Towards Design Criteria for Highway Aesthetics

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The objective of this paper is an attempt to establish a framework of investigations into design criteria which will not only include the traditional Newtonian criteria but measurable aesthetic considerations from the driver's point of view.

The driving task is developed as a system. The inputs are perceived by the driver, a value judgment is made and outputs are produced.

The experimental method suggested deals with the value judgment. It is suggested that the driver's outputs are a reflection of his state of mind. The galvanic skin response and other apparatus are suggested to measure these outputs.

By relating the state of mind or an acceptable level of risk to geometric elements, design criteria can be developed to allow the driver freedom to enjoy the beauty of the environment. Until this is accomplished, there is little logic in providing, at additional costs, so-called aesthetic qualities in design.

•WITHIN recent years, a great furor has arisen because of the highway designers apparent lack of concern for aesthetics. The major indication of the people's feelings is reflected in the United States by the enactment of Public Law 89-285. This law does not define beauty nor does it suggest the best means of incorporating beauty into highway design, but by its existence it does show that there is a dissatisfaction with what we, as engineers, have been giving the people. It should tell us that something is missing in our technical solutions. It would be naive to suggest that a highway designer who toils with traffic forecasts and highway location and geometrics under economic, time and political constraints is not concerned with how the final product looks. However, it might well be that these practical exigencies have used up our time leaving little thought towards incorporating beauty.

Aesthetics cannot be thought of as visual elements alone, but as Snowden suggests (1): "beauty is that which exalts or lifts up the mind or spirit. It may come to us through any one or more of the senses.... beautiful highways then, are those which uplift us in whatever way we experience them!" The definition indicates not only the presence of visual order is necessary but the viewpoint of the beholder must also be defined. Aesthetics is a function of age, sex, culture, occupation, etc. of the individual. For example, the same outer reality can cause different impressions to the same viewer at different times. In discussing highways, the viewpoint external to the road user is important in urban and other built up areas. In rural areas, the point of view of the driver and his passengers is more important. For the driver or the passenger the physical reality is also warped by other environmental factors such as weather, traffic density, and speed.

In the past, roads were "hacked" through the wilderness and did fit the topography. Although these roads may be visually pleasing, the driving task may be difficult because of poor geometrics. Todays highways, although incorporating satisfactory surface design and safety properties may not provide the basis for an enjoyable trip for many reasons. The driver may be confused by small design "errors," may be irritated by traffic congestion, may be upset by a previous experience (before or during the trip) or the highway itself may destroy rather than show-off the landscape. It is generally

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accepted that our modern rural highways incorporating long tangents and shallow curves, although safe in the Newtonian sense lead to driver boredom and hence to unsafe conditions.

The objective of this paper is an attempt to establish a framework of investigations into design criteria which will not only include the traditional Newtonian criteria but measurable aesthetic considerations from the driver's point of view. The investigation is restricted to the internal roadway effects on the driver on rural roads. It is the authors' belief that in defining the total problem this is the logical place to start.

HIGHWAY DESIGN

The objectives in highway design may be stated as follows: (a) maximize level of traffic service, (b) maximize safety, (c) maximize beauty, and (d) minimize costs. These objectives are not compatible and certain trade-offs must be made. Our problem is one of measurement; that is, there is no rational method or value function which relates all of these objectives so that an "equation" can be maximized or minimized.

Once a need for a facility has been established, a location is selected. Normally, this selection is the result of economic, service and political dictates. Geometric standards are then applied to carry the anticipated volumes safely. These standards have generally resulted from vehicular characteristics for horizontal alignment and some human characteristics as well as vehicular characteristics for vertical alignment.

Generally then, objectives (a) and (d) are considered directly and trade-offs made. The safety objective is usually considered as part of (a). Aesthetic considerations may be taken into account but these considerations normally do not involve road location or geometry but may involve structures and roadside development.

AESTHETICS IN DESIGN

Aesthetics or beauty in highways has been considered by designers and other interested people over the years. This is evident from the literature. Lately there has been a resurgence of interest in the total field of aesthetic design. This is probably due, in a large degree, to our more affluent society.

Generally, in highway aesthetics, the literature has dealt with how the road looks from the external and internal viewpoint. Subjective criteria or rules can be derived from this literature to aid the designer in making aesthetic judgments. Such criteria have been adopted and are being used by some authorities today (2).

These rules attempt to incorporate the third objective (maximize beauty) subject to the objective of minimized total cost. Other tools involve the use of models to create the environment before final designs are made. These may be the inverted periscope, motion pictures, photographs, perspective drawings, etc. Even though these aids exist and are valuable, the designer must keep in mind that he is not driving the road and thus cannot experience the impact of the total facility on the driver.

These techniques appear to be solutions to particular problems; however, they do not objectively establish any measurable criteria which reflect the driving experience.

