DEPARTMENT OF TRAFFIC AND OPERATIONS

A Comprehensive Analysis of Motor Vehicle License Plates

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This comprehensive analysis of motor vehicle license plates was conducted with the following objectives:

1. To determine the functions of license plates and the relative importance of these functions.
2. To determine what information should be displayed on a license plate and the importance of each item of information.
3. To design the most effective and efficient license plate.

To determine the functions of a license plate and their relative importance, 475 questionnaires were distributed to persons concerned with vehicle licensing. Analysis of the questionnaire returns provided information whereby the other two objectives of the study could be analyzed. This, together with an extensive literature search, was supplemented by additional field and laboratory tests. This report provides the necessary factual information for the design of the most effective, efficient, and economical license plate.

• MOTOR VEHICLE license plates are familiar objects. License plates of all types and sizes are displayed on motor vehicles in all parts of the world. Current plate designs feature a variety of colors, words, phrases, symbols, numbers, and letters—items which have been placed on the plate to accomplish various functions.

The number of motor vehicle registrations has risen rapidly in recent years, and this has caused license plates to become increasingly important. The adoption of new types of identification systems, the modification of older types, and the placement of publicizing slogans and symbols on plates by many states have created new problems in the design and arrangement of plate content. Several states are issuing plates with reflective backgrounds and legends in an effort to increase plate visibility and legibility. The combined effect of these new design considerations and the increased importance of license plates accentuates the need for a comprehensive study of the purpose of motor vehicle license plates.

The study of motor vehicle license plates was conducted in two phases. The

first phase was directed toward the determination of the functions of license plates and the relative importance of the various functions. It also included investigations to determine what information should be placed on license plates and the relative importance of the various types of information. The types of information studied were:

1. Desired legibility distances for registration number, state name, and year number.
2. Important characteristics of the registration number.
3. Importance of color in year identification.
4. Value of county or area identification.
5. The value of slogans in state identification.
6. Importance of two license plates.

The second phase of the study was directed toward a determination of the best methods of presenting the information found most essential in the first phase. The design of the most effective and efficient license plate was also included in this phase of the study. Plate design items studied were:

1. Plate size and shape.
2. Number and letter-number combinations.
3. Legibility of letters and numbers.
4. Size of state name and year numbers.
5. Effect of slogans on legibility.
6. Color combinations.
7. Miscellaneous factors such as registration procedures, area identification, motor vehicle laws.

A study of reflectorized license plates was also conducted as a part of the second phase. The purposes of this study were to investigate and prescribe design criteria for a reflectorized license plate which would provide optimum legibility both day and night under traffic conditions and to investigate the effect of these plates on nighttime motor vehicle collisions.

FUNCTIONS OF MOTOR VEHICLE LICENSE PLATES

A review of the license plate designs used by the states and provinces in the United States and Canada indicates that license plates are being used to carry many different items of information. Registration numbers and letters, county names, county or area code numbers or letters, congressional district numbers, state names, year numbers, state slogans, emblems, and weight indications are items currently found on passenger car plates. There is, therefore, no general agreement concerning the important functions of license plates and the information required to accomplish these functions in accord with their relative importance.

The initial phase of the study of license plates was directed toward the determination of the functions, or purposes, of license plates, the relative importance of the various functions, and the information required to accomplish these functions. The study procedure, results, and conclusions were described and illustrated in detail in the progress report. (*5*)

A questionnaire relating to license plate information was prepared and sent to 475 American and Canadian law enforcement officers, motor vehicle administrators, and officials who frequently use the information presented on license plates. The plate design items were number and placement of plates, desirable legibility distances, the vehicle registration number, year identification, county or area identification, and slogans or emblems.

Sixty-two percent of the questionnaires were completed and returned. The replies were tabulated, correlated to occupation, and analyzed to form the basis for the study conclusions.

On the basis of the replies and comments received and from discussions with interested persons considering the many facets of license plate design, the following conclusions concerning the functions of license plates were evident:

1. The primary function of license plates is to display the information necessary for fast and accurate identification of

a motor vehicle under actual traffic conditions. This function is accomplished by placing the individual registration number and the state name on the plate.

2. The second function of license plates is to display the information necessary to show compliance with the motor vehicle registration laws by the owner of the vehicle. This function is accomplished by placing the year number on the plate, by changing the color of the plate, and by using special designations for differing types and weights of vehicles.

3. The designation of the vehicle owner's county or area of residence is not a true function of license plates. (a) In cases where distribution is on a county or local level, county or area designations may help in the enforcement of registration laws. (b) In cases where identification is difficult and inaccurate due to the type of numbering system in use, the number of vehicle registrations, and other design considerations, county or area designations may facilitate the accomplishment of the function of identifying the vehicle quickly and accurately under actual conditions. (c) County or area designations usually require more complex and costly administrative procedures, especially in states where distribution is from a central office.

4. The advertising and publicizing of the state is not a function of license plates. Although such advertising may be of intangible value to the state, the placement of slogans and emblems on license plates tends to reduce the effective accomplishment of the important functions of license plates.

The answers and comments, together with the considerations of plate size and methods of manufacturing, formed the basis for several conclusions regarding the characteristics of the information required on license plates to accomplish the functions of plates in accordance with their relative importance and by the most efficient methods, as follows:

1. For effective identification of motor vehicles under actual traffic conditions, each vehicle should be issued two plates, one to be displayed on the front of the vehicle and the other on the rear.

2. The vehicle registration number should be the most legible item of information on the plate, and should have the greatest legibility distance possible in consideration of plate size and design.

3. Research in license plate identification systems must continue to be directed toward the development of a system which possesses maximum legibility under actual traffic conditions. The system must also possess the characteristic of being easy to remember, but legibility is more important.

