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Use of Computerized Roadway-Information System in Safety Analyses

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The investigation of safety problems at a site requires that accident patterns be identified to aid in defining whether a safety problem exists and the level of the safety problem. Traditionally, safety engineers have identified accident patterns based on a combination of a visual inspection of collision diagrams and a site review of the study location. This approach, although enabling the engineer to identify accident patterns at a site, fails to define whether the magnitude of the patterns is sufficient to warrant the critical review of specific patterns and to recommend countermeasures to alleviate them. Rather, these decisions are made based on the engineering judgment of the safety engineer. A procedure that describes a mathematical approach used to identify safety problems and recommends countermeasures is described. By using a comprehensive roadway-information data base, this procedure is being used in Michigan by the Oakland County Road Commission in its highway risk management program. Similar roadway sites are selected based on geometric and operational parameters provided in the data base. These data, in combination with an accident data base for the defined roadway system, permit the analysis and comparison of accident characteristics of a study site to other similar sites. These analyses are also used in the identification of favorable countermeasures by comparing accident characteristics between similar sites with and without a particular countermeasure. These findings can also be used to develop accident-reduction factors for specific countermeasures.

Highway-safety professionals have long recognized the need for an organized approach for the correction of safety problems. This objective led the Federal Highway Administration (FHWA) to establish several programs to assist state and local agencies in improving safety on highways under their jurisdiction. These programs served to guide, assist, and encourage highway agencies to upgrade and maintain their highway system based on highway-safety objectives. The programs ranged from funds provided to identify and correct hazardous locations to the earmarking of funds for specific categorical programs and for the development of procedures to efficiently and effectively maintain a highway-safety improvement program (HSIP).

The HSIP was described in Federal Highway Program Manual (FHPM) 6-8-2-1. The FHPM described a systematic procedure for organizing a safety-improvement program. FHPM 6-8-2-1 was superceded in 1979 by FHPM 8-2-3. FHPM 8-2-3 recommends that processes for planning, implementing, and evaluating highway-safety projects be instituted on a statewide basis. It is planned that each state develop and implement, on a continuing basis, a HSIP that has the overall objective of reducing the number and severity of accidents and decreasing the potential for accidents on all highways.

A major component of the HSIP is the planning component. The planning component consists of the collection and maintenance of traffic, highway, and accident data; the identification of hazardous locations; the application of engineering studies; and the development of safety projects and their implementation. Prior to the development of safety projects, individual site investigations are required. The investigation requires that the site and its roadway, traffic, and accident characteristics be reviewed and that safety problems be identified in order to select favorable countermeasures. A review of the cost-effectiveness, safety impacts, and other significant factors for each countermeasure results in the development of a safety project.

To aid in the development and maintenance of the HSIP and highway risk management program for Oakland County, Michigan, the Oakland County Road Commission developed a comprehensive roadway-information system. This system uses computerized roadway, roadside, and accident data bases and a statistical computer package to assist the Road Commission in its safety analyses. The system not only permits the maintenance of highway, traffic, and accident data but allows a variety of safety analyses to develop and maintain the county's safety program. One specific tool developed from this system is intended to aid in the definition of safety problems and deficiencies and to assist in the countermeasure-selection activity. The purpose of this paper is to describe this analytical tool, its development, and its application for use in the county's highway-safety and highway risk management programs.

BACKGROUND

As part of the Road Commission's highway risk management program, Road Commission officials sought to develop a computerized roadway-information system that could be related to an existing computerized accident data base [monitored by the Traffic Improvement Association (TIA) of Oakland County]. This system was intended to permit accident information to be merged with roadway-information system characteristics. This system would then allow for the analysis of accident characteristics based on the roadway and roadside features established in the roadway-information system. The services of Goodell-Grivas, Inc., were obtained to develop the computerized roadway-information system and its analysis capabilities.

Development of Data Bases

Initially, roadway and roadside-obstacle inventories were developed from photolog records. Parameters recorded in the roadway inventory included the following: main-street name, cross-street name (where applicable), beginning and end points of roadway characteristics, intersection type (where applicable), number of through lanes, number of turn lanes, surface type, curb type, shoulder type, shoulder width, approach width, and median width, type, and presence of curbing. Other parameters that were also recorded included direction of travel that inventory is proceeding, date that roadway characteristics are initiated or updated, land use characteristics, speed limit (posted or unposted), horizontal geometrics (degree of curve, direction of outside of curve, radius of curvature, and rate of superelevation) in direction of travel, vertical geometrics (grade direction and percentage of grade) in direction of travel, passing-zone markings, date of initial paving for a section of roadway, average daily traffic (ADT), and stopping-sight distance.

