User Manual for the

Target Visibility Predictor (Tarvip)

Computer Model

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INTRODUCTION

The TarVIP model is a deterministic model for nighttime retroreflective and diffuse reflective object visibility evaluation. The TarVIP model is a freeware, and can be obtained at no cost from the Operator Performance Laboratory (OPL) of the University of Iowa. To obtain the latest version of Tarvip, please visit Tarvip website at: [http://opl.ecn.uiowa.edu/Tarvip](http://opl.ecn.uiowa.edu/Tarvip). For a serial number for Tarvip installation, please contact the Operator Performance Laboratory.

TarVIP features numerous modules that have been incorporated into the model during its last five years of development. These modules have been developed under grants and contracts from Federal agencies as well as private industry. Further modules are being developed as the need for comprehensive and deterministic models arise for transportation related human factors applications. TarVIP has proven to be a valuable tool in evaluating retroreflective material performance, and is currently being used as a major part of this project.

Tarvip is not a regression model. In some of its modules, it employs regression-based equations (such as the effect of age on contrast sensitivity) built upon years of empirical data. However, for the most part, it is a deterministic model that concurs with the dynamics of light, retroreflection, and atmospheric conditions in precise terms under nighttime driving conditions. The physical component of Tarvip that determines the actual contrasts of roadway objects is fairly accurate. The human factors component of the Tarvip model is based on empirical threshold contrast data. This component yields an average figure for the contrast detection capabilities of human observers under diverse lighting and contrast conditions. The underlying contrast threshold data for pavement marking and diffusing target modules come from Blackwell [1] [2]. For traffic sign legibility, data come from extensive legibility contrast threshold research conducted by Schnell [3]. Although Tarvip gives an unbiased point estimate, the reality in visibility (legibility) is a wide distribution of responses. Therefore, the estimate given by Tarvip represents an average figure.

Right from the very inception, the TarVIP model was designed in a modular fashion to allow plug-in type module development and expansion capabilities. The model uses empirical data obtained in laboratory and field studies, and its functionality encompasses not only the physical nature of light, but also the visual capabilities and perceptive limitations of driver population. This way, TarVIP exercises a visibility analysis approach by comparing the photometric signal perceived by the driver with the capabilities of the driver to assess visibility (and legibility in case of traffic signs) of a specific roadway object (for SST, traffic signs).

The Tarvip model is incorporated into SST in a way that each scenario in SST can be easily transferred into Tarvip from within SST. The resulting sign scenario can be run in Tarvip, which will yield the legibility distance for that scenario as given in SST. Yet, the advantage of transferring a scenario into Tarvip is the greater flexibility in assigning values for numerous variables, and as such, the insight into the workings and outcome of a scenario in detail. Each of the variables defined in Tarvip can be altered to conduct a
sensitivity analysis for a specific scenario by manipulating the independent variables, one at a time.

The Tarvip model also features a “batch mode”, in which up to 256 scenarios can be run in series without user intervention. The scenario content comes with a set of files located inside the “SBF Files” (Scenario Batch File) folder at the installation folder of SST. The SBF files are tab-delimited text files, which can be opened with a spreadsheet application such as Microsoft Excel (or any text editor). The user is discouraged to alter these files and the folder structure, because the tool uses the content of these files to identify a particular scenario number, and extract the information from corresponding SBF file. However, the user can copy a specific batch file to another location, and run Tarvip model to process that batch file. To analyze the output of the batch file, the user can also use the Tarvip model. A step-by-step explanation of how to process and analyze a batch file is given in further sections of this appendix.

The following sections of this manual explain the steps in transferring a scenario into the Tarvip model and how to modify and run a scenario in Tarvip, and how to interpret the results.
SCENARIO BATCH FILES (SBF FILES)

Scenario batch files provide multiple scenario content for Tarvip, when the Tarvip model is required to evaluate multiple scenarios at once. This way, a number of scenarios can be evaluated without user intervention. However, the user does not need to use scenario batch files to use Tarvip. The default Tarvip operation mode is the single scenario mode. Nevertheless, all scenarios used in the generation of the tool database are packaged together with the tool inside the “SBF Files” folder. The tool accesses the SBF files to generate the scenario input files (.vip) for the Tarvip model. This feature is described in “Transferring a Scenario from SST to Tarvip” section of this manual.

SBF files are text-delimited files containing all of the scenarios evaluated in the development of the tool database. Batch files were instrumental in evaluating up to 256 scenarios at a time in Tarvip. The default operation mode of Tarvip is a single-scenario mode, yet it has the capability of processing multiple scenarios if organized in a certain format referred to as the batch files.

A batch file has the extension .sbf, thereby referred to as the SBF files. All scenarios in the SST database are included in the SBF files located inside the “SBF Files” folder in the SST root folder. The folder structure is designed in a tree structure with the folder names corresponding to the three sign types: Guide Sign, Warning Sign, and Regulatory Sign. Furthermore, each of the three folders contains six subfolders corresponding to the six evaluated material types, each contain the corresponding SBF files. For Guide Signs, the subfolder tree goes one level further with three sub-subfolders: Destination and Distance Signs (DDS), freeway guide sign, and street name sign sub-subfolders. This folder structure is illustrated in Figure 1.
Figure 1. SBF file folder structure.

The user is highly discouraged from altering any part of SBF file and folder name and/or structure. The tool is configured to determine the path of, and have access to, any SBF file with the virtue of the unique folder and file name settings. In case the folder and file name and structure is altered, the tool will most likely not be able to access any files, hence incapable of producing Tarvip scenario files. Nevertheless, the user may wish to change one variable in all the scenarios at once in a specific SBF file and re-evaluate them in Tarvip in batch mode. To do so, the user is encouraged to copy the corresponding SBF file into another folder, rename it, and make changes to that file prior to processing the SBF file. The user is also encouraged to read and understand the contents of a batch file explained below prior to changing any component thereof.

How to Open an SBF Batch File

A batch file can be opened with any text editor/viewer. It contains tab-delimited text, which is easier to view and process from a spreadsheet program such as Microsoft Excel. To open a batch file from Excel, start Microsoft Excel, and go to “Open” menu option in the “File” menu. From the “Files of Type” pull-down menu at the bottom of the “Open” dialog window, choose “All Files (*.*)” to view files of all types as shown in Figure 2. Alternatively, the user can type in “*.sbf” in the “File Name” edit box and hit enter.
(carriage return) key to view only the SBF files. Once an SBF file is selected, the user can open an SBF file by double-clicking on the file name or by clicking on the “Open” button. Although the “Open” dialog window shown in Figure 2 may slightly differ from one version of Microsoft Excel from another, the steps in opening an SBF file is the same in all versions of Excel in principle.

![Image of Excel opening a SBF file](image)

**Figure 2.** Opening a Tarvip input batch file with Microsoft® Excel.

### Contents of a Batch File

Batch files are tab-delimited ASCII files. The first string (the first row that ends with a carriage return) in the file is the version of the batch file. The second row contains column headers for the rest of the file. The first two column headers are always “description” and “variable_name”, whereas the rest of the second row contains the names of the scenarios in the batch file. Those names become the filenames for the output files when the batch file is processed with Tarvip. Therefore, each scenario name should be different in a batch file. Tarvip takes each of the column headers after the starting from the third column, and appends a “.xls” extension to designate output file names that contain the results of each scenario in the batch file. A batch file does not need to contain
all variables that Tarvip requires be defined, however, if a variable is not specified in a batch file, Tarvip uses its default value for that variable. The first two columns should not be changed in a batch file. Variable names are intrinsic to Tarvip, and a change in a variable name may cause Tarvip to use its own default values rather than those in a batch file. Notice that not all variables are relevant to a traffic sign scenario but to pavement marking or glare scenarios, yet caution should be exercised changing any value that pertains to a variable even though it may seem irrelevant to a traffic sign scenario. Figure 3 shows a screenshot of the first few columns and rows of an SBF file.

Figure 3. A screenshot of an SBF (Tarvip Scenario Batch) file.

The first column of a batch file contains explanations of the variables on each row starting from row 3 as shown in Figure 3. For instance, on row 3 in Figure 3 the variable description is “left lane width in meters”. On the same row, the second column is the variable name in Tarvip associated with the “left lane width in meters”. This variable contains the distance from the road centerline to the left edge line in each scenario as given in each column. Starting from column 3, each column consists of the values
associated with each variable of a particular scenario. For the scenario given in column 3 in Figure 3, the name of the scenario is “DDS-EG-001” (which refers to destination and distance scenario no. 1 for engineer grade material). The right edge line in this scenario is 7.3152m (24ft) right of the centerline. The easiest way of transferring a particular scenario content to Tarvip is by using the tool as described in “Transferring a Scenario from SST to Tarvip” section starting on page 14.

How to Process a Batch File in Tarvip

From the “File” menu in Tarvip, choose “Open Structured Batch File” option as shown in Figure 4. Choosing this option will initiate the Tarvip Batch Process window as shown in Figure 5. On the Tarvip batch process window, click on “Open Batch File” button, and choose a batch file from the familiar “Open File” dialog window as shown in Figure 6. The file-opening process may take a while depending on the size of the batch file and the configuration of the computer. Once a batch file (SBF file) is opened, Tarvip will populate the listbox in the batch file process window with the scenario names as outlined in the batch file. An example batch file process window with a batch file opened is shown in Figure 7. The number of scenarios in the batch file will also appear right below the “Open Batch File…” button.

Each item in the listbox on the right half of the batch process window corresponds to a scenario in the batch file. To see the contents of a particular scenario in the listbox, the user can click on the scenario name. The scenario input information for the selected scenario will appear in a “User Input Information” window as shown in Figure 8.
Figure 5. Tarvip batch file process window.

Figure 6. “Open Structured Batch File” dialog window in Tarvip.
Figure 7. Batch process window after opening a batch file.

Figure 8. Scenario input information display.
Before processing the scenarios, the user has the flexibility to remove any unwanted scenarios from the list by selecting the scenario to be removed from the listbox, and then by clicking on the “Delete Selected Scenario” button. Removing a scenario this way does not delete that particular scenario in the original SBF file, but simply removes that scenario from the list of scenarios to be evaluated.

In order to process the scenarios in the listbox, click on the “Run Batch File” window at the lower-left of the batch process window. Note that evaluating a batch file may take hours depending on the number of scenarios in the batch file and the processing capabilities of the computer.

Tarvip processes each scenario in the order given in the listbox, and after finishing each scenario, it produces a tab-delimited ASCII file with a name “ScenarioName.xls” where ScenarioName is the name as given in the listbox for each file. Thus, it is important that each scenario in the batch file have a different name. In case a name is common to more than one scenario in a batch file, the output file will be automatically overwritten by each time a common-name scenario is processed. For the example shown in Figure 7 on page 9, the first output file will have “DDS-EG-001.xls” as the filename. All output files are automatically generated in the folder the original SBF file is located.

Each output file can be opened with any text editor. A spreadsheet application such as Microsoft® Excel may be suitable for most users for viewing the output. Tarvip also features an output file plotter functionality, which can be used to view graphical representations of each output file. To use the output plotting functionality, choose “Output Plotter…” option from the Tarvip “File” menu. This will initialize the “Tarvip Output File Process” window as shown in Figure 9.

![TarVIP Output File Process](image)

**Figure 9.** Tarvip output file plotter main window.

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The “Browse…” button on the upper-right corner of the output plotter window opens an “Open File” dialog window for locating the output file. Once an output file is selected (in this case the DDS-EG-001.xls), the listbox in the body of the window is populated by the column headers in the output file as shown in Figure 10. The user can plot as many different variables as the user selects, all against the distance traveled in the scenario. All scenarios in the SST have the traffic signs located at 300m (984ft) ahead of the vehicle starting point. Therefore, no distance entry is required for the edit box that appears above the listbox shown in Figure 10. To select different output items hold down the “CTRL” key while clicking on the items. Although any of the listed items can be selected and plotted against the traveled distance, usually the contrast plots are the most visited ones. Actual vs. threshold contrast graphs gives the user the visibility distance. When the actual contrast exceeds the threshold contrast the first time while approaching the traffic sign, the sign becomes legible at that distance. In all tool scenarios, the sign is located at 300m (984ft).