4. The year number should be legible at a distance approximately one-half that of the registration number.

5. The state name should be legible at a distance slightly greater than that required for reading the year number.

6. The year number is more important than the color combination in identifying the year of issuance of out-of-state plates. Cooperation and coordination among the states is necessary for color combinations to be of great help in identifying the year on out-of-state plates.

7. County or area designations, in the opinion of law enforcement officers, aid in fast and accurate identification of vehicles.

8. County or area designations usually require more complex and costly administrative procedures, especially in states where distribution is from a central office.

9. The county name is the least popular method of effecting a county designation.

10. The effect of address changes on the value of county and area designations is slight in states where new plates are issued annually. Where plates are renewed for one or more years, the harmful effect of address changes is greater.

11. County and area designations are of little value to persons outside the state of registration.

12. State slogans and emblems may have some value in the identification of the state.

13. The removal of state slogans from license plates and the use of the increased space for a larger state name would make state identification easier.

14. The removal of state slogans from license plates and the use of larger vehicle registration numbers could be a significant improvement in plate design.

It is emphasized that these conclusions are based primarily on the replies, comments, and opinions of law enforcement officers, motor vehicle administrators, and other persons interested in license plate information from throughout the United States and Canada, and are not the result of specific testing and investigative procedures. Therefore, although the conclusions are considered to be valid, it is important to investigate the effect of varying circumstances in applying them to the licensing procedures of a particular state. These conclusions, however, served as important guides for the subsequent research which was directed toward the design of more effective and efficient license plates.

DESIGN OF LICENSE PLATES

License plates must be designed so that they will accomplish their functions efficiently and economically. The items of information which are placed on the plate are the means of accomplishing these functions, and are the primary design considerations. The simplest and most effective method of presenting the important information must be utilized in the design of license plates.

The information that must be presented consists of (a) the vehicle registration number, (b) the name of the state or province, and (c) the year of issuance. Plates must be designed so that these three items may be quickly and accurately perceived at a desirable distance. The general methods of presenting this required information have been developed in the last fifty years, but many variations are currently used because there is no agreement about the best method of presentation.

Plate design items which were studied are (a) composition and size of the vehicle registration number, (b) size of state name and year number, (c) the effect of slogans and emblems, and (d) color combinations. The size and shape, which would logically be determined on the basis of the decisions made with regard to the design items, have instead been standardized and become constant. Size and shape, therefore, become the controlling design factor.

Miscellaneous factors that affect design are materials and paints, distribution methods, registration procedures, and various motor vehicle laws.

Plate Size and Shape

The size and shape of license plates have undergone many changes since plates first appeared on motor vehicles. Basically, the only requirement is that a plate have dimensions which permit the placement of all important information through the use of letters, numbers, and/or symbols which are large enough to be read at a desirable distance. The distance at which the plate should be legible is an arbitrary decision, and so the size has always been chosen on an arbitrary basis.

After more than twenty years of thought, discussion, and recommendations, the American Association of Motor Vehicle Administrators adopted a standard 6- by 12-in. plate size in 1953 (Fig. 1). The standard plate has given auto manufacturers an opportunity to provide better mounting, and in most cases, plates are now recessed to protect them from damage. Many new cars, however, do not provide suitable protection for the front plate, and it often becomes badly damaged and illegible.

Those states which have adopted the standard plate have realized a certain amount of convenience and economy. Figure 2 illustrates the variety of sizes and shapes used prior to adoption of the standard size. The plate bearing the legend NWB 872 has the standard 6- by 12-in. dimensions.

The most important effect of the standard plate is its effect on legibility. Prior to the adoption of the 6- by 12-in. plate, 17 states (with more than 40 percent of the total automobile registration in the United States) used plates 12½ in. or

of traffic has, however, made fast and accurate readability the determining factor in plate identification. Therefore a test was designed to determine which combinations are easiest to perceive quickly and accurately.

The test procedure consisted of showing a series of slides illustrating various number and letter-number combinations to a group of observers. The slides were exposed for ½ sec and the observers immediately recorded what they had read before viewing the next slide. These tests were conducted with the assumption that those number and letter-number combinations which are easiest to perceive quickly and accurately when exposed for a short interval of time in an indoor test would also be easiest to perceive under actual traffic conditions. It was also assumed that those combinations which are most difficult to perceive in an indoor test would have this same characteristic under actual traffic conditions.

A total of 128 test slides, illustrating 16 combinations of numbers or letters and numbers, were prepared. The letters and numbers for each slide were chosen at random. The slides were designed so that the only variables were the number of letters, numbers, or both, and the grouping of the characters. When projected, the test plates had the following characteristics:

1. They were white, 6 in. high, and from 10⅜ in. to 13⅞ in. long, depending on the number of characters.
2. The numerals and letters were black, 2⅜ in. high, 1⅜ in. wide (except "1" and "I"), with 5/16-in. stroke width.
3. Spacing between adjacent characters was ⅜ in.; between groups, 1 in.; and at the edges, ½ in.
4. The letters and numbers were centered vertically, and there was no year number, state name, slogan, or insignia.

The following list indicates the general form of each of the 16 combinations tested. In explanation; 12 345 means the plates in that group displayed 2 numbers, a space and 3 numbers, AB 123 is the general form for plates which had 2 letters, a space, and 3 numbers.

Group No.	General Form
1	12 345
2	123 456
3	1234 567
4	1234567
5	A 1234
6	1A 234
7	123 A4
8	AB 123
9	123 AB
10	A1 2345
11	1A 2345
12	1234 5A
13	1234 A5
14	AB 1234
15	1234 AB
16	ABC 123

Examples of the test plates are shown in Figure 3.

