is a blank card. Card sets are simply stacked so that as many cases can be run as desired. To facilitate adaptation to a particular computer, both CBC and IBM operational versions of the programs have been prepared. The computer programs are small, and run times are minimal.

Interpretation of the computer output results is not difficult. For example, Figure 1 shows a typical COCOST output sheet, in which it can be seen that the guardrail types are ranked by state cost, societal cost, total cost, and benefit-to-cost ratio in the order of decreasing preference (the best is number 1 and the worst is number 11), along with the corresponding values. Thus, the G2 system is the preferable guardrail for this site from the standpoints of either societal cost, total cost, or benefit-to-cost ratio. The analyst can select the cost-effectiveness measure desired and can extract the indicated values, along with the corresponding state cost, for subsequent analyses to establish priorities for appropriation of funds or for other uses.

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Abridgment

Computerized Inventory and Priority Analysis for Roadside Obstacles

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Highway safety is significantly influenced by the design and maintenance of the roadside environment. During 1976, over 26 percent of all fatal accidents in Michigan involved collisions with fixed objects in or adjacent to the roadway. Recent highway safety programs emphasize hazard-free roadway facilities and have resulted in reduced accident severity associated with single-vehicle collisions with roadside obstacles. Such programs generally involve the removal, relocation, or protection of roadside obstacles. Even though the potential safety benefits derived from roadside improvement programs are substantial, the traffic engineer is faced with the high cost of removal or relocation of roadside obstacles and the need for a practical program for the identification and prioritization of hazardous roadside obstacles.

In order to make informed decisions regarding the allocation of safety funds for roadside hazard removal, the traffic engineer must first establish a comprehensive data base of the type and location of all potential hazards as they exist along the highway and the relative hazardousness of each. With this information, a systematic roadside safety program may be developed to eliminate or protect those obstacles that present the greatest hazard to the motorist.

This paper describes a computerized information system consisting of a comprehensive inventory of all roadside obstacles in the city of Livonia, Michigan. Livonia is located in the northwestern part of the Detroit metropolitan area and covers 92.9 km^2 (36 $miles^2$) with a population of 110 000 persons. The highway system consists of approximately 483 km (300 miles) of roadway.

In 1976, Livonia experienced a total of 3889 accidents, of which 6 percent were collisions with fixed objects. However, these fixed-object accidents accounted for over 33 percent of all 1976 fatal accidents in the city.

The inventory system incorporates a prioritization mechanism that provides the traffic engineer with a measure of the relative hazard potential associated with each type of roadside obstacle and with the priority to be given to eliminating or protecting that obstacle.

INVENTORY OF ROADSIDE OBSTACLES

Data Collection

The data source from which information on roadside obstacles' type and location was extracted for the development of a computerized inventory of roadside obstacles was 35-mm color photologs. Photologging is a photographic data-collection technique that records a pictorial representation of the roadway and its environs. An instrumented vehicle equipped with a 35-mm color movie camera, distance-measuring instrument (DMI), and a camera actuation device were used for the photologging process. Camera actuation was set at 62 frames/km (100 frames/mile) or every 16.1 m (52.8 ft). The distance traveled by the vehicle from predetermined benchmarks was recorded by the DMI and superimposed on the photolog along with the street name, date, time of day, and direction of travel.

Data Extraction

Data extraction involved viewing the photologs using photoviewing equipment on a frame-by-frame basis. The criteria for identifying an object as a roadside obstacle included the following factors:

1. Type of object,
2. Lateral distance of the object from the edge of the roadway,
3. Physical dimension of the object, and
4. Existence of curbs along the roadway.

During discussions with city officials, the following conventions were established for the determination of what objects would be recorded in the inventory. On curbed roadway sections, obstacles were recorded if they were located within 1.22 m (4 ft) of the curb. For uncurbed roadways, 3.05 m (10 ft) was used as the lateral distance criterion.

Data extraction was performed by trained photoviewing analysts using photolog viewing devices. Roadside obstacles were located longitudinally with respect to the nearest cross street by using the DMI reading on each photolog and adding to that the distance to the obstacle from the photologging vehicle. This distance was determined by the use of a calibrated grid placed on the viewing screen. The grid was also used to determine the lateral distance of the obstacle from the curb or edge of the roadway.

