First Draft

A Proposal for Extending the Visibility Design Concept

Ian Lewin Ph.D., FIES L.C.
Lighting Sciences Inc.

The Present State of Visibility Design

After long and painful labor and birth, the STV system is available for roadway lighting design. Its use is not widespread, but it serves as a tool for research and the development of further understanding of design issues that influence visibility, and presumably, safety. The relationship between STV and safety, however, is unproven. Efforts to correlate accidents and STV have been unsuccessful.

Our challenge now is to consider how the visibility approach might be modified and improved. The method needs to be extended to be more fully representative of the driver's visual tasks, with the aim of providing a system that will give a robust correlation with accident data.

This is not a criticism of past work. It has always been recognized that STV is just a beginning, and that refinements would be made as experience with the system is gained.

A problem is that accidents may not primarily be caused by hazards that are well represented by 18 cm (7 ins.) square targets. Small targets are not unimportant, but other forms of visual tasks are likely to be involved when a serious accident occurs. Examples of such tasks are pedestrians, large animals, and other vehicles.

Another point must be considered. We should concentrate our efforts on those visual tasks that are known to be strongly related to accidents and where improved lighting is likely to have a strong impact on visibility and safety. Research is needed to improve our understanding of such tasks, but already information is available.

Sullivan and Flanagan of the University of Michigan Transportation Research Institute have investigated the frequency of certain types of accidents in relation to lighting conditions. While their interest was chiefly in identyfying the safety benefits of improved vehicle headlighting, they draw a highly significant general conclusion: "This research provides evidence of the strong effect of light on fatal pedestrian crashes." Another form of accident, single vehicle run-off-road, "do not appear to be as sensitive to light level as pedestrian crashes." It seems reasonable to conclude that if pedestrian accidents are the type of accidents most likely to be reduced by improved lighting then the same would be true of vehicle/animal accidents, and accidents involving other vehicles in traffic conflict areas.

A critical issue in maximizing the safety benefits of roadway lighting is being overlooked: The driver must detect hazards that first appear in the peripheral field, in order to increase the time available to recognize and avoid the hazard. On this point Olson, in his book "Forensic Aspects of Driver Perception and Response" has written: "The limited size of the foveal area, combined with the relatively poor visual performance characteristic of the peripheral area, must be kept in mind when assessing visibility ..." "Because this area is so small relative to the entire visual field, detection typically occurs in the periphery. The eyes may then be shifted to bring the detected object into sharp focus in the fovea as part of the identification process. However, in order to be detected, an object in the periphery must have greater attention-gaining characteristics (conspicuity) than if its image had fallen on the fovea."

The present STV methodology therefore should be extended to cover what research has indicated is a highly significant area related to lighting and safety.

Foveal and Peripheral Visibility

The author proposes that a new metric be established that considers both foveal and peripheral visibility, and addresses large visual tasks.

The basic methodology proposed for this new system is:

- Compute STV per present method.
- Compute "Peripheral Target Visibility", PTV, by new methodology.
- Develop a new visibility measure from the weighted results of STV and PTV. Weighting will be determined by the relative importance of foveal and peripheral tasks in influencing safety, as discussed later. This new metric may be termed "Composite Visibility", CV.

Peripheral Target Visibility

The new system involves establishing standard conditions to represent realistic peripheral targets, as follows:

Target:	A large object approximating a pedestrian, perhaps with a diffuse reflectance of 20%.
Locations:	Longitudinal locations identical to STV targets. Targets displace 1m right of the rightmost lane line, and 1m left of the leftmost lane line. Figure 1.
Background:	Until further information is available from a new project that is now about to be commenced, assume a uniform diffuse reflectance of 15%.