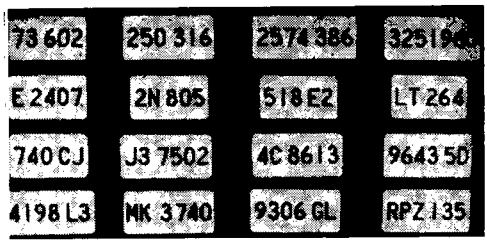

Figure 3. Examples of character combinations used in perception study.

The test was conducted in a darkened room using a 500-watt slide projector, an Ilex tachistoscope, and a 70- by 70-in. screen. Three, four, or five observers were seated at a table 20-ft from the screen with a data sheet and a pencil. Before the test, they were briefed on the conduct of the test, and were informed that all slides would have 5, 6, or 7 characters, and that the letters and numbers might appear in any position. They were also told to record as much of what they had read as possible. Three sample viewings were made to acquaint the observers with the test procedure.

During the test each slide was exposed on the screen for ½ sec. Following the exposure, the observers were given all the time they required to record their read-

ing. The call, "Ready," meant that the next slide was about to be exposed. The exposure time was chosen after preliminary tests indicated that observers could read and record correctly slightly more than 50 percent of the slides using ½-sec exposure.

Observers for the main portion of the experiment were chosen from one group —male college students. Because the objective of the test was the determination of the relative ease of perceiving various combinations of characters quickly and accurately, this decision appears justified. Observers from other age or occupational groups might be more or less proficient at reading combinations of characters, but it is expected that the relative ease or difficulty of perceiving various combinations would remain almost constant for all groups.

The 50 male student observers used in the perception tests made a total of 6,400 viewings of the test slides. The percentage of correct readings and the relative rank of the 16 combinations tested are given in Table 1.

Table 1 shows a variation in perception ability from 92 percent to 26 percent. This indicates that the test procedure produced data which show the degree of ease, or difficulty, with which a combination can be perceived quickly and accurately.

The results of the perception tests of certain combinations were analyzed to determine the effect of increasing the number of letters or numbers on the ease of perception. The data were analyzed by student's "t" test. The mean score is the percent read correctly, the number of observers (N) is 50, and the degrees of freedom are 118.

TABLE 1

RESULTS OF STUDENT PERCEPTION TESTS

Form	Rank	% Read Correctly
12 345	1	92.0
A 1234	2	90.8
AB 123	3	89.8
123 AB	4	86.8
123 A4	5	83.0
1A 234	6	80.4
123 456	7	75.0
AB 1234	8	70.0
1234 AB	9	58.8
1A 2345	10	58.6
1234 A5	11	55.6
ABC 123	12	53.4
A1 2345	13	51.0
1234 5A	14	32.8
1234 567	15	28.9
1234567	16	26.0

In Section 1 of Table 2, all comparisons are between combinations which differ only in the number of numerals and the total number of characters. In each of the first four comparisons, the number of numerals in a group increased from 3 to 4. The percentage decreases ranged from 19.8 to 28.0 and all were significant at the 1 percent level.

In Section 2 of Table 2, two comparisons are made between combinations which differ only in the number of letters and the total number of characters. Increasing the number of letters from 1 to 2 decreased the percentage read cor-

TABLE 2

EFFECT OF INCREASE IN NUMBER OF LETTERS OR NUMBERS ON PERCEPTION

Section	Char. Comb.	% Correct (Mean Score)	Char. Comb.	% Correct (Mean Score)	Diff. Betw. Means (%)	Value of "t"	Means Differ Signif.	Conf. Level (%)
1	AB 123	89.8	AB 1234	70.0	19.8	4.79	Yes	1
	1A 234	80.4	1A 2345	58.6	21.8	4.73	Yes	1
	123 A4	83.0	1234 A5	55.6	27.4	4.68	Yes	1
	123 AB	86.8	1234 AB	58.8	28.0	5.80	Yes	1
	12 345	92.0	123 456	75.0	17.0	3.92	Yes	1
	123 456	75.0	1234 567	28.9	46.1	9.05	Yes	1
2	A 1234	90.8	AB 1234	70.0	20.8	4.74	Yes	1
	AB 123	89.8	ABC 123	53.4	36.4	7.65	Yes	1

TABLE 3

EFFECT OF GROUPING LETTERS AND NUMBERS ON PERCEPTION

Section	Char. Comb.	% Correct (Mean Score)	Char. Comb.	% Correct (Mean Score)	Diff. Betw. Means (%)	Value of "t"	Means Differ Signif.	Conf. Level (%)
1	12 345	92.0	1A 234	80.4	11.6	3.01	Yes	1
	1A 234	80.4	AB 123	89.8	9.4	2.65	Yes	1
	AB 123	89.8	12 345	92.0	2.2	0.73	No	—
2	AB 1234	70.0	1A 2345	58.6	11.4	2.10	Yes	5
	AB 1234	70.0	A1 2345	51.0	19.0	3.65	Yes	1
3	1234 AB	58.8	1234 A5	55.6	3.2	0.50	No	—
	1234 AB	58.8	1234 5A	32.8	26.0	4.75	Yes	1
	123 AB	86.8	123 A4	83.0	2.8	1.08	No	—

rectly by 20.8 percent. Increasing the number of letters in the first group from 2 to 3 decreased the percentage read correctly by 36.4 percent. A comparison with Section 1 shows that increasing the number of numerals in the first group from 2 to 3 (12 345 and 123 456) resulted in a 17.0 percent reduction in the percentage read correctly. Therefore, the additional letter had a more detrimental effect on fast, accurate perception than did the additional number.

In some of the character combinations tested, letters were separated from the numerals by a space, while, in other combinations, the letters and numbers were not separated into groups. Student's "t" tests were used to analyze the data to determine the effect of separating letters from numbers.