![Tarvip output file plotter window after opening a Tarvip output file.](image)

Figure 10. Tarvip output file plotter window after opening a Tarvip output file.

When the total actual contrast between the sign legend sheeting and sign background sheeting is plotted against the threshold contrasts, the intercept of the two plots reveals the legibility distance as shown in Figure 11. Note that the sign is at 300m (984ft) and the vehicle starts traveling from 0m and ends its course at 300m (984ft). The default distance axis behavior can be changed by choosing “Distance from car origin to POI” radio button on the upper-left corner of the plot window. The Y-axis scale can also be toggled between linear and logarithmic scales by using the radio button under the Y-Axis heading on the left side of the plot window. The plots also feature a zoom capability, where clicking on the any point on the plot will zoom in by centering that...
point. A region can also be selected and zoomed-in by clicking-and dragging the mouse pointer on the plot to specify a rectangular region.

The visibility distance information can also be obtained by plotting the required luminances (the bottom three items on the list) on the sign legend and/or background and the actual total observed luminances on the sign legend and/or background. For the same example given above, Figure 12 illustrates the plot for the actual luminance on the sign legend vs. required legend luminance. Again, the plots intercept at the same point in both Figure 11 and Figure 12, which refers to the legibility distance. Yet, note that the legibility distance is 300m minus the intercept: 300m-258m = 42m (138ft). All plots feature the zoom-in capability in Tarvip.

The user is encouraged to plot the output variables that have the same unit against each other. Otherwise, the Y axis will correspond to entities with different units rather than representing a fixed unit. In Figure 11, the Y axis does not have a unit (for contrast), but in Figure 12, the unit is cd/m² (for luminance).

![Plot of actual contrast vs. threshold contrast](image)

**Figure 11.** Total actual contrast vs. threshold contrast between the sign legend and background for the scenario entitled “DDS-EG-001”.
Figure 12. Total sign legend luminance vs. required sign legend luminance for the “DDS-EG-001” scenario example.
TRANSFERRING A SCENARIO FROM SST TO TARVIP

A particular scenario of interest can be chosen from the “Scenario Explorer” tab in the tool output. To select a scenario, the user can actively click on the content on the row corresponding to that scenario, by using the up and down arrows keys, by using the “page up/down” keys, or by using the “< Previous Record” and “Next Record >” buttons until the desired scenario is selected. Once selected, the active scenario is highlighted in blue background. The scenario chosen in the Scenario Explorer tab is also the one that will be transferred to Tarvip if desired. In Figure 13, the selected scenario ID is 18755.

To perform the transfer, the user has to switch to the “Post Analysis” tab located next to the “Scenario Browser” tab in the Selection Results window. Once a scenario is highlighted, and the “Post Analysis” tab is opened, the same scenario number will appear at the bottom-right frame of the panel right above the “Launch Tarvip” button as shown in Figure 14. The scenario that will be transferred to Tarvip can be changed at any time by switching back to the “Scenario Browser” tab and selecting another scenario from the scenario list spreadsheet. In Figure 14, the scenario ID 18755 selected in the “Scenario Explorer” tab as shown in Figure 13 is transferred into the “Post Analysis” tab and appears at the bottom right frame dedicated to Tarvip – tool interface. Clicking on the “Launch Tarvip” button initiates a series of internal functions that perform the following in the given order:

i) Determines the filename (and path in the SBF folder structure) for the SBF file which contains the scenario,

ii) Opens the corresponding SBF file and locates the column that corresponds to that particular scenario,

iii) Reads the scenario content from the SBF file and generates a Tarvip scenario file “Scenario.vip” in the SST root folder (the folder that the SST program is located).

If “Scenario.vip” file already exists, it is overwritten. However, the user can save the “Scenario.vip” file with another name (while keeping the “.vip” extension) to use it at a later time. Saving with a different filename can be done from Tarvip via File Menu/Save Scenario As… option, or simply by copying the Scenario.vip file to another location, and renaming it.

Tarvip scenario input files (i.e. scenario.vip) are text files (ASCII), and their content can be viewed with a text editor such as Notepad® or Wordpad® (or even Microsoft® Excel®). The user should exercise caution not to change any variable names, but the values can be changed within the text editor. Yet, the best way of changing scenario input is through Tarvip File Open/Save options.

1 Detailed information about the Scenario Batch Files (SBF Files) is given in Scenario Batch Files (SBF Files) section of this manual.
Figure 13. Selection results window – “Scenario Browser” tab
Figure 14. “Post Analysis” tab – Tarvip scenario transfer button and scenario number indicator.
PROCESSING AND ANALYZING A SCENARIO IN TARVIP

Once the scenario is transferred into Tarvip through the scenario transfer functionality of the tool as shown in Figure 14, Tarvip main window will appear. For the users who had chosen not to install Tarvip during the tool installation, this feature will not be available.

When initialized from the tool (as described in “Transferring a Scenario from SST to Tarvip” section), Tarvip opens and loads the corresponding scenario (scenario.vip file in the tool folder) automatically. The Tarvip main window looks similar to that shown in Figure 15. The Tarvip version and the scenario input file name are displayed on the Title bar of Tarvip.

If the user wants to run the scenario without any modifications (identical to that evaluated in the tool), “Perform Visibility Analysis” option under the “Run Menu” initiates Tarvip scenario evaluation. Running a simple traffic sign scenario may take a few minutes. Once Tarvip completes scenario evaluation, the originally inactive “Output” menu becomes active, and various output information, usually in the form of graphical plots are accessible through the “Output Menu” of Tarvip.

![TarVIP 4.6 - Scenario.vip](image)

Figure 15. Tarvip main window.

File Menu

File Menu consists of various scenario file input/output functions, Tarvip scenario batch file (SBF Files) related functions, as well as a few graphical visualization tools. The “File” menu in Tarvip is shown in Figure 16.

“New” option initializes a sequence of input windows starting from the “Road Input window. Choosing “New” option from the file menu does not clear the contents of
the current scenario, but rather initiates a sequence of interconnected windows, analogous to a “Scenario Wizard”.

![File menu in Tarvip](image16)

**Figure 16.** File menu in Tarvip.

“Open Scenario…” option displays the “Open Tarvip Scenario File” dialog window as in with many other applications in Windows®. The only file type that can be opened with Tarvip is those with .vip extensions. Figure 17 shows the “Open Tarvip Scenario File” dialog window. Once a file with .vip extension is selected and opened, Tarvip opens the selected scenario file (.vip), retrieves its content, and loads the values of each Tarvip variable into the current Tarvip session.

![Open TarVIP Scenario File](image17)

**Figure 17.** “Open Tarvip Scenario File” window.

“Save Scenario” option saves the values of each Tarvip variable in the current session into the original file with the filename as indicated in the title bar.
“Save Scenario As…” option gives the user an option to save the scenario content of the current session into a file with a different name.

“Open Structured Batch File…” option is related to the batch-scenario feature of Tarvip. These features, their functionalities and related user interface are described in the Scenario Batch Files (SBF Files) section of this manual starting on page 3.

“Analyze Batch Output…” option can be used only after a batch scenario is processed with Tarvip. Suppose that a batch file contains 100 scenarios. After running this batch file, the user has 100 output files containing all the output variables in each scenario in 100 separate tab-delimited ASCII files (with .xls extensions). If the only interest of the user is to obtain the legibility distances (or visibility distances in the case of pavement marking and diffusing objects), then normally the user would need to open each output file, compare total actual contrasts with threshold contrasts and determine the legibility (or visibility) distance most likely by linear interpolation. Or alternatively, the user can use the “Output Plotter…” option as described below to open each output file and determine the legibility (or visibility) distances. In either case, the process can be very time consuming. Instead, Tarvip allows the user to quickly process the output files generated by the batch-file evaluation with the “Analyze Batch Output…” option. This option generates a summary file containing the visibility distances achieved in each scenario as given in the SBF file, and places the summary file in the same folder as the original SBF file. The summary file is entitled “BatchResults-SBFFileName.rtf”, where SBFFileName is the name of the original scenario batch file (SBF File). To generate the batch output summary, the user needs to specify the original SBF file.

“Output Plotter…” provides a graphical analysis medium for previously processed scenarios. After analyzing a scenario, the “Output” menu option provides plenty of graphical representations of the output for the user. However, sometimes the user may want to store the output and analyze it at a later time. This is where the “Output Plotter…” comes handy.

Each time Tarvip evaluates a scenario, it produces a tab-delimited ASCII (text) file consisting of the values of all output variables. When a single scenario is evaluated by the user through the “Run” Menu, a single output file, “output.trp” is produced and stored in the Tarvip root folder (the folder where Tarvip is installed, i.e. in a typical installation, C:\Program Files\Tarvip folder). Every time a scenario is processed in Tarvip through the “Run” menu, Tarvip overwrites this file. Yet, the user can simply rename this file to prevent from being overwritten if he/she would like to return to the output at a later time. One useful way of renaming .trp files is changing the filename and replacing the .trp extension with .xls extension. This way, the user can have access to the output of a scenario at a later time by using Microsoft Excel®. Although the user can open and view these output files (i.e. output.trp or renamed output file) with any spreadsheet program or text editor (i.e. Microsoft Excel®), a quick and useful way of viewing the output is through graphical charts.

In the case of batch mode where multiple scenarios are evaluated in series without user intervention, Tarvip automatically saves the output file for each scenario in the folder where the batch file (SBF File) is located. The output plotter can also open each of these output files (which have .xls extension) and view them graphically. A detailed
explanation of the “Output Plotter” functionality is given in “How to Process a Batch File in Tarvip” section starting on page 7.

“Print Input File…” option can be used to print out the snapshot of the Tarvip variables and their values as they exist at the time. After loading a Tarvip scenario input file with the “Open Scenario File…” option, “Print Input File…” option can be used to document the content of the scenario input file. Figure 18 shows a sample “Print” dialog window displayed after choosing the “Print Input File…” option. The pull-down menu can be used to choose the printer to print the scenario file content. “Print to file” checkbox can be used to produce a postscript file.

Figure 18. Tarvip input file print dialog window.

“Show Current Scenario’s Input…” option displays a window that lists all existing variables and their corresponding values. “Print” option is also available through this window. A sample scenario input display window is shown in Figure 19. The “Show Current Scenario’s Input…” option provides a practical method to view and print the content of a Tarvip input scenario, where only limited information is available about the same scenario in the SST tool.
"Plot Headlamp Iso-Candela Graph" option can be selected if the user wants to view the iso-candela contour plot of a certain headlamp. When selected, the “Plot Headlamp Iso-Candela Graph” option asks the user to select a headlamp file from the default headlamp folder (Headlamps folder inside the tool folder). Upon user selection, a contour plot is displayed for the selected headlamp, where (0,0) on the plot corresponds to the direction of headlamp longitudinal axis. The horizontal and vertical beam angles are shown in degrees. The iso-candela plot shows the spatial beam distribution for the selected headlamp in terms of luminous intensities given in candelas [cd]. Figure 20 shows the iso-candela plot for the 50th percentile US low-beam headlamp sampled from 20 best-selling passenger cars in the year 2000 [4]. Like all other plots in Tarvip, the iso-candela plots are zoom-enabled. Left-clicks on the plot area with the mouse pointer center the selected point and enlarges the graph (zooms-in). Similarly a rectangular section can be selected with the mouse pointer by holding the left mouse button and dragging the pointer to specify the opposing corners of the rectangle, which will be enlarged to occupy the plot area. To zoom-out (shrink) the plot, the user can right-click on any point on the plot area, or for complete zoom-out to the original plot, double-click on the plot.
Contour labels can be shown and hidden by using the “Contour Labels” checkbox on the upper left corner of the iso-candela plot window. On the bottom-left corner of the window, a pull-down menu controls the color fill option for the plot. The maximum headlamp luminous intensity at headlamp hotspot is also given at the bottom of the plot window in blue text as shown in Figure 20.

