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Retroreflection 시스템의 다체형 회전체의 변환모형에 관한 연구

A Conversion Model of the Various Rotational Body Shapes in the Retroreflection System

박 범*
Peom Park

ABSTRACT

This study is for the development of a model to convert a set of rotational bodies into the new theoretical design for the equivalent volume transformation between the geometric angles and the specific intensity in the traffic control material system, called the retroreflection system to guide the night driver for safety. There are five new models theoretically identified with the concept of the retroreflective performance and human environment of the night driver. The new system can evaluate the design in retroreflective transportation material system with better performance, safety, and economy.

국문요약

본 논문은 야간 운전자들의 안전을 위한 교통안전제어 시설체계인 주행안내 반사체시스템(Retroreflector)에 있어서 기하도형각과 명확도 사이에 성량 변형이 등가적인 새로운 이론적 설계에 의한 다체형 회전체의 전환 모형에 관한 연구이다. 야간운전자의 주행안내 반사체 성능과 운전자 환경을 고려하여 이론적으로 동질적인 다섯가지 모형을 검증한다. 이 모형은 주행안내 반사체 교통체계를 설계하는데 좀더 나은 운전성과, 안전, 그리고 경제성 등을 고려하여 평가할 수 있을 것이다.

1. Introduction

This study is for the development of a model to convert a set of rotational bodies into another set of selected rotational bodies with equal volumes, that concerns the new theoretical design for the equiva-

* 아주대학교 산업공학과

lent volume transformation between the geometric angles and the specific intensity in the traffic control material system, called the retroreflection system to guide the night driver for safety. The initial volume shape, parabola type, can be formed with observation angle and specific intensity in each entrance angle case of the retroreflection system. Then, the initial model shape can be converted to the another theoretical model shape with the equivalent volume transformation algorithms.

There are five new theoretical models, the flat-cylinder shape, the trapezoid-1 shape, the trapezoid-2 shape, the bell shape, and the volcano-crater shape, which are all identified by equalizing the same volume given by the particular retroreflector data file. These five models are developed theoretically with the concept of the retroreflective performance and the human environment of the night driver.

This model for the traffic control material system is considered a user-friendly interactive system and the reliable human performance with the several other built-in factors, such as reliability, quality, efficiency, and human aspects(Robinson, 1993; Alloum, 1993). The new output matrix can be used for the simulation of the performance evaluation of the traffic control material system with reflector performance evaluation program. In evaluating the alternatives, the best model can be chosen for the most performable traffic control material system.

This study concerns the design of the system as follows(Park, 1988; Hunter, 1992). First, the new models are developed with the considering factors to be related with the reflection system. The new models should be reliable to the human performance and the traffic control material system. Second, a conversion model is built in which users can take a regular specific intensity curve and reshape the five new model shapes. These new model shapes are subject to the equal volume in a given entrance angle case. Third, this user-friendly model is independent from the reflector performance evaluation program, but it is designed to be able to use the same input and output data files as that evaluation program does. Fourth, a new data matrix of the specific intensity sheeting reflector with a new model shape to evaluate the reflector performance is created. Then additionally, after evaluating the new models, the value of threshold multiples among the initial type and the new theoretical models are compared in order to find the better system design for performance, safety, and economy in the traffic control material system.

2. Retroreflection and Luminous Intensity

Retroreflection is defined as the reflection in which radiation is returned in directions close to the direction from which it came, this property being maintained over a wide variations of the direction of the incident radiation. The retroreflection can be achieved by retroreflectors. The retroreflectors may be a device or surface from which most of the reflected radiation is retroreflected (Cook, 1969; Johnson, 1982).

Illuminance(E) is the ratio of the luminous flux (o) to the area of the surface(A), when the latter is uniformly illuminated(E=o/A).