In Section 1 of Table 3, the percentages of correct scores for combinations of the forms 12 345, 1A 345, and AB 123 are compared. The difference between the scores for combinations 12 345 and AB 123 was 2.2 percent, which is not statistically significant. Both of these combinations were read correctly a significantly greater percent of the time than the combination 1A 234. Combining a letter and a number in the first group significantly reduced the percent read correctly. Similar reductions are observed in the comparisons made in Sections 2 and 3 of Table 3.

To determine the statistical significance of the differences between the percentages read correctly for various combinations of characters which can be used as a vehicle registration numbering system, student's "t" test was used.

In Sections 1, 2, and 3 (Table 4), combinations of 5, 6, and 7 numbers which would be used in a straight numerical registration numbering system are compared with 5- and 6-character combinations of letters and numbers. Combinations of 2 letters and 3 or 4 numbers (AB 123 and AB 1234) are compared with the straight numerical combinations in Section 2 of Table 4, and the values for combinations of three letters and three numbers (ABC 123) are compared with straight numerical combinations in Section 3.

Results of the analyses in Sections 1, 2, and 3 (Table 4) show that combinations of 5 numbers were read correctly more often than 5-character combinations with 1 letter, and that combinations of 6 numbers were read correctly more often than 6-character combinations with 1 or 3 letters. Also, 7-number combinations were read correctly a smaller percentage of the total times observed than the 6-character combinations with 1, 2, or 3 letters. These results suggest that, as long as it does not become necessary to use more than 6 characters, a straight numerical registration numbering system can be read quickly and accurately with less difficulty than numbering systems which use 1 or 3 letters in the forms tested. It also appears that there is no significant difference between a straight numerical system and a system using 2 letters in the form tested. Sections 1, 2, and 3 (Table 4) show that it is desirable

TABLE 4

RESULTS OF "t" TESTS COMPARING VARIOUS CHARACTER COMBINATIONS

Section	Char. Comb.	% Correct (Mean Score)	Char. Comb.	% Correct (Mean Score)	Diff. Betw. Means (%)	Value of "t"	Means Differ Signif.	Conf. Level (%)
1	12 345	92.0	1A 234	80.4	11.6	3.01	Yes	1
	123 456	75.0	1A 2345	58.6	16.4	3.04	Yes	1
	1234 567	28.9	1A 2345	58.6	29.7	5.82	Yes	1
2	12 345	92.0	AB 123	89.8	2.2	0.73	No	—
	123 456	75.0	AB 1234	70.0	5.0	0.96	No	—
	1234 567	28.0	AB 1234	70.0	41.1	8.30	Yes	1
3	12 345	92.0	ABC 123	53.4	38.6	8.12	Yes	1
	123 456	75.0	ABC 123	53.4	21.6	3.86	Yes	1
	1234 567	28.9	ABC 123	53.4	24.5	4.62	Yes	1
4	1A 234	80.4	AB 123	89.8	9.4	2.65	Yes	1
	1A 2345	58.6	AB 1234	70.0	11.4	2.10	Yes	5
5	AB 123	89.8	ABC 123	53.4	36.4	7.87	Yes	1
	AB 1234	70.0	ABC 123	53.4	16.6	2.99	Yes	1
6	AB 123	89.8	123 AB	86.8	3.0	0.95	No	—
	AB 1234	70.0	1234 AB	58.8	11.2	2.10	Yes	5
7	12 345	92.0	A 1234	90.8	1.8	0.23	No	—
	12 345	92.0	123 A4	83.0	9.0	2.57	Yes	5
8	123 456	75.0	1A 234	80.4	5.4	1.14	No	—
	123 456	75.0	123 A4	83.0	8.0	1.74	No	—
9	1234567	26.0	1234 567	28.9	2.9	0.60	No	—
	A1 2345	51.0	1A 2345	58.6	7.6	1.42	No	—
	1234 A5	55.6	1234 5A	32.8	22.8	3.63	Yes	1

to use some combination of letters and numbers when the vehicle registration exceeds the limits of a 6-figure straight numerical system.

In Sections 4 and 5 (Table 4) the letter-number combinations using 1, 2, or 3 letters are compared to determine which is most suitable for use when vehicle registration exceeds the limits of a 6-figure straight numerical system (999,-999).

In Section 4 (Table 4) 5- and 6-character combinations with one and two letters are compared and combinations of the form AB 123 and AB 1234 were compared with 3-letter, 3-number combinations (ABC 123) in Section 5.

The results of the analyses in Sections 4 and 5 in Table 4 suggest that combinations of the form 1A 234 and 1A 2345, where a letter follows an initial number, are never desirable for use in a registration numbering system. Combinations with 2 letters and 3 or 4 numbers were significantly less difficult to read quickly and accurately and also provide a larger number of combinations. They also suggest that combinations of 3 letters and 3 numbers should not be used unless the vehicle registration exceeds the capacity of a system using a maximum of 2 letters and 4 numbers. The 3-letter, 3-number combinations were significantly more difficult to read accurately than combinations of 2 letters and 4 numbers.

The effect of placing combinations of 2 letters after 3 or 4 numbers is shown in Section 6 (Table 4). In Section 7, the straight numerical combinations of 5 numbers are compared with two forms of 1-letter, 4-number combinations not previously tested. The combinations of the form A 1234 were read correctly only 1.8 percent less often than combinations of the form 12 345, and this difference is not statistically significant. This combination (A 1234) is suitable for use when registrations are small. The combination 123 A4, and its expanded form 1234 A5 are not suitable because of the placement of the letter-number group at the end.

Section 8 (Table 4) compares the 6-number combination with combinations

of 1 letter and 4 numbers. The differences are not statistically significant. These results indicate that it is not advantageous to restrict the total number of characters to 5 by the use of letters in all positions in 5-character combinations. As pointed out in a later section, permitting letters to appear in any and all positions also causes problems in attempting to maintain an effective and efficient filing system.