Other information including the direction of travel, main street and cross street names, and obstacle type was recorded and added to the roadside obstacle inventory program. A total of 2342 roadside obstacles were recorded during the data extraction process for Livonia.

Figure 1 shows a typical printout of the roadside obstacle inventory.

SEVERITY RANKING PROCEDURE

A practical priority-ranking scheme that can be easily used and understood at the local level is necessary, if limited roadside improvement funds are to be optimally allocated. The procedure for developing the replacement indices contained in this roadside obstacle inventory was developed to meet this need. Other research (1, 2) conducted to date has resulted in prioritization techniques that have made a significant contribution to the state of the art. However, they are somewhat complicated and often prove to be impractical for use in large-scale applications such as a comprehensive inventory of all roadside obstacles for a community. The priority-ranking procedure used in the determination of the replacement indices is based on the following basic assumptions:

1. For curbed roadway sections, obstacles located within 1.22 m (4 ft) of the edge of the curb constitute a potential hazard in a single-vehicle collision.
2. For uncurbed roadway sections, obstacles located within 3.05 m (10 ft) of the edge of the roadway constitute a similar hazard.
3. The probability of an obstacle being involved in a

Figure 1. A typical printout of a roadside obstacle inventory.

CITY OF LIVONIA, ROADSIDE OBSTACLE REPORT AS OF : 07-28-77 PAGE 001
DEPARTMENT OF PUBLIC WORKS

OBSTACLE NUMBER	MAIN STREET	CROSS STREET	DIST & DIREC FROM INTERSEC		SIDE OF STREET	OBSTACLE TYPE	CURB	DATE	CURB DIST	SEVER RANK	REPL INDEX
01020000100	ANGLING	SEVEN MILE	1148	NORTH	EAST	TREE(S)	NOCB	110976	9	12	24
01020000200	ANGLING	FLORAL	100	NORTH	EAST	TREE(S)	NOCB	110976	5	12	72
01020000300	ANGLING	FLORAL	186	NORTH	EAST	TREE(S)	NOCB	110976	3	12	96
01020000400	ANGLING	FARGO	196	NORTH	EAST	ROCK(S)	NOCB	110976	3	4	32
01020000500	ANGLING	FARGO	330	NORTH	EAST	ROCK(S)	NOCB	110976	4	4	28
01020000600	ANGLING	FARGO	317	NORTH	WEST	WOOD UTILITY	NOCB	110976	8	11	33
01020000700	ANTAGO	SEVEN MILE	50	NORTH	EAST	FIRE HYDRANT	NOCB	110976	7	5	20
01020000800	ANTAGO	VASSAR	45	SOUTH	EAST	FIRE HYDRANT	NOCB	110976	7	5	20
01020000900	ANTAGO	GRAND RIVER	246	SOUTH	WEST	ROCK(S)	NOCB	110976	7	4	16
01020001000	BRENTWOOD	SEVEN MILE	0		WEST	NO OBSTACLES	CURB	110976	0	0	0
01020001100	BRETTON	PARKVILLE	0		SOUTH	NO OBSTACLES	NOCB	110976	0	0	0
01020001200	BRETTON	MAPLEWOOD	0		SOUTH	NO OBSTACLES	CURB	111276	0	0	0
01020001300	BRIDGE	RENSELLOR	153	EAST	NORTH	TREE(S)	NOCB	111276	6	12	60
01020001400	BRIDGE	INKSTER	30	WEST	SOUTH	ROCK(S)	NOCB	111276	5	4	24
01020001500	DEERING	ST MARTINS	10	SOUTH	WEST	TREE(S)	NOCB	110976	6	12	60
01020001600	DEERING	PEMBROKE	50	NORTH	EAST	FIRE HYDRANT	NOCB	110976	7	5	20
01020001700	FARGO	DEERING	159	EAST	NORTH	HEAD WALL	NOCB	111276	8	7	21
01020001800	FARGO	DEERING	120	EAST	SOUTH	TREE(S)	NOCB	111276	9	12	24
01020001900	FARGO	WEYHER	153	EAST	SOUTH	POLE(S)	CURB	111276	4	6	6
01020002000	FARGO	BRENTWOOD	63	WEST	SOUTH	TREE(S)	CURB	111276	3	12	24
01020002100	FLORAL	PEMBROKE	0		WEST	NO OBSTACLES	NOCB	110976	0	0	0
01020002200	GILLMAN	NORFOLK	0		WEST	NO OBSTACLES	NOCB	110976	0	0	0
01020002300	LATHERS	DEAD END	414	SOUTH	WEST	TREE STUMP	NOCB	110976	5	12	72

single vehicle collision and, therefore, its relative hazardousness is a function of its distance from the curb or edge of the roadway.

