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DeBernardo of SDEDC Receives Smokey Bear Award Posthumously

A New *FIELD NOTES* Feature: The Software Spot

Tree-Planting Machines — Can You Afford One?

Identifying Road Capacity & Traffic Service Level

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DeBernardo of SDEDC Receives Smokey Bear Award Posthumously

Barbara DeBernardo, on behalf of her late husband, Luigi, accepts the 1983 Silver Smokey Award.

Mr. Luigi U. DeBernardo was posthumously honored at the 74th annual Western Forestry and Conservation Association meeting held during December 1983 in Portland, Oregon. DeBernardo's widow, Barbara, accepted a 1983 Silver Smokey Award on behalf of her late husband who was being honored for his work as the Nation's leading authority on spark arresters.

The Silver Smokey, the highest Smokey Bear award given to individuals, recognizes significant achievements by fire prevention professionals who are nominated by the Cooperative Forest Fire Prevention program's executive committee to receive the award. This committee is composed of representatives from the National Association of State Foresters and the Forest Service.

DeBernardo's work to keep internal combustion engine sparks from starting wildland fires has resulted in a large variety of spark arresters. These devices are used in exhaust systems on cars, trucks, locomotives, small multiposition engines, and all sizes of stationary engines.

At the time of his death in 1980, DeBernardo was staff assistant for fire prevention at the Forest Service's Equipment Development Center in San Dimas, California (SDEDC). Previously, he had served as the Assistant Director for Development and Test, and he had applied for a patent on a self-cleaning spark arrester for railroad locomotives.

DeBernardo's further accomplishments include the Forest Service "Spark Arrester Guide," used worldwide by fire prevention inspectors, and several standards adopted by the Society of Automotive Engineers. In San Dimas, he established the only spark arrester qualification test facility in the Nation.

A New *FIELD NOTES* Feature: The Software Spot

Constance A. Connolly
Technical Information Specialist
Washington Office

In response to both a need expressed by Region 1 (See figure 1) and a recommendation in the Report of the National Systems Management Review (p. 30), we are initiating a new section of Engineering Field Notes that we hope will become a regular feature. This section will showcase your contributions regarding software availability in Engineering--a "Who has what? Where? Do we need it? Could we use it too?" of Engineering software. If response is good, this information could later become an on-line data base that is accessible and easily updated in your office. You also might want to consider establishing a software conference in the Engineering Conference System.

If you have contributions, include not only internally developed software but also any off-the-shelf or modified off-the-shelf systems that you have found useful. Your description of the system should include the following:

(1) Name of software (version number or date if more than one system).

(2) Compatible hardware.

(3) Language.

(4) Capabilities (including accuracy if critical).

(5) Brief description of what you use it for.

(6) Contact point for further information (name and phone number).

United States Department of Agriculture — Forest Service — R-1

Reply to: 7100 Engineering Operations

Date: FEB 27 1984

Subject: Engineering Field Notes, Computer Software

To: Chief

To meet the need for computer solutions to engineering problems, the Regions are generating a multitude of programs (software). Many of them are probably duplication of effort. To reduce this unnecessary cost, we propose that a section of the "Engineering Field Notes" be used exclusively for the publication of software program availability, with written descriptions of language, content, hardware used, etc.

To generate this exchange we have included several software programs available in R-1 Engineering which we would recommend for publication.

BERYL L. JOHNSTON
Director of Engineering

Enclosures

Figure 1.--Letter from Region 1 expressing need for a new feature in ***Engineering Field Notes.***

Please send contributions to:

Forest Service-USDA
Engineering Staff, Room 1113 RP-E
Technical Information Center
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Let's see if we can cut costs and improve productivity by exchanging information in this rapidly changing area. Congratulations to Region 1 for starting the ball rolling! Now let's hear from the rest of you.

THE SOFTWARE SPOT: PROGRAMS AVAILABLE FROM REGION 1

The following programs, written in BASIC are available in Region 1 for use on an Olivetti P8080 or a Texas Instruments 990. Persons desiring information or software should contact Roger White, Engineering, Region 1, (FTS) 585-3310.

BOTARCH Bottomless arch hydraulics for road crossing. Program generates depth, flow, and velocity in 10ths of a foot from streambed to top of culvert. Excellent for fish passage.

ROUND Circular culvert hydraulics (replaces old "CIRC" program) generates depth, flow, and velocity in 10ths of a foot for circular culverts. Program allows burial of pipe (in 10ths of a foot) up to one-half diameter. Excellent option for fish passage.

SPILL Bridge hydraulics for trapezoidal "spill thru" bridge design. Uses Manning's "N" of 0.06 for slopes of section and allows for "N" value input for streambed. Depth, flow, and velocity generated in 10ths of a foot.

TIMBER Bridge hydraulics for rectangular, "vertical wall" bridge design. Uses Manning's "N" of 0.07 for vertical timber sidewall sections and allows for "N" value input for streambed. Depth, flow, and velocity generated in 10ths of a foot.

MANING Generates "Q" from Manning's formula.

Tree-Planting Machines — Can You Afford One?

