U.S. Department
of Transportation
**Research and
Special Programs
Administration**

Evaluation of Retroreflective Markings to Increase Rail Car Conspicuity

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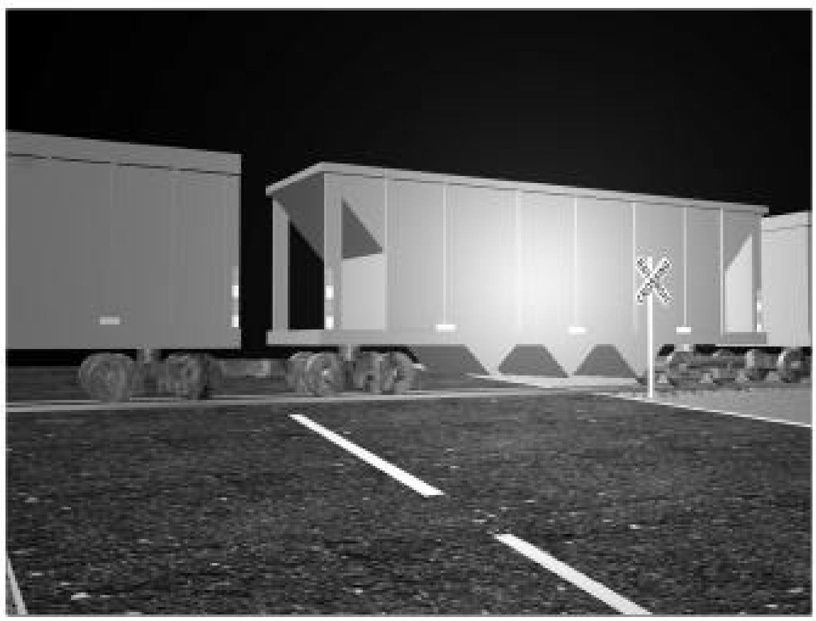

Safety of Highway-Railroad Grade Crossings

DOT-VNTSC-RR897-PM-98-22

Project Memorandum
October 1998

always expect a train

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
October 1998

3. REPORT TYPE & DATES COVERED
Final Report
July 28, 1993 - February 2, 1994

4. TITLE AND SUBTITLE
Evaluation of Retroreflective Markings To Increase Rail Car Conspicuity -
Safety of Highway-Railroad Grade Crossings

5. FUNDING NUMBERS
R9071/RR997

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-RR897-PM-98-22

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Research and Special Projects Administration
Volpe National Transportation Systems Center
55 Broadway Street
Cambridge, MA 02142-1093

10. SPONSORING OR MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
*Safety of Highway-Railroad Grade Crossings Series

12a. DISTRIBUTION/AVAILABILITY
This document is available to the public through the National Technical Information Service, Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
The purpose of this study was to develop guidelines and recommendations for the design of retroreflective marking systems to enhance the conspicuity of rail cars at night. Three methods were used to generate and evaluate the marking systems for a standard hopper car. First, a group of human factors and transportation engineers used the Nominal Group Technique to generate candidate retroreflective marking systems. Secondly, two panels, one comprised of individuals with expertise in the area of conspicuity markings and one without this expertise, made subjective judgements as to the effectiveness of the marking systems. Finally, a computer controlled real-time experiment was conducted to establish the relative performance of the systems based on detection and recognition times.

The evaluations indicated that any of the retroreflective systems tested improved rail car conspicuity when compared to a nonreflective marking. The data suggest that bright colors distributed to give an indication of the size or shape of the rail car were most effective, and distributions that concentrated the markings along the lower side of the car were less effective, regardless of the color pattern. For detection the fluorescent yellow was the most effective color pattern regardless of the distribution pattern. However, for recognition, fluorescent yellow or red, i.e., single color patterns, were more effective than a color pattern made up of red and white. Additional studies should be performed to determine the dynamic effectiveness of different color and distribution patterns when fitted to different types of rail cars.

14. SUBJECT TERMS
Conspicuity, Grade Crossings, Normal Group Technique, Rail Cars, Reflectorization

15. NUMBER OF PAGES
228

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

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EXECUTIVE SUMMARY

Overview

This study focused on developing guidelines and recommendations for the design of retroreflective marking systems to enhance the nighttime conspicuity of rail cars. Several candidate marking systems were generated and these systems provided the basis to identify and evaluate the design parameters important to rail car marking systems. The research included five principle tasks:

1. A review of pertinent highway and rail safety literature to identify significant visual conspicuity research as well as previous experience with retroreflective materials, and marking systems;

2. The generation of rail car marking designs that would enhance the detection and recognition of rail cars at night;

3. A subjective assessment by a panel of transportation experts of the effectiveness of the candidate designs;

4. A subjective assessment by a panel of transportation novices of the effectiveness of the candidate designs; and

5. An objective and quantitative assessment of a set of rail car marking systems with those attributes deemed most important by the subjective panels.

In the first task, the literature was reviewed for information about previous experience with rail car conspicuity marking systems, related highway vehicle conspicuity research; the physical attributes that affect the conspicuity of trains or highway trucks, and field and laboratory methodologies that have been employed to evaluate conspicuity.

In the second task, a "nominal" group of five human factors and transportation experts generated 25 candidate retroreflective marking systems that they believed were capable of enhancing the conspicuity of rail cars. The participants in this task reviewed and discussed the merits of each candidate until a subset of eight marking systems were identified as being worthy of further evaluation.

In the third task, a questionnaire was developed and administered to 44 individuals with expertise in the area of conspicuity markings. These individuals were asked to make their assessment of the effectiveness of the candidate marking systems based on color photographs of the markings displayed on the sides of scale models of open top hopper cars. The panel members also completed a semantic differentiation assessment to provide insight into the marking systems' attributes that they believed important.

For the fourth task, a novice panel technique was used to further evaluate the designs generated in the second task. The novice panel consisted of 51 ordinary licensed drivers. These "novices" were administered the same questionnaire as the expert panel (Task 3), except the novices viewed the actual scale models of the rail cars under simulated nighttime conditions. Illumination was provided by simulated automobile head lights positioned a scale 400-500 feet from the models.

In the final task, an objective evaluation of nine marking systems was performed to identify and assess attributes important to effectiveness of rail car marking systems. The nine systems were generated based on the findings of the subjective questionnaires administered to the expert and novice panels. Subjects viewed a series of color slides in a nighttime laboratory simulation of the visual environment of a passive rail-highway grade crossing to establish detection and recognition times and distances for each marking system. Each slide in a series was viewed for five seconds. The first slide of a series presented the rail car image size as if viewed at 5000 feet and each succeeding slide simulated moving the subject 240 feet closer to the marked rail car. The subjects indicated when they first detected the rail car and also when they were able to correctly identify the marking applied to the car. Each subject randomly viewed each series of slides four times. The data collected were used to compute descriptive and inferential statistics for each of the marking systems. These statistics provided a quantitative assessment of the relative performance of the marking systems.

Results of the Literature Review

The literature review provided guidance in the selection and evaluation of the marking systems that are the subject of this study. The key issues revealed by the review are:

1. The application of retroreflective materials to rail cars and highway trucks is an effective means to enhance the nighttime conspicuity of these vehicles.

2. Retroreflective materials are available which have the durability and brightness to make retroreflective marking systems a practical means of enhancing the conspicuity of rail cars.

3. There is a lack of consensus in the literature (and among the rail and highway communities) as to what the optimal marking system for rail cars should be.

4. The key attributes for rail car marking systems are:
   - coefficient of reflectivity;
   - color pattern;

- contrast between the color pattern and the color of the rail car;
- amount (area) of material used;
- geometric shape used for the marking;
- profile of the rail car; and
- distribution pattern of the marking on the car side.

5. Distribution patterns that outline the shape of a large object (i.e., a rail car) enhance recognition of the object.

6. If a fixed amount of material is to be located near the lower edge of the object, a few larger markings are superior to many smaller markings.

7. Two contrasting colors improve the daytime conspicuity.

8. Geometric shapes of high reflectance material are difficult to distinguish from one another (in other words, individual marker shape is not critical).

9. If shape coding is necessary, discrimination is enhanced when only the border is reflectorized.

10. Fluorescent colors have superior conspicuity because they do not occur naturally.

11. Red|White color patterns are often used for highway related marking systems because of their association with danger and regulation messages.

Results of the Nominal Group

The five expert nominal group was asked to generate candidate rail car marking systems using one to eight colors of commercially available diamond grade retroreflective sheeting. This sheeting was chosen because of its durability and high coefficient of retroreflection. The nominal group's achievements were:

1. Twenty-five candidate retroreflective marking systems were generated.

2. Eight of these marking systems were selected for further evaluation based on group consensus. From the eight colors available, these eight systems used only fluorescent yellow, red, white, and orange. Fluorescent orange, yellow, green, and blue were not used. Three distribution patterns were defined — (1) a fixed amount of material concentrated in a relatively small area; (2) a fixed amount of material outlining the shape of the rail car; and (3) a fixed amount of material spaced uniformly over a relatively large area of the rail car side.

3. Two systems replicating retroreflecting systems currently in use — one on rail cars and another on large highway truck trailers — were added to the set of candidate marking systems for further evaluation.

4. Nonreflective Association of American Railroads (AAR) standard markings were added to the set to provide a baseline for comparison.

Results of the Subjective Evaluation

Expert and novice panels were administered similar questionnaire surveys to solicit subjective input on the effectiveness of the 11 marking systems resulting form the nominal group procedure. The results indicated that:

1. The expert panel judged the Yellow Fence, the Yellow Outline, and the Yellow Dash to be the most effective marking systems.

2. The novice panel judged the Yellow Fence, the Red-White Sawtooth, and the Yellow Outline to be the most effective marking systems.

3. The expert panel judged the Red-White Chevrons, the Red|White Field Test, and the Red Crossbucks to be the least effective marking systems.

4. The novice panel judged the Yellow Dash and the Red/White Diamonds in Bars to be the least effective marking systems.

5. The expert panel selected the Yellow Fence 60% of the time, the Yellow Outline 20% of the time, and the Yellow Dash 20% of the time as the most preferred for all of the semantic differential scaling questions.

6. The novice panel selected the Yellow Outline 40% of the time, the Red-White Sawtooth 40% of the time, the Red Crossbucks 10% of the time, and the Red-White Chevrons 10% of the time as the most preferred for all semantic differential scaling questions.

7. Both panels ranked the Standard Car with AAR markings last and chose it as the least preferred for all semantic differential scaling questions.

8. Three color patterns — fluorescent yellow, red|white, and red — were selected to generate marking systems for the objective evaluation.

9. Three distribution patterns were selected to generate marking systems for the objective evaluation. The first pattern concentrated the retroreflective material along the side sill

(named the dash), the second distributed the material as vertical stripes over a relatively large area of the car side (named the fence), and the third outlined the shape of the rail car (named the field test).

10. Nine marking systems were generated by combining the three color patterns and three distribution patterns.

11. The AAR standard car was again included as a tenth marking system to be used as a baseline.

Results of the Objective Evaluation

A controlled human factors laboratory experiment was designed and administered to 34 driver subjects to assess the performance of the 11 marking systems resulting from the subjective evaluations. The measures of performance included detection time and distance, recognition time and distance, and recognition error rate.

In the following discussion, a marking system with small or low mean time to detection or recognition (or the equivalent large or high mean distance to detection or recognition) is referred to as having performed the best or better than another marking system with which it is being compared. The results of this experiment indicate:

1. Relative to the Standard Car with AAR markings, all of the retroreflective marking systems performed very well relative to mean time to detection and mean time to recognition.

2. For mean time to detection, the Yellow Field Test, the Red|White Fence, and the Red Field Test performed the best (statistically, there was no difference between the Red Field Test and the Red Fence).

3. For mean time to recognition, the Yellow Field Test, the Red Fence, Red Field Test, and the Red|White Fence performed the best.

4. For mean time to detection, the Yellow Dash, the Red|White Dash, and the Red|White Field Test performed the worst. (Statistically, there was no difference between the Yellow Dash and the Red Dash nor was there any difference between the Red/White Field Test, and the Red/White Dash.)

5. For mean time to recognition, the Red/White Field Test, the Yellow Fence, and the Red|White Dash, performed the worst. (Statistically, there was no difference between the Yellow Dash and the Red|White Field Test and the Yellow Fence.

6. In general, the retroreflective marking systems with the least recognition errors also had the better mean times to recognition.

7. For mean time to detection, the yellow, red, and red|white color patterns were ranked first, second, and third, respectively and the differences were statistically significant.

8. For mean time to recognition, the yellow, red, and red|white color patterns were ranked first, second, and third, respectively. (Statistically, there was no difference between the yellow and red color patterns.)

9. For mean time to detection, the fence, the field test, and the dash distribution patterns were ranked first, second, and third, respectively. (Statistically, there was no difference between the fence and the field test distribution patterns.)

10. For mean time to recognition, the fence, the field test, and the dash distribution patterns were ranked first, second, and third, respectively. (Statistically, there was no difference between the fence and the field test distribution patterns.)

Conclusions

Comparing all of the research results, the following conclusions are supported about rail car marking systems with a fixed amount of diamond grade retroreflective materials that had been attached to scale models of black open top hopper cars. These systems were photographed under ideal simulated lighting and viewing conditions and the photographs were used to evaluate the marking systems in a laboratory setting.

1. For each of the measures of performance, all of the retroreflective marking systems were much more effective than the standard white paint AAR markings.

2. The combination of color pattern and distribution pattern contributed more to the effectiveness of the marking systems than did either the color pattern or the distribution pattern alone.

3. Distribution patterns that outlined the shape or that spaced the retroreflective material over a relatively large area of the rail car side were superior to a distribution that concentrated the retroreflective material along the bottom of the car.

Recommended Design Features

Based on the outcome of this study, it is recommended that marking systems intended to enhance the detection and recognition conspicuity of rail cars in any future experiments or studies have the following design features:

1. Fluorescent yellow color;

2. A distribution pattern that indicates the profile (i.e., size and shape) of the rail car; and

3. Simple rectangular shapes to establish the distribution pattern.

Future Research

To expand and complement this study of limited scope, it is suggested that the following research be considered:

1. Test the effectiveness of retroreflective marking systems when there is relative motion between the subject and the train.

2. Evaluate the effects of different distribution patterns required by different rail car profiles (i.e., box and hopper cars as compared to intermodal flat cars or tank cars).

3. Compare the effectiveness of other color patterns with high coefficients of retro-reflection with the fluorescent yellow, red|white, and red colors used in this study.

4. Determine the minimum width for different amounts (square inches) of retroreflective material to maintain a very conservative detection distance under "real world" conditions.

5. Determine the maximum number of strips into which the total amount of material can be divided.

6. Test the effectiveness of retroreflective marking systems with "nominal" attenuation due to atmospheric and windshield conditions.

7. Evaluate the effects of different contrast ratios between the reflectorization colors and the colors of freight cars.

8. Determine the maximum approach angles and profile angles for which retroreflective marking systems retain their effectiveness.

9. Investigate the possible conflicts in color codes as specified in the *Manual on Uniform Traffic Control Devices for Streets and Highways* that may arise if fluorescent yellow is used for a marking system.

10. Investigate if there are any strobe effects that could result in photo-induced epilepsy.

11. Compare benefits and costs, if any, recommended retroreflective systems to other grade crossing rail car conspicuity of alternatives (e.g., use of street lights at passive grade crossings).

I. INTRODUCTION

Background

The application of retroreflective material (or markings) to the sides of rail cars has the potential to reduce those rail-highway grade crossing accidents in which motorists run into the side of a train behind the locomotive during hours of darkness. It is presumed that many of these "run-into-train" accidents occur because the motorist did not perceive the train in time to stop his or her vehicle before reaching the crossing, and that the lack of conspicuity of the train contributes to the motorist's perception difficulties. For the purpose of this report, "visual conspicuity" refers to the characteristic of an object in its roadway setting to: (1) command the attention of motorists; and (2) be recognizable to the reasonably prudent motorist. This lack of visual conspicuity is the result of the dark colored paints generally used on rail cars and/or the fact that rail cars are often covered with dust and grime which are inherent in the rail environment. At night and especially at rural passive crossings, rail cars tend to blend into their surroundings, i.e., they lack contrast and target value. Retroreflective markings attached to the sides of the rail cars reflect light from a motor vehicle's headlights back towards the vehicle. The markings appear as light sources against a dark background, thus alerting the vehicle's driver to the presence of the train.

Magnitude of the Problem

Of the 4,677 grade crossing traffic accidents reported for 1991 in the Railroad Accident/ Incident Reporting System (RAIRS) database, 746 or 16% of these accidents involved vehicles striking a stationary or moving train during nighttime hours, i.e., between 6:00 p.m. and 6:00 a.m. These 746 run-into-train accidents resulted in 361 injuries and 53 fatalities. Since 1975, the percentage of all run into train accidents has consistently been near one quarter of all rail-highway grade crossing accidents (Carroll and Yaffee, 1994). This consistently high percentage suggests that motorists may have difficulty seeing trains which are occupying a crossing at night. Furthermore, significant gains in crossing safety can be achieved through the increased conspicuity of rail cars by adding retroreflective markings to their sides.

Causality

Generally, drivers involved in grade crossing accidents are familiar with the crossing and with roadway features at the crossing. Also, most crossing accidents occur in good weather (Mortimer, 1988), and only in a few cases are the drivers impaired by drugs, alcohol, or excessive fatigue. Thus, other causal factors besides weather and driver impairment must be considered. In the case of nighttime run-into-train accidents, two important driver or human factors have been identified as contributing to these accidents. These are driver expectancy (or "habituation" in human factors terminology) (NTSB, 1981) and the driver's failure to perceive the train (which is related to the train's conspicuity).

Drivers generally do not expect a train to be occupying a crossing, (Sanders, 1976) particularly a rural passive crossing at night. This "negative expectancy" is a result of previous driving experience and conditioning. A motorist's ability to perceive the presence of a train at a dark passive crossing is affected by both auditory and visual stimuli. Unfortunately, once a train has reached the crossing, the engineer stops sounding the horn and it is no longer available as an audible stimuli. This lack of "auditory conspicuity," coupled with the poor visual conspicuity discussed previously, seriously hampers the driver's perception and recognition of a train's presence.

Various remedies for run-into-train accidents should be considered. First, improvement in the behavior of the driver may be affected through better education and enforcement. Secondly, enhanced conspicuity of rail cars by the application of retroreflective markings may be warranted. It has been demonstrated that the application of retroreflective material to freight cars increases the conspicuity of trains (Stalder and Lauer, 1953; McGinnis, 1979). Stalder and Lauer demonstrated that the amount and distribution of reflective material enhanced the visibility and perception of lateral motion of box cars in a laboratory simulation. The 1979 McGinnis study indicated that, while effectiveness of reflectors are reduced by dirt and grime, atmospheric conditions and the condition of the car's windshield, they are invariably more visible than nonreflectorized objects. However, these studies did not explore the visual coding dimensions sufficiently to specify the form the rail car markings should take. This topic is the focus of the present research.

Study Purpose

The purpose of this study was to develop guidelines and recommendations for the design of retroreflective marking systems to enhance the conspicuity of rail cars at night and in other low contrast environments, such as in daytime rain, snow, or fog. Additionally, the research provides human performance data that may be extended to the design and evaluation of other marking systems, i.e., marking systems for pedestrians, buses, trucks, motorcycles, highway obstructions, or any large object that needs to be detected by motorists in a low contrast environment. In order to accomplish the purpose of this research, the following objectives were established:

1. Identify an initial set of promising retroreflective marking systems capable of enhancing rail car conspicuity from the large number of possible systems proposed by a group of transportation experts;

2. Subjectively assess the set of promising marking systems as to their effectiveness in enhancing rail car conspicuity, and based on the subjective assessments, identify a subset of candidate markings to be objectively evaluated;

3. Objectively and quantitatively evaluate the subset of candidate markings to determine which of the candidates are most effective in enhancing conspicuity; and

4. Identify the primary physical parameters which must be controlled in order to provide a

high probability of detection, recognition, and identification.

Research Plan

The general research plan used to accomplish the objectives of the study is outlined by the flow diagram presented in Figure 1. This plan includes the five major research tasks described below.

Task 1: Literature Review. Highway and railroad safety literature was reviewed to identify pertinent visual conspicuity research and applications of retroreflective materials. Human factors literature dealing with visual detection, information processing, and accident prevention was also examined. Researchers in Australia were queried to assess their parallel efforts in evaluating and improving rail car conspicuity.

Task 2: Create Rail Car Conspicuity Designs. A group of human factors and traffic experts generated rail car marking designs using the Nominal Group Technique. This test resulted in the selection of eight marking systems that the experts believed would be effective in improving rail car conspicuity. In addition to the eight created by the group, three systems representing marking systems that are currently used on rail cars and highway trucks were included in Section IV.

Task 3: Expert Evaluation of Conspicuity Designs. Individuals (called judges) with expertise in the area of conspicuity markings were asked to make subjective judgments relative to the eleven marking systems generated in Task 2. A mailout questionnaire was used to gather input from the judges, and in the questionnaire survey the judges based their subjective assessments on color photographs of the various marking systems applied to scale models of open-top hopper cars. The eight marking systems were ranked based on the judges subjective preferences. In addition, a semantic differentiation section of the questionnaire provided insight into the coding dimensions that the judges believed to be important.

Task 4: Novice Evaluation of Conspicuity Designs. This task used a jury technique to further evaluate the designs generated in Task 2. The jury consisted of drivers who possessed a valid license but had no special knowledge of conspicuity issues. The "novices" as they were called, rated the designs using the same questionnaire developed in Task 3, except the novice jury viewed the actual scale models, with the conspicuity markings attached, under simulated nighttime conditions. The models were illuminated by simulated auto head lamps at scale distances of 400-500 feet. This range of distances was judged to be well within the detection range for actual rail cars. Scaling techniques were employed to evaluate the novices' assessments of marking system effectiveness.

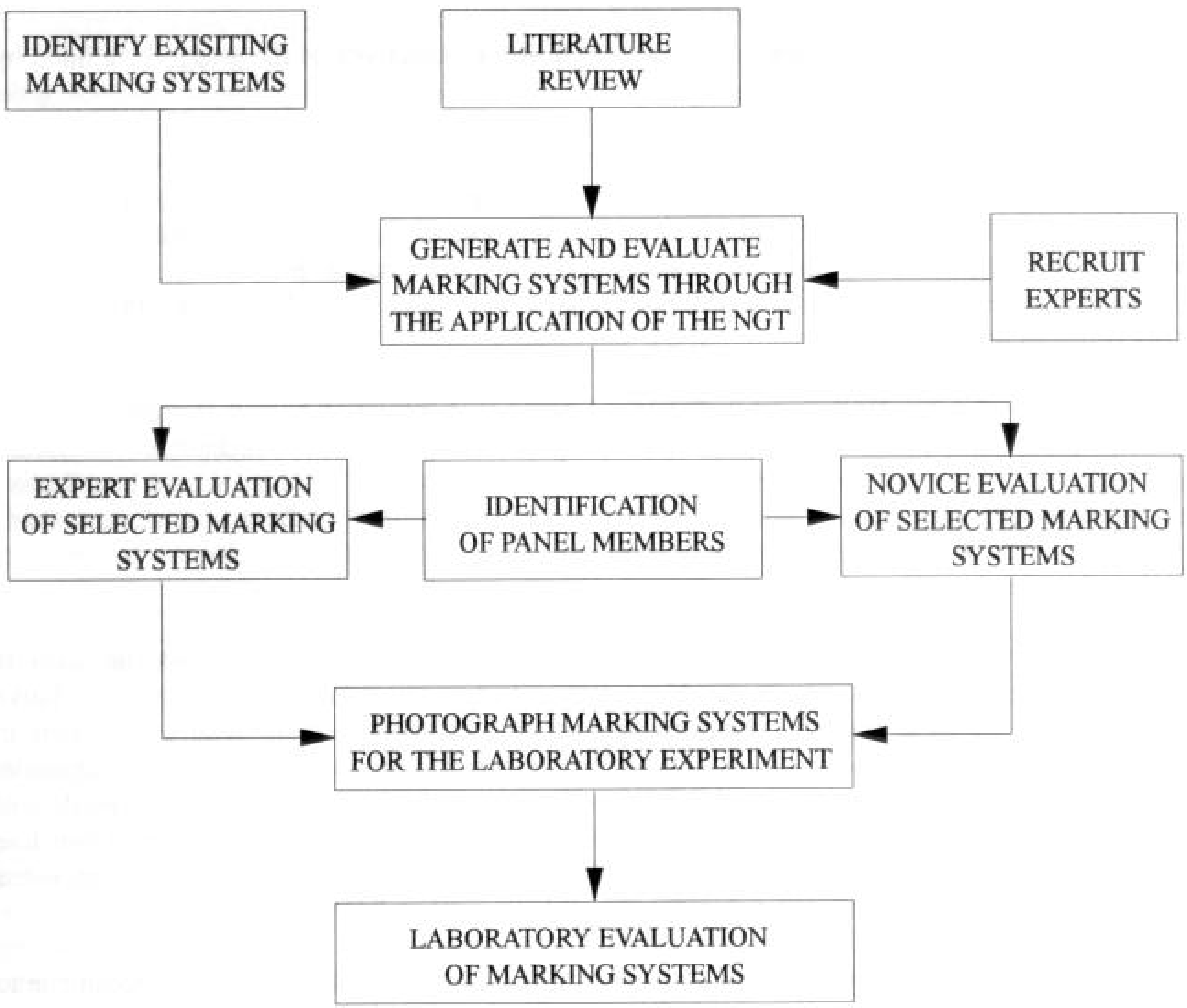


Figure 1. Research Plan.

Task 5: Evaluation of Photographed Railroad Freight Car Markings. Color slides of the rail car markings were used in a computer-assisted, real-time experiment to establish detection and recognition times and distances for the various markings. In this visual detection experiment, 34 driver subjects viewed a series of slides of each of the marking designs. Each slide in the series was displayed for five seconds. The first slide of the series began with the rail car image size projected on the viewing screen as if viewed at 6,000 feet. Each succeeding slide simulated moving the subject 100 feet closer to the marked rail car. The subjects were asked to press a computer key when they first detected the car and then to press another computer key when they were able to correctly identify the marking. This process was repeated until the subject had randomly viewed each marking system four times.

Scope

As stated earlier, this study focused on developing guidelines and recommendations for the design of retroreflective marking systems for rail cars. It was not intended to develop the optimal marking design for rail cars in the real world, but to identify markings with validity for use based on laboratory experiments. The issues inherent in developing an optimal design applicable to all types and colors of rail cars were beyond the scope of the study. The marking systems generated in this study were used to identify and evaluate the design parameters important to rail car marking systems. The research was not intended to be a definitive study of rail car retroreflective systems; it was recognized early in the research that there may be other designs that merit consideration as well as real world considerations that must be evaluated before any such systems can be implemented (e.g., the effectiveness of markings where both the train and the auto are in motion).

The in-depth literature search provided examples of retroreflective markings that had been previously used on rail cars and/or tractor-trailer trucks. This information, along with research on the use of retroreflective materials for highway signs, was the basis for defining the marking parameters to be evaluated. The parameters that are of interest in this study are discussed fully in the literature review presented in Section III.

This study recorded the relative, not the absolute, performance of marking systems based on the assessments of volunteer expert and novice subjects in a laboratory simulation of the visual environment typical of a passive rail-highway grade crossing at night. The methodology employed the use of photographic transparencies of scale model open top hopper freight cars marked with passive retroreflective systems which had been placed in a diorama representing the grade crossing. A car painted with conventional nonreflective markings in accordance with AAR standards was included in the experiment to serve as a baseline reference condition.

II. LITERATURE REVIEW

A survey of pertinent grade crossing safety and human factors literature was conducted as part of the research effort. Numerous references for this survey were obtained from the libraries at The University of Tennessee and the Volpe National Transportation Systems Center. A computer-assisted literature search was also conducted using the Transportation Research Information Service (TRIS), and the relevant reports, journal articles, and other documents identified in this inquiry were obtained and reviewed. To complete the survey, telephone interviews were conducted with selected transportation and human factors professionals in the United States and Australia to solicit their input on any remaining information sources.

Literature Survey Scope

The literature survey focused on those topics directly related to the conspicuity of trains and the enhancement of train and vehicle conspicuity through the application of reflective or retroreflective marking systems. Within this limited scope, the following four subtopics were addressed:

1. Previous experience with rail car conspicuity marking systems;
2. Related vehicle conspicuity research;
3. Physical parameters of train/vehicle marking systems which affect conspicuity performance; and
4. Methodologies which have been employed to evaluate marking systems, particularly in a laboratory setting.

It should be noted that much of the literature on rail car conspicuity is concerned with the durability of retroreflective materials and the degradation of the materials' reflective properties over time in the railroad environment. While material durability and degradation were not the focus of this study, this literature does document the various marking patterns/ designs which have been used, as well as some of the marking parameters, such as color and size, that influence conspicuity performance. The balance of the literature on rail car conspicuity deals with the various conspicuity factors that affect the detection and recognition of trains. Some of this literature also provides insight into methodologies previously used to study train and vehicle conspicuity or conspicuity in general.

Laboratory Studies of Rail Car Conspicuity and Markings

One of the earliest studies of the effects of applying markings to rail cars was conducted by Harold Stalder and A. R. Lauer (1954) at Iowa State College. Based on this study, the researchers concluded that the addition of limited areas of reflectorized material along the side sill of boxcars aids in "the discrimination of lateral motion under conditions of mesopic vision." Secondly, the amount and distribution of reflectorized material proportionally affects the level of visibility and accuracy of perception of lateral motion. That is, by using materials with high coefficients of reflection against a high contrast background, the amount of illumination was increased as well the motorist's ability to discriminate the movement of the boxcars across the line of vision. Also, for a fixed amount (area) of reflective material, concentration of the material was preferred over dispersion (i.e., the use of multiple smaller markings).

The work by Stalder and Lauer (1954) reported previous work by Donald Hoppe which Hoppe concluded that: (1) increasing the horizontal visual angle reduced the time for perception of the direction of relative motion between moving vehicles, and (2) with a contrast of sufficient magnitude, increasing the horizontal or vertical visual angle reduces perception time for the direction of speed differential. The variations in contrast of the target vehicle were obtained by using markings that differed in size and reflective characteristics. A 1951 study by Donald Hoppe and A. R. Lauer, reported by Stalder and Lauer (1954), established that using *reflectors* to provide a greater definition of a vehicle being overtaken increased both the speed and accuracy of the perception of changing distances between two vehicles at night. In this study, both field and laboratory data were collected, and the results showed a high agreement. The researchers concluded that laboratory studies were a valid approach to investigate vehicle conspicuity parameters. Then in 1952, Stalder and Lauer conducted laboratory studies to investigate the effect of pattern distribution on perception of relative motion at low levels of illumination. From this work, they concluded that the distribution pattern of reflectorized material affected response time and the difficulty to perceive relative motion. They also determined that when the same amount of reflective material was used to create two patterns, one that outlined the side of the car and another that formed a checked pattern over the side of the car, the outline gave better results.

In 1955, A. R. Lauer and Virtus Suhr (1956) conducted an experiment using scale representations of boxcars to assess the performance of four selected distributions of a fixed amount of reflective material placed at intervals and symmetrically along the side sill. The experiment was based on the premise that, for a given amount of reflectorized material, an optimal utilization of this material must exist.

The first of the four markings evaluated consisted of one large square marking located on the side sill and centered between the ends of the boxcar. The second marking system had two smaller squares, each one-half the area of the large square marking in the first system, located on the side sill towards the ends of the boxcar. The third pattern had three squares, each one-third the area of the initial large square marking, placed one in the middle and one towards the ends of the boxcar. The fourth marking system had 11 small markers, each one-eleventh the area of the initial large square, and equally spaced along the side sill of the boxcar.

Lauer and Suhr found no statistical differences between the two square and three square designs; also no differences were detected between the single square and two square design or between the single square and three square design. However, the one, two, and three square designs performed significantly better than the 11 square design. It was determined that the 11 square design required 3.57 times more illumination compared to the single square design, for a motorist to perceive the direction of motion. These results again confirm that a mass application is superior to a widely distributed application of reflective material.

In 1979, Richard McGinnis reported on the effectiveness of retroreflectors on the sides of freight cars as a means of reducing run-into-train accidents. As part of his work, McGinnis developed a FORTRAN® program to analyze and predict the amount of light reflected by a marking system based on the parameters of the markings and viewing conditions. He then compared the model prediction to visual detection standards to determine if a train would likely be detected given a set of viewing conditions and marking parameters. The factors that McGinnis considered were reflective intensity of the markings, marking size, the intensity of the light source, atmospheric transmissivity, windshield transmittance, and the observing distance. In the time of this analysis, engineering grade and high intensity retroreflective sheeting were the only materials available. To maximize the reflective intensity, silver (white) high intensity material was chosen. A reflective efficiency of 50% was assumed in the absence of reliable degradation data. Also, McGinnis treated the markings as point light source, thus limiting the marking size to 0.25 feet^2 in the shape of a 6-inch square. The values for the other factors were also conservatively established and are documented in the citation. McGinnis concluded that under railroad operating conditions, the markings described above will permit detection distances in excess of 800 feet with low beam headlights as the source of illumination. He also surmised that this detection distance would provide sufficient time for motorists to stop safely under most highway situations.

Previous Demonstration and Field Tests of Rail Car Markings

Poage et al. (1982) described a Canadian freight car reflectorization program that was begun in 1959. In this program, retroreflective materials in the shapes of circular discs and squares were applied to the sides of rail cars for the purpose of assessing their long term durability and performance. Four (4) inch disks were used to mark a fleet of Canadian National Railway cars, and 4 inch squares were applied to a fleet of Canadian Pacific Railway cars. In both cases, 4 reflectors were placed on both sides of freight cars 52 feet or less in length; six reflectors per side were used on cars more than 52 feet in length. The marking material used in these trials was Silver Scotchlite Brand Reflective (commonly referred to as "high-intensity" sheeting) sheeting manufactured by the 3-M Company of Canada.

Reflective intensity measurements made on the Canadian cars after six months, one year, and two years of service indicated rapid deterioration of the retroreflective material. Only 23% of the material's original reflectivity remained at the end of six months. This declined to 14% after one year and to 5% at the end of two years of service. After these reflectivity measurements were taken, 24 of the Canadian cars were washed and the marking reflectivity measurements were repeated. The washing did increase the reflectivity, but after three years of service the markings had less than 25% of their original reflectivity even after washing. Poage et al. (1982) concluded that, with this rapid decline in reflectivity, markings of 1.5 $feet^2$ would have to be used to maintain threshold conspicuity, if an annual wash cycle was initiated. If the wash cycle were increased to every other year, the marker size would have to double to 3 $feet^2$ to retain threshold conspicuity over time. The researchers recommended a 12 inch by 36 inch rectangular shape to achieve this required area; however, the general conclusion was that markings of this size and level of care would not be practical for widespread application.

Poage, et al. (1982) also reported on 1981 tests conducted by the Boston and Maine Railroad involving 33 dedicated service sand-and-gravel hopper cars. For these tests, 4 inch by 12 inch rectangles of high intensity grade Scotchlite Brand Reflective sheeting were installed just above the side sill. Each marking consisted of alternating (i.e., concatenated) silver and orange colors. The time to evaluate these markings used on the Boston and Maine was very limited; however, the data indicated a rapid rate of deterioration similar to that reported in the Canadian studies.

Recent Studies

The improvements in retroreflective materials, both in reflective intensity and durability, since the early 1980's prompted the U.S. Department of Transportation to conduct new research into the feasibility of rail car marking systems. The Volpe National Transportation Systems Center began a demonstration study in 1991 to identify the most suitable marking material(s) and to assess the design and configuration of a marking system for a nationwide in-service test (Carroll and Yaffee, 1994). Three types of materials were evaluated in the Volpe demonstration tests — bonded, encapsulated, and prismatic retroreflective sheeting. For the tests, nine open top hopper cars were treated with groups of three 4 inch by 4 inch diamond shaped markings placed near the side sill; each group was comprised of the three types of materials being evaluated. Five more hoppers had groups of two or three 4 inch by 2 inch rectangular markings attached to the wheels at 90, 120, or 180 degrees of separation. Only prismatic material was used on the wheel application. One car had a 4 inch by 108 inch vertical strip applied to the corner post at each end of the car. All of the marking systems evaluated in the Volpe demonstration studies were either all white, all red, or a combination pattern of red and white.

The demonstration tests indicated that the white prismatic material performed satisfactorily, while the bonded and encapsulated materials did not. The white prismatic material maintained 87% of its reflectivity after one year, and in the 4 inch by 4 inch markings of this material retained enough reflectivity to be well above the minimum conspicuity threshold. The enclosed lens material lost approximately the same percent of reflectivity as the prismatic material, but this loss was sufficient for it to fall below the minimum reflectivity required. The red prismatic material degraded approximately the same as the white. However, none of the all red markings evaluated in the study met the minimum reflectivity requirements after one year. Also, all of the materials placed on the wheels degraded very quickly and became ineffective in only a few months. Of the markings that were comprised of both red and white materials, only the performance of the vertical 4 inch by 96 inch strips of prismatic materials (applied to the corner post of the car) was reported. The reflectivity of this marking decreased to about 67% of its initial value after one year. Because of the relatively large size of the markings, this amount of reflectivity was well above the conspicuity threshold level.

Based on the preliminary results of the Volpe demonstration tests, larger scale trials were initiated with several railroads participating. For these trials, the white and the red concatenated with white prismatic material was selected based on the demonstration tests (and based on the input gathered from several railroads). The marking configuration selected consisted of three 4 inch by 8 inch white rectangular markings applied horizontally every nine feet just above the side sill, and a 4 inch by 36 inch strip of red|white material applied vertically at the side sill on both ends of the car. In 1990, the markings were applied to 115 Burlington Northern coal hoppers and 108 covered hoppers in grain service. Burlington Northern also has applied the markings to a captive fleet of 150 taconite cars operating in Minnesota. Beginning November 1991, this marking system was adapted to 30 tank cars carrying petroleum products on the Alaskan Railroad. The adaptation required that the markings be placed higher on the tank body because of the curvature of the tank body. In January 1992, the markings were applied to 150 double stack intermodal flat cars of the Norfolk Southern. This was followed in March 1992 and April 1992 with 74 captive Norfolk Southern open top hopper cars and 150 boxcars in clay service, respectively, receiving the marking system.

Other Experiences with Rail Car Markings

In addition to the extensive demonstration and field tests, the Volpe National Transportation Systems Center has conducted a case study of the Southern Company's use of high intensity yellow retroreflective material on its open top hopper cars. The Volpe National Transportation Systems Center has also surveyed the rail industry and identified several railroads that are currently using retroreflective markings on some portion of their fleets. These include the Burlington Northern, the Atchison, Topeka, and Santa Fe, the Soo Line, Amtrak, and the Georgia Power Company.

The Burlington Northern Railroad (reported by Uber, 1994) is using a rail car marking system which has eleven 5 inch by 8 inch rectangular white diamond grade markings along the side sill on each side of its freight cars. Smaller markings (3 inch by 8 inch) are used where surface space is limited, such as under boxcar doors. Burlington Northern has also placed two markings of unknown configuration on each end of the freight car. The Atchison, Topeka, and Santa Fe has applied 6 inch by 6 inch white markings at 8 foot centers to approximately 20,000 new and rebuilt freight cars. The Soo Line has applied retroreflective material to its cars for advertisement purposes and to improve the safety of nighttime yard operations. Amtrak applies reflective tape to its passenger cars to make them visible at night for safety reasons. The Georgia Power Company has used 3 inch by 12 inch yellow prismatic markings on its coal hoppers since 1981. Each car has 12 retroreflectors located 42 inches above the top of the rail along the side sill.

None of above mentioned railroads have conducted any formal evaluations of their marking systems; however, the Soo Line and Amtrak report satisfaction with their programs. Both of these railroads report no maintenance problems with the materials. In fact, some materials applied to the Soo Line cars in the mid 1960s are still performing adequately.