The scores for additional combinations are compared to determine their statistical significance in Section 9 (Table 4). Straight numerical combinations of 7 numbers were tested in 2 forms; equally spaced, and in groups of 4 and 3 with a space between the groups. Grouping the numbers improved the percentage read correctly by 2.9 percent, but this difference was not statistically significant. This test was made because Illinois has used 7 numbers, which had the appearance of being equally spaced, on some passenger plates in recent years. Combinations of the form 1A 2345 were read correctly 7.8 percent more often than combinations such as A1 2345, but this difference was not statistically significant. Neither combination should be used; there are other letter-number combinations which are easier to read quickly and accurately.

To supplement the readings of the student observers, a limited number of police observers from the Champaign and Urbana City Police Departments, the University of Illinois Police, and the Illinois State Highway Police, were also tested. Although it was anticipated that their readings would be influenced by familiarity with current identification systems, police observers were tested to determine their proficiency in reading various character combinations. The results of the perception tests made with police observers are given in Table 5.

In considering the results of the police tests, the following is noted: (a) the number of observers was small, and the values could possibly change with additional observers, rearranging the rankings; (b) all policemen tested were from east central Illinois and are most familiar with the Illinois system of 1 to 7 numbers and the Indiana system of 2 letters with 1 to 4 numbers; and (c) the police observers were accustomed to reading those combinations currently in use, but unaccustomed to reading those which differ from current practice.

TABLE 5

RESULTS OF POLICE PERCEPTION TESTS[1]

Form	Rank	% Read Correctly
12 345	1	98.7
AB 123	2	92.7
A 1234	3	89.4
1A 234	4	82.7
123 AB	4	82.7
123 456	4	82.7
AB 1234	7	82.0
123 A4	8	79.4
1A 2345	9	58.0
A1 2345	10	47.3
1234 567	11	42.2
ABC 123	12	40.7
1234 AB	13	38.7
1234 A5	14	36.0
1234567	15	30.7
1234 5A	16	21.3

[1] Fifteen observers.

In general, the results of the tests with police observers are similar to the results of the student tests. The police, however, were more proficient at reading the straight numerical combinations and the combinations of 2 letters and 3 or 4 numbers. The police observers were less proficient with those combinations which had letters at the end. In this case, their lack of familiarity with those combinations was probably responsible.

The results of the tests with police observers suggest the need for a certain degree of uniformity in the identification systems used by all the states. All combinations of letters and numbers should be properly grouped and spaced, letters should always appear at the beginning or end and be separated from the numbers, and, so far as possible, all states should use the same identification system. If this were done, the police and the public would be able to read out-of-state plates with the same degree of proficiency as they read plates from their own states.

Legibility Distance of Letters and Numbers

The combination of characters used to make up the registration number should possess characteristics which make them legible at a desirable distance. The desired daytime legibility distance of the registration number, although an arbitrary figure, is generally in the range of 100 to 150 ft. Wiley (*17*) stated: "In a well-designed plate, the license number should have a legibility distance in daylight of at least 125 ft."

Many factors not related to character design affect the legibility distance of letters or numbers, but this investigation was directed toward determining the characteristics of letters and numbers which affect legibility distance.

There is a definite correlation between the height of characters and their legibility. Forbes and Holmes (*3*) suggest that the relationship between letter height and distance is not linear; that is, uniform increases in letter height do not result in equal increases in legibility distance. Matson *et al.* (*11*) say that "legibility distances increase curvilinearly with letter height for a given series in the smaller letters, and linearly in large letters." Regardless of the relationship, an increase in character height results in an increased legibility distance, provided that the width of the character increases proportionately.

The daylight legibility per inch of letter height of the U. S. Bureau of Public Roads alphabets has been reported as follows: Series B, 33 ft per in.; Series C, 42 ft per in.; and Series D, 50 ft per in. (*11*).

Soar (*16*) analyzed two styles of characters, each with 4 height-to-width ratios, and prescribes 1.33:1 as an optimum height-to-width ratio. Lauer, in an unpublished memorandum, indicates that the legibility distance increases as the height-width ratio approaches unity.

The references studied suggest the following conclusions: (a) the height-to-width ratio of a character is an important determinant in its legibility distance; (b) there is a correlation between the height of a character and its legibility.

A review of the dimensions of numbers and letters currently used on license plates shows that, in general, their height-to-width ratio is too large. As a general guide, the height-to-width ratio of characters used on license plates should be reduced to 2:1 or less, if possible. The present standard 12-in. plate limits the width of characters to approximately 1⅜ in. when six characters are used with correct spacing and grouping. It would appear, then, that as long as the standard plate remains 6 by 12 in., the letters and numbers used as part of the vehicle registration number should have approximately the following dimensions: height, 2½ to 3 in. and width, 1¼ to 1¾ in.

The optimum stroke width of a character is dependent on its height and width, and on the colors of the character and plate background. The reporting of stroke width determinations is generally done with respect to the height of the character and its stroke width (H/SW). The height is measured from the centers of the top and bottom horizontal strokes.

Kuntz (*7*) says the optimum H/SW ratio is 5.0:1, but that the difference between 5.0:1 and 6.0:1 or 4.0:1 is not significant. This would indicate a range of ratios wherein differences in legibility would be negligible.

As a portion of the study of reflectorized plates, the effect of stroke width on legibility was studied for 3-in. white painted numerals on blue painted backgrounds, and for 3-in. blue painted numerals on white painted backgrounds. Pure legibility tests were conducted in a darkened indoor area with the plates illuminated with low beams of a standard headlight system. The results of the tests with regular painted plates are given in Table 6.

