Adapting the U.S. Department of Transportation Rail-Highway Crossing Resource Allocation Model to the Microcomputer

JOHN M. MUTH and RONALD W. ECK

ABSTRACT

The U.S. Department of Transportation developed a resource allocation model to assist state highway agencies in setting priorities for rail-highway grade crossing improvement programs. Because of the size of the supporting data bases, use of the model has required a mainframe computer. Use of the microcomputer for the resource allocation model avoids the lengthy turnaround times and high costs associated with mainframes. The process of adapting the model and associated data bases to an Apple II+ microcomputer is described. Data needed by the user are manipulated on a mainframe by using an appropriate data base management system. When the data for a given state are in an acceptable format, they are transferred to diskette using a commercial communications software package. The user can then implement the programs that make up the resource allocation model. Guidance on implementing the package is given. The adapted programs are written in Applesoft BASIC and are user friendly. The resource allocation procedure has been made interactive; users can change funding levels or equipment costs and determine in a matter of minutes the impact on the grade crossing program. Several conclusions have been drawn and recommendations made. Various methods for making the results of this effort available to interested parties are suggested.

The need to reduce accidents at rail-highway grade crossings has led to the development of various methods of warning drivers about the crossings or potential train-vehicle conflicts or both. Grade crossing warning devices include signs, pavement markings, flashing lights, and automatic gates. With these various driver-warning methods available, the problem becomes one of selecting the appropriate warning device for a given situation. Obviously, the ideal solution would be to install gates at all rail-highway grade crossings for which separation is not economically feasible. However, this is not practical because of budget constraints, so use of gates is usually reserved for the most dangerous crossings and less-effective devices are installed at the other locations.

The problem of budget constraints dictates that whatever money is available must be spent in a manner that will realize the most benefits (e.g., reduction in accidents). For this reason, the federal-aid highway program requires that each state have a systematic procedure for determining grade crossing improvement priorities.

The most reliable source of data regarding all grade crossings is the National Railroad-Highway Crossing Inventory of the U.S. Department of Transportation (DOT) and the Association of American Railroads (AAR). Instituted in 1975, the inventory is a cooperative effort among FHWA, FRA, AAR, and the individual states. The objective of the national inventory was to assign a unique identification number (national crossing inventory number) to each crossing and to place on a computer file data about the physical and operational characteristics (e.g., rail and highway traffic, warning devices, and administrative responsibility) of all public grade crossings, grade separations, private crossings, and pedestrian crossings.

J.M. Muth, Vanasse/Hangen, 60 Birmingham Parkway, Boston, Mass. 02135. R.W. Eck, Department of Civil Engineering, West Virginia University, Morgantown, W. Va. 26506.

At about the same time as the establishment of the inventory, FRA decided to revise accident reporting requirements. Before this time, the reporting of grade crossing accidents was incomplete and lacked detail as to the exact location of an accident. However, the new requirements provided for more accurate locating of such accidents and the reporting of all accidents or incidents, not just those above a threshold value. The new accident reporting form (known as an accident/incident report form) included the national crossing inventory number. This provided a link between the inventory file and the accident data file. The railroads have been required to use this form since January 1975. Thus, comprehensive accident data are available back to 1975.

Budget constraints require that states have a systematic procedure for determining improvement priorities. This procedure should allocate funds in a manner likely to produce the greatest accident and casualty reduction benefit. Most state agencies favor use of a hazard index formula to indicate crossings with the greatest need for improvement. Previously, the procedure in making safety improvement decisions was to first rank all the crossings by some hazard model. From this list, the most hazardous crossings were selected for further consideration. On the basis of information gathered from on-site visits, the applicability of available alternatives, and expected safety improvements, a final decision was made. The result was a list of the most hazardous crossings.

The availability of the DOT/AAR National Railroad-Highway Crossing Inventory and accident data permitted development of the Resource Allocation Model (RAM). Development of accident prediction formulas was a necessary intermediate step. The DOT rail-highway crossing accident prediction formulas were developed by utilizing nonlinear multiple regression techniques applied to the crossing characteristics in the national inventory and the accident data compiled by FRA. The model calculates the expected annual accident rate at a crossing.

Note that the DOT accident prediction formulas produce an absolute prediction, which stands alone, as compared with available hazard indices (e.g., the so-called New Hampshire index), which produce a relative index for each crossing; the latter have value only in comparing the individual index for one crossing with that of another crossing similarly developed. The DOT accident prediction formulas were developed because no commonly accepted absolute prediction process was available, and one was needed for the RAM.