Each section of roadway was divided into 0.1-mile segments for analysis purposes. Based on previous research and study efforts (1,2), this segment length was determined to be reliable to adequately define a section of roadway based on its roadway characteristics.

The roadside-obstacle inventory was also developed from photolog records. This inventory included the following parameters: main-street name, cross-street name, distance and direction of object from a reference cross street, side of street that object is situated, presence or lack of curbing, horizontal geometrics (degree of curve, direction of outside of curve, radius of curvature, and rate of superelevation) in direction of travel, vertical geometrics (grade direction and percentage of grade) in direction of travel, rigidity of fixed object (assigned by Road Commission for each obstacle type), ADT, speed limit, distance object is located from roadway (pavement) edge, roadway type (primary or local), obstacle type, and priority factor (based on formula derived by Road Commission staff).

A common location-reference system was applied to both inventory data bases in order to allow a merge of the roadway, roadside-obstacle, and accident characteristics. The reference system used was based on the Michigan Accident Location Index (MALI), part of a statewide reference system that involves the designation of a primary road (PR) number for each roadway or roadway section and a system of mile points used to locate the reference distance along the roadway. This reference system was selected due to its availability, accuracy, and current use in the accident data available to the Road Commission.

The accident data base currently existed as a part of the statewide MALI system. These data records are periodically sent to TIA, which is responsible for the local use and needs of the accident data. The information supplied on each accident record includes the following: PR number for street in which the accident occurred, mile point along street in which the accident occurred, accident report number, date and day of accident, time of accident, functional classification of route in which the accident occurred, weather conditions during accident, lighting conditions during accident, road surface conditions during accident, road defects (if any), traffic controls in the accident area, highway area type, roadway alignment (general), accident location (general description of roadway type), accident type, accident where (e.g., at intersection, at driveway, not at intersection), accident how (accident situation, e.g., head-on, rear-end, etc.), and accident severity. The accident record also included information on the following characteristics: drinking-related accident; police agency performing investigation; contributing circumstances; police enforcement action; driver age, residence, sex, and degree of injury; vehicle information; driver or pedestrian intent; hazardous actions; presence of visual obstructions (if any); object hit (if object-related accident); vehicle impact codes; and other special information.

Once the individual data bases were developed (i.e., roadway, roadside, and accident), a merged roadway-accident-roadside information system was developed. The purpose of this system was to provide a single data base that contains the roadway, accident, and roadside characteristics along all sections of county-maintained roads. This merged system would allow the detailed analysis capabilities for all merged roadway, accident, and roadside characteristics. By using a common reference system for each data base, the merge system was easily generated.

Data-Analysis Capabilities

To permit desirable data-analysis capabilities with the comprehensive roadway-information system developed for the Oakland County Road Commission, the use of a statistical computer package was employed. The statistical package selected was in use in the Oakland County Computer Center and, as such, was readily available.

The selected computer package was the Statistical Package for the Social Sciences (SPSS). SPSS is specifically designed for analysis of social-science data. Its use is readily intended for analysis of the data bases provided in the developed inventories. SPSS affords the user the capabilities of sorting, ranking, duplicating, and searching various options, numerous data transformations, and various statistical and numerical analyses.