Figure 20. Iso-candela plot for the 2000 US median low-beam headlamp file used in the SUV/light-truck scenarios in the tool.

“Exit” option closes the Tarvip session.

Input Menu

The “Input” menu features a set of graphical user interface windows for the user to define a Tarvip scenario. Each option under the “Input” menu displays a particular input window containing variables that belong to the same logical group (i.e. roadway, driver, target type, etc) with user-friendly and familiar input structures. Each input window corresponding to the options under the “Input” menu is also accessible sequentially from one another through “< Previous” and “Next >” buttons in each input window. These interconnected sequential input windows are designed to help user with the famous “Wizard” interface. Thus, the non-expert user is encouraged to use the “< Previous” and “Next >” buttons while defining or modifying a scenario.

The Input pop-up menu is shown in Figure 21. Input Menu Structure and its relationship to the input windows is illustrated in Figure 22.
Figure 21. Input menu in Tarvip.
Figure 22. Tarvip input menu structure and input menu window relations.
The “Road” option under the “Input” menu opens the “Road Input Window” shown in Figure 23. The user can select a roadway geometry and the locations of right and left edge lines relative to the road centerline in this window. Rather than a pull-down menu structure, Tarvip provides a pushbutton option to specify the roadway (geometry) for a scenario, which provides flexibility for the user to create custom roadway files and use them as needed. This way, the user is not limited to a predefined set of roadway geometries. A set of roadway geometry files (a straight, 90° right and left curves with 100m and 200m radii) is already provided with Tarvip. The “Load Road Geometric File (*.txt)” button opens a file selection window, and by default, it shows the contents of “Roads” folder inside the Tarvip root folder (where Tarvip is installed) where the predefined set of roadway geometry files are located.

All roads in the scenarios used in SST database are straight and level roads, which is defined in LongStraightRoad.txt road geometry file. The content and format of the road geometry files in Tarvip are given in detail in “Road Geometry Files” section. If the user chooses to create new roadway geometry files, the format of the files should meet the specifications for such files as outlined in the “Road Geometry Files” section.

The “Show Road Picture” button opens a window that contains the representation of Tarvip coordinate system and dimension definitions. This window is shown in Figure 25.

The “Apply” button registers the changes in the dimensions in the “Road” input window. The changes also take effect by pushing the “Next >” button at the bottom right of the window.

The “Next >” button closes the Road Input window and opens the “Type of Object” input window.

Figure 23. Tarvip roadway characteristics input window.
Figure 24. “Open Road Data File” file selection window in Tarvip.

Figure 25. Definition of roadway dimensions, road center, centerline, and vehicle coordinate system.
Type of Object

The “Type of Object” input window is not accessible through the “Input” menu structure but through the “Next >” button in the roadway window. This window is where the user determines the type of object that is of interest. For the SST tool, the type of object in interest is traffic signs. Other types of objects available for analysis in Tarvip are pavement markings and pedestrians (diffusing targets). The “Type of Object” input window is shown in Figure 26.

![Type of Object Input Window](image)

Figure 26. Type of object input window.

“Type of Object” window is not accessible from the Input Menu. Instead, the “Input” menu offers a cascade “Target Object” menu structure. The available options are the same as presented in the “Type of Object” window: “Pavement Markings”, “Signs”, and “Diffusing Targets”. Opening a particular type of object configuration window sets the object type to that particular target object type. For instance, opening the pavement marking configuration window sets the object type to pavement markings and the visibility analysis will be performed accordingly, for the existing settings of the pavement marking scenario. Therefore, while modifying a scenario, the user is encouraged to proceed via the “< Previous” and “Next >” buttons. The “< Previous” button on the “Type of Object” window opens the “Road” input window and the “Next >” button displays one of the three object configuration windows based on the user selection in this window: Diffusing Targets, Traffic Signs, or Pavement Markings.

Traffic Sign Window

Traffic Signs Input Configuration window in Tarvip is shown in Figure 27. The values shown in Figure 27 are for the scenario ID number 18,755, following the example given throughout this section.

The pull-down menu provides a variety of sign shape selections: Diamond, Rectangle, Triangle, and Octagon (Stop Sign). The sign shape does not affect the legibility distance in Tarvip, yet it is included for future module development purposes. The dimensions of the sign also has no effect on the legibility distance calculations in Tarvip, however, the actual size of the sign may affect the legend size in reality.

The controls on the left size of the “Signs” window are used to define the sign orientation with respect to the roadway tangent at the location of the sign. An upright sign
is assumed to have a reference axis (the axis perpendicular to the sign plane) parallel to the roadway tangent at the longitudinal location of the sign. The sign can be rotated using the slider or typing a rotation angle in degrees in the corresponding box. Similar functions can be performed for sheeting rotation (without rotating the sign), sign twist and sign lean. All units of sign orientation are in degrees. Rotation is defined as the sign and/or sheeting to rotate transversally around the sign reference axis, causing a change in the datum axis. Positive rotation refers to counter-clockwise direction both for sign and sheeting rotations.

Figure 27. Tarvip traffic sign configuration input window.

Sign twist is a measure of the angle with which the sign is rotated about its pole. The sign twist thereby changes the direction of the reference axis on the horizontal plane. *Note that twist precedes lean in Tarvip.* The sign is assumed to be first twisted around its pole by the twist angle, and then leaned by the lean angle. Not the vice versa. Positive sign twist is defined to be in clockwise direction from top view (i.e. positive twist for right-mounted signs turns them toward the approaching traffic).

Once the sign is twisted, the sign can be leaned forward (+) or rearward (-) by using the slider or typing in the angle directly in the edit box and clicking anywhere on the sign. Leaning the sign rotates the sign pole (or datum axis if there is no sheeting rotation) and the reference axis on the vertical plane constituted by these two axes. Sign orientation can

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be adjusted by simply typing the angle [degrees] into its corresponding edit box, and clicking on anywhere on the sign illustration.

Upon selecting a sign shape, a **sign sheeting material** can be assigned for the sign background by clicking on the “Select Sheet ing Material (.sgn)…” pushbutton. This action will prompt the familiar file selection window, and automatically direct the user to the “Sign Sheetings” folder as shown in [Figure 28](#). To assign a sheeting material for the sign background, select a file from the list, and click “Open”. Once a sheeting material is specified, a material identifier will appear below the “Select Sheet ing Material (.sgn)…” pushbutton.

![Select Sign Sheeting File](image)

**Figure 28.** Sign Sheeting File Selection Dialog Window.

The sign dimensions [cm] can be specified by entering numerical input to the corresponding edit boxes. If the sign shape requires more than one dimension be specified, Tarvip will present two boxes, each for one dimension of the sign. Although these dimensions are not being used in legibility distance calculations, they are incorporated into the input interface for future purposes.

Sign offset (X1) [m] represents the offset of the sign center point from the road centerline. Offset can be negative or positive, where positive offset indicates an object on the right side of road centerline. Note that the lateral locations of the edge lines, the vehicle origin, and all relevant target objects are defined with respect to the road centerline (which is constituted by the points in the selected **roadway geometry file**). In the example window shown in [Figure 27](#) the sign center is 9.2964m (30.5ft) right of road centerline.

Material efficiency is a direct multiplier of the sign sheeting retroreflectivity $(R_A [cd/m^2/lx])$ values for all angles. Although such uniform degradation across the board for all entrance and observation angles is not likely, it represents the relative retroreflective
performance of the material in the scenario to the new material performance as represented in the sheeting material files. A material efficiency of 1 indicates a new white sheeting material as measured in the laboratory which is what the Tarvip sign sheeting files represent, whereas a material efficiency less than 1 indicates a material inferior in reflectivity to the brand new white sheeting material of the same type. Such degradation may represent material deterioration, dirt accumulation on the sheeting, or a different color of the same material. In the example window shown in Figure 27, the material efficiency of 0.8 was chosen to represent yellow sheeting material of type “Stinsonite 6200-1998). Note that Tarvip allows using any nonzero numerical efficiency, which may be bigger than 1.

The “< Previous” button closes the “Traffic Signs” window and opens the “Type of Object” window while saving all input specified in the sign window. The “Next >” button closes the “Traffic Signs” window, and opens the “Sign Typographical Parameters Window”, and saves all user input in the “Traffic Signs” window.

Sign Typographical Parameters Window

Sign typographical parameters input interface window allows the user to define the sign legend face type (Standard Highway Series Fonts B, D, or F), physical letter height [cm], sign legend sheeting material, and sign legend sheeting material efficiency. A sample sign typographical parameter window is shown in Figure 29.

![Sign Typographical Parameters Window](image)

**Figure 29.** Sign typographical parameters and sign legend sheeting input window in Tarvip.

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The user does not need to choose a particular standard highway font series for all these parameters. Tarvip allows using combinations of these parameters, where the user has the flexibility to define a legend font type with a Series B Width/Height ratio and a Series D spacing to height ratio. This functionality allows font optimization and analysis, which is derived from extensive empirical data on human legibility threshold contrasts for various combinations of these parameters, albeit not practical for most real-world applications. The definition of the typographical parameters in Tarvip is illustrated in Figure 30.

![Figure 30. Typographical parameters as defined in Tarvip.](image)

Note: Figure adapted from [3]

The letter height is the actual letter height of the sign legend in cm. Tarvip currently does not have the standard highway font series E-modified – E(m) – but in the future versions, the letter height for E(m) will be defined as the letter height of the first uppercase letter of the text.

Width/Height ratio is the average letter width to height ratio across the alphabet for the font type of the sign legend. For standard highway font series B, D, and F, the pull down menu right next to the edit box for Width/Height ratio can be used, in which case, Tarvip automatically fills in the edit box. In the example window shown in Figure 29, the pull down menu shows “Standard Highway Font Series D”, for which the average letter width to height ratio is 0.67.

The stroke width to height ratio is defined as the ratio of the letter stroke width to the letter height for a particular series. For standard highway font series, these ratios are approximately 0.13, 0.16, and 0.19 for series B, D, and F, respectively. However, Tarvip
has a definite limitation, in that it only allows for stroke width to height ratios ranging from 0.05 to 0.15. Therefore, although the width/height ratio and spacing/height ratio can be defined as that of series D, the maximum stroke width/height ratio is 0.15, which is still below that of the Series D (0.16). More research is needed to obtain further legibility threshold contrast data for other standard highway series fonts such as E(m) and for higher stroke width/height ratios to represent Series D and above.

The spacing/height ratio represents the average ratio of inter-character spacing to the letter height across the alphabet. Again, the pull-down menu can be used to specify a series and automatically fill-in the corresponding value.

The “Select Legend Sheeting (.sgn)…” pushbutton opens a file selection dialog window for the user to specify the sheeting material for the sign legend. A window similar to that shown in Figure 28 is displayed for the user to specify the sign legend sheeting material type. Again, note that the sheeting materials represent brand new materials for all commercial material types. In addition to the retroreflective sheeting types, Tarvip also features vinyl-paint type dark material used in signs with dark (black) legends. Although these materials are not measured in the laboratory environment for all angles, an approximate lambertian surface represents such dark legends. Materials with reflectivity coefficients of 0.01, 0.05, and 0.15 can be chosen (all lambertian – or diffusing – materials). Other coefficients can be obtained by assigning various material efficiencies to the selected material. A description of the selected material appears just below the button upon selection of a sheeting material.