On the completion of the DOT accident prediction formulas, the RAM was developed (1). The model determines at which crossings motorist warning devices should be installed so as to achieve the maximum crossing safety benefit for a given level of funding. The net result is a list of the most cost-effective improvement decisions. Possible grade crossing improvements include changing (a) passive devices to flashing lights, (b) passive devices to gates, and (c) flashing lights to gates.

Inputs to the RAM include the predicted accident rate of the crossing, costs and effectiveness of the different improvement options, and the budget level available. Cost data required are the life-cycle costs of implementation and maintenance for each of the possible upgrade options. Effectiveness is defined as the fraction by which accidents are reduced after installation of a warning device at a crossing.

The RAM provides a ranked list based on benefit/cost ratios. Benefit is expressed as predicted accidents prevented per year and cost is the life-cycle cost of the equipment. The algorithm considers the benefit/cost ratios beginning with the largest ratio and continuing in decreasing order. The process continues until the monies spent (life-cycle costs of recommended warning devices) equal or exceed the available budget. Thus, an optimal list of recommended improvements is obtained.

The primary function of the resource allocation procedure is to assist states and railroads in preparing statewide grade crossing improvement programs. Because of the magnitude of the inventory and accident data bases, use of the model has required a mainframe computer. In many cases the mainframe computer may be shared by several agencies, creating availability problems and lengthy turnaround times. In other cases, computer facilities may be operated by a separate agency and user costs may be quite high. Compounding these problems is the fact that most practicing engineers are not skilled in working with such large data bases. Thus, support personnel may be required to install and use the system.

Most state transportation agencies currently have personal computers and microcomputers available for their engineers to use. Thus, it would appear appropriate to try to adapt the resource allocation procedure and the associated data bases to the microcomputer. By doing so, the need for a mainframe computer is eliminated along with the potential related problems just identified. The use of a microcomputer should produce other benefits as well. The resource allocation procedure would become an interactive program. That is, the engineer or technician would be able to adjust funding levels or equipment costs and determine the impact on the grade crossing program in a matter of minutes. Also, the adapted version of the resource allocation procedure would likely be in the BASIC programming language, which is relatively easy to learn and simple to use. This should enable engineers or technicians with no prior programming experience to modify the model.

In order to adapt the RAM and associated data bases to a microcomputer, there are a number of issues that must be addressed. The main question is whether the microcomputer can handle such a large data base and perform the necessary calculations while storing the results. Assuming that this question can be answered affirmatively, there is a need to develop a "turnkey" program, that is, one for which no prior computer experience is required. Finally, the necessary documentation and a user's manual to supplement the software must be prepared.

OBJECTIVES

The overall goal of the effort being reported here was to make the DOT rail-highway grade crossing RAM operational on the Apple II+ microcomputer. Specific objectives of the study were

1. To translate the accident prediction and resource allocation programs from the FORTRAN language used on the mainframe computer to the BASIC language used with microcomputers,
2. To adapt the DOT/AAR National Railroad-Highway Crossing Inventory and accident data for a given state from magnetic tape format to floppy disk format,
3. To confirm that the model and data base have been successfully adapted to the microcomputer by presenting a sample problem using data for a particular state, and
4. To prepare a user's guide to running the RAM on a microcomputer that will assist practicing engineers in using the results of this study.

DATA ACQUISITION AND ADAPTATION OF PROGRAMS

Data Files

In order to adapt the RAM to the microcomputer, it was also necessary to transfer the data base from magnetic tape to floppy disk. The steps necessary for preparation of the data base are discussed and the procedures used to transfer the West Virginia data, which were used as an example to illustrate the procedure, to floppy disk are outlined.

Preparation of Data Base

Copies of the DOT/AAR National Railroad-Highway Crossing Inventory and the FRA accident file for 1975 through 1982 were available on three magnetic tapes at West Virginia University. The data base had been obtained by sending blank magnetic tapes to FRA in Washington, D.C. Through a series of programs utilizing the Statistical Analysis System (SAS) package, the data were manipulated on a mainframe computer in such a manner that the accident history and crossing characteristics pertinent to the RAM took the form of one line of data per public at-grade crossing. Additional data contained in the data base but not utilized by the model were eliminated to make efficient use of disk space. When the data file just described was in the proper format for purposes of the RAM, it was stored on magnetic tape and then transferred to an active disk within the mainframe's active memory so it could be copied to floppy disk.

Transfer to Floppy Disk

The data file was copied onto floppy disk utilizing a commercial communications software package (2). The necessary equipment included the following: Apple II+ microcomputer, video monitor, disk drive, telephone, and micromodem (or equivalent). The transfer procedure entailed accessing the data file on the mainframe computer via the microcomputer, loading the data into the microcomputer's active memory (buffer), and copying the contents of the buffer onto the floppy disk.