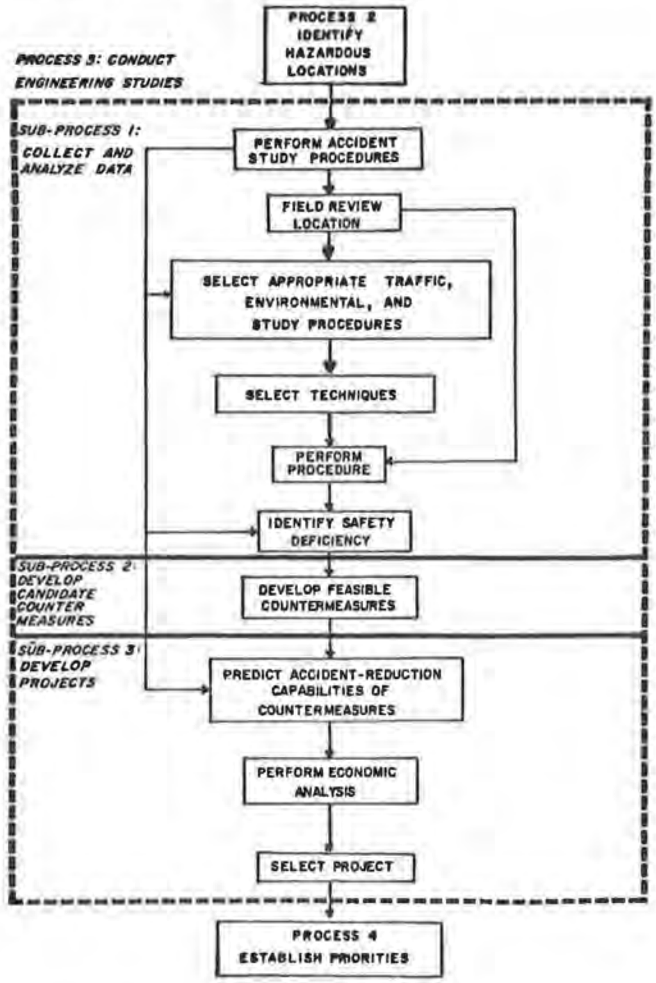
Although most of the available SPSS capabilities are employed in the SPSS version available to the Road Commission, the most common subroutines planned for use consist of the following:

1. Frequencies,
2. Crosstabulations,

3. Condescriptive
4. Regression,
5. Breakdown,
6. Analysis of variation (ANOVA),
7. Report,
8. NPAR tests, and
9. Various bi-variate correlation analysis subprograms.

Other subroutines are available that can provide further detailed statistical analyses of the data bases. Their uses are documented in the SPSS manuals (3,4).

Figure 1. Safety engineering investigation procedure.



SYSTEM USE IN SAFETY PROBLEM ANALYSIS

One of the planned uses of the computerized roadway-information and analysis system developed for the Oakland County Road Commission is in the identification of safety problems and countermeasures for identified hazardous locations or features. The use of this system for these purposes is based on the premise that a site or feature has previously been identified as hazardous and requires identification of safety problems.

The basis for determining safety problems at a location is by identifying patterns in accident characteristics. Accident characteristics that recur at a location provide information used to aid in identifying safety problems. For example, the occurrence of a pattern of wet-weather accidents may indicate a slippery roadway surface as a possible safety problem. Other accident information or engineering studies may verify that a slippery roadway surface did or did not cause a safety problem. Initially, however, a safety problem was indicated by the occurrence of an accident pattern related to wet-weather conditions. Accident patterns, therefore, are the primary means used to identify safety problems.

Once the safety problems are defined, accident patterns are used to suggest feasible countermeasures to reduce or alleviate the defined safety problems. Cost-effectiveness studies and the results of other considerations are used to select a safety project for a site. A flow chart of the safety engineering study process is shown in Figure 1.

In the safety engineering study process displayed in Figure 1, the review of accident characteristics is vital in various steps of the process. For instance, the accident data are used as input in the field review; the selection of traffic, environmental, and special studies; and the identification of safety deficiencies. As a result, the need for accurate identification of accident patterns is critical to the safety study of a location. For accident-analysis purposes, two approaches to identify an accident pattern are typically available: (a) cluster analysis and (b) expected-value analysis.

The cluster-analysis method involves the visual inspection of accident-collision diagrams or summaries to observe the clustering or grouping of specific accident characteristics. Patterns are normally identified by an abnormal occurrence of a specific characteristic in relation to other accident characteristics that occur at a site. For instance, at a spot location with one rear-end accident, four run-off-road accidents, and two sideswipe accidents, the run-off-road accidents could be defined as a pattern. In some cases, the sideswipe accidents may also comprise a pattern. The identification of accident patterns in these cases is primarily based on the engineering judgment of the safety engineer. However, in everyday use, the accident activity that will comprise a pattern may vary from site to site and agency to agency, depending on the safety engineer's past experience in accident analysis.

A more reliable means of accident-pattern identification employs the statistical analysis of accident information. One means of statistical analysis is expected-value analysis. Expected values for specific accident characteristics are determined based on a statistical review of similar type sites. The expected values are used to define overrepresentations or critical values of the accident patterns for a study site. A comparison of the accident characteristics at the study site with other similar sites is made to determine accident patterns at a site. Assuming that the accident occurrences are normally distributed, accident characteristics below the critical value will not represent a pattern; however, values at or above the critical value will identify an accident pattern. This type of analysis defines critical values for accident characteristics at all types of locations.