Dan W. McKenzie
Mechanical Engineer
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Staff Forester, Resources
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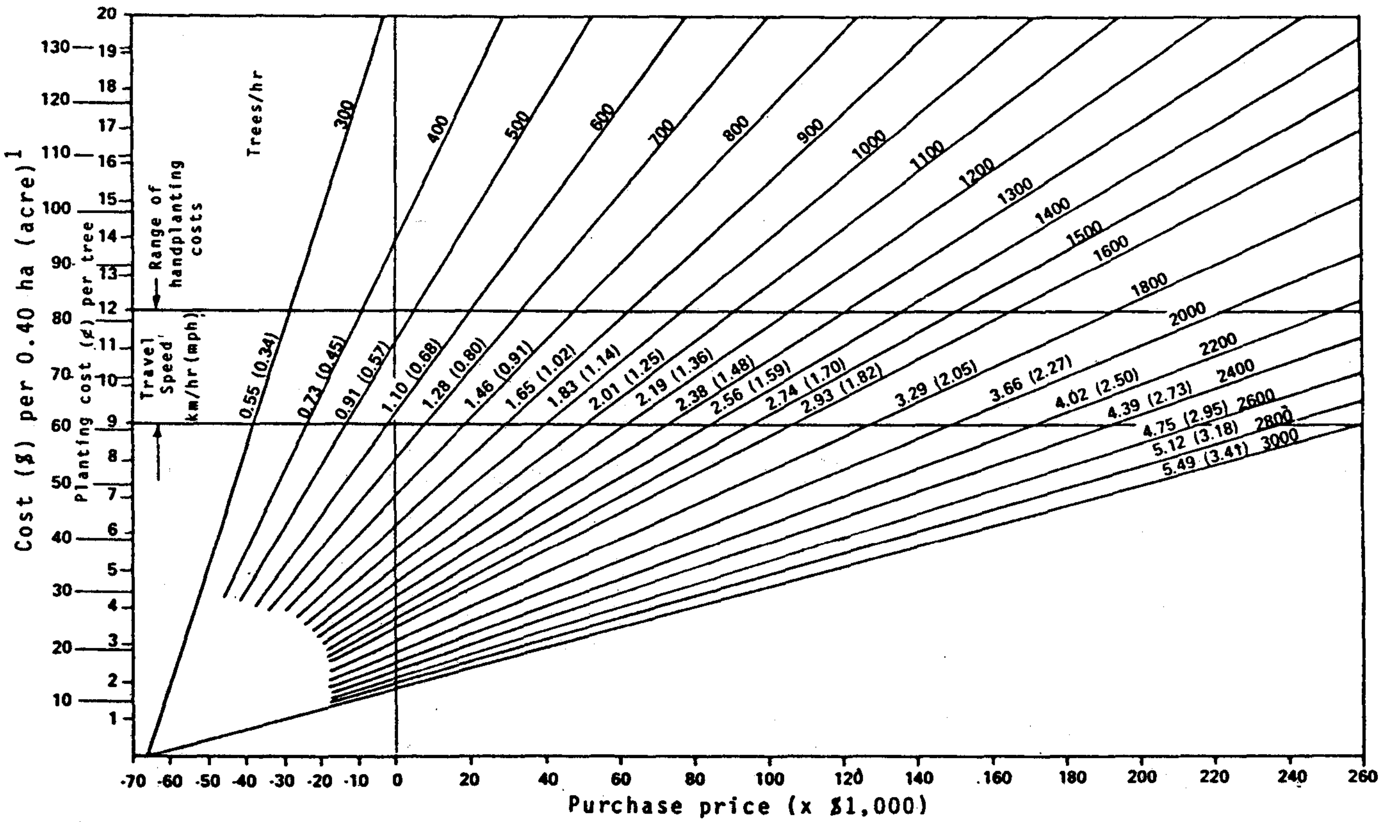
INTRODUCTION

An effective tree-planting machine not only must plant trees successfully; it also must be affordable. To be affordable, a tree-planting machine must plant seedlings at, or less than, the cost of handplanting. Handplanting cost data are readily available. Machine planting costs are not as readily available, so engineers at the San Dimas Equipment Development Center (SDEDC) devised a method to predict an affordable price for a tree-planting machine.

SDEDC was assigned a project for the development of an intermittent tree-planting machine. The first task was to establish performance criteria for a tree-planting machine--one that would meet minimum requirements for quality, dependability, safety, and reliability. Second, the machine would have to be cost-effective; that is, it would have to compete economically with handplanting. This would require machine planting costs to be equal or less than handplanting costs.

