HIGHWAY RESEARCH RECORD

Number 280

Roadside Development

5 Reports

Subject Area
22 Highway Design
24 Roadside Development

HIGHWAY RESEARCH BOARD

DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

Washington, D. C., 1969 Publication 1657

Price: $2.00

Available from

Highway Research Board
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Washington, D.C. 20418

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Foreword

The five reports in this RECORD are intended for the use of persons interested in the art and science of roadside development. The reports are published in a sequence that relates their respective subjects to roadside maintenance and wildlife, urban roadside design, highway aesthetics, safety rest area water systems, and rest area design.

The first report discusses emerging concepts of roadside vegetation management and the resulting implications for ground-nesting birds and small mammals in the Midwest. A growing trend toward minimum mowing creates more acres of nesting cover and habitat for small birds and mammals. The author suggests research for an appraisal of possible safety hazards resulting from the increasing use of highway roadsides by nesting birds.

The second report discusses the highway roadside as an element in urban design. The author describes the roadside as an extension of its adjacent environment and stresses the importance of coordinated and collaborative planning and development of all environmental elements and needs. He cites a number of areas in which highway and urban design can be made compatible.

The third report examines the function and use of aesthetic criteria for the highway development process and recommends directions for future study and implementation. The scope of the study identifies visual performance and evaluation criteria for highway user benefits. The authors hope to develop procedure and evaluation criteria for highway planning and design through further examination and testing.

The fourth report describes the quantity and quality aspects of water systems for safety rest areas. The author discusses the problems created by demands during peak periods of visitor use, as well as the chemical and mineral content and quality of water. He stresses the need for standardization in the design, capacity, and operation of water systems.

The last report describes a computer simulation model used to design comfort station facilities within rest areas. Systems analysis techniques were used to simulate the operation of a comfort station. The model determines the number of facilities—toilets, urinals, wash basins and dryers—needed to satisfy certain levels of service for specified volumes based on assumed design criteria. Tabulations show the required facilities for both men's and women's comfort stations.

—Earl A. Disque

Contents

Wildlife—An Essential Consideration Determining Future Highway Roadside Maintenance Policy

G. BLAIR JOSELYN, Illinois Natural History Survey, Urbana

•PRIMARILY because of economic considerations, many states are altering their programs of vegetation management on highway roadsides by reducing the frequency of mowing. This change in maintenance policy will result in substantial increases in acreages of nesting cover along highway roadsides for songbirds and game birds. In the Midwest the ring-necked pheasant (Phasianus colchicus) could be a prime beneficiary, but at the same time may cause some concern for motorist safety. This report traces the history of roadside development, and discusses newly emerging concepts of roadside vegetation management and the resulting implications for ground-nesting birds and small mammals in the Midwest.

HISTORICAL BACKGROUND OF ROADSIDE DEVELOPMENT

The first hard roads constructed in the United States followed the shortest and most direct routes, without regard for trees or other natural features, and resulted in "railroad cross section" types of roadbeds (12). In 1924, the first public motor parkway in America (the Bronx River Parkway in Westchester County, New York) was opened to traffic. Here, for the first time, the roadway was the primary feature in parkway design (65), and represented ". . . the forerunner of our nationwide system of controlled-access highways" (30).

Concepts that emerged from the construction of early parkways were the stimulus for three periods in the evolution of roadside development between 1930 and 1965 (66). The period of interpretation (1930-1946) saw the coordination of roadside development with roadway construction programs. Roadside development started with erosion control along the first all-weather roads constructed in the 1920's (30). The concept of the "complete highway," first delineated by the Highway Research Board in 1943 (30), included 4 points:

1. Utility—The ability to serve commercial, recreational, local, interstate, and other categories of traffic.
2. Safety—The orderly movement of vehicular and pedestrian traffic. . . .
3. Beauty— . . . a basic element in the harmonious integration of engineering, architectural, and landscape techniques. . . .
4. Economy—A combination of effective design and pleasing appearance at a reasonable cost for construction and maintenance. . . .

Miller (55) wrote that the central idea of the complete highway is ". . . the adaptation of an artery of motor traffic into the natural setting of the countryside, thereby conserving both the beauty of the countryside and the land values for future generations." This concept has greatly influenced the planning for construction of new highways.

The period of communication (1947-1965) "among the States in the buildup of experience for progress in esthetics and roadside development" (66) featured the 1956 Act for the National System of Interstate and Defense Highways. When completed, the

Paper sponsored by Committee on Roadside Development.

Interstate System will consist of 41,000 miles of mostly divided four- or six-lane limited-access highways. This program is bringing aesthetics to the forefront in highway construction as ". . . some hard looks were taken at the concept that highways were not merely pavements in selected right-of-way corridors but important elements in the environments they passed through" (62). Guidelines established for design of highways in the Interstate System stressed the four points of the complete highway. For example, the U. S. Bureau of Public Roads approved the "Geometric Design Standards" adopted by the American Association of State Highway Officials (1), which stated, "Divided highways should be designed as two separate oneway roads to take advantage of terrain and other conditions for safe and relaxed driving, economy, and pleasing appearance. . . ." Haile (28) stated that this proposal means that the approach to design held in the past, which was to adopt a fixed cross section, a constant width of median, and identical gradelines on the two roadways, should be discarded and that each one-way road should be located and designed independently of the other.

The policy on landscape development for the Interstate System published by AASHO (2) stressed, among other things, the following points: (a) conservation of "all desirable landscape features and land values"; (b) variation in width of right-of-way "to conserve landscape features and to fit the localized requirements of grading, drainage, erosion control, and planting for each portion of the highway"; and (c) provision of "at least 50 feet of roadside border. . . beyond the outer edges of roadway shoulders." But on rural highways, there should be acquisition of "additional right-of-way to natural demarcation lines such as streams, shorelines, cliffs, and tops of ridges. . . ." These changes in the concepts of highway design and associated roadway development resulted in substantial acreages in roadsides, medians, and interchanges created in conjunction with highways now being constructed, particularly those in the Interstate System.

The period of action for highway natural beauty (1965), according to Simonson (66), "witnessed a dynamic acceleration of pace in highway landscape planning and construction. . ." and was "a period of intense action for highway esthetics and roadside development." The White House Conference on Natural Beauty resulted in the President's submitting to Congress a bill of consequence to roadside development, recommending legislation on (a) control of outdoor advertising, (b) control of junkyards, and (c) broadening of existing authority to use federal funds for the cost of landscape and roadside development. This proposal was enacted into law by the 89th Congress as the Highway Beautification Act of 1965. The sections of the Act serving to control outdoor advertising and junkyards concern not only the area along the roadside, but that beyond the normal right-of-way line.

VALUE OF WIDE RIGHTS-OF-WAY

Fulfilling the four requirements of the complete highway is, to a great extent, contingent on having adequate rights-of-way. Acquisition of wide rights-of-way for modern highway construction can usually be justified for reasons of economy alone. Many older roads had a standard 66-foot width, and when it became necessary to add lanes or widen a road, adjacent property had to be purchased at high cost. Engineers now consider it good practice to require rights-of-way wide enough to accommodate the ultimate expected development (57). A cross section with flat slopes, possible on wide rights-of-way, minimizes the need for expensive guardrails and provides roadside slopes that may be mowed easily and rapidly with mechanized equipment instead of hand labor (51).

Many safety features of highways are enhanced with wide rights-of-way. Deakin (16), Gnau (27), Ives (42), and Stonex (71) have mentioned the safety benefits of flat, well-rounded side slopes and wide, gently rounded drainageways that help prevent the overturning of out-of-control vehicles. Substantial rights-of-way allow functional as well as aesthetic plantings. Vegetation may be planted to direct the line of sight of the motorist around the highway curvature (25) and to accent danger areas (bridge abutments, culvert head walls, etc.) near the outer edge of the shoulder (19, 42). Sufficient width of right-of-way and controlled marginal lands will provide drivers with safe sight distances commensurate with the design speed (4, 18, 42).

Noise abatement by border plantings and provision for rest areas and safety turnouts are possible utility features of liberal rights-of-way (2, 5, 49).

Wide rights-of-way are important from the standpoint of preserving and developing roadside beauty. In rural areas they permit blending the road into the natural landscape and provide space to plant screening vegetation in front of objectionable and unsightly objects (4, 57).

TRENDS IN ROADSIDE MAINTENANCE PRACTICES

Prior to 1940, the quality and quantity of highway roadside turf management were negligible. Maintenance consisted of a few mowings a year, weed control was just starting, and the requisite labor was available. It was difficult to control erosion along new highways where little attention was given to roadside development during the construction phase. As development of vegetation on roadsides became integrated into the construction phase, increased attention was given to roadside maintenance, which centered around mowing and weed control. Today, control of roadside vegetation (primarily mowing) constitutes a sizable portion of maintenance operations.

Roadsides are mowed to improve appearance, control noxious weeds, aid drainage, improve turf density, reduce fire hazards (10, 47), and "because it is considered desirable to keep the neatness and well-kept appearance of adjacent fields unbroken" (59).

Development of Roadside Vegetation Management

Management of roadside vegetation became a significant segment of total highway maintenance costs as the number of highways increased. Ohio cut maintenance costs by restricting the mowing schedule in at least one division as early as 1943 (10). The 1950's saw a surge of activity in chemical weed and brush control as it became apparent that chemicals were often more effective and economical than mechanical methods (26, 72). Despite rapid development of methods of chemical weed control, improvement in maintenance equipment, and changes in highway design favoring easier roadside maintenance, highway administrators were listing rising maintenance costs second only to highway safety as their most important problem by the early 1950's (64, 79).

Impact of the Interstate System on Concepts of Roadside Maintenance

Completion of the Interstate System will provide an additional 1 million acres of roadside area. When added to the estimated 3.5 million acres already being mowed each year (13), the economic aspects of this added maintenance burden become awesome. The growing maintenance problem emphasized the need to modify existing concepts of roadside management. Parker (58) cited Paragraph 109, Public Law 85-767 (1958), which called for "economy of maintenance" and "maintenance at a reasonable cost" as requirements for approval of projects on any federal-aid system. Because a direct reference to the need for economy in maintenance operations did not appear in previous federal highway legislation, Parker concluded that "the law surely points out that there was dissatisfaction with previous roadside concepts and that maintenance could be performed at a reasonable cost."

Typical of many published accounts calling for a new approach to highway roadside management on the Interstate System, particularly intensive mowing, was the comment by Gordon in the discussion moderated by Brant (11): "On extensive roadside areas. . . maintenance of closely mown lawn-type areas will often be unnecessary, particularly in wide operation country at a distance from metropolitan population centers." Hottenstein (31), in discussing the implications of the 1 million acres of roadside to be added by the Interstate System, stated:

> Considering the fact that these many acres of roadside are being added to the maintenance engineer's responsibility without a corresponding increase in his budget, it is almost inconceivable that so little has been done to develop management standards....Mowing to achieve a lawn or fairway appearance from fence-line to fence-line through rural and forested countryside belongs in the luxury category, and besides, it cannot be justified aesthetically.

Strangely, such practices evoke favorable comments for the reason that they create a neat appearance. Such high-class, city-park type mowing is not within the capacity of the maintenance engineer's budget. Even from an appearance standpoint such practices cannot be justified. Many of the roadside areas within the right-of-way should be managed to achieve a natural effect, thus making them an integral part of the adjoining countryside. The picture of mile after mile of neatly maintained turf areas resembling lawns and fairways is neither distinctive nor indicative of the character of the natural environment of the State or locality the motorist views.

The basic elements of a common sense mowing program are as follows:

1. It is not necessary to mow every acre of roadside vegetation in order to maintain properly the right-of-way of a modern highway.

2. The mowing program must be planned. Roadside areas should be arranged in categories and a vegetation management program prepared to fit the needs. Cultural practices and land-use patterns along the right-of-way should dictate the roadside treatment. As a general rule it should not be necessary to mow the following locations: slope areas 2.5:1 and steeper; roadsides adjacent to natural woodland and swamp areas; and areas in agricultural sections with dense uniform stands of desirable species of grasses and legumes beyond ditch lines.

3. There must be a reason, a justification, for mowing the various areas comprising the roadside.

Hottenstein (31), citing "Guide for Roadside Mowing" by the maintenance standards committee of AASHO (3) as encouraging "evidence of positive action to develop control policies for turf management. . . ," nevertheless felt that the document does not entirely clarify the big question, "Where to mow?"

Fundamental changes in concepts of turf management were no doubt partially prompted by public acceptance and by success of minimum mowing schedules on such privately financed and operated highways as the Illinois Tollway (48), the New York Thruway (50), and the Ohio Turnpike (80). Even rural or local road jurisdictions have been called on to eliminate unnecessary mowing (6).

Current Roadside Management Practices

During December 1966, questionnaires were sent to the Chief Highway Engineers in 13 states and to two turnpike commissions. Included in the survey were Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, Pennsylvania, Wisconsin, and the Ohio and Pennsylvania turnpikes. Portions of each of these states possess sizable populations of ring-necked pheasants. The questionnaire was designed (a) to obtain information on current practices of roadside maintenance and (b) to determine the attitude of highway administrators regarding management of highway roadsides for nesting birds. All 15 questionnaires were returned.

Of the 15 respondents, 5 (33 percent) reported that highway roadsides were mowed from fence to fence, beginning with the first mowing each summer. Six (40 percent) mowed beyond the ditch only once, in late summer, and four (27 percent) carried out no mowing beyond the ditch. Thus, 10 of 15 respondents were, in effect, employing minimum mowing schedules beyond the ditch.

Eleven respondents (73 percent) reported that spraying was used to supplement mowing, and five reported that spraying was used to eliminate one or more mowings. Ten respondents revealed that changes had been made in mowing policy over the last 10 years; however, 13 (87 percent) did not anticipate any further changes in the near future. One of the two respondents that expected changes to be made anticipated less mowing; the other expected more mowing in areas where herbicides have proved ineffective.

Eight (73 percent) of the 11 responding to a question on changing costs of mowing reported increases in mowing costs; three (27 percent) reported decreases. According to these estimates, per-acre mowing costs increased an average of 5 percent each year since 1960. Ten respondents provided figures on mowing costs. Annual per-acre mowing costs for two-lane highway roadsides were $11.86, and for four-lane and Interstate roadsides, $17.78; the average cost for all highways was $15.19 per acre. Butler and Yoerger (13), reporting on data collected in 1959 and 1960, calculated total mowing costs of $10.21 per acre per year.

Two significant points can be made from these data: (a) the trend toward increased costs of vegetation control along highways shows no signs of abating without major changes in maintenance policies; and (b) through the use of selective herbicides and realistic mowing programs, many states among those surveyed are attempting to place costs of roadside vegetation management in a better perspective relative to the total highway maintenance budget.

Published data from the Illinois Department of Public Works and Buildings, Division of Highways (32, 33, 34, 35, 36, 37, 38, 39, 40, 41), provide an example of rapidly rising costs of roadside maintenance (Table 1). Illinois follows a policy of mowing virtually all accessible areas within highway rights-of-way two to four times each summer. The cost of clearing and cutting vegetation along "regular highways" increased from $221 per mile in 1955 to $446 per mile in 1964, an increase of over 100 percent. Data on roadside vegetation control along Interstate Highways in Illinois are limited to only 3 years, but show a cost of $950 per mile in 1962, $989 per mile in 1963, and $1,026 in 1964, an increase of $76 per mile over the 3 years. Cutting and clearing vegetation along Interstate highways represented 23.6 percent of total maintenance costs for these roads in 1962, 22.7 percent in 1963, and 21.5 percent in 1964. These rapidly rising mowing costs come at a time when Illinois highway administrators are increasingly concerned over high maintenance costs (54, 67).

Construction of additional four-lane highways in many parts of the country can be expected after the completion of the Interstate System. For example, the Illinois Legislative Highway Study Commission has before it a proposal for the construction of 2,175 miles of supplemental freeways to be added to the 1,623 miles of road in the Interstate System still under construction (68). Many existing two-lane highways may be upgraded and expanded in Illinois, as elsewhere. Because of mounting costs, the increased acreage of roadsides resulting from improved highway systems will probably receive even less intensive maintenance (primarily mowing) than is true today in at least one-third of the states contacted. The result will no doubt be substantial acreages of largely undisturbed grassy vegetation along most highways. In the Midwest, such areas will provide an additional source of nesting cover for the primary game bird of the region, the ring-necked pheasant. This prospect may be encouraging to game managers, but the safety implications of this development will require close scrutiny by highway administrators.

TABLE 1

COST OF CUTTING AND CLEARING ROADSIDE VEGETATION IN ILLINOIS

Year	Regular Highways (1955-1963)		Interstate Highways (1962-1964)	
	Cost per Mile ($)	Percent of Total Maintenance Budget	Cost per Mile ($)	Percent of Total Maintenance Budget
1955	221	13.8	—	—
1956	245	15.0	—	—
1957	242	14.1	—	—
1958	280	14.9	—	—
1959	301	15.4	—	—
1960	344	15.4	—	—
1961	338[a]	15.4	—	—
1962	330	13.0	950	23.6
1963	413	15.6	989	22.7
1964	446	15.7	1,026	21.5

[a]Includes Interstate Highways.

HIGHWAY ROADSIDES AND WILDLIFE

Wildlife as a Hazard to Traffic

During the 1930's, when wildlife research and management were still in the formative stages, several papers were published documenting the destruction of wildlife on highways. Dickerson (17), Linsdale (52), Scott (61), and Starrett (69), among others, presented data revealing that substantial numbers of birds, mammals, reptiles, and amphibians were killed on highways. Today, with a much greater volume of traffic and higher speeds, wildlife mortality on highways continues.

The growing acceptance of minimum maintenance procedures intensifies the need for investigating the possible safety implications of increased use of highway roadside cover by nesting game birds, particularly in the Midwest. The literature reveals that this question has received little attention. A recent Highway Research Board publication summarizing current knowledge on roadside development (30) discusses safety in roadside development during the planning, design, construction, and maintenance phases; the publication calls for minimum mowing of highway roadsides, but makes no mention of any safety problems that might be created from increased utilization of unmowed roadsides by wildlife. Similarly, Hottenstein (31), while advocating nonmowing of areas beyond the ditch in agricultural regions where grasses and legumes exist, does not refer to possible safety problems in the pheasant states.

Of all wild and domestic animals that cause accidents on highways, deer constitute the greatest menance. Nearly 200 deer were reported killed on Wisconsin highways in 1937 (14); Jahn (44) reported that 6,416 deer were killed on the highways in the state between 1946 and 1955; mortality of deer on highways was 29,129 for the 3 years 1964 through 1966 (75, 76, 78). In Michigan (19) the number of highway-killed deer increased each year from 1959 (2,761 killed) to 1966 (6,290 killed). Data from turnpikes and tollways reveal the magnitude of accidents involving deer (Table 2). Between 1964 and 1966, of the 31,601 accidents occurring on seven such highways, 1,984 or 6.3 percent were caused by deer. Problems arise in wooded terrain where deer travel-lanes intersect highways (7, 8, 73), and the danger is increased during the breeding season and when the animals seek salt spread on roads for snow and ice control. In Wisconsin (77), biologists feel that the primary reasons deer are found along highways are (a) to feed during spring, summer, and fall; (b) because of normal daily movements (including rutting season activity); (c) to escape insects; and (d) to obtain salt. Jahn (44) and Wilson (74) also report that utilization of roadside cover by deer is responsible for some accidents.