Australian Experience with Rail Car Markings

Charles Uber (1994) reported on a field test in Victoria, Australia, to determine the loss of retroreflectivity of rail car markings over time. In this test, which began in 1991, markings were applied to a captive fleet of hoppers operating in quarry service. Two grades of sheeting, diamond grade and high intensity, supplied by five manufacturers were evaluated in the test. Each of the quarry hoppers had six white markings attached along the side sill (approximately 55 inches above the top of rail) and distributed symmetrically about the vertical center line of the car. The marking sizes used in the field trials were either 5 by 15 inches, 10 by 10 inches, 10 by 20 inches, or 10 by 40 inches. All of the markings on a hopper were of the same size, type of material, and manufacturer.

Uber found that the markings applied to the quarry hoppers had lost at least 60% of their reflectivity during the first four months of the trial. After eight months, the ratio of degradation in reflectivity slowed; however, after 24 months, the markings only had 10.5 to 14.5% of their initial reflectivity values. The high intensity grade materials were all inferior to the diamond grade materials. At the end of this two year study, the markings were washed and the reflectivity measured again. The diamond grade retroreflectors were restored from 13.5 to 40.2% of their initial reflectivity, and the high intensity retroreflectors were restored from 21.8 to 33.7% of their initial reflectivity. Uber concluded that a "Fix and Forget" retroreflectorization program using diamond grade material may be feasible, with washing as part of routine maintenance. Uber did not investigate the reaction of drivers to any of the marking systems on the accident experience of the captive fleet.

Two additional trials of retroreflective markings, one on the Queensland Railways rolling stock in 1984 and the other on the New South Wales Railways bulk grain wagons (freight cars) circa 1989, were also reported by Uber (1994). The markings applied to the Queensland Railway cars was high intensity white sheeting. Four 5 inch by 15 inch retroreflectors were attached to each car. The New South Wales markings were 2.5 by 4 feet and only one marking was applied to each side of a car. The color, type of material, and their location on the car side was not reported.

The Queensland Railways and New South Wales Railways did not conduct formal evaluations of their marking systems, though they report that the markings "are very effective."

Queensland Railways indicated that they expect their markings to have an eight-year useful life, and that natural cleaning (by rain) has been sufficient to maintain a satisfactory level of reflectivity.

Related Conspicuity Research

Relevant literature dealing with the conspicuity of locomotives, the rear of trains, and large highway vehicles was also reviewed. Much of the literature relating to locomotive and end-of-train conspicuity deals with lights, strobes, and horns, and therefore is not relevant. However, some research has considered the effects of colorful paint schemes and color contrast on train conspicuity. The research involving the application of marking systems to the sides of large highway vehicles is especially pertinent to the present study.

A paint scheme of two colors contrasting in hue and brightness was recommended in 1970 by Aurelius and Korobow to improve the daytime visual conspicuity of railroad locomotives. This research indicated the preferred colors are yellow, fluorescent yellow, or fluorescent yellow orange with a contrasting background color of red, blue, or black. Aurelius and Korobow found that these fluorescent colors are up to four times more reflective than standard colors, and that they are visually different from colors occurring in nature enhancing their natural contrast with many backgrounds. All of their observations related to daylight conspicuity, but the researchers surmised that fluorescent colors may offer similar advantages at night. John Hopkins and A. T. Newfell (1975) also noted the use of high conspicuity fluorescent yellow/orange material for safety devices such as markers for slow moving vehicles on public highways and on portable highway barriers. John Hopkins (1973) has investigated methods to enhance the conspicuity of the trailing ends of trains. He suggested the use of fluorescent plastic retroreflectors as a low cost alternative to large area sheeting or painting. Hopkins also recommended that the marking pattern (formed with reflectors or paint) should have a contrasting shape when compared to the delineated area.

Zwahlen et al. (1989) conducted a study to determine the recognition distance of shape coded, white retroreflectorized warning plates. He found that the recognition distance was a function of the shape of the plate and the amount of reflectorization, but not target brightness. Zwahlen considered five different shapes, each 18 inches^2 in area. For each shape, he also considered the case of full-area reflectivity versus border-only reflectivity. Three types of materials were investigated — prismatic (high intensity); encapsulated lens (medium intensity); and enclosed lens (low intensity) sheeting. Illumination of the various targets was provided by a stationary car with headlights on low beam and positioned to maximize target illumination.

The results indicated that target brightness had little effect on correct target recognition distances for both full and borders only reflectorization. Also, the triangle shape was recognized at the greatest distance with fewer errors for both full and border reflectorization. (The other shapes were circle, square, diamond, and polygon.) The low intensity sheeting transmitted the most information about marking shape and produced the highest percentage of correct responses, while the high intensity sheeting transmitted the least information and produced the highest percentage of incorrect responses. Zwahlen et al. associated this result with the glare produced by the higher intensity material. Shape plates with border-only reflectorization were recognized at greater distances than were the fully reflectorized shapes. These results indicate that, to maximize both detection distance and recognition of a fixed area of reflectorization, a larger size, shape coded target with reflectorized borders should be used.

Large Vehicle (Truck) Conspicuity

Olson et al. (1992) conducted research on large vehicle conspicuity to define a range of "minimally acceptable" truck marking enhancements. The goal of this research was to determine the design parameters for truck markings to promote detection under nighttime conditions. The issues considered by Olson which are also relevant to rail car conspicuity are maximum and minimum reflectivity for proposed treatments; the value of using color patterns to identify an object as a potential hazard, as an aid in the perception of relative motion, and in judging changes in distances; the amount and arrangement of material that should be used; and an assessment of reflectivity values and widths of the markings. The study employed both laboratory and field investigations to assess these issues.

Olson et al. reached the following conclusions from their research:

- Existing retroreflective materials (i.e., prismatic material) are suitable for truck side markings.

- Only high performance retroreflective material will provide adequate visibility distance.

- A red-white marking pattern outlining the sides and rear of the trailer significantly enhances recognition of the object hazard.

- Doubling the width of the material has the same effect on detection distance as doubling its specific intensity per unit area.

Based on these results, Olson made the following recommendations:

- Large truck marking systems should be as uniform as possible within the constraints imposed by the variety of trailer-types in order to facilitate the identification of the marked object as a truck.
- An alternating red-white pattern with approximately equal amount of each color is preferred.
- A partial outline of the rear of the trailer should be delineated with the markings to assist approaching drivers in judging relative speed.
- A side marking along the bottom rail of the trailer is sufficient.
- Markings wider than the assumed 2 inch minimum can be used with the minimum reflectivity values decreased proportionally to the increased area of the marking.

- Markings should have a maximum SIA (Specific Intensity per unit Area) of 60 at an observation angle of 1.8°.
- The recommended minimum SIA for trailer side and rear markings are shown in Figure 2 (Olson et al., 1992).

Summary

The literature review focused on the conspicuity of trains and large highway trucks and on the enhancement of their conspicuity through the application of reflective or retroreflective marking systems. The information found in the literature provided guidance in the selection and evaluation of the marking systems that are the subject of this study. A summary of the key issues revealed by the review is presented below.

1. The application of retroreflective materials to rail cars and trucks does enhance their conspicuity.

2. Retroreflective materials now exist which have the durability and coefficient of reflection to make retroreflective marking systems a practical means of enhancing the conspicuity of rail cars.

3. There is a lack of consensus among railroads or researchers as to what the optimal marking system for rail cars should be.

4. The key attributes for rail car marking systems are:
   - The coefficient of reflectivity;
   - The color pattern;
   - The contrast between the color pattern and the color of the rail car;
   - The amount (area) of material used;
   - The geometric shape used for the marking;
   - The profile of the rail car; and
   - The distribution pattern of the marking on the car side.

5. Distribution patterns that outline the shape of the object enhance recognition.

6. If a fixed amount of material is to be located near the lower edge of the object, a few larger markings are superior to many smaller markings.

SIDES			
	Weighted Average SIA	Typical SIA for 8" White and 11" Red Blocks	
	White/Red Pattern	White Blocks	Red Blocks
Standard 2 inch	70	125	30
1.5 inch	88	157	38
4 inch	35	63	15
6 inch	23	41	10
2 inch with gaps	88	157	38
REAR			
Standard 2 inch	140	250	60
1.5 inch	176	314	76
4 inch	70	125	30
6 inch	46	82	20

Notes: Observation angle = 0.2 degrees. Entrance angle = 30 degrees. Assumes red SIA is 25 percent of white. Relative SIAs for different colors vary.

Source: Olson, Paul L. "Visibility Problems in Nighttime Driving," SAE Technical Paper Series 870600. In *Accident Reconstruction: Automobiles, Tractor-Semitrailers, Motorcycles, and Pedestrians*, Proceedings No. P-193, pp. 97-112. Society of Automotive Engineers, Warrendale, PA, 1987.

Figure 2. Recommended Minimum Weighted Average SAIs for Various Treatments.

7. Two contrasting colors improve the daytime conspicuity.

8. Geometric shapes of high reflectance material are difficult to distinguish one from another.

9. If shape coding is necessary, discrimination is enhanced when only the border is reflectorized;

10. Fluorescent colors have superior conspicuity because they do not occur naturally.

11. Red|White color patterns are often used for marking systems because of their association with warning displays.

12. Laboratory methods have been successfully used to assess experimental marking systems.

13. A doubling of the area of a marking system or doubling the reflectance effectively doubles the detection distance.

III. DEVELOPMENT OF CANDIDATE MARKINGS

Although the literature survey was successful in identifying important parameters for rail car markings, it did not strongly support any system design over another. In fact, an infinite number of marking systems satisfying the basic parameter requirements can be conceived, and there are dozens of configurations which have been used with varying degrees of success. Therefore, the first logical step in developing an effective and practical rail car marking system was to generate a "reasonable" number of candidate systems for more indepth evaluation. This was accomplished using a subjective group input technique, called the Nominal Group Technique or NGT. The NGT methodology and the results of the NGT evaluation are described in this section.

NGT Description

The NGT is a controlled, focused, and efficient method to collect subjective information in a limited amount of time. A detailed description of NGT and how it was applied in this research is presented in Appendix A. In general, NGT is a four-step procedure directed by a trained facilitator where the interaction of a group is tightly controlled and focused on the subject of interest. The four steps are: (1) silent generation phase; (2) round robin phase; (3) clarification step; and (4) voting and ranking of alternatives. The sequence and relationships of these four steps are shown in Figure 3.

NGT Panel Selection

It was deemed appropriate for the NGT participants to have some knowledge of the subject matter, i.e., experience with traffic engineering, railroads, and/or human factors. Thus, an initial list of 28 such individuals was generated based on the researcher’s contacts; from this list six volunteers were selected. (Six is an optimal size for an NGT session.) The final participants represented diverse interests and experience, and included employees of railroads, government agencies, academia, and an engineering consultant.

NGT Application

The NGT panel was assembled in the conference room at The University of Tennessee Transportation Center in Knoxville, Tennessee, for a three-hour session. A facilitator guided the participants through the four-step process. First the participants were introduced by the facilitator, then they were given a set of written instructions and task statement. A short discussion period was allowed to amplify and clarify the written instructions which read as follows:

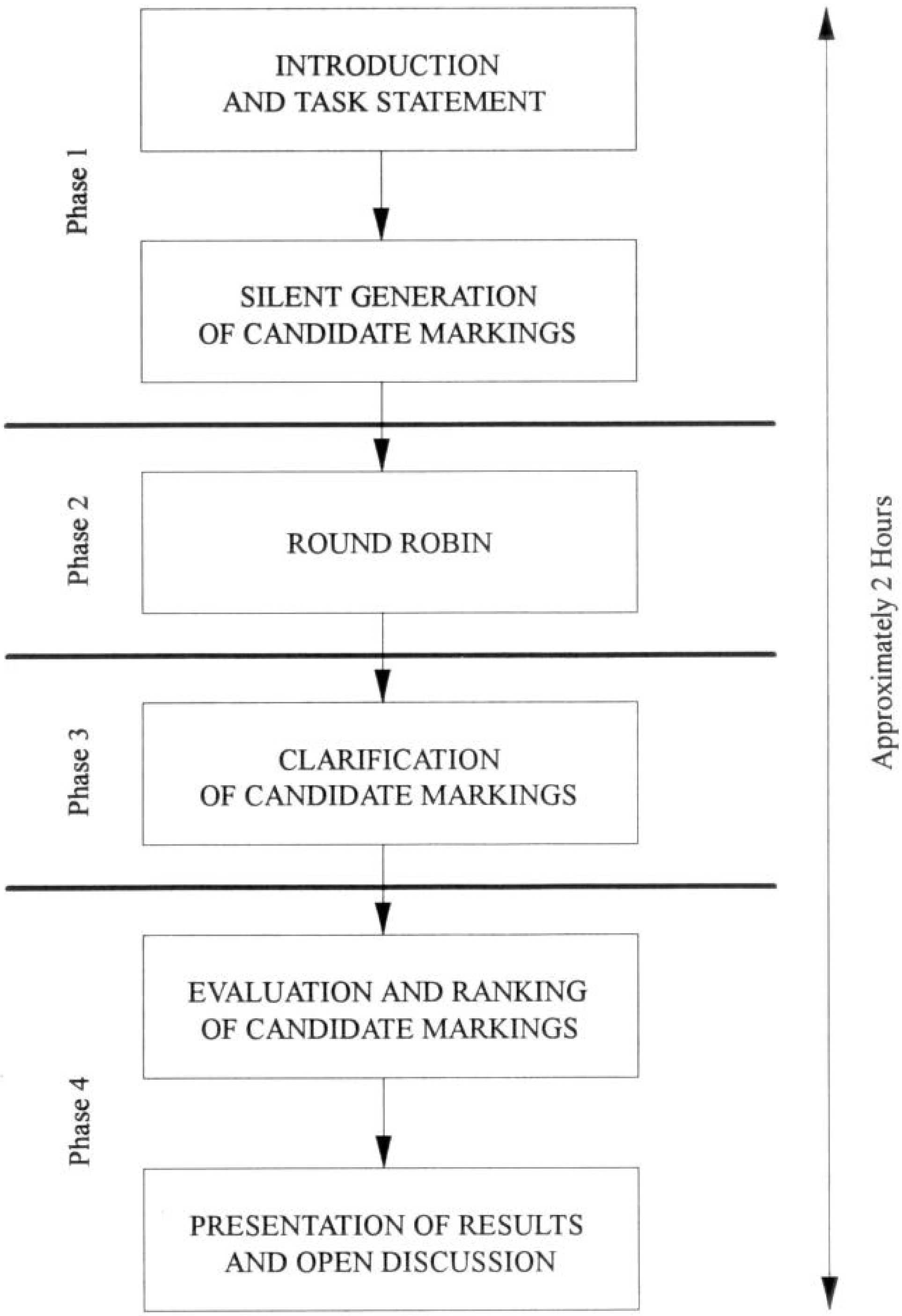


Figure 3. Summary of the Nominal Group Technique.

> Write a description of your retroreflective marking on a sheet of paper or draw a colored sketch of it on the isometric paper provided. Do not worry about the scale of your sketch. Indicate the distribution of the marking on the drawing of the hopper car. Samples of retroreflective sheeting are displayed at the front of the room.

The written task statement that was distributed read as follows:

> The purpose of this exercise is to generate a set of retroreflective markings to be applied to railroad rolling stock to increase the conspicuity of trains at railroad grade crossings with passive controls at night. The question to be answered is what combination of geometric shape, color or pattern of colors, size, and distribution of a given marking will be most effective in improving a driver's detection of a train?

Next, marking samples in the colors of white, red, yellow, orange, green, blue, fluorescent yellow, and fluorescent orange were shown to the group and displayed for later reference during the silent generation phase and throughout the session. All the samples were commercially available diamond grade retroreflective sheeting. Also, each participant was provided silhouettes of a freight car, blank isometric sketch paper, pens, pencils, a straight edge, and eight colored marking pens to match the available marking colors. Upon completion of the introductions and clarification of the instructions, the facilitator instructed the participants to silently generate as many marking systems as they could.

Next, the marking systems generated by the panelists were presented to the group one by one in round robin fashion until all designs were exhausted. The facilitator assigned a number to each one, and then responded to any questions regarding "clarification of the idea." The participants were asked to select by identification number the eight of the designs that they thought would be the most effective in enhancing drivers' detection of a train, and to rank these eight, with 1 being the lowest score and 8 being the highest score. These results were tallied by the facilitator and presented to the group. The ranking process is described in detail in Appendix A.

Marking System Assumptions

Based on the literature review and on practical concerns, it was deemed appropriate to fix some of the parameters of the candidate marking systems and/or the setting in which they would be considered. The fixed elements (or assumptions) included the following:

1. All the marking systems would be constructed of diamond grade retroreflective sheeting.

2. Marking color would be limited to any and all colors of commercially available diamond grade sheeting.

3. The total reflective area of the marking systems would be equal and nominally set at 382 square inches. (This area was based on experience and ongoing Federal Railroad Administration field trials and is somewhat arbitrary.)

4. The marking systems would be evaluated on dark, open top hopper cars, as this car type is common *and* provides reasonable surface area for marking application.

NGT Results

The NGT process generated a set of 25 candidate marking systems. The following sections describe these individual systems and summarize the similarities, differences, and trends among the systems. The systems selected for further evaluation by expert and novice panels (see Section V) are identified in the final subsection of this chapter.

Color or Color Patterns. Although the NGT panelists were given a variety of colors from which to choose, 14 of the 25 generated systems had markings of only one color; 10 had markings of two colors, and one consisted of a marking pattern made up of three colors. Table 1 summarizes the color selection results for the 8 systems that were ranked the highest by the NGT panel and the remaining 17 preferred systems. From the table, four of the top eight systems used only one color.

Table 2 summarizes the colors selected by the NGT panelists. Fluorescent yellow was the most popular color overall, appearing in 13 of the 25 systems. However, red and white were the most popular colors used in the eight most preferred designs. Red was used in five of the top eight systems, while white was used in four of the top eight. Table 3 summarizes the use of color combinations by the NGT panelists. From Table 3, there were no strong trends expressed by the NGT panel regarding color combinations; however, combinations of red and white were slightly favored over other combinations.

Finally, Table 4 summarizes the NGT panelists' preference for color in single-color systems. From Table 4, fluorescent yellow was the most common color appearing in single color systems (three of the top eight systems).

Geometric Shapes and Distribution of the Markings. With only four exceptions, all of the marking systems consisted of rectangular markings distributed as strips on the side of the hopper car. Of the four exceptions, two systems used diamond shaped markings placed on the lower side of the car and the remaining two systems used crescent shaped markings placed on the trucks. (Figure 4 establishes the nomenclature used throughout this report in discussing the positioning and configuration of the marking systems.)

Table 1. Number of Colors Used in a Marking System.

Number of Colors	Best 8	Remaining 17	Total
1	4	10	14
2	3	7	10
3	1	0	1
	--	--	--
Total	8	17	25

Table 2. Frequency of Color Use.

Colors	Best 8	Remaining 17	Total
Fluorescent Yellow	3	10	13
Red	5	4	9
White	4	3	7
Fluorescent Orange	1	5	6
Orange	0	3	3

Table 3. Frequency of Use for Multiple Color Marking Systems.

Color Combinations	Best 8	Remaining 17	Total
Red/White	1	1	2
Red-White	2	0	2
Red/White + Fluorescent Orange	1	0	1
Orange/Fluorescent Yellow	0	1	1
Red/Fluorescent Yellow	0	1	1
Fluorescent Orange-Fluorescent Yellow	0	3	3
Flyorescent Orange/White	0	1	1
	--	--	--
Total	4	7	11

Table 4. Frequency of Use for Single Color Marking Systems.

Colors	Best 8	Remaining 17	Total
Fluorescent Yellow	3	5	8
Red	1	2	3
Fluorescent Orange	0	1	1
Orange	0	2	2
	--	--	--
Totals	4	10	14

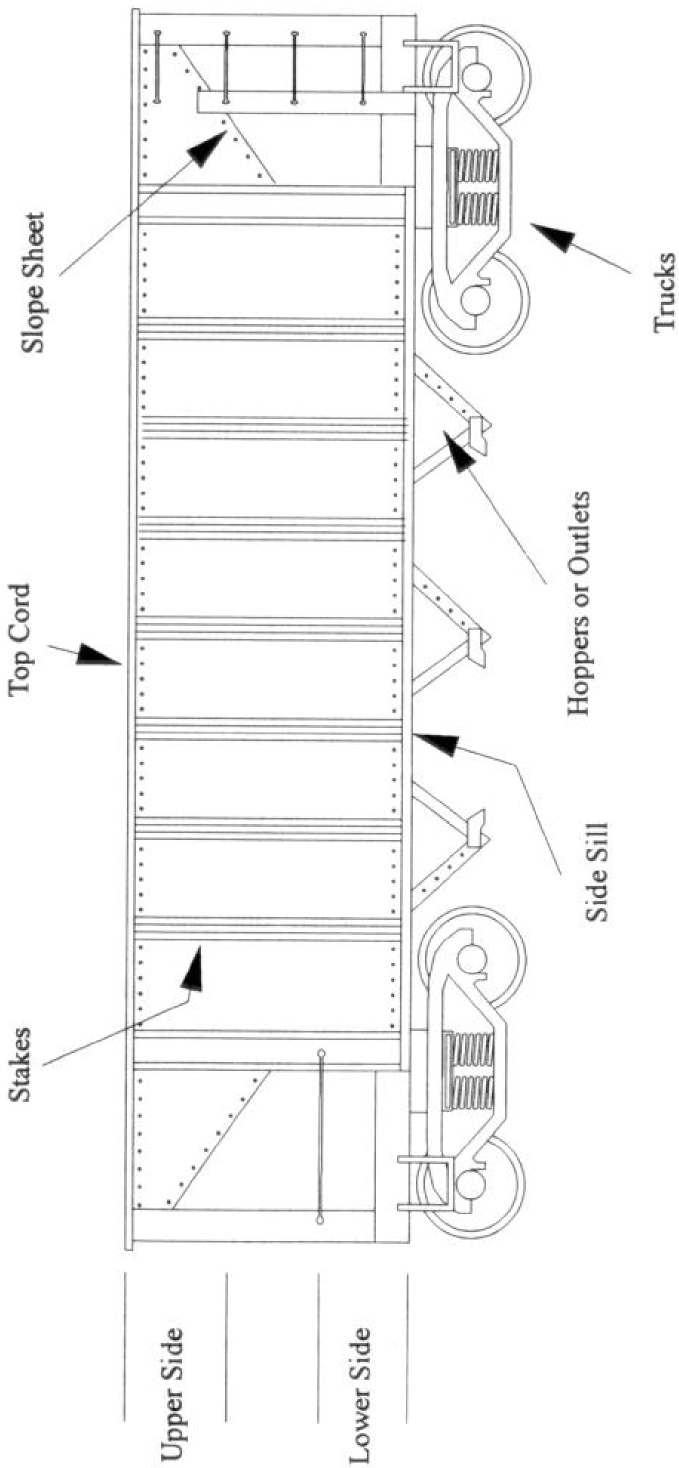


Figure 4. Freight Car Nomenclature, Side View.

Table 5 summarizes the positioning of the markings for the 25 candidate systems, broken down by the most preferred and least preferred systems. From Table 5, the "Lower Side" location was most preferred location for the markings. It was the selected location for 10 of the 25 systems, and the location of two of the top three systems. Two of the top eight marking systems were placed on the "Top Cord to Side Sill Diagonal and Vertical" location. During the clarification phase the NGT panel indicated that the chose the lower side of the car so that the retroreflectors would reflect more light from low beam headlights.

Designs Selected for Further Evaluation

Each NGT panelist was asked to select and rank the top eight marking systems from the 25 candidate systems based on their opinion that the system would enhance the conspicuity of freight cars. (The ranking procedure is described in Appendix A.) The facilitator tallied and combined the individual rankings to yield composite rankings. From these composite rankings, the eight designs that received the highest scores were selected for further evaluation by expert and novice panels. These eight conspicuity designs were designated Marking System #1 through Marking System #8, and are illustrated in Figures 5 through 12.

The eight highest ranked marking systems were all combinations of rectangular shaped markings. Four were markings comprised of a single color, three were combinations of two colors, and one system used a combination of three colors. The three-color system was made up of red-over-white markings distributed as a stripe with four 10 inch fluorescent orange diamond-shaped markings imbedded symmetrically in the stripe (Figure 9). The remaining six marking systems, including those comprised of a single and two color markings, were simple combinations of rectangular-shaped marking strips distributed on the car body in various combinations.

Of the four single color marking systems, one was a fluorescent yellow marking distributed along the side sill (see Figure 10). Another also had a fluorescent yellow marking along the side sill as in the previous system, but with additional fluorescent yellow markings distributed along the top cord and on four of the side stakes, as well as completely covering the sides of the hopper outlets (Figure 7). As a side note, during the discussion phase the group decided to eliminate the material from the hopper outlets because they thought it would be very difficult to keep the material clean. The third single color marking system was also comprised of fluorescent yellow markings with the material applied vertically to the side stakes (Figure 12). The final single color system was a large red "X" (a symbolic crossbuck) affixed to the left and right extremes of the car side (Figure 11).

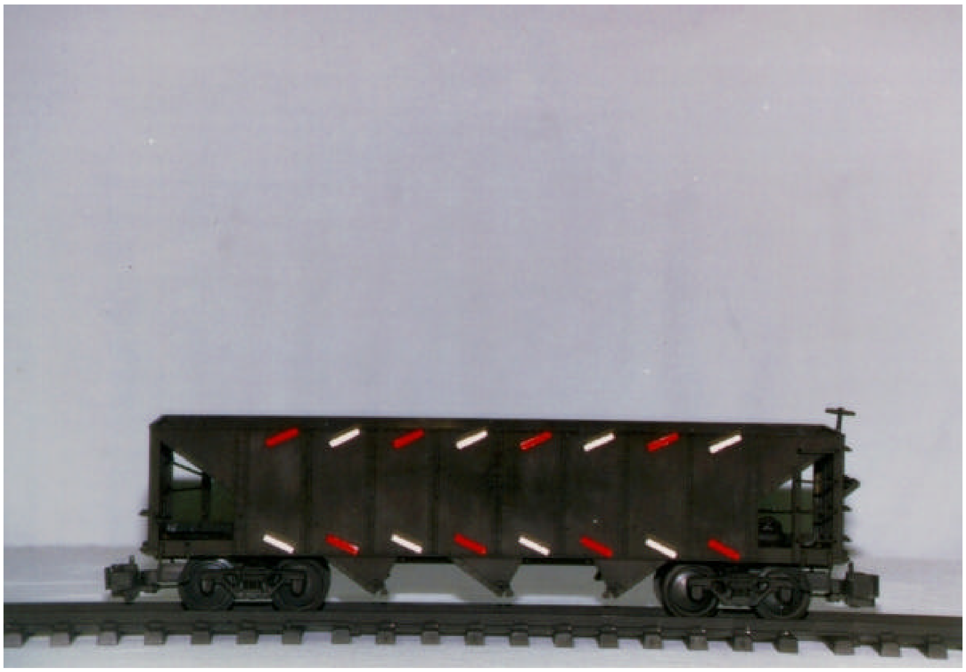
All of the two-color systems used red and white markings. One was a series of alternating red markings and white markings (designated as Red|White) placed adjacent to one another to form a stripe of diagonal red over white distributed along the side sill (Figure 5); one consisted of

Table 5. Placement of Markings.

Location	Best 8	Remaining 17	Total
Side Sill	2	1	3
Lower Side	2	8	10
Upper Side	0	2	2
Lower and Upper Sides	1	3	4
Truck and Wheels	0	2	2
Lower Side and Undercarriage	0	1	1
Top Cord to Side Sill Diagonal and Vertical	2	0	2
Top Cord to Side Sill and Undercarriage	1	0	1
	--	--	--
Totals	8	17	25

Description: Alternating red and white left to right diagonal strips applied as a strip to the full length of the car body on or just above the side sill.

Figure 5. Red|White Crossing Gate (Marking System #1).



Description: Alternating red and white strips applied in a 30° counterclockwise sawtooth pattern just below the top cord for the full length of the car body; then with a mirror image white and red 30° clockwise sawtooth pattern just above the side sill for the full length of the car body.

Figure 6. Red-White Sawtooth (Marking System #2).

Description: Outline of the car body with: (1) fluorescent yellow strips applied vertically to each end of the car body; (2) with fluorescent yellow strips, 2.5 feet long, spaced symmetrically every 5 feet about the horizontal centerline or the car body just above or on the side sill; and (3) with two strips just below the top cord that are each 1/3 the length of the car body spaced 1/3 the length of the car body symmetrically about the horizontal centerline. Any hoppers or gates showing below the side sill are also covered with fluorescent yellow sheeting.

Figure 7. Yellow Outline (Marking System #3).

Description: A red-gap-white-gap-red left facing chevron that is the full height of the car applied to the left side of the car body and a red-gap-white-gap-red right facing chevron that is the full height of the car applied to the left right of the car body.

Figure 8. Red-White Chevrons (Marking System #4).

Description: A red over white stripe applied the full length of the car body just above the side sill with fluorescent orange diamonds superimposed on the red over white stripe every 8 feet beginning at the horizontal centerline of the car.

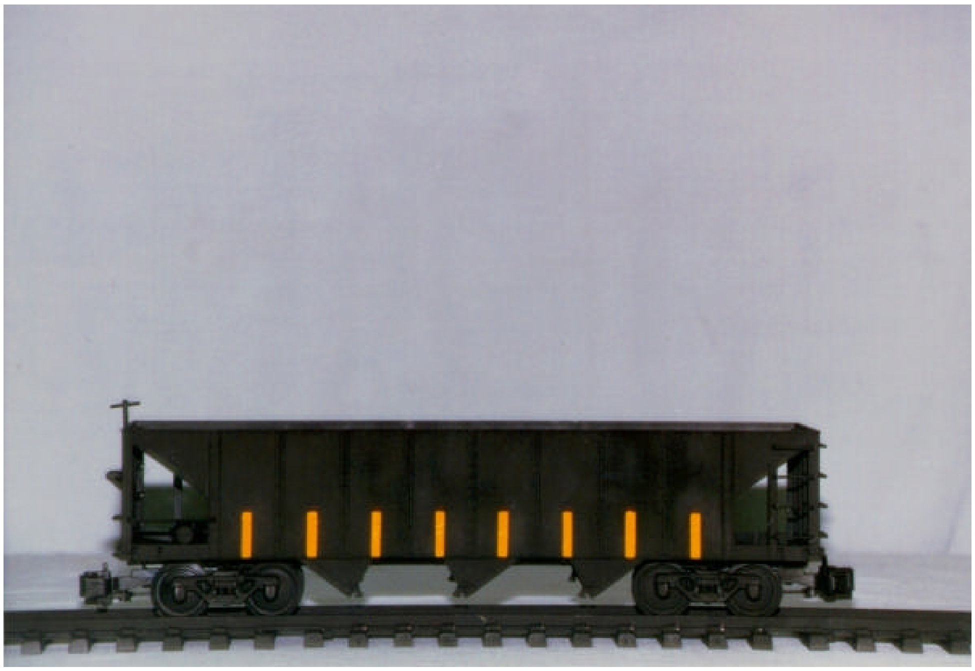
Figure 9. Red/White Diamonds in Bars (Marking System #5).

Description: Horizontal fluorescent yellow strips, 2.5 feet long, spaced symmetrically every 5 feet about the horizontal centerline of the car body just above or on the side sill.

Figure 10. Yellow Dash (Marking System #6).

Description: A red crossbuck applied to the left and right ends of the car sides that is the full height of the car.

Figure 11. Red Crossbucks (Marking System #7).

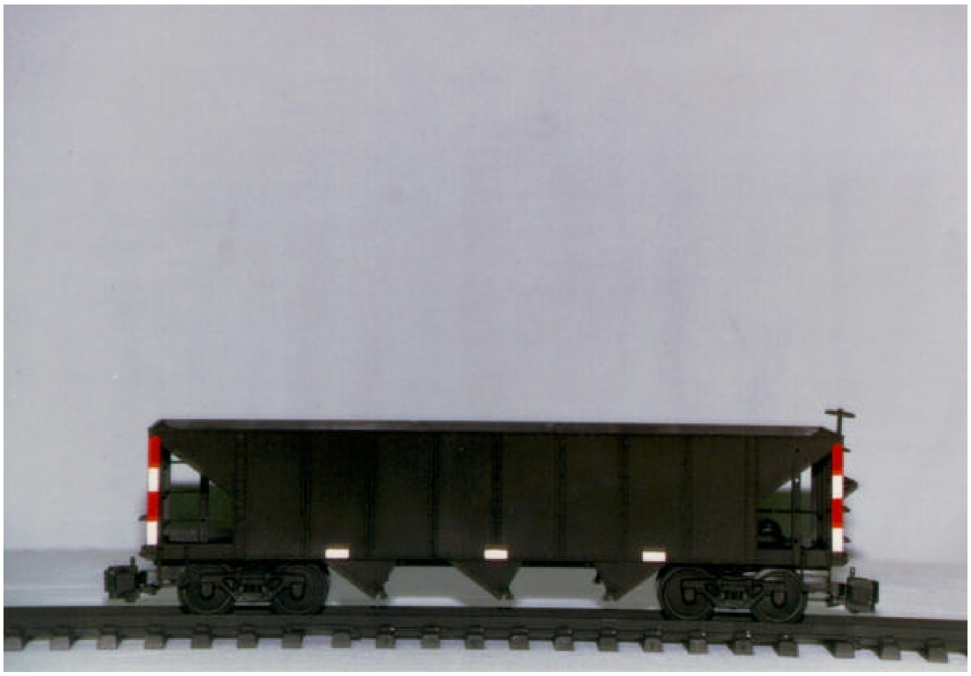


Description: Vertical fluorescent yellow strips, 2.5 feet long, spaced symmetrically every 2.5 feet about the horizontal centerline of the car body just above or on the side sill.

Figure 12. Yellow Fence (Marking System #8).

large alternating red or white markings (designated as Red-White) in the form of chevrons that were almost the full height of the car (Figure 8); and one was alternating red and white diagonal markings that formed two sawtoothed patterns, one just below the top cord and one just above the side sill (Figure 6).

In addition to the eight marking systems selected by the NGT panel, three additional systems were included in the set of designs evaluated by the expert and novice panels. The first, designated Marking System #9, is the subject of ongoing Federal Railroad Administration field testing to evaluate loss of reflective properties under railroad operating conditions. The second, designated Marking System #10, is patterned after the recently mandated marking system for large truck and tractor-trailer units. Both of these marking systems consisted of continuous, alternating rectangles of red and white retroreflective material (designated as Red|White). The third is comprised of the standard AAR nonretroreflective markings. It was included as a baseline system (designated Marking System #11). These three additional systems are shown in Figures 13-15.



Description: Vertical red/white strips full height of car, placed on the corners of the car body with three short horizontal white dashes placed symmetrically above the vertical centerline or the car body just above or on the side sill.

Figure 13. Red|White Field Test (Marking System #9).

Description: A red/white stripe applied the full length of the car body just above the side sill with white corner marking applied just below the top cord on the last two full side panels at the ends of the car body.

Figure 14. Red|White Highway Truck (Marking System #10).

Description: A black car with nonreflective white markings indicating reporting marks, logo, and car data.

Figure 15. Standard Car (Marking System #11).

IV. SUBJECTIVE EVALUATION OF THE CANDIDATE MARKING SYSTEMS

This section describes the subjective evaluations conducted to determine the perceived effectiveness of the 11 candidate marking systems generated through the NGT. These evaluations were performed by "expert" and "novice" panels assembled for this purpose, using a survey instrument and ranking procedures. The subjective ratings by the two panels were used to narrow the field of candidate marking systems to the subset analyzed in the objective evaluation experiment (Section VI).

Overview of Methodology

For the subjective evaluations, the two panels independently rated the 11 candidate marking systems generated in the NGT process. One panel was comprised of experts in traffic and railroad engineering and/or human factors, and the other was comprised of ordinary drivers possessing no specialized knowledge of the subject matter. In each case, the panel members were administered a questionnaire survey to solicit their input and rankings of the candidate markings. The expert panelists were shown photographs of the marking systems which were displayed on scale model hopper cars. The novice panelists, on the other hand, viewed the actual scale model cars equipped with the candidate marking systems.

Model Construction. Each of the candidate marking systems was fabricated from diamond grade retroreflective material. The markings were attached to both sides of a 1:22.6 scale model of a standard hopper car. Each system had the scaled-down equivalent of 384 square inches of retroreflective material, in the prescribed colors and geometric shapes, to create the marking systems in miniature. The scale equivalent of 384 square inches was chosen so that each of the markings would have the same amount of retroreflective material as marking system #9 that is currently undergoing field testing to evaluate loss of reflective properties under railroad operating conditions (Figure 13 in Section IV). Because the area for each marking system was fixed, the SIA was not the same for each marking system tested. Color photographs of the individual model cars set against a plain dark background were then made for use in the expert panel survey.

Panel Selection. The expert and novice panels were formed to represent the two primary interest groups, i.e., those who must design, install and/or maintain the systems, and those who rely on and benefit from the markings. The expert panel was composed of "experts" drawn from the private, regulatory, and research sectors of the transportation industry. Expert panelists had to have experience and knowledge in grade crossing safety, conspicuity, signing, or human factors. The novice panel included ordinary drivers drawn from the general populace. Novice panelists had to have been a licensed and practicing driver for a minimum of two years and have at least 20/40 corrected vision.

Evaluation and Ranking Procedures. Three independent methods were employed to subjectively evaluate the candidate marking systems. It was decided that using several techniques would enhance the validity and credibility of the results; also, the combined techniques yielded more information than a single technique. Thurston's Paired Comparisons Technique provided insight into the panelists' relative rankings, without requiring individuals to judge "by how much" one marking system is more effective than another. This technique also provided a quantitative scale in which each system is ranked from "best" to "worst" for perceived effectiveness, and it yielded an interval measure of how much better one system is relative to another.

Next, a simple ranking exercise was included whereby panelists ranked the candidate systems from "best" to "worst." This technique produced a quick ranking of all systems collectively. The third and final technique, the Semantic Differential Technique, was used to identify those attributes which may explain why one system is perceived as more effective than another. A detailed description of the Semantic Differential Technique, as well as Thurston's Paired Comparison Technique is presented in Appendix A.

Survey Administration

A questionnaire survey was developed to collect the responses of the panelists. The questionnaire contained five sections, the first three of which gathered input for the paired comparison, simple ranking, and semantic differential evaluations, respectively. The fourth section allowed panelists to design their own system(s) and display it on a side view line drawing of a hopper car. The final section solicited biographical information from the panelists.

For the paired comparison section of the questionnaire, the experts were asked to view pairs of color photographs of the marking systems and indicate which system in the pair they judged to be the most effective for enhancing the visibility of freight trains. For the simple ranking technique, color photos of all 11 marking systems were presented on the same page, and the panel members were asked to rank the systems from best to worst as to how they judged their effectiveness in enhancing the visibility of freight cars. In the Semantic Differential Section, the experts were asked to evaluate the attributes of each marking system by marking a scale pertaining to the particular attribute, while viewing a color photograph of the system. Written instructions preceded each section of the questionnaire. Appendix B presents a copy of the questionnaire sent to the expert panel.

A questionnaire almost identical to that used by the experts was administered to the novice panel, and the novice panel members were asked to perform the same evaluations as were the expert panel members. A copy of the novice questionnaire is included in Appendix C. The major difference between the novice and expert panel evaluations was that the experts viewed color photographs of the systems, whereas the novice panelists viewed the actual models with the retroreflective marking systems, illuminated by simulated car headlights, thus getting the full effect of the retroreflective properties of the markings.

Instructions were given to the novice panel both verbally and in writing. As with the expert panel, the written instructions preceded each section of the questionnaire. The novice panel was comprised of 51 ordinary drivers drawn from the general population in the Knoxville area.