The results of these studies with painted plates show the effect of stroke width on legibility. With a white background, decreasing stroke width reduced the legibility distance, probably because the numbers "faded" into the background. With white numerals, however, the reduction in stroke width did not reduce the distance

TABLE 6

EFFECT OF STROKE WIDTH ON LEGIBILITY OF NUMBERS

Stroke Width (in.)	Legibil. Dist. (ft)	
	White on Blue	Blue on White
7/16	112.4	107.3
3/8	109.8	103.1
5/16	110.2	100.1
1/4	109.5	98.4

materially. However the space between numbers on these test plates was large. Closer spacing would tend to cause white numbers to merge and become illegible when their stroke width was large.

In view of the results of these studies and with due consideration for the effects of spacing, it appears that characters used on painted plates should have a H/SW ratio similar to that of the Bureau of Public Roads Series C alphabet (7:1). Assuming a height-to-width ratio of approximately 2:1, 2-in. characters should have a stroke width of 1/4 in.; 2½-in. characters, 5/16 in.; and 3-in. characters, 3/8 in. These values are general guides, subject to change when the height-to-width ratio is significantly greater or less than 2:1.

There are many factors involved in the determination of an optimum character styling, but the most important are (a) simplicity or complexity of the character outline, (b) amount of open space within the outline of the character, and (c) emphasis on one component of the character which differentiates it from another.

Character styles can be grouped into four general categories; block, rounded block, rounded, and open (Fig. 4). Neal (*12*) says that rounded letters are more visible than block, and do not tend to run together as much when closely spaced. Aldrich (*1*) states that the open style of numeral is more visible than either the round or block. According to Matson *et al.* (*11*), the rounded block style letters yield about 5 percent greater legibility distance than pure block capital letters.

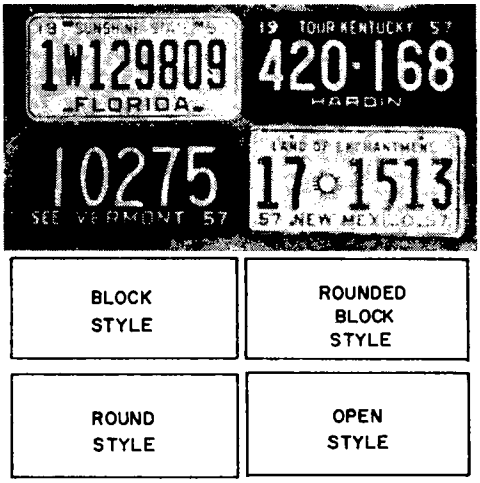

Figure 4. Typical character styles used in 1957.

Currently, license plates from almost every state show a different character style. Although it does not appear necessary that every state use the same style, those states which use block characters or characters with an unusual style should adopt some version of the open or round style. This would eliminate the similarity between characters which results from the use of block characters and the confusion which results when attempting to read characters with a highly unusual style. Character styles should be similar to the Bureau of Public Roads Series B or C alphabets, or the American Association of Motor Vehicle Administrators standard alphabet for license plates.

It is generally agreed that the spacing between the characters is an important consideration when studying legibility, and that generous spacing is advantageous.

The method of manufacturing plates requires that the dies used for all characters be of equal width, and that the characters within a group have a uniform center-to-center spacing. Generally, therefore, characters are designed so that they all have the same width (except 1 and I) and the same size of space between the extremities of adjacent characters.

The Bureau of Public Roads recommends that the spacing vary from 1.2

times the stroke width for parallel strokes, to almost zero for strokes of opposing slope. Neu (*13*) studied the problem from the standpoint of the limitations of the human eye, and presented a formula for determining the minimum spacing between parallel lines. This formula is

$$S = 0.0035D$$

in which S is the required spacing, in inches, between the parallel lines, and D is the required legibility distance, in feet. For a minimum legibility distance of 150 ft, the minimum spacing is computed to be about ½ in. These values are for painted surfaces. When reflective surfaces are used, spacing requirements vary (*4, 6*).

The references cited indicate that (a) the spacing between characters on current plates is too small; (b) spacing requirements vary with the size and shape of character; (c) for a legibility distance of 150 ft, spacing between characters on painted plates should be approximately ½ in., and (d) the spacing of characters on reflectorized plates must be considered separately.

Certain letters and numbers are less legible than others because of similarity in form. In choosing letters and numbers for use in the registration number, it may be necessary to eliminate those characters which are least legible. There have been several studies of relative legibility.

Kuntz (*7*) stated that those numerals having the most curved lines are least legible due to their similarity of form. The order of legibility according to his data was 1, 7, 0, 4, 3, 2, 9, 6, 5, and 8.

Aldrich (*1*) noted that the digits which were confused least were 1, 2, 4, 5, 6, 7, and 0; the digits 3, 8, and 9 were confused most. He also noted that a 3 with a flat top was found to be "very bad," being easily confused with a 5.

Neu's (*13*) table of the relative legibility of the letters compares the legibility of all the letters of the alphabet with E as a standard. The legibility of letters will vary with the letter style, size, and shape, but the relative legibility values presented by Neu can serve as a guide in the choice of letters. His values show A, I, L and T to be the most legible, and B, H, and G to be the least. All others are in the group of fair legibility.

Although previous studies have verified the conclusion that some numbers or letters are more legible than others, there is no conclusive evidence that either letters or numbers are, in general, more legible.

A pure legibility test, using 20 test plates bearing either all numbers or all letters, was conducted to determine the relative legibility of groups of letters and numbers. Numbers used were from the Bureau of Public Roads Series B, 3 in. high, $1\frac{17}{64}$ in. wide, and with a ⅜-in. stroke. The letters used were modified Series B, 3 in. high, with a ⅜-in. stroke. The width of letters varied from 1¼ in. to 1½ in. All characters were centered on the test plate with ½-in. spacing between adjacent characters. All of these test plates carried white characters on a blue background and were of the standard 6- by 12-in. size.