Expected-Value Analysis

The expected-value analysis is a systematic mathematical procedure for identifying abnormal accident characteristics. To use this approach, accident data for similar sites (geometrics, volume, traffic control, etc.) are obtained and the average number of specific accident characteristics is determined. To account for variability or fluctuations in the data between sites, the use of the variance of the frequency of the specific accident characteristic is made to establish a range for an expected value. Assuming that accidents are normally distributed, the range of expected values can be defined as follows (5):

$$EV = \bar{X} \pm Ks \quad (1)$$

where

EV = expected range of frequency of an accident characteristic,
$\bar{X}$ = average frequency of an accident characteristic (e.g., accidents per number of sites),
K = factor that relates selected level of confidence that a site will have a specific accident frequency, and
s = standard deviation of accident frequencies.

Average and standard deviations may be obtained by standard statistical relations:

$$X = \Sigma FX/n \quad (2)$$

and

$$S = \sqrt{[\Sigma F(X - \bar{X})]^2/(n-1)} \quad (3)$$

where

$\bar{X}$ = average frequency of an accident characteristic (accidents per number of sites),
F = number of sites with a given frequency of a selected accident characteristic,
X = accident frequency of nth site,
n = total number of sites, and
S = standard deviation of frequency of accident characteristic.

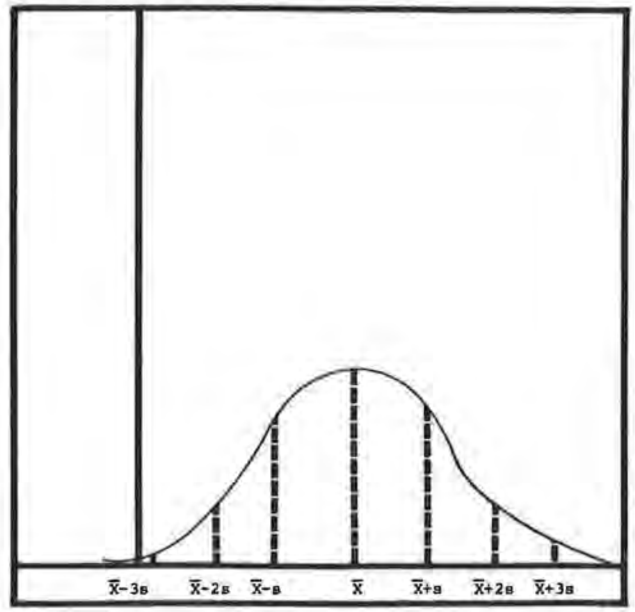
The K-value is based on the desired level of confidence that a site will have accident characteristics in a defined range. Values of K and their respective confidence levels are shown in the table below (note: 50.0 is the average value):

K	Confidence Level (%)
0.00	50.0
1.00	68.3
1.96	95.0
3.00	99.7

The expected range values for any given section with similar characteristics increase as the confidence level increases. Figure 2 displays this relation.

The above values are used in defining a range of expected values for an accident characteristic of $X \pm Ks$. For accident-analysis purposes, safety analysts are typically concerned with the expected values along the right-hand portion of the normal curve. In the past, many safety engineers have used average values as the critical level used to define an accident pattern. This situation would allow for a 50 percent level of confidence that an accident characteristic would occur above the critical value. However, to increase the reliability that the expected value is defining an accident pattern, a greater level of confidence is desired, as shown in Figure 2. From this figure, it is shown that all accident frequencies to the right of the critical or expected value would represent an overrepresentation, i.e., an accident pattern.

Figure 2. Relation of confidence level in a normal distribution.



An example of the use of expected-value analysis is shown below. Accident-type characteristics for 14 similar sites reveal that the average annual frequency for the sites are as follows: 2.05 left-turn accidents, 3.56 rear-end accidents, 1.52 right-angle accidents, 1.32 sideswipe accidents, and 0.50 pedestrian accidents. Accident-type characteristics for the similar study site were as follows: 1.42 left-turn accidents, 2.48 rear-end accidents, 3.52 right-angle accidents, 0.78 sideswipe accidents, and 0.00 pedestrian accidents. By using expected-value analysis at the 50 percent level of confidence (average values), the right-angle accidents result in an overrepresented condition or accident pattern. The other accident types are below the defined critical level and do not represent accident patterns.