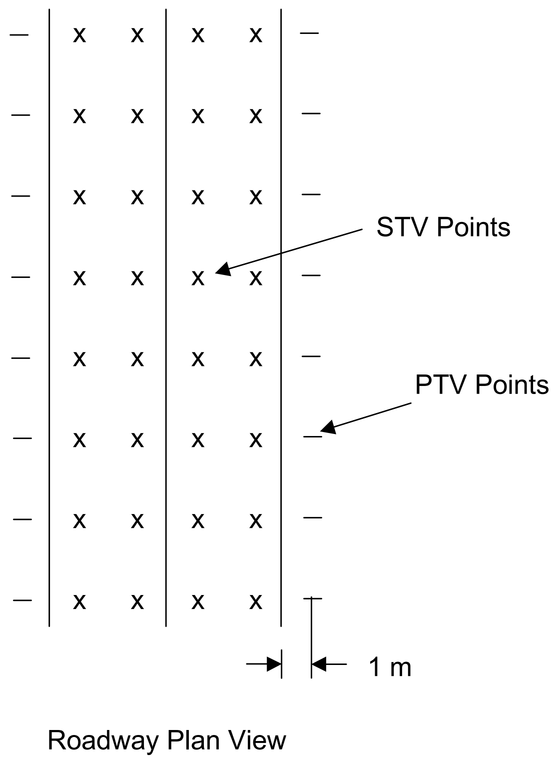

Figure 1

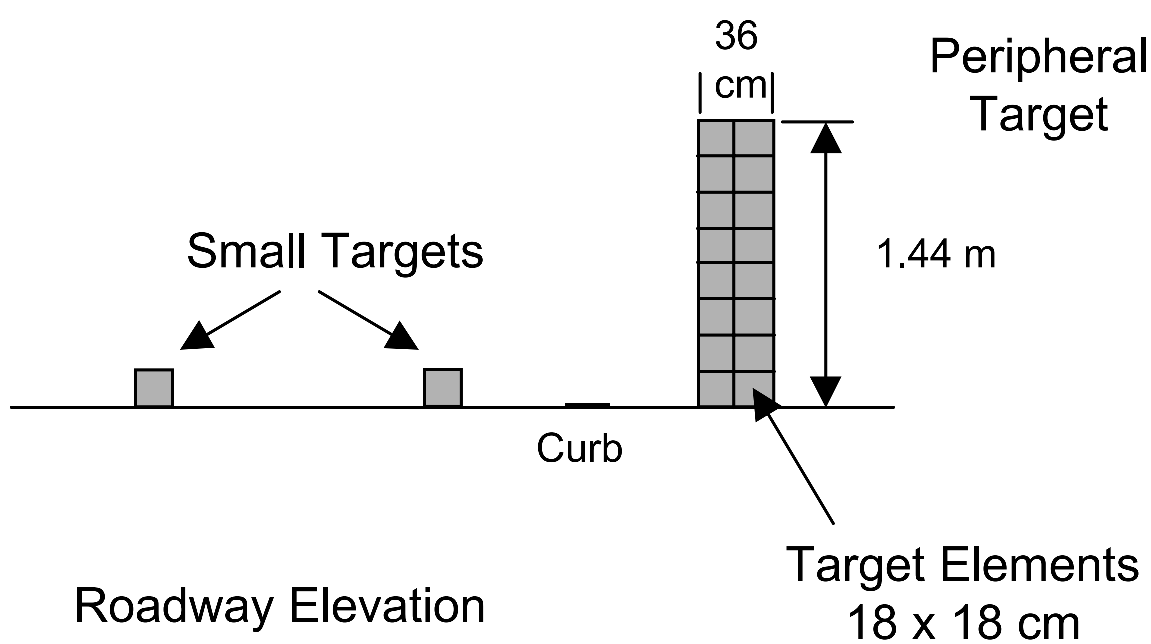

Figure 2

The large targets, figure 1, are proposed to be 36 cm wide and 1.44 m high. For the purposes of calculations these will be divided into 16 elements, each measuring 18 x 18 cm.

Each target element will be computed individually for its luminance and background luminance. Target luminance will be computed at the center point, or perhaps the edge, of the element. Background luminance can be at the target edge(s) that contrasts with the background.

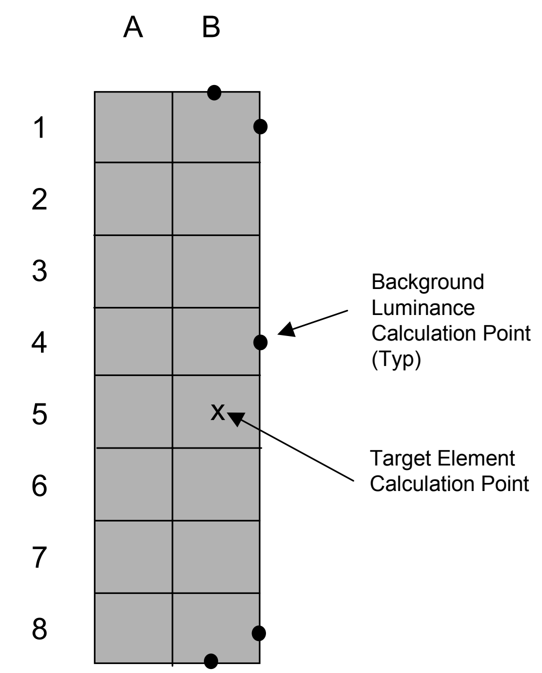

Figure 3

For convenience, each target element can be labeled in spreadsheet fashion, A1 through B8 figure 3. Figure 3 illustrates the computation points for example sub-targets B1, B4 and B8.

Visibility levels can be computed for each target element individually. The maximum absolute VL from the VL's of all target elements is proposed to be used as the VL of the large target. (This assumes a large object's visibility is determined by the visibility of its most visible component).