To generate the expert panel, a pool of 150 "experts" were contacted and invited to participate in the subjective evaluations. Seventy-nine of these subjects agreed to participate and were mailed a questionnaire. Forty-eight questionnaires were completed and returned; however, four of the questionnaires were incomplete and were not used, yielding a panel of 44 expert respondents.

Data Analysis

Thurston's Paired Comparisons. The data collected from the expert and novice panels were entered into separate spreadsheets for analysis using Thurstonian scaling. In Thurstonian scaling, it is assumed that each time a stimulus is presented, it is represented by a point along a psychological scale that is determined by an underlying discrimination process which causes a person to react to the stimulus. This discriminal process may be different from one moment to the next because of an inherent variability within a person. The frequency distribution that is produced by this process is assumed to be normal. Therefore, when a pair of stimuli are presented to a person, two points are produced along the psychological scale and the differences of normally distributed random variables are also normally distributed. Thurstone assumed that a person makes a decision about a pair of stimuli based on the value difference of the pair. This distribution has a mean = $s_j - s_k$ and a standard deviation = $\sqrt{\sigma_j^2 + \sigma_k^2 - 2r\sigma_j^2\sigma_k^2}$. Because it is assumed that r = 0, and $\sigma_j = \sigma_k = \sigma$, then the standard deviation of the difference distribution is $\sqrt{2}\,\sigma$.

After all pairs of n objects have been presented to the subjects on a comparison task, a dominance matrix is prepared which shows the proportion of time j is preferred over k. These proportions are then used to determine an average z-value. This z-value can then be used to order the preferences on an interval scale. A high z-value indicates a highly preferred attribute whereas a low z-value near zero indicates an attribute that was not preferred.

Simple Ranking. The simple ranking data, like the Thurston's Paired Comparison data, was entered into a statistical spreadsheet for analysis. This analysis consisted of summing the ranking scores assigned by the participants. For the expert panel, smaller sums indicated higher preference rankings, whereas the opposite was the case for the novice panel (i.e., smaller sums indicated low rank). This dichotomy occurred because the experts were instructed to rank the systems with scores of 1 to 11, with 1 being the system judged to be the most effective. On the other hand, the novice panel was instructed to rank the systems with scores of 11 to 1 with 11 being the system judged the most effective. The scores for the experts were later transformed to be consistent with the scores for the novice panel (e.g., the marking system with the largest sum is ranked the most effective).

Semantic Differential Technique. The data were entered and analyzed using the same statistical spreadsheet used for the other procedures. Numeric values, ranging from 1 to 6, were assigned to each of the adjectives on the semantic scales. An arbitrary decision was made to assign a 6 to the adjective that carried the most positive or best connotation and the 1 to those that carried the most negative or worst connotation. For each attribute and each system, the mode response (most common rating) was calculated. The mode was chosen over the mean because the mode statistic can indicate when a panel was nearly evenly divided in their assessment of a given attribute.

Expert Panel Results

The rank ordering for the paired comparison scaling and the simple ranking for the expert panel are shown in Figure 16 and Table 6. The experts were very consistent in their choices of the marking systems they perceived to be the most effective in enhancing the visibility of rail cars. Both the paired comparison scaling and the simple ranking produced the same rankings with the exception of the Red-White Chevrons (Marking System #4) and the Red|White Field Test (Marking System #9) which were reversed in the eighth and ninth positions.

The three systems that were judged to be the most effective in enhancing the visibility of freight cars, in the order of preference, were the Yellow Fence (Marking system #8), the Yellow Outline (Marking System #3), and the Yellow Dash (Marking System #6). Ignoring the Standard Car (Marking System #11) which was not reflectorized, the two methods ranked the least effective systems in a slightly different order. The paired comparison technique produced the following rank ordering of the three least effective systems in the order of decreasing preference: the Red-White Chevrons (Marking System #4), the Red|White Field Test (Marking System #9), and the Red Crossbuck (Marking System #7). By comparison, the Simple Ranking showed the Red|White Field Test (Marking System #9), the Red-White Chevrons (Marking System #4), and the Red Crossbuck (Marking System #7) to be the least effective systems. The remaining four marking systems, in the order of descending preference, were the Red|White Crossing Gate (Marking System #1), the Red/White Diamonds in Bars (Marking System #5), the Red|White Highway Truck (Marking System #10), and the Red-White Sawtooth (Marking System #2). Both ranking methods produced the identical ranking of those middle four systems.

The expert panel's Semantic Differential evaluation of the 11 marking systems also produced consistent results. The panel's ratings for the six attributes and four dimensions are presented graphically in Figures 17-26. Each figure shows the Semantic Differential mode score

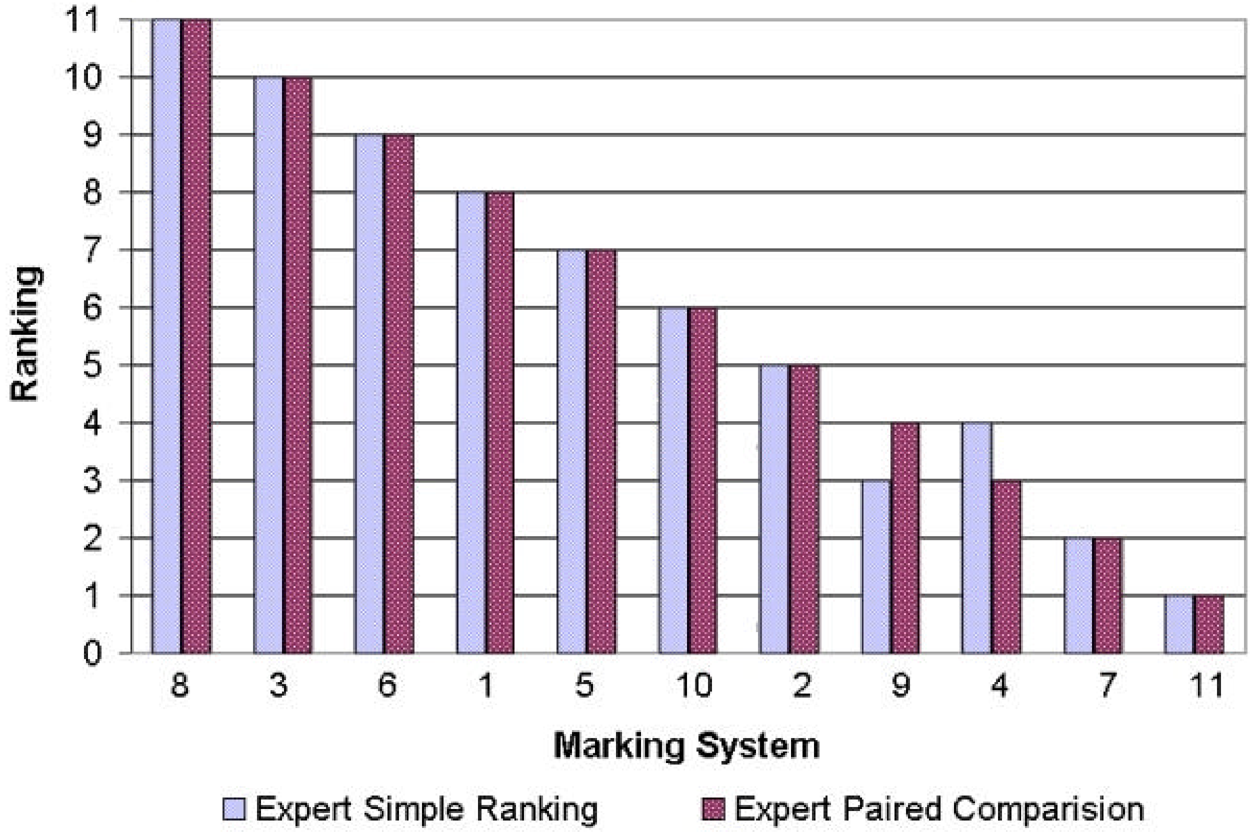


Figure 16. Subjective Evaluation by Transportation Experts.

Table 6. Subjective Evaluation by Transportation Experts.

Rank	Simple Ranking Marking System	Paired Comparisons Marking System
1	#8, Yellow Fence	#8, Yellow Fence
2	#3, Yellow Outline	#3, Yellow Outline
3	#6, Yellow Dash	#6, Yellow Dash
4	#1, Red|White Crossing Gate	#1, Red|White Crossing Gate
5	#5, Red/White Diamonds in Bars	#5, Red/White Diamonds in Bars
6	#10, Red|White Highway Truck	#10, Red|White Highway Truck
7	#2, Red-White Sawtooth	#2, Red-White Sawtooth
8	#4, Red-White Chevrons	#9, Red|White Field Test
9	#9, Red|White Field Test	#4, Red-White Chevrons
10	#7, Red Crossbucks	#7, Red Crossbucks
11	#11, Standard Car	#11, Standard Car

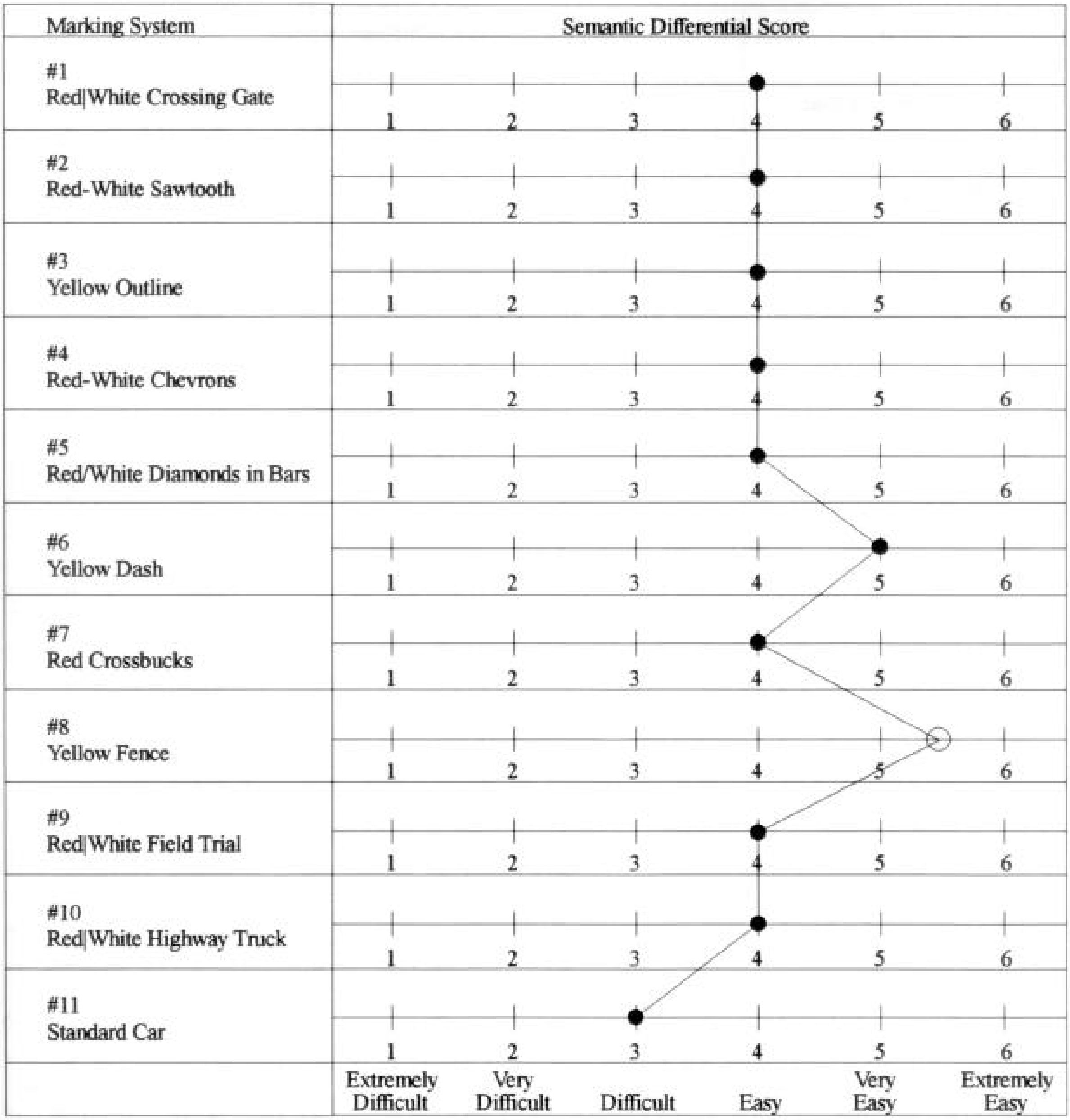


Figure 17. Expert Panel Response to Statement 1, "The marking will make detecting the freight car:"

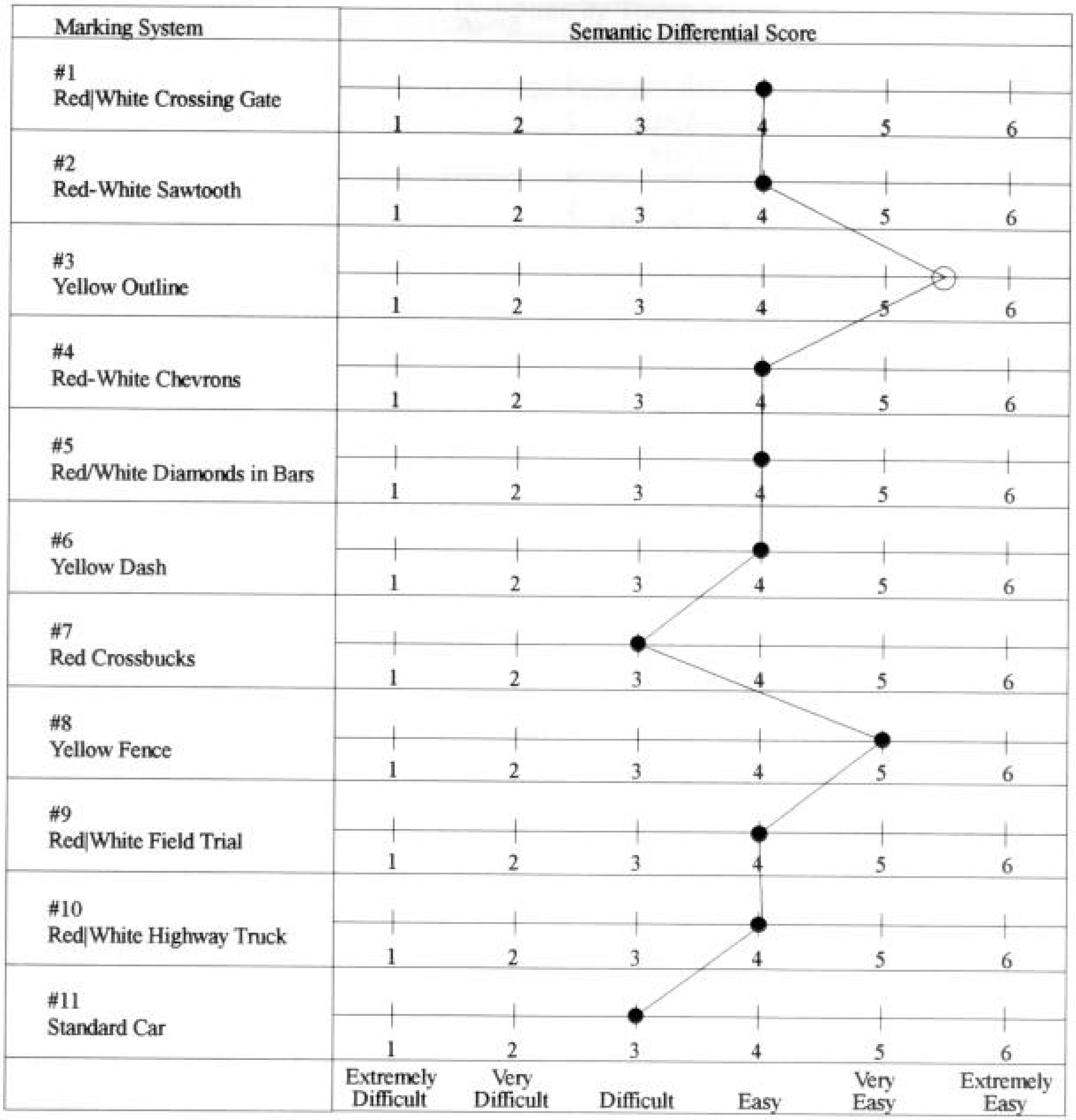


Figure 18. Expert Panel Response to Statement 2, "The marking will make recognizing the freight car:"

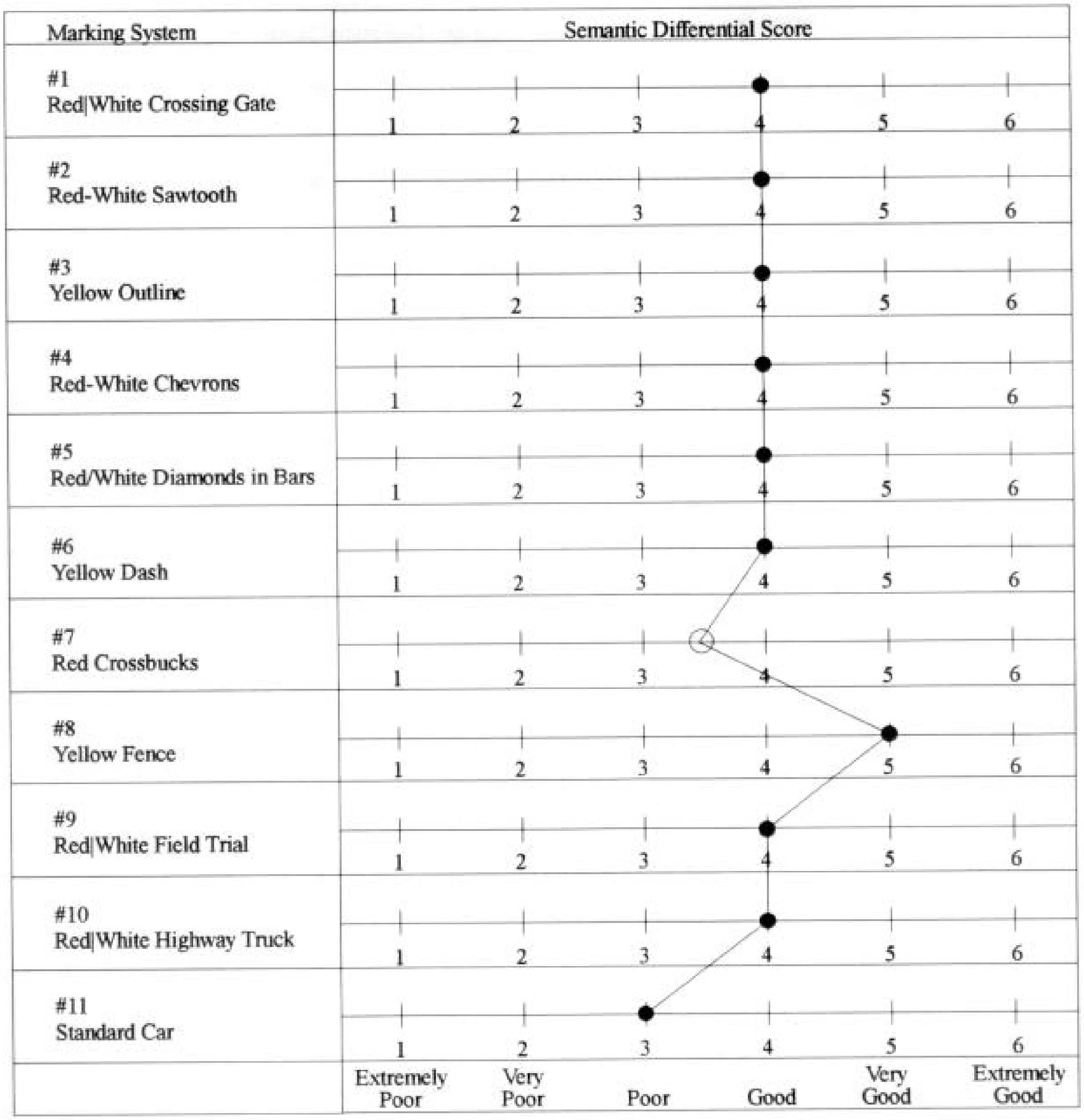


Figure 19. Expert Panel Response to Statement 3, "The understanding of the marking is:"

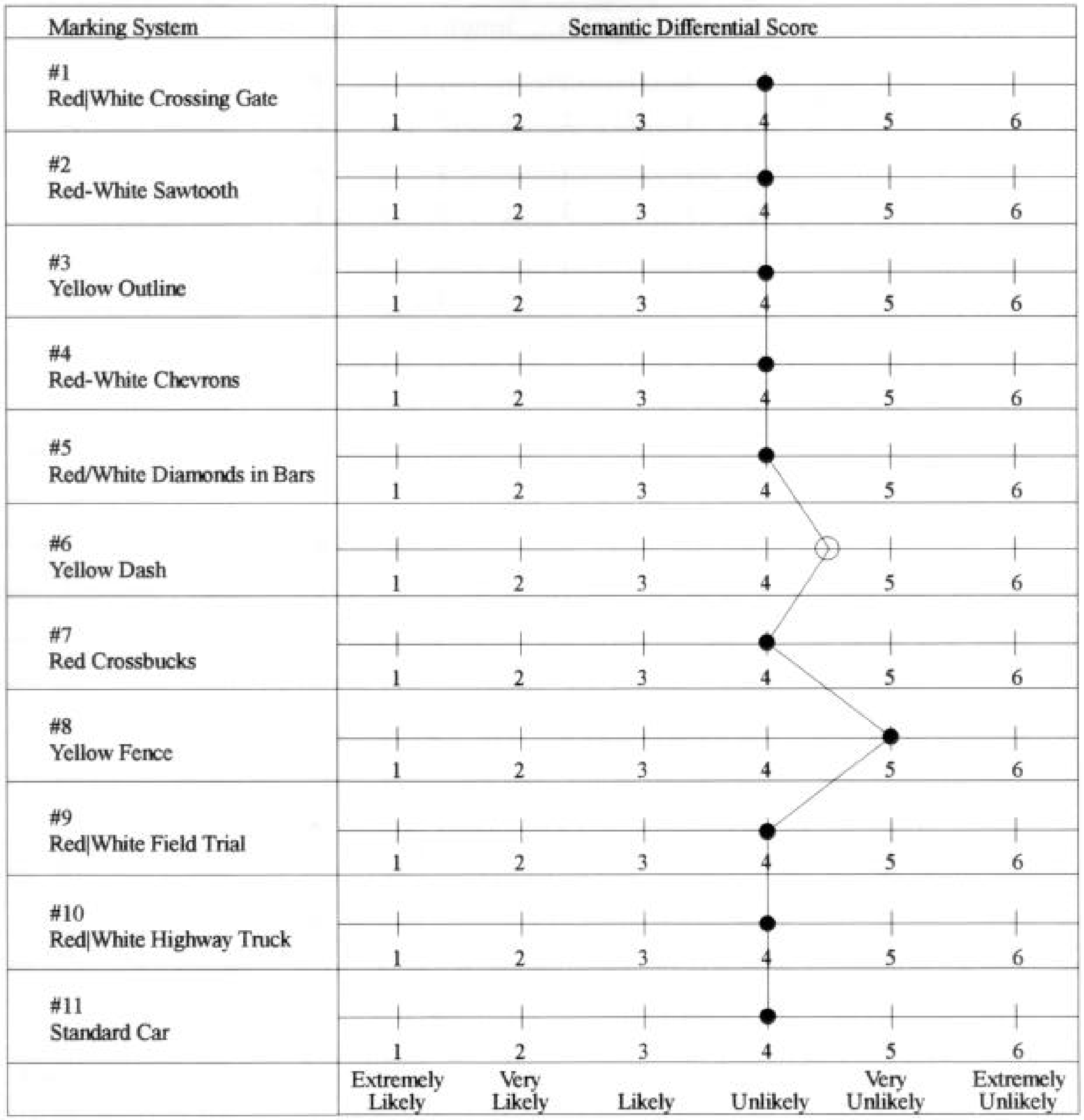


Figure 20. Expert Panel Response to Statement 4, "Confusing the marking with another marking is:"

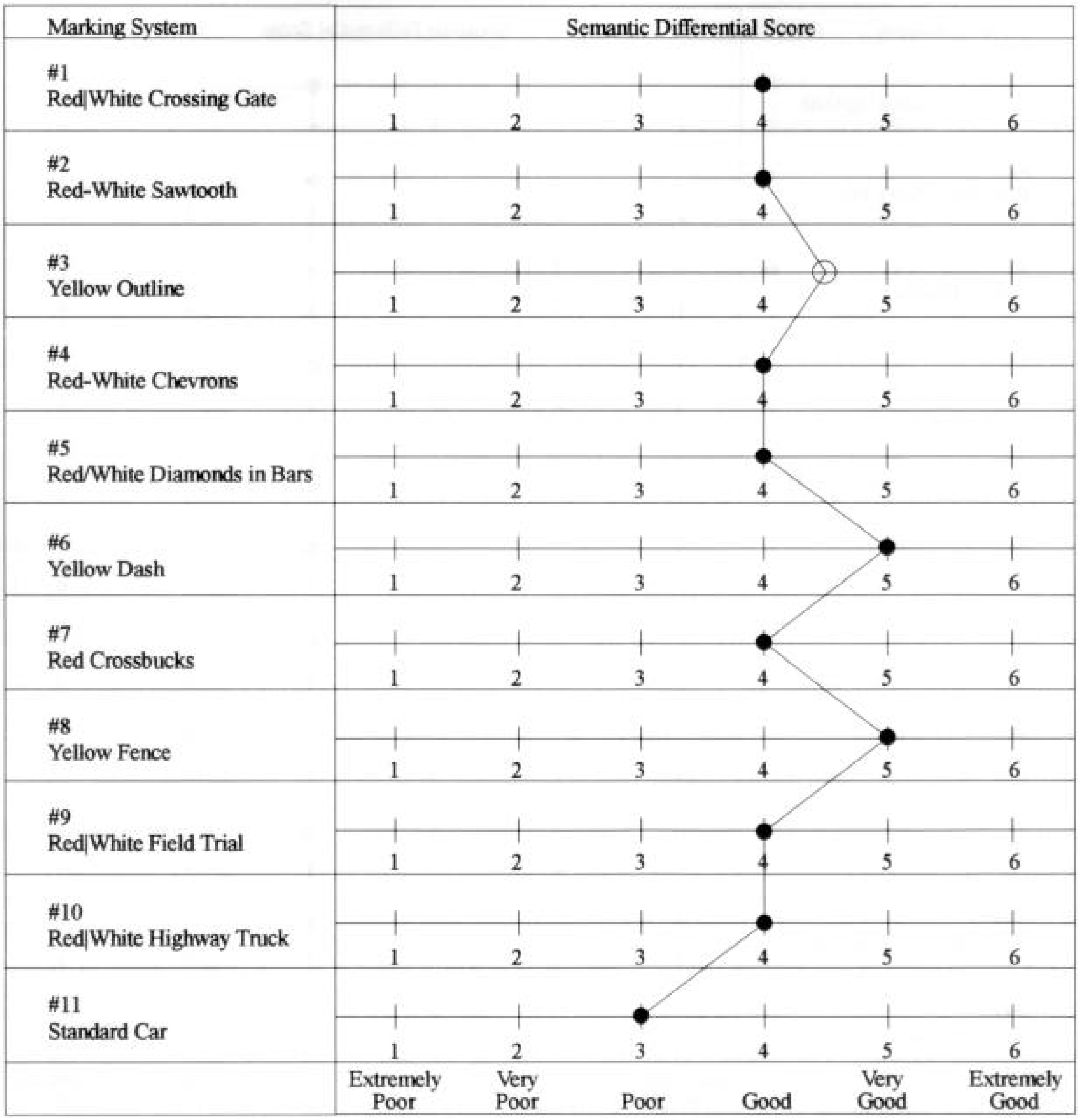


Figure 21. Expert Panel Response to Statement 5, "The conspicuity of the marking is:"

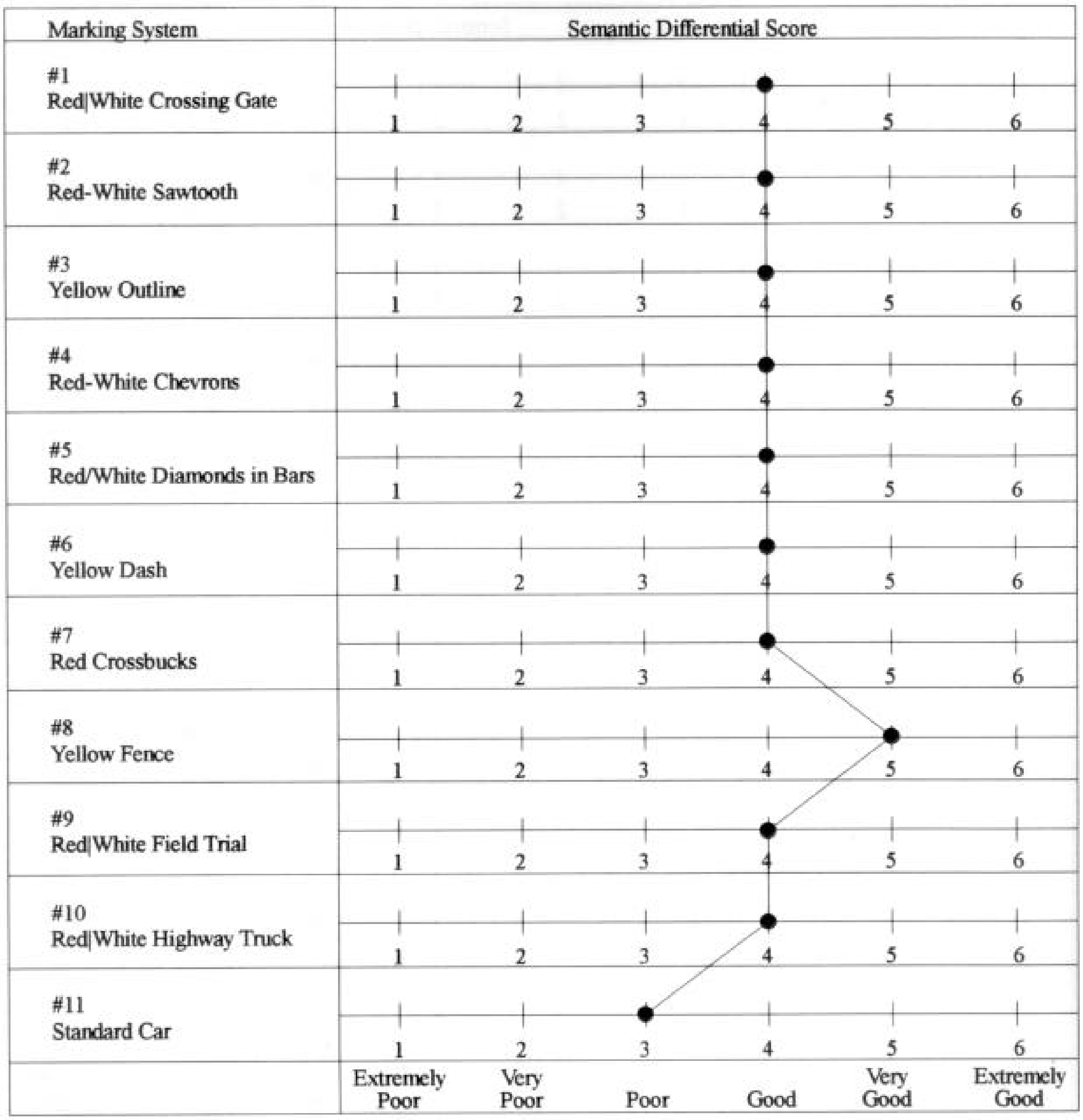


Figure 22. Expert Panel Response to Statement 6, "The uniqueness of the marking is:"

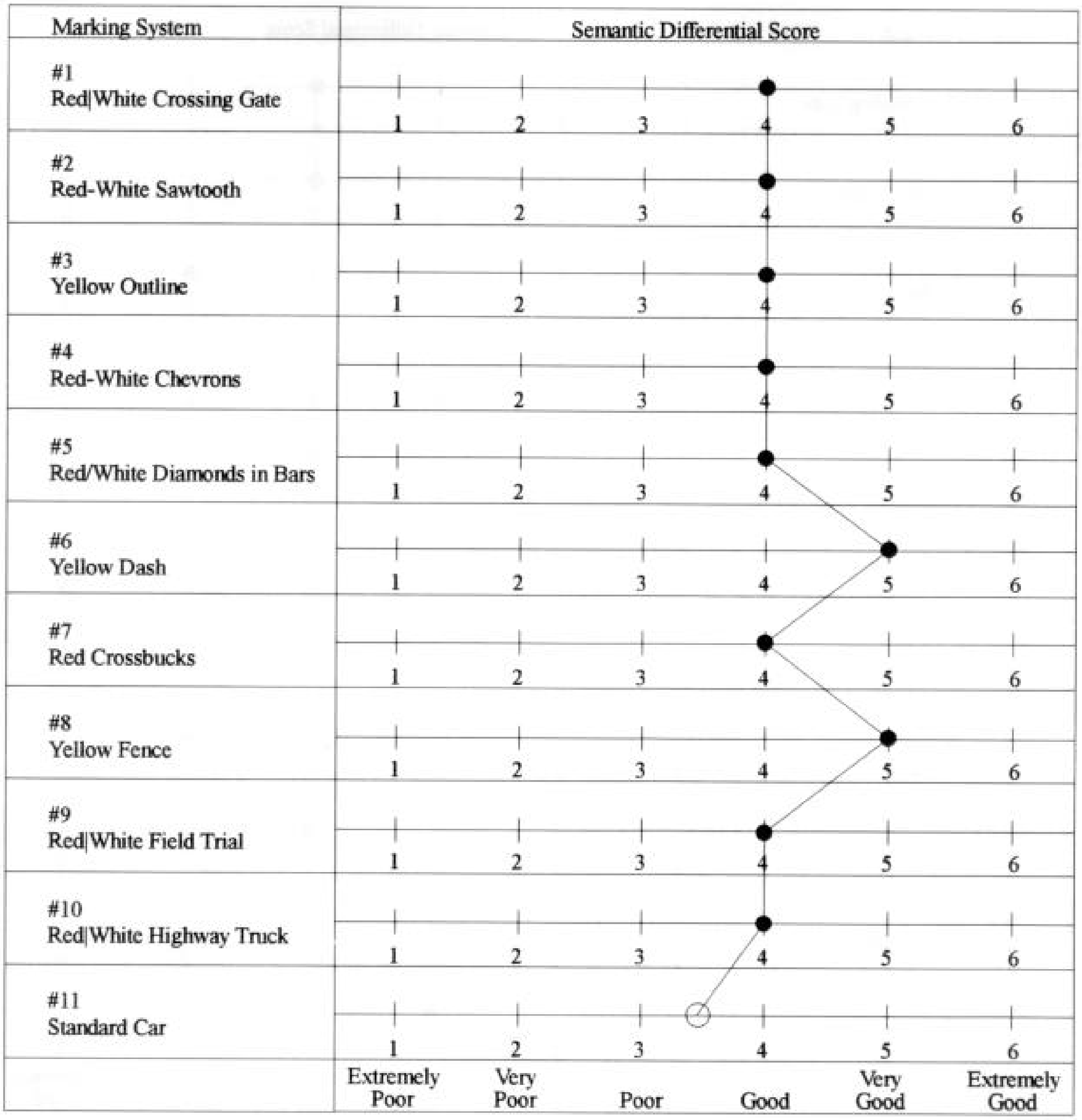


Figure 23. Expert Panel Response to Statement 7, "Contrast of the marking with the freight car background is:"

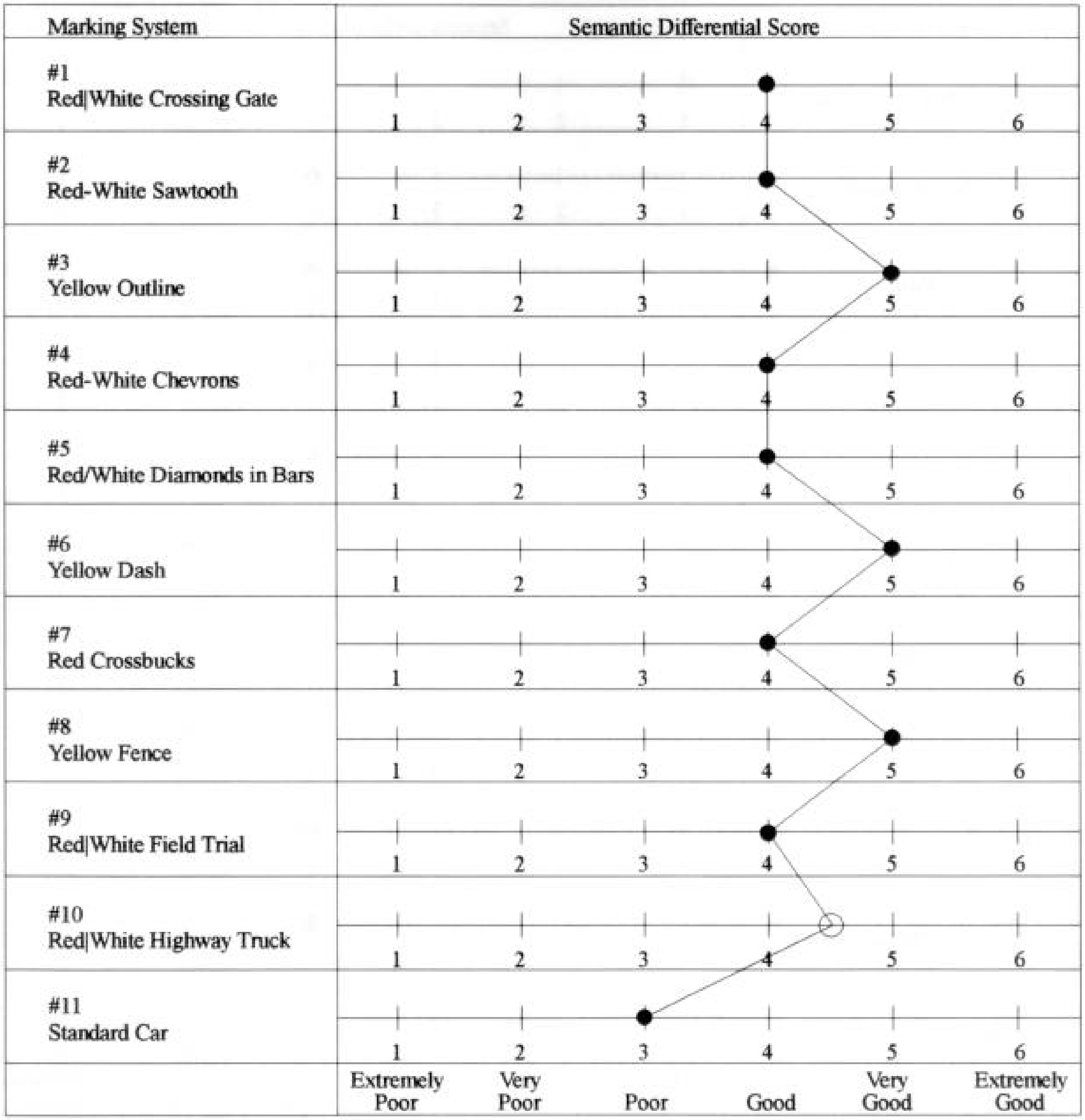


Figure 24. Expert Panel Response to Statement 8, "Placement of the marking on the freight car makes detectability:"