The extensive use of retroreflectors on highways requires their performance to be evaluated in terms of how much light reaches the observer(driver's eyes) and also how many times it is greater than the minimum amount of light required to detect an object. The phenomenon in night driving is, the light beam emitted by the vehicle head lamps hits the reflectors fixed on the road in front of the vehicle, gets reflected by the reflectors and received by the driver. The amount of light received by the reflector depends upon the following factors :

- the type of beam used and its efficiency,
- the angle at which the beam hits the reflector,

taking into account the angular misalignment of the beams,

- the distance from the source to the reflector,
- the atmospheric transmissivity.

To find the reflector intensity, the type of reflector used also should be considered. The reflector may be either beaded sheeting material or prismatic reflector material. The reflector intensity is computed for a combination of the entrance angles and the observation angles(ASTM, 1982; CIE, 1982; Venable, 1982). The reflector matrix is given in the form of two-dimension with the entrance angles as the column elements and the observation angles as the row elements. To compute the reflector intensity for a combination of the entrance angles and the observation angles, a two-dimensional linear interpolation technique is used.

3. Conversion Model of Retroreflective Transformation

Conversion Model of Retroreflective Transformation(CMRT) is the equivalent volume shape transformation and matrix generation used to perform the equivalent volume transformation of the retroreflector specific intensity on the five theoretical model shapes, such as the flat-cylinder shape, the trapezoid-1 shape, the trapezoid-2 shape, the bell shape, and the volcano crater shape(Fig. 1). The original shape, which is formed by the initial model shape of the retroreflector, can be transformed into the new five models. Then the new matrix is generated by the new theoretical transformation algorithm. These five theoretical models can be simulated with the retroreflector performance evaluation program. The best model shape with the most performable retroreflection can be developed for night drivers.

For this traffic control material system, some of the major characteristics of the system, that are considered desirably and which are included in this model, are reliability, understandability, efficiency, structuredness, consistency, robustness, testability, human factors, modifiability, and portability.

It is necessary to realize that these characteristics may not be measurable and, therefore, may not provide a means for controlling the quality of the product, that is, the system output. From an ergonomics' point of view, the system was designed for ease of use. This term is to a high degree synonymous with user-friendliness and does include the following design qualities.