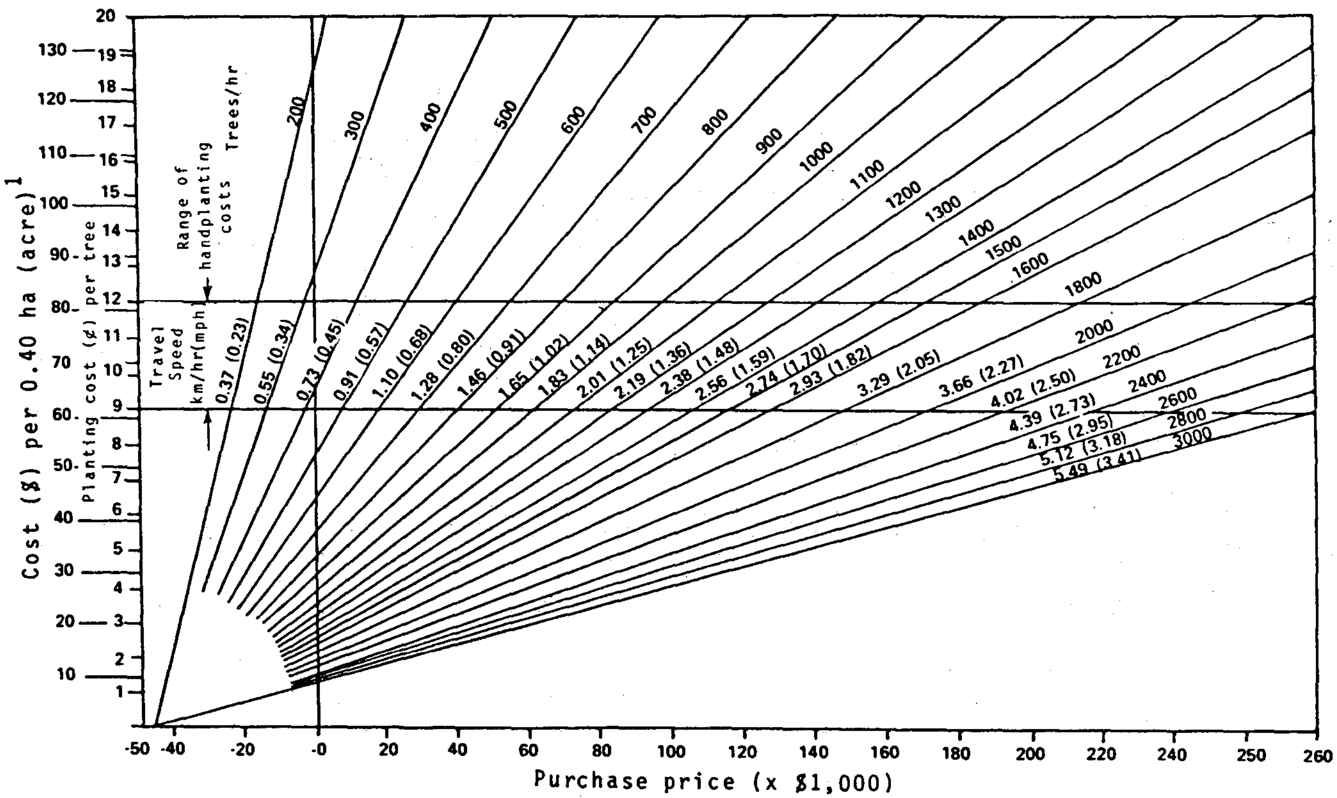
ASSUMPTIONS & METHODOLOGY

The Southeastern United States is the most favorable area in the Nation for tree farms, has a long planting season and large areas to be planted, and has been seeking mechanized planters. The charts in figures 1 and 2 were developed using data and assumptions from this area. If a different area is considered or if the assumptions do not fit, they can be changed and new charts developed. The method presented can provide information on an affordable price for a tree-planting machine.



[1]For typical plantings in southeastern United States:
1.8 x 3.3 in (6 x 10.7 ft) spacing, or 680 trees per 0.40 ha (acre).

Figure 1.--Planting cost at various production rates for a towed tree planter.



[1]For typical plantings in southeastern United States:
1.8 x 3.3 in (6 x 10.7 ft) spacing, or 680 trees per 0.40 ha (acre).

Figure 2.--Planting cost at various production rates for a self-propelled planter.

We used the following assumptions in developing the charts:

(1) The Southeastern United States is the prime area of concern, and the charts are based on its climate, terrain, and labor equipment rates.

(2) While the affordable tree-planting machine can be either an intermittent or a continuous-row machine, the intermittent planter is the one under consideration.

(3) Site preparation costs are the same for an intermittent tree-planting machine as they are for hand-planting.

(4) Within the rows, tree seedlings are to be planted 1.8 meters (6 feet) apart.

(5) Tree-planting machines have an 85-percent availability and productive equipment time equal to 85 percent of labor time; and, for a towed planter, the prime mover has an availability of 90 percent.

(6) Equipment life is 6,000 hours of operating time over a 10-year period.

(7) Overhead plus profit on labor are equal to direct labor cost.

(8) Maintenance cost is equal to straight-line machine depreciation cost, without the cost of capital.

(9) Machine depreciation cost is calculated by employing the capital recovery factor in conjunction with the cost of capital and equipment life.

(10) Overhead and profit on equipment are equal to the straight-line depreciation cost, without the cost of capital, plus maintenance cost; <u>or</u> twice the direct straight-line equipment depreciation cost; <u>or</u> twice the maintenance cost.

(11) The cost of capital is 15 percent.

(12) The crawler tractor that tows a tree planter ranges in size from 4,500 to 6,300 kilograms (10,000 to 15,000 pounds) and can travel at a speed of approximately 2 kilometers per hour (1.24 miles per hour) on cutover areas.

(13) The passthrough equipment cost (renter's overhead and profit) equals 0.25 times the equipment cost.

(14) The salvage value of the equipment after 10 years of use is zero.

(15) Tree survival rates for intermittent machine planting are equal to handplanting.

(16) Government experiences the same direct and overhead costs as private enterprise.

Using these assumptions, the families of straight lines in figures 1 and 2 can be developed and expressed as a linear equation that provides the answer to the question "How much can you afford to pay for a tree planter?":

$$X = C_1 + C_2 \times HPC \times MPR$$

where

X = *the maximum affordable tree planter purchase (in dollars);*

C_1 = *a negative constant (in dollars) determined by extending the straight lines to their point of convergence as they intercept the X-axis;*

C_2 = *a constant (in hours) that, when multiplied by HPC (handplanting cost in dollars per tree), gives the additional amount in dollars, that can be paid for a mechanized tree planter with an increase of one tree per hour in the production rate;*

HPC = *the handplanting cost known to exist in the planting location being considered;*

MPR = *the machine production rate in trees per hour for the unit under consideration.*

By inspection of figure 1, C_1 = -\$67,500 for towed tree planters; and by inspection of figure 2, C_1 = -\$46,700 for self-propelled tree planters. The constant C_2 has been determined by "plugging in" various sets of values for X, HPC, and MPR in the straight-line relationships in both figures 1 and 2. These solutions for C_2 have resulted in 1,203 hours for a towed planter, and 1,202 hours for a self-propelled planter.

As an example of determining the maximum economical purchase price, say that handplanting in your area costs $0.12 per tree and a towed tree-planting machine, being considered for purchase, can plant 1,100 trees per hour. The maximum economical purchase price for that planter is derived as follows:

$$\begin{aligned} X &= C_1 + C_2 \times HPC \times MPR \\ &= -\$67,500 + 1,203 \text{ hours} \times (\$0.12/\text{tree}) \\ &\quad \times (1,100 \text{ trees/hour}) \\ &= \$91,300 \end{aligned}$$

Alternatively, you could use figure 1.