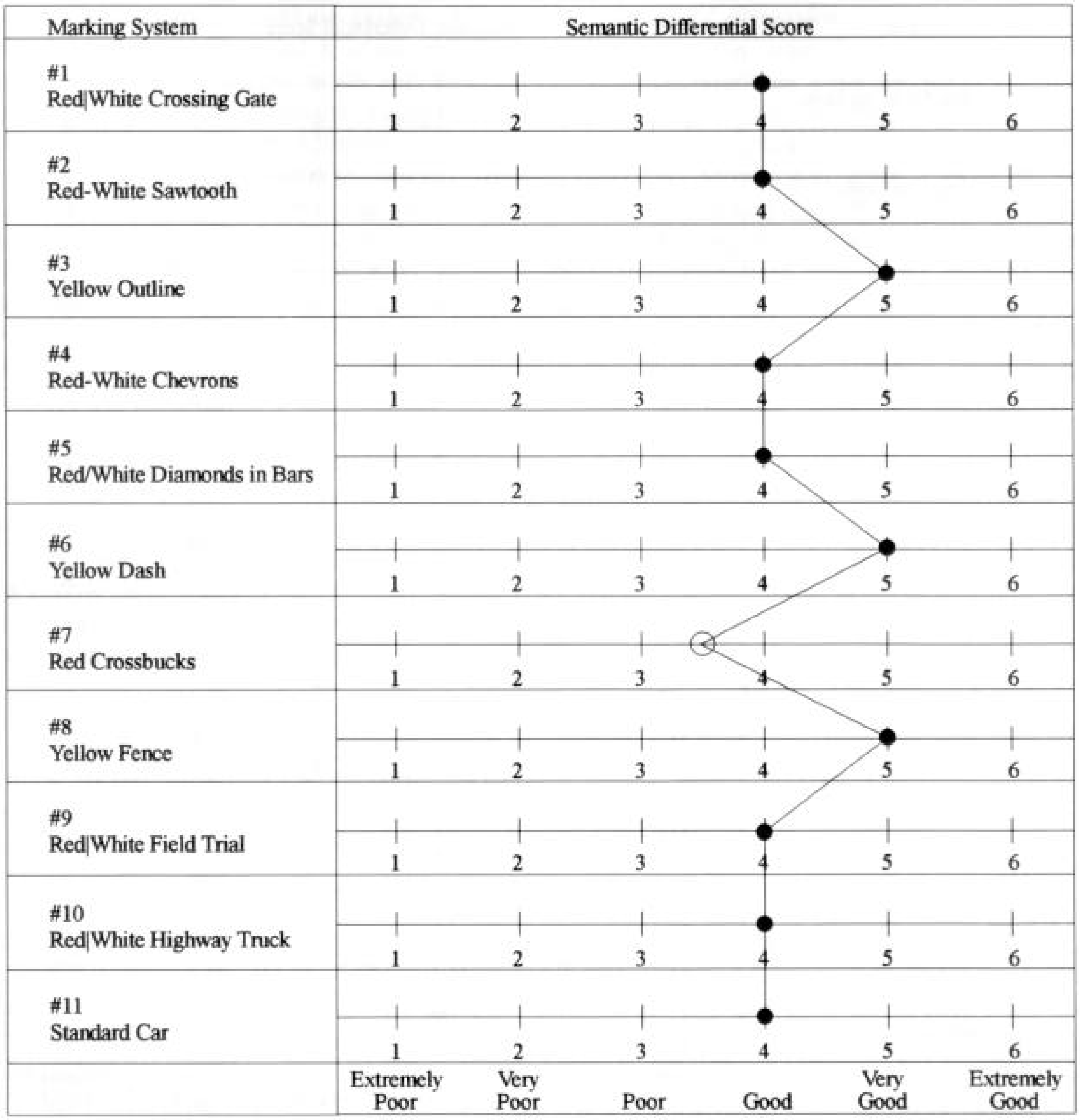


Figure 25. Expert Panel Response to Statement 9, "The marking color(s) make the detectability of the freight car:"

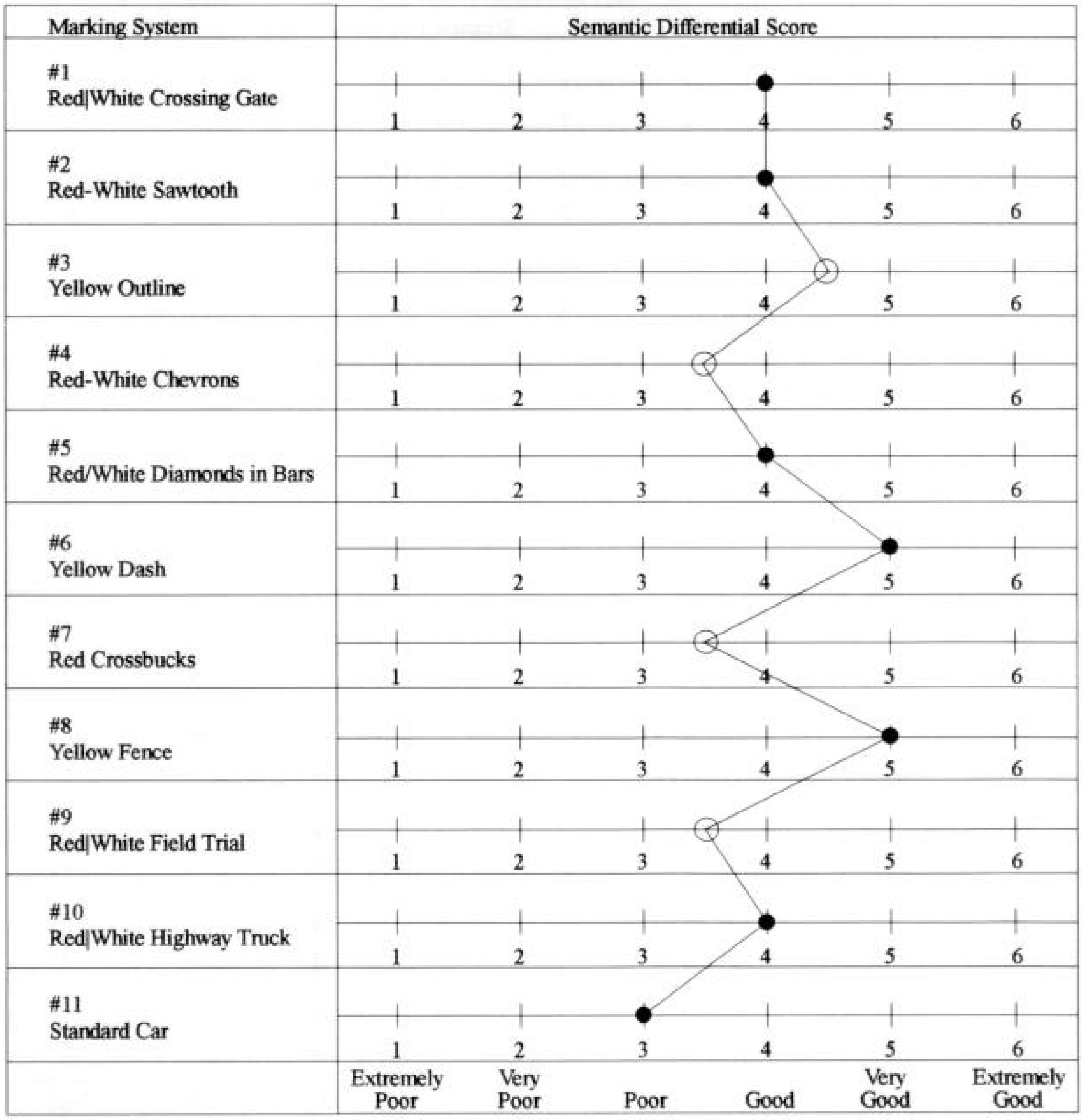


Figure 26. Expert Panel Response to Statement 10. "The marking pattern makes detectability of the freight car:"

for the various marking systems for a given attribute or dimension. A black or closed dot for the mode indicates a strong majority response from the panel for that marking. A white or open dot for the mode indicates two nearly equal responses from the panel for that marking. In all ten semantic categories, the experts judged the Yellow Fence (Marking System #8) as the most effective relative to all the other markings. The Yellow Dash (Marking System #6) and the Yellow Outline (Marking System #3) were judged to be effective, but not as effective as the Yellow Fence. They also judged the Red Crossbuck (Marking System #7) and the Red|White Field Test (Marking System #9), along with the Standard Car (Marking System #11), as the systems that were least satisfactory over all ten semantic categories. Table 7 presents the comparative rankings for the top three and the worst two marking systems for each semantic category. In cases where panel member responses were divided nearly equally between two adjectives, the second most common adjective is listed in parentheses.

Color Preference. Combining the results of the three evaluation techniques gives some indications of the color attributes that may have been used by the panel in judging the marking systems. The experts preferred marking systems that used fluorescent yellow color patterns. In fact, the top three systems in both the paired comparisons and the simple ranking consisted of yellow color patterns. In the Semantic Differential questions dealing with placement of the markings on the car and with the pattern formed by the markings, the systems with yellow color patterns were judged superior.

The lowest ranked color pattern, other than the white on the Standard Car (Marking System #11), was the red color pattern used for the Red Crossbuck (Marking System #7), which ranked tenth. In the Semantic Differential results, adjectives with a negative or poor connotation were chosen four times for this system. The only other system that was described negatively more often was the standard car.

Pattern Preference. Three pattern distribution classes were defined — Class I (a fixed amount of material concentrated in a relatively small area), Class II (a fixed amount of material outlining the shape of the rail car), and Class III (a fixed amoung of material spaced uniformly over a relatively large area). It is interesting to note that three of the four Class III distribution patterns (a fixed amount of material spaced uniformly over a relatively large area) are ranked in the worst five; the one exception is a system with a yellow color pattern, the Yellow Fence (Marking System #8). The only other grouping by pattern distribution consisted of the three Class I patterns (a fixed amount of material concentrated in a relatively small area), which were ranked 3 through 5. The color patterns used with these three Class I patterns uses yellow, red|white, and red/white. These results suggest that the expert panel did not believe the "novelty" distribution patterns (the sawtooth, crossbuck, and chevrons) would be effective marking systems. The only apparent reason for the low ranking for the Red|White Field Test was the panel preference for any yellow marking over red or red and white markings.

Table 7. Subjective Evaluation by Transportation Experts — Comparative Rankings.

Statement		First[1]	Second	Tenth	Eleventh
1.	The marking will make detecting the freight car:	#8, Yellow Fence Very Easy (Extremely Easy)	#6, Yellow Dash Very Easy		#11, Standard Car Very Difficult
2.	The marking will make recognizing the freight car:	#3, Yellow Outline Very Easy (Extremely Easy)	#8, Yellow Fence Very Easy	#7, Red Crossbucks Difficult	#11, Standard Car Very Difficult
3.	The understanding of the marking is:	#8, Yellow Fence Very Good		#7, Red Crossbucks Poor	#11, Standard Car Poor
4.	Confusing the marking with another marking is:	#8, Yellow Fence Very Unlikely	#6, Yellow Dash Unlikely (Very Unlikely)		#7, Red Crossbucks Unlikely (Likely)
5.	The conspicuity of the marking is:	#8, Yellow Fence #6, Yellow Dash Very Good			#11, Standard Car Poor
6.	The uniqueness of the marking is:	#8, Yellow Fence Very Good			#11, Standard Car Poor
7.	Contrast of the marking with the freight car background is:	#6, Yellow Dash #8, Yellow Fence Very Good			#11, Standard Car Poor (Good)

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[1] A parenthesis around a response indicates a nearly equal bimodal response.

Table 7. (continued).

Statement		First	Second	Tenth	Eleventh
8.	Placement of the marking on the freight car makes detectability:	#3, Yellow Outline #6, Yellow Dash #8, Yellow Fence Very Good	#10, Red|White Highway Truck Very Good (Good)		#11, Standard Car Poor
9.	The marking color(s) make the detect- ability of the freight car:	#3, Yellow Outline #6, Yellow Dash #8, Yellow Fence Very Good			#7, Red Crossbucks Good (Poor)
10.	The marking pattern makes detectability of the freight car:	#6, Yellow Dash #8, Yellow Fence Very Good	#3, Yellow Outline Good (Very Good)	#3, Red Crossbucks #9, Red|White Field Test Good (Poor)	#11, Standard Car Poor

Novice Panel Results

The novice panel's rank ordering for the paired comparisons and the simple rankings are shown in Figure 27 and Table 8, respectively. As seen in the Table 8, the novice panel was less consistent in its rankings of the marking systems as compared to the expert panel. However, the top four and the last three ranked systems were the same in the paired comparisons and the simple rankings by the novice panel. The four marking systems that were judged to be the most effective in enhancing the visibility of freight cars, in order of preference, were the Yellow Fence (Marking System #8), the Red-White Sawtooth (Marking System #2), the Yellow Outline (Marking System #3), and the Red|White Highway Truck (Marking System #10). The three marking systems judged to be the least effective, in descending order of preference, were the Red/White Diamonds in Bars (Marking System #5), the Yellow Dash (Marking System #6), and the Standard Car (Marking System #11). The middle four ranks, 5, 6, 7, and 8 in the paired comparisons became ranks 8, 7, 6, and 5, respectively, in the simple ranking. These were the Red Crossbuck (Marking System #7), the Red-White Chevrons (Marking System #4), the Red|White Field Test (Marking System #9), and the Red|White Crossing Gate (Marking System #1). An examination of the attributes and dimensions of these four systems did not reveal a reason for this inversion of the ranks.

The Semantic Differential evaluation results were consistent within the novice panel. These results for the six attributes and four dimensions are presented graphically in Figures 28-37. Each figure shows the Semantic Differential mode scores for the various marking systems for a given attribute or dimension. In all of the ten semantic differential categories, the novice panel preferred either or both the Yellow Outline (Marking System #3) or the Red-White Sawtooth (Marking System #2). The Yellow Fence (Marking System #8) was chosen as the second most effective system. As with the expert panel, the Standard Car (Marking System #11) was the judged the least effective. However, the novice panel expressed their dislike for this system much more strongly than did the expert panel; the novice panel selected the most negative adjective whereas the expert panel selected adjectives that were more neutral. There was no consistency among the novice panel regarding the least preferred retroreflective marking system. In fact, four different systems were rated as worst in some category. These systems were the Red/White Diamonds in Bars (Marking System #5) twice, the Red Crossbuck (Marking System #7) twice, the Yellow Dash (Marking System #6) twice, and the Red|White Field Test (Marking System #9) twice. Table 9 presents the comparative rankings for the marking systems which received the best and worst scores in each of the ten semantic categories.

Color Preferences. Combining the two rankings and the semantic differential results yielded no obvious trends for color preference among the novice panelists. (This was not the case with the expert panel.) However, the Semantic Differential results indicate that the novice panelists had an equal preference for the yellow and red-white color patterns as the most preferred. There was not a color or color group that was consistently disliked by the novice panelists.

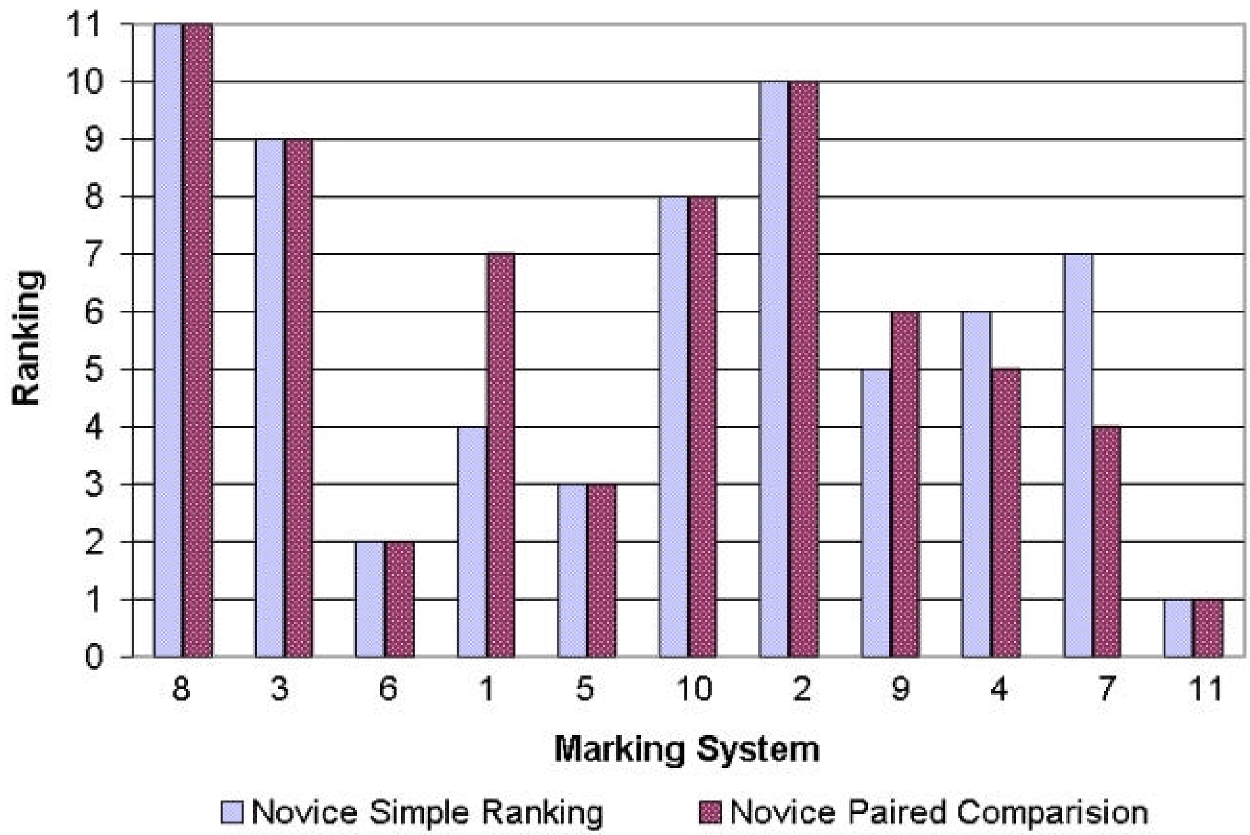

Figure 27. Subjective Evaluation by Transportation Novices.

Table 8. Subjective Evaluation by Transportation Novices.

Rank	Simple Ranking Marking System	Paired Comparisons Marking System
1	#8, Yellow Fence	#8, Yellow Fence
2	#2, Red-White Sawtooth	#2, Red-White Sawtooth
3	#3, Yellow Outline	#3, Yellow Outline
4	#10, Red|White Highway Truck	#10, Red|White Highway Truck
5	#7, Red Crossbucks	#1, Red|White Crossing Gate
6	#4, Red-White Chevrons	#9, Red|White Field Test
7	#9, Red|White Field Test	#4, Red-White Chevrons
8	#1, Red|White Crossing Gate	#7, Red Crossbucks
9	#5, Red/White Diamonds in Bars	#5, Red/White Diamonds in Bars
10	#6, Yellow Dash	#6, Yellow Dash
11	#11, Standard Car	#11, Standard Car

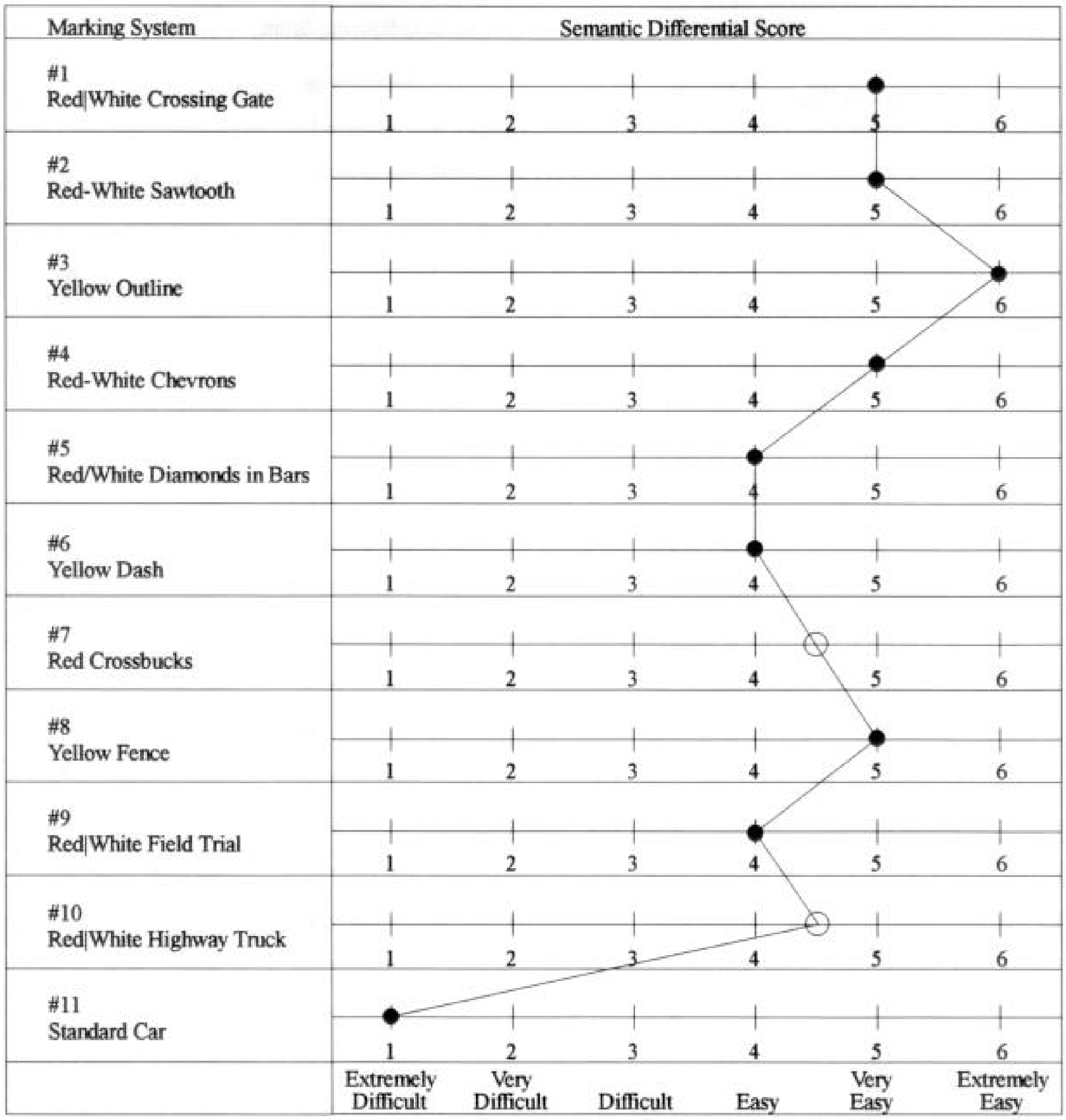

Figure 28. Novice Panel Response to Statement 1, "The marking will make detecting the freight car:"

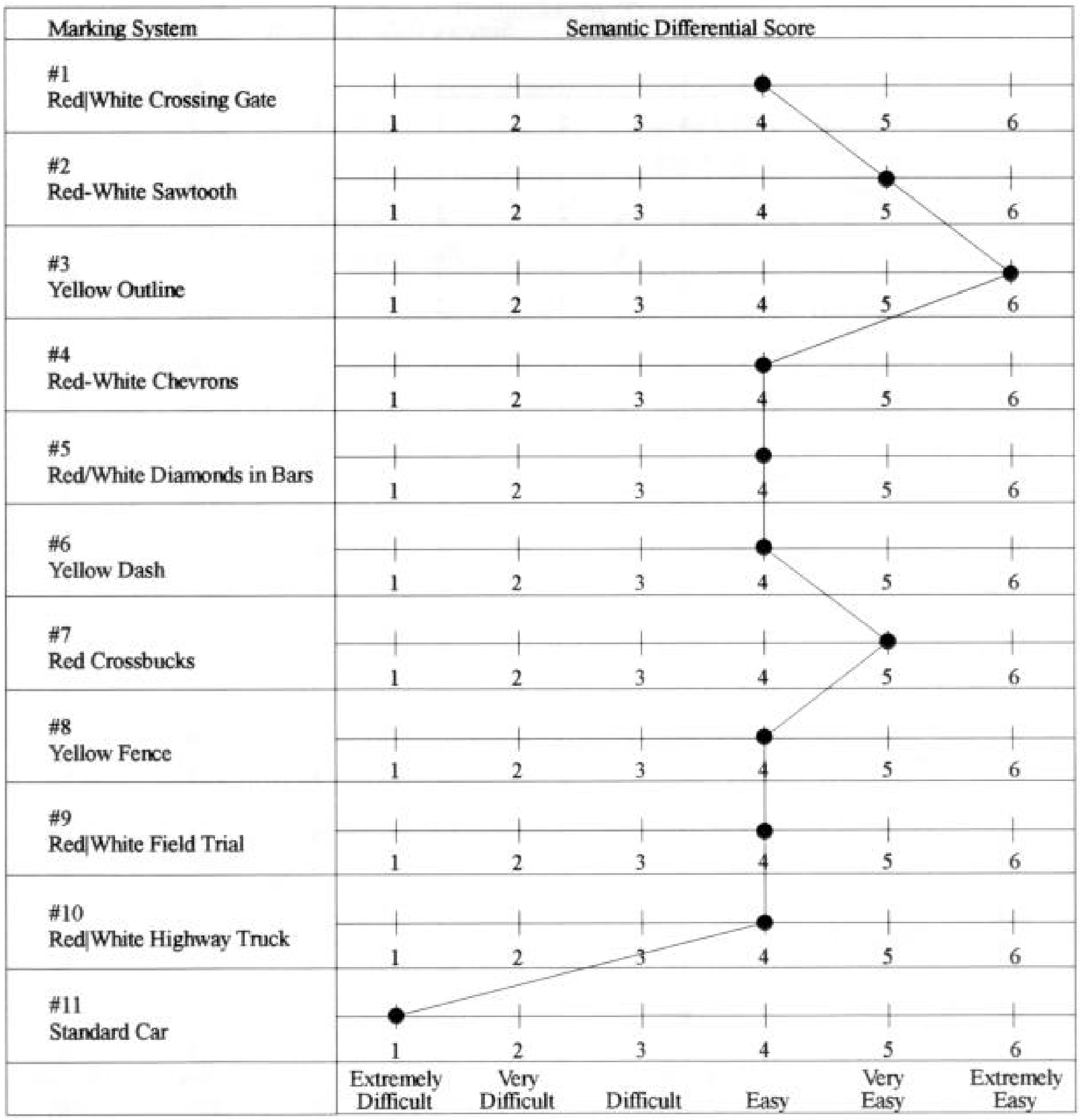

Figure 29. Novice Panel Response to Statement 2, "The marking will make recognizing the freight car:"

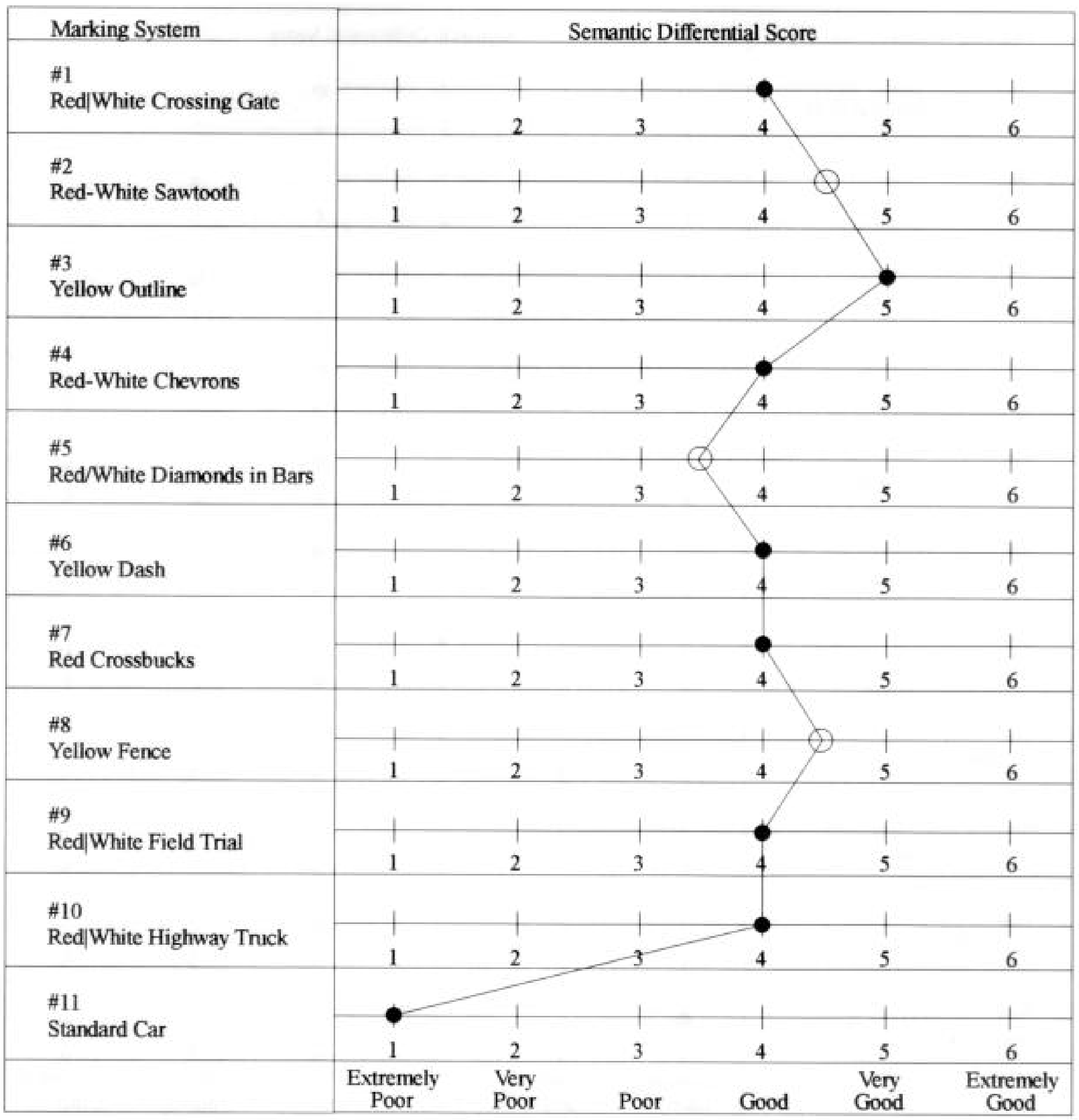

Figure 30. Novice Panel Response to Statement 3, "The understanding of the marking is:"

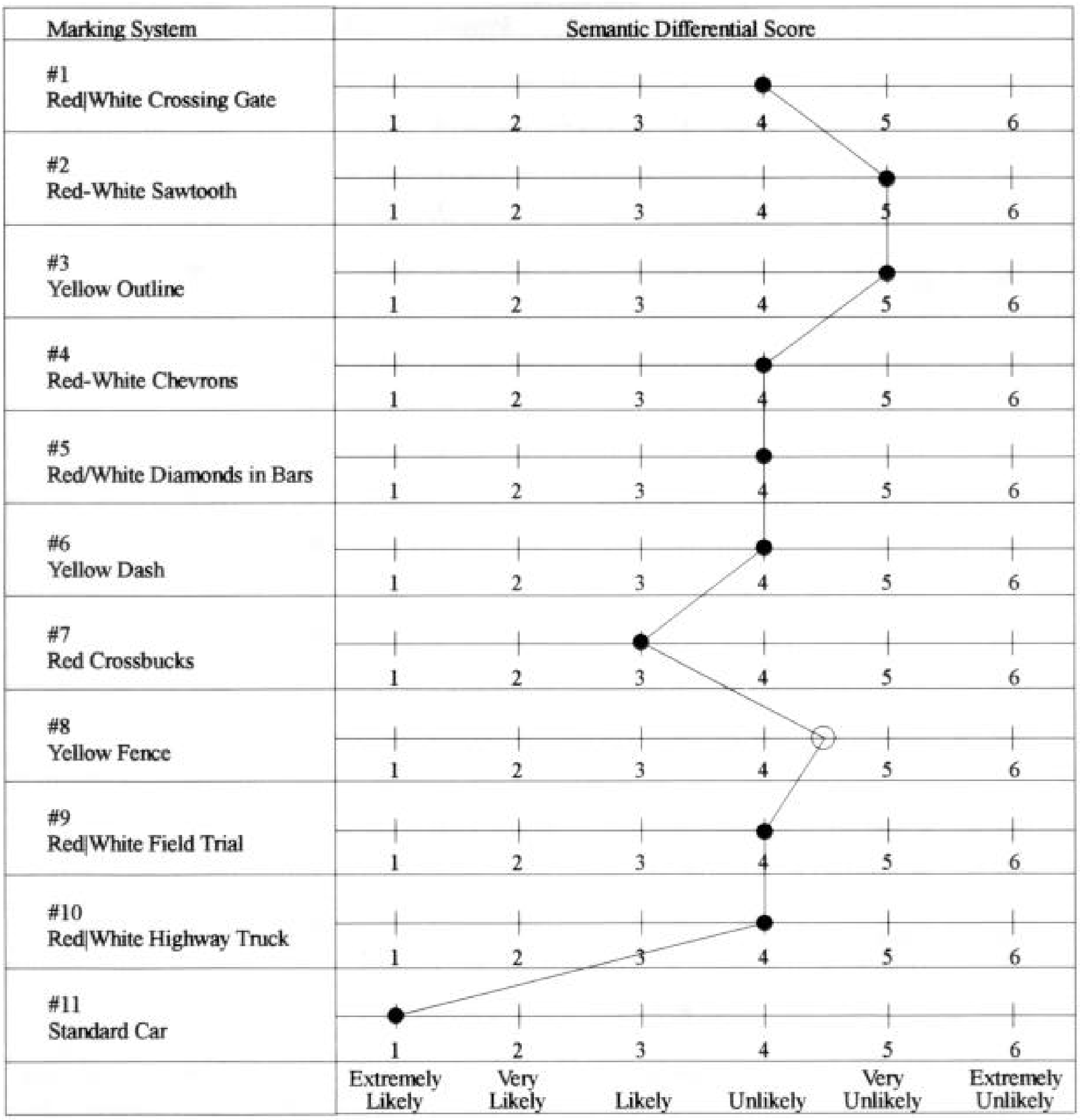

Figure 31. Novice Panel Response to Statement 4, "Confusing the marking with another marking is:"

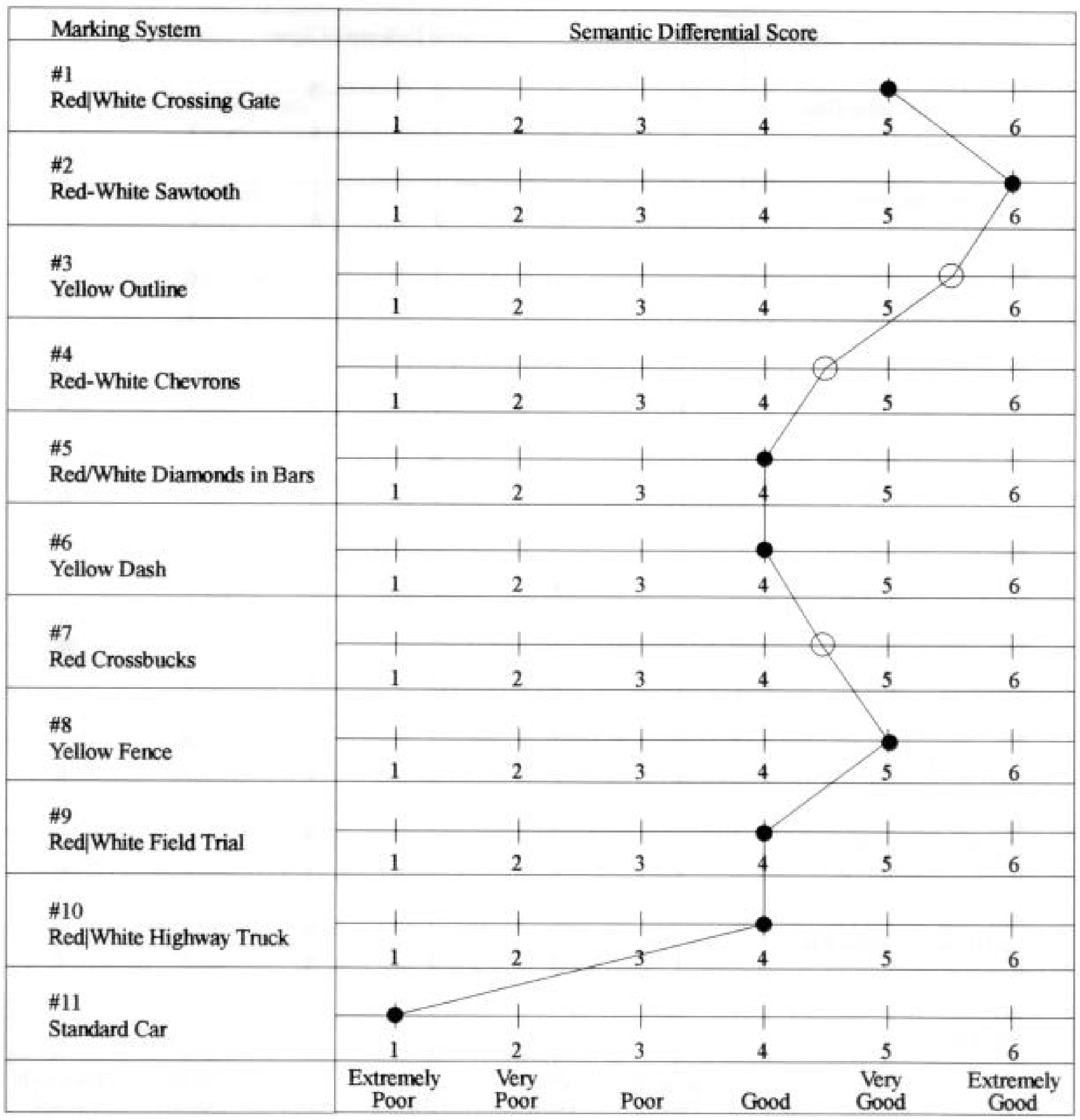

Figure 32. Novice Panel Response to Statement 5, "The conspicuity of the marking is:"