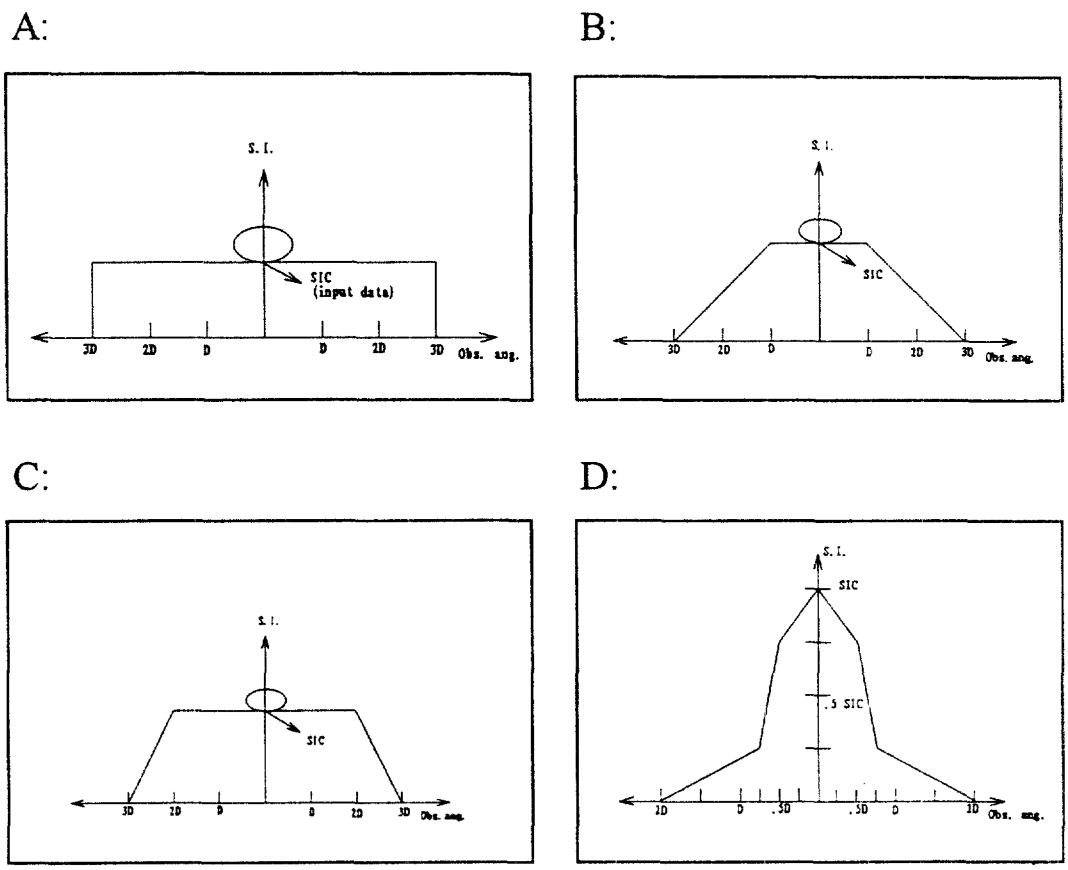
1) Comprehensive-the system should be understandable (plain simple English) and the flow of information and commands should be logical, orderly and meaningful.
2) Self-explanatory-steps should be obvious or clarified by the system itself.
3) Forgiving-the system should be tolerant of human errors.
4) Consistent-the system should look and act uniform.
5) Acknowledging-the system should acknowledge all actions and give in-progress messages during long processing periods.
6) Responsive-the system should give error messages, allow immediate return to the point of origin, or permit immediate exit if desired.

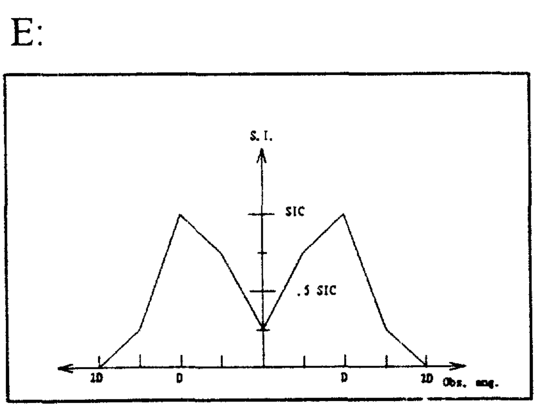
Then the several human factors requirements are considered in this study.

1) The interaction with the software should be simple and interesting.
2) Human errors during interaction should be so handled as to take corrective action.
3) There should be some kind of feed back from the computer to the user for each interaction.

This system model is built with a following system design approach :

1) Using the same data in the use of retroreflection system, the total volume of the Specific Intensity(cd/fc) times entrance angle(degree) is calculated. Data files are CIL-23, CIL-80, CIL-120, SILVER, STIMRPM33, RFLX-