It is normally accepted that curvilinear alignment is more pleasing than long tangent short curve alignment. However, it is not known objectively what range of degree of curvature would be optimal. A driver may find a curvilinear (or spiral) alignment more pleasing than a straight section at night, not because he can see the total curve set in the environment, but because of reduced headlight glare. This example has been cited to show the influence of environmental factors, other than those stated in the general rules on aesthetics.

The problem of establishing measurable criteria has unintentionally been overlooked or skirted in the quest to develop solutions. It is not by any means an easy problem to understand and because of its complexity may never be completely quantitatively defined. It not only deals with how a facility or its environment looks, but how the driver (and his passengers) react to all inputs that highway designers have created. Except for a few isolated studies (3, 4) little work has been done to determine the inputs to which the driver reacts. An understanding of the driving process is essential if one hopes to define the problem.

THE DRIVING PROCESS AS A SYSTEM

The driver can be thought of as a system. This system receives inputs from the environment, places values on these inputs and reacts or produces outputs based on perceived values related to some objective function.

Inputs

The inputs themselves can be classed into two types: real time and lag time. The real time inputs are perceived in the environment when they are required. Road alignment, centerline markings and traffic signs would constitute some of the visual real time inputs. The lag time inputs are the result of previous experience which are held in the conscious mind. Particular knowledge about the vehicle's condition could constitute a lag time input. The real time inputs are sampled and in the light of lag time inputs a value judgment as to course of action is made. For this discussion, the lag time inputs will be assumed to have little or no effect on the driving behavior. Real time inputs will be referred to as inputs.

Signals from all elements in the environment exist simultaneously. Psychologists suggest that, although all the signals in the field of perception are received, there are only a few of these signals that one is aware of at any one time. The elements exhibiting the strongest signals are those to which one reacts. Reaction can result from inputs received by one sense to that received by another instantaneously. Consider a driver whose automobile suddenly develops engine trouble that he perceives through the sense of sound. The driver who had been performing his task with inputs of visual reception has now responded to an audio reception.

The major inputs can be classed under the four senses associated with driving (Table 1). Each input can be thought of as exhibiting qualities from pleasing to irritating. The inputs with the strongest signals will have the greatest weight.

Outputs

The outputs take the form of the driving task. The driver accelerates, decelerates, turns the steering wheel, changes lanes, etc. Methods have been devised to measure these outputs (5, 6).

Driver Evaluation

Each driver will evaluate the inputs differently; thus, different drivers will enjoy a trip for different reasons. To some users it may be enjoyable no matter what the road looks like as long as it is drivable. This class of users obtain their pleasure from the mere challenge of driving. Another class of users may find their exhilaration by placing themselves in a certain element of risk (7). Most, however, enjoy a trip if they feel secure on the road, and feeling secure, are able to divert their attention momentarily to other elements in the environment besides the roadway. It is this majority class of road users that enjoy aesthetics and must be considered if beauty is to be incorporated.

As the inputs are presented, the driver evaluates them. This evaluation develops a state of

TABLE 1

INPUTS ASSOCIATED WITH THE DRIVING TASK

Input Perception	Directly Associated With Driving		Indirectly Associated With Driving
	Roadway Elements	Non-Roadway Elements	Non-Roadway Elements
Visual	Total roadway Centerline Shoulder markings Shoulders Opposing lane	Traffic signals Traffic signs Information signs Parked vehicles Abutments	Natural environment Man-made environment
Sound	Noise of tires on pavement	Engine noise Traffic noise	
Feel	Road roughness		
Smell		Engine of associated trouble	Natural gas Industrial odors

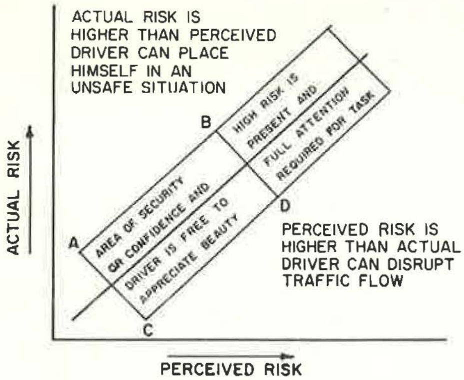

Figure 1. The concept of the value judgment.

mind under which the driving task is carried out. The driver perceives a level of risk which he compensates for in his task. If he perceives a great risk his attention will be occupied with the driving task, and even though certain elements in the environment might be considered aesthetic he will not be able to enjoy them. Partial attention to these elements may place the driver in an unsafe situation. (An actual situation and not a perceived one.) On the other hand, if a driver perceives a safe environment (and the design and prevailing conditions are such that it is safe) he will be free to enjoy the beauty of the trip.