The amount of data that could be transferred in one step was constrained by the size of the buffer. It was necessary to repeat the process several times until all the data had been transferred (data for 200 crossings were transferred per iteration). Total time required to transfer the data for West Virginia's 2,451 crossings was approximately 4 hr.

Because the procedure for conversion of data from magnetic tapes is strongly system specific, additional details will not be provided here. Potential users are encouraged to familiarize themselves thoroughly with the particular communications software package they are using before attempting the conversion process.

Before the data files were used on the microcomputer, they were condensed to utilize floppy disk space more efficiently. Blanks between the items of data were deleted and replaced with commas.

Programs

The adaptation of the programs that make up the RAM procedure to the Apple II+ microcomputer is outlined here. The procedure consists of the following three programs, which are run consecutively: accident prediction program, accident-reduction/cost program, and resource allocation program. The programs utilized in this effort are adaptations of the programs developed at the Transportation Systems Center (TSC) for use on a mainframe computer (3). The most notable difference is that the programs used on the Apple II+ microcomputer are written in Applesoft BASIC (the native language of the Apple computer), whereas the TSC programs are written in FORTRAN.

Accident Prediction Program

The accident prediction program takes the characteristics of a rail-highway grade crossing along with its accident history and predicts the number of accidents for that crossing. This program combines two programs normally run on the mainframe into one program to be used on the microcomputer. While the crossings are being processed, a list of the top 500 crossings, based on predicted accidents, is being established and updated. The functions of the accident prediction program are as follows:

- To calculate the predicted accidents for each crossing,
- To sort the output from the previous steps in descending order based on number of predicted accidents, and
- To generate as output the list of the top 500 crossings to be used in the accident-reduction/cost program.

The basic accident prediction formula computes the initial predicted accident rate for each crossing on the basis of the crossing's current warning-device class. If, during the last 5 years, a change in warning-device class took place, the formula computes the predicted accidents on the basis of the previous warning-device class. An adjustment is then made to the predicted accidents by using the appropriate effectiveness factor, shown in Table 1, to account for the influence of the warning-device change. This will more accurately determine the short-term (less than 5 years) change in the crossing's accident rate compared with the use of the basic formula for the new warning device. For example, if a passive crossing was upgraded to gates, the passive formula would then be used. The result would then be multiplied by the effectiveness factor for gates (0.84) to obtain the initial predicted accidents for the crossing with gates. If a downgrade took place, the predicted accidents would be divided by the effectiveness factor of the new warning device.

TABLE 1 Effectiveness of Warning-Device Improvements (3)

	Effectiveness Factor by Source	
Warning-Device Improvement Option	DOT Study (1980)	California Study (1974)
Passive to flashing lights (E1)	0.65	0.64
Passive to gates (E2)	0.84	0.88
Flashing lights to gates (E3)	0.64	0.66

After the basic number of predicted accidents has been calculated on the basis of the crossing's characteristics, it will be modified to reflect the crossing's actual accident history. The result is the final predicted accident rate for the crossing.

Based on final predicted accidents, a list of the top 500 crossings (i.e., the crossings with the highest number of predicted accidents) will be compiled. The remaining crossings (i.e., all crossings not in the top-500 list) will be deleted from further consideration.

The top 500 crossings serve as input to the accident-reduction/cost program. The final predicted accidents for each crossing along with its basic predicted accidents, record number, DOT/AAR crossing identification number, county identification number, present warning device, number of main tracks, and number of other tracks is written to a data file called PRED. The remaining characteristics for each crossing are not used in future calculations and have been deleted in order to make more efficient use of the limited space available on the data diskette.

A report program has been written that outputs the top-500 list in descending order based on predicted accidents. The output includes the crossing's rank, DOT/AAR crossing identification number, county identification number, and final predicted accidents. Additional variables may be included as desired.

Accident-Reduction/Cost Program

The accident-reduction/cost program is the second program in the rail-highway grade crossing resource allocation procedure. This program utilizes the list of the top 500 crossings (based on predicted accidents) that was developed in the accident prediction program. The functions of the accident-reduction/cost program are summarized as follows:

- Calculate the accident-reduction/cost ratio for all 500 crossings,
- Sort the output from the previous step in descending order on the basis of the accident-reduction/cost ratio, and

• Output the new data to a data file that will be used in the resource allocation program.

The program uses the data file PRED created by the accident prediction program along with input costs shown in Table 2 and effectiveness (shown in Table 1) for the possible upgrades. Suggested values for cost and effectiveness data have been determined by nationwide DOT studies (4). The program uses effectiveness and cost figures that were current when the work was accomplished but that have subsequently been updated (5). Incorporation of the new values into the program is recommended.

