions involving animals.
5. Analyses of specific locations initiated both internally within the Highway Commission and externally by other state and local agencies.

A recently completed project has established the framework for future data systems that will be used for the correlation of collision records and highway design and operating variables. Expansion of the data is now underway, as is a first step research project that includes an examination of at least the following relationships: (a) collision severity and collision type, (b) collision rate and intersection configuration, (c) collision rate and type of traffic control device, (d) collision rate and access control, and (e) collision rate and traffic volume.