The test plates with numbers were prepared in two groups. Group A had 3 numbers, and Group B had 4 numbers. To neutralize the effects of number difficulty, the number combinations for both series were chosen according to the results of legibility studies made with painted plates as part of the study of the effect of reflective plates.

The test plates with letters were also prepared in 2 groups. Group C had 2 letters, and Group D had 3 letters. The letters used in each series were chosen according to the relative legibility values reported by Neu (*13*).

For purposes of comparison, three actual plates were added to the test. The plates were (a) a 1956 California plate with 3 letters and 3 numbers, black characters on a yellow background; (b) a 1957 Wisconsin plate with 2 letters and 4 numbers, black characters on a yellow background; and (c) a 1957 Indiana plate with 2 letters and 4 numbers, blue characters on a gold background.

The test was conducted in a dark indoor area under controlled artificial lighting. Test plates were displayed on a cart

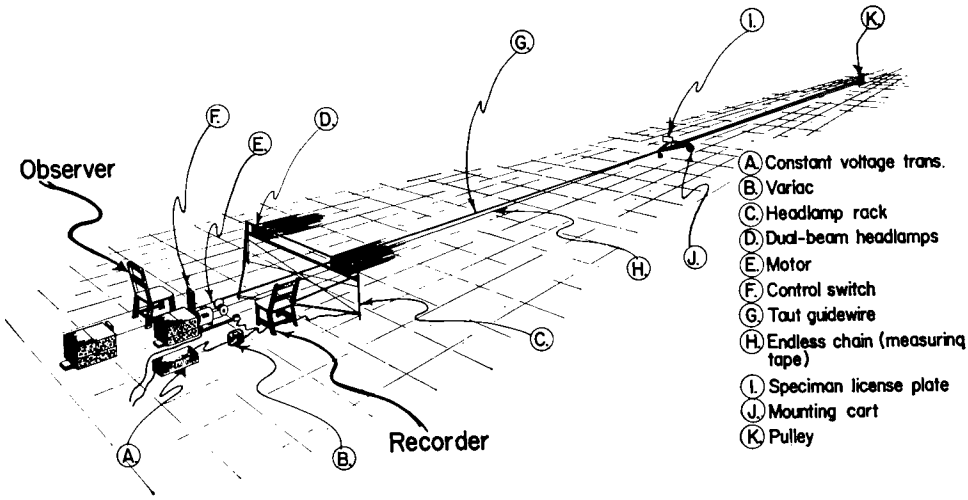

Figure 5. Test apparatus.

which was advanced toward the observer at a constant rate of approximately 1 ft per sec (Fig. 5). The observer was instructed to read aloud the characters on the plate. When all characters had been correctly identified, the legibility distance was recorded on the data sheet and the cart was returned to the starting position for the test plate. Only one legibility distance was recorded for those plates which carried all letters or all numbers—the distance at which all characters were correctly identified. Two distances were recorded for the 3 actual plates: the distance at which all letters were read correctly, and the distance at which all numbers were read correctly. Twelve observers (9 male and 3 female) viewed the test plates and made a total of 312 observations.

The results of the distance tests (Table 7) indicate that numbers in groups of 3 or 4 are legible at a greater distance than letters in groups of 2 or 3. The data were analyzed by student's "t" test to determine the statistical significance of the differences between the legibility distances of the various groups of plates (Table 8).

The legibility distances of the letters and numbers on the actual California, Wisconsin, and Indiana plates substantiate the results of the tests with the test plates. Although the letters were placed at the front on all 3 actual plates (and on the California plate were wider than the numbers) the average legibility distances of the numbers were greater than those of the letters.

TABLE 7

RESULTS OF LETTER AND NUMBER LEGIBILITY TESTS

Plate	No. of Plates	No. of Observ.	Avg. Legibil. Dist. (ft)
Group A (3 numerals)	5	60	136
Group B (4 numerals)	5	60	129
Group C (2 letters)	5	60	124
Group D (3 letters)	5	12	111
1956 Calif. NWB	1	12	95
872	1	12	110
1957 Wis. AK	1	12	110
9679	1	12	120
1957 Ind. XY	1	12	99
6779	1	12	103

When vehicle registrations exceed 1 million, the use of letters and numerals in the registration number is necessary if the use of 7 characters is to be avoided. Letters used in letter-number combinations must be designed so that they will have legibility distances equal to those of numbers. Wiley (*17*) has stated: "For balanced legibility, the letters should be somewhat larger than the numbers."

Assuming a linear relationship between legibility distance and letter height, and

TABLE 8

RESULTS OF STUDENTS "t" TESTS ON LEGIBILITY DATA

Plate Group	Avg. Legibil. Dist. (ft)	Plate Group	Avg. Legibil. Dist. (ft)	Diff. in Legibil. Dist. (ft)	Value of "t"	Means Diff. Signif.	Conf. Level (%)
A	136	D	111	25	5.20	Yes	1
A	136	D	124	12	2.17	Yes	5
B	129	D	111	18	5.62	Yes	1
B	129	C	124	5	0.98	No	—
C	111	D	111	13	2.43	Yes	2
A	136	B	129	7	1.55	No	—

using the legibility distance values from Table 6, letters in groups of 3 should be 22.5 percent larger than numbers in groups of 3. Similarly, letters in groups of 2 should be 4.0 percent larger than numbers in groups of 4 and 9.7 percent larger than numbers in groups of 3.

Additional Considerations

In addition to possessing characteristics which allow quick and accurate perception at the required distance, the registration number should be readily adapted to various administrative and filing procedures. In some states, a part of the registration number consists of a code identification for a particular area or county.