Recent (1980) contracts in the Southeastern United States indicate that the HPC range is from $0.09 to $0.12 per tree. At $0.12 per tree, the maximum that you should be willing to pay for an intermittent tree planter with an MPR of 1,100 trees per hour is $91,300 for a towed planter, and $112,000 for a self-propelled unit. If one were to assume a two-row machine with an MPR of 1,500 trees per hour, the maximum affordable price for an HPC of $0.12 per tree is $149,000 for a towed machine and $169,000 for a self-propelled one. Also, from figures 1 and 2, a machine must have a planting rate of at least 540 trees per hour (if one assumes a minimum machine cost of $10,000 for a towed unit and $27,000 for a self-propelled unit) to be affordable. At a planting rate of 540 trees per hour, this will only allow 6.7 seconds to plant each tree. At this rate, planting cannot be a stop-and-go operation, and specific spot selection for seedling insertion cannot be made. At higher, more desirable (and possibly necessary to make the machine affordable) planting rates, the problems of stop-and-go operation and specific spot selection become more acute.

CONCLUSION

The most important factor that a designer of a tree planter has control over is the production rate of the machine. A production rate of at least 600 trees per hour must be achieved, or else an intermittent tree planter will not be economical (affordable). Much higher planting rates than 600 trees per hour are desirable and may be necessary for the machine to be affordable, depending on the cost of the machine and other circumstances.

If you want more details about this subject, request Project Record 8124 1203, June 1981, "Tree-Planting Machine--How Much Can You Afford to Pay for One?" available from SDEDC.

Identifying Road Capacity & Traffic Service Level

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INTRODUCTION

A key factor in designing and managing a Forest Service road network is reliable information about the number of vehicles that use the road system, their operating characteristics, and their costs when they use the system. Accurate data can help in making more cost-effective decisions involving capital investment in roads and in establishing budget levels for operation and maintenance.

Up to March 1982, the traffic volume limits established for safe and efficient operation of single- and double-lane Forest Development Roads provided the basic direction for this type of evaluation (FSM 7720). For example, 100 vehicles per day was considered heavy enough to require an investigation into increasing the road standard from single lane to double lane. Often this volume criterion became a major factor in triggering construction of a two-lane road.

In March 1982, the Forest Service revised its national standards for road system development and gave road managers much more flexibility in selecting road standards. By combining consideration of design, maintenance, and traffic control, the road managers could achieve a more efficient use of existing roads or planned roads with lower standards, rather than just upgrading the road standard by adding lanes or increasing road width. To take full advantage of the concept of traffic service level and traffic management, however, required a more comprehensive way of evaluating road capacity.

In August 1982, Region 6 proposed to the Engineering Development Group of the Washington Office that a procedure be developed for identifying road capacity and traffic service level. The reason for this request was a field and Regional Office concern regarding how the new standards being developed would affect the determination of whether roads are adequate or inadequate for timber haul and public access. These determinations affect the commitment of millions of dollars in reconstruction funds in both the Purchaser Credit and the Forest Road and Transportation Programs.

The opportunity for the study was further enhanced when the Gifford Pinchot National Forest (GP) indicated a potential timber-haul and traffic-control problem related to the moving of salvage sales from the Mount St. Helens volcanic damage area. Under the proposed sale program, within a 2-year period more than a billion board feet of timber would have to be hauled out over a road system that had limited haul capacity. The Forest, working with the Regional Transportation Development and Planning Group, requested that a Mount St. Helens study be established to quantify how this high anticipated use would affect traffic flow and traffic operation on a variety of roads under various haul conditions. The proposal established a steering committee made up of Forest, Regional, and Washington Office personnel (including Lee Collett, Al Hessel, and Jerry Knaebel) to monitor the intent and purpose of the study and to direct the data collection and analysis operation to ensure that the desired results were achieved.

The steering committee established the following objectives for the Mount St. Helens project:

(1) The principal traffic to be studied would be Forest Service timber-haul and support vehicles. Although it would be desirable to study the large volumes of anticipated public traffic on the road system during the weekends, limited manpower, dollars, and equipment ruled out this phase of the operation.

(2) Emphasis would be placed on road operations under maximum traffic loadings. This would enable the analysis to evaluate the differences that various road standards have on traffic movement, speed, and volume. Data collection and analysis would also provide information

about how each type of road performs under full capacity. This would involve classifying existing roads in the system as to road type based on such factors as sight distance, pavement type, shoulder width, passing on single-lane road conditions, turnout spacing, and so forth.

(3) The study would result in a series of charts, graphs, and descriptions of the various conditions, travel time, and traffic-flow characteristics that could be expected on a Forest Service road used for hauling timber when certain volumes and conditions are assumed. This information would make it possible to assign a traffic service level to an existing Forest Development Road based on anticipated traffic conditions and haul rates. An evaluation of these conditions, along with the associated operation, construction, and maintenance cost, would provide an analytical procedure for selecting the most economical road standard. The cost savings could be considerable.

To accomplish these objectives and obtain the best use of available personnel, the study was organized as follows:

(1) A technical and analytical section would work on the analysis and planning of the sample data evaluation and would develop the charts and graphs. Personnel assigned to this group were Dave Nordengren of the Region 6 Transportation Planning and Analysis Group and Fong Ou, Transportation Planner on the GP. A Field Operation Engineer would be assigned to conduct traffic surveillance studies and to coordinate the use of crews for traffic observations and data collection. This individual was Rob Keeney of the Region 6 Transportation Development Section. Keeney would be assisted by Clarence Petty and Lonnie Gray of GP.