TABLE 2

VEHICULAR ACCIDENTS INVOLVING DEER AND OTHER ANIMALS ON EIGHT TOLL ROADS AND TURNPIKES, 1964-1966

Toll Road/Turnpike	Total Accidents	Accidents Involving Deer	Accidents Involving Animals Other Than Deer	Accidents Involving Deer and Other Animals
Illinois State Toll Highway	3,522	75(2.1)[a]	—	—
Indiana Toll Road	2,688	188(7.0)	—	—
Kansas Turnpike	1,765	96(5.4)	3(0.2)	99(5.6)
Massachusetts Turnpike	2,204	73(3.3)	—	—
New Jersey Garden State Parkway	4,988	281(5.6)	54(1.1)	335(6.7)
New Jersey Turnpike	5,088	—	—	36(0.7)
New York State Thruway	13,236	1,197(9.0)	105(0.8)	1,302(9.8)
Ohio Turnpike	3,198	74(2.3)	17(0.5)	91(2.8)
Totals	36,689	1,984	179	1,863
Proportion of appropriate total (percent)		5.7	0.8	8.0

[a]Percentages are in parentheses.

Whereas the hazard of deer to vehicles is obvious, the significance of small mammals and birds as a safety threat is less clear. Few data are available on accidents caused by animals other than deer. Here again, the turnpikes and tollways are the best sources of information, although only four of the eight contacted could provide specific information. On the New York Thruway between 1964 and 1966, 105 accidents were caused by animals other than deer, accounting for approximately 0.9 percent of all accidents during the period; involved were 72 dogs, 9 cows, 2 birds, and 22 other animals. The Kansas Turnpike reported there were no accidents caused by animals other than deer in 1964 and 1965, but there were three in 1966 (one coyote, two steers) accounting for about 0.2 percent of all accidents over the 3-year period. Small mammals caused 54 accidents on the New Jersey Garden State Parkway between 1964 and 1966, or 1.1 percent of all accidents during that time. Those involved were "dogs, raccoons, and skunks, etc.," but no birds were known to have caused accidents. The Ohio Turnpike reported 17 of 3,198 accidents (0.5 percent) caused by small mammals and birds, usually pheasants, over the 3-year period.

Several studies in recent years have shown that sizable numbers of small mammals and birds are killed on highways, although none discussed the implications for traffic safety. Jackson (43) reported that during 1948, 14,096 wild birds and mammals were killed on highways in seven northwestern Pennsylvania counties, with rabbits being the most frequent victims. Another study in southern Minnesota (70) showed that 3,356 small mammals and birds were found dead in 153,000 miles of driving between 1947 and 1952. From 1932 to 1950 Schorger (60) kept a record of all dead birds on the highway between Madison, Wisconsin, and Freeport, Illinois, which he traveled 693 times during the period. A total of 64 species of birds were observed dead on the road, with pheasants constituting 5 percent of the total killed and songbirds the balance. In Minnesota, a 1949 through 1951 study reported by Longley (53) showed that pheasants, striped skunks, and rabbits were the species most frequently killed. Other Minnesota workers (24) found an average of one dead pheasant every 235 miles over 113,000 miles of highway throughout the pheasant range in that state.

Roadside Management Considerations for Wildlife

The primary concern of highway administrators has justifiably been for the safe, efficient movement of the increasing volume of traffic. Conservation considerations, as related to highways, have been almost entirely confined to those having direct bearing on the highway user (e. g., roadside erosion control, functional control, functional plantings). Development of habitat for wildlife on highway rights-of-way has been rarely, if ever, undertaken. Conservationists have argued for roadside management practices beneficial to game birds and mammals (15, 21, 22, 23), but have generally not called for specific projects for development of wildlife habitat along highways.

Dreesen (20) saw the need for a national policy on highway roadside management in relation to wildlife. In discussing the future of chemicals in roadside maintenance programs, he stated, "Some of the most important questions that require answers are concerned with the relationship of wildlife to roadside rights-of-way. . . . Will future highway management policies in this era of high speed transportation dictate that wildlife must also be excluded from the highway rights-of-way as a safety measure?" Seeker suggested (63) that removing roadside cover with herbicides "constitutes a service to the interest of conservation" because roadkills of game birds and mammals were reduced.

Implications of Changing Roadside Management Practices

Changing concepts of maintenance applied to newly constructed and existing roadsides can and are resulting in substantial increases in acreages of undisturbed highway roadside cover. At the same time in the Midwest, agricultural land-use changes are affecting the quantity and quality of cover available to nesting pheasants and songbirds. For example, in the four counties constituting the major center of pheasant abundance in Illinois, recent trends in land use reveal increased acreages in row crops (corn and soybeans) at the expense of small grains (oats and wheat) and the prime pheasant nesting covers of tame hay and pasture (45). Concurrent with the decrease in hay and pasture is an accelerated trend toward agricultural use of other pheasant nesting cover such as fencerows and similar areas not previously farmed. As more intensive land-use practices develop, pheasants are being forced to make greater use of the remaining nonfarm land for nesting. Roadsides along both secondary roads and highways will be important in this regard, and in the near future could constitute virtually the only nesting habitat in some parts of the Midwest. Thus, the occurrence of substantial acreages of undisturbed roadside cover along highways coincides with a greater need for such cover by pheasants and songbirds.

Greater use of highway roadsides by wildlife in the Corn Belt may have significant safety implications. Of the small mammals and birds that frequent roadside cover, only the pheasant appears capable of constituting a serious hazard to traffic. Pheasant-auto collisions probably will continue to occur irrespective of agricultural land-use trends or roadside maintenance practices. At least some of these collisions result in property damage to vehicles and can cause personal-injury accidents. Beyond this, the literature reveals that little is known about the pheasant as a hazard to traffic. Previously cited studies of pheasant roadkills provide little basis for detailed evaluation of the safety problem. That the greatest number of roadkills occurs during the spring and summer is evident from the work of Norstog (56), who showed that the greatest frequency of pheasant roadkills in South Dakota occurred in May during the reproductive season; in Michigan, roadkills were highest in August (29).

Since 1954, the Illinois Department of Conservation and the Illinois Natural History Survey have conducted pheasant research on a 23,200-acre study area in Ford and McLean counties in east-central Illinois. Illinois Highway 47 passes through the study area for 6 miles. This highway has provided limited data on the temporal distribution of pheasant roadkills and on association of such kills with roadside mowing dates. During 1962 and 1963, 28 and 90 pheasant roadkills, respectively, were located on Highway 47 in the study area between April 15 and August 1. In both years a greater proportion of roadkills occurred during May than in other months (Fig. 1). Mowing of the roadsides apparently failed to cause an increase or decrease in the number of roadkills. For those years, the peak had been reached and a downward trend had begun prior to the time mowing took place. Because the decline in roadkills began prior to mowing, it appears that standing cover along the highway had little effect on the number of birds killed.

Although not definitive, these data may provide an insight, which might be borne out by more detailed studies, into an important characteristic of pheasant-auto collision: of pheasant roadkills, a substantial proportion is a result of breeding behavior rather than of a direct association of the bird with roadside cover. This does not imply that pheasant use of highway roadside cover never results in roadkills, but that factors implicit in pheasant behavior could be of greater significance in causing most highway kills. One of the questions asked of the highway administrators in the mail survey was whether they had data indicating that the hazard to motorists from wildlife was in any way affected by curtailed mowing schedules or partial mowing of roadsides. All 15 respondents answered in the negative.

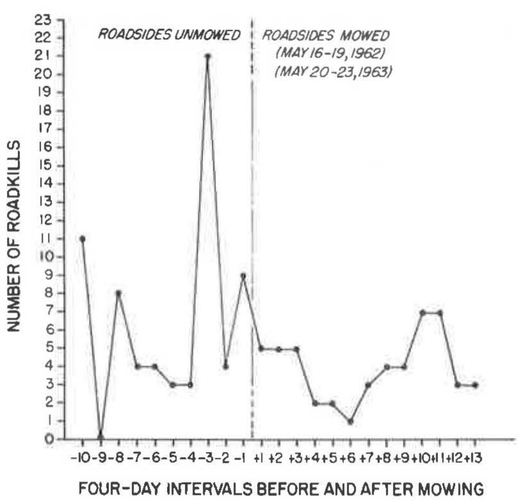

Figure 1. Distribution of pheasant roadkills along Highway 47, Sibley Study Area, 1962 and 1963 combined.

Since 1962, research has been under way in and near the study area to determine the feasibility of establishing and maintaining grass-legume cover on roadsides for nesting pheasants. The bluegrass-broadleaf weed composition of most east-central Illinois roadsides does not generally constitute high-quality pheasant nesting cover. This research seeks to determine if the quality of roadsides as pheasant nesting cover can be improved by seeding with a mixture of tame grasses and legumes. Nearly 11 miles of secondary (township) roadsides (22 acres) have been seeded with a grass-legume mixture (brome, alfalfa, orchard grass, timothy, and red clover); adjacent roadsides equivalent in acreage, left unseeded, were designated as managed control roadsides. Seeded and managed control roadsides were left unmowed until late summer and searched for pheasant nests during June and July each year beginning in 1963. Searches were also made in a sample of agricultural cover types in the study area, which included roadsides designated as unmanaged control (some were mowed and some were not mowed during the summer). During the 5-year period of 1963 through 1967, densities of pheasant nests established on seeded roadsides (2.9 per acre) exceeded those on managed control (2.0 nests per acre) and unmanaged control roadsides (1.3 nests per acre). Seeded plots had a substantially larger number of hatched nests than either managed or unmanaged control plots. The hatch of pheasant nests on seeded roadsides, on a per-acre basis, exceeded that in all other cover types on the study area during 4 of the 5 years.

This research has not been completed, but it is possible to conclude tentatively that grass-legume seedings on roadsides constitute a habitat that is attractive to nesting pheasants and in which they are successful. The research has also demonstrated that pheasants attracted to seedings adjacent to secondary roads do not constitute a hazard to motorists on these roads.

Secondary roadsides, by virtue of their greater mileage, provide more potential for management than do highway roadsides, but highways, with their wide rights-of-way, also provide interesting possibilities for management. Within the context of the current trend toward minimum maintenance of highway roadside vegetation, it seems appropriate that the relationship between utilization of highway roadside cover by pheasants and traffic safety be investigated in detail. It should be determined by controlled field tests whether roadside management practices along high-speed highways that unintentionally (through minimum mowing) or intentionally (through seeding grasses and legumes) result in greater use of these roadsides by wildlife constitute an increased hazard to motorists.

RESEARCH NEEDS

Safety ramifications of the use of highway roadsides by nesting pheasants should be investigated from the following standpoints:

1. The distribution and characteristics of roadkills as a function of (a) pheasant population densities, (b) traffic volume and speed, and (c) pheasant behavior;
2. The number of personal-injury and property-damage accidents involving pheasants; and
3. The effects of roadside management on the frequency of pheasant roadkills.

Distribution and Characteristics of Roadkills

In Illinois, there is some evidence that the frequency of roadkills is higher on US 66 (four-lane highway), in an area with relatively few pheasants, than on two-lane highways farther to the east in an area of higher pheasant population levels with lower traffic volume. When related to traffic volume, however, the probability of hitting a pheasant is still higher on these two-lane highways than on US 66. This suggests that pheasant utilization of roadside cover along Interstate or limited-access highways may be no more hazardous to motorists than along two-lane highways. The evidence indicates that the breeding season is the time when most birds are hit on highways. What is not known, however, is what proportion of the birds hit by vehicles are associated with roadside cover, and what proportion are birds crossing between fields completely unassociated with roadside cover.

Number of Accidents Involving Pheasants

Data on the number of accidents involving pheasants are virtually nonexistent because highway departments generally lump reports of such accidents into larger categories, making analysis difficult. The Illinois Division of Highways has undertaken a study of accident report forms to determine the number of accidents involving pheasants during April, May, and June in four counties for 1967, 1968, and 1969. Property damage claims to insurance companies may also provide data on pheasant-auto collisions. In Illinois, however, only those accidents resulting in personal injuries or property damage in excess of $100 would appear in Division of Highways records.

Effects of Roadside Management Practices on the Frequency of Roadkills

Extensive field tests are needed to determine the effect of various roadside maintenance practices on the frequency of pheasant roadkills. These practices to be studied are (a) intensive mowing of the entire roadside, beginning in late May; (b) mowing of the entire roadside once in late summer (August) only; and (c) intensive mowing of shoulder and foreslope, combined with late-summer mowing of the area beyond the ditch. These three mowing programs should be carried out along two- and four-lane highways where "natural" and seeded grasses and legumes are present under conditions of differing traffic volumes and speeds and high, intermediate, and low pheasant population levels. Such research should help determine if any of these management practices increase or decrease, or leave unchanged, the degree to which the pheasant already is a hazard to traffic.

Data from the questionnaires sent to the Chief Highway Engineers in states with sizable pheasant populations show that 10 of 15 agencies employed minimum mowing beyond the ditch. This practice has no doubt already improved pheasant nesting cover along many of the highways in those states. Yet, none of the respondents felt they had sufficient data to demonstrate whether curtailed mowing schedules of highway roadsides affected the frequency of pheasant-auto collisions. Three reasons for this dearth of information may be that (a) few objective data are available about the pheasant as a hazard to traffic, (b) the hazard from pheasants is considered relatively inconsequential compared with the lower costs of minimum mowing, and (c) little or no discernible change in the frequency of pheasant-auto collisions has been attributed to the reduced mowing programs. Some states evidently do not consider the pheasant hazard excessive, because 6 of the 15 agencies had formal or informal agreements with their respective conservation departments to delay mowing to provide undisturbed nesting cover for game birds. However, 9 of the 15 agencies felt it would not be compatible with the primary function of highways to provide roadside nesting cover for birds in conjunction with efforts to reduce mowing costs or with programs for roadside beautification, even if research showed that greater use of highway roadsides by birds did not increase the hazard to motorists. (Two of these nine agencies were also in the group of six having agreements with their state conservation departments to delay mowing during the summer nesting season.)

A recent study was carried out (46) to ascertain "present experience in the multiple use of lands within controlled-access highway rights-of-way for purposes other than the movement of traffic." In this study, a questionnaire sent to 49 state highway departments and 16 toll road authorities identified over 20 types of multiple uses that employed all portions of highway rights-of-way; these included uncommon uses, such as agriculture and stream-access sites, in addition to the usual safety rest areas and service plazas. No states reported wildlife utilization of roadsides as a multiple use. This is of interest in view of the agreements to leave highway roadsides unmowed during portions of the summer months, as reported by six states in the present survey.

Whether management of highway roadsides for nesting birds will be accepted and practiced as a multiple use will depend on the results of research that should be undertaken to determine the safety implications of such management. Conservationists are not justified in arguing for the development of highway roadside cover for nesting birds without regard to these safety implications; similarly, highway administrators who arbitrarily preclude wildlife considerations from roadside management programs without evidence that a hazard is created lack a substantive basis for their stand.

ACKNOWLEDGMENTS

The author wishes to thank the following personnel of the Section of Wildlife Research, Illinois Natural History Survey: Dr. Glen C. Sanderson and Mr. William R. Edwards for administrative, technical, and editorial supervision; and Mrs. Helen C. Schultz for a critical reading of the manuscript. The assistance and encouragement of Dr. John E. Baerwald, Director of the Highway Traffic Center, University of Illinois, is gratefully acknowledged. Professor Ellis Danner, Department of Civil Engineering, and Jack Butler, Department of Agricultural Engineering, University of Illinois, reviewed the manuscript, as did Mr. W. L. Hottenstein, U. S. Bureau of Public Roads, and Mr. Thomas Mracek, Illinois Division of Highways. The cooperation of the Chief Engineers of the state highway departments and turnpikes who were kind enough to complete and return questionnaires is acknowledged along with that of officials of the various turnpikes who provided data on the number and causes of accidents occurring within their jurisdiction.

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The Highway Roadside as an Element in Urban Design

JOSEPH C. FEDERICK, District Engineer,
New York State Department of Transportation, Binghamton, N. Y.

•THE DEVELOPMENT of most communities in America may be described as a process of natural growth in contrast to controlled evolution. The growth from a central nucleus has taken various forms depending upon restrictive physical elements. Consequently, we have circular cities and linear cities, and those presenting irregular patterns without geometric similitude. The development was generally unplanned and uncontrolled. Action was dictated by economic returns rather than the most desirable form or direction of development.

Land speculation may be considered as the generating force behind municipal development. The real estate agent rather than the city planner has determined the structure of our communities. We are now struggling with the results of the formative periods of unguided growth.

Engineers, economists, sociologists, planners, and the ordinary citizen are now talking in terms of city plans or development programs. Urban renewal, model cities, and other federally funded programs are stimulating progressive communities to action.

Irrespective of the type of agencies available for planning, the need for a community development program is fundamental. A broadly conceived and soundly executed community plan serves as a basic pattern or framework about which existing deficiencies may be adjusted and desirable growth may occur. A community plan will encompass the entire physical environment of the urban area. Segments of the design will be concerned with a circulation plan; a recreational plan including parks, playgrounds, and other recreational facilities; a transportation plan for airports, railroad terminals, bus depots, and other elements; and additional plans for neighborhoods, housing developments, public buildings, and utilities.

THE NEW EXPLORATION

The objective of the community plan is to achieve compatible land-use patterns. An organized and balanced allotment of space for residential, business, industrial, recreational, and public use is required for present conditions and future anticipated growth. Space relationships, arrangement, and organization must be in scale and harmony.

With the crisis in our cities, planning concepts are in a state of flux. Should the educational function be planned around educational parks or the traditional school orientation? Is industry to be developed in ghetto areas to bring employment to the locale or is the area to be rebuilt and the inhabitants rehoused on the scene or relocated? Is the neighborhood concept utilizing the school building as the focus of group activities to be replaced? Are new buildings to be constructed as district community centers?

It is within the urban framework that those responsible for highway planning must function. Interstate highways, expressways, and arterial routes serving metropolitan areas exert a profound influence on community values, growth, and structure. Consequently, the highway planner must be involved in the total planning process. These arteries must be an integrated element of the broad concept of a community, and the integration must be accomplished with a minimum disruption of community values. Highways are concerned with moving people and goods safely, expeditiously, and economically. Of greater importance, highways must serve the community and improve and enhance the human environment.

Paper sponsored by Committee on Roadside Development and presented at the 48th Annual Meeting.