The program calculates an accident-reduction/cost ratio for each crossing based on the present warning device and the number of tracks at the crossing. The possible options are discussed in the following paragraphs.

TABLE 2 Warning-Device Improvement Costs, 1980 (*3*)

Warning-Device Improvement Option	Installation Cost[a] ($)	NPV Maintenance Cost[b] ($)	NPV Life-Cycle Cost ($)
Passive to flashing lights (C1)	36,700	21,400	58,100
Passive to gates (C2)	54,700	33,800	88,500
Flashing lights to gates (C3)	49,200	34,100	83,300

Note: NPV = net present value.

[a] 1977 cost times 1.34.

[b] 1977 cost times 1.39.

A crossing that already has gates (warning-device class 8) will be deleted from further consideration because it cannot be upgraded further in terms of warning device. If a crossing has flashing lights or some other active device (warning-device classes 5, 6, and 7), the accident-reduction/cost ratio (AR/C) is calculated in the following manner:

$$AR/C = A(E3/C3) \quad (1)$$

where A is the predicted accidents for the crossing and C3 and E3 are the cost and effectiveness of the upgrade, respectively. If a crossing is passive (warning-device classes 1, 2, 3, and 4) with multiple tracks, the accident-reduction/cost ratio for upgrading to gates is calculated as follows, in accordance with federal guidelines:

$$AR/C = A(E2/C2) \quad (2)$$

If a crossing is passive with only one track, the accident-reduction/cost ratio for upgrading to flashing lights is calculated as

$$AR/C = A(E1/C1) \quad (3)$$

In the event that E2/C2 is greater than E1/C1, the accident-reduction/cost ratio for all passive crossings, regardless of the number of tracks, will be calculated in the following manner:

$$AR/C = A(E2/C2) \quad (4)$$

The reason for this is that the installation of gates is always more cost-effective than the installation of flashing lights. To make the numbers more manageable, all accident-reduction/cost ratios are multiplied by 10^6. Thus, the ratio is expressed in accidents reduced per million dollars.

As mentioned previously, the accident-reduction/cost ratio is calculated for each crossing in the top-500 list. The list is then re-sorted into descending order on the basis of the accident-reduction/cost ratio. All crossings that already have gates will have a ratio of 0 and will be dropped to the bottom of the list during the sorting process.

The top-500 list (now sorted in descending order by accident-reduction/cost ratio) will serve as input to the resource allocation program. The accident-reduction/cost ratio for each crossing along with its final predicted accidents, DOT/AAR crossing identification number, county identification number, present warning device, and the total number of tracks are written to a data file called BENEFIT. A report program has been written that outputs the list of crossings.

Resource Allocation Program

The resource allocation program determines an initial list of recommended crossing improvements that will provide the greatest reduction in accidents for a given budget. The states may use the recommendations as a guide for determining a rail-highway crossing improvement program. The program uses the results from the accident-reduction/cost program as input. The crossings are read in order, starting with the crossing that has the highest accident-reduction/cost ratio.

If a crossing is passive with a single track, an additional incremental accident-reduction/cost ratio is calculated for making an upgrade to gates by using the following equation:

$$AR/C = A(E2 - E1)/(C2 - C1) \quad (5)$$

This is done because the original accident-reduction/cost ratio was determined for an upgrade to flashing lights, and it may prove beneficial to revise the earlier decision from flashing lights to gates. A temporary decision to install lights is made, which is written as TEMP-LIGHTS. The crossing is stored in a separate list while it is determined whether sufficient funds are available to install gates.

Every time a crossing is examined, its accident-reduction/cost ratio is compared with the incremental accident-reduction/cost ratios calculated for the crossings on the temporary-decision list. All crossings on the temporary-decision list with incremental accident-reduction/cost ratios greater than that for the crossing being examined are recommended for further upgrade to gates and are removed from the temporary-decision list. If the crossing currently under consideration is passive with a single track, a temporary decision to install flashing lights is made and the crossing is added to the temporary-decision list. Otherwise, the decision is made to install gates.

As the upgrade recommendations are made, a cumulative cost is calculated. When the cumulative cost exceeds the available funding level, no further crossings will be considered for upgrading. Those crossings still on the temporary-decision list are recommended for flashing lights. After the algorithm has exhausted the available funds and made recommendations for warning-device upgrades, the user will be prompted for further instructions. At this time, the user may elect to input a new funding level or terminate execution of the program. Sample output (partial) for a funding level of $3,000,000 is shown in Table 3.