A: Cylinder Shape

B: Trapezoid-1 Shape

C: Trapezoid-2 Shape

D: Bell Shape

E: Volcano Shape

Fig. 1 Theoretical Conversion Model Shapes

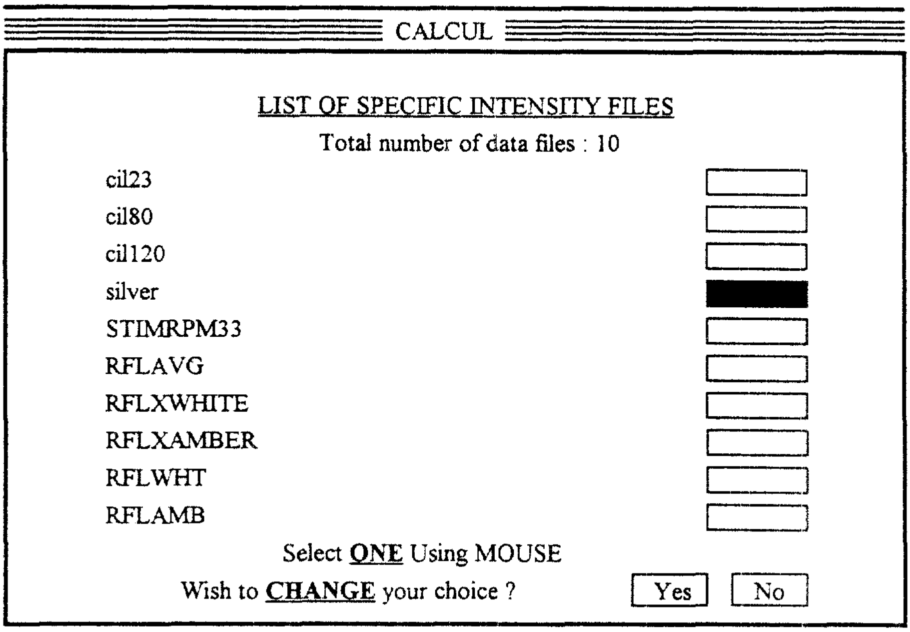


Fig. 2 List of Specific Intensity Files

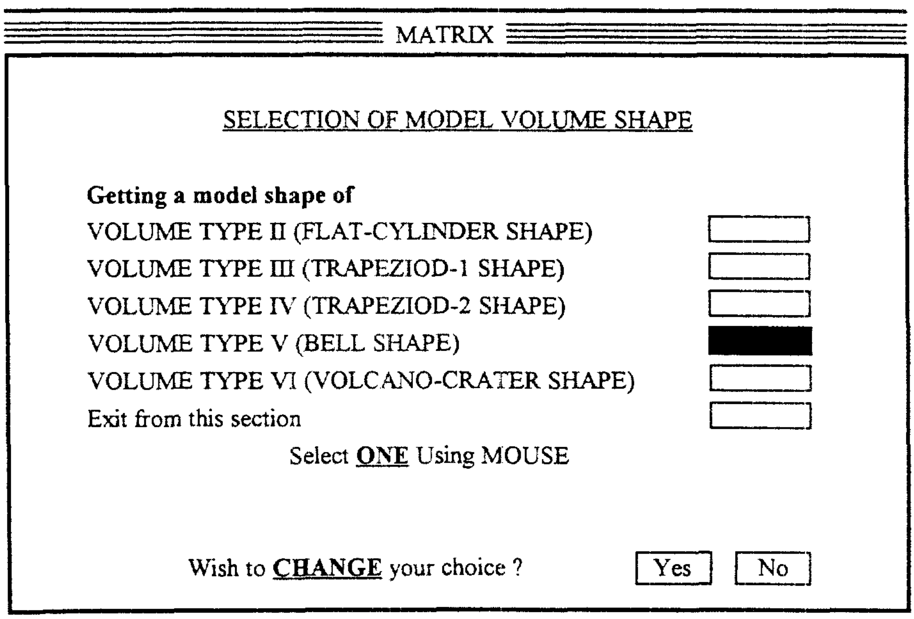


Fig. 3 Conversion Model Shapes of Equivalent Transformation

WHITE, RFLXAMBER, RFLWHITE, RFLAMBER, and RFLAVERAGE(Fig. 2).