Combining STV and Peripheral Target Visibility, PTV

The PTV can be developed from the Visibility Levels of the individual peripheral targets using methodology similar to that now used for STV. Composite Visibility, CV, which combines STV and PTV, requires the introduction of weighting factors. Such factors are proposed to be based on the relative importance of foveal and peripheral tasks as related to safety. While this point requires much discussion, it is proposed that a scale of 1 to 10 be used, based on the estimated significance of a particular task type, foveal or peripheral, to safety.

Safety Rating	Weighting
Extremely high	10
Very high	9
	8
High	7
	6
Moderate	5
	4
Low	3
	2
Very low	1
Not significant	0

As an example, consider a limited access highway. Foveal tasks may be rated high in significance, while peripheral tasks may be given a low rating. In computing CV, therefore, foveal tasks may be given a weighting of 7 versus a weighting of 3 for peripheral tasks. Composite Visibility would be:

$$CV = \frac{7 \times STV + 3 \times PTV}{10}$$

Another example is a major roadway with high pedestrian conflict. Foveal tasks are important but may rate as moderate, giving a weighting factor of 5. Peripheral tasks may be considered highly significant, with a rating of 9. Then

$$CV = \frac{5 \times STV + 9 \times PTV}{14}$$

The IESNA Roadway Lighting Committee could develop consensus ratings for foveal and peripheral tasks for each of the 14 roadway categories provided in RP8. Designers could be free to change these ratings to suite particular design circumstances when they believe such changes are justified. The foveal and peripheral ratings would be two input values to future computer software, which then would automatically apply the weighting when computing CV.

Thus CV becomes a rating system based on visibility, but taking into account the safety implications of the different tasks.

Spectral Effects

The proposed procedure provides an opportunity to incorporate known spectral effects into the design. Research has shown:

- Spectral effects can vary from non-existent to major, depending on the type and location of the visual task.
- Foveal tasks involving small targets appear adequately addressed by use of the $V(\lambda)$ curve.
- Peripheral task visibility is strongly affected by rod response, $V'(\lambda)$. Mesopic functions have been developed, which more properly express visibility of such tasks, rather than $V(\lambda)$. Berman, and the research group at the Lighting Research Center, have proposed techniques for relatively simple calculation and application of mesopic effects.

In computing the task and background luminance for STV, it can be assumed that the tasks will be viewed foveally. Conventional photopic quantities will be used. When computing peripheral task visibility, the mesopic function relevant to that task should be used.

If it is assumed that the retina undergoes localized adaptation, each peripheral luminance calculation should use the mesopic function relevant to that luminance level. The visual response function used will therefore vary point-to-point. This is recognized as being a simplification, but is probably the best assumption given our current knowledge. The overall effect of any error introduced is likely to be small as many computation points are used in developing the CV value.

Using Berman's procedure, for example, a correction factor is developed based on the S/P ratio of the light source, which then is applied to the photopic luminance value to provide the mesopic luminance value. Using the LRC method, a mesopic response function is employed. The procedure becomes an automatic correction to the photopic quantity when suitable software is available.

Note that this procedure addresses peripheral target *detection*. It has been argued that peripheral target *recognition*, which follows detection, is important and that foveal vision will be used for recognition when the driver directs his line of sight to the task. Research indicates, however, that for large objects such as pedestrians, when viewed under low light levels, recognition may be achieved not by the fovea but by the rod system. On this point, Dr. Alan Lewis has conducted research where observers were required to detect a pedestrian at the curb and then recognize which way the pedestrian was facing. Reaction times for different light sources indicated strong spectral effects of a form that is most likely attributable to the rods. Regarding this, Dr. Lewis has written "Fourier analysis of the target indicates that most of the power is in the mid to low spatial frequency range, making foveal detection unnecessary. It is very likely that the task could be (and was) performed with extra-foveal viewing."

Mesopic response functions therefore appear to be appropriate for use for peripheral tasks. They consider both the rod and cone system response.

Summary

It is proposed that the Roadway Lighting Committee of IESNA consider extending the visibility concept to incorporate tasks representative of roadway hazards that lie in the peripheral field. While the visibility of such tasks could be developed as a separate visibility measure, the outlined procedure allows such task visibility to be incorporated into an overall measure of visibility for both foveal and peripheral tasks. This Composite Visibility further allows the relative importance of foveal and peripheral tasks in influencing safety to be addressed. Lastly, spectral effects can be introduced into the procedure to account for mesopic vision, presently a major gap in our design procedures.

This is an initial proposal only. Much evaluation and discussion is required to provide a consensus for handling the many details involved. Given the potential safety benefits, this is likely to be a worthwhile effort.