Legend material efficiency is a direct multiplier of the material reflectivity as given in the sheeting data files. The legend material efficiency can be specified by assigning a numerical entry in the “Legend Material Efficiency” edit box. In the example shown in Figure 30, the efficiency is defined as 4.1. The selected material is a lambertian (diffusing) surface with a reflectivity of \( \rho = 0.01 \) asb/lux (1% reflectivity). In this case, a material efficiency of 4.1 adjusts the overall material reflectivity to 1 asb/lux \( \times 4.1 = 4.1 \) asb/lux (an approximate value for most black vinyl products). The same could also be achieved by selecting the lambertian surface with a reflectivity of 0.05 asb/lux, and assigning a material efficiency of 0.82 to it (in which case the overall material reflectivity would be 0.05 asb/lux \( \times 0.82 = 4.1 \) asb/lux).

“Calculate legibility threshold contrast for a static set of parameters” checkbox enables the contents of the frame located at the bottom left of the typographical parameters window. Checking this box allows the user to use a legibility threshold contrast calculator. The status of this check box does not affect the outcome of the scenario, that is, it is not a part of the user input structure. It is only a feature of Tarvip that allows user to obtain the Tarvip legibility threshold contrast for the specified letter height, distance to the sign, the font series, and the background luminance. Contrast in Tarvip is defined as:

\[
C = \frac{\text{Luminance}_{\text{Foreground}} - \text{Luminance}_{\text{Background}}}{\text{Luminance}_{\text{Background}}} \quad (1)
\]

In the case of traffic signs, the foreground is the sign legend sheeting, and the background is the sign background sheeting. For pavement markings, the foreground is
the pavement marking, and the background is its immediate roadway surface. For diffusing targets (pedestrians), the foreground is the diffusing surface, whereas the background is the pavement surface or the sky along the observation axis (connecting the driver eye to the center of gravity of the diffusing target) behind the target.

The “< Previous” button closes the typographical parameters window and reopens the traffic signs window. The “Next >” button closes the current window, and opens the “Point of Interest” window.

**Point of Interest Window**

The point of interest window is shown in Figure 31.

![Figure 31. The Point of Interest window in Tarvip.](image)

The Point of Interest window allows the user to define where the target object is located longitudinally from the road origin in meters. The distance is measured along the roadway trajectory, which is the distance along the road centerline from the roadway origin to the point where the object is located. In the sample window shown in Figure 31, the object is located 300m away from the roadway origin. This distance is measured along the roadway centerline (i.e. with a wheel traveling on the road centerline) up to the point abeam the target object. For most pavement markings scenarios, the point of interest is already on the roadway centerline. For other targets, there is usually a lateral offset defined from the road centerline. Points on a line perpendicular to the road centerline are assigned the same quantity for the point of interest distance measure. Nevertheless, such points may have different lateral offsets.

The available roadway length [meters] as defined in the *roadway geometry file* is also presented to the user in this window below the title bar.

For the specified value to take effect, the user has to push the:
- “< Previous” button, that closes this window and returns back to the pavement marking, sign, or diffusing target configuration window depending on the object type
- “Apply” button that registers the specified value and keeps the window open
In all of the scenarios in the tool, the signs are located at 300m longitudinally from the road origin.

**Vehicle and Headlamp Window**

In this window, the user can define the vehicle characteristics and as many headlamps as he/she would like to assign to the vehicle. A sample window from one of the scenarios is shown in Figure 32.

![Vehicle and Headlamp Window](image)

**Figure 32.** The Vehicle and Headlamp window in Tarvip.

The vehicle speed is defined in km/h. The vehicle speed does not affect the legibility (or visibility) distance in Tarvip as long as the scenario does not include glare vehicles. When there are glare vehicles, the speed of each vehicle may change the relative position of the driver vehicle during the approach to the target, which in return may change the legibility distance. Nonetheless, if the does not include vehicles that cause glare, the speed does not affect the legibility (or visibility) distances.

Windshield transmission is the quotient of light flux that successfully penetrates the windshield. Most windshields have light filtration characteristics, and they exhibit reflective characteristics. This quantity is therefore the rate of visible light transmission of the vehicle windshield.
“Car origin relative to centerline” is defined as the lateral offset [meters] of the vehicle origin to the road centerline. A vehicle right of road centerline has a positive offset. The car origin is defined as the point in the middle of the two headlamps on the ground. This point is fixed to the vehicle. In Tarvip, the vehicle is assumed to maintain the distance defined as the “lateral offset” to the road centerline throughout its travel.

This window also informs the user about the length of the roadway as defined in the **roadway geometry file**. This information is given right below the “Show related vehicle dimensions” pushbutton.

Vehicle course defines the starting point, iteration interval, and the ending point for the vehicle trajectory. Tarvip evaluates the target visibility for each interval from the starting point to the end point as defined by the user in this window. These distances are defined similar to that of the “**Point of Interest**”, for which, the distances are measured longitudinally from the road origin [meters]. These distances are not necessarily the distance between the road origin and these points (i.e. the length of the line connecting these road origin to each of these points), but rather the distances along the road centerline from the road origin to these points. For straight roads, of course, these measures are the same.

“Plot iso-lux curves on road surface” button generates an iso-lux plot on the road surface due to the total headlamp illumination. Headlamp should be defined prior to using this function. A sample iso-lux plot (for the light truck/SUV headlamps and locations administered in the tool scenarios) is shown in Figure 33. The dimensions in both axes of the plot are in meters.

![Iso-lux observed from road surface](image)

Figure 33. A sample Iso-lux plot illustrating the total illuminance on the roadway surface induced by two headlamps.

Adding a headlamp or deleting a headlamp updates the list of headlamps shown in the headlamp list box. Total number of headlamps in the set of defined headlamps is also shown right above the headlamp list box.
To have the changes registered by Tarvip, the user can click on the:

- “< Previous” button, which returns to the “Point of Interest Window”
- “Apply” button, which registers the user input without closing the window
- “Next >” button, which closes the window and displays the “Driver Window”.

Add Headlamp Pushbutton

Add headlamp pushbutton allows the user to define and add another headlamp to the existing set of headlamps. Once clicked on, the button initiates a file selection dialog window for the user to select a headlamp file. The default location for the headlamp files is the “Headlamps” folder located inside the Tarvip root folder.

Upon selection of a headlamp file, a headlamp configuration window similar to that shown in Figure 34 will be prompted. This window allows the user

![Create Headlamp](image)

**Figure 34.** Headlamp configuration window in Tarvip.

This window allows the user to define the location of the headlamp with respect to the car origin, as well as the misaim angles and headlamp efficiency. The X, Y, and Z coordinates for the vehicle is shown in Figure 35, which can be viewed by clicking on the “Show Dimensions” button. Once a headlamp file is selected, its default identifier will be carried to the description edit box of this window. The user can alter the headlamp description by typing a short description into the “Description of headlamp” edit box to later be able to distinguish it in the output plots from other headlamps of the same type.

X axis in local vehicle coordinate system points forward on the roadway plane along the direction of the vehicle movement. Y axis is normal to the roadway surface, and points upward. Z axis is perpendicular to both X and Y, and it is the cross-product of the two (X×Y=Z). Hence, it points rightward from the driver viewpoint.
Headlamp position X is the longitudinal offset [meters] for the headlamps from vehicle origin. This quantity is usually zero, because the vehicle origin is defined as the point in the middle of the two headlamps (assuming the vehicle has only two headlamps) on the ground. Therefore, for the vehicles that have two headlamps, headlamp position X is zero. For additional headlamps, the headlamp position X quantity can be positive (ahead of the headlamp vertical plane) or negative (setback from the headlamp plane).

Headlamp position Y is the height [meters] of the headlamps from the ground.

Headlamp position Z is the lateral offset [meters] of the headlamps from vehicle centerline. Since Z is positive rightward from the vehicle centerline, the headlamps on the right side of the vehicle have positive Z. The headlamp shown in Figure 34 has a negative Z component, which refers to the driver side headlamp (on the left).

Vertical misaim angle [degrees] is the misaim of the headlamp measured from the horizontal plane (the angle between the H-H plane and the horizontal plane passing through the headlamps). A positive misaim indicates an upward misaim (positive Y direction).

Horizontal misaim angle [degrees] is the misaim of the headlamp measured from the vertical plane passing through the headlamp (the angle between the V-V plane and the vertical plane through the headlamp). A positive misaim indicates a rightward misaim (positive Z direction).

Figure 35. X, Y, and Z coordinates for local vehicle coordinate system in Tarvip.

Headlamp efficiency defines a constant multiplier for the headlamp luminous intensities given in the headlamp file. An adjustment in the headlamp efficiency affects the headlamp output the same way for all spatial beam directions. An adjustment may be necessary for different voltage feed, or to account for the dirt accumulation in the lens cover. In any case, the efficiency is a ratio of the luminous intensities to be used in the scenario to those given in the selected headlamp file. Note that, most effectors such as voltage change or lens dirt affect the headlamp output variably for different spatial beam directions.

This window also allows the user to view the iso-candela plot for the selected headlamp. To view the iso-candela plot, click on the “Iso-Candela Plot” button. The iso-
candela plot for the low beam headlamp used in SUV/light truck scenarios \[4\] is shown in Figure 36. Like all other graphical output plots in Tarvip, the iso-candela plot features a zoom in/out function activated via left/right mouse clicks.

Figure 36. Iso-candela plot for the 2001 US median low-beam headlamp \[4\].

After defining the new headlamp, click on the “OK” pushbutton to add the headlamp to the list of existing headlamps. To cancel, simply click on the red close button on the upper right side of the title bar.

Delete Headlamp Pushbutton

Delete headlamp pushbutton can be used to remove a headlamp from the existing set of vehicle headlamps. Clicking on the button pops up a new window, where the user can select the headlamp that he/she wants to remove as shown in Figure 37. Upon selection of the headlamp from the pull-down menu, clicking “OK” will remove the headlamp from the existing set of headlamps. Selecting a headlamp from the pull-down menu displays the configuration of the headlamp in the text fields of the window. To exit without deleting, close the window using the red close button on the upper right title bar.
Figure 37. Delete headlamp dialog window.

Driver Window

“Driver” window in Tarvip allows the user to define driver-related dimensions of the Tarvip variable space. A sample driver window is shown in Figure 38.

Figure 38. Driver input window in Tarvip.
Driver age [years] is a critical input in determining the driver needs. Tarvip incorporates a substantial human factors database, derived from years of empirical efforts. The contrast requirements usually have a tendency to change with changing driver age.

Exposure time does not affect the legibility criteria for traffic signs. However, it is a critical component for pavement markings, where shorter exposure times promote higher contrast requirements.

Probability of detection is disabled for traffic signs and diffusing targets, because the legibility threshold contrast database for traffic signs is obtained for only near 100% detection probability. For pavement markings, however, the probability of detection refers to an accommodation level, for which a certain percentage of people can detect a pavement marking. The higher the probability of detection, the lower the visibility distance for pavement markings.

Minimum required preview time does not change the legibility (or visibility) distance, but is nevertheless included to determine the required preview distance based on vehicle speed. Zwahlen and Schnell [5] recommend 3.65 seconds of preview time for pavement markings for safe nighttime driving, which accounts for 3 seconds of CIE recommendation [6] and an additional 0.65 seconds for eye fixation duration (visual information acquisition).

Driver’s eye location relative to car origin X, Y, and Z are defined similar those for the headlamp locations. The quantities are defined in accordance with the local vehicle X, Y and Z coordinate system as shown in Figure 35 on page 37. X is defined as the setback from the headlamps [meters], and is usually negative, because the driver eye is in negative X direction from the car origin. Y value represents the driver eye height [meters] from ground. Z value is the driver lateral offset of the mid-point of the driver eyes from vehicle centerline, and is negative for left side driver, and is positive for a right side driver (positive Z direction is rightward from vehicle centerline).

The frame toward the bottom of the window is for discomfort and disability glare purposes. Tarvip assumes that the driver is looking at a fixed point. However, in some cases, the user may want to see the effect of glare when the driver is looking at a fixed direction with respect to the vehicle rather than a fixed point outside the vehicle fixed to the global coordinate system. This type of analysis is most likely to take place for pavement markings, where the driver is not looking at a fixed point on the pavement markings, but rather looking towards a direction. In a glare encounter, these two cases generate different glare angles, and thereby different amounts of stray light in the eye. For most traffic sign and diffusing target scenarios, the driver is assumed to look toward the target even though he/she may not be seeing the target. For such fixed targets as signs and diffusing targets, choose “Driver is fixated at the POI” option.