Two other classes of roadways can be thought of in terms of a perceived risk function. On certain roads the driver will perceive a risk greater than there actually exists. The tourist driving a mountain road for the first time may feel a large risk and overcompensate for it. His perception and resultant action can cause interference with traffic flow and irritate other drivers. On the other hand, some of the prairie highways are examples, the driver can associate less risk with a certain road than does exist. He may then become bored, or uninterested in his task. As a result, the driver places himself in a true risk situation that he does not perceive and thus does not compensate.

By understanding the situations in which the driver is able to enjoy aesthetic values, when and why he feels safe on a highway and relating this to geometric elements, the basis of the complete highway can evolve. The basic element is the roadway and it should instill in the driver a perception of a level of risk that is consistent with the geometric design. The level of risk perceived by the driver should be reflected by his outputs. Once the limits of the level of risk have been established and related to geometric elements, then one can logically design those elements considered aesthetic. One does not ask the driver to isolate components of highway design as to their relative aesthetic merit. Presumably, the driver can appreciate beauty (or forms of it that appeal to him). However, one should be able to determine those elements that establish the acceptable limits of "level of risk" through measuring driver output.

FRAMEWORK OF EXPERIMENTAL ANALYSIS

The Value Judgment

The level of risk should be such that the driver perceives the actual risk and still feels free to appreciate aesthetic elements in the environment. Figure 1 is a schematic of the value judgment. The range that must be determined is shown by area ABCD.

Value Judgment's Relation to Geometrics

The concept of this value function is relatively simple. The human system perceives certain inputs. Each input will range in tolerance from pleasing to irritating. The inputs exhibiting the largest signals will have the greatest weight in determining the driver's perceived risk. If the geometric inputs are greatest and these are pleasing, the driver may associate little risk with his task. On the other hand, if the road roughness is irritating, this may exhibit a strong signal and the driver may decelerate or otherwise compensate. If one were to consider the basic roadway elements that could be quantitatively measured, the following components could be examined:

1. Horizontal alignment: (a) degree of curvature, (b) length of curve, (c) length of spiral, (d) degree of superelevation, (e) length of superelevation, (f) length of tangent, and (g) sight distance.
2. Vertical alignment: (a) radius of vertical curvature, (b) length of vertical curvature, and (c) sight distance.

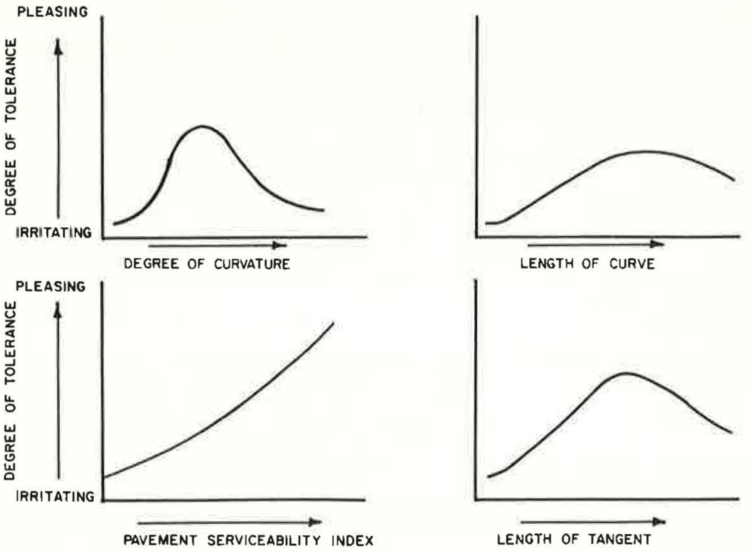

Figure 2. Schematic representation between levels of tolerance and geometric design standards.

3. Other roadway characteristics: (a) shoulder type, (b) shoulder condition, (c) shoulder width, (d) lane width, and (e) lateral clearance.
4. Interactions of all geometric elements.
5. Road surface characteristics, such as pavement roughness measures.

Relationships would be sought to establish levels of tolerance between the driver and the geometric standards. The relationships may be of the form suggested in Figure 2.

The Experimental Method

It must be determined which relationships or combination of relationships have the largest effect on the driver while he is performing his task. If the experiment were carried out in the field a large number of pavement sections would be required for examination. The degree of curvature, for example, could be varied in different sections showing similar properties.

An eye camera recording the inputs and simultaneous measurements of acceleration noise and steering wheel movements could be made. A galvanic skin response apparatus (8) could measure the level of risk perceived by the driver. By varying each of the selected elements, the data produced could be subjected to analysis and the significant ranges of each design element deduced. Most importantly, the eye camera would indicate under what geometric conditions the driver was able to perceive other elements in the environment.