(2) The steering committee would continue to function as a review and evaluation group to determine the type of work to be done and any changes necessary in the study program. A general project supervisor was selected, and a financial plan was established and approved by the Regional Office. The general project

supervisor was A.J. Hessel, Transportation Planning Engineer in Region 6.

The direction of this study and sample design were developed with the assistance of Dr. Ron Hudson of the University of Texas and Dr. Virgil Anderson from Purdue University. In a parallel research effort, a team headed by Dr. Robert Layton of Oregon State University also conducted a traffic survey in the study area. Their data may be used to refine the results of this study.

FACTORS AFFECTING TRAFFIC SERVICE LEVEL

As defined in FSH 7709, Chapter 11, traffic service level is a function of flow, volume, vehicle type, critical vehicle, safety, traffic management, user cost, alignment, and road surface. These factors can be classified into four groups. The first group is characterized by traffic performance and consists of flow, safety, and user cost. The second group consists of road characteristics such as alignment and road surface. The third group is defined by traffic characteristics and includes volume, vehicle type, and critical vehicle. The fourth group is defined by a single factor, traffic management.

Traffic performance is directly influenced by both road and traffic characteristics, while traffic characteristics may be controlled by traffic management strategy. For example, high design standards may result in high speed and low user cost, and it may make travel safer. On the other hand, high volume in general traffic or critical vehicles tends to reduce speed and increase user cost. Traffic management through the use of citizen band (CB) radios and the exclusion of critical vehicles may minimize this impact.

In this study six types of vehicles were considered: light vehicles, Forest Service light vehicles, recreation vehicles with trailers, empty log trucks, loaded log trucks, and other trucks. Factors considered in describing roadway were alignment, grade, lane width, number of lanes, surface type, shoulder, width, and roughness. The alignment was measured by the ratio of average radius to the number of curves per mile and was classified as poor, fair, good, and excellent based on ratios of less than 20, 20 to 50, 51 to 100, and over 100, respectively. This definition is adopted from the "Logging Road Handbook: The Effect of Road Design on Hauling Costs." The traffic characteristics included traffic volume and composition, for both single-lane and double-lane roads, and the distribution of traffic flow in both directions for single-lane roads. The environmental constraint was identified by visibility, with overcast, cloudy, and foggy as the three levels of driver's perception.

SURVEY DESIGN & DATA COLLECTION

Two basic factors considered in the survey design were the representativeness of the sample and the time and cost for data gathering. To minimize the sample size, a survey scheme that considered both the lower and upper extremes of various variables was developed. A typical scheme for paved, double-lane roads is shown in figure 1. In this example, alignment was classified as fair or excellent; grade was distinguished by flat or 6 percent or higher; sight distances were divided into those with one minimum sight distance and those with indefinite sight distance; template was identified by 10-foot and 11-foot lane widths; while shoulder was divided into 1- and 2-foot widths. A 6 percent grade was selected as the surrogate for distinguishing two groups of roads because that grade is used as the maximum for a 55 mph design speed on mountainous, rural highways.

The next step in the survey design was to select candidate study sites with road characteristics similar to those indicated by squares or circles in figure 1. Preferably, all sites would fit either all squares or all circles. Two factors were considered in the site selection: the road segment had to be long enough to obtain a good measurement for roughness, speed, and other variables; and the road segment had to be homogeneous enough to be identified under all temporally stable variables as indicated previously. With this consideration, 31 candidate sites were selected, with more than 70 percent of the sites falling into either the circle category or the square category for each type of road. The third step in the survey design was to perform field verification. After this verification, 10 candidate sites were eliminated. The locations of the 21 selected study sites are shown in figure 2, and their characteristics are listed in table 1. Statistics of the sample can be illustrated by various design standards. That is:

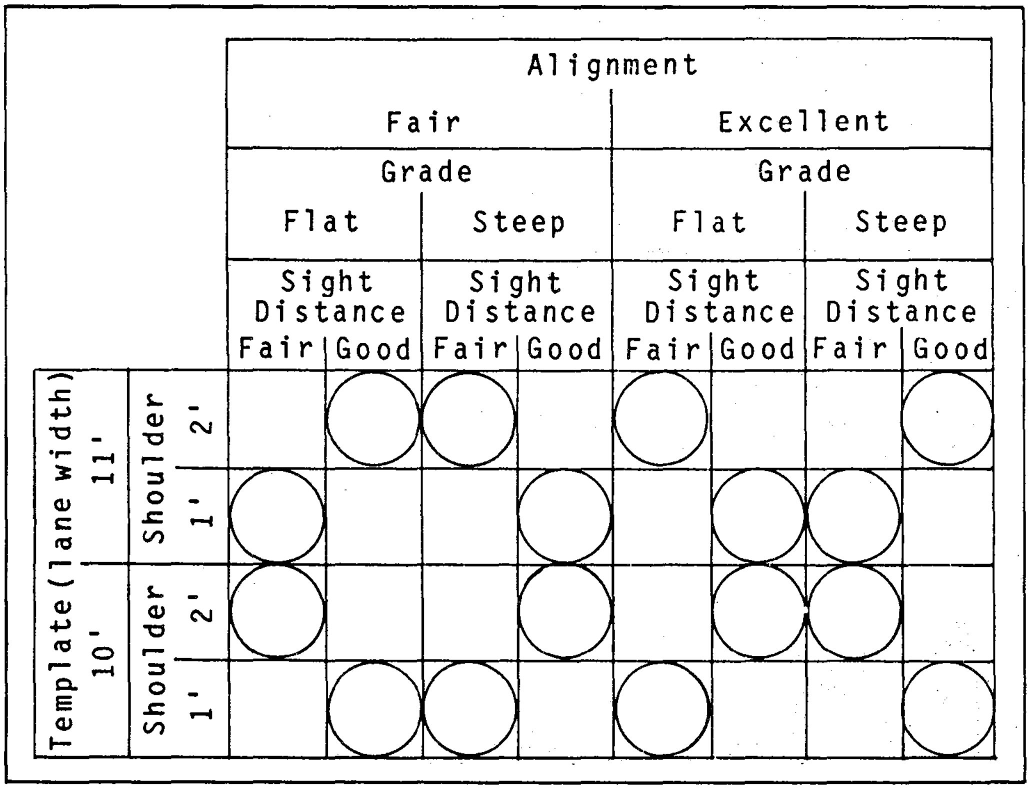

Figure 1.--Sample scheme for paved, double-lane roads.