Disability and Discomfort Glare Window

Disability and discomfort glare user input window is shown in Figure 39. For the scenarios used in the tool development, the effect of oncoming vehicle glare was not investigated. The legibility distances given in the tool reflects those without external glare sources.
However, if the user decides to investigate the legibility (visibility) distances under oncoming vehicle glare conditions, Tarvip provides extensive design options. The user can define as many vehicles as he/she wants, with as many headlamps as needed on each one of the glare vehicles. To activate the Tarvip glare module, user needs to check the checkbox on the top of the disability and discomfort glare window. A glare vehicle is defined by default in Tarvip with no headlamps. From the glare input window shown in Figure 39, the user can add/delete or modify the configuration of the glare vehicle scenario.

“Add Glare Vehicle…” pushbutton opens another input window similar to the “Vehicle and Headlamp Window” explained on page 34. A sample glare vehicle configuration window is shown in Figure 40.
Tarvip assigns the name “Glare Vehicle $n$” to the new vehicle, where $n$ is the number of existing glare vehicles plus one. The user can assign a different name to the vehicle by typing the name into the associated edit box.

The vehicle speed [km/h], by default is the same as that of the driver’s vehicle (in opposite directions). The speeds are important in determining the locations of each vehicle in the scenario at each step. A positive speed for the glare vehicle indicates that the glare vehicle is traveling toward the road origin from an initial point (approaching the driver’s vehicle). A negative speed can also be assigned, which will make the glare vehicle travel in the same direction as the driver’s vehicle (forward for driver’s vehicle, backwards for the glare vehicle).

Car origin relative to the centerline [meters] is defined the same as that for the driver’s vehicle. A negative quantity indicates that the vehicle is on the left side of the centerline from driver’s point of view. In the example shown in Figure 40 the glare vehicle is (-)1.8288 meters (6 ft) left of the centerline (in the middle of an opposing 12ft left lane).

Starting distance [meters] defines the initial longitudinal location of the glare vehicle on the roadway. This is the distance that would be traveled from the road origin to the location of the glare vehicle, along the road centerline.

The user can add headlamp to or remove headlamps from the glare vehicle by using the “Add Headlamp” and “Delete Headlamp” pushbuttons, respectively. When “Add Headlamp” button is clicked, a file selection dialog window will be presented for the user to select the headlamp file. Upon headlamp file selection, a headlamp configuration window similar to the one shown in Figure 41 is displayed.
Figure 41. Headlamp configuration window for glare vehicles in Tarvip.

User can rename the headlamp by typing in the name to the corresponding edit box. The iso-candela plot of the selected headlamp can be viewed by clicking on the “Iso-Candela Plot” button. Show dimensions window will display the window shown in Figure 42, which illustrates the local vehicle coordinate system in Tarvip.

X axis in local vehicle coordinate system points the direction of forward vehicle movement. Y axis is normal to the roadway surface, and points upward. Z axis is perpendicular to both X and Y, and it is the cross-product of the two (X×Y=Z). Hence, it points rightward from the driver viewpoint.

Headlamp position X is the longitudinal offset [meters] for the headlamps from the vehicle origin. This quantity is usually zero, because the vehicle origin is defined as the point in the middle of the two headlamps (assuming the vehicle has only two headlamps) on the ground. Therefore, for the vehicles that have two headlamps, headlamp position X is zero. For additional headlamps, the quantity for headlamp position X can be positive (ahead of the headlamp vertical plane) or negative (setback from the headlamp plane).

Headlamp position Y is the height [meters] of the headlamps from the ground.

Headlamp position Z is the lateral offset [meters] of the headlamps from vehicle centerline. Since Z is positive rightward from the vehicle centerline, the headlamps on the right side of the vehicle have positive Z. The headlamp shown in Figure 42 has a negative Z component, which refers to the driver side headlamp (on the left).
Vertical misaim angle [degrees] is the misaim of the headlamp measured from the horizontal plane (the angle between the H-H plane and the horizontal plane passing through the headlamps). A positive misaim indicates an upward misaim (positive Y direction).

Horizontal misaim angle [degrees] is the misaim of the headlamp measured from the vertical plane passing through the headlamp (the angle between the V-V plane and the vertical plane through the headlamp). A positive misaim indicates a rightward misaim (positive Z direction).

Headlamp efficiency defines a constant multiplier for the headlamp luminous intensities given in the headlamp file. An adjustment in the headlamp efficiency affects the headlamp output the same way for all spatial beam directions. An adjustment may be necessary for different voltage feed, or to account for the dirt accumulation in the lens cover. The efficiency is the ratio of the luminous intensities to be used in the scenario to those given in the selected headlamp file. Note that in real world, most effectors such as voltage change or lens dirt affect the headlamp output variably for different spatial beam directions.

Tarvip does not account for the roadway obstruction of light from glare vehicles due to vertical roadway curvature, at least for now. In a sense, vehicles in Tarvip travel on a virtual roadway suspended on atmospheric medium. Furthermore, glare vehicles with different speeds can travel through each other. Glare vehicles are modeled as a set of headlamps fixed to a point traveling on the roadway parallel to the road centerline. Therefore, the user is urged to consider such limitations while defining a glare scenario.

Unchecking the “perform disability and discomfort glare calculations” checkbox will not delete the user glare vehicle input, but will instruct Tarvip to disregard oncoming headlamp glare.

“< Previous” pushbutton closes the glare input window and returns to the “Driver window. “Next >” pushbutton closes the glare input window and displays the “Environment” input window.
Environment Window

Environment user input window is shown in Figure 43.

![Environment Window Image]

Figure 43. Environment user input window in Tarvip.

Ambient Luminance \([\text{cd/m}^2]\) is a measure of the luminance of the sign background sheeting (or pavement marking or diffusing surface) without the headlamp illumination. Such luminance may exist due to other external light sources under nighttime driving conditions such as moonlight, roadway lighting, or urban lighting. Ambient illuminance concept is fairly hard to implement, in that, most retroreflective materials are directionally sensitive and most materials are measured in the laboratory from a headlamp geometry standpoint. As such, most material files do not contain angles that correspond to ambient illumination. In determining the ambient luminance, assumptions such as directional uniformity is made to simplify the application. Thus, the light flux coming from each direction is assumed to be identical in quantity in Tarvip. Ambient luminance specified by the user is added to the luminance of the sign background sheeting (or roadway surface in the case of pavement markings and diffusing target surface in the case of diffusing targets) regardless of the direction of observation in Tarvip, where the luminance of the counterpart surface (sign legend sheeting, pavement markings, or roadway surface in the case of traffic signs, pavement markings, and diffusing targets, respectively) is calculated under the light of above assumptions and based on the ambient luminance value defined by the user for the counterpart surface.

Atmospheric transmissivity \([\text{km}^{-1}]\) is a measure of forward light attenuation due to particulate characteristics of atmospheric medium. Atmospheric transmissivity under a certain atmospheric condition can be calculated as the ratio of the directly transmitted light after passing through one unit length (here km) of the participating medium (atmosphere, rain, or fog) to the amount of light that would have passed the same distance through vacuum. While traveling through a non-homogenous medium, light is partially scattered and absorbed depending on the characteristics of the medium. Note that, even under clear weather conditions, the transmissivity is never perfect but rather suboptimal due to the air molecules, dust particles, water vapor, non-homogeneities due to temperature differences, etc.
Equation 2 gives the transmissivity-distance relationship, where $D$ denotes the unit distance usually in km, for which the transmissivity is $T_D$.

Meteorological visibility is defined as the distance where directly transmitted light is reduced to 5% of the initial value due to scattering and absorption by the participating medium. For instance, if the transmissivity of a standard atmospheric condition is 0.86 km$^{-1}$, the meteorological visibility would be around 20 km. An atmospheric transmissivity of 0.86 km$^{-1}$ indicated that approximately 86% of visible light flux successfully travels through 1 km of atmospheric medium, which generally refers to clear weather conditions. In reality, the atmospheric transmissivity is not a constant, not only because of non-homogeneities in the atmosphere in long distances, but also due to different absorption and scattering characteristics of the atmosphere for different wavelengths. Nevertheless, for the relatively short distances in headlamp illumination and related nighttime visibility, the wavelength effects are practically negligible.

Note that, Tarvip can also account for the veiling glare due to backscattering of light originated from vehicle headlights when the “Enable fog luminance calculations” checkbox is checked. If this button is not checked, Tarvip only accounts for forward attenuation, whereas in foggy conditions, what limits visibility is not only the lack of forward light transmissivity but also the backscattering of light that overlay the background view. The effect of light-backscattering in fog can be rather prominent in dense fog, and can be attested when high-beams are used. Thus, visibility based solely on forward attenuation is not realistic under foggy conditions. If the atmospheric transmissivity is below 0.22 km$^{-1}$ (thin fog) [7], the user is encouraged to enable fog backscattering calculations. Note that, Tarvip employs sophisticated Mie Scattering algorithms for the calculation of backscattering and veiling luminance calculations in fog, and such calculations take hours to complete for most scenarios. Table 1 gives extinction coefficients and corresponding transmissivities for various fog density levels.
Table 1. Transmissivities and corresponding extinction coefficients for various densities of fog.

<table>
<thead>
<tr>
<th>Weather</th>
<th>Maximum Meteorological Optical Range (kilometers)</th>
<th>Maximum Extinction Coefficient (per Meter)</th>
<th>Maximum Transmissivity Km⁻¹ (per statute mile)</th>
<th>Maximum Transmissivity Km⁻¹ (per nautical mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceptionally clear</td>
<td>50+</td>
<td>0.00006-</td>
<td>0.94+</td>
<td>0.91+</td>
</tr>
<tr>
<td>Very clear</td>
<td>50</td>
<td>0.00006</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>Clear</td>
<td>20</td>
<td>0.00015</td>
<td>0.86</td>
<td>0.79</td>
</tr>
<tr>
<td>Light haze</td>
<td>10</td>
<td>0.00030</td>
<td>0.74</td>
<td>0.62</td>
</tr>
<tr>
<td>Haze</td>
<td>4</td>
<td>0.00075</td>
<td>0.47</td>
<td>0.30</td>
</tr>
<tr>
<td>Thin fog</td>
<td>2</td>
<td>0.0015</td>
<td>0.22</td>
<td>0.090</td>
</tr>
<tr>
<td>Light fog</td>
<td>1</td>
<td>0.0030</td>
<td>0.050</td>
<td>0.0081</td>
</tr>
<tr>
<td>Moderate fog</td>
<td>0.5</td>
<td>0.0060</td>
<td>0.0025</td>
<td>0.000065</td>
</tr>
<tr>
<td>Thick fog</td>
<td>0.2</td>
<td>0.015</td>
<td>3.1×10⁻⁷</td>
<td>3.4×10⁻¹¹</td>
</tr>
<tr>
<td>Dense fog</td>
<td>0.05</td>
<td>0.060</td>
<td>9.5×10⁻²⁷</td>
<td>1.3×10⁻⁴²</td>
</tr>
<tr>
<td>Very dense fog</td>
<td>0.03</td>
<td>0.10</td>
<td>4.3×10⁻⁴⁴</td>
<td>1.6×10⁻⁷⁰</td>
</tr>
<tr>
<td>Exceptionally dense fog</td>
<td>0.015</td>
<td>0.20</td>
<td>1.8×10⁻⁸⁷</td>
<td>2.6×10⁻¹⁴⁰</td>
</tr>
</tbody>
</table>

Note: Table adapted from [7].

“< Previous” button closes the “Environment” window, and returns to the “Disability and Discomfort Glare Window”, in which case, the user input is registered. “Apply” button also registers the user input without closing the window. “Finish” button registers the user input, closes the “Environment” window and returns to the main window. This step completes the scenario development process in Tarvip.