2) Develop the new model shape, and draw the graphics to analyze the theoretical volume calculation. New model volume shapes are as follows : Flat-cylinder shape, Trapezoid-1 shape, Trapezoid-2 shape, Bell shape, and Volcano-crater shape(Fig. 3).
3) Build a theoretical equation of the new model volume shape which amount is equal to the initial total volume in special Entrance angle.
4) Get a output including Maximum Specific Intensity Height(MH) in each observation angle and Indicated Observation angle (O) with the given certain Specific Intensity Height.
5) Generate a new matrix(sheeting reflector data) with each Entrance angle output value.
6) Simulate for the performance evaluation : ① create the new sheeting reflector data; ② select the menu : Results threshold multiples; ③ get output for threshold multiples Table and Graphics.
7) Compare the threshold multiples output value with the initial shape and the new model shape.
8) Make a decision in accordance with traffic control efficiency and driver's safety.

There are several consideration factors of evidence that visual performance is generally better if there is a reasonable level of general illumination at this traffic control material system(Park, 1988; Proctor, 1994).

- Luminance Ratio : The luminance ratio is the ratio of the luminance of a given traffic control material to the surrounding area. By the ratio recommended by the IES for various areas related to the visual task (IES Lighting Handbook, 1972), the ratio for the task and its adjacent surroundings is given as 3 : 1. However at the traffic system environment at night, the ratio is bigger than this value.
- Reflectance : The distribution of light within the traffic environment is not only a function of the amount of light and the distance of the light source, but is also influenced by the reflectance of the traffic control material. Tied in with reflection is the concept of the utilization coefficient which is the percentage of light that is reflected, collectively, by the surfaces in that material. The influence of reflection on the utilization coefficient is illustrated by the size of surface, the color of material, and the shape of material.
- Glare : Glare is produced by brightness within the field of vision that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or less in visual performance and visibility. Direct glare is caused by light sources in the field of view, and reflected or specular glare is caused by reflections of high brightness from polished or glossy surfaces that are reflected toward an individual. Variations in the level of glare have been categorized in terms of three types(McCormick, 1982), as follows : (1) discomfort glare that produces discomfort, but does not necessarily interfere with visual performance or visibility; (2) disability glare that reduces visual performance and visibility and often is accompanied by discomfort; and finally (3) blinding glare that is so intense that for an appreciable length of the time after it has been removed no object can be seen(IES Nomenclature Committee, 1979).

4. Results and Analysis

The typical volume shape of the specific intensity in each point of the observation angle is actually a kind of parabola type(Table 1). There are five new theoretical models, the flat-cylinder shape, the trapezoid-1 shape, the trapezoid-2 shape, the bell shape, and the volcano-crater shape, which are identified by equalizing the same volume given from the particular retroreflector data file. New

Table 1 Volume Calcuration Table-Sheeting Refl. -cil23 volume=spec. int, *Obs. Angle(cd/fc*degree∧2)