Expected-Value Analysis by Using the Comprehensive Roadway-Information System

The concept of expected-value analysis is currently used by the Oakland County Road Commission to assist in the accident analysis and countermeasure-selection phases of its highway-safety and highway risk management programs. By using the comprehensive roadway-information system, similar sites can be identified. Site characteristics used in defining similar sites include the following:

1. Number of traffic lanes,
2. Intersection type (where applicable),
3. Roadway surface (paved versus unpaved),
4. Shoulder width (ranges),
5. Horizontal geometrics (tangent, 1°-3° curve, 4°-6° curve, etc.),
6. Vertical geometrics (flat, 1 percent grade, 2-3 percent grade, 4-6 percent grade, etc.),
7. Curb type (curbed versus uncurbed),
8. Presence of median (median type and width),
9. Land use,
10. Speed limit, and
11. Volume--ADT (ranges).

In some cases, to acquire a large enough sample of similar sites it is required that some of the roadway parameters be relaxed to allow a wider range for a specific parameter and permit a greater number of sites to fit the criteria. Also, in some cases certain parameters may be considered insignificant for a specific analysis and may be removed from the criteria for that specific analysis. The site characteristics of the study location dictate the values of the parameters to be used in the expected-value analysis. For example, if a rural two-lane curved section of highway is identified as the study location, the site characteristics for this site will set the parameter values.

The SPSS computer package is used to identify similar sites, their accident characteristics, and the standard statistics (mean, standard deviation, minimum and maximum values, number of cases, etc.) associated with the accident characteristics. Initially, the data bases are searched to select from the roadway inventory only those records with similar parameters, as specified by the user. For example, to select similar sites for rural two-lane curved sections of highway, the computer command may read as follows:

```
SELECT IF [(ROADLANE EQ 2) AND (LANDUSE EQ 2) AND
   (HORIZGEO GTE 002)].
```

It should be noted that in SPSS, all alpha values require recoding to a numeric character. The value of 2 for the LANDUSE parameter actually refers to a 2=rural condition.

Once the data file has selected only those roadway records that have the specific roadway characteristics, a statistical subroutine is applied to the subfile to define the key statistics for the required accident characteristics. For example, the SPSS command used for obtaining descriptive statistics is CONDESCRIPTIVE--VARACC01 TO VARACC12. This command will provide the descriptive statistics for those accident variables listed above (i.e., VARACC01 TO VARACC12).

The output of this command can supply all or some of the following statistics and numbers: mean, standard error, standard deviation, variance, kurtosis, skewness, range, minimum, and maximum. These statistics are used in the formula for the expected value to derive the critical level of accident characteristics for the study site.

The value of each accident characteristic for the study site is then compared with the critical values defined for the similar sites. By using the expected-value concept, accident patterns are identified where the study-site frequencies are at or above the critical values. Values below the critical numbers are not defined as a critical pattern.

To adequately use the expected-value analysis, two considerations should be observed. First, in order to develop significant critical values, it is necessary to select an adequate sample size of similar sites. Sample-size formulas are available in various sources (_6_,_7_). The sample size is a key determinant of the level of significance of the findings. Where a sufficient sample size is not available, parameters may be relaxed or removed where their impact is not considered significant, or a lower level of confidence for the findings must be assumed. On a county level, the sample size will typically be insufficient. However, the relaxation or removal of limiting parameters can significantly increase the sample sizes to acceptable levels.

A second consideration concerns the level of confidence chosen for the analysis. The effect of a high-confidence level will result in a short list of critical accident patterns. Less-stringent confidence requirements will result in a greater list of accident patterns. The length of the list is dependent on the safety engineer's experience and judgment. If the safety engineer desires to resolve the most critical safety problems, more stringent requirements should be made. However, if the objective is to resolve all levels of safety problems, lower requirements should be specified. With recent reductions in highway-safety budgets, a more stringent level may typically be used. By resolving the critical safety problems, more cost-effective solutions can be developed, thereby resulting in more efficient use of available safety funds.

OTHER SAFETY USES OF COMPUTERIZED ROADWAY-INFORMATION SYSTEM

In addition to the use of the computerized roadway-information system as a tool for identifying safety problems at a site, the system can also be used in selecting favorable countermeasures or safety projects for a site. The procedure involves the identification of accident characteristics for a group of similar sites. The analysis of a group of sites with field conditions similar to those of the study site, except for one altered condition, will provide a record of accident statistics for the field situation with the altered condition. For example, the safety impacts of paving the shoulder of a two-lane roadway can be predicted. A comparison of the accident characteristics for the two situations will identify whether the countermeasure has a positive or negative safety impact. In this way, accident-reduction factors can be developed. It can be assumed that the difference in accident characteristics represents the effect that a specific countermeasure (altered condition) will have on the field situation. These analyses can be made for several countermeasures to assist in determining the most favorable project based on highway-safety objectives.