The user can go back to any of the user input windows through the “Input” menu, or by navigating through the windows via the located in each window. To register any change and make Tarvip aware of the changes in any input, the user needs to click on the “Apply” button, or simply use the “< Previous” and “Next >” buttons on the window(s) that changes are performed.

**Run Menu**

The only option under the “Run” menu in Tarvip is the “Perform Visibility Analysis” option. Upon completion of scenario development through the [Input Menu] items, the user can start the Tarvip analysis by choosing “Perform Visibility Analysis” option under this menu.

“Perform Visibility Analysis” option initiates a series of modular internal functions that account for the physics of light (in the form of electromagnetic waves with known spectral characteristics) as defined in the scenario, as well as functions that account for human factors side of the equation.

In short, Tarvip calculates the actual contrast between the target and its immediate background for every distance that the vehicle is indexed. At each iteration, Tarvip calculates the orientation of the vehicle and the location of headlamps and driver eye, the
location of each glare vehicle, and calculates the light that hits the target and its background. The observed contrast depends on the type of object: for traffic signs, the legend and sign background sheeting materials; for pavement markings, markings and immediate pavement; and for diffusing targets, the target and the pavement in the background or the sky depending on driver eye height and the height of the center of gravity of the diffusing object. The veiling luminance (the equivalent luminance that overlays the image on observers retina) is also calculated for each step, and added to the calculated observed luminance of the target and its immediate background. For every step, Tarvip also calculates the required luminance to read the text on the sign in the case of traffic signs, or to detect the pavement marking stripe or diffusing target in the case of pavement markings and diffusing targets, respectively. These calculations are repeated for each step the driver vehicle moves toward the end of its course, and by comparing the actual and threshold luminances, Tarvip determines whether the target is legible (or visible). More detail about the calculations in Tarvip, and related limitations and assumptions are given in the Output Menu section of this manual.

The length of the code execution in Tarvip while a scenario is running depends on mainly the type of scenario alongside the FPU and hardware configuration of the computer. Pavement marking and diffusing target scenario analyses take usually less time, whereas traffic sign scenarios are relatively more time consuming. Additional module activation, such as those for disability/discomfort glare and fog may further add to the analysis time. Once the analysis is completed, the initially inactive “Output” menu becomes active and provides plenty of output graph options.

**Output Menu**

Output Menu is composed of a series of graphical user output interface windows showing numerous dynamic plots. Most plot windows are similar with identical features, and all plots feature zoom capabilities. The data plot depends on the user selection.

Tarvip automatically configures the options in the output menu based on the target object type. For instance, the threshold contrasts are legibility threshold contrasts for traffic signs, whereas, for pavement markings, the threshold contrasts are pavement marking detection threshold contrasts. Therefore, the corresponding output menu items have slightly different titles.

**Features of Output Plots**

All output plots are similar to that shown in Figure 44 in functionality and design. There are two X Axis viewing options: Distance from car origin to POI, or Distance traveled along road. The default is “Distance traveled along road”, in which, the X axis shows the longitudinal location of the vehicle origin with respect to the road origin. In this case, the target may be anywhere, depending on the user input, however, from left to right in increasing direction of X, the vehicle is approaching to the target. Alternatively, one may want to see the graphic relative to the target, where the distance to the target object is of concern. In this case, Tarvip reverses the X axis to maintain the increasing order of the X axis, but this time, x=0 corresponds to the location of the target. Note that the X axis in
this case does not necessarily start from zero, in the case where vehicle does not reach to the target. For instance, in the example plot shown in Figure 44, the POI is located at 100 meters, yet the vehicle travels only from 0 meters to 50 meters. The interception of “Blackwell threshold contrast” and “Total Actual Contrast” is the point where the target becomes visible. The location of the vehicle x=9 at the interception of the two contrast curves corresponds to approximately 100-9=91 meters of visibility distance. The plot can be seen in terms of the distance between the vehicle and the target when the viewing option “Distance from car origin to POI” is selected as shown in Figure 45.

Y axis viewing options provide a choice between linear and logarithmic scaling without changing the X axis.

Grid on/off button toggles the horizontal and vertical grids on and off. All output plots also provide a “Show Input” option, where the user revisits his/her scenario input. There are “Previous Plot” and “Next Plot” options to navigate between plots without using the “Output” menu. All plots can be printed, where the printouts contain the selected plot as well as user input.

![Image](image.png)

Figure 44. Sample Tarvip output plot.
All plots feature zoom capability, where the user can simply left click on a point inside the plot to re-center the plot about the selected point while increasing the plot resolution (zoom-in). Right click does the opposite of left click, where the plot is displayed with lower resolution. To return to original plot, simply double-click on the plot. To display a particular rectangular region, click on one of the corners of the rectangle and drag the mouse while holding the left mouse button until the opposing corner of the rectangle is reached. Releasing the left mouse button as shown in Figure 46 will display the plot with the selected rectangular region rescaled to fit the plot window as shown in Figure 47.
Figure 46. Selecting a rectangular region to zoom into the plot.

Figure 47. The zoomed-in appearance of the selected region shown in Figure 46.
Output Menu Options for Pavement Markings

The output menu options after running the default pavement marking scenario in Tarvip is shown in Figure 48.

![Tarvip output menu options for pavement markings.](image)

**Target Angles**

Target angle cascade menu present the user with various plot options for a large set of representative angles in pavement marking geometry. Three basic angular systems are widely used in international and national standards for driver-road-retroreflector geometric calculations as follows:

- **CIE Goniometric:** $\alpha$, $\beta_1$, $\beta_2$, $\varepsilon$

- **Intrinsic:** $\alpha$, $\beta$, $\gamma$, $\omega_s$

- **Application:** $\alpha$, $\beta$, $\varepsilon$, $\omega_s$

Entrance angles option show the entrance angles ($\beta$) as a function of distance traveled by driver’s vehicle. Entrance angle is defined as the angle between the illumination axis and the reference axis. Here, entrance angle $\beta$ is defined according to the application and intrinsic systems. Entrance angle $\beta$ is further partitioned into its goniometric first and second axis components, namely $\beta_1$ and $\beta_2$ in CIE goniometric system. Error! Reference source not found. illustrates the angles for a right edge pavement marking stripe and for the right side headlamp for CIE goniometric, intrinsic, and application systems. Figure 50 shows another illustration of observation and entrance angles for the left side headlamp. Figure 51 shows the angles for CIE goniometric system.
illustrated on a goniometer. For most retroreflective materials, coefficient of retroreflectance (R_L) is the highest for zero degree entrance angle (when the retroreflector axis R and illumination axis I are parallel).

Observation angle $\alpha$ [degrees] is the angle between illumination and observation axes. For most retroreflective materials, the smaller the observation angle, the higher the retroreflectivity coefficient R_A (or R_L for pavement markings).

For most pavement markings materials, coefficient of retroreflectance is sensitive to observation angle ($\alpha$) and entrance angle ($\beta$). Similar to most beaded materials including some traffic sign sheeting materials, pavement marking retroreflectance is relatively insensitive to the rotation ($\epsilon$), orientation ($\omega_s$), and presentation ($\gamma$) angles. Retroreflectance for such beaded materials is usually condensed to the term “cone of retroreflection”, in that holding observation angle $\alpha$ constant for a fixed illumination axis I (hence a constant entrance angle $\beta$) constitutes a cone around the illumination axis I, with its tip on the retroreflector surface. As such, as long as the observation is made on the surface of the cone, the observation and entrance angles are held constant, and so are the coefficient of retroreflection and thereby the observed luminance (in vacuum). This property is unique to beaded materials, where angular dependency can be represented by only two angles ($\alpha$ and $\beta$) due to the optical properties of spherical beads.
Figure 49.  Pavement marking angular geometry and angular definitions for CIE goniometric, Intrinsic, and Application Systems [9].

Note: $\beta=\beta_1$ and $\beta_2=0$ if observation plane is vertical (which is the case for most testing equipment such as retroreflectometers). Geometry illustrates right headlamp for a right edge pavement marking. First axis (F) is perpendicular to observation plane, and second axis (S) is on both the observation plane and retroreflector plane (roadway or sign surface plane). The First and Second axes are also illustrated in Figure 51 where roadway surface corresponds to goniometer plane.
Figure 50. Pavement marking angular geometry and representation on entrance and observation angles.

Note: Figure adapted from [8].

Figure 51. Angular definitions in CIE goniometric system applicable to all retroreflective surfaces such as traffic signs and pavement markings [9].
**NOTE** – The retroreflector axis is normal to the face of the sample goniometer. Angles $\omega_s$ and $\gamma$ are shown positive. The observer track revolves around the illumination axis for setting $\gamma$. The $\beta$ movement is restricted to the direction shown to avoid redundancy.

Figure 52. Angular definitions in Intrinsic goniometer system applicable to all retroreflective surfaces such as traffic signs and pavement markings [9].

*Note* – Angles $\omega_s$ and $\varepsilon$ lie in a plane perpendicular to the retroreflector axis and are shown positive.

Figure 53. Angular definitions in Application System applicable to all retroreflective surfaces such as traffic signs and pavement markings [9].
Beam angles [degrees] signify the direction of illumination toward the target object with respect to the headlamp. It is defined in horizontal and vertical components, which are similar to $\beta_1$ and $\beta_2$ angles in CIE goniometric system, and correspond to the rotation about the First and Second Axes of the goniometer to obtain the direction of illumination. Such definition is due to the fact that most headlamps are spatially characterized in a goniometric range, where the headlamp is mounted onto a goniometer. In most cases, the luminous intensity is measured either at a fixed receptor (replaced with the light source shown in Figure 51) while the headlamp is rotated around the horizontal axis (first axis or fixed horizontal axis, which adjusts the vertical beam angle), and then around the second axis (moveable axis on the vertical plane, which adjusts the horizontal beam angle) according to the CIE goniometric system. The vertical beam angle, therefore, is the angle around the first axis (horizontal fixed axis), and the horizontal beam angle is the angle around the second axis (moveable axis on the vertical plane). Figure 51 illustrates the First and Second axis, and related angles. Tarvip calculates the horizontal and vertical beam angles for each headlamp. Increasing direction is rightward for horizontal beam angles, and upward for vertical beam angles from the point of view of the headlamp.

Visual angles [degrees] correspond to the angles subtended by the two representative extremities of the object (pavement marking width, sign legend letter height, or the shorter one of the width and height for the diffusing targets) at the driver eye. The visual angle increases as the driver approaches the target object. Visual angles are important for Tarvip to determine visibility (legibility), because the human threshold data are given in terms of visual angles.

Presentation angle ($\gamma$) [degrees] is the angle between the observation plane and the entrance plane. Entrance plane is the plane constituted by the illumination axis (I) and the retroreflector axis (R). Observation plane is the plane constituted by the illumination axis (I) and the observation axis (E). The presentation angle ($\gamma$) is usually very close to entrance angle component $\beta_2$ when the entrance angle $\beta_2$ approaches to 90° (for pavement marking geometry). For entrance angles other than 90°, presentation angle ($\gamma$) is always larger in absolute value than entrance angle component $\beta_2$. Presentation angle ($\gamma$) can also be measured as the angle between the zenith axis (Z) and a vector perpendicular to the illumination axis (I) on the entrance plane. The presentation angle ($\gamma$) is usually measured from the zenith axis (Z) to the entrance plane in clockwise direction from observer point of view. Therefore, in most cases, the presentation angle is positive for the right headlamp, and negative for the left headlamp. These two planes coincide when the retroreflector axis (R) is parallel to the observation plane (i.e. an upright motorcycle on a flat road). Most retroreflectometers also perform measurements for a presentation angle of zero. Error! Reference source not found. illustrates the observation and entrance planes and the presentation angle ($\gamma$).