Obs. ang. (deg)	0.0	10.0	20.0	30.0	40.0	50.0
0.01	0.009	0.008	0.006	0.005	0.003	0.001
0.10	0.631	0.602	0.470	0.317	0.184	0.094
0.20	1.331	1.257	1.020	0.687	0.402	0.208
0.30	1.777	1.690	1.394	0.963	0.576	0.306
0.40	1.939	1.857	1.572	1.125	0.695	0.380
0.50	1.876	1.811	1.590	1.194	0.767	0.430
0.60	1.702	1.658	1.521	1.206	0.809	0.465
0.70	1.536	1.511	1.445	1.210	0.842	0.491
0.80	1.454	1.437	1.415	1.237	0.881	0.516
0.90	1.473	1.461	1.450	1.293	0.937	0.549
1.00	1.570	1.550	1.530	1.374	1.006	1.591
1.40	7.083	6.961	6.692	6.212	4.927	3.189
1.80	6.420	6.302	6.068	5.781	4.928	3.572
2.00	6.189	6.082	5.891	5.653	4.881	3.606
2.20	6.024	5.932	5.774	5.630	4.917	3.657
2.40	5.788	5.701	5.582	5.551	4.946	3.743
2.60	5.494	5.408	5.317	5.385	4.909	3.825
2.80	5.199	5.124	5.052	5.198	4.825	3.866
3.00	4.918	4.852	4.805	5.017	4.735	3.867
3.20	4.638	4.578	4.555	4.832	4.647	3.853
3.40	4.362	4.308	4.298	4.628	4.549	3.841
3.60	4.103	4.055	4.051	4.414	4.432	3.823
3.80	3.866	3.822	3.815	4.201	4.304	3.793
4.00	3.647	3.605	3.591	3.990	4.169	3.753
4.50	8.365	8.231	8.205	9.273	10.099	9.077
5.00	7.402	7.223	7.147	8.265	9.535	8.607
5.50	6.687	6.213	6.257	7.328	8.812	8.154
6.00	6.042	5.294	5.684	6.447	8.210	7.624
6.50	5.393	4.627	5.197	5.638	7.670	7.160
7.00	4.872	4.045	4.660	4.977	7.204	6.727
7.50	4.380	3.549	4.210	4.380	6.805	6.397
8.00	3.953	3.421	3.795	3.781	6.378	6.169
9.00	3.324	2.749	3.021	2.858	5.659	5.659
9.50	3.079	2.906	2.906	2.906	5.228	5.228
10.00	3.063	3.063	3.063	3.063	4.898	4.898

theoretical model algorithms are developed with characteristics of these new model shapes for the most performance and the most cost effectiveness.

The theoretical shape of the equalized volume with the specific intensity in each observation angle represents how to diffuse the specific intensity in each observation angle.

1) The flat-cylinder shape represents a diffuse suface such as a mat ceramic surface or a piece of paper. The specific intensity is equal at each observation point within the range of the specific observation angle case. Light is diffused with the same value of the specific intensity in each different observation angle.

2) In the trapezoid shape(Table 2 & 3), light is diffused with the same height of the specific intensity within a range, and then the x value is decreased in another ranges of the observation angle.

Table 2 Specific Intencity Matrix-Sheeting Refl.-Trape 1 Reflector Specific Intensity in cd/fc/sq.ft

Obs. ang. (deg)	0.0	10.0	20.0	30.0	40.0	50.0
0.00	6.500	6.500	6.500	6.500	6.500	6.500
0.20	6.500	6.500	6.500	6.500	6.500	6.500
0.60	6.500	6.500	6.500	6.500	6.500	6.500
1.00	6.500	6.500	6.500	6.500	6.500	6.500
1.20	6.500	6.500	6.500	6.500	6.500	6.500
1.60	6.036	6.036	6.036	5.750	6.036	5.750
2.00	5.107	5.107	5.107	4.750	5.107	4.750
2.20	4.643	4.643	4.643	4.250	4.643	4.250
2.60	3.174	3.174	3.174	3.250	3.174	3.250
3.00	2.786	2.786	2.786	2.250	2.786	2.250
3.20	2.321	2.321	2.321	1.750	2.321	1.750
3.60	1.393	1.393	1.393	0.750	1.393	0.750
4.00	0.464	0.464	0.464	0.000	0.464	0.000
4.20	0.000	0.000	0.000	0.000	0.000	0.000

Table 3 Specific Intencity Matrix-Sheeting Refl.-Trape 2 Reflector Specific Intensity in cd/fc/sq.ft

Obs. ang. (deg)	0.0	10.0	20.0	30.0	40.0	50.0
0.00	6.500	6.500	6.500	6.500	6.500	6.500
0.20	6.500	6.500	6.500	6.500	6.500	6.500
0.60	6.500	6.500	6.500	6.500	6.500	6.500
1.00	6.500	6.500	6.500	6.500	6.500	6.500
1.20	6.500	6.500	6.500	6.500	6.500	6.500
1.60	6.500	6.500	6.500	6.500	6.500	6.500
2.00	6.500	6.500	6.500	6.500	6.500	6.500
2.20	6.500	6.500	6.500	6.500	6.500	6.500
2.60	5.417	4.136	4.136	4.136	4.136	4.136
3.00	3.250	1.773	1.773	1.773	1.773	1.773
3.20	2.167	0.591	0.591	0.591	0.591	0.591
3.60	0.000	0.000	0.000	0.000	0.000	0.000