SUMMARY AND CONCLUSIONS

The development of the computerized roadway-information system for the Oakland County Road Commission provides a major advantage to the Road Commission's highway risk management and highway-safety programs. A significant increase in the roadway, roadside, and accident study and analysis capabilities occurred following the development of the system. As increased use of the system occurs, greater developments and innovations in its applications will result.

This paper discussed two current uses of the roadway-information system. They are (a) the identification of safety problems and (b) the selection of countermeasures. Some deficiencies do occur with the data base due to the limited number of similar sites typically afforded a county area. However, with the relaxation of constraints, this problem can be dealt with effectively. The roadway-information system does, however, allow the Road Commission to study and review the accident activity and their characteristics for the area under its jurisdiction. In this way, the county can more closely monitor and dictate the safety needs of its highways. The result is an increase in safety and an improved highway risk management program, thereby permitting more effective use of the highway tax dollar in the Oakland County area.

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Four Approaches to Instruction in Occupant-Restraint Use

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The results of four test programs for increasing teenage occupant-restraint use are presented. Each program contained an informational component while three programs provided additional learning experiences—a testimonial, operation of a vehicle, and use of a safety-restraint convincer. Conclusions show that the programs are a promising way to educate teenagers about using restraints.

Although the use of occupant restraints represents the single most valuable way of reducing traffic injuries and fatalities, use continues to be very low. The use rate for drivers in the United States is only about 10 percent while the rate for young people (ages 16-19) is even lower. Since young drivers are overrepresented in the number of traffic accidents, it is extremely important to encourage the use of occupant restraints in this segment of the population.

The National Highway Traffic Safety Administration funded a study for the development, implementation, and evaluation of several supplementary driver-education programs to be taught subsequent to the standard driver-education curriculum. One of these programs deals with occupant restraints.

The main objective of the restraint program is to teach teenage drivers to use safety restraints and encourage their passengers to do the same. Other objectives include teaching the students the value of safety belts in reducing injuries and fatalities as well as the risks associated with nonuse. In addition, the course encourages favorable attitudes toward restraints, including the belief that restraints are valuable and that the safety of passengers is the driver's responsibility.

NATURE OF PROGRAM

To attain these goals and objectives, four individual driver-restraint programs were developed. Each program contained an informational component while three of the programs provided additional learning experiences, which included a testimonial, operation of a vehicle, and use of a safety-restraint convincer. A brief description of each program is presented below:

1. Information only--The information program consists of 3 h of classroom instruction. No behind-the-wheel or other learning experience is provided. The classroom activities are, however, supported by a film. The information contained in the student materials and the film is directed toward cognitive and additudinal aspects of safety restraints. This program is designed to provide students with factual information about restraints and to increase their perception of the risks associated with nonuse.
2. Testimonial--The testimonial program includes the information contained in the previously described program. In addition, it provides an audiovisual presentation that consists of a testimonial in which an age peer describes an accident, the nature and extent of any injuries, and the disabilities that resulted from the crash.
3. Vehicle--The vehicle program adds to the information program the experience of riding in a vehicle, both restrained and unrestrained, through a series of emergency maneuvers. The maneuvers were selected to show the effect of restraint use on ability to control the vehicle in an emergency.
4. Convincer--The convincer program combines with the information program the use of a device designed to demonstrate the forces experienced in a crash. A sled with a car seat and safety-restraint system is mounted on an inclined plane at approximately a 45° incline. The sled is raised to the top of the incline and allowed to slide freely to the bottom. Persons, properly restrained, ride the sled and can feel the forces exhibited in a simulated crash.

METHODS

A before-and-after design was employed to evaluate each of the four programs. The programs were administered at four high schools in St. Louis, Missouri. Approximately 100 students were available at each school, each school administering only one program. The use of four different schools was necessary to be able to determine the effects of each program on actual restraint use. If more than one program had been given at each school, there would have been no way of knowing, as students arrived and left in their cars, which students received which program.

The measures employed to evaluate the program were as follows:

1. Knowledge test--A paper-and-pencil test that contained items on the facts of restraint use, the risks of injury, and the effects of nonuse on occupants;
2. Attitude test--A multiple-choice measure that presented scaled opinions concerning the use of restraints; and
3. Use of restraints--Observations were made on students' use of safety restraints while coming to