Road Width	10 for double-lane roads 11 for single-lane roads
Surfacing	12 for the paved 7 for the gravel 2 for the dirt
Grade	13 for grade less than 6 percent 8 for grade equal to or more than 6 percent
Alignment	3 for excellent 7 for good 9 for fair 2 for poor
Sight Distance	10 for good 11 for fair

Based on the pattern of circles and squares shown in figure 1, 13 sites (or 62 percent of the total sample) fall into the circle category and 8 sites (or 38 percent of the total) are characterized as the square category. The results of the analysis

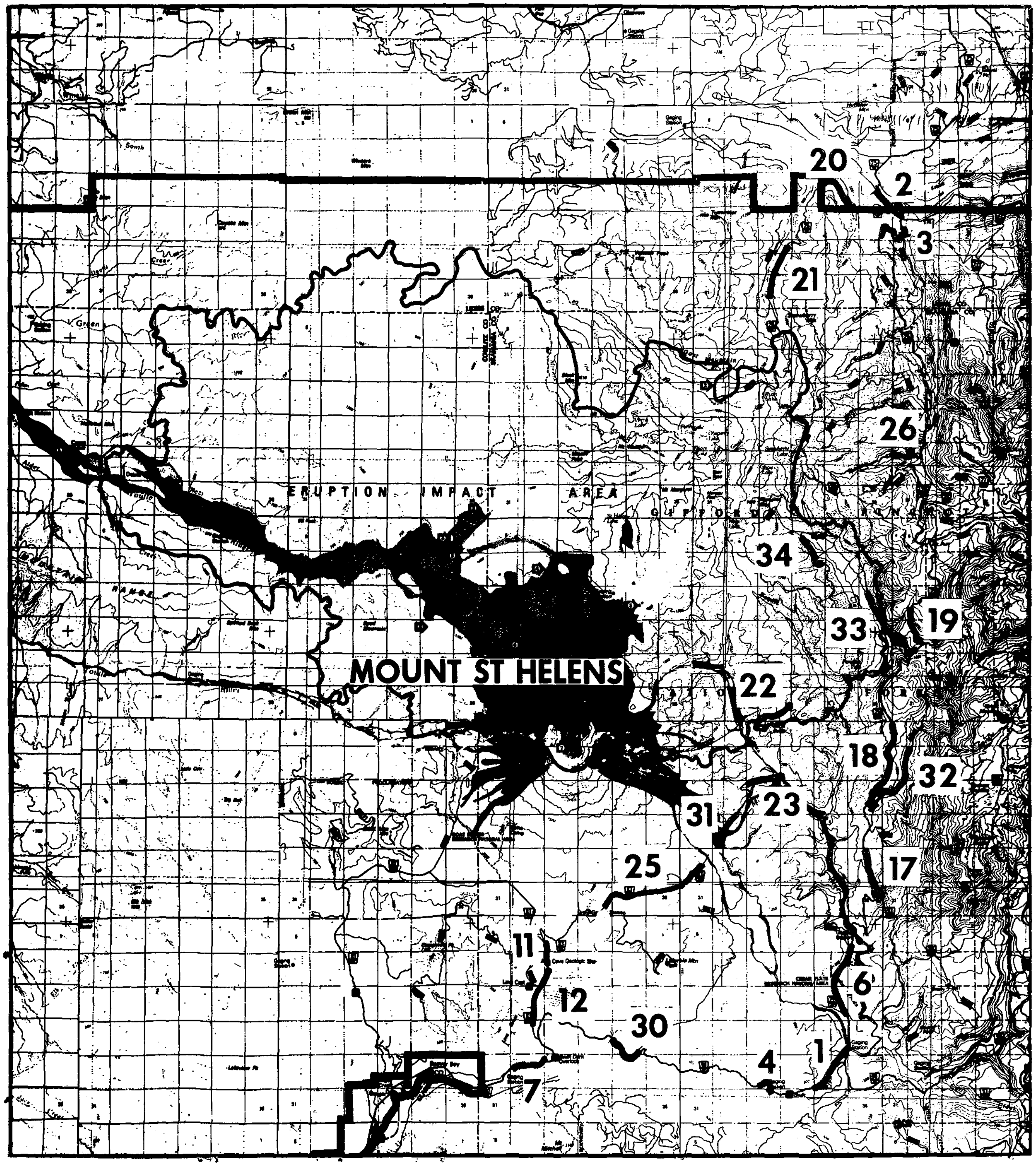

Figure 2.--Location of selected traffic study sites in Mount St. Helens Volcanic Monument area.

Table 1.--Road characteristics of selected traffic study sites.