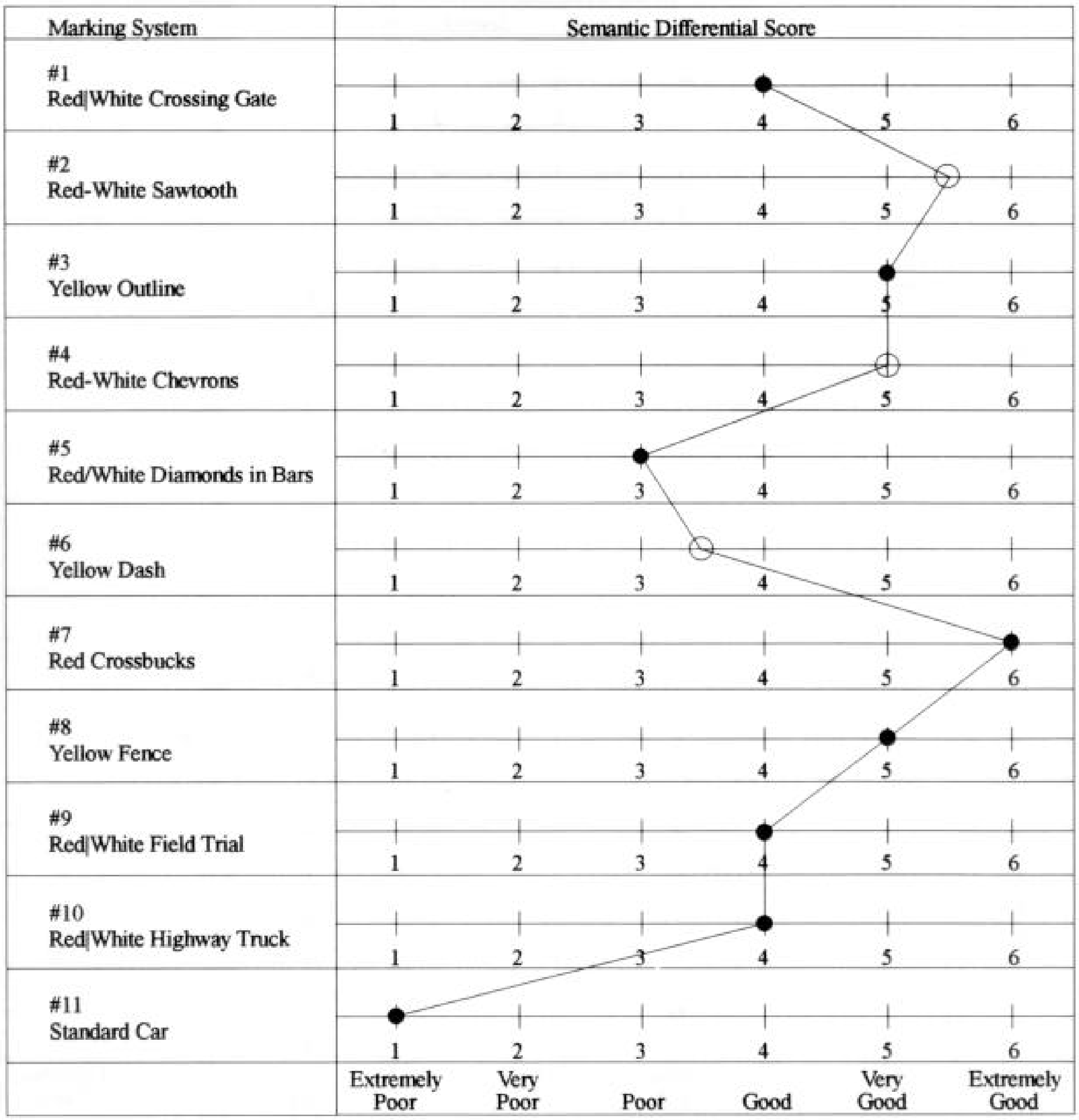

Figure 33. Novice Panel Response to Statement 5, "The uniqueness of the marking is:"

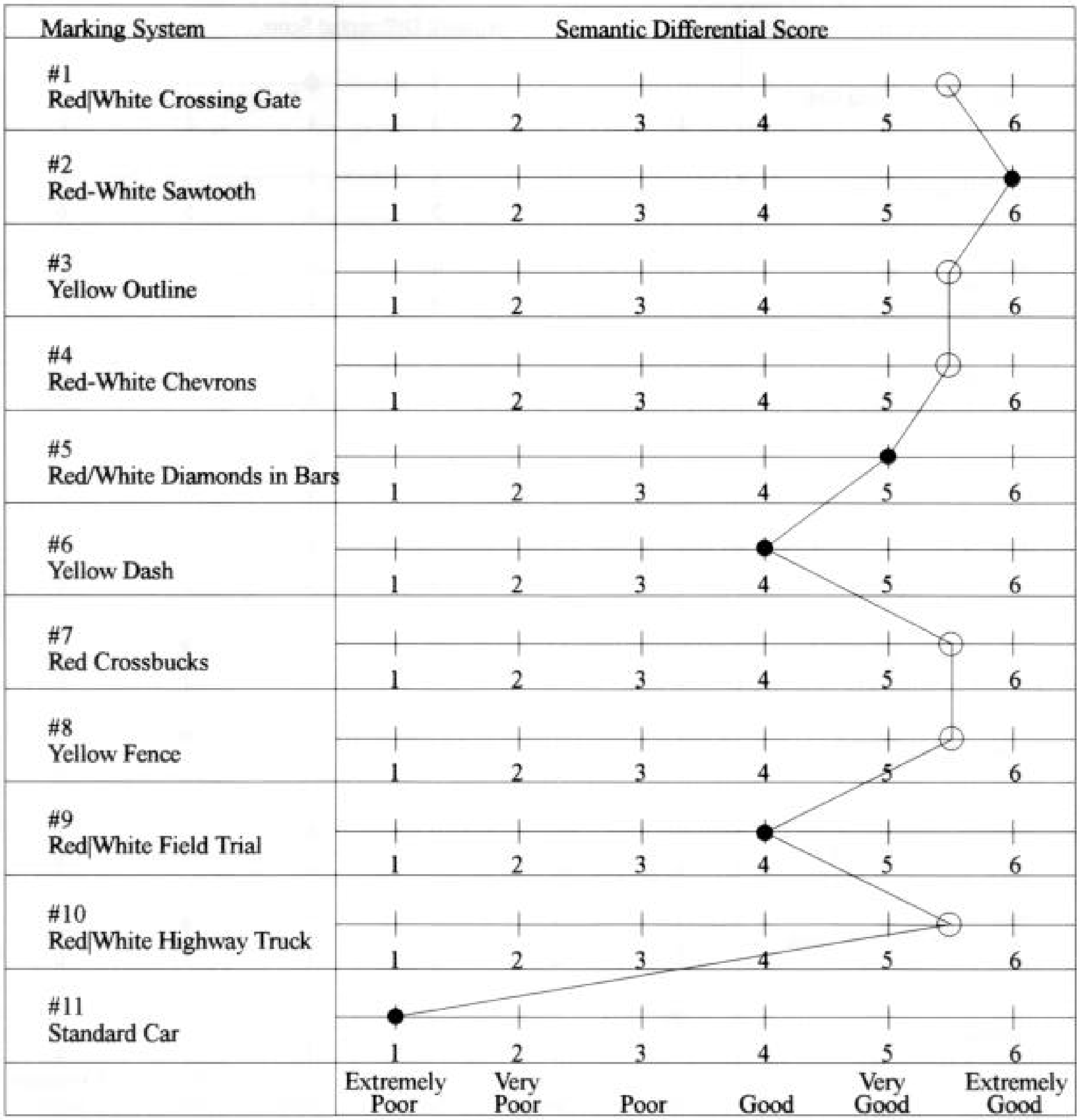

Figure 34. Novice Panel Response to Statement 7, "Contrast of the marking with the freight car background is:"

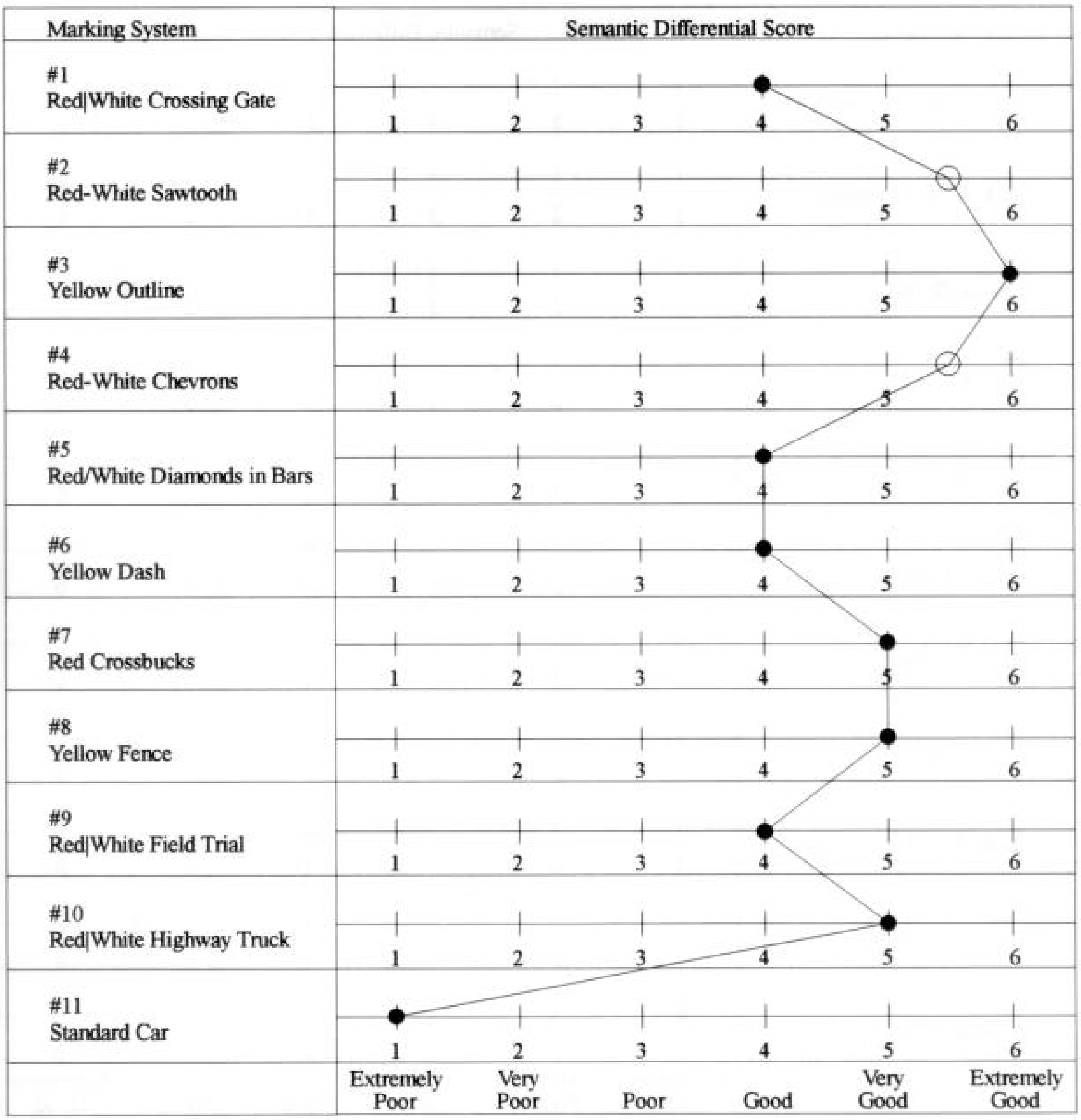

Figure 35. Novice Panel Response to Statement 8, "Placement of the marking on the freight car makes detectability:"

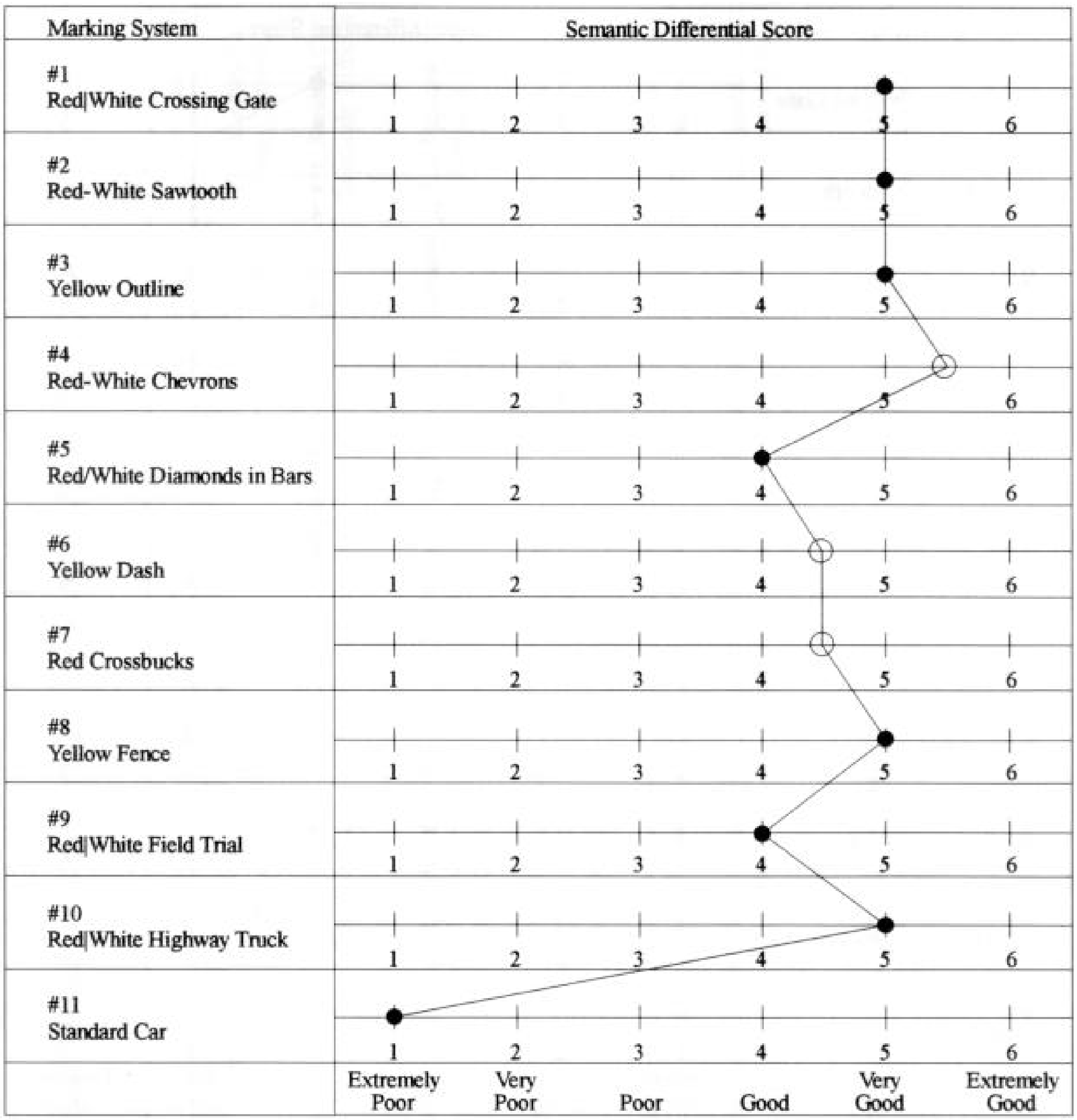

Figure 36. Novice Panel Response to Statement 9, "The marking color(s) make the detectability of the freight car:"

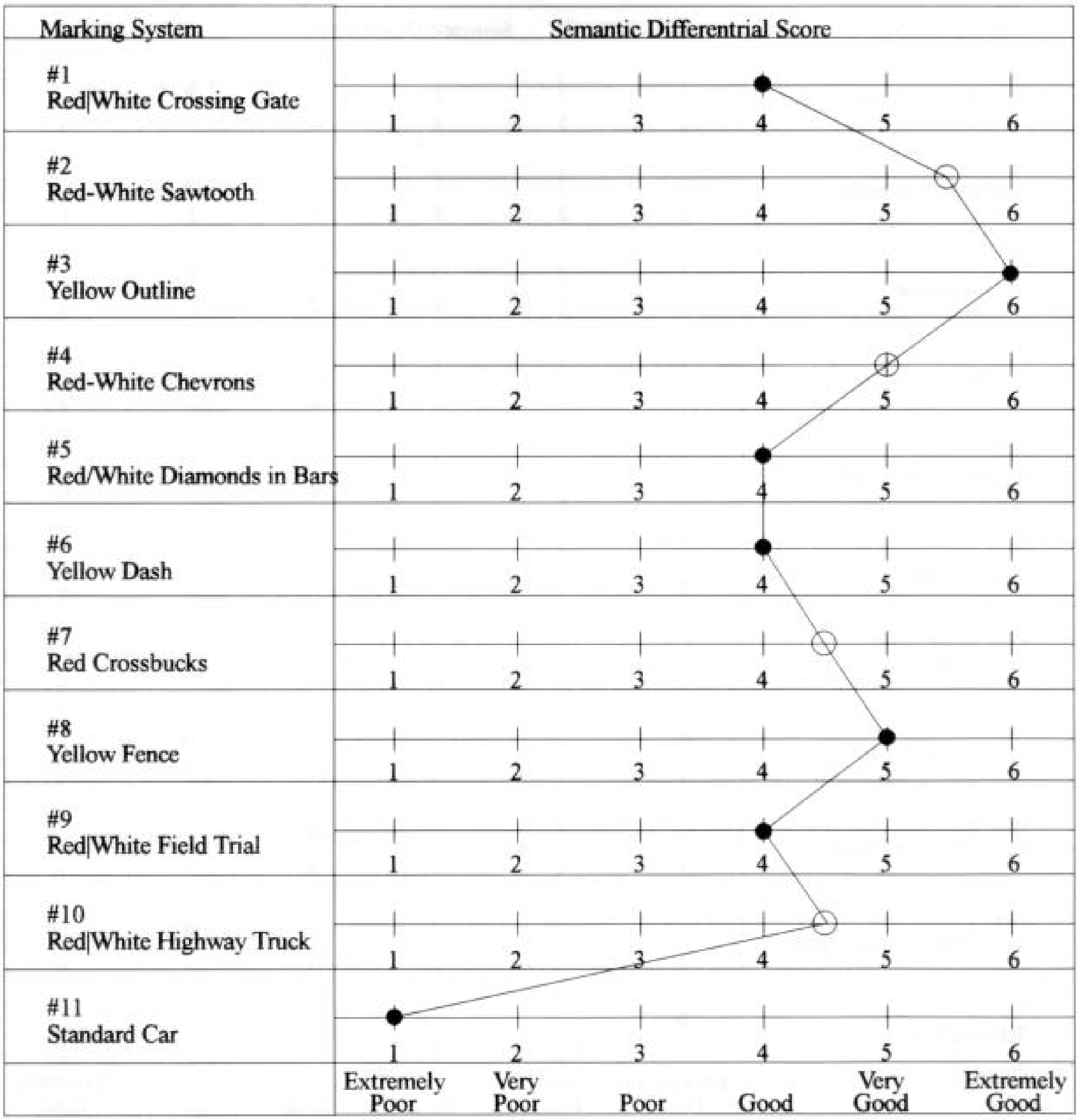

Figure 37. Novice Panel Response to Statement 10. "The marking pattern makes detectability of the freight car:"

Table 9. Subjective Evaluation by Transportation Novices — Comparative Rankings.

Statement		First[1]	Second	Tenth	Eleventh
1.	The marking will make detecting the freight car:	#3, Yellow Outline Extremely			#11, Standard Car Very Difficult
2.	The marking will make recognizing the freight car:	#3, Yellow Outline Extremely Easy (Extremely Easy)	#2 Red-White Sawtooth #7, Red Crossbucks Very Easy		#11, Standard Car Extremely Difficult
3.	The understanding of the marking is:	#2, Red-White Sawtooth #3, Yellow Outline Very Good	#8, Yellow Fence Good	#5, Red/White Diamonds in Bars Poor	#11, Standard Car Extremely Poor
4.	Confusing the marking with another marking is:	#2, Red-White Sawtooth #3, Yellow Outline Very Unlikely	#8, Yellow Fence Unlikely	#7, Red Crossbucks Likely	#11, Standard Car Extremely Likely
5.	The conspicuity of the marking is:	#2, Red-White Sawtooth Extremely Good	#3, Yellow Outline Very Good		#11, Standard Car Extremely Poor
6.	The uniqueness of the marking is:	#7, Red Crossbucks Extremely Good	#2, Red-White Sawtooth #3, Yellow Outline #8, Yellow Fence Very Good	#5, Red/White Diamonds in Bars #6, Yellow Dash Poor	#11, Standard Car Extremely Poor
7.	Contrast of the marking with the freight car background is:	#2, Red-White Sawtooth #3, Yellow Outline Extremely Good	Very Good	#6, Yellow Dash #9, Red|White Field Test Good	#11, Standard Car Extremely Poor

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[1] A parenthesis around a response indicates a nearly equal bimodal response.

Table 9. (continued).

Statement		First	Second	Tenth	Eleventh
8.	Placement of the marking on the freight car makes detectability:	#2, Red-White Sawtooth #3, Yellow Outline Extremely Good	#4, Red-White Chevrons Very Good		#11, Standard Car Extremely Poor
9.	The marking color(s) make the detect- ability of the freight car:	#4, Red-White Chevrons Very Good			#11, Standard Car Extremely Poor
10.	The marking pattern makes detectability of the freight car:	#3, Yellow Outline Extremely Good	#2, Red-White Sawtooth Very Good		#11, Standard Car Extremely Poor

Pattern Preference. All three methods suggest that the novice panel had a preference for Class II and Class III distribution patterns (a fixed amount of material outlining the shape of the freight car and a fixed amount of material spaced uniformly over a relatively large area respectively). Both ranking methods had the Class III distribution pattern ranked 1 and 2, and the Class II distribution pattern ranked 3 and 4. The ranking methods also placed the Class I (a fixed amount of material concentrated in a relatively small area) distribution pattern at the bottom of the rankings (in positions 9 and 10). Only the Standard Car ranked lower at 11.

Comparison of Expert and Novice Panel Assessments

The only area of agreement between the two panels was in their ranking of the marking systems using the paired comparison scaling and the simple ranking technique. Both panels ranked the Yellow Fence (Marking System #8) as the most effective and the Standard Car (Marking System #11) as the most ineffective (Tables 6 and 8). No other system shared an equal rank. The only agreement between the panels in the Semantic Differential Technique was that the Standard Car was the most ineffective (Tables 7 and 9).

This lack of consistency between the panels was not unexpected. While the experts are a subset of the general population from which both panels were drawn, the criterion for being on the expert panel was to have experience and knowledge in grade crossing safety, conspicuity, signing, or human factors. The novice was thus defined as a person who did not have this experience or knowledge. However, the factor that best explained the differences in results was the differences in how the methodologies were presented to the panel members. The expert panel evaluated color photographs of the systems while the novice panel evaluated the models under simulated nighttime driving conditions. The experts saw a representation of the markings as viewed in daylight while the novice panel saw representations reflecting headlights as viewed under nighttime conditions.

However, an evaluation of the data collected from each panel did give much needed guidance in selecting marking systems for the objective evaluation. The expert panel data suggested that yellow was the most effective color pattern to use for conspicuity markings while red was the least effective. However, the novice data suggested that either yellow or red-white color patterns were equally effective but did not give a clear indication of an ineffective color pattern. When the distribution pattern was considered independently, the novice data suggested that a Class III distribution pattern (a fixed amount of material spaced uniformly over a relatively large area) was slightly more effective than a Class II distribution (a fixed amount of material outlining the shape of the car). The expert data did not give any indication that any of the distribution patterns were more effective or ineffective than any of the others.

Summary

The purpose of the subjective evaluation was to provide information about a set of conspicuity systems that people perceived as being effective in increasing the conspicuity of a rail car. This evaluation was also to provide a set of perceived effective marking systems that could be evaluated objectively. The results of the subjective evaluation suggested that marking systems made from yellow or red|white retroreflective material either distributed over a relatively large area or outlining the shape of the rail car would enhance its conspicuity. The subjective evaluation also indicated that red or the combinations of red and white material, regardless of the distribution pattern, was not perceived to be as effective as either the yellow or red|white material. This evaluation also indicated that a concentration of any of the color patterns in a small area low on the side of the rail car would not be as effective as the same colors distributed so as to indicate the size or shape of the rail car.

Because the subjective evaluation did not give a clear preference for either a single color pattern, a single distribution pattern, or a unique set of effective conspicuity systems, it was decided to select three color patterns and three distribution patterns to create nine retroreflective marking systems for use in the objective evaluation. The criteria used to select the markings were:

1. That at least one marking system be judged by the panels to be highly effective in enhancing the conspicuity of hopper cars, one marking system be judged to be ineffective, and one to fall in the mid range of effectiveness;

2. That the marking systems selected be amenable to being duplicated in both the placement patterns and all three colors; and

3. That Marking System #9, the Red|White Field Test design, be included in all evaluations and experiments.

Three distribution patterns were created by concentrating the markings along the side sill of the car for the first distribution pattern, placing the markings on the end post and along the side sill to outline the shape of the car for the second distribution pattern, and attaching the markings to the side stakes to uniformly cover a relatively large part of the car side for the third distribution pattern. These three distribution patterns were produced in yellow, red|white, and red colors.

V. OBJECTIVE EVALUATION OF THE MARKING SYSTEMS

As noted previously, the subjective evaluations did not establish a clear preference for color, distribution pattern, or specific designs for a rail car marking system. However, the subjective evaluations did provide a basis to generate nine retroreflective marking systems which represented the levels of color pattern and distribution pattern preferred by the expert panel, the novice panel, or both. These nine systems were described at the close of Section V.

This section describes the objective laboratory experiment performed to evaluate these nine systems and to further access the key attributes of rail car markings which should be controlled to provide a high probability of detection and recognition of rail cars at night.

Methodology

The general methodology used in the objective evaluation was to have 36 volunteer subjects perform two absolute discrimination tasks — detection and recognition of rail cars with the various retroreflective marking systems. In both tasks, the subjects viewed sets of photographic slides, under simulated nighttime conditions, of the marking systems displayed on the side of a scale hopper car. Each slide in a set presented the marking system at a closer distance than did the previous slide. The subject responded by pressing a computer key when the marking system was detected and then pressing a second key when the marking system was recognized.

Choice of Performance Measures (Dependent Variables). The data on detection time, recognition time, and recognition errors were analyzed to determine the relative performance of each of the marking systems. A short detection time was considered indicative of an effective marking system for detection. Likewise, a short recognition time was considered indicative of an effective marking system for recognition. The number of errors made in recognizing a marking system would provide a measure of the relative uniqueness of the marking system. A marking system with a small proportion of incorrect responses (i.e., the system was not often mistaken for another system) would indicate that the marking system was less likely to be confused with the other marking systems.

Directly related to the performance measures of detection and recognition time were two other dependent variables — detection distance and recognition distance. Neither of these variables were chosen as performance measures because all of the subjects viewed each slide at the same distances but not for the same amount of time. However, since it is common to report detection and recognition in terms of distance (i.e., feet), times will have the equivalent detection distance and recognition distance given. Because of the viewing time allowed for each slide, These calculated detection and recognition distances will be less than or equal to the perceived distance of the image on the projection screen. Also, it should be noted that the distances in the slides are of the rail car illuminated and viewed under optimal conditions. That is, the simulated headlights are perpendicular to and centered on the car horizontally and aligned vertically to maximize the amount of light reflected back to the camera and the subject. Also, because the photographs were made indoors in a clean dry air, there was no measurable attenuation and scatter of the incident and reflected light, again maximizing the amount of light collected by the camera.

Attributes to be Varied (Independent Variables). Because the coding dimensions of reflectivity, geometric shape, size or area, visible area of the rail car, and contrast with background were fixed for each marking system, only the color pattern and the distribution pattern attributes of the marking systems varied for this evaluation. The geometric shape (a 6:1 or an 8:1 aspect rectangle) and the area (2 square feet) did not change from system to system. The contrast to the fixed black background color changed as each color pattern was changed but was not considered as a separate dimension since it is independent of the color pattern chosen for a given marking system.

Each of these attributes had three levels — fluorescent yellow (hereafter simply called yellow), red|white, and red for color pattern; and the distribution patterns called the dash, the fence, and the field test — creating the nine retroreflective marking systems. Table 10 shows the marking system identifiers assigned to each of these systems and the SIA values for the retroflective materials. Figures 38-47 show the 10 marking systems tested and the names assigned to each. The standard hopper car with AAR reporting marks (all nonreflective) was again included to provide a baseline to which the retroreflective systems could be compared. As in the subjective evaluation, each of the systems was replicated in miniature by cutting diamond grade retroreflective material to the appropriate shape and attaching it to 1:22.6 (17/32 of an inch to the foot) scale models of open top hopper cars.

Each of the nine marking systems was fabricated from diamond grade retroreflective material. The material was attached to 1:22.6 (17/32 of an inch to the foot) scale models of open top hopper cars. Each system had the scale equivalent of 384 square inches of retroreflective material in the prescribed colors and geometric shapes. The scale equivalent of 384 square inches was chosen so that each of the markings would have the same amount of retroreflective material as the marking system that is currently undergoing field testing to evaluate loss of reflective properties under railroad operating conditions. Because the area for each marking system was fixed, the SIA was not the same for each marking system tested. 35mm color transparencies of the individual models were made at 240 foot increments in a simulated nighttime grade crossing using only simulated headlights for illumination.

Experimental Design

A two-way factorial experiment in a randomized complete block design was selected for this evaluation. There were four observations by each subject for each of the 10 marking systems (9 experimental systems plus the standard AAR markings). For this experiment the subjects were a random effect and the 10 marking systems were fixed. Since each of the ten systems was replicated

Table 10. Marking System Identifiers.

Color Pattern	SIA[1]	Distribution Pattern		
		Fence	Field Test	Dash
Yellow (High Contrast)	700	#8	#9A	#6
Red|White (Medium Contrast)	449[2]	#8A	#9	#6A
Red (Low Contrast)	215	#8B	#9B	#6B

Note: Identifiers without a letter are the same as for the subjective evaluation.

1 Observation angle 0.2^{o}, entrance angle -4^{o}

2 Estimated SIA for 40% white and 60% red; 800(0.4) + 215(0.6).

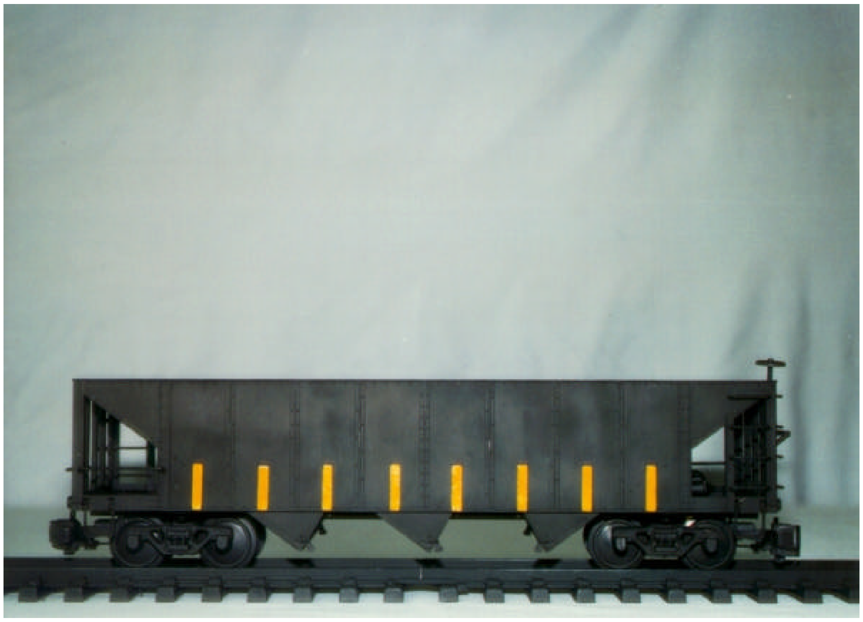


Figure 38. Marking System #8, Yellow Fence.

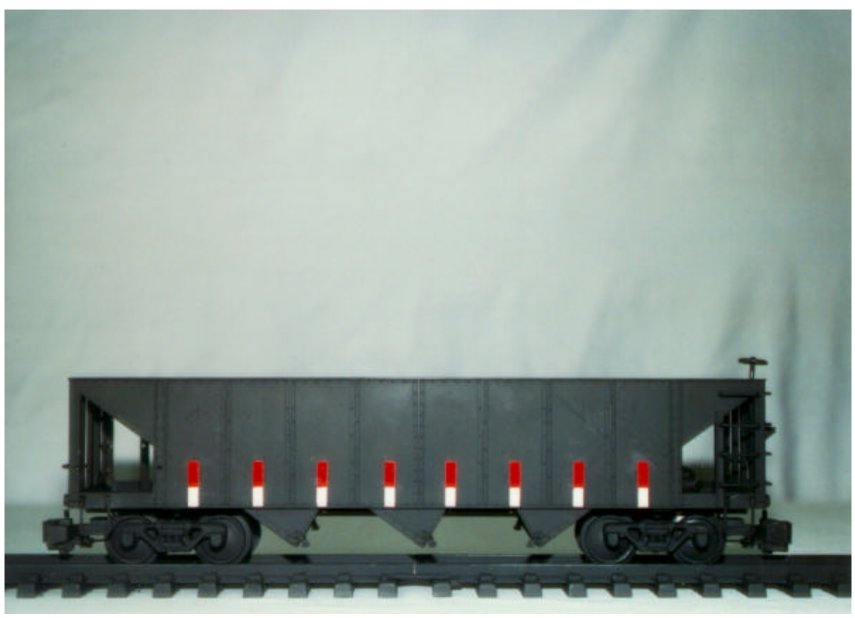


Figure 39. Marking System #8A, Red|White Fence.

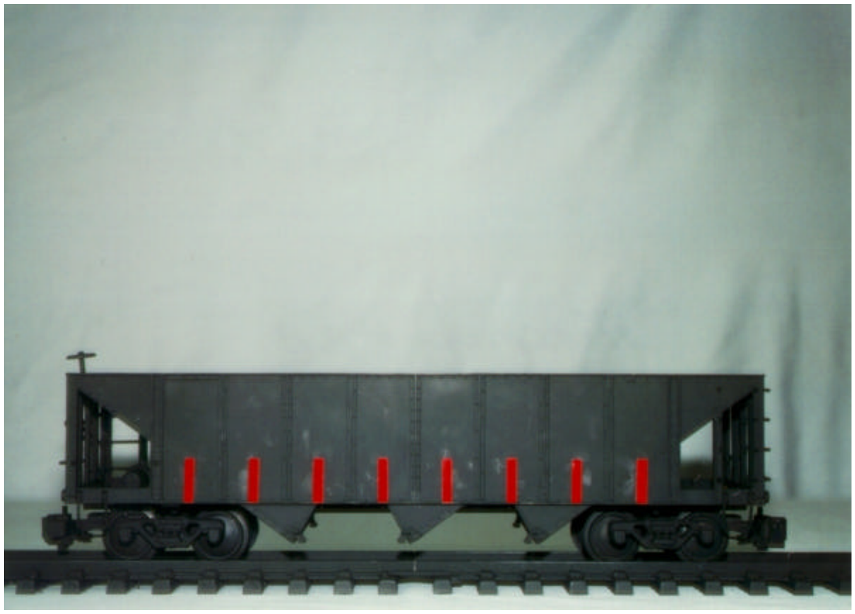


Figure 40. Marking System #8B, Red Fence.

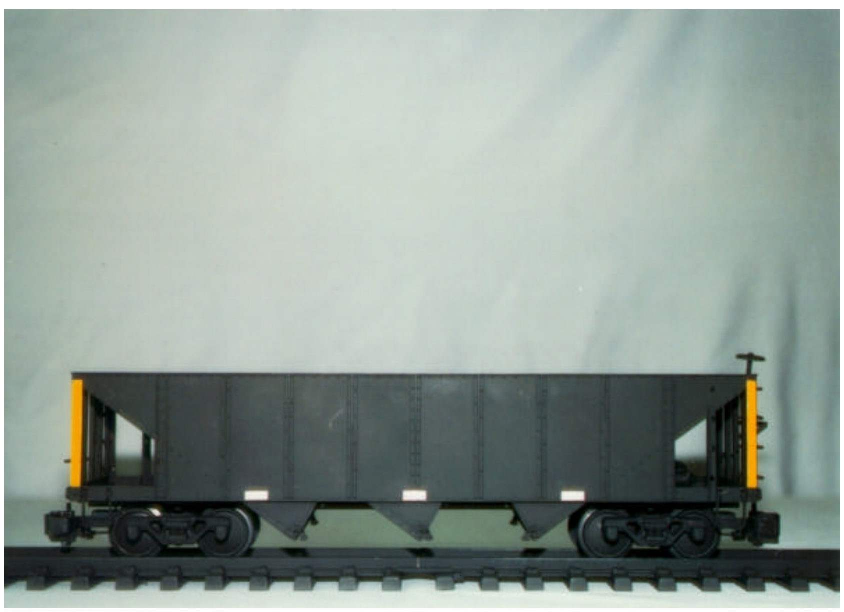


Figure 41. Marking System #9A, Yellow Field Test.

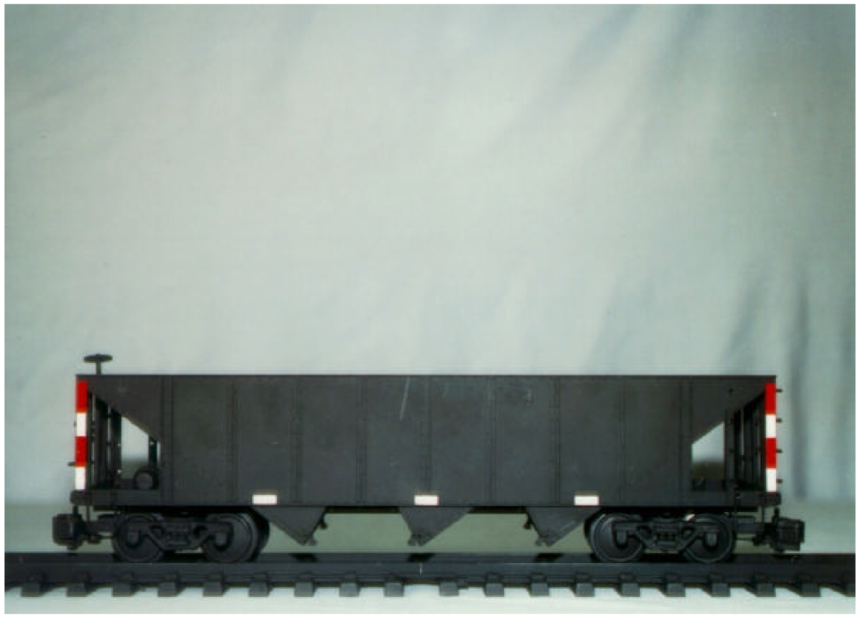


Figure 42. Marking System #9, Red|White Field Test.

Figure 43. Marking System #9B, Red Field Test.

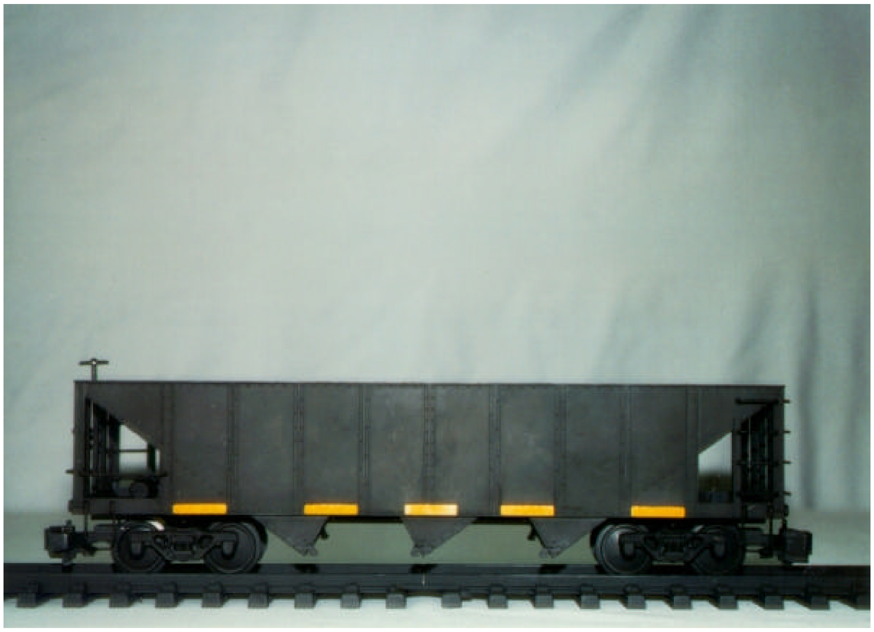


Figure 44. Marking System #6, Yellow Dash.

Figure 45. Marking System #6A, Red|White Dash.