4. The relative hazardousness of an obstacle is a function of its design and rigidity.

The type and rigidity are reflected in the severity-ranking index assigned to the 12 selected categories of roadside obstacles recorded in the inventory system. The severity-ranking values range from 1 to 12, based on the rigidity and type of the obstacle and its potential for causing harm to the occupants of a vehicle on impact. The highest severity ranking was assigned to trees, which had a value of 12, and the lowest severity-ranking value was shrubbery, which had a value of 1.

Two replacement index algorithms were developed for this application—one for obstacles located along curbed roadway sections $(RI)_c$ and others for uncurbed sections $(RI)_{nc}$.

For a curbed roadway, $(RI)_c = [(5 - \text{lateral distance}) \times \text{severity ranking}]$. For an uncurbed roadway, $(RI)_{nc} = [(11 - \text{lateral distance}) \times \text{severity ranking}]$.

The possible values for the replacement index range from 1 for shrubbery (severity ranking = 1) located 1.22 and 3.05 m (4 and 10 ft) from the edge of a curbed and uncurbed roadway section respectively to 132 for a tree (severity ranking [SR] = 12) located at the edge of an uncurbed roadway section. In addition, the analysis of roadside obstacles gave higher priority (replacement index) to obstacles along uncurbed than along curbed roadway sections.

It was determined that the roadside obstacles that present the greatest hazard potential (trees, SR = 12; utility poles, SR = 11; mast arm supports, SR = 10; buildings, SR = 9; guardrails, SR = 8) constitute 48 percent of the total number of roadside obstacles recorded in the inventory. The treatment of hazardous roadside locations on the basis of obstacle type alone represents lengthy and costly roadside improvement program requirements if all high-severity obstacles are to be removed, relocated, or protected. However, the application of the priority procedure indicates that, based on the underlying assumptions that form the basis of the replacement index algorithms, a significantly lower number of obstacles require immediate treatment. In terms of the magnitude of the replacement indices (RI), which have been qualitatively stratified as low (RI = 0 through 45), medium (RI = 46 through 90), and high (RI = 91 through 132), approximately 3 percent (78) of all roadside obstacles have been identified as exhibiting a high replacement index. These obstacles should be given first priority in the roadside improvement program. Furthermore, the replacement indices for those obstacles in the high-priority range will provide the traffic engineer with a rank ordering of those obstacles requiring preferential treatment.

CONCLUSIONS

The computerized inventory and priority-ranking scheme for roadside obstacles provides a community with a practical tool for managing and improving the roadside environment. With it, an application may be made for federal funding for the planned removal, relocation, or protection of the most hazardous obstacles along the roadway, thereby maximizing the accident-reduction potential for each safety dollar spent. Once improvements have been made, the capabilities of the inventory system allow for continued updating to reflect the type of work that was done.

For Livonia, Michigan, 2342 roadside obstacles were recorded, of which almost 50 percent were high-severity potential obstacles—trees, utility poles, buildings, or guardrails. However, the application of the replacement index algorithm identified only approximately 3 percent (78) of all roadside obstacles as being in a high replacement category. Thus, the planned improvement of these sites may provide a substantial savings in accidents and accident severity in a cost-effective manner.

It is our intent to refine the existing system by correlating single-vehicle, fixed-object accidents in Livonia with the roadside obstacle inventory to obtain a better picture of the severity potential associated with various roadside obstacles and their characteristics. Also, future refinements can be made in the prioritization algorithm to account for traffic volumes, roadway geometrics, and other roadway information that can be obtained from photologs to further define the degree of hazard potential of roadside obstacles. However, a conscious effort will be made to maintain the simplicity and practicality of this system as a roadside management tool.

ACKNOWLEDGMENT

The opinions, findings, and conclusions expressed in this paper are ours and not necessarily those of the state of Michigan or the U.S. Department of Transportation, Federal Highway Administration.

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