Within recent months, the use of computer graphics (9) has become an inherent part of some design processes. It appears possible to coordinate this method with the use of driving simulators. The simulator environment is easily controlled and has been found to have an acceptable relationship with the actual driving task.

Application of Results

It is hoped that the results of such an experiment would allow the calculation of geometric design standards related to an acceptable level of risk.

Consider the present state of knowledge. The visual field changes with speed. As speed increases objects alongside or in front of the car become blurred and the driver extends his field of vision to a static zone further down the road. This point of concentration increases from 600 ft at 25 mph to 1800 ft at 60 mph. Simultaneously, the cone of vision decreases from 180 to 40 deg. To allow the road to be within the driver's

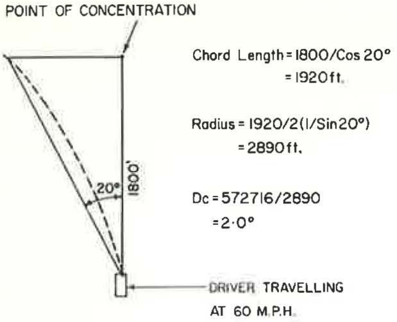

Figure 3. Calculation of Dc and R from driver limitations.

TABLE 2

COMPARISON OF MAXIMUM Dc AND MINIMUM R AT VARIOUS DESIGN SPEEDS

	Driver Limitation Standards		Vehicle Limitation Standards	
Design Speed	Dc	R	Dc	R
40	4.9	1170	11.3	508
50	3.3	1700	6.9	833
60	2.0	2890	4.5	1263

field of vision at all times, maximum degrees of curvature and minimum radii can be calculated for various design speeds. The method of calculation is summarized in Figure 3. Similar calculations were made for other design speeds and these were compared with the AASHO (10) minimum standards. The comparisons are given in Table 2. The AASHO standards are based on vehicular performance with maximum superelevation of 0.06 and a coefficient of friction from 0.11 to 0.15.

FOR THE PRESENT

Until such research is performed, considerations in design can be given. By assuring that the driver is always aware of the road alignment the first step in assuring driver confidence has been established. Geissler (11) has summarized the principles and tools that can be used in providing optical guidance. If optical guidance is properly provided, the driver can be free to enjoy the beauty present in the environment.

SUMMARY

1. The driving process has been presented as a system exhibiting inputs, outputs and a value judgment.
2. These value judgments may be related to the geometric design standards of rural highways.
3. The inputs perceived by the driver were hypothesized to exhibit levels of tolerance from pleasing to irritating and the form of possible relationships was established.
4. An experimental method was suggested to measure geometric standards and driver reaction. With the performance of such work acceptable limits of level of risk related to geometric elements can be deduced.
5. It is our belief that until the geometric standards and level of service are provided so that the driver is free to enjoy the aesthetic qualities of the environment there is little point in providing, at additional cost, so-called aesthetic qualities in design. When the road itself will allow the user to enjoy the environment there is logic in cleaning up the billboards. Perhaps then we will understand what the furor is all about.

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Discussion

E. H. GEISSLER and A. AZIZ, Department of Highways, Ontario, Canada—The authors suggest an experimental method to establish design criteria for highway aesthetics by measuring geometric elements and drivers' reaction. This is to be accomplished by setting acceptable limits of risk related to the geometric elements. This approach provides a welcome step toward the solution of a rather complex problem, but there are several other considerations which may be taken into account, some of which are mentioned in the following.

Two-Fold Viewpoint

The concept of providing determinate criteria for highway aesthetics may well include the understated points: (a) the view the highway offers to the onlookers across the environment the highway passes through, and (b) the view of the driver across the environment as he travels along the roadway.

Aesthetics as a Totality

The authors have done well to deal with the internal aesthetics of a highway, but we feel that to consider the external or the environmental elements at the same time will perhaps produce favorable results. It will from the very start give us an easier path for the integration of the internal and the external variables, namely geometrics and environment, under various topographic conditions.

Enhancement of Responsibility

As related to the considerations described above, "enhancement of responsibility" sounds a rather strange idea. We, as highway engineers and designers, have now come to realize that pure design and function by themselves very often jar our emotional and psychological sensibilities, and that there is something more required to make it satisfying for us to live with the things and environment around us, and this something we call aesthetics.

Traditionally, we have felt somewhat strange to the idea of aesthetics and form as it can be incorporated in finished highway work, and that architectural treatment is beyond us.

We feel that if we break out of this restraint, we would have a clearer perception and recognition of what beauty of function, design and form we wish to obtain.

P. M. PEARSON and W. A. McLAUGHLIN, Closure—The paper was confined to the relationships between the driver and the structural and geometric elements of the roadway. We felt that until there is a feeling of security on the part of the driver, there was no point in beautifying the roadway for his benefit. This was a stated constraint in that we did not consider the nondriving population.