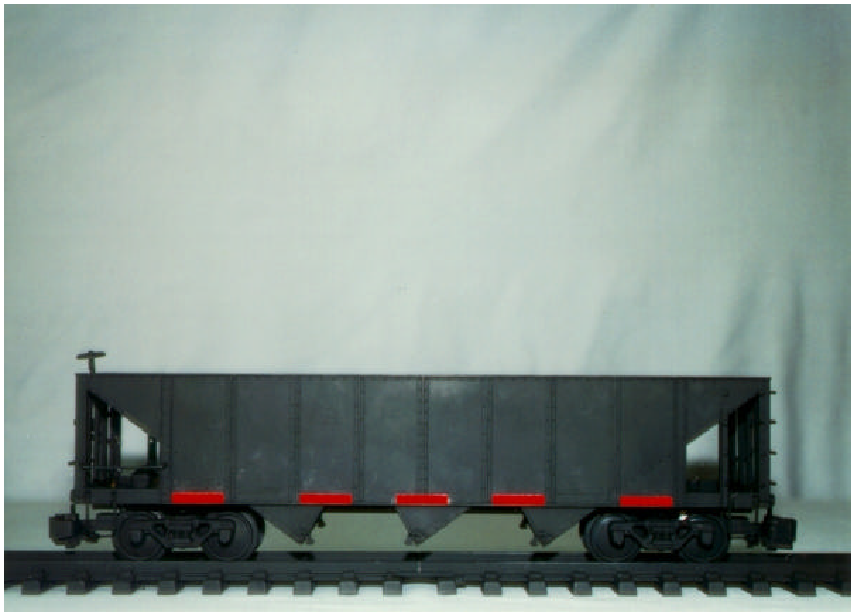


Figure 46. Marking System #6B, Red Dash.

Figure 47. Standard Car with AAR Markings.

four times, each subject responded to 40 trials. With 34 subjects successfully completing the experiment, there were 136 observations (4 x 34) for each marking system. With 10 systems, 1,360 observations (136 x 10) were collected for the experiment. Table 11 shows the experimental design and replications.

Mathematical Models Used to Describe the Experiment. The general model for the nine retroreflective marking systems that describes the main and interaction effects of color pattern, distribution pattern, and subjects is:

$$Y_{ijkm} = \mu + C_i + P_j + CP_{ij} + S_k + CS_{ik} + PS_{jk} + CPS_{ijk} + \varepsilon_{m(ijk)}$$

where:

Y_{ijkm} represents the m^{th} observation (m = 1, 2, ..., 4) on the k^{th} subject (k = 1, 2, ..., 34) for the i^{th} color pattern (i = 1, 2, 3) and the j^{th} distribution pattern (j = 1, 2, 3),

S_k represents the subject effect,

C_i represents the color pattern effect,

P_j represents the distribution pattern effect,

$\varepsilon_{m(ijk)}$ represents the within subject error as well as random effects.

The general model that describes the main and interaction effects of the ten marking systems and subjects is:

$$Y_{ijk} = \mu + M_i + S_j + MS_{ij} + \varepsilon_{k(ij)}$$

where:

Y_{ijk} represents the k^{th} observation (k = 1, 2, ..., 136) for the i^{th} marking system (i = 1, 2, ..., 10) on the j^{th} subject (j = 1, 2, ..., 34),

M_i represents the marking system effect,

S_j represents the subject effect.

$\varepsilon_{k(ij)}$ represents random or experimental error.

Hypotheses to be Tested. There were a total of seven hypotheses tested for the attributes of the nine retroreflective marking systems. That is, were any of the main effects of color pattern, distribution pattern, and subject, or their interactions statistically significant? These seven hypotheses were:

Table 11. Treatments.

	Treatment									
Subject	#8	#9A	#6	#8A	#9	#6A	#8B	#9B	#6B	Standard
S1	R1,1,1	R1,2,1	R1,3,1	R1,4,1	R1,5,1	R1,6,1	R1,7,1	R1,8,1	R1,9,1	R1,10,1
	R1,1,2	R1,2,2	R1,3,2	R1,4,2	R1,5,2	R1,6,2	R1,7,2	R1,8,2	R1,9,2	R1,10,2
	R1,1,3	R1,2,3	R1,3,3	R1,4,3	R1,5,3	R1,6,3	R1,7,3	R1,8,3	R1,9,3	R1,10,3
	R1,1,4	R1,2,4	R1,3,4	R1,4,4	R1,5,4	R1,6,4	R1,7,4	R1,8,4	R1,9,4	R1,10,4
S2	R2,1,1	R2,2,1	R2,3,1	R2,4,1	R2,5,1	R2,6,1	R2,7,1	R2,8,1	R2,9,1	R2,10,1
	R2,1,2	R2,2,2	R2,3,2	R2,4,2	R2,5,2	R2,6,2	R2,7,2	R2,8,2	R2,9,2	R2,10,2
	R2,1,3	R2,2,3	R2,3,3	R2,4,3	R2,5,3	R2,6,3	R2,7,3	R2,8,3	R2,9,3	R2,10,3
	R2,1,4	R2,2,4	R2,3,4	R2,4,4	R2,5,4	R2,6,4	R2,7,4	R2,8,4	R2,9,4	R2,10,4
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S34	R34,1,1	R34,2,1	R34,3,1	R34,4,1	R34,5,1	R34,6,1	R34,7,1	R34,8,1	R34,9,1	R34,10,1
	R34,1,2	R34,2,2	R34,3,2	R34,4,2	R34,5,2	R34,6,2	R34,7,2	R34,8,2	R34,9,2	R34,10,2
	R34,1,3	R34,2,3	R34,3,3	R34,4,3	R34,5,3	R34,6,3	R34,7,3	R34,8,3	R34,9,3	R34,10,3
	R34,1,4	R34,2,4	R34,3,4	R34,4,34	R34,5,4	R34,6,4	R34,7,4	R34,8,4	R34,9,4	R34,10,4
Total Observations	136	136	136	136	136	136	136	136	136	136

1. H_o: No color pattern effect.
   H_A: At least one color pattern effect.

2. H_o: No distribution pattern effect.
   H_A: At least one distribution pattern effect.

3. H_o: No color pattern-distribution pattern effect.
   H_A: At least one color pattern-distribution pattern effect.

4. H_o: No subject effect.
   H_A: At least one subject effect.

5. H_o: No color pattern-subject effect.
   H_A: At least one color pattern-subject effect.

6. H_o: No distribution pattern-subject effect.
   H_A: At least one distribution pattern-subject effect.

7. H_o: No color pattern-distribution pattern-subject effect.
   H_A: At least one color pattern effect.

Likewise, there were three hypotheses tested for the ten marking systems. That is, were any of the main effects, the marking systems and subjects, or their interactions statistically significant? These three hypotheses were:

1. H_o: No marking system effect.
   H_A: At least one marking system effect.

2. H_o: No subject effect.
   H_A: At least one subject effect.

3. H_o: No color marking system-subject effect.
   H_A: At least one marking system-subject effect.

Order of Experimentation and Method of Randomization. Each of the subjects, taken one at a time, were asked to make two responses during each trial — the first when the marking system was detected and the second when the marking system was recognized. The order in which each replication of each marking system (the 40 trials) was presented to a subject was completely random. The order and time of day that a subject participates in the experiment was not controlled but was random to the extent that the subjects selected the block of time when they could participate.

Subject Selection Criteria. All of the subjects who participated in this experiment were licensed operators of passenger cars who reported that they had normal (20/40 or better) or "corrected to normal" vision. Those subjects who required corrective lenses to operate an automobile were asked to wear their lenses while participating in the study. None of the subjects reported any color vision deficiencies. Each subject completed the biographical questionnaire shown in Figure 48 and a profile of the subjects is provided in Appendix D.

Experimental Procedures

The following seven-step procedure was used to objectively evaluate the 10 marking systems:

1. When the subject reported to the testing room, the subject completed the biographical data form.

2. The purpose of the experiment was explained with emphasis on that we wanted to know at what distances the subject could see and then recognize each marking system.

3. The main room lights were turned off and the subject was shown a set of 10 slides that clearly displayed each of the ten marking systems. The subject viewed the slides until the subject felt confident that he or she could recognize and name each system.

4. The subject was instructed to view the series of slides of hopper cars with the various marking systems attached. Each set of slides depicted one marking system and each subsequent slide in a set showed the hopper car and markings from a closer distance. The subject was also told that the hopper car image would be near the center of the screen and that there would be a rail car in all slides shown.

5. Subjects were instructed in the use of the 12 key control panel and were given several trial runs. Each subject was coached until he or she could perform satisfactorily and clearly understood what he or she was to do.

6. In the trial runs and in the actual tests, the subject was to initiate a trial by striking the key with a green back light. Then the subject was to respond when he or she saw (detected) one of the marking systems on the projection screen by pressing the key with a yellow back light. The subject was to continue watching the progression of slides until they were confident that they knew which of the 10 marking systems they were currently viewing. When the subject was certain that he or she had correctly recognized and identified the marking system, the subject pressed the back lighted key that corresponded to that marking system. Pressing this key terminated that trial.

Control # ___________

CONFIDENTIAL BIOGRAPHICAL INFORMATION FOR RAILROAD CONSPICUITY

1. GENDER: (Circle one) Male (0) Female (1)

2. AGE: (Circle one)
   20-30 (2) 31-40 (3) 41-50 (4) 51-60 (5) 61+ (6)

3. How many years have you been driving an automobile? (Circle one)
   1-5 (1) 6-10 (2) 1-20 (3)
   21-30 (4) 31-40 (5) 41+ (6)

4. Do you wear corrective lens? Yes (0) No (1)

5. Are you wearing you corrective lens now? Yes (0) No (1)

6. What color or colors, if any, do you have trouble seeing? (Circle all that apply)
   NONE (0) RED (1) GREEN (2) YELLOW (3) BLUE (4)

7. Have you had any training or experience in designing or evaluating (Circle all that apply):
   (0) no experience
   (1) signing (such as traffic signs)
   (2) rail traffic control devices
   (3) delineators
   (4) highway traffic control devices

Figure 48. Biographical Data Form.

7. The slide tray was then replaced and another trial was initiated by instructing the subject to strike the green key again. The sequence in which the marking systems were presented to the subjects was determined randomly.

Laboratory Configuration

The experiment was conducted in a windowless room where the amount of light that could affect the detection of the marking systems was minimized and fixed for all subjects. This room also provided for the control of background noise, disruptions, and other distractions.

The presentation of the slides and the recording of the subject's responses was accomplished using an IBM Personal System/2, Model 50 microcomputer coupled to a Kodak model 4600 autofocus slide projector with an f/3.5 102 to 152 mm zoom lens. A special back lighted 12 key control panel was used to input the subjects' responses and a standard keyboard was used by the laboratory assistant to control the experiment. A diagram of the system set up is shown in Figure 49 and the special keyboard in shown in Figure 50.

Special computer software was written to assign subject control numbers, control the timing of the experiment, randomize the trials, and store subject responses. The software was structured to prevent a subject from entering an improper sequence of responses. For example, once the initiation key was pressed, it was disabled until the current trial was completed. Also, prior to the initiation key being pressed, all other keys were disabled. Similar disabling of keys was used to prevent a recognition key being active until the detection key was pressed.

When the laboratory assistant initialized the computer for a series of trials, the software generated a control number that became the computer file name for that subject's responses. This control number was also displayed on the monitor and was transcribed to the biographical data sheet by the laboratory assistant. When control was transferred to the subject, the computer randomly selected a marking system to be tested, checked to see if it had been viewed four or fewer times, recorded the marking system identification number, and then notified the laboratory assistant which marking system was to be inserted into the slide projector. When the laboratory assistant notified the subject that the system was ready and the subject pressed the key to initiate a trial, the computer recorded the start time and projected the first slide and then incremented the slides in five-second intervals until the detection key was pressed. The computer continued to project slides at five-second intervals until a recognition key was pressed. When a recognition key was pressed, the computer terminated the trial, recorded the time the detection and recognition keys were pressed and the identification number corresponding to the selected recognition key. It took approximately 70 minutes for each subject to view the 10 marking systems four times each.

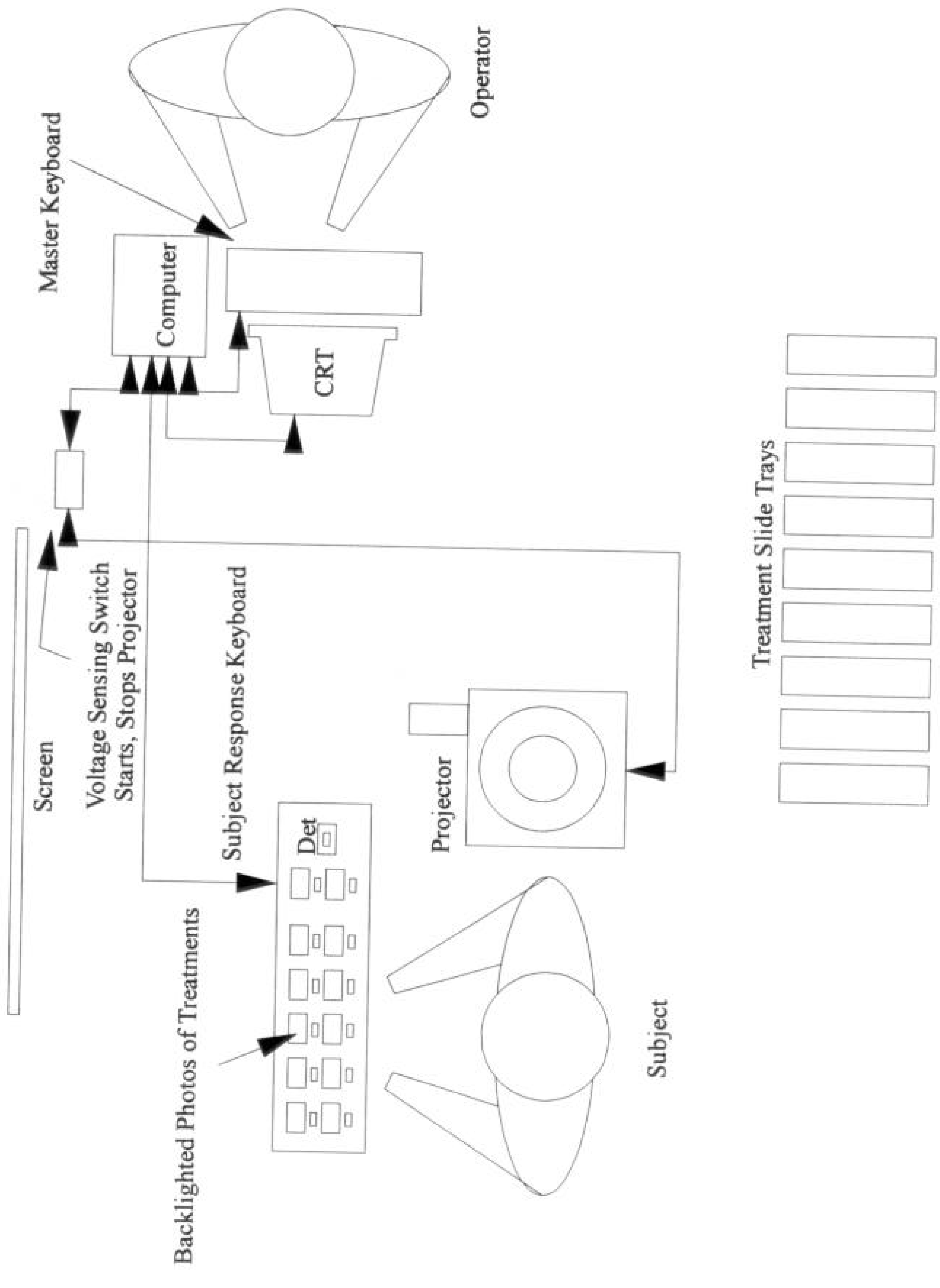


Figure 49. Diagram of the Testing System.

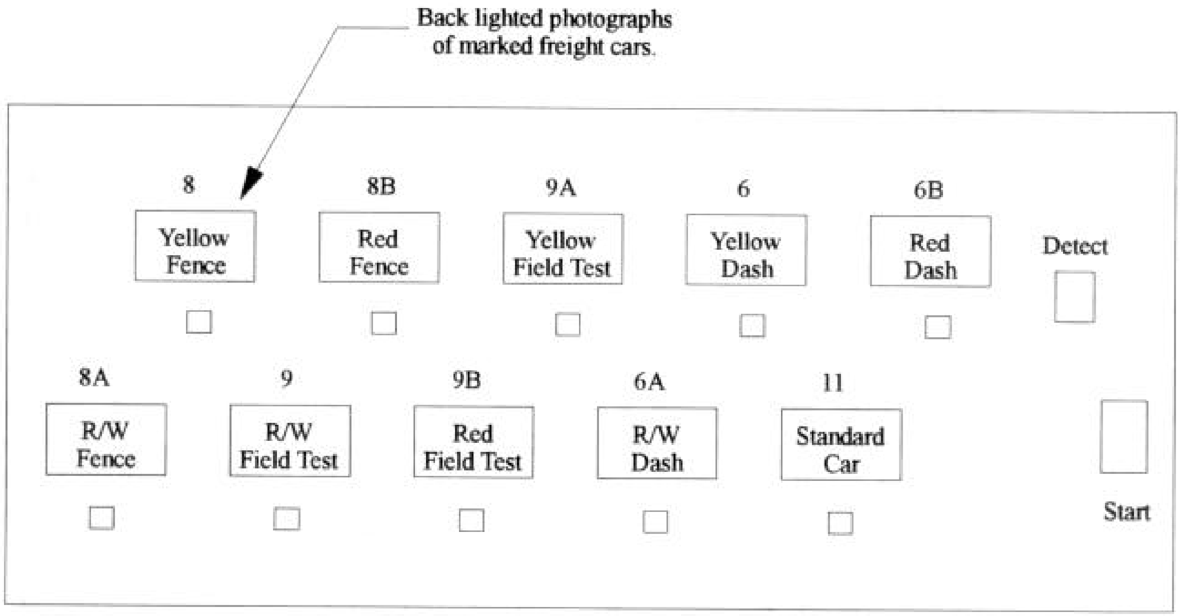


Figure 50. Subject Response Keyboard.

Data Analysis

After the 36 subjects had completed the experiment, their data were reviewed for completeness and errors. Two data files were found to have errors or missing data and were not used in the analysis, thus reducing the number of subjects to 34. This review also found that one marking system had an extra slide in the tray. This extra slide was placed so that it was viewed at the beginning of a trial. This resulted in a 5 second increase in the detection times and recognition times for this marking system. Since the duplicate slide was viewed well before it was possible to detect the projected image, all times recorded for that treatment were decreased 5 seconds. When this data integrity review was completed, the data files were combined into a single data set; detection and recognition times as well as the recognition errors were evaluated using SAS® statistical analysis software.

The main objective was to test different color patterns, distribution patterns, and marking systems that were the combinations of the color and distribution patterns. A two-way analysis of variance was run to assess the significance of the main effects of color pattern, distribution pattern, and the interactions of color pattern and distribution pattern on detection time and recognition time for the nine retroreflective marking systems. The Standard Car with nonreflective AAR Markings, was not included in this analysis because it was not replicated in all color patterns and distribution patterns. With the two-way analysis of variance providing the information to assess the color and distribution patterns, the marking systems were analyzed in a one-way analysis of variance to evaluate the effectiveness of the individual marking systems. This one-way ANOVA included the Standard Car (Marking System #11) to provide a baseline for comparing the retroreflective marking systems with current practice.

Descriptive statistics were also compiled to rank the systems by their mean time to detection and mean time to recognition. Detection time is the elapsed time from the beginning of a trial until the subject pressed the detection key on the control console, indicating that the subject was confident that there was an image on the projection screen. The mean time to detection for each marking system was the arithmetical average of the detection times for all 136 observations (34 subjects and four observations for each marking by each subject). Likewise, recognition time was the elapsed time from the beginning of a trial until the subject pressed one of the 10 recognition keys on the control console. This indicated that the subject was confident that the image on the projection screen had been recognized. The mean time to recognition for a marking system was the arithmetical average of the recognition times for all subjects. With the descriptive statistics compiled, a means comparison test was performed for all pairs using the Tukey Honestly Significant Difference Test to determine which of the marking systems were significantly different from the other systems for the response variables detection time and recognition time. A flow diagram of the data analysis is shown in Figure 51.

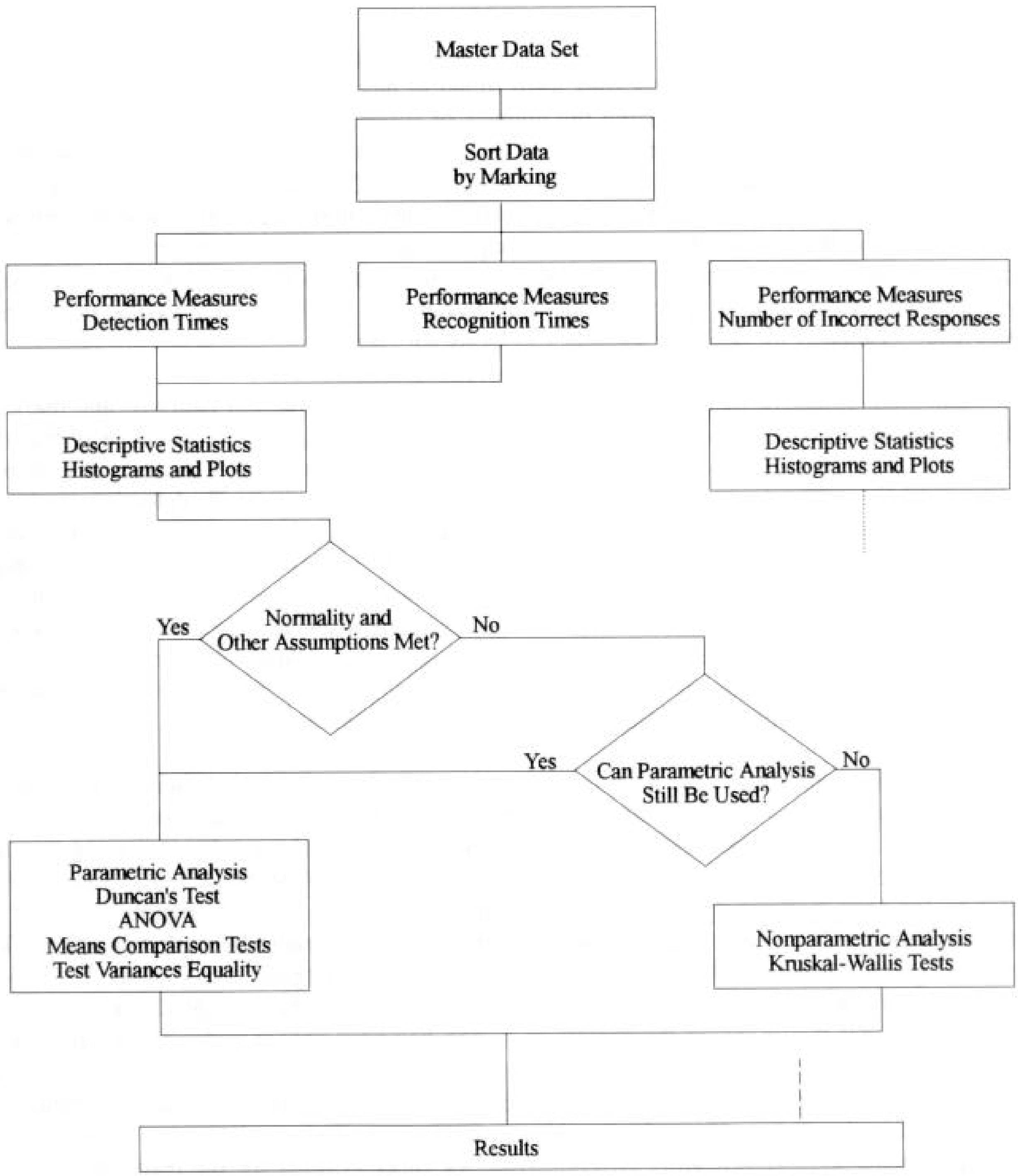


Figure 51. Flow Diagram of the Data Analysis.

Results

Analysis of Mean Time to Detection. The one-way analysis of variance rejected the null hypothesis that there was no difference between the marking systems. At least one marking system was significantly different from all the other systems. The calculated F Ratio was 3262.17 and the significance probability was 0.0001 under the null hypothesis of no marking system effect. Table 12 and Figure 52 show the mean times to detection and the equivalent detection distances for the nine marking systems and the standard AAR nonreflective markings. The detailed ANOVA results are presented in Appendix E.

The Tukey Honestly Significant Difference Test for the marking systems indicated that all of the retroreflective marking systems were significantly differently than the standard AAR nonreflective markings. The test indicated that the Red Field Test (Marking System #9B) and the Red Fence (Marking System #8B) were not significantly different from one another; likewise the Red Dash (Marking System #6B) was not significantly different from the Yellow Dash (Marking System #6) nor was the Red|White Field Test (Marking System #9) significantly different from the Red|White Dash (Marking System #6A). The remaining three marking systems were all significantly different from one another. This significance indicates that the responses to the marking systems were truly different and that their differences were not due to chance.

Likewise, the two-way analysis of variance rejected the null hypothesis of no attribute effects at the significance probability level of 0.0001. The analysis found that there were significant color pattern and distribution pattern effects and an interaction effect between color pattern and distribution pattern. Table 12 also shows the mean times to detection and the equivalent detection distances for the three color patterns and three distribution patterns.

The percent of the total variance explained by each of these effects gave a good indication of the relative importance of color pattern, distribution pattern and marking system in assessing the effectiveness of rail car marking systems. Color pattern, distribution pattern, and their interaction explained 5%, 24%, and 52% (81% total) respectively of the variation object effects, random error, and unknown effects accounted for the remainder of the variation. This significantly indicates that the responses to the marking systems were different.

The Tukey Honestly Significant Difference Test for the marking system attribute of color pattern indicated that the yellow, red|white, and red patterns were all significantly different from one another with a significance probability of 0.05. For the distribution patterns identified as the field test, the fence, and the dash, the test indicated that all patterns were significantly different from one another, again, with a significance probability of 0.05.

Interpretation and Significance of the Mean Time to Detection Results. For the previously described conditions under which this study was conducted, the interpretation of the detection times suggests:

Table 12. Comparison of Marking Systems, Color Patterns, and Distribution Patterns by Detection Time

Variable	Detection Time (s)	Equivalent Detection Distance (ft)
Marking System		
#9A, Yellow Field Test	24.8	4,808
#8A, Red|White Fence	34.5	4,328
#9B, Red Field Test	47.5	3,704
#8B, Red Fence	47.9	3,656
#8, Yellow Fence	52.4	3,464
#6B, Red Dash	55.3	3,320
#6, Yellow Dash	57.2	3,224
#9, Red|White Field Test	60.1	3,080
#6A, Red|White Dash	60.5	3,080
#11, Standard Car	118.8	296
Color Pattern		
Yellow	44.8	3,848
Red	50.2	3,560
Red|White	51.7	3,512
Distribution Pattern		
Field Test Pattern	44.1	3,848
Fence Pattern	44.9	3,848
Dash Pattern	57.6	3,224

Note: With a significance probability of 0.05, those systems that were not statistically different from one another are indicated by connecting brackets.

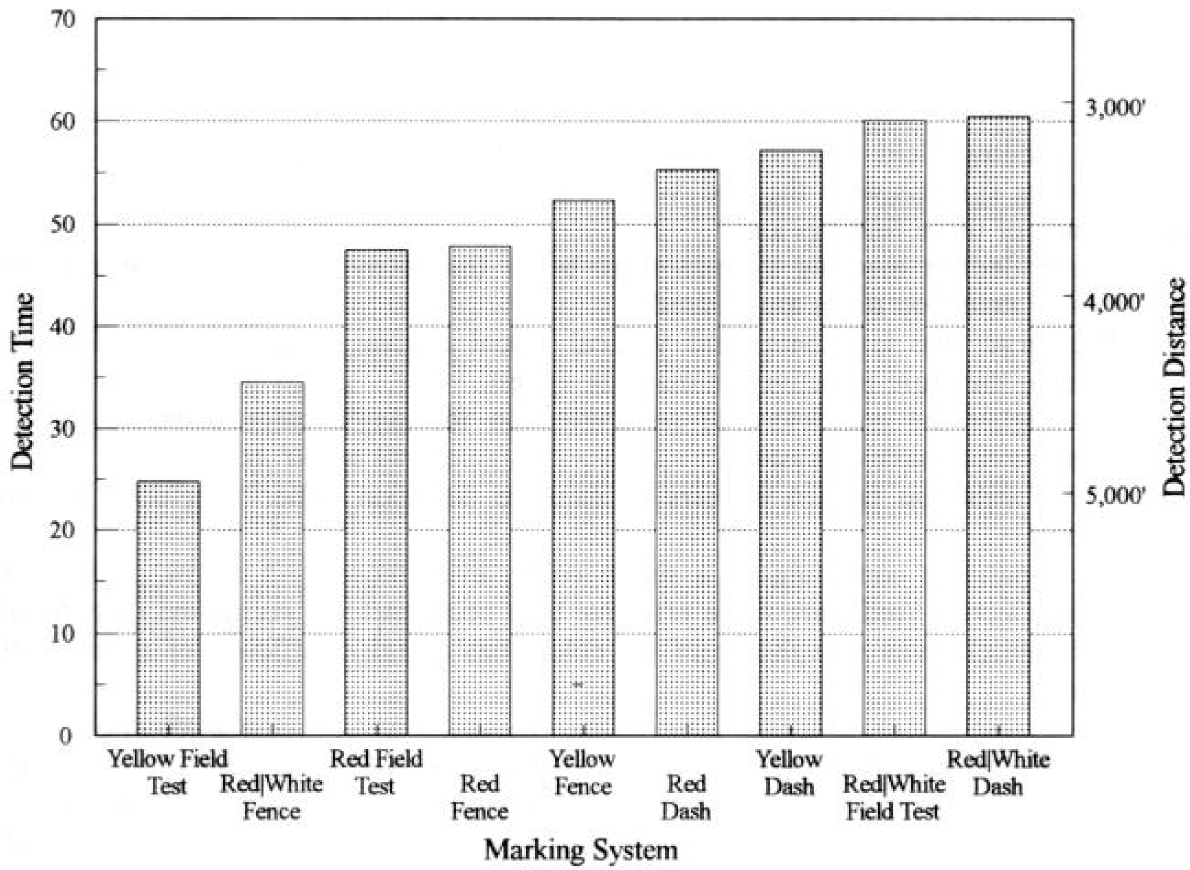


Figure 52. Mean Marking System Detection Time and Detection Distance.

- All of the retroreflective marking systems evaluated were more effective than the Standard Car.
- The fluorescent yellow color pattern was more effective than red or red|white color patterns and the red|white color pattern was the least effective.
- The field test distribution pattern was more effective than the fence or dash distribution patterns and the dash distribution pattern was the least effective.
- The Yellow Field Test was the most effective marking system. The least effective marking systems were the Red|White Field Test and the Red|White Dash.

The significance of these findings are:

- Retroreflective marking systems were better than conventional car markings when shorter detection times are desired.
- The larger the horizontal and vertical visual angles formed by the distribution pattern, the more effective the marking system.
- The higher the coefficient of retroreflection for single color patterns, the more effective the marking system.
- The distribution pattern appears to enhance detection better than does the color pattern.
- Color patterns consisting of a single color, even those with a low coefficient of retroreflection (red), are more effective than color patterns composed of two colors (red|white), even though one of the colors has a high coefficient of retroreflection (white).

The red color pattern being more effective than the red|white color pattern was an unexpected outcome. One would expect that the higher the SIA, the better the performance. Previous studies (e.g., Olson et al. 1992) have used red/white color patterns and a weighter average SIA for the red/white material that is higher than the SIA for red. This unexpected outcome cannot be explained by the results obtained by this study. However, it may be the result of the smaller amounts of high coefficient retroreflective material being more widely dispersed in the distribution patterns. That is, the individual sections of white retroreflective material will have smaller visual angle than the solid color patterns at a given distance and the solid visual angle is not as well defined by the red|white color for some of the distribution patterns. Another possible reason for the poor performance of the red|white color pattern was the lack of responsiveness of the cones in the eye to the additional color coding provided under the low level of illumination present in this study. Also, there may be some unknown phenomena affecting the results because of the techniques used to capture the images of the marking systems and presenting them to the subjects. Additional experiments may be required to determine if single color patterns are more effective.

Analysis of Mean Time to Recognition. Like the mean time to detection, the one-way analysis rejected the null hypothesis that there were no differences between the 10 systems. At least one of the marking systems was significantly different from all the other systems for the performance measure of recognition time. The calculated F Ratio was 373.16 and the significance probability was 0.0001 under the null hypothesis of no marking system effect. Table 13 and Figure 53 show the mean times to recognition and the equivalent recognition distances for the nine marking systems and the standard AAR nonreflective markings. Again, the detailed ANOVA results are presented in Appendix E.

Table 13. Comparison of Marking Systems, Color Patterns, and Distribution Patterns by Recognition Time

Variable	Recognition Time (s)	Equivalent Recognition Distance (ft)
Marking System		
#9A, Yellow Field Test	54.9	3,368
#8B, Red Fence	72.2	2,504
#9B, Red Field Test	73.3	2,456
#8A, Red|White Fence	74.5	2,408
#6B, Red Dash	80.6	2,120
#6, Yellow Dash	84.9	1,928
#9, Red|White Field Test	88.6	1,736
#8, Yellow Fence	88.7	1,736
#6A, Red|White Dash	90.7	1,640
#11, Standard Car	122.8	104
Color Pattern		
Yellow	75.4	2,360
Red	76.2	2,312
Red|White	84.6	1,832
Distribution Pattern		
Field Test Pattern	72.2	2,456
Fence Pattern	78.5	2,216
Dash Pattern	85.4	1,880

Note: With a significance probability of 0.05, those systems that were not statistically different from one another are indicated by connecting brackets.

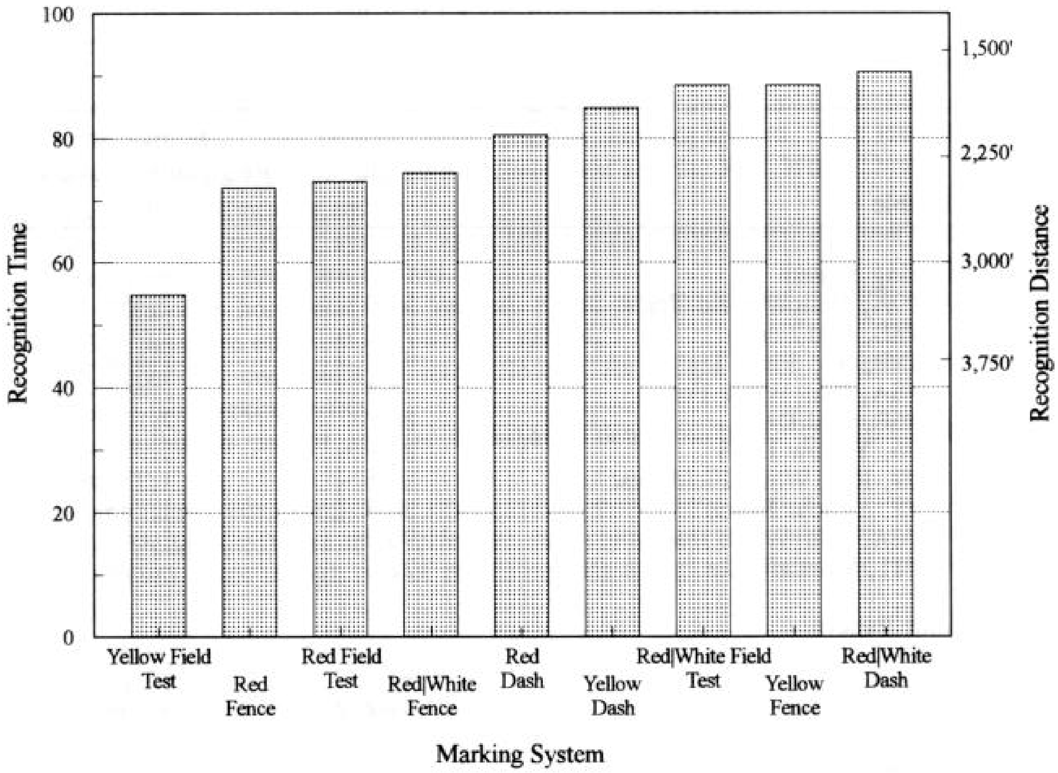


Figure 53. Mean Marking System Recognition Time and Recognition Distance.

The contrasts that were formed and tested by the Tukey Honestly Significant Difference Test to determine which of the marking systems were significantly different from the other marking systems for the recognition response variable indicated that the Red Fence (Marking System #8B), the Red Field Test (Marking System #9B), and the Red|White Fence (Marking System #8A) were not significantly different from one another. It also indicated that the Yellow Dash (Marking System #6), the Red|White Field Test (Marking System #9), and the Yellow Fence (Marking System #8) were not significantly different from one another. Likewise, the Red|White Field Test (Marking System #9), the Yellow Fence (Marking System #9A), and the Red|White Dash (Marking System #6A) were not significantly different from one another.

The Yellow Field Test (Marking System #9A), the Red Dash (Marking System #6B), and the Standard Car were the only marking systems that were significantly different from all the other marking systems.

The two-way analysis of variance rejected the null hypothesis of no attribute effects at the significance level of 0.0001. The analysis found that there were significant main effects as well as significant interactions. Table 13 also shows the mean times to recognition and the equivalent recognition distances for the three color patterns and three distribution patterns.

The percent of the total model variance explained by each of these effects gave a good indication of the relative importance of color pattern, distribution pattern and marking system in assessing the effectiveness of rail car marking systems for recognition. Color pattern, distribution pattern, and their interaction explained 8%, 13%, and 31% (52% total) respectively, of the variation. The subject random error, and unknown effects accounted for the remainder of the variation.

The means comparison test for the attributes of color pattern and distribution pattern indicated that the red|white color pattern was significantly different from the yellow color pattern and the red color pattern at the significance probability of 0.05 for mean time to recognition. However, at this significance level, the test indicated that the yellow color pattern was not significantly different from the red color pattern. Also at this significance level, the means test indicated that all three distribution patterns, the field test, fence, and dash, were significantly different from each other.

Interpretation and Significance of the Mean Time to Recognition Results. For the previously described conditions under which this study was conducted, the interpretation of the recognition times suggests:

- All of the retroreflective marking systems were recognized sooner than was the standard car.
- The field test distribution pattern was recognized sooner than were the fence or the dash distribution patterns.
- The dash distribution pattern required the most time before it was recognized.
- The red and yellow color patterns were recognized sooner than was the red|white color pattern.
- The red and yellow color patterns were recognized at the same time (i.e., at the same distance).
- The Yellow Field Test marking system was recognized well before any of the other systems.
- The Red|White Dash system required the most time before it was recognized.

The significance of these findings are:

- Retroreflective markings are recognized much sooner than are conventional markings.
- The larger the solid visual angle formed by the distribution patterns, the shorter the recognition time.
- The distribution pattern was slightly more important for short recognition times than was the color pattern.
- Single color patterns are recognized slightly sooner than are two color patterns.

Analysis of Recognition Errors. The final performance measure to be analyzed was the recognition errors. The number of times an incorrect recognition key was pressed for each marking system was counted as a recognition error. The recognition errors for the marking system, distribution patterns, and color patterns are shown in the confuson matrices (Figures 54-56). The confusion matrix (Figure 54) was constructed for the group data showing the frequency with which each marking system (stimulus) was mistakenly identified as one of the other marking systems. The larger entries in the matrix represent marking systems that are more easily confused with one of the other systems and the smaller entries represent dissimilar marking systems. Similar matrices were constructed for the color patterns (Figure 55) and the distribution patterns (Figure 56). The error frequencies and percentages for the 10 systems are shown in Figure 54 and Table 14. A smaller error frequency indicates that subjects were able to better differentiate a system from the other systems.

After the error frequency had been established for each marking system, color pattern, and distribution pattern, the expected number of errors was calculated and a Chi-square goodness of fit test performed to determine if the null hypothesis, that all error frequencies were equal, was true. The Chi-square statistic of 64.9 with 9 degrees of freedom lead to the rejection of the null hypothesis for the marking systems with a critical value of 16.9 and a significance probability of 0.05. Likewise the Chi-square statistics for the color patterns and the distribution patterns were 28.0 and 11.4, respectively, with 2 degrees of freedom also lead to the rejection of the null hypotheses of equal frequencies with a critical value of 5.99 and a significance probability of 0.05.