In the early stages of the project, the programs were translated to BASIC and executed on a VAX mainframe computer to verify the accuracy of the methodology and equations. Data for crossings shown in the sample problem in the User's Guide (3) were used and

TABLE 3 Sample Partial Output from RAM for Funding Level of $3,000,000

		Total Budget:	$3,000,000			
		Warning Device:	P→FL		P→G	FL→G
		Cost:	$36,700		$54,700	$49,200
		Effectiveness:	0.65		0.84	0.64
DOT-AAR ID No.	County ID No.	Recommended Device	Present Class	Tracks	Cumulative Cost ($)	Accident Reduction
225685	99	Gate	4	6	54,700	0.76
225526	39	Gate	4	4	109,400	0.73
517159	39	Gate	7	2	158,600	0.62
471589	59	Gate	4	2	213,300	0.51
473268	99	Temp-lights	4	1	250,000	0.33
146689	107	Gate	7	2	299,200	0.44
225736	11	Gate	7	1	348,400	0.44
470863	59	Gate	7	4	397,600	0.43
517167	39	Gate	7	2	446,800	0.42
225675	99	Gate	7	2	496,000	0.42

Note: P = passive; FL = flashing lights; G = gates.

the results were comparable with those in the sample problem. The final Applesoft BASIC programs were traced through by hand and the methodology was found to be accurate.

USING THE PROCEDURE

The procedural steps for using the RAM on the Apple II+ microcomputer will be briefly described here. The commands necessary to load and run the programs are provided. Both hard-copy listings of the programs described in the previous section and diskettes containing the programs can be obtained at nominal cost from the Department of Civil Engineering at West Virginia University.

Preparation

To use this package, the following equipment is necessary:

- Apple II+ microcomputer with one disk drive,
- Printer,
- Diskette containing RAM programs and output programs,
- Diskettes (number varies by state) containing crossing characteristics and accident data for particular state's crossings, and
- One blank diskette to store data files created by RAM.

Grade crossing inventory and accident data are available in magnetic tape format from FRA. However, it is necessary to put the data into a form from which they can be transferred to floppy disk and eventually accessed by the RAM. The transfer procedure used in this study is outlined in the following. It is recommended that users who are unfamiliar with either data bases or microcomputers contact their local computer center or someone familiar with database management for assistance in developing the details of the transfer procedure.

Data are prepared as described in the section on data acquisition. The data items used by the model are as follows:

- Record number
- Crossing identification number
- County identification number
- Latest upgrade beginning date
- Latest upgrade ending date
- Former class
- Present class
- Latest inventory beginning date
- Former class
- Present class
- Total trains
- Day trains
- Speed
- Main tracks
- Other tracks
- Paved
- Latest inventory ending date
- Pertinent accident history
- Functional classification
- Lanes
- Average annual daily traffic

Once in the proper format, the data files are transferred to the diskette by using a communications software package. On transfer to diskette, the data are condensed by standard editing commands to utilize disk space efficiently.

After the data are arranged in the proper format on the diskette, the resource allocation procedure is ready to be used. The procedure, shown schematically in Figure 1, consists of the three programs discussed previously, namely,

- Accident prediction program (Program 1),
- Accident-reduction/cost program (Program 2), and
- Resource allocation program (Program 3).

To initiate the resource allocation procedure,

- Insert diskette with programs into disk drive,
- Turn on computer, and
- Type CATALOG.

After these steps have been executed, the user is given a list of available programs. The following discussion describes the use of the three programs that make up the RAM.

Accident Prediction Program (Program 1)

Program 1 performs the first step in the resource allocation procedure: examination of the characteristics from the inventory and accident data files for each rail-highway grade crossing and calculation of the respective predicted number of accidents. During the execution of the program, a short routine maintains a current list of the top 500 crossings based on predicted accidents. This program required