NETWORK LAYOUT

In developing a highway network consisting of Interstate 81, Interregional Route 17, and an urban arterial system for the Binghamton, New York, metropolitan area, all the foregoing factors and values were considered. Alternate proposals were studied and evaluated in monetary and social terms. Alternate routes were analyzed with respect to present land use, population densities, neighborhoods, school sites, public buildings, church locations, recreation facilities, future land-use plans, and traffic origin and destination.

Interstate 81 through the urban area has been completed. Two sections of Route 17 are under construction. The major sections of the arterial system are completed or under construction, and the remaining connectors will be advanced to construction in the very near future.

AN URBAN ROADSIDE PARADIGM

In urban areas land values are high, and usable vacant property is at a premium. Yet it is precisely in the high-density, intensive-use locations that open space is an essential. To realize the full potential of urban highway design, as wide a marginal area should be acquired as the physical conditions and restrictive elements will permit. Such wider rights-of-way in a rural setting will help preserve the integrity of the highway by maintaining natural landscape features. In the urban environment these margins are an essential element in urban design. There is a uniqueness of the roadside in this context that needs exploration.

In accordance with Marshall McLuhan's dictum, "the medium is the message." Therefore, if the roadside is the medium, the roadside is the message. We now view the roadside as an extension of the adjacent environment or physical space. As a spatial determinant, the roadside is an element of the urban design in situ. A uniqueness is conferred by the spatial fusion of the private sector with the public domain. It is now possible to organize, mold, manipulate, and control its form and context. Monotony is avoided by treating each site as an individual design problem, but intergrating it into a dynamic cityscape. The interdependence of contiguous space and roadside transforms the physical environment into a visual entity.

Local thoroughfares are defined by the distance between curb lines. In contrast, the area occupied by urban expressways consists of wide bands rather than restrictive narrow strips. In essence these areas are large land masses devoted to a specialized use. They must be considered in the planning process in conjunction with residence, business, industrial, and other areas. The highway-use area has a varying intensity of use similar to other land-use districts. It must be developed in conjunction with the existing and projected land-use plan to serve the area and complement the environmental features.

The highway land-use area, in addition to being a large land mass, possesses characteristics peculiar to itself—it has continuity and linearity, and may be topological. These special attributes differentiate the highway land mass from other land-use areas. The highway as a communication system has a community-wide influence. As a tactile extension of the adjacent physical environment, the highway and the roadside enter into many facets of urban planning and design.

OPEN-SPACE PLANNING AND REGULATION

The Standard City Planning Enabling Act, recommended by the U.S. Department of Commerce in 1928 and adopted by many states, specifies that the purposes of the master plan to be made and adopted by the City Planning Commission shall be to guide and accomplish "a coordinated, adjusted, and harmonious development of the municipality and its environs which will, in accordance with present and future needs, best promote health, safety, morals, order, convenience, prosperity, and general welfare . . . including, among other things, adequate provisions for traffic, the promotion of safety from fire and other dangers, adequate provision for light and air, the promotion of the healthful and convenient distribution of population, the promotion of good civic design, wise and efficient expenditure of public funds, and the adequate provision of public utilities and other public requirements."

The Standard State Zoning Enabling Act also states, "For the purpose of promoting health, safety, morals, or the general welfare of the community, the local legislative body . . . is hereby empowered to regulate and restrict the height, number of stories, and size of buildings and other structures, the percentage of lot that may be occupied, the size of yards, courts, and other spaces, the density of population, and the location and use of buildings, structures, and land for trade, industry, residence, or other purposes."

It is indicated in these two statutes that the purposes and objectives of planning and zoning are identical. The plan is authorized, developed, and established as an official document under the fiat of the planning legislation. The integrity of the adopted plan is protected by the zoning district layout and controls under the aegis of the zoning powers. Of particular interest at this juncture are those elements in community planning relating to open space.

The ownership of the natural light and air about buildings is a common right. To prevent individual monopoly of these features of our physical environment, the location, height, and size of buildings can be restricted. Such restrictions control congestion of the sidewalks and streets by reducing the load on the land.

In addition to building size and height designation, adequate open space around buildings and structures must be provided. This open space is obtained by requiring front, side, and rear yards.

Front Yard Requirements

Adequate front yards afford room for lawns and trees; keep residences farther from the dust, fumes, and noise of the street; and add to the attractiveness and comfort of a residential district. They also provide play space for children and aid in keeping youngsters out of the street. The open space in front of buildings, which is necessary for light and air, is secured by providing adequate front yards. The aesthetic values of a neighborhood are enhanced by proper landscaping in keeping with the local environment.

Considering the requirements for light and air, the width of the open space between the fronts of houses should not be less than two times the height of the buildings, and preferably two and one-half to three times the height of such structures.

In a multiple-family or apartment house district, deeper front yards may be necessary rather than shallower ones as is the customary practice. Setting appartments well back from the street line, particularly on major thoroughfares, provides insulation from noises, fumes, and street dangers, enhances appearance, and promotes safety. It has been the practice to omit front yards in business and industrial districts. In some cases it has been felt that front yards should not be required in these zones. If, according to this viewpoint, inadequate light and air resulted because of narrow streets, the building height should be restricted. This procedure does not recognize the question of safety and freedom from congestion.

Rear Yard Requirements

Rear yard requirements rest on much the same premises as front yards. Rear yards should be deep enough to allow room for light, air, and vegetation so that a pleasant outlook is obtained. They should also provide access and egress to the rear of the buildings. Privacy is provided and space made available for accessory buildings. The minimum distance between the backs of residences should be 70 feet for two-story houses and 80 to 100 feet for two and one-half or three-story houses. Each rear yard would be 35 to 50 feet. This is equivalent to the height of the building, or the 45-degree angle from the rear lot line.

Rear yards are also necessary in business and industrial districts. Rear yard dimensions in such districts are often stated as a proportion of the building height. As previously stated, the preferred depth is equal to the height of the building.

Side Yard Requirements

A distance between buildings of twice the height of the building will provide adequate light and air irrespective of orientation. This is equivalent to stating that the side yard

Figure 1. Front yard enhancement, roadside separator.

Figure 2. Side yard enhancement, urban connection.

Figure 3. Rear yard enhancement, urban arterial.

shall equal the height of the building, which is the minimum desirable dimension. Side yards are needed to provide access in case of fire, to insure privacy, and to give an appropriate setting to the building.

Multiple-family dwellings require side yards for access in case of fire, for deliveries, for privacy, and for light and air. Half the height of the building is also the desirable side yard width in such a district.

This discussion of open space as provided by front, side, and rear yards has been made because it is in this area of urban design that the highway and its roadside make a major positive contribution to the living environment. The roadside is truly the "front yard of the nation."

Where buildings front on the highway, a properly landscaped, wide roadside margin extends the front yard legally required in the land-use control regulations with a consequent enhancement of this environment. All the benefits previously indicated accrue to the parcel so situated.

Similarly, a highway with its roadside traversing an alignment wherein the rear yards of the buildings are adjacent to it affords an improved outlook, adds to the dimension of the rear yard, and with greenery, trees, and shrubs, provides amenities otherwise not obtainable.

In some cases, urban expressways must traverse an area whereby the sides of the houses face the artery. In this situation the roadside adds to the side yard of this adjacent parcel. This is an increase in the side yard dimension insofar as the building is concerned. The benefits of side yards are enhanced accordingly. Figures 1, 2, and 3 show front, side, and rear yard enhancement.

URBAN DESIGN ELEMENTS

In the Binghamton metropolitan area (Fig. 4), the highway network and the roadside have been woven into the urban design fabric to achieve the following benefits and objectives: Buffer between disparate land uses; land-use transition; neighborhood delineation; miniparks and play areas; river-front park; sitting areas; automobile parking sites; open-space enhancement, front, side, and rear yards; daylight and sunlight zoning; marginal greenbelt; governmental complex, site planning; cultural center, site planning; multiple land use; pedestrian safety—bridge and underpass; highway interchange aesthetics; roadside landscape; marginal and environmental controls; wetlands preservation; embankment noise buffer; community services accessibility; and general

Figure 4. Interstate 81, Route 17, and urban arterial highways, Binghamton, New York.

community revitalization. The remainder of this paper consists of an illustration of these urban design elements.

Land-Use Transition

A challenging urban land-use problem is how to treat the borders of differing districts. The situation is particularly acute where industries abut residences. It is not a simple task to effect the transition from a higher intensity of use to a lower intensity, relieving detrimental characteristics in the process.

An urban highway roadside is a distinct asset in this situation. In such a setting it is desirable to acquire an adequate bordering area. An example of beneficent step-down land-use transition is shown in the marginal roadside of the Brandywine highway urban arterial route where it intersects Bevier Street (Fig. 5). The area between a fronting street of a residential district and an entering ramp affords a green lawn outlook and a location for local recreation space.

This arrangement is an effective transitional control with respect to prohibited activities within a specified distance of a residence district, which is a usual specification in zoning ordinances. The restrictive distance may vary from 50 to 200 feet for such uses as gasoline filling stations, public garages, dining cars, parking lots, and others.

Where a district is in a state of transition or change from a higher use classification to a less restricted one, the highway can be an arresting and adjusting instrument if the

Figure 5. Land-use transition, North Shore Boulevard.

Figure 6. Multiple land use, river front park, Interstate 81.

area is the proper location for the artery. The North Shore Boulevard arterial along the Susquehanna River is an excellent illustration. The residences and other structures were in a state of disrepair. Buildings were idle and deteriorating. The acquisition of the right-of-way and subsequent construction of the arterial highway removed most of the poor structures and improved the quality of the environment (Fig. 5).

Multiple Land Use

Illustrative of the multiple-use concept to achieve the full potential of a land resource consistent with community needs and values is a 200-acre river-front park to be developed bordering the Chenango River and adjacent to Interstate 81. The development includes open grassed areas for active recreation, the seclusion and shade of natural and created groves, picnic areas, the inspirational aspects of created ponds and wildlife, and the dominant feature of sweeping views of the river.

The landscape park exploits an idle land mass. It furnishes a need not otherwise available without usurping land required for community growth.

This roadside area is also an excellent illustration of the concept of level of service as applied to land use. The roadside in this particular use is at an optimum level of service. It will be devoted to highway, roadside rest areas, parking, recreation, and park use, and provide erosion control, scenic overlooks, and over-bank flood protection (Fig. 6).

Additional examples of multiple land use are a play area and parking facilities underneath the overhead highway structures of the North Shore urban arterial spanning Henry and Pine Streets. Tree plantings border the alignment (Fig. 7).

Figure 7. Under-structure parking area, urban arterial.

Figure 8. Arterial roadside minipark.

Arterial Roadside Minipark

Small park areas are a welcome respite from the heat of the summer's sun. The minipark shown in Figure 8 serves as an open space and buffer between the Brandywine arterial and a residential district. The arterial roadway at this location is a separator between an industrial district and a residential area.

Roadside Playground

Small neighborhood playgrounds are at a premium in urban areas. A marginal strip between the Brandywine arterial on-ramp and a local street affords an excellent location for a playground that includes a small pool (Fig. 9).

Roadside Sitting Areas

To prevent ramp areas from becoming points of traffic congestion, it is desirable to acquire strips along intersecting marginal streets whenever possible. Where local environmental conditions permit, such open space may be advantageously utilized as frontage sitting areas for the immediate residences. Figure 10 shows a sitting area at an off-ramp of the Brandywine arterial. Also shown is a parklike strip developed in the area between a flood control wall and an arterial connection. Apartment houses, residences, and businesses on the opposite side of the street face the area.

Governmental Center and Cultural Center Site Planning

The urban renewal program for the central core area of Binghamton, New York, includes the construction of a governmental center consisting of a municipal hall, a county office building, and a state office building. Adjacent to these structures will be a new YMCA building now under construction. These structures, including the necessary parking facilities, occupy most of the site. A landscaped loop ramp of an arterial and the bordering roadside provide desirable greenery and open space. This open area is an extension of the sites of these buildings (Fig. 11).

A cultural center consisting of an auditorium and a performing arts theatre will occupy a site opposite a loop ramp in the adjacent quadrant. An obsolete and closed shoe factory and attendant structures were removed from this area now used for the

Figure 9. Brandywine arterial neighborhood playground.

Figure 10. Roadside sitting area, Brandywine arterial.

Figure 11. Governmental center, site extension.

Figure 12. Cultural center, municipal auditorium, site extension.

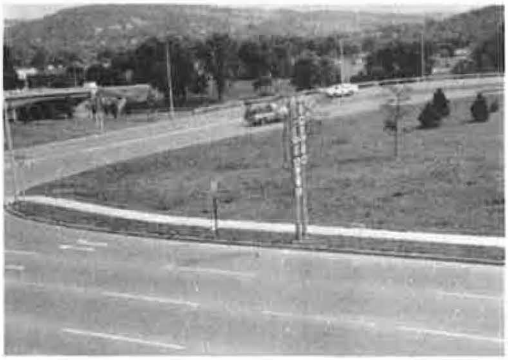

Figure 13. Urban arterial, court street area, landscaped loop interchange park.

Figure 14. Urban arterial, landscaped loop, industrial plant location.

Figure 15. Landscaped re-entrant area, arterial ramp connection.

Figure 16. Typical gore planting between frontage road and urban arterial.

Figure 17. Landscaped approaches, Bevier Street Bridge.

loop ramp. The areas within the loop and along the bordering streets have been landscaped with trees and shrubs. In an architectural competition for the design of the cultural center this landscaped open space was included as a part of the site for the development. The facilities will be built in the near future (Fig. 12).

These two illustrations are excellent examples of how an urban controlled-access artery can serve as a site extension providing amenities that would otherwise be lacking.

Landscaped Loop Interchanges

Urban arterial routes in central city industrial areas afford opportunities for revitalization of the region and for aesthetic enhancement of the environment. The characteristic atmosphere of the older areas is usually drab, dreary, and depressing. Smoke contaminates the air, and untreated industrial wastes pollute the streams. The North Shore and McKinley Avenue arterials provided the means for achieving a radical change in the local environment. At each location where an interchange was made with the local main thoroughfares, the loop open

Figure 18. Interstate 81 landscaped ramp, and cul de sac frontage road.

Figure 19. North Shore Drive urban arterial, river scene.

Figure 20. North Shore Drive, Vestal Parkway urban arterial, and Susquenanna River earth levee pedestrian walkway.

Figure 21. Route 17 expressway, wetlands preservation.

areas were landscaped. Additional bordering margins were taken for trees and shrub plantings. The Court Street area is a landscaped loop interchange park (Fig. 13). The Main Street interchange provides a spacious, parklike setting for the IBM plant in the background (Fig. 14).

Figure 15 shows the landscape treatment at a re-entrant area bordering an entry ramp connection to the North Shore urban arterial. Although the additional width of right-of-way has extended the side yard of the abutting property, it has exposed the junked pile of tires. The shrubs partially screen the rear yard from view.

Figure 16 shows a typical gore planting between a frontage road connection and the North Shore arterial.

Figure 17 shows the landscaped approaches bordering the Bevier Street Bridge in Binghamton. The open area contributed by the additional width of the right-of-way provides light and air to the adjacent properties.

Figure 18 shows a landscaped ramp to Interstate 81 with a cul de sac frontage road to serve adjacent residences.

Figure 19 shows a typical view of the Susquehanna River along the North Shore Drive and Route 17 in Binghamton. The bridge in the distance was awarded first prize in its class as the most beautiful steel bridge by the American Institute of Steel Construction.

Pedestrian Walkways

The North Shore and Vestal Parkway arterials for a portion of their length are protected from flood waters from the Susquehanna River by earthen flood control levees. The top of the earth levee provides a footpath for pedestrians who are just out for a stroll or who wish to fish from the water's edge. The levee affords attractive near and distant views of the river (Fig. 20).

Wetlands Preservation

Areas bordering the Susquehanna River in some locations are brush-covered and swampy. These marsh areas are the habitat for wildlife that are of interest with the changing seasons. Whenever the urban arterials and expressways are not too remote from the river's edge, these wetlands have been included in the highway roadside limits. Their acquisition preserves them for a natural ecological balance in addition to providing marginal and environmental controls (Fig. 21).

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Highway Aesthetics—Functional Criteria for Planning and Design

P. L. HORNBECK, R. R. FORSTER, and M. R. DILLINGHAM,
Graduate School of Design, Harvard University

This report examines the function and use of aesthetic criteria for the highway development process and recommends promising directions for future study and implementation. The major premise established for procedure of the study is that "aesthetics" is not an additive to the process of highway planning and design but must be identified and implemented as an integral component.

The research report identifies the visual parameters of the highway planning process related to a range of disciplines; evaluates them for their relevance to improved highway appearance and use; and driver behavior, suggests a methodology to identify and integrate visual and behavioral criteria for a more complete highway planning process; and applies this methodology in a demonstration case study.

•THE IMPROVEMENT of visual quality of highways, as with many aspects of the environment, has been a matter of increasing concern in recent years. As this concern for obtaining visual values increases for highways, considerable difficulties arise in identifying what the values are and the ways they may be implemented in highway planning and design. The primary problem, the ways in which aesthetics is significant and useful for the driving experience, has received little attention. To date it appears that these difficulties have not been solved. Much of the dilemma seems to relate to the need to identify aesthetics in a relative and functional context, and accordingly, to identify the evaluation and performance criteria with which aesthetics may be meaningfully utilized.

Unfortunately, visual quality in current practice usually implies planting a few flowering shrubs or removing the local junkyard from the roadside. Such actions are helpful but they certainly do not represent objective and comprehensive analysis or application of the role of aesthetics in the highway environment. This might be called the "Band-Aid" approach. Visual quality needs will not be met by such additive panaceas, but will involve functional problem diagnosis and development of criteria for treatment that are integral components of the highway system itself. This is fitting because the most significant aspect of the driver's experience of the highway is that it is comprehensive. It is a matter of interaction of the driver and all that he can see comprising the visual environment of the highway.

Consideration of highway aesthetics must involve all visual factors and the relationships that influence the linkage of a driver's seeing and reacting. Such factors are the major components of the highway environment and imply input to varying degrees of driver experience and behavior. They provide visual impact through the progression of landscape views, road alignment, enclosure by vegetation or buildings, and landmarks. Driver experience relates to his need and the perceptibility and location of highway components. This is the source of significant driver information, guidance, and pleasure.

Visual experience is also qualitative; therefore, it has aesthetic value. With the development of the aesthetic qualities of the road, there can be a more perceptually

Paper sponsored by Committee on Roadside Development and presented at the 48th Annual Meeting.

clear and meaningful highway environment. Thus, aesthetic values are integral to the visual geometrics and locale of the highway, making available its meaning and form, clarity and organization for highway components. A suitable analogy is the difference between music and noise. That aesthetics can be a means to a more visually comprehensible highway, and therefore a better functioning and safer highway, demonstrates the importance of development of really basic visual performance criteria; aesthetics is least useful as a tool for highway development when employed in additive or cosmetic ways.

This study has been undertaken on the basis that aesthetic values are integral components of the highway environment and, with behavioral and visual design criteria, offer one of the principal means to improve its organization and form for better driver performance and pleasure. This is the explanation for the title of the study.