Orientation angle ($\omega_3$) is the angle between the datum axis and the entrance plane. Hence, it does not depend on the location of the observer. This angle is one of the measures of the rotation of the retroreflector surface about the retroreflector axis with respect to the entrance plane, as illustrated in Figure 51 and Figure 52. If the datum axis makes a clockwise rotation around the retroreflector axis R (or if the light source makes a counterclockwise rotation around the retroreflector axis R), the orientation angle decreases. Thus, for right edge pavement markings (or for most right mounted traffic
signs on straight and flat road) the orientation angle is positive. This angle is not defined if the entrance angle $\beta$ is zero.

Rotation angle ($\varepsilon$) is the angle between the datum axis and the observation plane. Thus, unlike the orientation angle ($\omega_s$), it also depends on the location of the observer. Similar to the orientation angle ($\omega_s$), it is also a measure of the rotation of the retroreflector around the retroreflector axis. When the presentation angle ($\gamma$) is zero (when the retroreflector axis is on the observation plane), the rotation angle ($\varepsilon$) is the same as the orientation angle ($\omega_s$). Presentation angle is usually measured from the observation plane to the datum axis on the retroreflector plane in counterclockwise direction. Thus, a counterclockwise rotation of the datum axis (which is fixed to the retroreflector) around the retroreflector axis increases the rotation angle. For a right mounted traffic sign (with vertical datum axis) on a straight road, the rotation angle ($\varepsilon$) is usually positive for the left headlamp and negative for the right headlamp. For pavement markings, there is no rule of thumb, but for the left headlamp, the rotation angle is usually positive. For the right headlamp, the further the right edge line, the more likely it is for the rotation angle to be positive.

Entrance angle component $\beta_1$ is the angle between the zenith axis (Z) and the retroreflector surface (or the second axis S) as shown in Figure 51. Zenith axis (Z) is the axis perpendicular to the illumination axis on the observation plane. Entrance angle is a measure of the rotation of the retroreflector surface around the first axis (F). This angle is the same as the entrance angle ($\beta$) when the presentation angle ($\gamma$) is zero (or when the entrance and observation planes coincide). Since the entrance angle component $\beta_1$ is controlled by the observation plane, $\beta_1$ depends on the relative locations of the headlamp and the observer.

Entrance angle component $\beta_2$ is the angle between the retroreflector axis R and the observation plane as shown in Figure 51. The entrance angle component $\beta_2$ is usually very close in quantity to the presentation angle ($\gamma$) when the entrance angle ($\beta$) approaches to 90° (for pavement marking geometry). For entrance angles other than 90°, presentation angle ($\gamma$) is always larger in absolute value than entrance angle component $\beta_2$. $\beta_2$ angle is a measure of the rotation of the goniometer plane (retroreflector plane) about the second axis as shown in Figure 51, where second axis always lies on the observation plane. Another representation of $\beta_1$ and $\beta_2$ components in the CIE goniometric system is given in Figure 54.
Figure 54. A representation of the CIE goniometric system [9].

Photometry Output Menu

Figure 55. Photometry output menu in Tarvip for pavement marking scenarios.

Photometry output menu provides the user with graphical representations of photometric components that may be of interest to the user in the scenario. Tarvip uses a contrast
based approach in its visibility distance calculations, and it is designed to evaluate achromatic object contrasts. Although some traffic signs are not achromatic (i.e. shades of gray such as speed limit signs), studies show that visibility (or recognition or legibility) of traffic signs is primarily governed by the luminance of the legend and the background rather than the chromaticity thereof, whereas color contributes to the conspicuity of signs especially in nighttime [10][11][12].

The “Luminous Intensity” option provides the headlamp luminous intensity [cd] toward the Point of Interest (POI) from each headlamp in a standard Tarvip plot window throughout the vehicle course as shown in Figure 56. The user can zoom-in, turn the grid on or off, and rescale the plot in logarithmic scale as described in “Features of Output Plots” section.

![Plot of Luminous Intensity Values](image)

**Figure 56.** Tarvip headlamp luminous intensity output plot.

“Illuminance” option provides the illuminance [lux] at the POI due to each headlamp at their respective planes defined perpendicular to each illumination axes. Illuminance at the POI incorporates light attenuation through the atmospheric medium, but it does not account for the second or higher order refractions caused by atmospheric particles such as suspended water droplets that promote light scattering. Therefore, it is a simplified approach to atmospheric transmissivity, where only forward attenuation effect is considered. To calculate the illuminance at the reference plane (retroreflector plane), the user can refer to the entrance angles, and apply cosine correction at each distance as per the entrance angle at that distance for each headlamp.

Retroreflectivity coefficients ($R_L$) [mcd/m$^2$/lux] (or $R_A$ in the case of traffic signs usually given in [cd/m$^2$/lux]) gives a measure of the quotient of retroreflected light to the
incident light with directional components. For pavement markings, $R_L$ is defined as the luminance in the direction of observation per unit illuminance at the target from a particular direction of illumination. The luminance is usually obtained in millilambertas per square meter [cd/m²], and the incident illuminance is usually given in lux (or [lm/m²]), thereby rendering the unit for retroreflectivity coefficient as [mcd/m²/lux]. In Tarvip, roadway surfaces are also modeled as pavement markings, where the retroreflectivity of roadway surfaces is assumed to be determined by the two representative angles: observation angle ($\alpha$), and entrance angle ($\beta$). Therefore, the retroreflectivity coefficients menu has two options, one for pavement markings and the other for road surfaces. Each plot has as many curves as the number of headlamps, because the retroreflectivity coefficient is determined for each headlamp separately. Details about retroreflectivity coefficient data structures in Tarvip are given in the section starting on page 71.

"Actual Luminance" option gives the luminance [cd/m²] at the retroreflector in the direction of observation. It does not incorporate atmospheric attenuation, or any other losses such as light filtering by the windshield. It is therefore a raw luminance figure that provides the user with the information about the luminance as it would be observed through vacuum. This information is useful in understanding the effect of light extinction, scattering, and absorption especially in the case of fog. These figures are also useful in comparing the figures with those provided by other similar models such as ERGO. Actual luminance also includes the ambient luminance on pavement marking, sign background sheeting, or diffusing target induced by the ambient illuminance.

"Observed Luminance" option gives the luminance [cd/m²] as observed by the driver point of view inside the vehicle. It does not incorporate the light losses due to eye media, yet it incorporates the atmospheric losses and windshield transmission losses.

Output Menu Options for Traffic Signs

Output Menu Options for traffic signs is similar to those for the pavement markings in format, and to some extent, in content.

Target angles are the same as those for the pavement markings, except that for visual angles, the sign output menu provides the visual angles for the entire sign and sign legend separately. The definitions of these angles are given in the section starting on page 52. The target angles output menu for traffic sign module is illustrated in Figure 57. Sign legend visual angles are given in arc minutes, and they represent the visual angle subtended by the legend height from driver’s viewpoint.

Figure 58 gives the photometry output menu for traffic sign module in Tarvip. Luminous intensity option provides the luminous intensity [cd] in the direction to the POI from each headlamp defined by the user for each distance as the vehicle approaches the traffic sign.

Illuminance plot shows the illuminance [lux] at the sign surface at a plane perpendicular to the illumination axes of each respective headlamp. The atmospheric transmissivity is accounted for. If the illuminance at the sign surface plane is of interest, the illuminances need to be multiplied by the cosine of the entrance angle for the cosine correction.
Retroreflectivity coefficients \([\text{cd/m}^2/\text{lux}]\) are given for both the sign legend and sign background sheeting materials for each distance the vehicle is indexed. If the material is a diffusing surface (such as black legend), the unit in the plot is \(\text{asb/lux}\), which is also not a function of distance (as observed luminance of a diffusing surface is independent of the observation angle).

Actual luminance \([\text{cd/m}^2]\) provides the luminance of the sign background and sign surface luminances at the sign location, thereby excluding the effect of atmospheric attenuation of the retroreflected light. This is not to say that the effect of atmospheric media on light toward the sign is omitted. Thus, the “actual luminance” figure refers to the luminance that would be observed in the direction of observation at the location of the sign. For the most part, this figure was included for comparison purposes with other similar visibility models, and also to understand the effect of fog on the retroreflected light. Actual luminance is given for both the sign background and legend sheeting materials.

Required luminance plots are some of the key outputs that Tarvip can provide. Required luminance \([\text{cd/m}^2]\) shows the luminance required for the selected driver to be able to recognize the textual sign legend. The required luminance is based on the threshold legibility contrasts, which represent near 100 percent \((p=0.9998)\) probability of correct recognition (legibility) of the traffic sign legend text for the driver age defined by the user. Required luminance does not represent the required observed luminance, but rather the required luminance on the sign sheeting at the location of the sign in the direction of observation. These plots show the actual luminance on the sign vs. the required luminance on the sign.

When the required luminance is being calculated, the first consideration is the contrast polarity. For positive contrast signs (legend is brighter than the background), the required sign legend sheeting is given as the minimum required luminance. For the sign background, the luminance is given as the maximum luminance that would still permit the sign legend to be legible. For positive contrast signs, as the background sheeting luminance increases, the contrast between the legend and the background decreases, causing the legend to be illegible. For negative contrast signs, the opposite are correct.

There are three options in the required luminance menu. Two are for the sign background luminances, and one is for the sign legend luminance. In all cases, the required and actual luminance curves intercept at the legibility distance. Yet, there are subtle differences for the first two options given for the sign background luminance: “Legend luminance constant” and “legend luminance changing”. Legend luminance constant option provides the required luminance of the background sheeting for the actual legend luminance exactly the same as that in the scenario. This option assumes that the background sheeting luminance is increased while the legend luminance is unchanged (i.e. using a brighter material for the sign background but using the same legend material for the sign legend). The “legend luminance changing” option assumes that the legend luminance is changing at the same rate as the background luminance (i.e. using a brighter headlamp).

Figure 59 illustrates a sample required background luminance plot for a negative contrast sign (black legend on white background).
The required legend luminance option gives minimum legend luminance [cd/m²] for positive contrast, or maximum legend luminance for negative contrast.

The required luminance plots are suitable for determining the legibility distance when Tarvip falls short of legibility threshold contrast data, i.e. by means of linear extrapolation on logarithmic scale.

Observed luminance plot provides the luminance [cd/m²] observed by the driver from within the vehicle for sign legend and background sheeting materials.

Percent luminance contribution graph gives the contribution of each headlamp to the total luminance provided solely by the headlamps (excluding ambient illuminance) at each distance on both the sign legend and the sign background.

Figure 57. Target Angles Output Menu for Traffic Signs in Tarvip.
Figure 58. Photometry Output Menu for Traffic Signs in Tarvip

Figure 59. A Sample Required Background Luminance Output Plot in Tarvip.
Observed luminance due to fog provides the veiling luminance induced by each headlamp in the direction of observation by the driver. If the fog luminance calculation is activated from the environment input window, this plot will provide positive quantities for the luminance due to fog [cd/m²]. If the fog calculations are inactive, the luminance due to fog is assumed to be zero at all distances, yet the effect of forward atmospheric attenuation is still accounted for.

Contrast plot is another key output figure in Tarvip similar to the required luminance plots. The contrast plots gives the actual internal sign contrast as observed by the driver vs. the required contrast (or threshold contrast) for the driver to successfully read the sign text. Changing the driver age will alter the required contrast, but will not change the actual contrast. Changing the sheeting materials will most likely affect both the actual contrast and the required contrast. The point where the actual vs. threshold contrasts intercept is where the sign becomes legible to the design driver for the first time. It is possible that Tarvip runs out of threshold data that will yield a legibility distance estimate. Nonetheless, the user can still have an opinion about the legibility of the sign at the distances where Tarvip provides data for. In some cases, the user may consult with the required vs. actual luminance plots and perform extrapolations (preferably on a logarithmic luminance scale vs. linear distance scale) to obtain an approximate legibility distance.