3) In the bell shape(Table 4) and the volcano-crater shape(Table 5), light is diffused with the

value of the specific intensity in each specific point of the observation angle. It is possible to design the theoretical shape by equalizing the total volume to the original type to take a certain point of the observation angle.

The new model algorithms are developed while taking into account the characteristics mentioned above, and are represented and validated in the figures and equations(Park, 1988).

Table 4 Specific Intencity Matrix-Sheeting Refl.-Bell Reflector Specific Intensity in cd/fc/sq.ft

Obs. ang. (deg)	0.0	10.0	20.0	30.0	40.0	50.0
0.00	6.500	6.500	6.500	6.500	6.500	6.500
0.60	6.000	5.958	5.958	5.958	6.000	5.958
1.20	5.500	5.417	5.417	5.417	5.500	5.417
1.80	5.000	4.333	4.333	4.333	5.000	4.333
2.40	2.275	2.167	2.167	2.167	2.275	2.167
3.00	1.457	1.444	1.444	1.444	1.457	1.444
3.60	1.233	1.204	1.204	1.204	1.233	1.204
3.90	1.121	1.083	1.083	1.083	1.121	1.083
4.20	1.009	0.963	0.963	0.963	1.009	0.963
4.80	0.784	0.722	0.722	0.722	0.784	0.722
5.40	0.560	0.481	0.481	0.481	0.560	0.481
6.00	0.336	0.241	0.241	0.241	0.336	0.241
6.60	0.112	0.000	0.000	0.000	0.112	0.000
6.90	0.000	0.000	0.000	0.000	0.000	0.000

Table 5 Specific Intencity Matrix-Sheeting Refl.-Volcano Reflector Specific Intensity in cd/fc/sq.ft

Obs. ang. (deg)	0.0	10.0	20.0	30.0	40.0	50.0
0.00	1.625	1.625	1.625	1.625	1.625	1.625
0.20	2.167	2.167	2.167	2.167	2.167	2.216
0.60	3.250	3.250	3.250	3.250	3.250	3.398
1.00	4.333	4.333	4.333	4.333	4.333	4.580
1.20	5.023	5.038	5.038	5.038	5.023	5.200
1.60	5.614	5.688	5.688	5.688	5.614	5.850
2.00	6.205	6.338	6.338	6.338	6.205	6.500
2.20	6.500	6.057	6.057	6.057	6.500	5.525
2.60	4.727	4.284	4.284	4.284	4.727	3.575
3.00	2.955	2.511	2.511	2.511	2.955	1.625
3.20	2.068	1.625	1.625	1.625	2.068	1.300
3.60	1.182	0.975	0.975	0.975	1.182	0.650
4.00	0.591	0.325	0.325	0.325	0.591	0.000
4.20	0.295	0.000	0.000	0.000	0.295	0.000

5. Conclusions

This model is for the transformation of the new theoretical model volume shapes in the reflection system with the same data file as the performance evaluation program used, but the system is independent of the performance evaluation program. It is possible to convert the initial model shape to another theoretical model, for better performance in the traffic control material system, that is the retroreflrector. The new output matrix can be used with the simulation of performance evaluation program.

It is a very user-friendly transformation converting model and can be used with an interactive system in order to deal with the research in the traffic control material system. This model development is also oriented to quality, reliability, efficiency, and human factors.

After evaluating the performance, the output value and threshold multiples can be compared between the initial model and the new theoretical model shape. Therefore, evaluating the new systems can bring about better design in this transportation material systems, with better performance, safety, and economy.

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