Although aesthetics offers values of a primary nature, other criteria obviously must also be utilized for highway planning and development. Like construction criteria, aesthetics is only one part of the total process. Other primary criteria, for example, occur in social, economic, and natural science sectors and relate to different aspects of the planning and design process. It is suggested that among the most important considerations for physical design of highways are criteria of human behavior. Patterns of attention, vision, cognition, expectation, comfort, and pleasure illustrate basic needs and must be identified for performance and evaluation criteria which can be applied through engineering, planning, and visual design techniques for highway design. Without the integration of these resources it is not surprising that certain roads earn the epithets of "monotonous" and "accident-prone" and are visual anomalies of unrelated factors, information, and effects upon the driver. The "ideal" highway should be considered as a total system, interrelating driver and environment.

Techniques must be developed to identify and manipulate criteria from appropriate disciplines. Procedures must be coordinated for evaluation and decision-making for their application to the process of highway development. Almost no work has been done to determine what the driver sees and then reacts to. The problem of the relation of qualitative to quantitative criteria for decision-making has been another reason for the lack of use of visual criteria in highway design. Attention toward improvement of these matters is urgent to meet the needs and opportunities of highway design.

STUDY HYPOTHESES

Initial examination disclosed specific problems and opportunities. To study them, the authors established hypotheses to identify visual components and their relationship to the driver and to highway design. Once defined, however, a second problem arose in investigation of linking the driver's behavior with the factors relating to that behavior. Because of age, ability, prior experience and personality, drivers vary in what they can perceive and consequently as to how they operate a vehicle. However, when certain objects or locations have sufficient visual impact, it was postulated that drivers will respond with a degree of similarity. For example, increase in visual enclosure often induces drivers to decrease speed. Assuming such examples to be true, and emphasizing the significance of objects observed and their strength of impact, a hypothesis was formulated: Visual input = behavioral output, with specific qualifications. These qualifications were discussed on the basis of a postulated system of driver, vehicle, and roadside environment, defined by the authors as the visual performance corridor—all that the highway user can see from his position on the road. Because the study purpose was review, statements were accepted at face value and were not further quantified or tested, but only brought together to identify feasible study possibilities.

To study the relationships and interactions of driver and the "visual performance corridor," the "driver-vehicle-highway environment system" was hypothesized as follows: An understanding of relationships between the driver and his environment was felt to be necessary before meaningful aesthetic design criteria reflecting driver response could be developed. Relation of the visual elements of the roadscape to the total sequence of highway environment was stated as a function of the driver's information needs. Thus, for study purposes the driver and his environment were regarded as a "closed" system. The principal elements of the system are the driver operating his vehicle on a road complex with some prior driving experience within a physical roadside environment under the situational influence of climate, traffic conditions, and travel objectives.

For study purposes the system was viewed from two aspects: (a) the road complex, consisting of all geometric elements, structures, signs, etc., within the limits of the right-of-way, and (b) the roadside environment, consisting of all physical elements within the visual performance corridor. Thus, as the driver maneuvers his vehicle, he generates certain needs for information required for orientation, steering control, and so on. The information he seeks can be provided in a number of ways—for example, directly by means of signs, or indirectly by means of alignment, geometrics, and the overall visual characteristics of the road itself.

The transmission of visual information to the driver is modified by a number of factors. Conditions of climate and local traffic can be regarded as temporary modifiers of information. The vehicle is an added source of information, and the driver himself is a type of information modifier. His abilities, experience, and particular momentary mental and physical condition may greatly influence his perception and response to information. The driver has become quite different from a walker.

For the conveniences offered, particularly by automobile manufacturers, man has accepted comfort instead of awareness of his environment. The vehicle screens most sensations, except visual, of the highway environment; comfort and safety features and the effort to make "quiet cars" have left man dependent primarily on one sense, vision, for information on speed of his vehicle and its position on the highway in relation to other vehicles or fixed objects.

Relationships between driver and the highway environment are extremely complex. They are not well defined, nor can they be applied as criteria or guidelines for highway design. Relationships postulated by the authors as possibly occurring are shown in Figure 1.

The demands of operating in today's complex highway environment place a great responsibility on the driver to remain visually and mentally attentive to highway

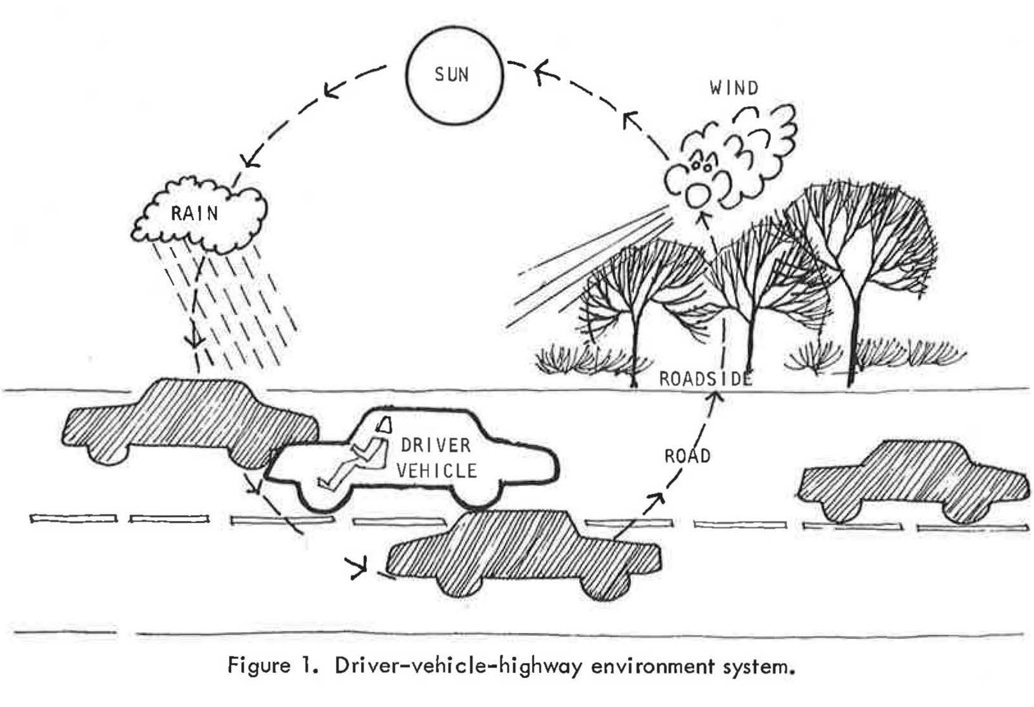


Figure 1. Driver-vehicle-highway environment system.

elements. To perform the driving task safely and pleasurably, and to find his way efficiently, the study hypothesized that the driver must be provided with well-structured, visually clear, and unambiguous information. Because most available information is visual, the sequence of highway experience therefore must be visually articulated to meet as closely as possible the driver's information needs, and must be provided in ways related to his patterns of cognition and response behavior. This might be paraphrased as the "driver system input-output relationship." Because of the many variables and unknowns involved, the study suggested a convenient way to indicate relationships of visual impact and resulting driver behavior—the mechanical input-output system concept. Thus, input comprises information available to the driver from the visual highway corridor. Output is driver behavior and performance in driving tasks (Fig. 2).

Thus, defining the driver, his vehicle, and the highway as a system may help to identify certain critical factors—those visual components which induce or condition driver response and behavior. These driver-environment patterns, when more clearly and quantitatively understood, should offer significant criteria and guidelines for highway design.

Some of the principal input-output relationships of the driver system were studied as functions of speed, i. e., changes in visual appearance of the highway to the driver, and the driver's ability to understand these changes. As speed increases, the driver's attention is drawn farther ahead of his vehicle, thus shutting out his perception of visual factors lateral to him; distant objects become more important as references to speed and direction. As speed increases, lateral detail disappears, concentration and tension mount, and the need for visual references for orientation and speed control increase. Thus, two general highway design needs arise. First is the need to build in factors which by their properties and arrangement are visually comprehensible for orientation, steering, and speed control, and relief of trip monotony at higher speeds. Second is the use of the same visual references in a corrective manner for increasing driver participation and cognition of the highway environment and prompt speed reduction. Clear and accurate orientation is one of the essential needs of the driving task. Unavailability of proper references and cues for orientation to the route and its environs does not allow the driver convenient decision-making. Orientation is also derived through formal and informal information—signs or specific guidance cues, regional and local character, and symbols and visual connotation of the highway environment. Lack of visual guidance is the primary problem in highway use. The highway should reveal and be related to the features and character of the region through which it passes.

It was suggested that orientation can best be accomplished by understanding and visually clarifying the possible image or character of the road locale for the motorist through geometrics "sympathetic" with landform and scale, selective cutting, planting, etc. Accordingly, the authors hypothesized that the landmark, the district, and the path are major components of an image used for orientation and way-finding, and can be visually revealed and strengthened by design. The view from the road should reveal elements of visual appeal such as trees or wildflowers, but it also should show the important elements in the landscape or city. The highway should indicate to the motorist what is happening beyond the right-of-way for his pleasure and information.

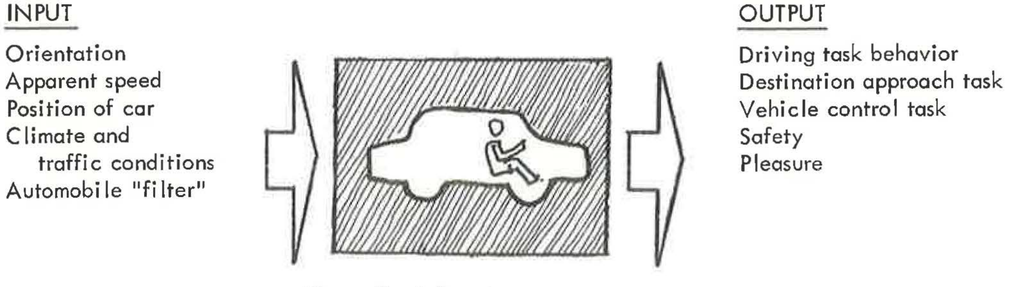


Figure 2. Driver input-output system.

Certainly, directional signing provides the only fail-safe method to insure way-finding. Major guidance cues, however, as suggested by Lynch et al (2), are provided by visual components which provide major impact on the driver. These informal cues, which may be considered primary information, are spaces, vistas, and landmarks. Secondary visual guidance for orientation occurs through informal and formal "smaller in scale" visual information, i. e., centerline, guardrails, grading or side-slopes, light standards, and specifically in the formal information of signs.

Primary and secondary information perceived simultaneously must be coordinated as visual support systems to be most useful to the driver. For example, a vista toward a town occurring after signing has indicated a turn toward that town will assist driver orientation and decision-making (Fig. 3). Highway location and visual design development must be coordinated toward these ends. Such visual information and the driver's pre-trip expectations for it relate to the following hypothesis for the linkage of how the driver sees and reacts for the continuity of his experience during travel time.

Behavioral criteria for visual planning of highways are illustrated in the concept of "attentional demand." In examining certain aspects of the visual components of highways, it is clear that the driver has two different tasks for which visual design must be developed and coordinated: (a) vehicle control (steering and speed), and (b) destination approach (identifying destination arrival point). While traveling, the driver does not have to devote the same amount of concentration to both tasks. The need for attention varies from the extremes of high or intense concentration to low or relaxed concentration. This need is called attentional demand. It varies over duration of travel as a function of time and the changing characteristics of the highway environment traversed. "The attentional demand of a road is a characteristic of that road and of the traffic situation which may exist upon it as well as the velocity at which it is traversed" (2).

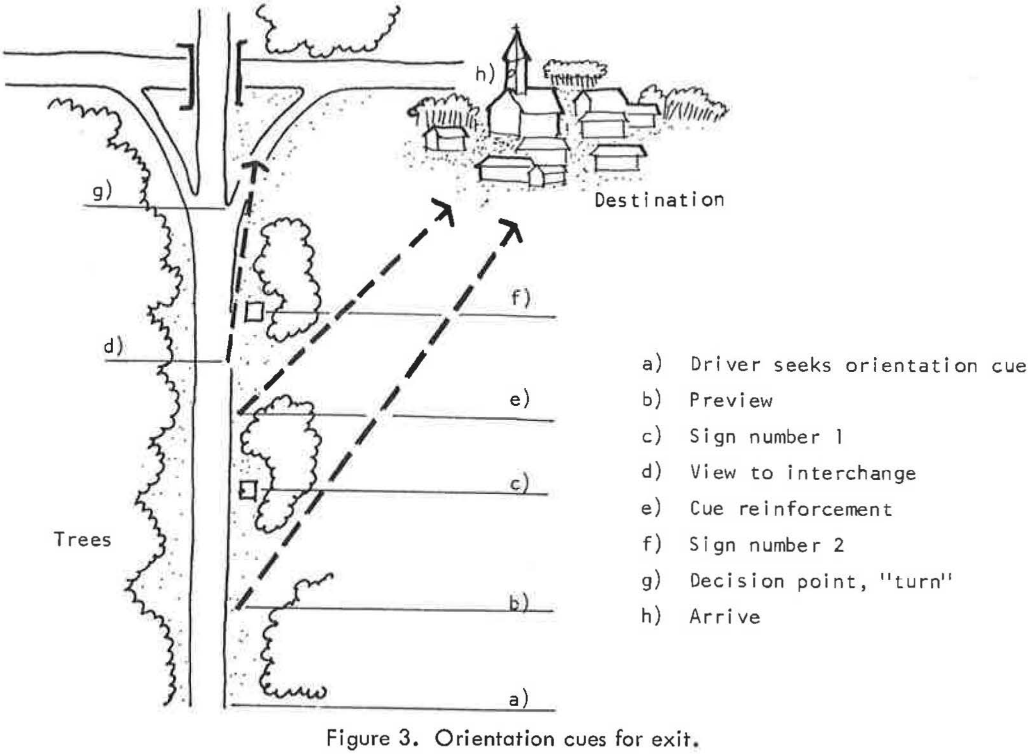
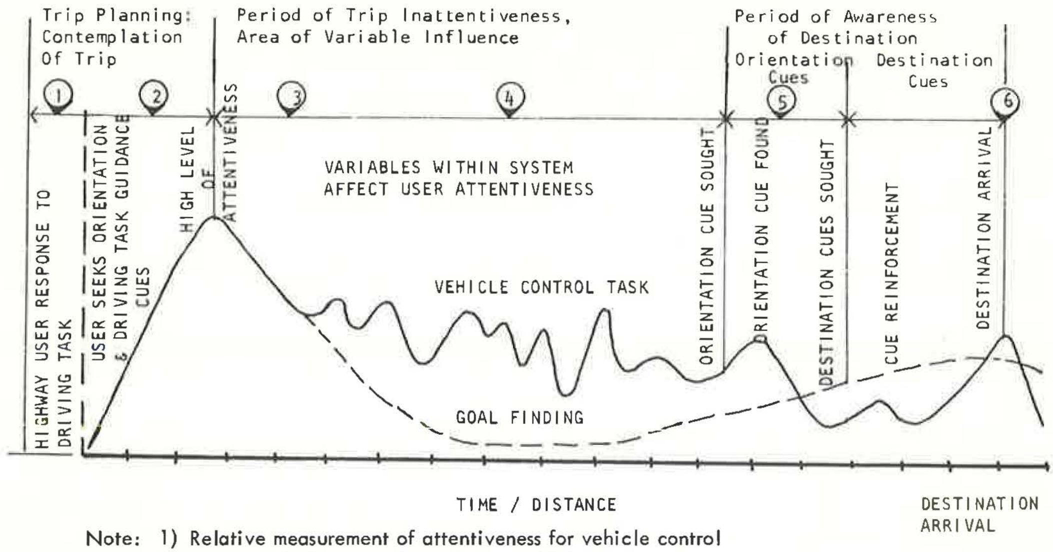


Figure 3. Orientation cues for exit.



Note: 1) Relative measurement of attentiveness for vehicle control
2) Sequence is for rural, limited-access highway
3) Time intervals are possible extreme variables

Figure 4. Attentional demand hypothesis.

The variations of attentional demand are interpreted for a road and are represented in a diagram (Fig. 4). At this stage the graph is not quantified, nor have the levels of low or high attentional demand been determined. But it can demonstrate the following driver situations which can typically occur during the duration of the trip:

Situation 1 represents the pre-trip planning phase. Interest is devoted to the destination approach task.

Situation 2 represents the start of the trip. Here the driver is not only aware of the route he will take, but that he must begin travel and must concentrate on his driving. Attentional demand is high.

Situation 3 represents a stretch of road having low attentional demand; that is, the driver only has to continue speed and steering of the vehicle, owing to lack of visual stimulation from roadside—for example, an area of flat topography, long tangents, and continuous forest enclosure at the right-of-way.

Situation 4 represents a sudden change possible in the attentional demand of the road. It may result from heavy traffic, an intersection, sudden change of lane, road obstacle, lane drop, or stopped lead car.

Situation 5 represents a situation when the driver may suddenly receive new information concerning his location in relation to his destination—e. g., a preview of his destination through a vista framed by trees. Attentional demand increases.

Situation 6 represents the driver approaching the end of the trip on the road, identifying the correct exit, and adjusting steering and speed control. This means high attentional demand and the accomplishment of the destination approach task.

However, along with this definition of attentional demand, Bolt, Beranek and Newman, Inc., hypothesized the following theory (2):

> A rather important notion which underlies the theoretical work is that drivers tend to drive to a limit. We suggest that the limit is determined by that point when the driver's information processing capacity, either real or imagined, is matched by the information generation rate of the road, either real or estimated. The drivers may be wrong in their estimates, but they will tend to achieve this balance of input information rate and information processing rate. A driver in unfamiliar territory sees a great

deal more uncertainty in the situation than a driver familiar with the territory. With familiarity there comes reduction of uncertainty, a reduction of information flow rate, and a higher permissible velocity, granted the same territory and circumstances. This is reflected in the different ways people behave in automobiles in familiar and in unfamiliar terrains. It might be said that a curving familiar road is "perceptually straight" since uncertainty about the road ahead is low.

Lastly, drivers will accept different levels of risk and drive to a limit such that the probability of an accident is not greater than, but approaches, some upper threshold. Subjective acceptable risk level is a measurable charactersitic of drivers and directly influences their behavior on the road.

A number of factors have been identified, which tend to control the speed of the driver traversing a road in the presence of traffic and other dynamic obstacles. These are, in brief: the width of the road and the frequency with which it turns; the estimated probability intrusion from other vehicles and animals; the uncertainty associated with the vehicle dynamics; the precision of the steering mechanism; the residual errors of vehicle aiming; and, lastly, a risk acceptance level which is a characteristic of each driver.