An examination of the recognition error frequency for the color patterns (Figure 55, Table 14) shows that systems that used the red|white color pattern had 64 recognition errors, making it the most misidentified color pattern. Systems that used red were the least misidentified systems. The red color pattern was identified as the red|white color pattern nine times but was never mistaken for the yellow color pattern. Similarly, the systems with the field test distribution pattern had only three recognition errors (Figure 56, Table 14). The marking systems with the fence distribution pattern were mistaken 55 times for other marking systems, almost two times more often than the field test distribution pattern). Figure 57 shows the relationship between the recognition errors and the mean times to recognition for each marking system. This plot indicates the general

	Response										
Stimulus	Yellow Fence	R|W Fence	Red Fence	Yellow Field	R|W Field	Red Field	Yellow Dash	R|W Dash	Red Dash	Std. Car	Row Total
Yellow Fence		8	3				1	6			18
R|W Fence	18		3				1	8	1		31
Red Fence									6		6
Yellow Field	1				3			1			5
R|W Field				2		14					16
Red Field			1		7						8
Yellow Dash		3				1		3			7
R|W Dash		3					12		2		17
Red Dash			4					2			6
Std. Car											0
Column Total	19	14	11	2	10	15	14	20	9	0	114

Figure 54. Confusion Matrix for Marking Systems Recognition Errors.

Stimulus	Response		
	Yellow	Red	R|W
Yellow	2	4	24
Red	0	11	9
R|W	33	20	11
Total	35	35	43

Figure 55. Confusion Matrix for Color Pattern Recognition Errors.

Stimulus	Response		
	Fence	Field	Dash
Fence	32	0	23
Field	2	26	1
Dash	10	1	19
Total	44	27	43

Figure 56. Confusion Matrix for Distribution Pattern Recognition Errors.

Table 14. Recognition Errors.

Variable	Error Frequency	% Error	% Correct
Marking System			
#11, Standard Car	0	0.0	100.0
#9A, Yellow Field Test	5	0.4	99.6
#8, Red Fence	6	0.4	99.6
#6B, Red Dash	6	0.4	99.6
#6, Yellow Dash	7	0.5	99.5
#9B, Red Field Test	8	0.6	99.4
#9, Red|White Field Test	16	1.1	98.4
#6A, Red|White Dash	17	1.2	98.8
#8, Yellow Fence	18	1.3	98.7
#8A, Red|White Fence	31	2.3	97.7
Color Pattern			
Red	20	1.6	98.4
Yellow	30	2.5	97.5
Red|White	64	5.2	94.8
Distribution Pattern			
Field Test	29	2.4	97.6
Dash	30	2.5	97.5
Fence	55	4.5	95.5

trend of increasing frequency of recognition errors for increased time to recognition. This trend was interpreted to mean that some designs were more difficult to distinguish from another, resulting in increased uncertainty and increased identification errors.

Interpretation and Significance of the Recognition Errors. For the previously described conditions under which this study was conducted, the interpretation of the recognition errors suggests:

- The red|white color patterns were most often confused with the yellow color patterns and, conversely, the yellow color patterns were almost as often confused with the red|white color patterns.
- The red|white color patterns were also often confused with the red color patterns; however, the red color patterns were confused much less often with the red|white color patterns.
- The yellow color patterns were rarely confused with the red color patterns and the red color patterns were never confused with the yellow color patterns.
- The fence distribution patterns were often confused with the dash distribution patterns and the dash distribution patterns were less often confused with the fence distribution patterns.
- The field distribution patterns were rarely confused with either the fence or dash distribution patterns and the fence or dash distribution patterns were rarely confused with the field distribution patterns.
- The Red|White Fence marking system was most often confused with the Yellow Fence marking system. The Red|White Field Test marking system was often confused with the Red Field Test marking system. Also, the Red|White Dash marking system was often confused with the Yellow Dash marking system.

The significance of these findings are:

- Color patterns are more easily confused than are distribution patterns.
- There appears to be a problem distinguishing between the color patterns with high coefficients of retroreflection.
- Likewise, there appears to be some problems distinguishing distribution patterns with smaller solid visual angles.

Conclusions

The first conclusion reached is that retroreflective marking systems enhance the detection and recognition of freight cars under the conditions simulated in this study. This conclusion is based on the comparison of detection and recognition times of the ten marking systems evaluated. (See Tables 12 and 13 for detection and recognition times.) All of the retroreflective marking systems evaluated in this study performed much better than the Standard Car with nonreflective AAR

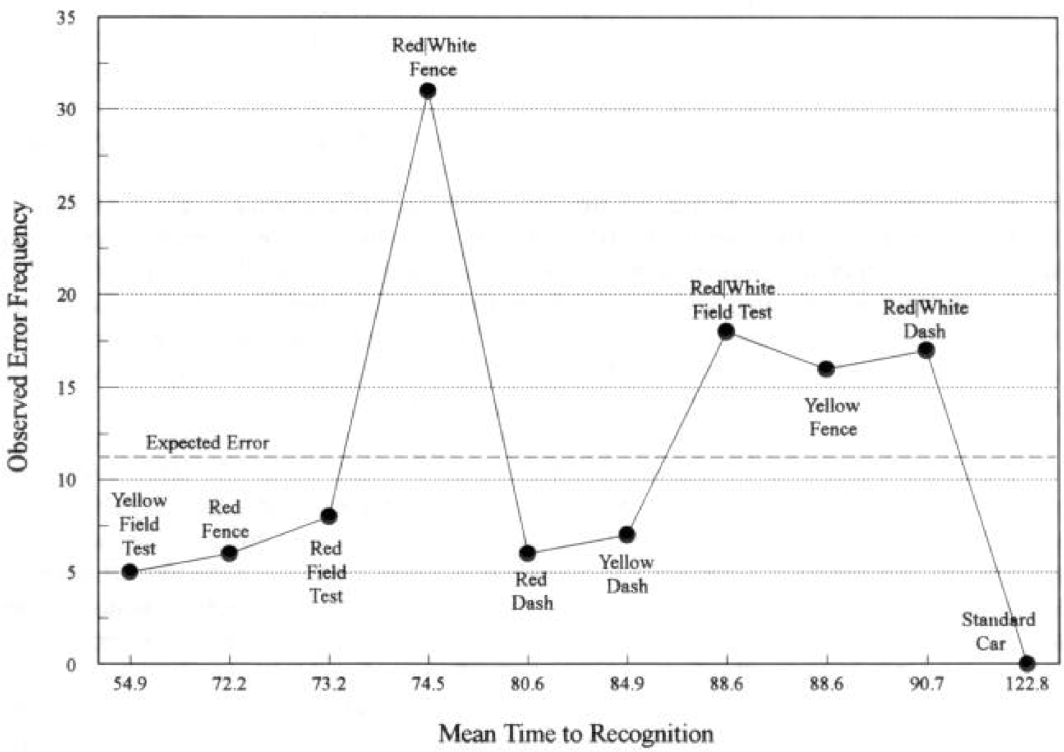


Figure 57. Comparison of Detection Time Means and Variances Ordered by Variance.

markings. The Standard Car required 58 more seconds to detect and 32 more seconds to recognize than it did the Red|White Dash, which was the least effective marking system. The Standard Car required 94 more seconds to detect and 68 more seconds to recognize than did the Yellow Field Test, which was the most effective marking system.

The second conclusion is that the use of multidimensional coding (i.e., the combination of color pattern and distribution pattern) contribute more to the effectiveness of the marking systems than do either the color pattern or distribution pattern alone. This conclusion is based on the statistics that indicated the color pattern-distribution pattern interaction accounted for 52% of the variation in detection time and 31% of the variation in recognition time, whereas color alone accounted for 5% and 8% of the detection and recognition times, respectively, and distribution alone accounted for 24% and 13%, respectively.

The third conclusion is that distribution patterns which form the largest solid visual angles are superior to the distribution patterns that form smaller solid visual angles. The field test distribution pattern, which outlined the shape of the rail car, formed the largest visual angle and had the shortest detection and recognition times along with the fewest recognition errors. The fence distribution pattern, which spaced the retroreflective material over a relatively large area of the rail car side, ranked second in detection time and recognition time. The fence and the dash distribution patterns were often confused with one another. The dash distribution pattern, which concentrated the retroreflective material along the bottom of the car and formed the smallest solid visual angle performed the worst of the three distribution patterns.

To briefly summarize the above discussion, the following conclusions about the relative performance of retroflective marking systems to enhance the detection and recognition of stationary rail cars were reached:

1. For each of the measures of performance, all of the retroreflective marking systems evaluated were much more effective than standard white AAR nonreflective markings.

2. The interaction of color pattern and distribution pattern contributed more to the effectiveness of the marking systems than did either the color pattern or the distribution pattern alone.

3. Distribution patterns that outlined the shape or that spaced the retroreflective material over a relatively large area of the rail car side were superior to a distribution that concentrated the retroreflective material along the bottom of the car.

4. For the fixed amount of retroreflective material used in this research, a single color pattern with a high coefficient of retroreflection placed on a uniform high contrast background was more effective than a 60:40 ratio contrasting two color pattern (e.g., red|white).

Recommended Design Features

Of the three colors used for marking systems in this study, fluorescent yellow is the recommended color because it was the color used for the most effective marking system for both detection and recognition (Table 15). Also, when color was considered independent of the distribution pattern, fluorescent yellow was the most effective color for detection and was as effective as red for recognition.

The marking systems that were the most effective in this study all had a distribution pattern that indicated the profile (i.e., size and shape) of the rail car, thus a distribution pattern that indicates the profile of the rail car is recommended. This recommendation is also supported by the research conducted by Stalder and Lauer (1954) and Olson et al. (1992).

The recommended shape for the individual pieces of retroreflective materials that comprise a marking system is simple rectangular shapes. This recommendation is based on the research conducted by Zwahlen et al. (1989) and Olson et al. (1992).

Future Research

The scope of this study was restricted in five major areas:

1. All treatments were evaluated with the rail car stationary.
2. Only open top hopper cars were used.
3. Only three colors of retroreflective materials were tested.
4. The amount of material used for all markings was fixed at 384 square inches of retroreflective material.
5. All colors were tested on a flat black background providing a high contrast ratio.

Therefore, future research should address several additional issues:

1. The effectiveness of retroreflective marking systems should be evaluated when there is relative motion between the subject and the train.

Table 15. Comparison of Marking Systems, Color Patterns, and Distribution Patterns Ranked by Performance Measure.

Variable	Detection Time[1]	Recognition Time	Recognition Errors
Marking System			
#9A,Yellow Field Test	1	1	2
#8A, Red|White Fence	2	4	9
#9B, Red Field Test	3	3	5
#8B, Red Fence	4	2	1
#8 Yellow Fence	5	8	8
#6B, Red Dash	6	5	3
#6, Yellow Dash	7	6	4
#9, Red|White Field Test	8	7	6
#6A Red|White Dash	9	9	7
#11 Standard Car	10	10	N|A
Color Pattern			
Yellow	1	2	2
Red	2	1	1
Red|White	3	3	3
Distribution Pattern			
Field Test Pattern	1	1	1
Fence Pattern	2	2	3
Dash Pattern	3	3	2

[1] Ranked from best to worst for detection time for comparison.

2. The effects of different distribution patterns mandated by different rail car profiles (i.e., box and hopper cars as compared to intermodal flat cars or tank cars) should be tested.

3. The effectiveness of other color patterns - both single color and two color patterns — with high coefficients of retroreflection should be tested along with the fluorescent yellow, red|white, and red colors used in this study.

4. The effects of different contrast ratios between the colors and the color of the freight cars should be considered.

5. Finally, it is necessary to determine the minimum width for different amounts (square inches) of retroreflective material to maintain a very conservative detection distance under "real world" conditions.

In addition to the limits discussed above, the subjects' perceptions of the marking systems were under ideal viewing conditions, i.e., there was no attenuation of the light incident on and reflected from the markings. Also the viewing angles were perpendicular to the side of the rail car, thus maximizing their detection. Therefore, additional research should be conducted to determine the maximum number of strips into which the total amount of material can be divided, the maximum approach angles and profile angles for which retroreflective marking systems retain their effectiveness, and the effectiveness of retroreflective marking systems with "nominal" attenuation due to atmospheric and windshield conditions.

One final recommendation is to do an epidemiological retrospective study to determine the characteristics of drivers involved in run-into-train accidents. In all the studies reviewed as well as this study, only drivers with near "normal" vision under controlled conditions evaluated retroreflective marking systems. Individuals that are involved in run-into-train accidents may have one or more characteristics that could affect the attributes of retroreflective marking systems whose function is to enhance the detection and recognition of rail cars at night.

In addition to the recommended research, two investigations also should be undertaken to ensure completeness of the study of the effectiveness of retroreflective markings on rail cars. These are to determine: (1) possible conflicts in color codes as specified in the *Manual on Uniform Traffic Control Devices for Streets and Highways* that may arise if fluorescent yellow (or other colors not yet evaluated) is used for a marking system; and (2) if there are any strobe effects that could result in photo-induced epilepsy.

Summary of the Objective Evaluation

Of the nine retroreflective marking systems evaluated, the data indicates that the Yellow Field Test (Marking System #9A), the Red|White Fence (Marking System #8A), the Red Field Test (Marking System #9B), and the Red Fence (Marking System #8B) were the most effective marking systems of those evaluated to enhance both detection and recognition of rail cars. All of the retroreflective systems performed well when compared to the Standard Car. For mean time to detection, the yellow color pattern was the best and either the fence or the field test distribution pattern were the best. For mean time to recognition, either the yellow or the red color patterns were the best and the best distribution patterns were either the fence or the field test. In general, the data indicates that bright color patterns distributed to give an indication of the size or shape of the rail car make the most effective marking systems.

APPENDIX A

DESCRIPTION OF THE NOMINAL GROUP TECHNIQUE, SEMANTIC DIFFERENTIAL TECHNIQUE, AND THURSTONE'S PAIRED COMPARISON SCALING

Nominal Group Technique

The Nominal Group Technique (NGT) is a structured group idea generation and evaluation technique that was developed at the University of Wisconsin by Delbecq, Van de Ven, and Gustfason (1975). The NGT involves the selection of one or more expert panels with five to seven members on each panel. The individuals invited to serve on a panel will have met some criteria that qualifies them as experts in the area or field being investigated.

Four-Step Procedure. NGT is a four-step procedure directed by a facilitator where the interaction of the group is tightly controlled. The four steps are: (1) silent generation step; (2) round robin step; (3) clarification step; and (4) voting and ranking of alternatives. The technique is controlled, focused, and efficient and enables researchers to collect a great deal of information in a limited amount of time. Ideally, groups should consist of only about five to seven members so the process can proceed efficiently. If there are more than five to seven participants, it is suggested that several groups be created, with each group having five to seven participants, its own facilitator, and the same mission.

The facilitator opens a session by introducing the purpose of the NGT session. Participants are presented with a carefully worded task statement such as "We would like to develop some candidate freight car markings applied to freight cars to make them more conspicuous to motorists. Please think about how you would design these markings and write a single idea or sketch a single design on each of the cards (or sheet of paper) that you have been provided." The cards can already have a picture of a freight car on it so that members merely have to mark up the card. A variation of this procedure would be that each member is provided with scissors and various retroreflective materials and asked to design a marking system and apply it to the freight car on the provided card or sheet of paper. The group members are then instructed to take ten minutes to write their ideas on the cards or sheets of paper. This first step is called "silent generation."

The second step of the NGT is the round robin. The facilitator asks each group member, in turn, to present one idea from his or her pile of idea cards. Discussion in this step is only between facilitator and participant and is limited to obtaining a concise understanding of each idea. Each idea is named and recorded by the facilitator or an assistant on a large sheet of paper on a flip chart mounted on an easel. Participants are encouraged to add ideas to their cards as new ones occur to them during the round robin. This step proceeds until everyone's ideas are exhausted and a redundancy of ideas begins to appear.

The third step of the NGT process is clarification. During this step each idea is discussed in turn to ensure that all participants understand each recorded item. This step allows participants to present the logic behind their ideas and to eliminate misunderstandings without undue argument. The facilitator controls the process so that no one dominates the group process. At this step of the process only discussion of an idea is permitted and not evaluation. Evaluation of ideas comes in the final step.

The final step involves voting and ranking of freight car marking concepts generated in earlier steps of the process. Each participant is instructed to select eight preferred designs from the list of designs generated by the group and recorded on the flip chart. Each participant is provided eight 3 x 5 index cards. The participant then spreads the eight cards in front of him or her so that all the cards can be seen simultaneously. Each person selects the single most preferred freight car marking idea and then writes an "8" on the card and puts it aside. Of the remaining seven cards, the least preferred design is selected and a "1" is placed on that card. The procedure continues with the next most preferred design which is designated with a "7." This rating is followed by selecting the next least preferred design and designating it with a "2." This rating process continues until all designs are scored. The process was designed so that participants can easily select the most preferred and the least preferred designs of a "good" set of candidate marking designs. The process of rating and elimination is a form of "paired comparison judgment" which humans do well; people do not make absolute judgments very well. Moreover, the process moves from ranking extremes where people are not indifferent about the alternatives towards ideas that about which they are somewhat ambivalent. This process ensures the rating process will minimize ranking comparative judgment errors. The process proceeds in the following steps:

Steps	Most Preferred Design Score	Least Preferred Design Score
1,2	8	1
3,4	7	2
5,6	6	3
7,8	5	4

During a short break, the results are compiled. The scores are recorded beside each idea on the clarified list on the facilitator's flip chart at the front of the room. Following the break, the results are reported and an open discussion is held. The facilitator can then summarize the results for participants and provide a written report later.

Advantages and Disadvantages. The NGT has several advantages over other techniques — there is equality of participation, it separates idea generation and idea evaluation, it engenders a sense of commitment to the task, disagreements occur over ideas and not personalities, it produces a large number of ideas, and it provides a sense of accomplishment and closure. Like any other technique some disadvantages are present in the process. A highly skilled facilitator is required to make the process work smoothly. The NGT lacks a flexibility in that only one idea at a time can be considered; however, that may be a strength and not a criticism of the technique. The NGT requires a certain amount of conformity by the participants; not all people are comfortable with the degree of structure required.

Semantic Differential Technique

The Semantic Differential Technique was developed by C. E. Osgood, C. J. Suci, and P. H. Tannenbaum as a tool to understand how groups interpreted the meaning of words (Wilson and Corlett 1990). The technique has since been used for many purposes, including the evaluation of such things as household goods. To use the technique, rating scales are generated which describe the objects that are being studied. The scales are normally seven categories long. The end points of the scales are anchored with adjectives that are polar opposites, such as easy-difficult, good-poor, or likely-unlikely. The participants in the study then rate each object according to these adjectively anchored scales. The data collected from a group of participants are analyzed to determine the assumed underlying factors or dimensions that are being used by the group to make judgements. The underlying dimensions may not be known beforehand and may not be part of the participants' normal vocabulary, whereas the adjectives used to anchor the scales are usually very common. This is somewhat like the Likert technique, but with one major difference. In the Likert technique all of the statements are about a single underlying issue. In the Semantic Differential Technique an individual scale may be examining a unique aspect of the object being evaluated that is unrelated to any of the other scales.

The great appeal of the Semantic Differential Technique is its ability to explain the underlying dimensions being used by the participants in the study and in identifying the relationships between the objects being evaluated. These dimensions are not necessarily known prior to conducting the study, and it is this power to identify those dimensions that might otherwise remain unknown that is the appeal. Like for all methods, this power is greatly dependent on the quality of the data collected and not on the analysis technique alone.

As mentioned above, each statement has a simple point scale associated with it. Typically these are 7-points scales, but 6-point and 8-point scales are common when a neutral or null center point is not important. Each point is assigned a scale value (for example 1 to 6 for a 6-point scale), and depending on which point is selected, the points scores are summed and the results represents the subject's judgement.

Thurstone's Paired Comparison Scaling

Thurstone's Paired Comparison Scaling is a psychophysical technique (Baird and Noma 1978). The technique is a very useful technique that takes advantage of one of a person's best abilities, i.e. a person's ability to make comparative judgments. Comparative judgments are judgments that require a person to determine whether one alternative is "better" than another. The two alternatives are viewed at the same time so that comparisons can be made without relying on a comparison against some mental model in memory such as is required when making absolute judgments. People are not particularly good at making absolute judgments but are very good at making comparative judgments. The researcher is not always certain why a person selects one alternative over another. A clear statement of the judgment task at the outset of the evaluation can help the subject make his or her evaluations. Follow-up questions and debriefing can help the researcher determine what criteria the observer was using to make selections.

Thurstone's Paired Comparison Scaling takes advantage of a person's best abilities. The subject is asked to select one alternative over another. This is a ranking of two alternatives on an ordinal scale. Thurstone's technique is administered to a group of observers. A questionnaire is developed. The questionnaire consists of instructions and a list of pairs of items to be evaluated. The subject is asked to circle the pair item he or she prefers over the other member of the pair. Sometimes the pairs are presented by using two slide projectors if evaluation of pictures is required. The group results are compiled and probabilities are calculated to express preferences. For example, a probability would be determined for how often the group preferred "Railcar Marking System #1" over "Railcar Marking System #4." All items are compared with each other. Probabilities are converted to Z-values, i.e., values from a normal distribution with a mean of 0 and a standard deviation of 1. The preferences can be scaled along a line to show how the various conspicuity marking preferences compare with one another. The ordinal preferences for the group are transformed to a preferences on an interval scale.

APPENDIX B

EXPERT PANEL QUESTIONNAIRE

SECTION I

PAIRED COMPARISONS OF EXPERIMENTAL CONSPICUITY MARKING SYSTEMS
FOR FREIGHT CAR

INSTRUCTIONS:

For each pair of freight car experimental conspicuity markings presented on the following pages, circle the marking number below the phtograph of the marking you judge to be the most effective in enhancing the visibility of freight trains. For example, if you think that the car with marking #20 is preferable to the car with amrking #15, you would draw a circle around the label "MARKING #20" that is below the preferred car.

PAIR 100

MARKING #15

MARKING #20

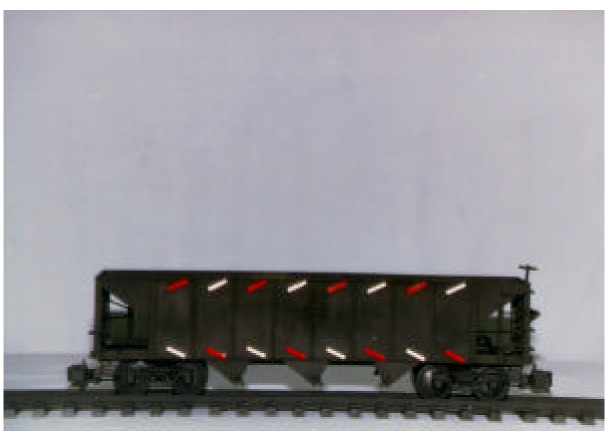
SURVEY PARTICIPANTS
PLEASE READ THE FOLLOWING INSTRUCTIONS BEFORE PROCEEDING FURTHER

The purpose of this survey is to obtain an expert evaluation of eleven experimental retroreflective marking systems for freight cars. The function of these marking systems is to increase the visibility of freight trains at night. It is believed that these markings can reduce run-into-train accidents at railroad grade crossings with passive controls. These marking systems have been applied to scale model hopper cars so that they can be evaluated in a laboratory setting. Hopper cars were chosen for this study because they often are operated in unit trains and are one of the most difficult freight cars for drivers to see.

The question this research is attempting to answer is: What combination of geometric shape, color or pattern of colors, size, and distribution of a given marking system will be most effective in increasing the visibility of freight cars for drivers? In order to answer this question, a series of evaluations have been planned. Also, the responses to this evaluation will be used to reduce the number of designs being considered by eliminating those designs that receive poor scores.

This questionnaire contains five sections and should take approximately 30 minutes to complete. Please complete the sections in the order presented. Do not hesitate to contact us if you have any quesitons or problems. When you have finished, please insert the questionnaire into the provided self-addressed stamped envelope and return it to us via United States Postal Service.

PAIR 1



MARKING #2

MARKING #8

PAIR 2

MARKING #10

MARKING #8

PAIR 3

MARKING #5

MARKING #4

PAIR 4

MARKING #7

MARKING #9

PAIR 5

MARKING #9

MARKING #8

PAIR 6

MARKING #3

MARKING #1

PAIR 7

MARKING #4

MARKING #11

PAIR 8

MARKING #1

MARKING #9

PAIR 9

MARKING #6

MARKING #5

PAIR 10

MARKING #11

MARKING #5

PAIR 11

MARKING #10

MARKING #9

PAIR 12

MARKING #1

MARKING #7

PAIR 13

MARKING #8

MARKING #7

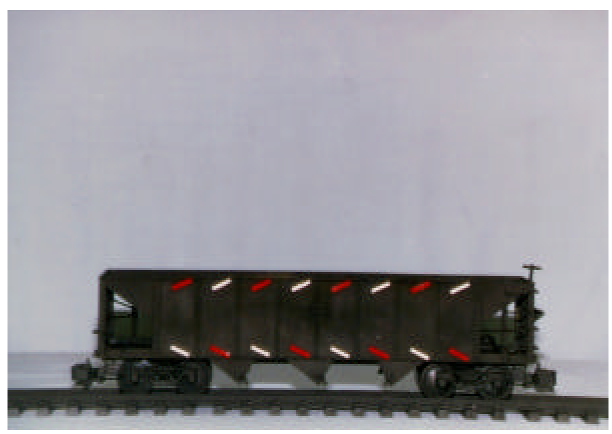
PAIR 14

MARKING #8

MARKING #6

PAIR 15

MARKING #7



MARKING #2

PAIR 16

MARKING #6

MARKING #1

PAIR 17

MARKING #11

MARKING #8

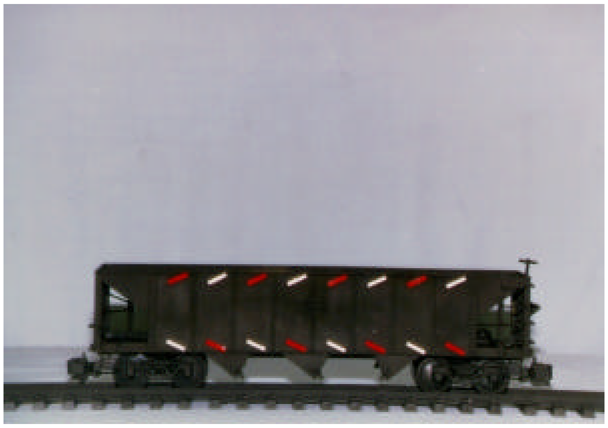
PAIR 18

MARKING #4

MARKING #3

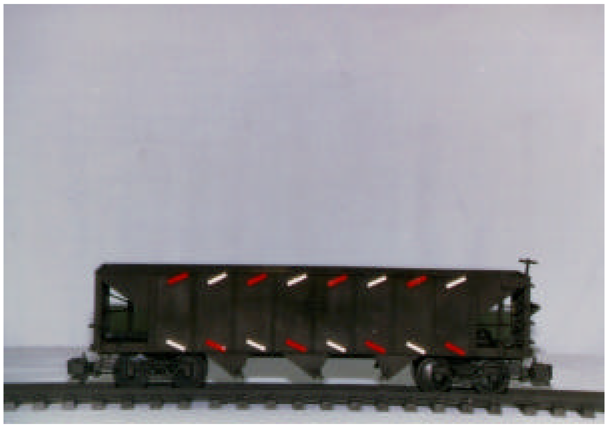
PAIR 19

MARKING #4



MARKING #2

PAIR 20

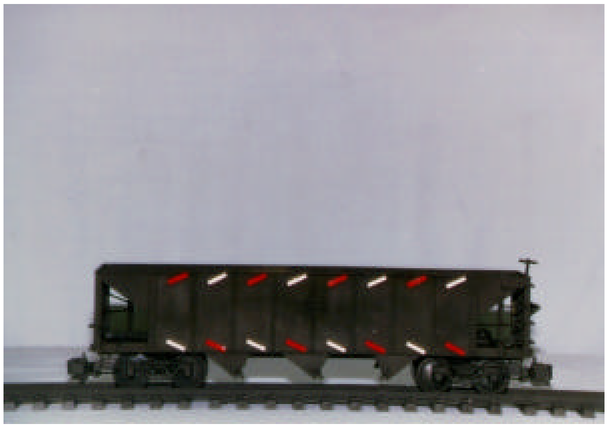


MARKING #2

MARKING #1

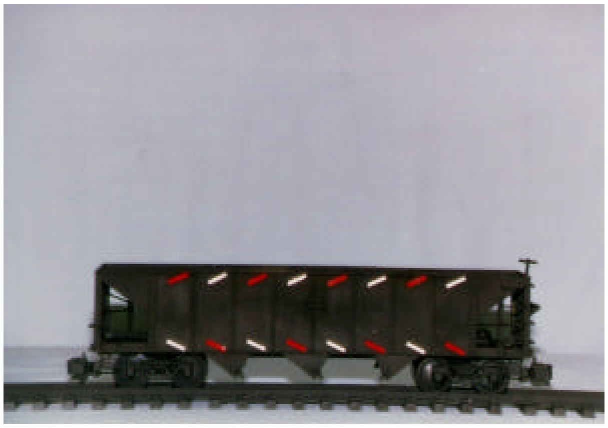
PAIR 21

MARKING #9



MARKING #2

PAIR 22



MARKING #2

MARKING #5

PAIR 23

MARKING #4

MARKING #8

PAIR 24

MARKING #1

MARKING #8

PAIR 25

MARKING #7

MARKING #6

PAIR 26

MARKING #10

MARKING #3

PAIR 27

MARKING #7

MARKING #5

PAIR 28

MARKING #4

MARKING #7

PAIR 29

MARKING #7

MARKING #10

PAIR 30

MARKING #10

MARKING #11

PAIR 31

MARKING #1

MARKING #10

PAIR 32

MARKING #4

MARKING #1

PAIR 33

MARKING #4

MARKING #9

PAIR 34

MARKING #5

MARKING #10

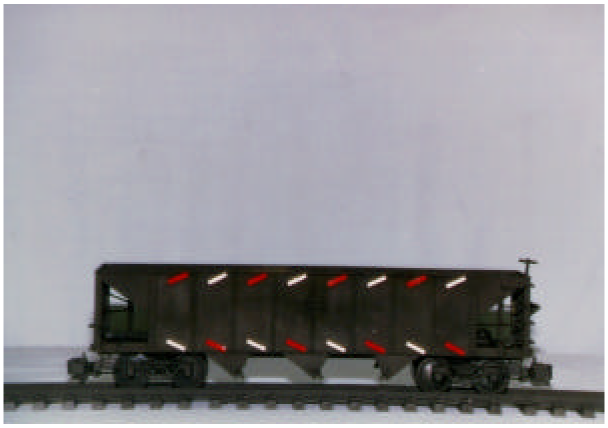
PAIR 35

MARKING #7

MARKING #3

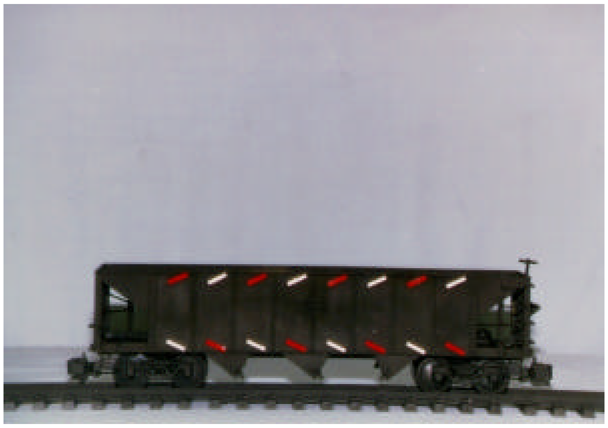
PAIR 36

MARKING #3



MARKING #2

PAIR 37



MARKING #2

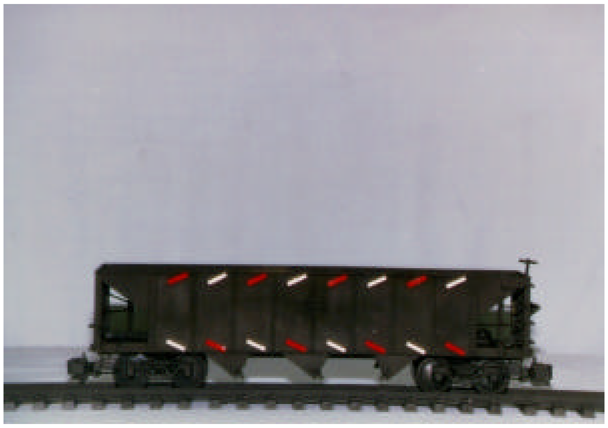
MARKING #1

PAIR 38

MARKING #5

MARKING #9

PAIR 39



MARKING #2

MARKING #6

PAIR 40

MARKING #3

MARKING #11

PAIR 41

MARKING #6

MARKING #11

PAIR 42

MARKING #11

MARKING #1

PAIR 43

MARKING #6

MARKING #3

PAIR 44

MARKING #3

MARKING #8

PAIR 45

MARKING #6

MARKING #9

PAIR 46

MARKING #9

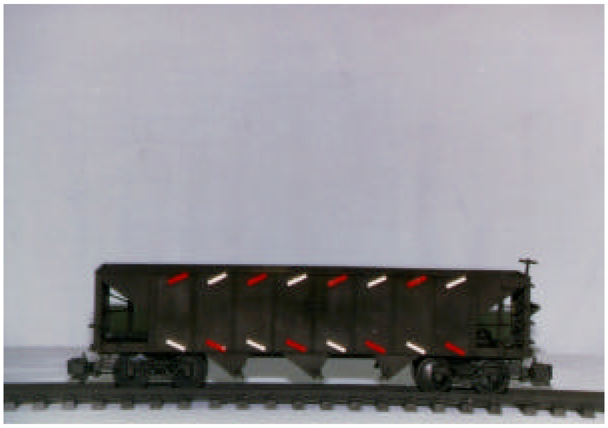
MARKING #11

PAIR 47

MARKING #4

MARKING #6

PAIR 48



MARKING #2

MARKING #10

PAIR 49

MARKING #5

MARKING #8

PAIR 50

MARKING #10

MARKING #6

PAIR 51

MARKING #11

MARKING #7

PAIR 52

MARKING #5

MARKING #3

PAIR 53

MARKING #4

MARKING #10

PAIR 54

MARKING #1

MARKING #5

PAIR 55

MARKING #9

MARKING #3

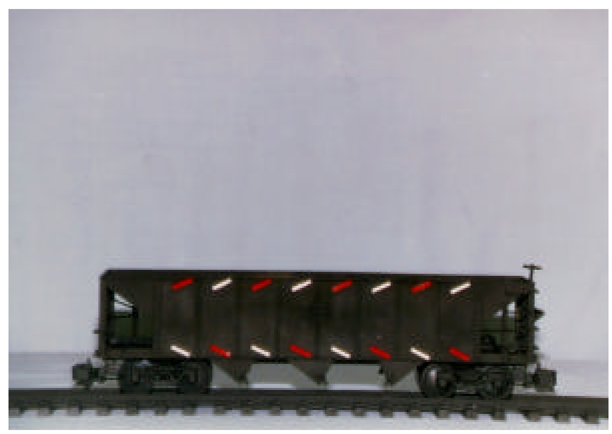
SECTION II

A RELATIVE RANKING OF EXPERIMENTAL CONSPICUITY MARKING SYSTEMS FOR FREIGHT CARS

INSTRUCTIONS:

Rank the eleven marking systems shown on the following two facing pages from best to worst as to how you judge their effectiveness in enhancing the visibility of freight cars. Assign rankings from "1" to "11" for most effective through least effective. Record these rankings in the blanks at the end of the identifying label below each design. For example, I might select marking #7 as the most effective, I would then write the rank, "1" in the blank below design 7, (e.g., MARKING #7 __1__). Then I might select marking #4 as the next most effective and I would write the rank, "2" in the blank below design 4, (e.g., MARKING #4 __2__). Repeat this procedure until all markings have been scored and recorded.

RANKING OF MARKING #1 _____



RANKING OF MARKING #2 _____

RANKING OF MARKING #3 _____

RANKING OF MARKING #4 _____

RANKING OF MARKING #5 _____

RANKING OF MARKING #6 _____

RANKING OF MARKING #7 _____

RANKING OF MARKING #8 _____

RANKING OF MARKING #9 _____

RANKING OF MARKING #10 _____

RANKING OF MARKING #11 _____

SECTION III

RATING OF ATTRIBUTES AND DIMENSIONS OF CONSPICUITY MARKINGS

INSTRUCTIONS:

Several attributes of conspicuity have been identified as being of interest in this study. These attributes are detectability (is something there?), recognizability (what is there?), uniqueness (it is like no other), confusibility (different from all others). The dimensions that define these attributes are color(s), high contrast with the background, the pattern of the marking, and the placement of the marking on the freight car. The evaluations performed in the previous sections may not be sufficient to identify which attributes and dimensions made one system preferable to another, this section will ask you to rate each attribute and dimension that you consider as to its importance in creating conspicuity marking systems. On the following pages, please indicate how strongly you rate each of these attributes and dimensions by circling one of the numbers on the scale for each of these dimensions.

MARKING 9

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING 6

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

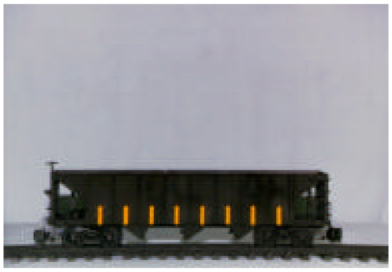
MARKING 3

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



MARKING 8

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING 5

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING 11

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

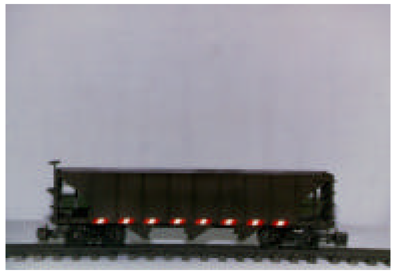
MARKING 7

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



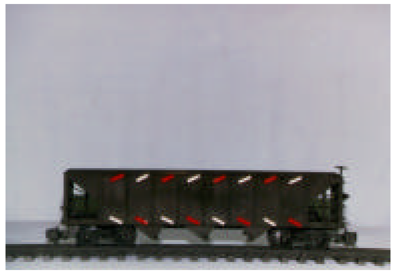
MARKING 1

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



MARKING 2

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING 10

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING 4

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

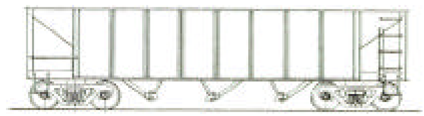
SECTION IV

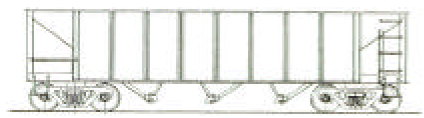
SUGGESTED CONSPICUITY MARKING SYSTEMS FOR FREIGHT CARS

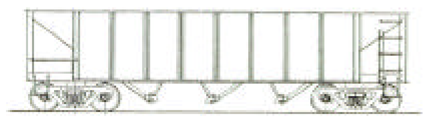
INSTRUCTIONS:

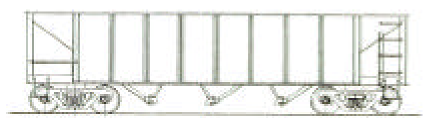
This section contains diagrams of a hopper car on which you may draw your own suggestions for conspicuity marking systems if you desire. We hope you will share with us any ideas you may have.

You may use colored pencils or pens to sketch your ideas or you may use a black or blue pen and indicate what the color or combination of colors are. The size of the marking is also important.









SECTION V

CONFIDENTIAL BIOGRAPHICAL INFORMATION

INSTRUCTIONS:

Please provide the information requested on the following two pages. This information will allow us to develop a profile of the participants in our survey. As indicated above, all information provided in this section will only be used to develop a profile of the participants. All responses and opinions are confidential and your anonymity is guaranteed.