Material performance summary window provides summary information about the output such as the maximum legibility distance, standard Rₐ, Multiples of threshold (MOT), and preview time. A sample material performance window is given in Figure 60. Maximum legibility distance given in Figure 60 is 84.4 meters (277ft).
Help Menu

Help menu is still under development. It will include this help file in the near future. As of Tarvip version 4.7, help menu provides a help menu option to launch Tarvip website at:

http://opl.ecn.uiowa.edu/tarvip/
TARVIP DATA FILE STRUCTURES

Road Geometry Files

Road geometry files are located inside the “Roads” folder in the Tarvip root folder (where Tarvip is installed). By default, the contents of this folder are shown in the file selection window when the user selects the “Road” option as shown in Figure 24 on page 26.

The contents of a roadway geometry file are similar to that shown in Figure 61. Figure 62 shows an illustration of the same roadway geometry file as defined in Tarvip.

Figure 61. Contents of a Sample Roadway Geometry File.

The first string in a roadway geometry file is a general description of the roadway geometry (must have no spaces). The second row is reserved for future use, and always contains two zeros separated by a tab character. Each row after the third row contains four numbers, which represents a point in space. The sequence of these points defines the road center. The first coordinate is always (0,0,0), which is defined as the “Global Origin” in Tarvip. The last column need not be zero.
The first column represents the total length of the travel trajectory (distance traveled by the vehicle, which is not always the x coordinate in the global coordinate system). In a straight road, the distance traveled is equal to the x coordinate at that point, yet for roads with curves, the x coordinate of a point need not match the distance traveled. For instance, for the 100m radius right-curved roadway shown in Figure 62, the total distance traveled at the end of the 90° curve will be approximately 157 meters, whereas the x coordinate at the point is 100m. Tarvip calculates the x coordinates for each point internally.

The second column represents the y coordinate of each point along the roadway center. Global Y axis is defined perpendicular to both X and Z, pointing upward (outward the road surface). Y coordinates of all points given in the roadway geometry file shown in Figure 62 are zero. This geometry with zero y coordinates indicates that the roadway has no vertical curvature. An increasing y coordinate indicates an upward slope, whereas a decreasing one indicates a downward slope.

The third column in a roadway geometry file contains the z coordinates of the points defining the road centerline. In the global coordinate system, Z axis is defined to originate from the global origin and point toward the right edge line in a direction perpendicular to the X axis, as shown in Figure 62 (X×Y=Z). All points shown in the example in Figure 61 and Figure 62 have nonnegative z coordinates.
Figure 62. An Illustration of Tarvip Coordinate System for a 100m Radius, Circular Right-Curve Roadway Geometry File.

The fourth and last column contains the superelevation of the roadway at each point. The superelevation is given in degrees, where a positive superelevation indicates a upward slope from left to right edge line (i.e. in a banked left-curve).

Note that Tarvip uses the roadway file selected by the user to determine the vehicle position and attitude along the roadway at any given point. The accuracy of the coordinates and vehicle attitude depends on the spatial resolution in a roadway file. If the point that Tarvip positions the vehicle falls between two points defined in a roadway file, Tarvip employs linear interpolation using the two closest points in the roadway geometry file. Therefore, the roadway between the two consecutive points is assumed to be straight in Tarvip. As such, for Tarvip, the roadway centerline is a collection of lines that connect each consecutive point similar to those in GPS roadway databases. A roadway can be defined by non-linearly spaced points. The straight sections of a roadway can be defined by the two points at either end of the straight section, but sections with curvature are best defined by higher number of data points along the centerline of the curve. The higher the number of points to define a roadway curvature, the higher the accuracy of vehicle position and attitude at the curve.
Sign Sheetinng Files

Sign sheeting files in Tarvip are the same as those given in ERGO model [13] in their content. The ERGO model was developed by Avery Dennison, and features six unused pavement marking materials measured in 1998. All sheeting material files in Tarvip are tab-delimited ASCII files, which can be opened with a text editor or a spreadsheet program.

The sign sheeting files are four dimensional matrices that comprise coefficient of retroreflection [cd/m²/lux] in the body of the matrices. The four dimensions are the four representative angles defined in Application Angular System [9].

All sign sheeting materials are located inside the “Sign Sheetings” folder in the Tarvip root folder. These files have a “.sgn” extension, and are best viewed by a spreadsheet program.

Figure 63 shows the file header section and part of the data in the body of a sample sign sheeting material viewed with a spreadsheet program.

![Figure 63](image)

The first line of the file consists of a general file description. There is no limit for the length of the first line string, where this line is separated from the second line by a carriage return. The second line consists of the number of data entries for each of the following angles defined according to the Application System, respectively: Alpha (α), Beta (β), Epsilon (ε), and Omega (ω). For an illustration of these angles, please refer to Figure 53 on page 56. Note that these numbers represent the number of angles in each array representing the four dimensions of the data matrix. The third, fourth, fifth, and...
sixth lines give the actual angles [degrees] for the aforementioned angles Alpha (\(\alpha\)), Beta (\(\beta\)), Epsilon (\(\varepsilon\)), and Omega (\(\omega_s\)), respectively. The number of entries in each row needs to match that given in the second line. For instance, the number of entries for Alpha (\(\alpha\)) needs to be the first entry in the second line (41 in the example shown in Figure 63), number of entries for the Beta (\(\beta\)) angle needs to be second entry (13 in the example shown in Figure 63), and so on. If more entries are made than declared in the second line for any of the angles, only the declared number of entries will be accounted for. The rest will be simply ignored. The data that forms the body of the data matrix starts at seventh line.

The number of entries in each row starting from the seventh line is the product of the last two entries in the second line (13×5=65 in the example shown in Figure 63). The numbers represent the coefficient of retroreflection in cd/m²/lx. The first entry of the data matrix corresponds to the set of four angles in the first column (rows 3, 4, 5, and 6, respectively). Thus, the entry 212.1962 [cd/m²/lx] represents the coefficient of retroreflection (\(R_A\)) for the set of angles (\(\alpha,\beta,\varepsilon,\omega_s\))=(0°,0°,-180°,-180°), which are all in first column. For the second entry in the data matrix (seventh row, second column, 212.2516 [cd/m²/lx] in the example), the only angle different from the first entry is \(\omega_s\), where the set of angles are (\(\alpha,\beta,\varepsilon,\omega_s\))=(0°,0°,-180°,-90°). Notice that none of the angles \(\alpha, \beta, \) and \(\varepsilon\) are changed from the first entry to the second, but the \(\omega_s\) is the next angle defined after (-180°) for \(\omega_s\) in row 6. Likewise, the third entry is for the set of angles (\(\alpha,\beta,\varepsilon,\omega_s\))=(0°,0°,-180°,-180°), the fourth entry is for the set of angles (\(\alpha,\beta,\varepsilon,\omega_s\))=(0°,0°,-180°,90°), and so on. There are 5 orientation angles declared in row 6, so after the fifth entry, the \(\omega_s\) angle rolls back to the first entry in row 6 (-180°), but this time the \(\varepsilon\) angle is advanced to the second declared angle in its corresponding row (5), which is (-150°). It is analogous to an odometer with digits from right to left with as many numbers in each digit as defined in row 2. The rightmost digit advances with every entry, whereas the second from right advances after the rightmost digit completes one turn. The third digit from right advances only after the second digit makes a complete turn, and so on. Remember that each row consists of as many entries as the product of the number of \(\varepsilon\) angles and the number of \(\omega_s\) angles (13×5=65 in the example shown in Figure 63). Thus, every row represents an advance in \(\beta\) angle. The \(\alpha\) angle advances to the next declared value after as many rows as the number of \(\beta\) angles (13 in the example shown in Figure 63).

**Pavement Marking and Road Surface Files**

There are several pavement marking and road surface reflectivity files that feature the coefficient of retroreflection [mcd/m²/lux] as a function of entrance and observation angles. The format of pavement marking (.pmm) and road surface files (.pm) is identical. However, one should not confuse the road surface files in the context of headlamp illumination and in the context of overhead lighting illumination. The reflectivity of the roadway surface under overhead illumination is rather complex, and Tarvip is undergoing a module development for overhead luminaires.
Figure 64 shows a screenshot of a pavement marking retroreflectivity sample file viewed with a spreadsheet program. Pavement marking and road surface retroreflectivity files are tab-delimited ASCII files.

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The third row thereby consists of the entrance angles [degrees]. The first entry is an empty string in the third row (only a tab character). This is intentionally left blank to maintain the column header position for each column, which represent the entrance angles. If not left blank, Tarvip will still process the file as intended and without errors.
however, when the file is opened with a text editor or spreadsheet, the columns will not line up with the corresponding entrance angles as column headers.

Starting from row four, the first entry is the observation angle [degrees] for that row, and the remaining values constitute the body of the matrix that represent the coefficient of retroreflection [mcd/m²/lx]. Note that for sign sheeting files, the unit is cd/m²/lx, not mcd/m²/lx. The observation and entrance angles do not need to be uniformly spaced.

Headlamp Files

Headlamp files are obtained from various sources in Tarvip. Some are characterized by the researchers in the lab throughout the development of many visibility models, and some are obtained from headlamp testing laboratories. They are two-dimensional matrices with luminous intensity [cd] values comprising the body of the matrix, and the vertical and horizontal beam angles comprise the two dimensions. Most headlamps are measured on a triaxial goniometer by adjusting the $\beta_1$ and $\beta_2$ angles (CIE goniometric system). Thus, horizontal and vertical angle calculations should be made accordingly.

Figure 65 shows a screenshot of a sample headlamp luminous intensity photometric spatial distribution file. Headlamp files are tab-delimited ASCII files.

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Figure 65. A screenshot of a sample headlamp luminous intensity photometric spatial distribution file.

The first row of the file consists of a short description of the headlamp file. It needs to be a single string without delimiters, and each row is separated from the succeeding row by a carriage return.
The second row declares the number of horizontal beam angles and the number of vertical beam angles, respectively. The third entry in row 2 is reserved for future use, and is not being used by the current version of Tarvip.

The third row consists of the horizontal beam angles [degrees]. The first entry is an empty string, so that the column headers line up with the corresponding columns in the two dimensional matrix form. The first entry does not need to be empty for Tarvip to process the file, nonetheless, when viewed with a text editor or a spreadsheet program, the column headers would be shifted left and may become confusing. A negative horizontal beam angle corresponds to the left half of the beam space, whereas a positive horizontal beam angle corresponds to the right half of the beam space from the headlamp point of view. A horizontal beam angle of zero corresponds to the vertical centerline (V-V line) of the field of view. The horizontal beam angles do not need to be uniformly spaced, in that, the spatial resolution can be different across the beam space.

The first column after the third row consists of vertical beam angles [degrees]. Starting from the fourth row, the first entry is the vertical beam angle [degrees], and the remainder of the row is the luminous intensity values [cd] for that vertical beam angle, and the corresponding horizontal beam angle directly above the entry in row 3. A positive vertical beam angle corresponds to the upper half the beam space, whereas a negative vertical beam angle corresponds to the lower half of the beam space from the headlamp point of view. A vertical beam angle of zero corresponds to the horizontal centerline (H-H line) of the field of view. The vertical beam angles do not need to be uniformly spaced, in that, the spatial resolution can be different across the beam space.

Tarvip features a headlamp beam distribution plot (iso-candela plot) as shown in Figure 20 on page 22. Tarvip also features an illuminance distribution plot on the road surface (iso-lux plot) as shown in Figure 33 on page 35.
REFERENCES


GLOSSARY OF TERMS

Datum Axis: An axis defined on the surface plane of a retroreflective object, the direction of which is usually indicated with a mark referred to as the datum mark. Datum axis is perpendicular to the reference axis.

Reference Axis: An imaginary axis perpendicular to the surface plane of a retroreflective object.

SST: Sheeting Selection Tool for Traffic Signs developed as a part of NCHRP Project 4-29 entitled “Selection of Sheeting Materials to Optimize Sign Performance”

Tarvip: Target Visibility Predictor