By examining the level of attentional demand, the study postulated that it is possible to predict the speed the driver will be likely to maintain. Conversely, the alignment of the road can be adjusted and the driving speed accordingly influenced by increasing and decreasing the level of attentional demand of the road. The ways in which attentional demand may influence speed change, pleasure, boredom, etc., along highways, and the extreme high and low levels of attentional demand are of great interest to this study as indication of driver needs and reaction to visual stimuli and their organization along the road.

The effect of visual stimuli on the driver's senses can vary in intensity, and the accurate effect of stimulation from the highway is difficult to measure quantitatively; that it occurs in what seem, so far, to be generally predictable patterns and levels indicates opportunity for further definition.

The principal visual factors that affect driver behavior and are of principal visual importance are given in Table 1 with concomitant behavioral relationships. "Tie-in" was made with functional needs for driving task accomplishment.

The driver system is like any mechanical system; it has a definite capacity which copes optimally with a certain amount of input and output. In other words, the system could function best when a certain amount of driving task is expected of the driver at a given time and over a period of time. The exact amounts are undefined and may be unnecessary. From investigation of the current accident rate, it is obvious that there are two extremes when the driver system fails to perform the driving task adequately under high stimulation or not enough stimulation. Like machinery, the driver system must constantly perform at least a minimum of activities to be constantly ready to perform at full capacity when the situation arises. Similarly, the system needs time to warm up to reach top running condition. The driver system also has a maximum capacity. This is mainly determined by the driver and the characteritsics of the vehicle.

SEQUENCE HYPOTHESIS

As suggested, all the visual inputs of the highway to which a driver reacts, such as edge, object dominance, and enclosure, together provide his total visual impact; thus, there is a continuity or sequence of these impacts on a road for optimal conditions. Conceptually, the experience of this sequence must be varied so that it will relate to the range to be identified, preferably the driver's attentional demand. Therefore, it is suggested that a road with a total sequential experience and impact range which fits or relates to the driver's attentional demand level may be developed by manipulating the visual factors of the highway. Criteria for this manipulation can comprise guidelines for visual improvement of old roads and the location of new ones. However, the problem of developing evaluation criteria for the application of this thesis is great. Also, the designing of a highway that is sequentially and visually meaningful is like

TABLE 1

VISUAL FACTORS AFFECTING DRIVER BEHAVIOR

Inputs	Visual Inputs	Behavioral Outputs
1. Edge—i.e., from spatial boundaries which limit view due to adjacent topography, vegetation, etc., within or at right-of-way (Fig. 5a)	a. "Whiz-by" blurring b. Visual impact increases with duration and height of edge over time c. Apparent motion	Steering control
2. Enclosure—sense of confinement and spatial definition, owing to closeness of vegetation, cuts, walls, overpasses, etc., to driver's field of vision (Fig. 5b)	a. Degree of spatial containment b. View enframement c. "In and Out" sequence experience from change in lateral enclosure (Fig. 5c)	Speed control: 1. Speed influence 2. Orientation 3. Attentional demand stimulation
3. Object Dominance—visual prominence of landmarks, etc. (Fig. 5d)	a. Dominance of objects via: (1) contrast (2) size (3) nearness	Attentional demand overload and underload
	b. Meaning, symbolism (emotional significance for the observer)	Orientation and way-finding
4. Object Diversity—unrelated size and shape of objects in driver's visual field; e.g., commercial strip development (Figs. 5e, 5f)	a. Diversity of objects relative to their visual dissimilarity b. Nearness to driver (re: edge)	Attentional demand overload and underload Steering influence Speed influence
5. Visual Alignment—visual consistency of highway with topography and views (Fig. 5g)	a. Horizontal curvature b. Vertical curvature c. Directional views	Attentional demand Speed influence Orientation

TABLE 2

RELATIONSHIP OF VISUAL FACTORS TO ATTENTIONAL DEMAND

Low Attentional Demand	High Attentional Demand
Speed	
Speed increase:	Speed decrease:
1. Lack of apparent motion effect as in highway on high fill in open landscape; little "whiz-by" effect (Fig. 5h)	1. Apparent motion affected by the addition of objects (vegetation, etc.) along the side of the road which provide scale and speed reference (Fig. 5g)
2. Views often unrestricted for long sections of road ahead such as on long tangents (Fig. 5f)	2. Diverse and interesting views
3. Very little stimulation from roadside objects, with infrequent interchanges and decision points	3. Much stimulation from roadside objects as individual objects or as vistas, with frequent interchanges and decision points
4. Long tangents	4. Diversity of horizontal and vertical alignment
5. Low traffic volume and good weather conditions	5. Heavy traffic and bad visability owing to weather
Steering	
Steering easy:	Steering difficult:
1. Long tangents, few and generous curve radii	1. Variation of horizontal, vertical alignment
2. Simple objects along the roadside, if any at all, as guidance reference for steering control; i.e., white line or guardrails	2. Highly complex objects along the roadsides which distract driver as in urban road with commercial strip development
Destination Approach Task	
Destination approach easy:	Destination approach difficult:
1. Little need for orientation information	1. Need for much orientation information
2. Simple, clear signing	2. Complicated, poorly located signing
3. Simple and noticeable objects as landmarks	3. Diverse view of a city; scenic area on ocean

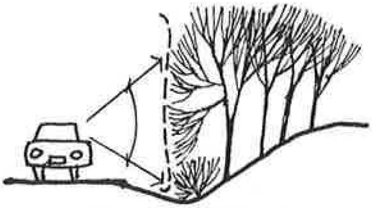


Figure 5a. "Edge."

Figure 5b. "Enclosure."

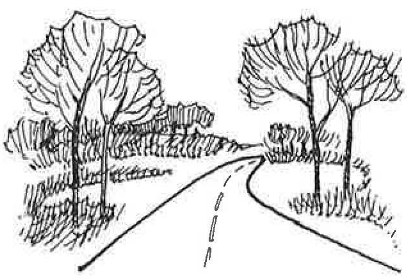


Figure 5c. "In-out" sequence.

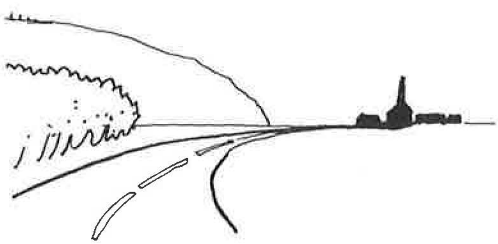


Figure 5d. "Object dominance."

Figure 5e. "High diversity."

Figure 5f. "Low diversity."

Figure 5g. Visual alignment.

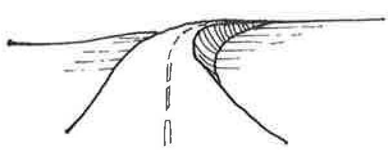


Figure 5h. Lack of speed reference.

making a film that could be played forward and backward from any point and still retain meaning in its entirety and in its parts.

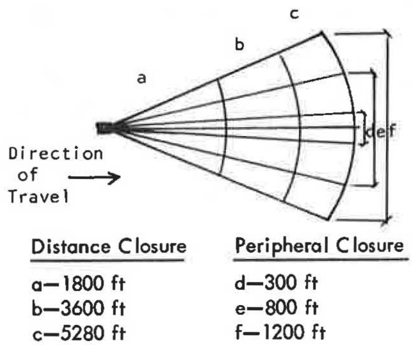
Clarkeson (3) suggests that designing such a sequence is like composing a piece of music. One might first separate components and examine them individually according to their functions, and then group them for desired relationships. In music there are (a) basic elements, (b) theme development, and (c) form or total experience. As an analogy, if these musical components are compared with the visual components discussed earlier, the following relationships appear:

Musical Components	Visual Components
1. Basic elements (notes, bars, etc.)	1. Visual inputs on the highway (edge, enclosure, objects alignment, profile, cross section)
2. Theme organization	2. Attentional demand
3. Composition or total musical sequence	3. Trip character and total visual sequence
4. Expression (aesthetics)	4. Clarity of effect and meaning (aesthetics)

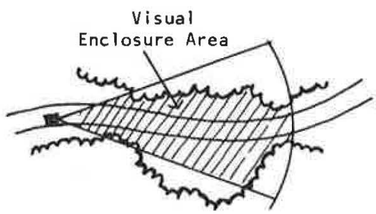
If the earlier diagram illustrating the probable profile of attentional demand for the duration of a trip is examined (Fig. 4), it can be seen that the total demand during the trip is composed of two separate curves. One relates to execution of the vehicle control task, and the other to the solution of goal finding—the execution of the destination approach task. The variation in levels of attentional demand for the vehicle control task is directly linked with the physical elements in the visual corridor. For example, demand level is high at the beginning of a trip; this is because the driver must perform a certain amount of vehicle manipulation to get his trip under way. This manipulation involves coping with the vehicle and finding initial guidance information in the visual corridor. To a certain degree this is independent of the situation in which the driver is beginning his trip. For example, if a person has been traveling and he stops, his attentional demand for the vehicle control task on starting could be comparable to that of an initial start. This explanation could also apply to the high attentional demand for guidance at the end of travel. The attentional demand at mid-trip when traffic or unforeseeable road complications are met is also an example of direct response to factors in the visual corridor. Thus, task completion is directly linked to factors in the visual corridor, and is generally predictable.

In this way it is postulated that the highway could, in fact, be designed for basic organization of the variations of attentional demand for vehicle control. For instance, the designer could deliberately create more variation in the alignment by varying the degree of curvature and tangents to demand more attention from the driver for execution of vehicle control tasks at certain locations. Increasing lateral enclosure by vegetation or landform often causes drivers to reduce speed. Therefore, by means of varying the attentional demand level for execution of vehicle control tasks by these devices, the designer may visually compose the interim parts of the highway to provide suitable content for driver experience. The visual form and clarity of the highway can thus be seen as a determinant of driver performance and an integral part of the design of the highway.

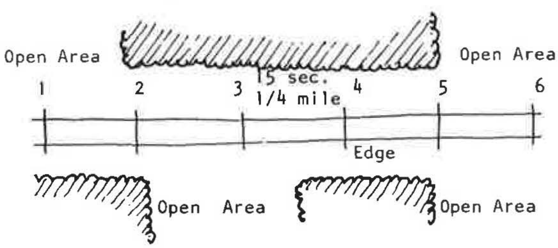
Having identified probable highway visual components and their impact on the driver, and through the definition of attentional demand, having postulated an operable relationship between visual design of the highway and driver behavior, we may now study these criteria for application to route design. However, as noted, a problem lies with the fact that the entire trip experience does not necessarily coincide with the entire length of the road, and may be experienced either way. Therefore, a road must be designed with no single beginning or end but with the opportunity for identification of various sequence points or highway experience increments. Any segment of the road may become a trip beginning or end. It is suggested that this approach may be useful for two different highway design scales: (a) the (generalized) overall "rhythm" of visual change for the total route; and (b) specific decision-point areas. It is not necessary to design for overall or total prediction of driver behavior (as in a one-to-one relationship) but, because most drivers may react similarly at a very general level to what they see, design should establish only those elements of major visual impact and meaning on the larger scale, with specific attention to specific small-scale locations. Because of selective perception (if related to driver needs with appropriate



a. Cone of vision at 60 mph



b. Measurement of enclosure actual area



c. Identify component

Figure 6. Visual components analysis process.

visual information and stimuli), a trip could take on sequential experience with its relative beginning and end. However, if orientation cues do not exist at the times needed, meaningful sequence experience and proper orientation, decision reinforcement, and guidance may fail to exist. Therefore, it is important for a number of orientation cues of different types to be developed at the location where it is highly probable that the driver will need them. For example, different types of orientation information (from enclosure, directed views, alignment, signs, etc.) should be carefully coordinated near entrance and exit ramps and a short distance before the exit ramp. These must be visually designed and related in proper sequence so that the driver can experience them at travel speed. The destination approach task illustrates a possible sequence of this kind (Fig. 3).

Attentional demand cycles can thus be postulated to occur for trip duration. Because various trips of a very short or very long duration may be undertaken on the same road and may occur over any distance, the highway environment should be designed for minimal attentional demand at the beginning of trips or at their conclusions at all entrance and exit locations, the primary locations for attentional demand requirements. In addition, proper attention level should be stimulated for the through traveler as well as the interchange-to-interchange traveler. Visual stimuli and information must be simultaneously available for completion of driver tasks, including major orientation (macroperformance), coping with traffic, direction finding (mesoperformance) and tracking-speed control (microperformance). The degree of coordination of demand highs and lows as they are prompted by visual conditions and tasks with typical patterns of driver behavior (for expectation, reception of visual stimuli, orientation, and so on) may provide the degree of interesting and meaningful trip experience. Thus, criteria are conceptually available to be developed for aesthetic design of the highway linking visual, behavioral, and engineering criteria.

Two major problems must be solved before this interrelation is fully possible by study and testing. First, it is necessary to identify the degrees of visual impact that are probable from visual factors of the highway. Second, it is necessary to know the relative effectiveness of visual components when in combination as experienced in sequence over various lengths of time.

A real area case study using an actual highway was developed to test and apply the analysis of visual and behavioral criteria for practical highway location and alignment purposes. A route was selected using the visual criteria described.

Incidence of Edge		Duration of Edge: Percentage of 15 Sec. 100%	75%	50%	25-0%
		4	3	2	1
EDGE BOTH SIDES	4	16	12	8	4
OPEN OPPOSITE SIDE	3	12	9	6	3
OPEN DRIVING SIDE	2	8	6	4	2
OPEN BOTH SIDES	1	—	—	—	1

Figure 7. Quantifying matrix (edge as example).

Postulation of Visual Components and Analysis Process

The significant problem in visual component analysis is quantifying qualitative data. Visual factors must be described in terms of duration plus the degree of their impact, in terms of factors along the route under consideration. To accomplish these tasks the authors propose the following process for a case study area. This analysis sequence should be undertaken for each visual component (edge, enclosure, etc.) along an existing or proposed centerline. Evaluation criteria are decided on definition of visual impact factors as identified earlier.

1. Identify—A graphic notation technique is used to locate geographically on a plan to scale (Fig. 6) the existing visual components within the visual corridor of the road (i.e., edge, enclosure, etc.).
2. Quantify—A numerical matrix is used to quantify qualitative values of the visual factor's potential impact upon the driver, which is ascribed a numerical rating for each factor (Fig. 7).
3. Record—The quantitative value relative to each component is ascribed and recorded in 15-second intervals along the chosen route (Fig. 8).
4. Sequence—To illustrate the visual impact in sequence of time/distance, the recorded values are illustrated as composite graphic overlay sheets on a sequential analysis chart which relates the visual impacts to time/distance (Fig. 9).

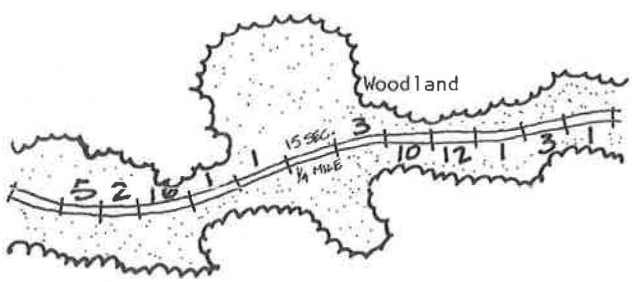


Figure 8. Recording of impact.

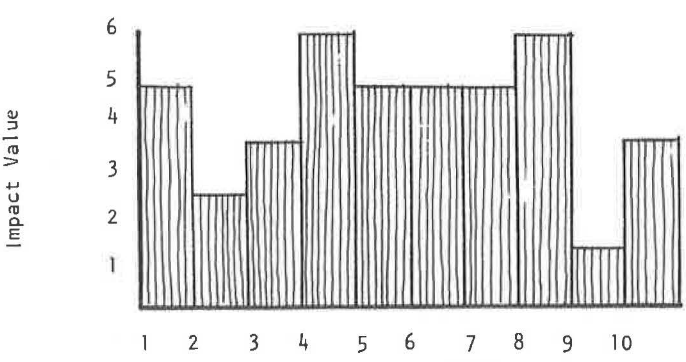
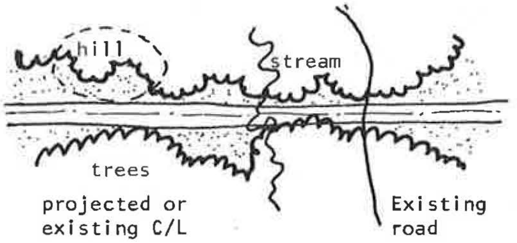
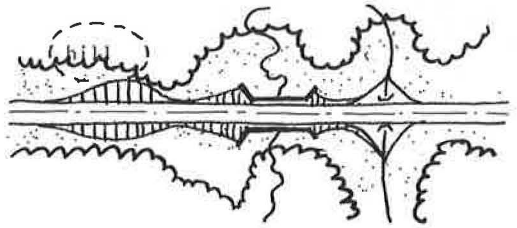


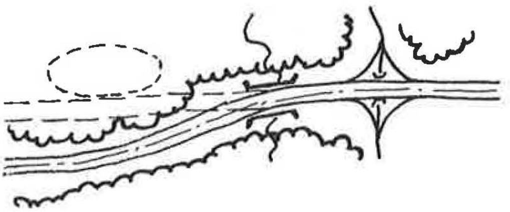
Figure 9. Analysis chart for edge sequence.



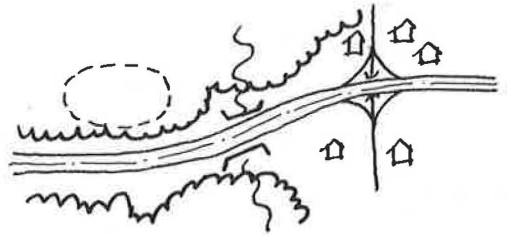
a. Step 1: T + 0



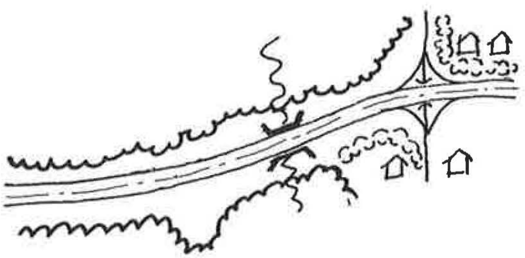
b. Step 2: Projected engineering inputs.



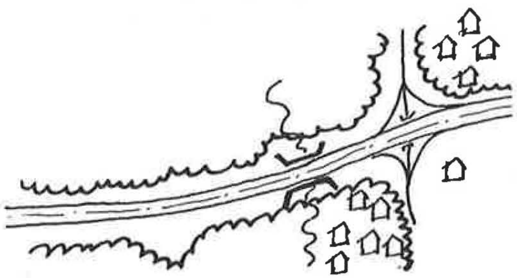
c. Step 4: T + 0, Re-evaluation



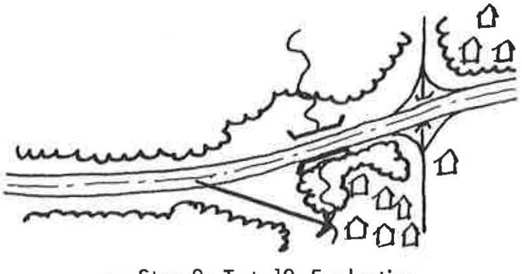
d. Step 5: T + 5, Projected urbanization



e. Step 6: T + 5, Re-evaluation



f. Step 7: T + 10, Anticipated development



g. Step 8: T + 10, Evaluation

Figure 10. Sensory data manipulation: Comprehensive route selection process.