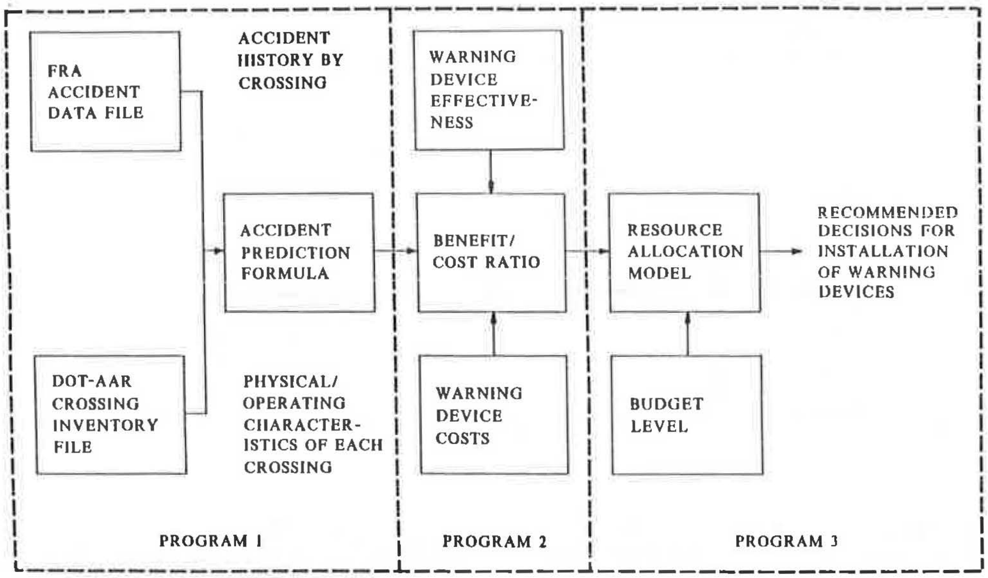

FIGURE 1 Relationship between the three BASIC programs and the overall resource allocation procedure.

an execution time of 18 hr to process West Virginia's 2,451 crossings. It should be emphasized that this program need be run only once a year or as often as the crossing inventory is updated. The commands used to execute the program are as follows (commands input by the user are underlined):

```
[LOAD PREDICTED ACCIDENTS
[RUN
THE FIRST DATA FILE TO BE PROCESSED IS? WVA
    .
    .
execution
    .
    .
INSERT NEXT DATA DISKETTE AND HIT <RETURN> TO
CONTINUE
    .
    .
execution
    .
    .
INSERT DISKETTE THAT TOP 500 LIST IS TO BE SAVED
ON AND HIT <RETURN> TO CONTINUE
```

When the program has finished execution, a file containing the top 500 crossings based on predicted accidents is written to a separate data storage diskette for use in Program 2.

Two programs have been written as part of the effort to output the results of Program 1 in convenient tabular format. The first output program (CHECKPRED) prints the top 500 crossings in descending order based on predicted accidents. The second program (COUNTY) prints the results sorted by FRA county identification number. The commands for executing the first output program are as follows (commands input by the user are underlined):

```
[LOAD CHECKPRED
[RUN
INSERT THE DATA DISKETTE AND HIT <RETURN> TO
CONTINUE
    .
    .
obtain listing
```

TABLE 4 Sample Output from Accident Prediction Program (CHECKPRED)

Rank	DOT-AAR ID No.	County ID No.	Predicted Accidents
1	517159	39	0.97
2	225685	99	0.90
3	225526	39	0.87
4	146689	107	0.69
5	225736	11	0.68
6	470863	59	0.67
7	517161	39	0.66
8	225675	99	0.66
9	471588	59	0.65
10	471589	59	0.61
11	517149	39	0.60
12	471561	59	0.55
13	517152	39	0.55
14	517165	39	0.51
15	473268	99	0.50

A sample of the output from CHECKPRED is shown in Table 4. On verifying the output, the user is ready to use the accident-reduction/cost program.

Accident-Reduction/Cost Program (Program 2)

Program 2 utilizes as input the data file created by Program 1 along with the cost and effectiveness of the different upgrade options. Cost data required are the life-cycle costs of installation and maintenance for each of the three possible upgrade options currently considered by the model. Suggested values for cost were determined by nationwide DOT studies (4). Effectiveness factors, defined as the fraction by which accidents are reduced after installation of a warning device, are available from previous research (3). The standard values for these variables, shown in Table 5, are incorporated into the program. Should these values need to be updated or should the user desire to input other values, such as the more detailed stratifications examined by Morrissey (6) and by Eck and Halkias (7), the appropriate program lines may be edited relatively easily.

With these inputs, Program 2 calculates a bene-

TABLE 5 Standard Effectiveness Factors and Cost Data for Warning-Device Improvements Used in Current RAM (3)

Warning-Device Improvement Option	Effectiveness Factor	Installation Cost ($)	NPV Maintenance Cost ($)	NPV Life-Cycle Cost ($)
Passive to flashing lights	0.65	36,700	21,400	58,100
Passive to gates	0.84	54,700	33,800	88,500
Flashing lights to gates	0.64	49,200	34,100	83,300

Note: Costs are as of 1980. NPV = net present value.