Site	Type of Road	Type of Surface	Alignment	Grade	Sight Distance	Template		Passing	No Passing	Shoulder (ft)		
						10 ft	11 ft			0	1	2
1	Double lane	Paved	Excellent	Flat	Good	X						X
2	Double lane	Paved	Fair	Flat	Fair		X				X	
3	Double lane	Paved	Fair	Steep	Fair		X				X	
4	Double lane	Paved	Fair	Flat	Fair	X						X
6	Double lane	Paved	Excellent	Flat	Good	X				X		X
7	Double lane	Paved	Fair	Steep	Fair	X						
11	Double lane	Gravel	Fair	Steep	Good	X					NA	
12	Double lane	Gravel	Excellent	Steep	Good	X					NA	
17	Single lane	Paved	Good	Flat	Good			X			NA	
18	Single lane	Paved	Good	Flat	Good			X			NA	
19	Single lane	Paved	Fair	Steep	Fair			X			NA	
20	Single lane	Paved	Fair	Steep	Fair			X			NA	
21	Single lane	Paved	Good	Flat	Good			X			NA	
22	Single lane	Dirt	Poor	Flat	Fair			X			NA	
23	Single lane	Gravel	Poor	Steep	Fair			X			NA	
25	Single lane	Gravel	Good	Flat	Good			X			NA	
26	Single lane	Gravel	Good	Flat	Good			X			NA	
30	Double lane	Paved	Fair	Flat	Good	X						X
31	Single lane	Gravel	Good	Flat	Fair			X			NA	
33	Single lane	Gravel	Good	Steep	Fair			X			NA	
34	Single lane	Dirt	Fair	Steep	Good			X			NA	

indicate that the sample is well distributed among various classification schemes.

We collected the data from June to November in 1982, with each site having more than one traffic count. The duration of the traffic counts ranges from 2 to 3 hours. For single-lane roads, CB radios controlled most of the traffic, and public use was excluded.

SPEED-VOLUME RELATIONSHIP

Based on the average speed and volume at each site, we developed the speed-volume relationships for single-lane roads and double-lane roads with various surfacing (figure 3). As indicated in figure 3, the speed responds to the volume differently between one-lane and double-lane roads and among various surfacing. For single-lane roads, the difference in speed between the dirt and the other two types of surfacing is significant. The speed difference between the paved and gravel surfacing is relatively small and diminishes when the volume reaches 43 vehicles per hour (vph). For double-lane roads, the difference in speed between the gravel and paved roads is also very significant. Comparing both single-lane, paved roads and double-lane, gravel roads reveals that the difference in speed between these two types of roads is small, but this difference tends to increase when the volume increases. The differences in speed between various types of roads are listed below:

Single-Lane Roads.

(1) Basic condition: Hourly volume is equal to or less than 15 vph

(Speed on gravel roads) - (Speed on dirt roads) = 9.65 + .51(Hourly volume)

(2) Basic condition: Hourly volume is equal to or less than 40 vph

(Speed on paved roads) - (Speed on gravel roads) = 8.47 - .19(Hourly volume)

Double-Lane Roads.

Basic condition: Hourly volume ranges from 10 to 70 vph

(Speed on paved roads) - (Speed on gravel roads) = 15.17 - .06(Hourly volume)