5. Analysis—The composite visual sequence is analyzed for its assistance or value for task performance at specific situations along the highway. The parameters of analysis for study purposes were attentional demand duration, information needed for driver decision-making, and overall relation of factors to attentional demand cycles, as defined by criteria relative to a driver traveling at 60 mph, looking straight ahead, with weather, traffic, and climate considered as optimums. This study explored the

ramifications of driving under these limited conditions because the authors were primarily concerned with exploring possible criteria for future study. Future research should consider driving at various speeds and under various conditions and possible impact of input from the various visual factors (edge, etc.) upon the driver.

The significance of the process of visual analysis is that it illustrates in a preliminary way the possible sequential driver visual experience over time and distance, and also the possible relative effects of impact of each sequential 15-second increment as postulated for driver behavior, establishing the hypothesis of linkage of visual characterisitcs of highways and their significance for drivers.

The method of visual impact data manipulation to be included as part of a comprehensive route selection process is summarized in the following. Similar analysis may be undertaken to improve existing roads.

Step 1—Using the preliminary route selected on the basis of engineering, economic, and other route selection criteria as a start, record and evaluate the sequential visual component data (edge, enclosure, landmarks, etc.) in terms of visual performance ratings as mentioned earlier (Fig. 10a).

Step 2—Finding selected route satisfactory relative to postulated attentional demand curve, orientation needs, etc., record the necessary engineering inputs—structures, areas of cut and fill, etc. (Fig. 10b).

Step 3—Re-record visual data resulting from step 2 input.

Step 4—Re-evaluate visual impact data to determine areas of optimum driver response, orientation, etc. (Fig. 10c). Adjust visual components and route alignment within the corridor concurrent with engineering feasibility analysis as necessary to maintain optimum attentional demand cycles for all increments of the route.

Step 5—Re-record visual data as a result of predicted development of highway and adjacent area patterns for five years hence, T + 5 (Fig. 10d).

Step 6—Re-evaluate visual data as a result of T + 5 input. Adjust visual components and route alignment or provide right-of-way development constraints as necessary (Fig. 10e).

Step 7—If possible, re-record visual data as a result of anticipated development pattern for ten years hence, T + 10 (Fig. 10f).

Step 8—Re-evaluate and adjust as necessary (Fig. 10g).

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Water Systems for Interstate Safety Rest Areas: Quantity and Quality Aspects

ROBERT L. JOHNSON, Engineering Research Institute, Iowa State University

Interstate safety rest area facilities provide unusual water use demands. The design of water system elements can be based on the peak instantaneous, maximum hourly, and maximum daily water demand rates. The peak instantaneous demand rate establishes the required pipe sizes and the capacity of elements such as the pumps to the hydro-pneumatic tanks. The water source capacity should be equal to the maximum daily water use rate while the required storage volumes are determined by the maximum hourly use rate.

Water available from natural sources such as wells is not pure. Numerous types and concentrations of impurities present in the water supply will influence the suitability of the source. The need for bacteriologically safe water is obvious. Other constituents and characteristics, such as iron, manganese, sulfates, chlorides, nitrates, and hardness, must be considered in selection of a water source. The adequacy of the available water quantity and water quality must be considered in the early planning and development of the safety rest area facilities.

The sucessful operation and maintenance of numerous rest area facilities throughout each state will depend to a great extent on the standardization of the water systems. This design approach will be particularly adaptable to the hydraulic elements and is also applicable to many of the treatment elements of the water system.

•THE ADVENT of the Interstate Highway System and the resulting large traffic volumes from "America on wheels" led to the concept of safety rest area facilities in a number of states. Individual state requirements and desires have led to a variety of creatively designed facilities. Such rest areas are a pioneering effort to furnish a service to the traveling public. The acceptance and the current rate of use in Iowa dramatically show that the rest areas provide a service that the public uses and appreciates.

Because the author is primarily familiar with the Iowa facilities, this paper is oriented toward the Iowa safety rest area development and design program. However, the material presented on the water systems should be applicable to other design solutions for rest areas of other states.

Rest area buildings provide unusual water use and water demand rates. The major problem is that there are few specific applicable guidelines from previous installations. The magnitude of the problems involved is shown by the fact that the projected water use and demand variations of each rest area building in Iowa are equivalent to the water supply for a community of approximately 100 people. However, the water demand characteristics are different from the normal domestic situation in a community.

Thirty, forty, or more of such facilities throughout each state are development, design, operation, and maintenance problems of the first order. Yet the basic underlying problem is simply to provide water for "one of those stops." The available quantity and quality of a potential water supply are factors that must enter into the planning of the rest areas at a very early stage. In fact, the availability of water in adequate

Paper sponsored by Committee on Roadside Development and presented at the 48th Annual Meeting.

amounts and of proper quality can and should dictate the site selection for the rest area and the extent of facilities to be provided at the site.

WATER DEMAND

One of the first steps in selection of a suitable water supply for a rest area facility is determining the rate of demand that will be placed on the source. The vital elements of water use demand are the average daily water consumption and the peak demand rates for various time periods important in the design of facilities, such as the maximum daily, maximum hourly, and peak instantaneous demand rates. These peak demand rates need to be estimated for determination of the pipe sizes, pressure losses, storage requirements, and pumping capacity to supply sufficient water during these periods of high water use.

Some studies (1, 2, 3) have been conducted on the flow variations at the service areas along some national turnpike and toll roads. These service areas generally provide more facilities than are anticipated in the safety rest areas. The studies point out the wide variation in demands to be expected and the rapidity with which they can occur. The data, however, are not directly applicable to the safety rest areas.

The extent and type of water-consuming devices provided in a rest area building will establish the potential water use. Traffic volumes, number of parking spaces, and other factors will determine how fully the water-using potential will be realized.

Water demands and other aspects of the water systems in the Iowa rest area buildings will be referred to for comparative purposes throughout this paper. The rest areas are usually in pairs, nearly opposite each other. Currrently, each building has a separate water system. Approximately half of each 30- by 34-ft building is devoted to rest room facilities. In total, each building has eight toilet fixtures, (water closets or urinals), four lavatories, three drinking fountains, and one service sink as the primary water-consuming devices. Two outside hose connections are provided for watering lawns.

Various portions of a water system will be designed for the water demand during particular time periods. For example, the individual pipes to each fixture must be sized to meet the maximum momentary water-use rate for that fixture at adequate pressures. The main water supply piping, however, does not need to meet the sum of all fixtures simultaneously because all fixtures will not be used at the same instant.

The peak demand flows on which to base the design of the water system should reflect the expected pattern of operation and meet the needs of the particular type of installation. Any numbers must be tempered with experienced judgment.

Peak Instantaneous Water Demand Rate

If all fixtures installed in one Iowa rest area building were used simultaneously, the total water demand would be 590 gpm (gallons per minute). Obviously, and fortunately, this will never happen. The demand imposed on building water supply systems cannot be predicted exactly. Although some fixtures, such as hose bibs, will impose a continuous water use, it must be recognized that the plumbing fixtures are used intermittently and the probability of simultaneous use of such fixtures cannot be definitely established.

A standard method (4) for estimating the peak instantaneous demand on a building water supply system has evolved that has proved to be satisfactory for many combinations of building fixtures, occupancy, and use. The studies of plumbing installations using statistical methods by Hunter (4) were a landmark in engineering design. The results of this work have been incorporated into the National Plumbing Code (5).

Numerous field tests as well as the test of time have proved that this standard method is widely applicable. In the standard method, fixtures that use water intermittently under different service conditions are assigned demand load values in terms of fixture units. One fixture unit is equivalent to a flow rate of 1 cu ft per min or 7.5 gpm. Applicable values for different fixtures are given in Table 1 (5, 6). The relationship between the total fixture units and the peak instantaneous water demand rate is shown in Figure 1.

Applying the fixture unit values in Table 1 and the relationship in Figure 1 to the rest area buildings in Iowa (79 fixture units) yields an estimated peak instantaneous water demand rate of slightly over 60 gpm. This is somewhat less than the 590 gpm based on the simultaneous use of all the fixtures. Any continuous water demand such as a connection for lawn watering should be calculated separately and added to the peak instantaneous demand. Any water system using pumping as the basic supply device should have a pumping rate nearly equal to this peak instantaneous demand rate. This situation fits the hydro-pneumatic tank and the direct booster pumping systems.

TABLE 1

WATER DEMAND LOAD OF FIXTURES, PUBLIC OCCUPANCY

Fixture	Supply Control	Fixture Units[a]
Water closet	Flush valve	10
Water closet	Flush tank	5
Urinal	Flush valve	5
Urinal	Flush tank	3
Lavatory	Faucets	2
Service sink	Faucets	3
Drinking fountain	Valve	1

[a]The given weights are for total demand. For fixtures with both hot and cold water supplies, the weights for maximum separate demands may be taken as three-fourths of the listed demand for supply.

The fixture unit values of Table 1 and the relationship to peak instantaneous water demand rate in Figure 1 show that the flush tank type of plumbing system could reduce this demand rate by about half. However, the flush tank system is more susceptible to vandalism, uses more water per flush even though at a lower peak rate, and the rate of proper fixture use is controlled by the time for refilling the flush tank. For these reasons, the flush valve system is used almost exclusively for public facilities such as the rest area buildings.

This particular peak instantaneous rate for a water system is based on considerable past operational experience, and as such is estimated on a sound basis.

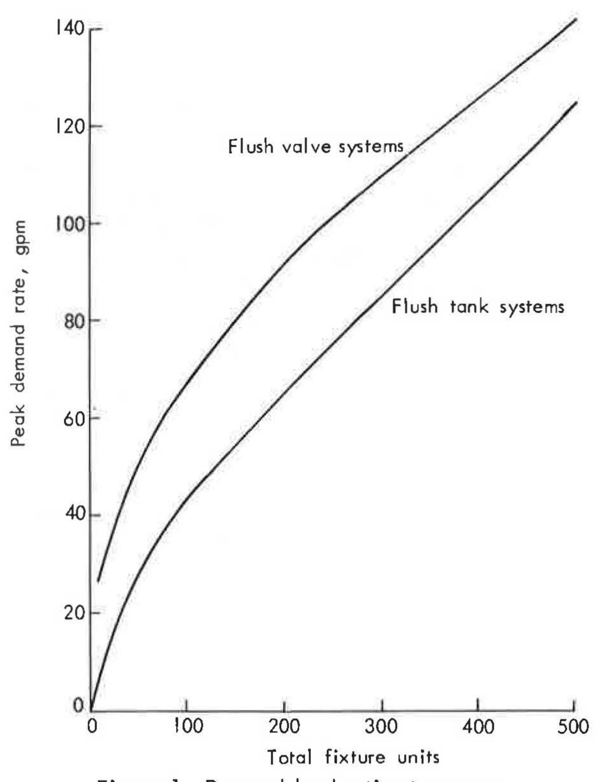

Figure 1. Demand load estimate curves.

Maximum Hourly Water Use Rate

Unfortunately, the water use rates for other time periods are not so well determined. There is a real paucity of specific data applicable to the rest area buildings.

An estimate of the ratios between the peak instantaneous and the maximum hourly water use rates can be obtained from criteria such as the "Federal Housing Authority Guide for Engineers—Rural Community Water Systems" and other criteria and studies (1, 2, 3, 7, 8, 9). It must be pointed out that none of these criteria or studies provide the desired ratio directly, peak instantaneous demand rate to maximum hourly water use rate. But by considering the ratio of average daily use to maximum daily use and the maximum hourly use to maximum daily use and in turn the estimated peak instantaneous water demand, an expected ratio of two can be reached. When this ratio is applied to the situation in the Iowa rest area buildings, the estimated maximum hourly water use rate would be 30 gpm. It is quite apparent that this number leaves considerable room for doubt. The extension of some of the studies is difficult, but as was pointed out before, engineering judgment and common sense are required.

In an attempt to provide a more rational design basis, several studies were conducted by Iowa State Highway Commission personnel, including hourly water use readings as well as traffic counts on the main traffic stream and on the traffic into the safety rest areas. These studies confirm the validity of the rate given. By actual count, 2067 people per 16-hour day enter a single safety rest area site for an average of 130 people per hour. A great many counts at these rest area sites have established that the peak hour traffic in flow volume is about three times the average or 390 people per hour entering the site.

These studies have further shown that about 70 percent of the people use the rest room facilities. This means that during the maximum hour, about 295 people are using the rest room facilities. Estimating a water use of 5 gal (3 to 5 gal per water closet or urinal, $^3/_4$ to $1^1/_2$ gal per lavatory use), this yields a maximum hourly water use rate of about 25 gpm, which is quite close to the 30 gpm previously determined. It is interesting to note that the recommended water use criteria (8, 10) for service stations of 10 gal per vehicle will yield approximately the same water demand rate, allowing 3 people per vehicle, as previously determined.

Maximum Daily Water Use Rate

Similar considerations yield a ratio of the maximum hourly to the maximum daily water demand rate equal to approximately two. This ratio can be estimated with a fair degree of accuracy from a number of sources (7, 8, 9). Applied to the Iowa rest area buildings, this ratio would yield a maximum daily water use rate of 15 gpm.

This particular water use figure will be highly dependent on other factors, notably parking spaces provided and traffic volumes. The potential for this water use can be present, but the actual use limited. Several years of operating experience are going to be needed to more fully define this situation.

Daytime Water Use Rates

In the normal design of a water system for domestic services, the high hourly water use rates will occur in the early morning, at noon, and in the evening, roughly corresponding to meal times. Safety rest areas present a quite different pattern, as shown in Figure 2. The data shown in Figure 2 are the average and the maximum hourly water uses determined at twelve different rest area buildings in the studies by Iowa State Highway Commission personnel. As can be seen, the demand rate for a considerable length of time during the middle of the day is above the average for that day. This means that an appreciable draw will be placed on the water supply facilities for a number of consecutive hours in the middle of the day.

Also, more than 80 percent of the daily water use will occur in the 16-hour period from 6:00 a. m. to 10:00 p. m. It is for this reason that the average daily flow is such a poor design value to consider.

Summary of Water Demands

Two particular aspects of the water use variations dictate that the design basis for Interstate safety rest areas should be the maximum daily use rate with its attendent maximum hourly and peak instantaneous demand rates. First, the peak instantaneous water demand could occur on any day of the year, even the lowest water use day. In fact, a single busload of people could exert this demand rate several times during a 10- or 15-minute period. Second, the maximum daily water use rate or just slightly less will probably occur for extended periods of days during the summer vaction travel period in a pattern similar to that shown in Figure 2. The maximum daily water use rate establishes the required capacity of the water supply source. This is an important design parameter because it is anticipated that this demand rate or slightly less will be sustained for several days at a time during the high summer use period.

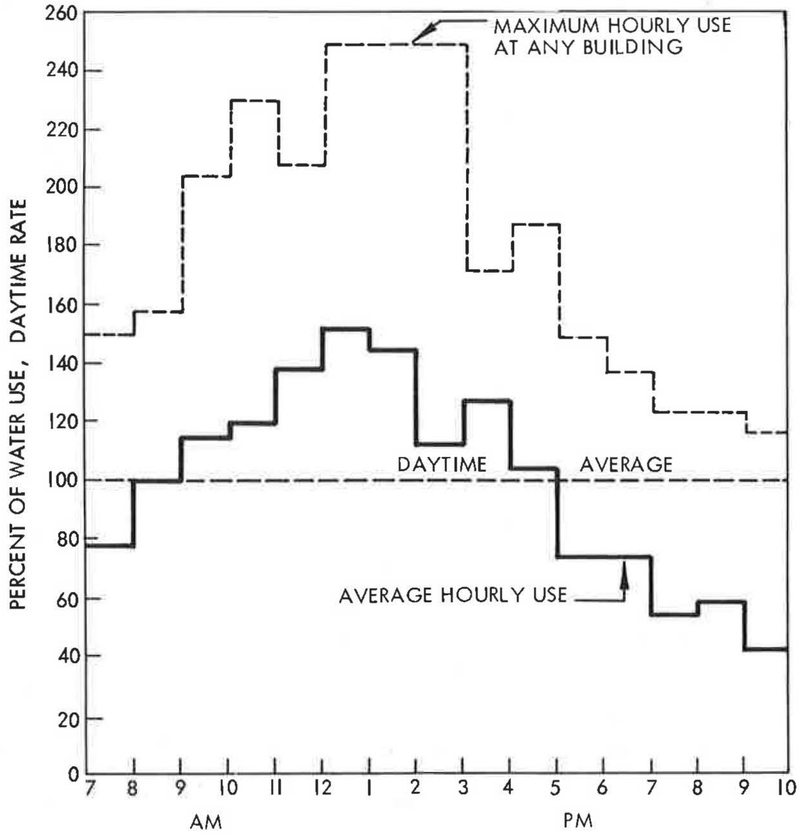

Figure 2. Interstate rest area water use variation (12 buildings).

The individual fixture water use rates determine the pipe sizes to the particular fixture. The combination of fixture units through the development of the peak instantaneous demand rate will establish the main supply pipe sizes all in accordance with standard plumbing design.

As previously mentioned, the peak instantaneous water demand also will establish the required capacity of the supply pump for a hydro-pneumatic tank or a booster pump system. The hydro-pneumatic tank is the most common installation of the safety rest area buildings.

The maximum hourly water demand rate and the rates during the daytime demand period are used in the design of storage volumes or pump cycle times, as will be discussed later.

WATER QUALITY

The quality of available water supply sources is an extremely important consideration because it will affect the design of several other elements of the water system. This parameter of quality should be considered very early in the planning stage. The quality of potential water supply sources should be considered strongly in the safety rest area site selection. People expect drinking water to be biologically safe, attractive to the senses, soft, and nonstaining as well as noncorrosive or non-scale-forming. The public will demand this type of water and will get it.

The basic criteria for water quality evaluation are the "Drinking Water Standards" of the U. S. Public Health Service (11). These standards are the criteria used by most government agencies and are obligatory for water supplies furnishing water to interstate carriers. If not legally bound, the individual state highway agencies should certainly feel morally obligated to meet these minimum standards for drinking water along Interstate rest areas.

Water quality is determined by the bacteriological, physical, and chemical characteristics of the water. The first and most important criterion to be met is the provision of a bacteriologically safe drinking water. Well water supplies are generally quite safe, and because wells are the most common water source for the Interstate safety rest areas, the bacteriological quality is usually no problem. However, it is not axiomatic that all wells are bacteriologically safe, and well supplies should be tested, not just at the time of completion and start-up, but on a regular periodic basis. A monthly sample is the minimum that should be considered. A proper sampling program will provide an adequate safeguard for this aspect of drinking water quality.