fit/cost ratio for each of the 500 crossings and ranks them in descending order based on the ratio. Benefits are expressed as predicted accidents prevented per year and costs are life-cycle costs of the equipment. The list is written to a new data file on the diskette. For the West Virginia data, the program required approximately 1 hr to execute. The commands necessary to run the program are as follows (commands input by the user are underlined):

```
[LOAD BENEFIT
[RUN
INSERT DATA DISKETTE WITH "PRED" FILE AND HIT
<RETURN> TO CONTINUE
      .
      .
execution
      .
      .
INSERT DATA DISKETTE THAT FILE "BENEFIT" IS TO BE
SAVED ON AND HIT <RETURN> TO CONTINUE
```

When Program 2 has been executed, a file is created containing the top 500 crossings ranked in descending order based on predicted benefits. This file is written to the data storage diskette for use in the RAM.

A program was written to output the results of Program 2 in tabular form. The program (CHECKBENEFITS) lists the top 500 crossings in descending order based on benefit/cost ratio. As mentioned previously, benefit is expressed as predicted accidents prevented per year and cost is the life-cycle cost of the equipment. The commands used to execute the output program are as follows:

```
[LOAD CHECKBENEFITS
[RUN
INSERT DATA DISKETTE AND HIT <RETURN> TO
CONTINUE
      .
      .
obtain listing
```

A sample of the output from CHECKBENEFITS is shown in Table 6. On completion of this step, the user is ready to use the resource allocation program.

Resource Allocation Program (Program 3)

The final program utilizes the ranked list of benefit/cost ratios in conjunction with the available funding level. The algorithm considers the benefit/cost ratios beginning with the largest (i.e., the crossings that will yield the most benefit) and continues in descending order. The process continues until the monies spent equal or exceed the available budget. Thus, an optimal list of improvements is obtained. The program has an execution time of several minutes. The output is an optimized list of recommended warning-device upgrades. The program is

TABLE 6 Sample Output from Accident-Reduction/Cost Ratio Program (CHECKBENEFITS)

Rank	DOT-AAR ID No.	County ID No.	Present Class	Initial AR/C Ratio	Predicted Accidents
1	225685	99	4	13.9	0.90
2	225526	39	4	13.3	0.87
3	517159	39	7	12.6	0.97
4	471589	59	4	9.37	0.61
5	473268	99	4	9.02	0.50
6	146689	107	7	8.98	0.69
7	225736	11	7	8.94	0.68
8	470863	59	7	8.83	0.67
9	517167	39	7	8.70	0.66
10	225675	99	7	8.69	0.66
11	471588	59	7	8.53	0.65
12	471561	59	4	8.48	0.55
13	517149	39	7	7.92	0.60
14	517152	39	7	7.16	0.55
15	517165	39	7	6.70	0.51

interactive in that the user is prompted to input a new funding level after each iteration of the model. At that time, the user may elect to input a new funding level or discontinue the procedure. Typical commands are as follows:

```
[LOAD RAM
[RUN
THE TOTAL BUDGET AVAILABLE = ?  $1,000,000
INSERT THE DATA DISKETTE WITH DATA FILE "BENEFIT"
AND HIT <RETURN> TO CONTINUE
 .
 .
execution
 .
 .
DO YOU WISH TO INPUT A DIFFERENT FUNDING LEVEL?
(YES/NO) YES
THE TOTAL BUDGET AVAILABLE = ?
$3,000,000
```

The foregoing process will continue until the user elects to stop. The program produces a written record of the results. The output for the various funding levels may be compared immediately. Sample output from the RAM is shown in Table 7.

CONCLUSIONS AND RECOMMENDATIONS

This study involved the adaptation of the DOT rail-highway grade crossing RAM to the Apple II+ microcomputer. As a result of this study, several conclusions have been drawn and recommendations made. Overall conclusions are summarized first, followed by recommendations for additional work. Various methods for making the results of this effort available to interested parties are suggested.

The ability to run the RAM on the microcomputer offers several advantages over use of the mainframe:

- The user need not worry about the problems commonly associated with a mainframe, such as availability of computing time, high user costs, slow turnaround, and the need for support personnel.
- The programs used on the microcomputer are written in BASIC. A user with no previous computing experience who desires to modify the program will find BASIC easier to learn than FORTRAN.
- Because the program is relatively easy to modify, variables such as effectiveness factors or equipment costs may be altered to reflect recent research.
- The program is interactive in that the funding level may be adjusted on a single computer run

TABLE 7 Sample Rail-Highway Crossing RAM Results

		Total Budget:	$3,000,000			
		Warning Device:	P→FL	P→G	FL→G	
		Cost:	$36,700	$54,700	$49,200	
		Effectiveness:	0.65	0.84	0.64	