1. GENDER: (Circle one) Male Female
2. AGE: (Circle one)
   20-30 31-40 41-50 51-60 61+
3. What color or colors, if any, do you have trouble seeing? (Circle all that apply)
   NONE RED GREEN YELLOW BLUE
4. How are you affiliated with the transportation industry? (Circle all that apply)
   Federal Government State Government
   Railroad Industry Contractor
   Consultant Signal/Supply Industry
   University Regulatory
   Researcher
   Other (____________________)
5. How many years have you been affiliated with the transportation idustry? (Circle one)
   0-5 10-15 20-25 30-35 5-10 15-20 25-30 35+ _____
6. How would you best describe your "expertise" in transportation, e.g., human factors, highway-rail safety engineer?
   ____
7. Have you had any training or experience in designing or evaluating (Circle all that apply):
   (0) no experience
   (1) signing (such as traffic signs)
   (2) rail traffic control devices
   (3) delineators
   (4) highway traffic control devices
8. Are you aware of any efforts in the railroad industry to apply any type reflective markings to rail cars? If so:
   YES NO
   If yes, please answer the following:
   Who is doing this? __________
   What is being done? ____________________
   Was there a change in accidents rates? __________

APPENDIX C

NOVICE PANEL QUESTIONNAIRE

JURY EVALUATION OF EXPERIMENTAL CONSPICUITY

MARKING SYSTEMS FOR FREIGHT CARS

The conspicuity markings in this questionnaire are strictly experimental and are not intended to be applied to any type of railroad freight car in their current configurariton.

This questionnaire is part of A HUMAN ENGINEERING STUDY OF THE RETROREFLECTION OF RAILROAD FREIGHT CARS AND TRAIN CONSPICUITY AT HIGHWAY-RAILROAD GRADE CROSSINGS

Performed by the: Transportation Center
The University of Tennessee
Knoxville TN 37996-0700

JURY PARTICIPANTS PLEASE READ THE FOLLOWING INSTRUCTIONS BEFORE PROCEEDING FURTHER

The purpose of this survey is to obtain an evaluation of a set of experimental retroreflective marking systems for freight cars by automobile drivers. The function of these marking systems is to increase the visibility of freight trains at night. It is believed that these markings can reduce run-into-train accidents at railroad grade crossings with passive controls. These marking systems have been applied to scale model hopper cars so that they can be evaluated in a laboratory setting. Hopper cars were chosen to represent this category of freight cars because they often are operated in unit trains and are one of the most difficult freight cars for drivers to see.

The question this research is attempting to answer is: What combination of geometric shape, color or pattern of colors, size, and distribution of a given marking system will be most effective in increasing the visibility of freight cars for drivers? In order to answer this question, a series of evaluations have been planned. The purpose of this evaluation is to establish a ranking based on the collective judgement of a panel of automobile drivers as to which of the eleven marking systems they perceive would be the most effective in enhancing the visibility of hopper cars.

This evaluation contains five sections and should take approximately 60 minutes to complete. Do not hesitate to ask if you have any questions or problems. When you have finished, please return the questionnaire to the person conducting the evaluation.

SECTION I

CONFIDENTIAL BIOGRAPHICAL INFORMATION

INSTRUCTIONS:

Please provide the information requested on the following two pages. This information will allow us to develop a profile of the participants in our survey. As indicated above, all information provided in this section will only be used to develop a profile of the participants. All responses and opinions are confidential and your anonymity is guaranteed.

1. GENDER: (Circle one) Male Female
2. AGE: (Circle one)
   20-30 31-40 41-50 51-60 61+
3. How many years have you been driving an automobile? (Circle all that apply)
   1-5 6-10 11-20 21-30 31-40 41+
4. Do you wear corrective lens? YES NO
5. Are you wearing them now? YES NO
6. What color or colors, if any, do you have trouble seeing? (Circle all that apply)
   NONE RED GREEN YELLOW BLUE
7. Have you had any training or experience in designing or evaluating (Circle all that apply):
   no experience
   signing (such as traffic signs)
   rail traffic control devices
   delineators
   highway traffic control devices
8. Are you aware of any efforts in the railroad industry to apply any type reflective markings to rail cars? If so:
   YES NO
   If yes, please answer the following:
   Who is doing this? ___________
   What is being done? ______________________
   Was there a change in accidents rates? ___________

SECTION II

PAIRED COMPARISONS OF EXPERIMENTAL CONSPICUITY MARKING SYSTEMS FOR FREIGHT CAR

INSTRUCTIONS:

As each pair of hopper cars are presented upon the stage, you are to judge which single car of the pair would be the most effective in enhancing the visibility of freight trains. On the following pages indicate your preference for each pair by circling the marking number label that corresponds to the marking you judged to be the most effective. Using the first pair of cars for an example, if you think that the car with marking #3 is preferable to the car with marking #9, draw a circle around the label "MARKING #3" for this pair as shown below.

PAIR 1	MARKING #9	MARKING #3
PAIR 2	MARKING #1	MARKING #5

PAIR 1	MARKING #9	MARKING #3
PAIR 2	MARKING #1	MARKING #5
PAIR 3	MARKING #4	MARKING #10
PAIR 4	MARKING #5	MARKING #3
PAIR 5	MARKING #11	MARKING #7
PAIR 6	MARKING #10	MARKING #6
PAIR 7	MARKING #5	MARKING #8
PAIR 8	MARKING #2	MARKING #10
PAIR 9	MARKING #4	MARKING #6
PAIR 10	MARKING #9	MARKING #11
PAIR 11	MARKING #6	MARKING #9
PAIR 12	MARKING #3	MARKING #8
PAIR 13	MARKING #6	MARKING #3
PAIR 14	MARKING #11	MARKING #1
PAIR 15	MARKING #6	MARKING #11

PAIR 16	MARKING #3	MARKING #11
PAIR 17	MARKING #2	MARKING #6
PAIR 18	MARKING #9	MARKING #5
PAIR 19	MARKING #2	MARKING #1
PAIR 20	MARKING #3	MARKING #2
PAIR 21	MARKING #7	MARKING #3
PAIR 22	MARKING #5	MARKING #10
PAIR 23	MARKING #9	MARKING #4
PAIR 24	MARKING #4	MARKING #1
PAIR 25	MARKING #1	MARKING #10
PAIR 26	MARKING #10	MARKING #11
PAIR 27	MARKING #7	MARKING #10
PAIR 28	MARKING #4	MARKING #7
PAIR 29	MARKING #7	MARKING #5
PAIR 30	MARKING #10	MARKING #3
PAIR 31	MARKING #7	MARKING #6
PAIR 32	MARKING #1	MARKING #8
PAIR 33	MARKING #4	MARKING #8
PAIR 34	MARKING #2	MARKING #5
PAIR 35	MARKING #9	MARKING #2
PAIR 36	MARKING #2	MARKING #11
PAIR 37	MARKING #4	MARKING #2
PAIR 38	MARKING #4	MARKING #3
PAIR 39	MARKING #11	MARKING #8
PAIR 40	MARKING #6	MARKING #1
PAIR 41	MARKING #7	MARKING #2
PAIR 42	MARKING #8	MARKING #6

PAIR 43	MARKING #8	MARKING #7
PAIR 44	MARKING #1	MARKING #7
PAIR 45	MARKING #10	MARKING #9
PAIR 46	MARKING #11	MARKING #5
PAIR 47	MARKING #6	MARKING #5
PAIR 48	MARKING #1	MARKING #9
PAIR 49	MARKING #4	MARKING #11
PAIR 50	MARKING #3	MARKING #1
PAIR 51	MARKING #9	MARKING #8
PAIR 52	MARKING #7	MARKING #9
PAIR 53	MARKING #5	MARKING #4
PAIR 54	MARKING #10	MARKING #8
PAIR 55	MARKING #2	MARKING #8

SECTION III

A RELATIVE RANKING OF EXPERIMENTAL CONSPICUITY MARKING SYSTEMS FOR FREIGHT CARS

INSTRUCTIONS:

Rank the eleven marking systems shown on the stage from best to worst as to how you judge their effectiveness in enhancing the visibility of freight cars. On the following page, assign a rank from "11" to "1" for most effective through least effective. Record the marking identification number in the blank next to the ranking you assigned that marking system. For example, you might select MARKING #7 as the most effective, you would then write the number "7" in the blank to the right of the ranking, 11 (as shown below). Then you might select MARKING #4 as the next most effective, then you would write "4" in the blank next to the ranking, 10 (again, as shown below). Repeat this procedure until all markings have been scored and recorded.

RANKING	MARKING #	
11	__7__	(Most Effective)
10	__4__	
9	_____	
.	_____	
.	_____	
.	_____	
1	_____	(Least Effective)

RANKING OF RAIL CAR CONSPICUITY MARKINGS

RANKING	MARKING #	
11	______	(Most Effective)
10	______	
9	______	
8	______	
7	______	
6	______	
5	______	
4	______	
3	______	
2	______	
1	______	(Least Effective)

SECTION IV

RATING OF ATTRIBUTES AND DIMENSIONS OF CONSPICUITY MARKINGS

INSTRUCTIONS:

Several attributes of conspicuity have been identified as being of interest in this study. These attributes are detectability (is something there?), recognizability (what is there?), uniqueness (it is like no other), confusibility (different from all others). The dimensions that define these attributes are color(s), high contrast with the background, the pattern of the marking, and the placement of the marking on the freight car. The evaluations performed in the previous sections may not be sufficient to identify which attributes and dimensions made one system preferable to another, this section will ask you to rate each attributes and dimension that you consider as to its importance in creating conspicuity marking systems. On the following pages, please indicate how strongly you rate each of these attributes and dimensions by circling one of the numbers on the scale for each of these dimensions.

MARKING #9

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #6

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #3

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #8

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #5

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #11

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #7

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #1

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #2

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #10

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

MARKING #4

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking of the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

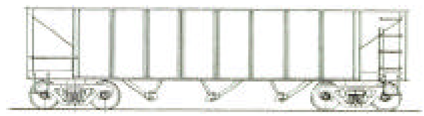
SECTION V

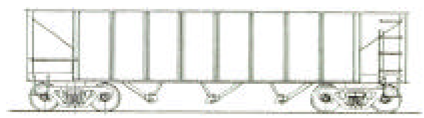
SUGGESTED CONSPICUITY MARKING SYSTEMS FOR FREIGHT CARS

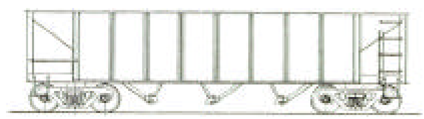
INSTRUCTIONS:

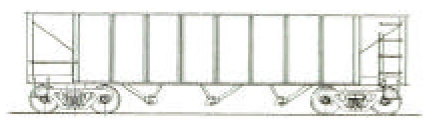
This section contains diagrams of a hopper car on which you may draw your own suggestions for conspicuity marking systems if you desire. We hope you will share with us any ideas you may have.

You may use colored pencils or pens to sketch your ideas or you may use a black or blue pen and indicate what the color or combination of colors are. The size of the marking is also important.









AGAIN, THANK YOU FOR TAKING PART IN OUR SURVEY

APPENDIX D

PANEL AND SUBJECT PROFILES

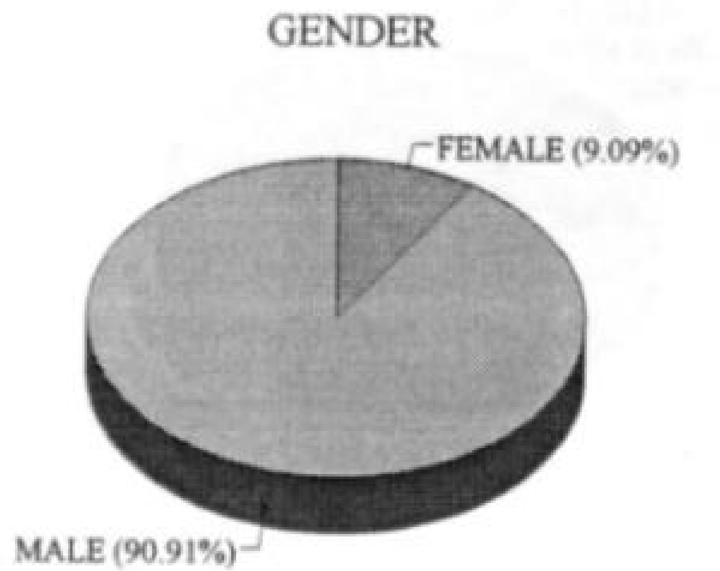


Figure D-1. Gender Distribution - Expert Participants

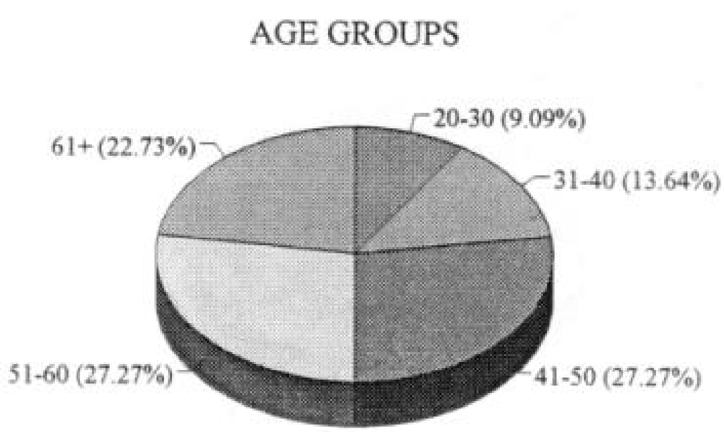


Figure D-2. Age Distribution - Expert Participants

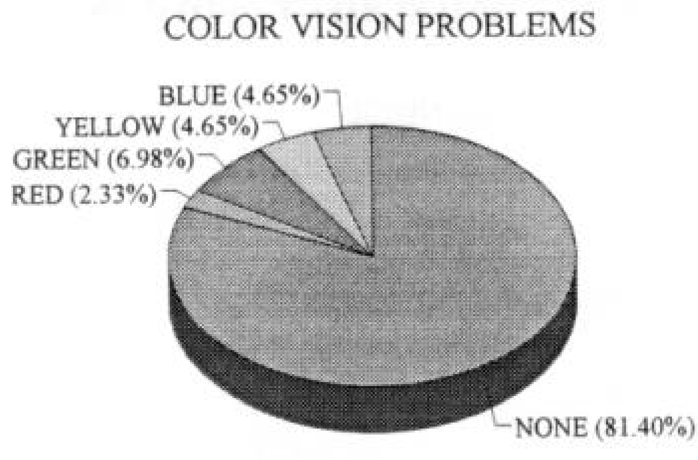


Figure D-3. Color Vision Problems - Expert Participants

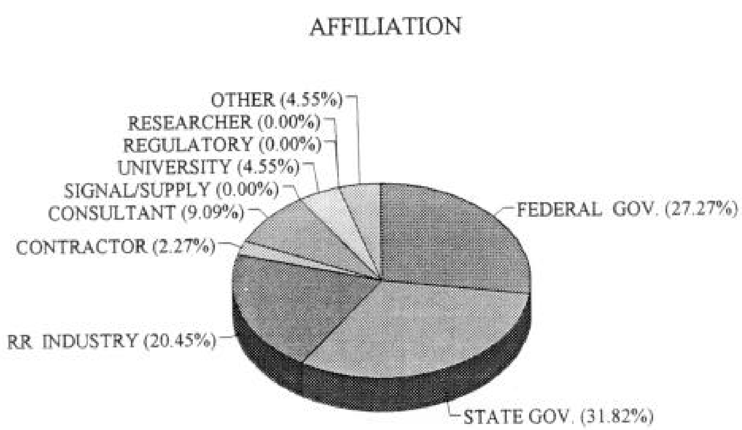


Figure D-4. Affiliations - Expert Participants

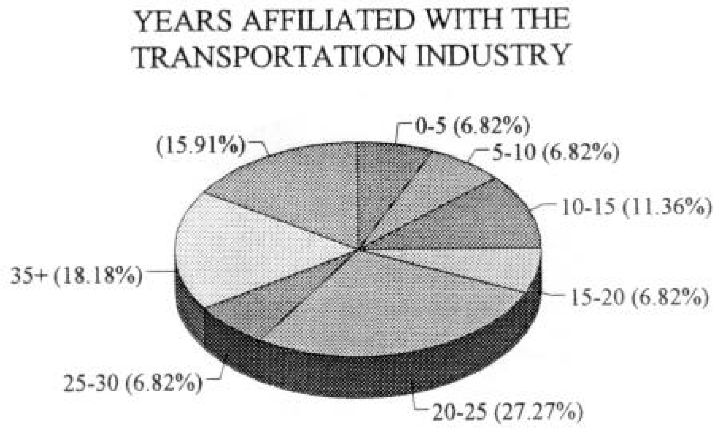


Figure D-5. Professional Experience - Expert Participants

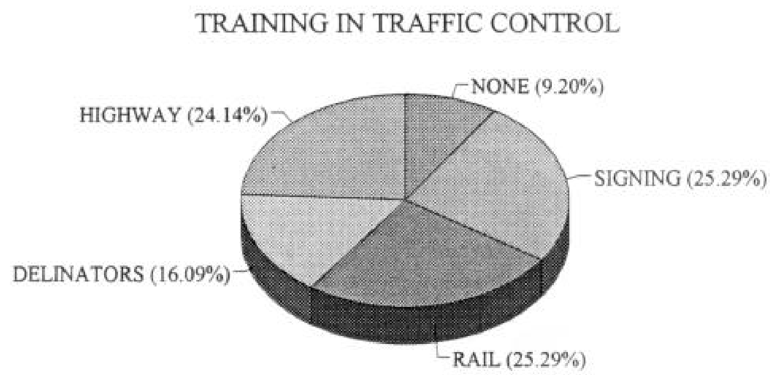


Figure D-6. Training Background - Expert Participants

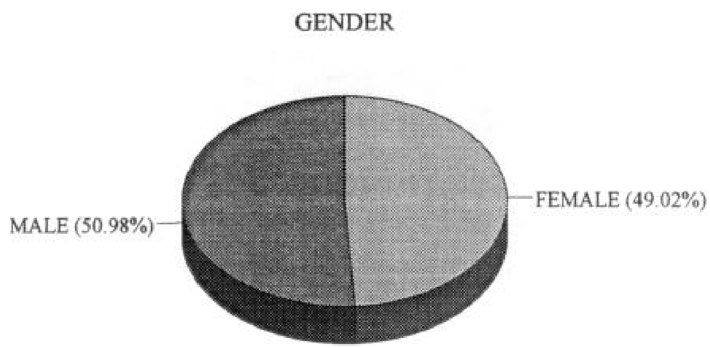


Figure D-7. Gender Distribution - Novice Participants

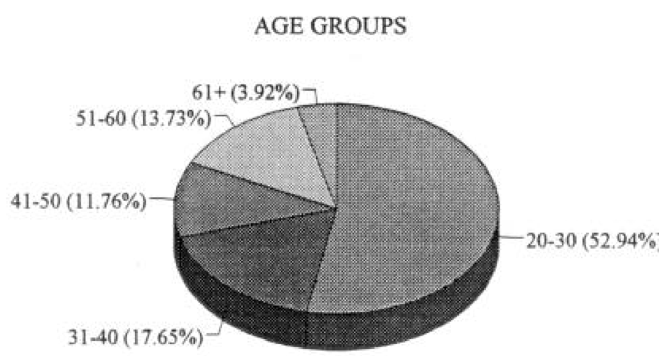


Figure D-8. Age Distribution - Novice Participants

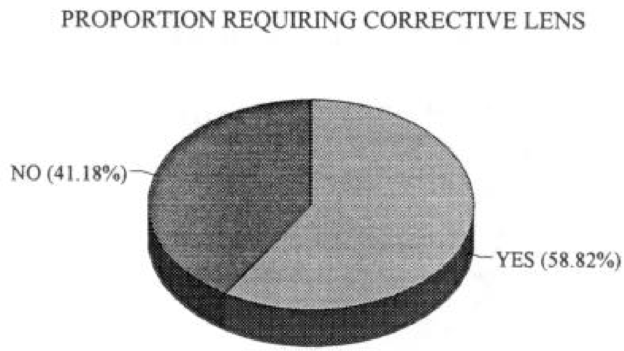


Figure D-9. Visual Acuity Distribution - Novice Participants

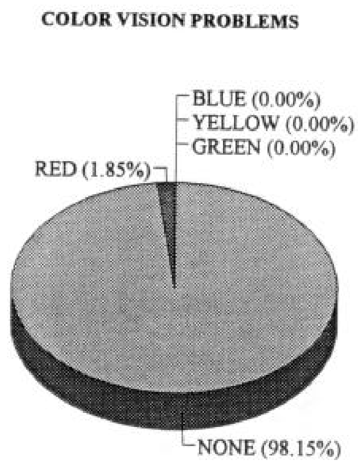


Figure D-10. Color Vision Problems - Novice Participants

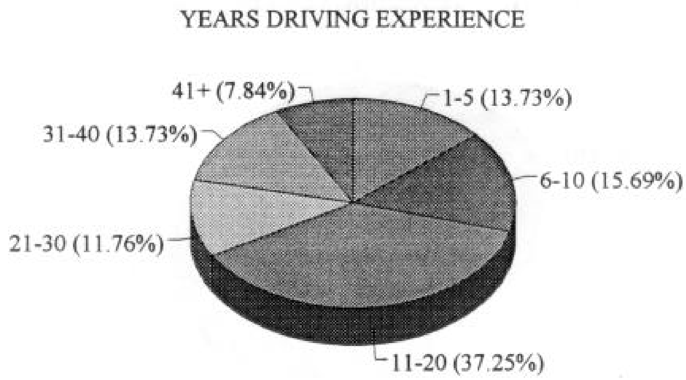


Figure D-11. Driving Experience - Novice Participants

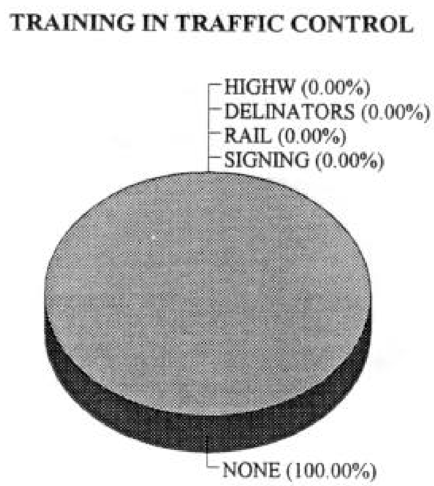


Figure D-12. Training Background - Novice Participants

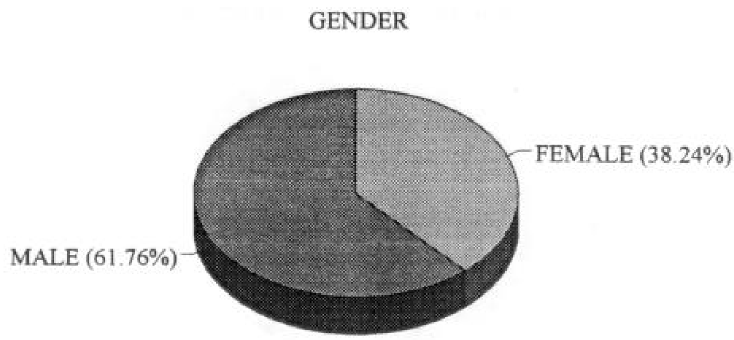


Figure D-13. Gender Distribution - Objective Experiment Participants

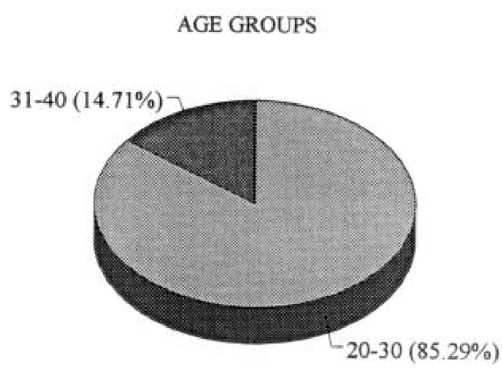


Figure D-14. Age Distribution - Objective Experiment Participants

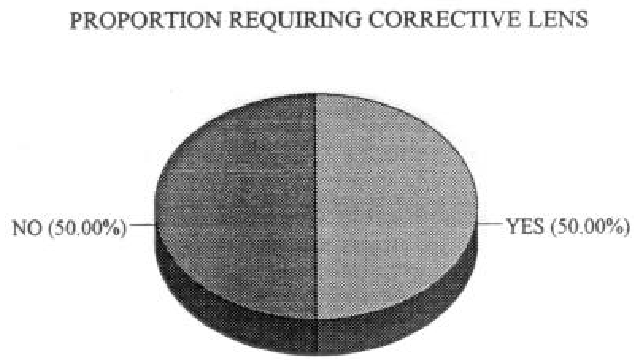


Figure D-15. Visual Acuity Distribution - Objective Experiment Participants

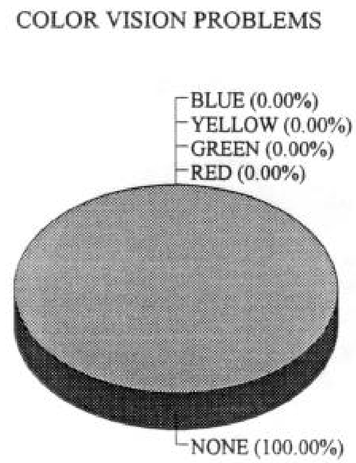


Figure D-16. Color Vision Problems - Objective Experiment Participants

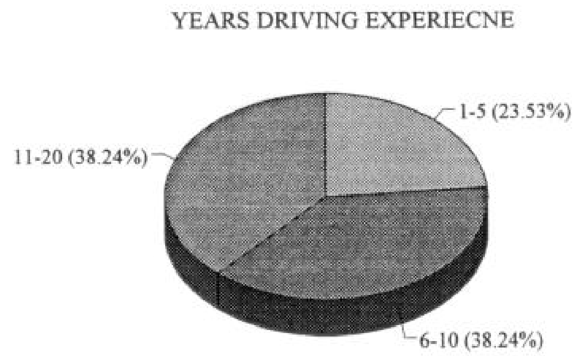


Figure D-17. Driving Experience - Objective Experiment Participants

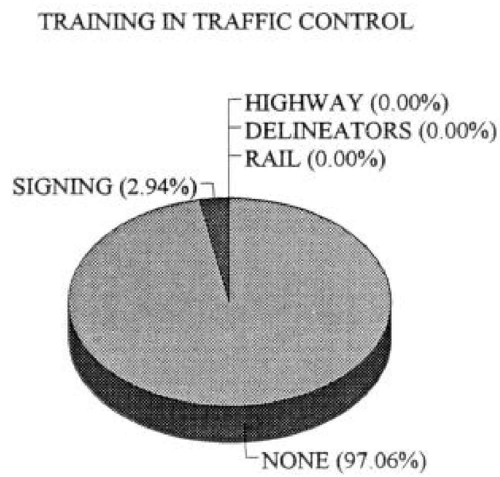


Figure D-18. Training Background - Objective Experiment Participants

APPENDIX E

ANOVA RESULTS

Dependent variable: Detection Time for the Attributes

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	305	185031.75	606.66	50.12	0.0001
Error	918	11112.00	12.10		
Corrected Total	1223	196143.75			

R-Square	C.V.	Root MSE	Detection Time Mean
0.943348	7.113617	3.4792	48.908

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pattern	2	46868.91	23434.45	1936.00	0.0001
Color	2	10639.01	5319.51	439.46	0.0001
Subject	33	20130.42	610.01	50.40	0.0001
Pattern*Color	4	101712.64	25428.16	2100.71	0.0001
Pattern*Subject	66	1472.76	22.31	1.84	0.0001
Color*Subject	66	1469.99	22.27	1.84	0.0001
Patten*Color*Subject	132	2738.03	20.74	1.71	0.0001

Dependent variable: Detection Time for the Marking Systems

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	339	785990.90	2318.56	160.60	0.0001
Error	1020	14725.50	14.44		
Corrected Total	1359	800716.40			

R-Square	C.V.	Root MSE	Detection Time Mean
0.981610	6.797092	3.7996	55.900

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Marking	9	757525.44	84169.49	5830.22	0.0001
Subject	33	20802.35	630.37	43.66	0.0001
Marking*Subject	297	7663.11	25.80	1.79	0.0001

Tukey's Studentized Range (HSD) Test on Marking Systems for Detection Time

$\alpha = 0.05$ df = 297 MSE = 25.8017
Critical Value of Studentized Range = 4.508
Minimum Significant Difference = 1.9637

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Marking
A	118.82	136	Standard Car
B	60.07	136	R|W Dash
B	60.46	136	R|W Field Test
C	57.20	136	Yellow Dash
C	55.28	136	Red Dash
D	52.45	136	Yellow Fence
E	47.90	136	Red Fence
E	47.51	136	Red Field Test
F	34.49	136	R|W Fence
G	24.82	136	Yellow Field Test

Tukey's Studentized Range (HSD) Test on Distribution Patterns for Detection Time

$\alpha = 0.05$ df = 66 MSE = 22.31452
Critical Value of Studentized Range = 3.391
Minimum Significant Difference = 0.793

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Distribution Pattern
A	57.65	408	Dash
B	44.13	408	Field Test
C	44.95	408	Fence

Tukey's Studentized Range (HSD) Test on Color Attributes for Detection Time

$\alpha = 0.05$ df = 66 MSE = 22.27255
Critical Value of Studentized Range = 3.391
Minimum Significant Difference = 0.7923

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Color Pattern
A	51.67	408	R|W
B	50.23	408	Red
C	44.82	408	Yellow

Dependent variable: Recognition Time for the Attributes

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	305	230757.77	756.58	15.11	0.0001
Error	918	45973.00	50.08		
Corrected Total	1223	276730.77			

R-Square	C.V.	Root MSE	Recognition Time Mean
0.833871	8.990562	7.0767	78.712

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Pattern	2	35545.72	17772.86	354.89	0.0001
Color	2	21491.86	10745.93	214.58	0.0001
Subject	33	61101.49	1851.56	36.97	0.0001
Pattern*Color	4	84774.23	21193.56	423.20	0.0001
Pattern*Subject	66	9616.56	145.71	2.91	0.0001
Color*Subject	66	8328.75	126.19	2.52	0.0001
Patten*Color*Subject	132	9899.16	74.99	1.50	0.0006

Dependent variable: Recognition Time for the Marking Systems

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	339	468942.24	1388.31	30.50	0.0001
Error	1020	46263.50	45.36		
Corrected Total	1359	515205.74			

R-Square	C.V.	Root MSE	Recognition Time Mean
0.910204	8.102198	6.7347	83.122

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Marking	9	379817.75	42201.97	930.45	0.0001
Subject	33	55535.59	1682.90	37.10	0.0001
Marking*Subject	297	33588.90	113.09	2.49	0.0001

Tukey's Studentized Range (HSD) Test on Marking Systems for Recognition Time

$\alpha = 0.05$ df = 297 MSE = 113.0939
Critical Value of Studentized Range = 4.508
Minimum Significant Difference = 4.1113

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Marking
A	122.89	136	Standard Car
C B	90.73	136	R|W Dash
C B	88.69	136	Yellow Fence
B	88.65	136	R|W Field Test
D	84.90	136	Yellow Dash
E	80.65	136	Red Dash
F	74.49	136	R|W Fence
F	73.17	136	Red Field Test
F	72.24	136	Red Fence
G	54.89	136	Yellow Field Test

Tukey's Studentized Range (HSD) Test on Distribution Patterns for Recognition Time

$\alpha = 0.05$ df = 66 MSE = 145.7055
Critical Value of Studentized Range = 3.391
Minimum Significant Difference = 2.0264

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Distribution Pattern
A	85.43	408	Dash
B	78.47	408	Fence
C	72.23	408	Field Fest

Tukey's Studentized Range (HSD) Test on Color Patterns for Recognition Time

$\alpha = 0.05$ df = 66   MSE = 126.1931
Critical Value of Studentized Range = 3.391
Minimum Significant Difference = 1.8858

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Color Pattern
A	84.62	408	R|W
B	76.16	408	Yellow
B	75.36	408	Red

APPENDIX F

COMPARISON WITH OTHER STUDIES

How effective a retroreflective marking systems is at providing information to a motorist depends on the attributes of color, contrast, geometric shape or symbol, amount of material used (size), distribution pattern or configuration, and coefficient of retroreflection of the material chosen for the marking. In the past 40 years, there have been few studies that addressed determining the best values for one or more of these attributes for the enhancement of the conspicuity of mobile objects such as trucks and trains. Trucks and trains require a high degree of visibility, whether stationary or moving, in order to be detected and recognized by motorists. Prior to the mid-1980s, retroreflective materials were not very durable and their reflectivity degraded rapidly. The early studies that addressed trucks or trains were concerned with the size and reflectivity of the markings so as to meet a minimum standard (e.g., 45 Candela/Foot Candle) after the markings had degraded due to exposure to the elements and kept the other parameters fixed at a single value (Hopkins and Newfell, 1975; McGinnis, 1979; Poage, 1982; Poage et al., 1982). However, some early studies (Aurelius and Korobow, 1971; Lauer and Suhr, 1956; and Stalder and Lauer, 1952, 1954), were concerned with one or more of the attributes of color, contrast, placement pattern, or geometric shape. Since the mid-1980s, retroreflective materials have been improved considerably in both durability and reflectivity. Studies by Zwahlen et al. (1989) and Olson et al. (1992) give insight into the use of retroreflective materials to enhance the conspicuity of trucks and trains. The following discussion on pattern distribution and brightness and color contrast will compare the inferences of these studies with the findings of this study.

Pattern Distribution

Stalder and Lauer (1952) found that the pattern distribution affected the time and difficulty for perception of relative motion. They concluded that for a fixed area of retroreflective material, an outline pattern gave better results than did a checkerboard design. In the current rail car study this finding was supported by the novice panel in the subjective evaluation. The novices chose placement patterns that gave an indication of size and shape of the hopper car (yellow fence, red-white sawtooth, yellow outline, and red|white field test) as the most preferred of all the patterns available for review in the simple ranking, the paired-comparison, and in the semantic differential tests. In the objective evaluation, the distribution patterns that indicated the size or shape (the fence and the field test) of the hopper car had mean times to detection and recognition that were statistically the same and that were considerably better than the dash distribution pattern that concentrated the retroreflectors along the side sill regardless of the color. The field test distribution pattern also had the fewest recognition errors. It was the only mistaken for the other two distribution patterns 3 times in 136 trials, making it the placement pattern least likely to be confused with any other pattern. The expert panel did not show a clear preference for any of the placement patterns and always appeared to make their decisions based on the color of the marking system.

A study by Olson et al. (1992) found that the application of retroreflective markings that gave an indication of size or shape enhanced the detection and recognition of large semi-truck trailers at night. They also found that this marking system was beneficial for estimating distance and closure rates when both the truck and the observer were moving in the same direction. They recommended that 2-wide strips of retroreflective material be applied to the rear of the trailer in a distribution pattern that would provide a partial outline of the unit. They also recommended a noncontinuous stripe along the bottom rail of the trailer side. This recommendation was primarily for detecting the trailer when it was static and perhaps obstructing the highway. The distribution pattern for the rear of the trailer consisted of a continuous strip across the bottom and short strips in the form of an inverted "L" at each of the top corners. The color pattern recommended for bottom of the rear and along the bottom rail should have near equal amounts of red concatenated with white. The inverted "L's" were white. The red|white color pattern was chosen because of the established value of red as a hazard identification and the improved daytime visibility of red|white as compared to either red or white alone.

The use of a distribution pattern that indicates the shape or size of the trailer was supported by the current rail car study. However, Olsen et al.'s conclusion that neither full or partial outlining of the side of the trailer was necessary does not compare favorably with the results of the current rail car study. The difference in how the motorist approaches the truck or rail car may be the reason for this discrepancy. In the truck study the motorist was overtaking the truck from the rear while traveling in the same direction as the truck. In the current rail car study the motorist was traveling perpendicular to the rail car. This discrepancy may also be the result of having investigated only the one color pattern in the truck study. In the freight car study, a red|white stripe along the bottom edge of the hopper car was greatly superior to no retroreflective treatment at all but did not perform well when compared to outlined patterns or other single color markings.

Brightness and Color Contrast

Stalder and Lauer (1954) conducted a second experiment in which they determined that the use of materials giving the greatest brightness-contrast at night significantly decreased both the amount of luminance needed and the difficulty of discriminating movement of box cars crossing the line of vision. They also concluded that the larger the area of the patches of reflectorized material the lower the level of luminance need for detection and that, for a given area of material, concentrating the material in one place on the side of the box car was more effective. The results of the current rail car study using retroreflective materials with higher coefficients of retroreflection support their findings. The greatest brightness-contrast ratio used in this study from a single color was the application of the fluorescent yellow diamond grade material to the hopper cars. White retroreflective material was never used as a single color in any of the marking systems evaluated in any of the experiments. Any marking system that used fluorescent yellow was preferred by the expert panel to be the most effective in enhancing the conspicuity of the hopper cars. This was also the most preferred color by the novice panel, provided that it was used to indicate the shape of the rail car. The marking system that had the lowest mean time to detection was the yellow field test, again indicating that yellow contributed to creating a highly effective marking. The analysis of the three colors, independent of the placement pattern, support this conclusion. The concentration of the material is not as strongly supported, but the results of this study do give some indication that concentrating the material improves performance by the number of time the fence was ranked second or third to those placement patterns that outlined the shape of the rail car. A later study by Lauer and Suhr (1956) confirmed that concentrating the reflective material was superior to a distribution of the same material.

Aurelius and Korobow (1971) concluded in their locomotive conspicuity studies that the paint scheme used should use two contrasting colors, one dark and one light. While their design recommendation do not compare directly with any of the marking systems that were evaluated in the current rail car study, some of the attributes of conspicuity do. They recommended the use of bright, highly visible colors, such as fluorescent yellow, against a contrasting background and that the conspicuity enhancement also indicate the size and shape of the locomotive or freight car. These are the same attributes that were found to be important in the current rail car study.

In a nighttime shape recognition study of retroreflective warning plates (Zwahlen et al. 1989) it was found that recognition distances decreased and recognition errors increased as the intensity of the reflected light was increased. That is the observers could not easily distinguish between a rectangle, square, triangle, circle, or octagon of equal area as the grade of white retroreflective material used for the shape was changed from enclosed lens (105 candelas/foot candle/square foot), to encapsulated lens (305 candelas/foot candle/square foot), then to prismatic lens (1080 candelas/foot candle/square foot). In the current rail car study, the Nominal Group ranked all marking systems that employed squares or diamond shaped markings as inferior to designs that were made up of simple stripes. Only two marking systems evaluated by the expert and novice panels had a shape other than a rectangle included in the distribution pattern. These were the diamonds in bars and the highway truck designs. The novice panel did not even notice the three orange diamonds embedded in the red/white stripe in the diamond in bars marking system. The Zwahlen study also found that recognition performance improved slightly when a designed constant brightness-contrast ratio was provided. This may explain why single color markings in the present study out performed the red|white markings used in the recognition part of the current rail car study. The red|white marking had the additional contrast of the red concatenated to the white and that the increased glare from the prismatic material may have led to the higher incidence of recognition errors.

Summary

This comparison of the current rail car study to previous studies indicates a high degree of consistency for many of the results. The type of material, that is the reflectivity of the marking, is important in early detection but may degrade recognition of colors and geometric shapes. The shape or symbol chosen for the marking system is not as important as the color pattern, placement pattern, and contrast. Perhaps the most important finding is that a placement pattern that gives an indication of the size or shape of the freight car is of prime importance. Finally, when the size or shape factor is combined with the factor of a highly reflective color pattern with a large contrast ratio to its background, a highly conspicuous marking system is created.

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