The physical quality of a water supply is related to the temperature, color, turbidity (clarity), taste, and odor. The color and turbidity limitations of the "Drinking Water Standards" (11) are such that the general public will reject use of a water long before these particular limits are reached. The excellent quality water supplied daily by the municipal waterworks industry has set pseudo-standards of quality that the public will also demand from the safety rest areas.

The taste and odor aspect of a water is difficult to evaluate in a quantitative manner, because each person has a different sensitivity to this quality. A particular source of problems is the hydrogen sulphide odor (rotten eggs) prevalent in many well supplies. This is easily removed in water treatment, however.

The water temperature plays an important role in the taste problem. Many tastes will not be noticeable when the water is cold. For this reason it is strongly urged that water coolers be used when the temperature of the water source is high. A single bad taste of water can ruin an individual's good will toward the rest area facilities and vista.

The third area of the standards to be considered is the limitation on certain chemical constituents. The limitations of permissible concentrations of toxic materials such as arsenic, boron, and selenium must be met. Other far more commonly found chemical constituents, the allowable concentration, and the effect of these constituents are considered in the following.

Iron and Manganese

The presence of iron and manganese can cause stains on plumbing fixtures and coatings in pipes and hot water heaters, as well as some taste problems. In addition, red or, more commonly, yellowish-red colored water will occur when the water is exposed to the atmosphere. Almost all well waters in Iowa and in many other parts of the country contain these minerals in excess of the limits of 0.3 mg/l.

Calcium and Magnesium

Hard water is caused by calcium and magnesium salts; although there is no limit on hardness per se, the magnesium level should be below 125 mg/l. The calcium and magnesium salts in hard water can cause deposits in pipes, reducing their capacity, and in hot water heaters particularly.

The possible extent of such coatings was well demonstrated in an Iowa rest area building that had an extremely hard water supply. In that instance, a $1\frac{1}{2}$-in. drain pipe connected to a urinal was coated to a point where the inside diameter of the pipe was about the size of a pencil. This had occurred within about a year of operation. The possible problems in 15 or 20 years of operation are quite apparent under these circumstances. The need to soften the hard water is obvious in this instance in order to prolong the life of the piping and fixtures.

Nitrates

The presence of nitrates near the 45 mg/l level can cause nitrate-cyanosis in infants (blue babies) if the water is used in formula. Most uncontaminated water supplies are considerably below this limit, but it is an important item to consider in evaluating water quality for rest areas.

Chlorides

Above the level of 250 mg/l, particularly in conjunction with high sodium concentrations, drinking waters may have a salty taste to some people. Certain people may also experience a degree of laxative effect from this type of water.

Sulfates

Drinking waters with a sulfate concentration above 250 mg/l will produce a laxative effect on most people, particularly if the sulfate is combined with a high magnesium concentration (epsom salts). The presence of high total dissolved mineral content also promotes this laxative effect.

Many communities in the United States have water supplies that exceed these sulfate concentration limits and the inhabitants become acclimated to the water. The acclimatizing process can be discomforting under normal domestic conditions. The traveling public does not have the time to become acclimated and the laxative effect on a traveling family could be completely disastrous. Rest areas could not be spaced closely enough.

WATER SYSTEMS

Sources

There are three primary sources of water for the Interstate safety rest areas. The first and probably the most desirable, if close enough, is a municipal supply. The capital and maintanance costs involved with water supply and treatment for a rest area building could pay for appreciable pipe line construction from nearby communities. In any case, this is a first consideration when investigating water supply sources.

The second and by far the most commonly used water supply source is wells. There are relatively few areas in the United States where a well supply cannot be developed. The water quality from well supplies, however, can sometimes be less than desirable.

The third possible source is surface water such as a river or lake. Because of exposure to the atmosphere and the elements, such water supplies can be extremely variable in quality. They are always subject to pollution, and treatment will always be needed. Chlorination is the very minimum treatment possible. As such, a surface supply will present many more operational and maintenance problems than a well supply for small installations. Surface water sources should be avoided if at all possible.

Water Treatment

The wide variation in water quality that can be expected across the country means that a single series of treatment operations will not be satisfactory for every water supply. The quantity of water required will also play an important role in the treatment process selection. In fact, the relatively small size of the rest area water systems creates problems in this respect. The water systems are larger than the single-family size but considerably smaller than most municipal systems, both sizes of which have treatment processes and equipment commonly available. Because so many of the water sources are wells, the following comments are intended solely for a well supply source.

Iron and Manganese—With relatively few exceptions, iron and manganese removal for well water supplies will be needed. No one treatment method is satisfactory for all iron- and manganese-bearing waters. The soft, low pH waters of the southern and southeastern states will require entirely different treatment from the hard, neutral, or alkaline waters common in the midwestern and western states. The basic process recommended for the Iowa water supplies was pressure aeration followed by pressure sand filtration. Provision for pH adjustment or chlorination in a few well supplies was also recommended. Even then, there were some well supplies in the state with excessive carbon dioxide that were not suitable for this basic and simple process.

The iron and manganese problem occur most commonly when there is a need for relatively large storage of the water due to hydraulic capacity limitations. When the iron-bearing water is exposed to the air, the iron or manganese is oxidized, which leads to the yellow color and turbidity of the water. This will be a problem in Iowa, where large 10,000-gal storage tanks are being installed with no provision for iron and manganese removal.

Waters that have iron and manganese only slightly above the limits can often be treated with phosphate compounds. These compounds can prevent the oxidation of the iron or manganese and thus prevent the color and stain problem.

Softening—As with iron and manganese removal, the need for softening will vary. The tendency toward corrosion or scale formation is directly related to the hardness of the water through the calcium content. The treatment process, then, becomes quite important in adjusting the characteristic of the water to a non-scale-forming or non-corrosive water.

There are situations where the need to soften is quite apparent, as in the case previously mentioned. Most water supplies will not be this hard, however. Although this limit is somewhat arbitrary, when water supplies are harder than 200 mg/l of $CaCO_3$, softening should be seriously considered.

Common commercial cation exchange units can be used to soften the water supplies in most cases. These units are cation exchangers on the sodium cycle (zeolite softening). The reduced maintenance costs and increased life of the facility fixtures and plumbing can pay for the extra cost of water softening many times over, particularly as the hardness of the water increases.

A subtle but important benefit which can often be obtained in the water softening process is that the cation exchange resins will also remove iron and manganese. In fact, these are two elements which tend to foul the resins if too much iron and manganese removal is attempted. However, for those waters where the iron and manganese level is only slightly above the recommended limits, a softening unit can provide the needed treatment in one step.

Sulfate Removal—The following comments about sulfate removal are also generally applicable to chloride and nitrate removal, all of which are extremely difficult.

One available method for sulfate removal is complete demineralization of the water, together with blending of a portion of the untreated water to provide some taste in the drinking water because demineralized water is not palatable. The only water use requiring such treatment would be the supply to the drinking water fountains, and thus the quantities involved are small. The demineralization process is expensive and requires periodic regeneration of resin beds with strong acids and strong caustics. It is not a simple process to consider and should be avoided if at all possible.

A second possibility for sulfate removal is treatment by reverse osmosis. This is one of the methods being proposed and under study for desalting sea water. Again, both the first cost and the operational costs are high. This process is currently in use and under study by the Iowa State Highway Commission; it is hoped that some results will be available in the near future.

In this writer's opinion, if the magnesium removal is provided by softening the rest area water supplies, the problem will be greatly alleviated even if the sulfate concentration is somewhat above that outlined in the "Drinking Water Standards" (11).

Provisions for Water Pressure

There are three general methods of providing the required water pressure for operation of the rest area facilities. The first to consider would be elevated water storage, either tank or standpipe type. This system has the advantage of easily providing water for the variable and peak-type water demands that exist in the rest area facilities. The primary disadvantage is the initial cost where relatively flat terrain is encountered. Freezing problems may also occur during the low demand periods in the winter months. The freezing problems can be handled by judicious operating procedures. For example, only a portion of the storage volume available could be used during low demand periods to insure adequate turnover of the stored water to prevent freezing. The cost problem in flat terrain still remains. Where the terrain is favorable, i. e., a hill 40 to 50 ft or more above the rest area buildings, this type of pressure supply is recommended over all others, particularly when the rest area buildings are in a pair and can be combined into one water system.

There are a number of design possibilities for elevated storage, such as architectural treatment for aesthetics and incorporation into uses such as lookout towers. This is an area where some very original and creative designing is possible. Whenever possible, the provision of elevated storage should be considered as the first alternative to provide water pressure. In fact, this could and should be incorporated into the planning process of site selection.

The second possibility is booster pumps used in parallel to provide the water pressure required with only nominal storage for pump suction purposes. This type of pressure system is well-suited to a fairly uniform water demand with only occasional periods of high usage. This is not the type of water demand experienced at the rest areas, and thus this type of direct booster pumping system is not applicable.

The third possibility is a hydro-pneumatic tank system, which is the system presently used in most rest area facilities. Although not as well-suited to widely varying demand rates as is elevated storage, a properly designed hydro-pneumatic system will function very satisfactorily. A common misconception about the hydro-pneumatic tank is that it provides water storage. It does not. The primary purpose of a hydro-pneumatic tank is to provide water pressure between certain limits, commonly 40 to 60 pounds per square inch (psi). The ability of a hydro-pneumatic system to meet the peak water demands is dependent solely on the capacity of the pump supplying the hydro-pneumatic tank. This pump should be equal in capacity to the peak instantaneous demand rate in order to insure proper use of all the fixtures.

The total tank volume required is determined by the number of pump cycles that can be tolerated during the maximum hourly water use period. The maximum recommended number of pump cycles per hour varies from two to ten depending on the guidelines used and on the degree of reliability required. Ten cycles per hour is the most common recommendation for the normal 1800 rpm pump motor. The number of cycles per hour is reduced as the horsepower and/or the speed of the electric motor increases.

As shown in Figure 2, the water demand rate for the period from about 10:00 a. m. to 3:00 p. m. is sustained only slightly below the maximum hourly demand rate. The commonly used submersible well pump motors generally operate at 3600 rpm. In view of this it is recommended that, when a well pump supplies a hydro-pneumatic tank directly, the number of pump cycles per hour be limited to five. However, when booster pumps (which operate at 1800 rpm) supply the hydro-pneumatic tank, the number of pump cycles per hour can be increased to ten.

On this basis, the pump supplying the hydro-pneumatic tank for the Iowa rest area buildings should be capable of meeting the peak instantaneous demand of 60 gpm previously determined. Likewise, for a maximum hourly demand rate of 30 gpm previously determined, the total volume of the hydro-pneumatic tank should be 360 gal for an 1800-rpm booster pump. The tank would need to be 720 gal if a 3600-rpm well pump is used. Both of these volumes are based on using the 40- to 60-psi operating range.

The maximum possible volume of the hydro-pneumatic tank used per cycle when operating at the 40- to 60-psi range is 27 percent, if the tank is 27 percent full at 60 psi and empty at 40 psi. This is not particularly satisfactory in practice, and generally the hydro-pneumatic tank would be operated so that the tank is 30 percent full of water at 60 psi and 5 percent full at 40 psi, thus allowing some safety factor.

In order for the hydro-pneumatic system to function properly, controls should be provided to add or vent air as required and thus maintain the proper air-water ratio in the tank.

Operation and Maintenance

One of the most important features that must be designed into rest area water systems is simplicity of operation. It is important that all of the equipment and treatment processes selected be simple, automatic, and essentially free of the "human element." The desired water system design and equipment should produce excellent quality water satisfactory to all people, even when the system and equipment is improperly operated and not maintained. This is somewhat of a Herculean task and not a design problem for the novice. Qualified expert design advice is needed. The problems of the small water system are practically as complex as the much larger municipal and industrial water systems.

The operation and maintenance of these water supply systems at scattered locations throughout each state will be difficult. Just the problem of spare parts for 30 or 40 well pumps, each slightly different, is unpleasant to contemplate. Multiply this problem by the five to ten major components of each water system and a real nightmare could occur.

The need for standard design water systems is apparent. Yet, as was pointed out earlier, each water supply source will have different quality and quantity aspects. Nevertheless, it is possible to standardize many of the major components of the water systems. For successful operation, the rest area water systems must have a high degree of interchangeability of all elements. This may mean a limited degree of overdesign in the case of some installations.

In Iowa highly standardized water systems have been recommended and partially implemented, particularly the hydraulic components such as well pumps, booster pumps, and hydro-pneumatic tanks. This is further outlined in the Appendix and is a major item of design consideration.

A second item which should be obvious, but is neglected in many designs, is the provision of adequate space for the equipment needed. It will be impossible to properly operate and maintain the water system equipment if too little space is allowed.

BASIC DESIGN RECOMMENDATIONS

1. Because the rest area facilities are a water supply service to the public, the water supply capacity and water quality should be an important and early factor in planning the rest area facility. It is strongly urged that the exploration for the water source be completed before final site selection is made. Many operational problems can thus be prevented.
2. Owing to the expense involved with wells and water treatment processes, it would be desirable to use connections to municipal water supplies whenever possible.
3. To reduce the overall costs of the water systems and to increase the treatment process unit capacities to more desirable levels, the water systems of the rest area buildings, if in pairs as in Iowa, should be combined whenever possible.
4. Whenever the topography is favorable, elevated storage should be used to supply water pressure.
5. The water systems should be capable of supplying the estimated peak instantaneous water use rate for the required short durations.
6. Because the water use rate during the midday hours is often near the maximum hourly use rate, the essential elements of the system should be capable of sustained operation at or near the maximum hourly demand rate.
7. The capacity of the water supply source should be at least equal to the estimated maximum daily water use rate.
8. The maintenance and operational problems involved with the number of different water systems in each state is staggering to contemplate. As discussed earlier, a high degree of standardization of all elements is essential. This is often difficult to attain under the bid procedure limitations of public agencies, but the potential savings to the public far outweigh the bidding problems.
9. A second area of maintenance and operation to be considered is the personnel involved and management organization. The problems will be quite different from those previously encountered by highway personnel. A staff either within the existing organizations or separate, trained and educated in this area of engineering, may be needed for successful operation and maintenance of the rest area facilities.

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Appendix

IOWA REST AREA WATER SYSTEM SCHEMES

The following material is included to demonstrate that standardized designs are possible and feasible. The following water system schemes were recommended to the Iowa State Highway Commission and have been partially implemented, with other portions of the schemes to follow.

The main body of this paper has shown the development of the various demand rates for the Iowa rest area buildings. These are shown in Table 2. Most of the well water supplies in Iowa will require iron and manganese removal and softening. The development of the proposed water schemes is guided by these two treatment processes, if needed.

The following schemes are based on use of a hydro-pneumatic tank system to provide pressure; however, the schemes can be easily adapted for use of elevated storage where the topography allows.

Proposed Water System Schemes

The possible arrangement of the water systems is quite varied depending on well capacity available, treatment required (i. e., softening only or iron removal plus softening), and whether or not the water systems of the rest area building pairs can be combined. The following schemes take into account the wide variation possible in each of the three variables.

Scheme A-1—This scheme fits the following situation: (a) well capacity is 60 gpm or more; (b) softening is the only treatment required; and (c) each building water system is separate. In this scheme the well pump would discharge through the softening unit into two 360-gal hydro-pneumatic tanks. This is the simplest and most inexpensive system. However, it fits a situation found infrequently in Iowa, because most well waters require iron removal.

Scheme A-2—The following situation is applicable for this scheme: (a) well capacity is about 30 gpm; (b) softening is the only treatment needed; and (c) each building water

TABLE 2

ESTIMATED WATER DEMANDS FOR IOWA INTERSTATE SAFETY REST AREA BUILDINGS

Water Demands	Flow Rate (gpm)[a]	Flow Rate (gpd)[b]
Peak instantaneous	60	86,400
Maximum hourly	30	43,200
Maximum daily	15	21,600
Average daily	4	5,760

[a]Gallons per minute.
[b]Gallons per day.

system is separate. The system arrangement would have the well pump discharging through the softening unit into an intermediate storage of 1000-gal capacity. A 60-gpm booster pump then would take suction from the intermediate storage and discharge into one 360 gal hydro-pneumatic tank. As can be seen, this system is quite similar to Scheme A-1.

Scheme A-3—This scheme is identical to Scheme A-1 except that the well capacity is now about 15 gpm (the estimated maximum daily demand) and the intermediate storage volume required is 3600 gal.

Scheme A-4—This scheme is identical to Scheme A-1, except that the well capacity is 60 gpm and two 60-gpm booster pumps, one for each building, take suction from the 1000-gal intermediate storage. In other words, the two building water systems are combined.

Scheme A-5—In this scheme the two building water systems are again combined with a well capacity of 30 gpm and 7200 gal intermediate storage is required. The scheme is identical to Scheme A-4 except for the intermediate storage volume.

The A-series of schemes can be further compressed by providing an intermediate storage volume of 7200 gal minimum whenever intermediate storage is required. This allows development of only two basic plans when only softening of the water is required:

Plan A—In this plan, (a) well capacity is 60 gpm, (b) each building water system is separate, and (c) the well pump discharges through the softening unit into two 360-gal hydro-pneumatic tanks.

Plan AA—In this plan, (a) intermediate storage is 7200-gal capacity; (b) well capacity is 30 gpm and the sides are combined, or the well capacity is 15 gpm and the sides are separate (note that there is no advantage to having a well capacity greater than 30 gpm in this case); (c) the well pump discharges through the softening unit into the intermediate storage; (d) booster pumps of 60-gpm capacity, either one or two, are provided; and (e) the booster pumps take suction from the intermediate storage and discharge into 360-gal hydro-pneumatic tanks, one per side.

The following B-series of schemes can be organized into a similar pattern when iron and manganese removal is required in addition to softening. There is one additional restriction to be considered when iron and manganese removal is required. The additional limitation is that a minimum time period for filter run of about 3 hours is required to prevent the "flush-out" from the filters of the iron and manganese that has previously been removed. The flushing effect would occur under a frequent start-stop condition; thus there is no Scheme B-1 comparable to the Scheme A-1. Because of this limitation, the intermediate storage volume must be larger than the comparable A-series schemes.

Scheme B-2—In this scheme the following is applicable: (a) well capacity is 30 gpm; (b) iron, manganese, and softening treatment are needed; (c) each building water system is separate; (d) the booster pump is 60-gpm capacity; (e) intermediate storage volume is 7200 gal, dictated on minimum filter run length, assuming three-fourths of the storage volume is used in the operational cycle; (f) the well pump discharges through the iron and manganese removal unit into the softening unit and in turn into the intermediate storage; and (g) the booster pump takes suction from the intermediate storage and discharges into a 360-gal hydro-pneumatic tank.

Scheme B-3—This is identical to Scheme B-2 except that the well capacity is 15 gpm and the intermediate storage volume of 7200 gal is dictated by the need to meet the water demands and not by the minimum filter run lengths. Thus there is no advantage to having the well capacity greater than 15 gpm if the building water systems are separate and iron and manganese removal is required.