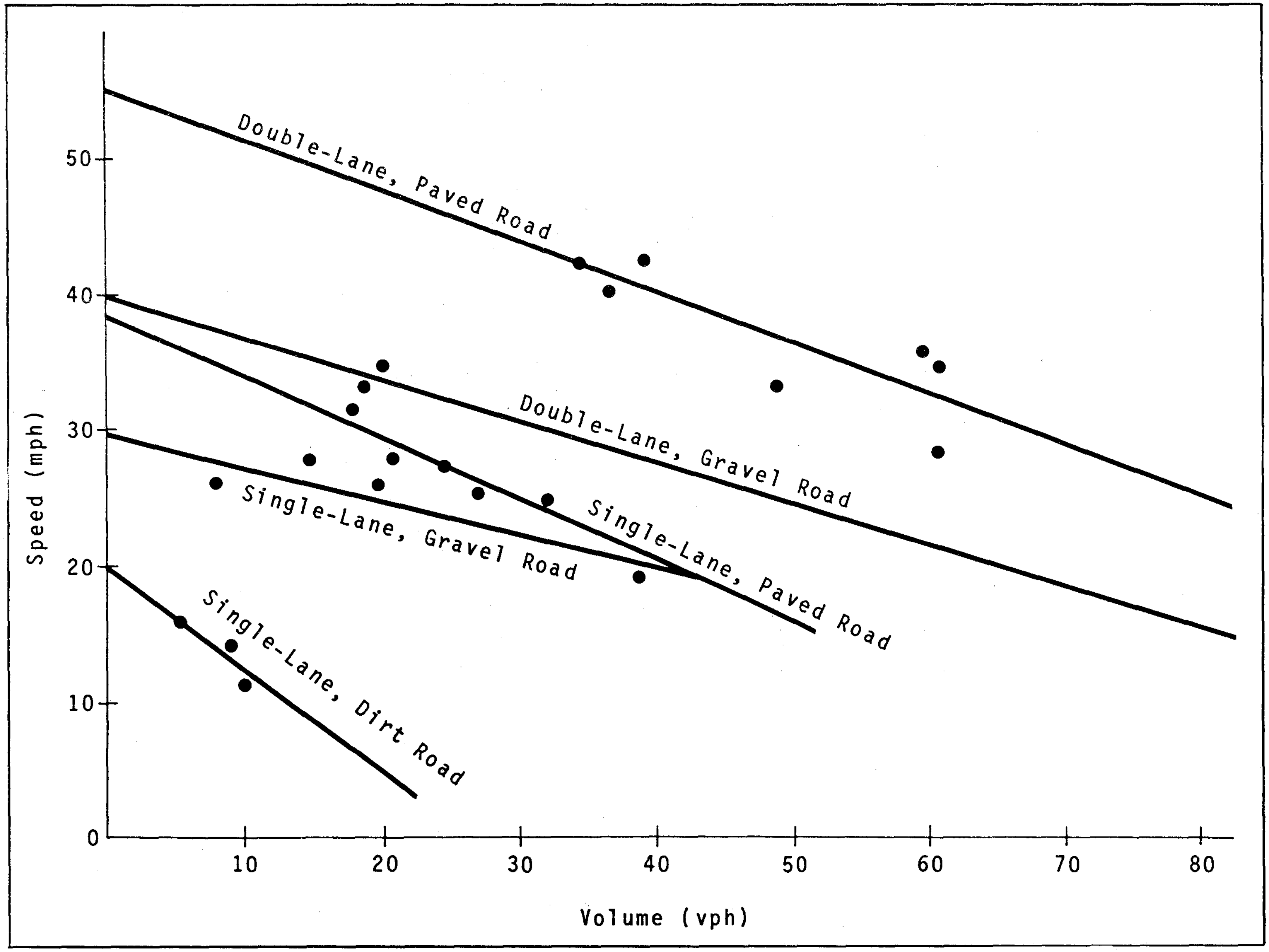

Figure 3.--Speed-volume relationship.

Single-Lane and Double-Lane Roads.

(1) Basic condition: Hourly volume ranges from 10 to 30 vph

(Speed on double-lane, gravel roads)
- (Speed on single, gravel roads)
= 10.20 - .06(Hourly volume)

(2) Basic condition: Hourly volume ranges from 10 to 40 vph

(Speed on double-land, paved roads)
- (Speed on single-lane, paved roads)
= 19.90 - .07(Hourly volume)

(3) Basic condition: Hourly volume ranges from 10 to 40 vph

(Speed on double-lane, paved roads)
- (Speed on single-lane, gravel roads)
= 25.37 - .12(Hourly volume)

The above traffic performance comparisons were made according to the given basic conditions. Any interpretation beyond the range of these conditions requires a verification of local data samples. In other words, the curves shown in figure 3 should be treated as segments of speed-volume relationship curves. Because there were only two sites for double-lane, gravel roads, the slope of the curve for this type of road was derived from the average of slopes for single-lane, gravel roads and double-lane, paved roads. A site of single-lane, gravel road was categorized as single-lane, dirt road because its roughness was found to be equivalent to that of a dirt road surfacing.

APPLICATION

With a list of hypothetical unit cost data as shown in table 2, the speed-volume relationships of figure 3 can be applied to select the most cost-effective road type in terms of road surfacing and the number of lanes. Since a procedure for selecting a single-lane between dirt and aggregate surfacing is discussed elsewhere,[1] the dirt surface will not be considered in this application.

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[1]Fong L. Ou and L. W. Collett, "Procedure for Determining Capacity of Unrocked Roads," Transportation Research Record 898 (1983), pp. 145-150.

Table 2.--Hypothetical unit costs by road type.

Road Type	Construction Cost ($/mile)	Maintenance Cost ($/mile/year)	Operating Cost of Log Trucks*		
			Fixed Cost ($/year)	Time Cost ($/min.)	Tire Cost ($/mile)
Single Lane					
Dirt	25,000	200	2,500	0.15	0.25
Gravel	30,000	800	2,500	0.15	0.17
Paved	40,000	500	2,500	0.15	0.07
Double Lane					
Gravel	50,000	1,200	2,500	0.15	0.17
Paved	70,000	800	2,500	0.15	0.07

*Operating costs were estimated from the Logging Road Handbook.

Assume that a transportation planner is asked to perform an economic analysis for planning a 5-mile Forest Road with an hourly volume of 10 vph. With a further assumption that the road will be used 10 hours per day and 200 days per year, the annual traffic demand will be 20,000 vehicles. The life of the planned road is assumed to be 20 years, while the discount rate is 10 percent. The main task the planner has is to select the least-cost alternative. The following procedures may be used to compute annual construction cost, annual maintenance cost, and annual operating cost.

Annual construction cost
= Initial construction cost ($/mile)
x 5 (miles) x .1175

Annual maintenance cost
= Maintenance cost ($/mile/year) x 5 (miles)

Annual operating cost = $2,500 + [5 (miles)
x 60 (min.) x .15 ($/mile)
x 20,000 (vehicles)/speed (mph)]
+ [5 (miles) x Tire cost ($/mile/vehicle)
x 20,000 vehicles]

The result of the computation is shown in table 3.

With an annual cost of $66,322, it appears that the single-lane, paved road is the least-cost alternative. Following are the double-lane, paved road; the single-lane, gravel road; and the double-lane, gravel road.

The second example assumes that all the conditions of the first example hold constant except traffic

Table 3.--Annual cost in dollars for the 5-mile road in the example.

Road Type	Construction	Maintenance	Operating	Total
Single Lane				
Gravel	17,625	4,000	55,790	77,415
Paved	23,500	2,500	40,322	66,322
Double Lane				
Gravel	29,375	6,000	46,207	81,582
Paved	41,125	4,000	28,448	73,573

volume, which increases from 10 vph to 20 vph. The annual transportation cost for the four road categories are as follows: $130,706 for single-lane, gravel; $104,144 for single-lane, paved; $125,288 for double-lane gravel; and $99,520 for double-lane, paved. In other words, the double-lane, paved option with a cost of $99,520 per year becomes the most cost-effective alternative for meeting the traffic demand of 20 vph.

CONCLUSIONS

The speed-volume relationship curves developed from the Mount St. Helens traffic study can be used to select the most cost-effective road type to meet a particular traffic demand. Its application has been illustrated by two hypothetical examples. The results show that the need for a given type of road system is sensitive to traffic volume. However, the curves developed in this report must be used within the range of conditions that were present in this study. Where local conditions lie outside this range, road managers should obtain local data samples to verify that the results of this study are applicable to that situation.

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