DOT-AAR ID No.	County ID No.	Recommended Device	Present Class	Tracks	Cumulative Cost ($)	Accident Reduction
225685	99	Gate	4	6	54,700	0.76
225526	39	Gate	4	4	109,400	0.73
517159	39	Gate	7	2	158,600	0.62
471589	59	Gate	4	2	213,300	0.51
473268	99	Temp-lights	4	1	250,000	0.33
146689	107	Gate	7	2	299,200	0.44
225736	11	Gate	7	1	348,400	0.44
470863	59	Gate	7	4	397,600	0.43
517167	39	Gate	7	2	446,800	0.42
225675	99	Gate	7	2	496,000	0.42
471588	59	Gate	7	2	545,200	0.41
471561	59	Gate	4	3	599,900	0.46
517149	39	Gate	7	2	649,100	0.38
517152	39	Gate	7	1	698,300	0.35
517165	39	Gate	7	2	747,500	0.32
225513	39	Gate	4	2	802,200	0.34
226632	45	Gate	7	1	851,400	0.30
225739	11	Gate	7	1	900,600	0.30
146688	107	Gate	7	3	949,800	0.29
226599	45	Gate	4	2	1,004,500	0.31

and the engineer can determine the impact on the grade crossing program in a matter of minutes.

At the outset of this study the main question was whether the microcomputer could handle the large data base. The answer to this question appears to be yes. The programs were able to utilize data for West Virginia (2,451 crossings) with no difficulty. The data were stored initially on three single-sided diskettes after being transferred from the mainframe. After the data were edited and condensed, they fit easily on two single-sided diskettes. It is concluded that the accident prediction program can handle a very large data base. The only constraint is that the data be transferred to floppy disk in files of no more than 200 crossings each. This is because of the limited working space of the Apple II+ memory. The accident prediction program calls a file into the working space, performs the desired calculations for each of the crossings, updates the list of the top 500 crossings on the basis of predicted accidents, retrieves the next file, and repeats the process. This can be done for an unlimited number of files. The accident prediction program requires the longest execution time of the three programs in the process. The time required to process West Virginia's 2,451 crossings was approximately 18 hr. It should be emphasized that the accident prediction program need only be executed once to obtain the top-500 list of crossings based on predicted accidents. Subsequent runs are necessary only when grade crossing data change and the top-500 list may be affected. Updating the data base can be accomplished easily. A crossing's record may be accessed and the appropriate data modified in a matter of minutes.

Perhaps the length of time required by the accident prediction program could be reduced by using a faster sorting routine or by converting the program to machine language. Reducing the execution time of the accident prediction program would prove beneficial, especially if a state that has many more crossings is under consideration. For example, Texas and Illinois have 14,570 and 13,290 crossings, respectively.

An effort should be made to keep the accident and inventory data updated. This would tie in with the regular grade crossing inspection program. On returning to the office, the technician could edit and update the floppy diskettes containing the data base. Accident data would be modified when the accidents were reported.

Continued efforts to expand and update effectiveness factors will serve to improve the manner in which funds are allocated for railroad crossing improvements. Also, cost data should be updated to determine benefit/cost ratios more accurately. Once new values have been determined, they may be incorporated into the model with relative ease.

Because of the many and varied models of microcomputers available, a major concern is program compatibility. Many microcomputers have software available that will translate the program to the appropriate language. The programs do not utilize any functions or subroutines that cannot be found in other languages. Thus, adaptation to other microcomputer systems is a workable alternative that should be investigated. To assure wider use of the model, it is especially important that the package be adapted to systems compatible with the IBM Personal Computer. The amount of effort required to translate from Applesoft BASIC to the MS BASIC of IBM-compatible systems should not be too great because the languages are somewhat similar.

The interactive processes of the final step would be more useful if the user could vary the cost data, both for classes of projects and for individual projects. Very few projects are average, and as special information regarding a particular project is gained, the ability to change its cost and to realize the overall implications would be very useful. Development of such a capability is recommended.

A major problem encountered by most researchers is determining the best method to distribute the results to interested parties so that the findings may be put into practice. To this end, several possibilities are suggested.

Copies of the programs could be distributed to a software clearinghouse such as Safety and Traffic Engineering Applications to Microcomputers (STEAM). STEAM is part of FHWA's technical assistance program established to provide assistance to transportation officials in the effective use of microcomputers. interested parties could send in blank diskettes so that the programs could be copied and returned.

Alternatively, FRA could provide copies of the programs to interested parties. They could also make available diskettes containing each state's crossing data arranged in the proper format. Sending copies of the programs or diskettes to all state highway agencies might encourage greater use of the RAM.

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