Scheme B-4—This is identical to Scheme B-2 except that the well capacity is 60 gpm and the building water systems are combined. The intermediate storage volume of 7200 gal is again dictated by the need to have a minimum 3-hour filter operational run.

Scheme B-5—This is identical to Scheme B-2 except that the building water systems are combined and the 7200-gal intermediate storage volume is dictated by the need to meet the water demand.

It is interesting and unusual that the B-series of schemes is essentially identical. As can be seen, there is no advantage to having the well capacity greater than 30 gpm if the building water systems are combined or greater than 15 gpm if separate. In fact, there is a disadvantage of larger capacity wells in that the treatment units would have to be larger and more expensive.

The B-series can be reduced to one plan which is very similar to Plan AA:

Plan B—In this plan, (a) intermediate storage volume is 7200 gal; (b) well capacity is 30 gpm and the water systems are combined, or the well capacity is 15 gpm and the water systems are separate; (c) the well pump discharges through the iron and manganese removal unit into the softening unit and then into the intermediate storage; (d) booster pumps of 60-gpm capacity, either one or two, are provided; and (e) the booster pumps take suction from the intermediate storage and discharge into 360-gal hydropneumatic tanks, one per side.

At this point, there are really only two basic plans, Plan A and Plan B, since Plan AA is only a special case of Plan B where iron and manganese removal is not required. These two plans will cover quite a wide variety of possible well capacities and water qualities. The advantages and disadvantages of these plans are summarized below. The plans are shown schematically in Figure 3.

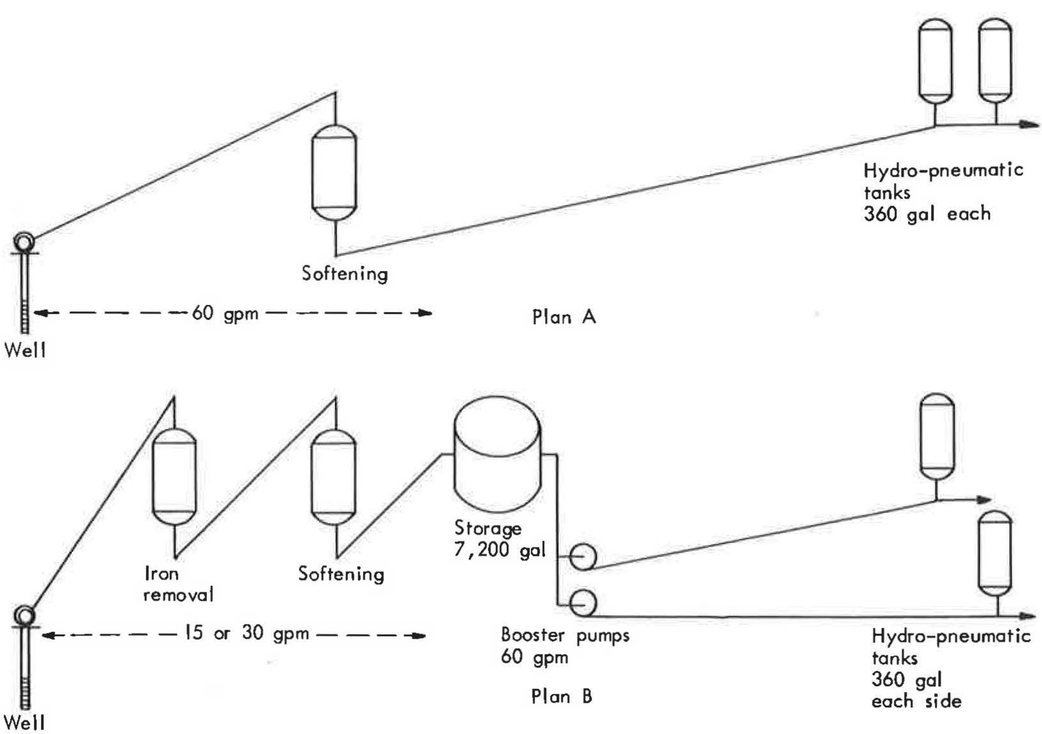

Figure 3. Basic water systems.

Advantages

1. Well pumps are used in only three capacities—60, 30, and 15 gpm; the majority will fall into the 30-gpm category.
2. The intermediate storage volume of 7200 gal is identical in all cases.
3. The booster pumps of 60-gpm capacity used will all be identical.
4. The hydro-pneumatic tanks will all be the same size, 360 gal, installed either singly or in pairs to meet the various situations.
5. A high degree of standardization can be achieved in well pumps, booster pumps, hydro-pneumatic tanks, treatment units, and controls.
6. When the building water systems are combined, the piping can be easily arranged to serve both sides from one booster pump, thus increasing the relability of the service.
7. Where the topography is favorable, the intermediate storage should be elevated storage, thus eliminating the booster pumps and the hydro-pneumatic tanks.
8. The use of intermediate storage provides a limited source of fire-fighting water.

Disadvantages

1. In the case where no iron removal is needed, the intermediate storage is oversized to some extent. However, the number of cases where iron removal will not be needed in Iowa will be in the minority. The relative cost of this oversized segment is quite low.
2. There may be occasions when chlorination could be required since the water will be exposed to the atmosphere before use and the potential for contamination is increased. With proper design, this need will be rather rare.

Design of Rest Area Comfort Facilities by Systems Analysis

HOWARD McCANN and GARY MARING, U. S. Department of Transportation, Bureau of Public Roads

This report describes a computer simulation model used to determine the number of comfort station facilities needed within rest areas. Systems analysis techniques are used to simulate the operation of a comfort station. The model determines the number of facilities—including toilets, urinals, wash basins, and dryers—necessary to satisfy certain levels of service for specified volumes.

The model is based on a limited sample of data and assumed design criteria, and therefore is presented primarily as a demonstration of technique. It is hoped that this report will stimulate further research in this area.

•SAFETY rest areas are designed to serve the needs of motorists. As a result of public demand, comfort stations are now included in rest areas on the Interstate System and on other major highways.

This report describes a computer simulation model for determining the number of facilities—toilets, urinals, wash basins, and hand dryers—necessary in the comfort stations. The research was undertaken in an attempt to satisfy a commonly recognized need for uniform standards in comfort station design. Systems analysis techniques were used to determine the optimum number of service facilities using assumed criteria for optimization.

The systems analysis approach in this case is based on the collection of data regarding individual service times at the facilities. To avoid infringing on personal privacy, the comfort station service times were not collected through a survey of the general public. Instead, service times were reported by volunteers from the Office of Planning of the Bureau of Public Roads. Considering this limitation, tests were made to measure the effects of possible errors in the reported service times. The results were found to be relatively insensitive to minor changes in the service times.

The model results were sensitive to changes in the proportion of persons using the toilets and urinals. However, little information was available concerning the division between toilet use and urinal use in rest areas. For this analysis, a proportion of 80 percent for urinals and 20 percent for toilets was used. This proportion was based on a review of limited data reported by North Dakota and South Dakota in 1968.

THE SYSTEMS APPROACH

The systems approach consists of four distinct phases: (a) orientation phase, including definition of the problem; (b) analytical phase, where the problem is represented mathematically; (c) evaluation phase, where the problem is solved; and (d) verification phase, where the model results are tested against the real operation. The application of these four phases to the comfort station problem is described in the following.

Paper sponsored by Committee on Roadside Development.

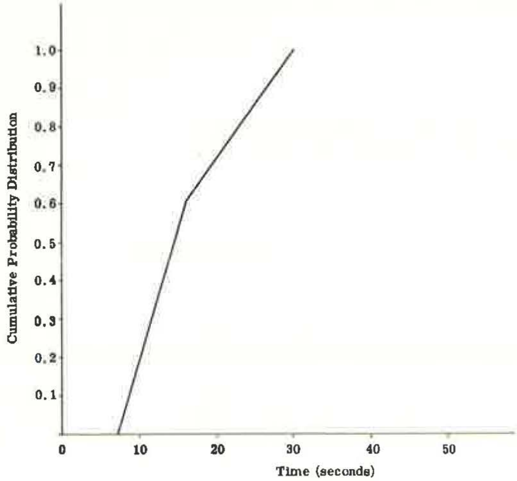

Figure 1. Cumulative distribution of times men spent washing their hands.

Orientation Phase

The comfort station operation may be described as a waiting-time problem, where the arrivals are randomly spaced and the service time is of random duration, within the limits of distribution functions. Problems arise when there is either too much demand or too little demand on the service facilities. The situation requires the determination of the optimum number of service facilities under known or assumed criteria for optimization.

Analytical Phase

Complex mathematical models are usually required to solve waiting-time problems. However, Monte Carlo procedures may be used to approximate, in relatively simple fashion, the solution of waiting-time problems. The Monte Carlo technique is a means of introducing probability in the description of an operation. The process is so named because it is necessary to generate a random number, in a manner similar to spinning a roulette wheel, to decide an action at a probability step. Random number generation is readily accomplished in computer programming.

In this model, the Monte Carlo technique was used to determine the arrival times and service times of each person using the comfort station facilities. Probability distributions were established for arrival times and service times. Generated random numbers determined individual arrival times and service times on the basis of the probability distributions.[1]

The following example illustrates the use of a probability distribution in determining service time. Figure 1 shows a cumulative array of the times men spend washing their hands. A random number is generated to represent the time that one sampled male will spend washing his hands. Assume that the number 0.29428 is generated. This produces a wash time of 11 seconds.

Arrival gap data were collected during a few hours of observation at three rest areas on Interstate 95 and Interstate 66 south of Washington, D. C. The service time data represent 74 observations reported by seven volunteers within the office.

The simulation model was designed for optimum use to be made of the facilities. If a user encountered a queue at multiple facilities, the user was assigned to the facility where the ultimate wait would be less. The model also made multiple use of the toilets in allowing use for urinal purposes.

In addition to simulating the arrival times and service times of rest area users, the computer tallied the number of persons that had to wait at each facility, their waiting times, and the total time each person spent within the comfort station. This information was used in the evaluation phase of the project.

Evaluation Phase

Once a model is formulated, it may be used in evaluation. In this case, the level of service criteria relating to the waiting times of persons were input to the model. The model determined the number of service facilities necessary to satisfy the criteria.

[1]The original manuscript of this paper included Appendix A, containing probability distribution used for arrival gaps and service times, and Appendix B, containing a flow chart and a program listing of the simulation model. The two Appendixes are available in Xerox form at cost of reproduction and handling from the Highway Research Board. When ordering, refer to XS-25, Highway Research Record 280.

TABLE 1

DESIGN CRITERIA FOR COMFORT STATION FACILITIES

Facility	Number of Persons[a] Who Had to Wait at Facility	
	Minimum	Maximum
	Men's Room	
Urinal	2	20 percent of users
Toilet	1	(no wait over 5 minutes)
Wash basin	2	20 percent of users
Hand dryer	2	20 percent of users
	Women's Room	
Toilet	1	20 percent of users (also no wait over 5 minutes)
Wash basin	2	20 percent of users
Hand dryer	2	20 percent of users

[a]Based on simulation of 60 users.

TABLE 2

REQUIRED NUMBER OF MEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Urinals	Toilets	Wash Basins	Dryers (air)
30	1	2	2	2
60	1	2	2	2
90	2	2	3	3
120	2	2	3	3
150	3	2	3	4
180	4	3	4	5
210	4	3	4	5
240	4	3	4	5
270	5	4	4	6
300	6	4	5	7
330	6	4	5	7
360	6	4	6	7
390	7	4	6	8
420	8	4	6	8
450	7	4	6	8
480	7	4	6	8
510	8	5	6	8

In these tests, 60 persons and 120 persons respectively were simulated through the women's and men's comfort stations. These volumes were found to be necessary to stabilize the model results. If the criteria (Table 1) were not satisfied, the number of facilities was adjusted and the simulation repeated. When all criteria were satisfied, the computer results were printed.

The tests were run for volumes of 30 to 510 persons per hour in increments of 30 persons per hour. The same number of persons was simulated in the model for all volume levels. Volume increases were accomplished by shortening the arrival gaps.

Tables 2 through 5 give the facilities required for volumes of 30 to 510 persons per hour, in increments of 30 persons per hour. The four tables show the number of facilities required for men and women, with two types of hand dryers. Table 2 and 4 give results for air dryers, and Table 3 and 5 give the results for paper towels. The dryers were analyzed separately owing to the longer drying time required with the air dryers.

Verification Phase

Model results should be verified by comparisons with actual comfort station operation. To avoid infringing on personal privacy, surveys were not conducted within comfort stations. Limited tests were made of the total time persons spend within comfort

TABLE 3

REQUIRED NUMBER OF MEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Urinals	Toilets	Wash Basins	Dryers (paper towels)
30	1	1	2	2
60	2	2	2	2
90	2	2	3	2
120	3	2	3	3
150	3	3	4	3
180	3	3	4	3
210	3	3	4	3
240	4	4	4	4
270	4	4	5	4
300	4	4	5	4
330	5	4	5	5
360	5	4	5	5
390	6	4	5	5
420	7	4	5	5
450	8	5	6	5
480	9	5	7	6
510	9	5	7	6

TABLE 4

REQUIRED NUMBER OF WOMEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Toilets	Wash Basins	Dryers (air)
30	2	2	2
60	3	2	2
90	4	3	3
120	4	3	3
150	4	3	3
180	6	4	4
210	8	5	5
240	8	5	5
270	8	5	5
300	11	6	7
330	11	6	7
360	10	6	6
390	11	7	7
420	12	8	7
450	12	8	8
480	13	8	8
510	13	8	8

TABLE 5

REQUIRED NUMBER OF WOMEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Toilets	Wash Basins	Dryers (paper towels)
30	2	2	1
60	4	3	2
90	5	3	2
120	5	3	2
150	6	4	3
180	7	4	3
210	7	5	3
240	9	6	4
270	8	5	4
300	10	6	4
330	10	6	4
360	10	6	4
390	11	8	5
420	12	8	5
450	14	8	5
480	12	8	5
510	13	8	5

TABLE 6

COMPARISON OF MODEL RESULTS WITH ACTUAL REST AREA OPERATION – MEN'S COMFORT STATION (Rest Area on I-95 South of Washington, D.C.)

Time in Comfort Station (seconds)	Volume = 30 Persons/Hour		Volume = 57 Persons/Hour	
	Observed Values (percent of users)	Simulated Values (percent of users)	Observed Values (percent of users)	Simulated Values (percent of users)
0-29	–	–	–	–
30-59	15.6	0.8	7.7	–
60-89	9.4	21.7	30.8	24.2
90-119	31.2	40.0	23.1	27.5
120-149	18.8	20.0	15.4	20.0
150-179	9.4	2.5	3.8	4.2
180-209	9.4	4.2	–	5.8
210-239	3.1	5.8	3.8	7.5
240 and over	3.1	5.0	15.4	10.8
Total	100.0	100.0	100.0	100.0

TABLE 7

COMPARISON OF MODEL RESULTS WITH ACTUAL REST AREA OPERATION – WOMEN'S COMFORT STATION (Rest Area on I-95 South of Washington, D.C.)

Time in Comfort Station (seconds)	Volume = 30 Persons/Hour		Volume = 47 Persons/Hour	
	Observed Values (percent of users)	Simulated Values (percent of users)	Observed Values (percent of users)	Simulated Values (percent of users)
0-29	–	–	–	–
30-59	–	–	–	–
60-89	6.9	12.5	2.7	10.0
90-119	10.4	34.2	10.6	26.7
120-149	10.4	32.5	10.6	30.0
150-179	20.7	3.3	21.0	10.9
180-209	3.4	3.3	21.0	8.3
210-239	20.7	1.7	13.0	6.7
240-269	6.9	7.5	10.5	1.7
270-299	6.9	3.3	7.9	5.0
300-329	3.4	1.7	2.6	0.8
330-359	6.9	–	–	–
360 and over	3.4	–	–	–
Total	100.0	100.0	100.0	100.0

stations. These tests were made at two rest areas on Interstate 95 south of Washington, D. C. The results (Tables 6 and 7) indicate that the model offers a fair approximation of actual rest area operation for the men's comfort stations. The model tends to show a higher percentage staying for shorter lengths of time in the women's comfort stations.

Sensitivity tests for the model were run to evaluate the results with varying input data. Service times were appreciably altered, as was the division between toilet use and urinal use. As mentioned, the model results were shown to be relatively insensitive to changes in service time. The "toilet-urinal" use division had more effect on the results.

DISCUSSION OF RESULTS

Tables 2 through 5 give the results of the simulation. The number of facilities increases as the volume increases, although not in a direct proportion. Occasionally the number of facilities is reduced with an increase in the volume of users. This occurs owing to the randomness feature of the model. Engineering judgment must be used in evaluating the model results, and in establishing design criteria.

To be effective in highway design, the criteria must be related to ADT. Table 8 gives the number of facilities required by volumes of users per hour and by ADT groups. The following equation was used to relate persons per hour with ADT (the values for the variables represent average conditions in rest areas on rural interstate highways):

$$\text{Persons/hour} = \text{ADT} \;\; K \cdot D \cdot N \cdot V \cdot R$$

where

ADT = Average daily traffic,
K = Ratio of design hour volume to ADT (13.5 percent),
D = Directional distribution (60 percent),
N = Percentage of vehicles that stop at rest areas during peak hours (10 percent),
V = Vehicle occupancy (3.5), and
R = Percentage of persons stopping at rest areas who use comfort stations (75 percent).

TABLE 8

DESIGN GUIDE FOR COMFORT STATIONS ON RURAL INTERSTATE REST AREAS

ADT	Persons per Hour Using Rest Rooms During Design Hours	Number of Facilities				
		Urinals	Toilets	Wash Basins	Hand Dryers	
					Paper Towels	Air Dryers
Men's Room						
0-10,000	0-105	2	2	2	2	2
10,000-21,000	105-225	3	3	4	3	4
21,000-30,000	225-315	4	4	5	4	6
30,000-35,000	315-375	5	4	5	4	7
35,000-41,000	375-435	7	4	5	5	7
41,000-47,000	435-500	9	5	7	5	8
Women's Room						
0-10,000	0-105		4	3	2	2
10,000-21,000	105-225		6	4	3	4
21,000-30,000	225-315		9	6	4	6
30,000-35,000	315-375		10	6	4	7
35,000-41,000	375-435		12	8	5	7
41,000-47,000	435-500		14	8	5	8

The values of N, V, and R were obtained from a preliminary analysis of the 1968 national rest area survey. The persons per hour entering the men's and women's facilities was set at half the total persons per hour.

Table 8 is applicable only to rest areas with values of K, D, N, V, and R similar to those given. Where these values are different, the designer should compute the persons per hour figure. Tables 2 through 5 would then be used for determining the number of facilities.

ACKNOWLEDGMENTS

Mr. Kenneth H. Welty, Highway Research Engineer, Current Planning Division, provided technical assistance in the development of the computer model.