It is very important that the identification numbering system be easily adapted to efficient filing procedures. Information must be taken from the files in response to police inquiries, and the replies must be fast and accurate. Uniformity in the identification system is an aid in the maintenance of effective files. If the identification system is purely numerical, or if a system contains letters which are always in the same position (preferably at the front), filing problems are minimized.

Certain states, especially those who issue plates through county or district offices, place some form of area code in their registration numbers. In some states (Iowa, Idaho, Florida, Alabama, and others) the desire to retain a county or area code has forced a reduction in the size of the identification numbers, or has resulted in a crowded design (Fig. 6).

The investigation of the suitability of various combinations of characters for use

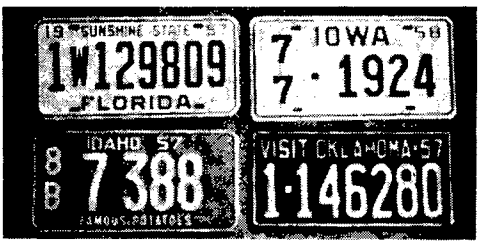

Figure 6. Plates with crowded legends and small characters.

in identification systems has been conducted primarily with reference to automobile plates, because automobiles are, by far, the largest class of motor vehicles. The results of the investigation can also be applied to the choice of suitable identification systems for other classes of vehicles.

The use of a classification letter, or letters, for trucks appears to be a satisfactory procedure. As with passenger plates, the letters should be larger than the numbers and separated from the numbers. To eliminate confusion, it would appear desirable to place the classification letter or letters at the end of the combination, especially where truck plates are of the same color combination as passenger car plates.

Depending on state practice, special registration series are assigned to other types of vehicles such as trailers, taxis, buses, and government-owned vehicles. For example, Illinois issues special plates to members of the legislature, delivery vehicles, disabled veterans, motor vehicle dealers, and amateur radio operators. Suggestions have been made that doctors and clergymen should also receive special

plates so that they may be readily recognized.

Special plates should be limited to those types which are absolutely necessary, because they are non-uniform, more costly to manufacture, and cause complex recording systems. Although ready recognition of members of certain professions might be desirable, the individuals should be given the choice of displaying this information by means of special insignia which can be purchased.

The results of the perception and legibility studies, together with the results of previous studies, form the basis for the following conclusions regarding identification numbering systems:

1. A registration numbering system must be composed of combinations of characters which (a) can be perceived quickly and accurately, (b) are legible at a distance of approximately 125 ft under daylight conditions, and (c) are readily adapted to filing and administrative procedures.

2. For fast and accurate perception, the total number of characters should not exceed six.

3. Combinations of letters and numbers should (a) have the letters grouped and separated from the numbers by a space and (b) have characteristics of uniformity in that the letters should always appear at the beginning (preferably) or end of the combination.

4. The total number of letters, in a system using a combination of letters and numbers, should not exceed 2 unless the vehicle registration exceeds the capacity of a 2-letter 4-digit system.

5. Assuming that a registration system using uniform positioning of letters and numbers is to be chosen, and that all digits and letters are used (except Q), the results of perception and legibility tests suggests the following rankings of suitable identification systems for states of indicated passenger car registrations:

Less than 250,000
- a. Straight numerical (1 to 250,000)
- b. 1 letter, 1 to 4 digits (A 1 to Z 9999)
- c. 2 letters, 1 to 3 digits (AA 1 to ZZ 999)
- d. 1 to 3 digits, 2 letters (1 AA to 999 ZZ)

250,000 to 500,000
- a. straight numerical (1 to 500,000)
- b. 2 letters, 1 to 3 digits (AA 1 to ZZ 999)
- c. 1 to 3 digits, 2 letters (1 AA to 999 ZZ)

500,000 to 1,000,000
- a. straight numerical (1 to 999,999)
- b. 2 letters, 1 to 4 digits (AA 1 to ZZ 9999)

1,000,000 to 6,000,000
- 2 letters, 1 to 4 digits (AA 1 to ZZ 9999)

Above 6,000,000
- 3 letters, 1 to 3 digits (AAA 1 to ZZZ 999)

6. The numbers should be round or open in style, 2½ to 3 in. high, 1¼ to 1¾ in. wide, and have a stroke width of 5/16 to ⅜ in. The minimum values are for a 12-in. plate; the maximum values are for a 14-in. plate.

7. The letters should be round or open in style, 2¾ to 3½ in. high, 1⅜ in. to 2 in. wide, and should have a stroke width of 5/16 to 7/16 in. (for 12-in. and 14-in. plates, respectively).

8. For balanced legibility, the letters in a letter-number combination should be 5 to 10 percent larger than the numbers when 1 or 2 letters are used. When 3 letters must be used, the letters should be 20 to 25 percent larger than the numbers.

9. Registration systems for trucks and other special vehicle classes should be chosen from one of the systems listed in conclusion 5, or from one of the following systems: (a) 1 to 4 digits, 1 letter (1 A to 9999 Z) and (b) 1 digit, 1 letter, 1 to 3 digits (1A 1 to 9Z 999).

State Name and Year Number

With the increased use of state slogans and/or symbols on license plates, the

space available for important information such as the state name and the year of issuance has been reduced considerably. The preliminary report (*5*) showed that police officers, motor vehicle administrators, and others feel that the state name and year number should be legible at one-half the distance that the vehicle registration number is legible. The report stated, "72 percent of the law enforcement officers felt that it would be easier to identify the state if state slogans were removed and the size of the state name was increased."

Examples of states which have their names in small letters are District of Columbia, ½ in.; Illinois and Michigan, 9/16 in.; Minnesota and Maryland, ⅝ in.; and Arizona and Idaho, 11/16 in. Two of the largest names are Iowa, 1⅛ in.; and Oklahoma, 1 1/16 in. With such variations in the height of state names and year numbers (Fig. 7), it was necessary to study character sizes to determine what height should be used to obtain the desired legibility.

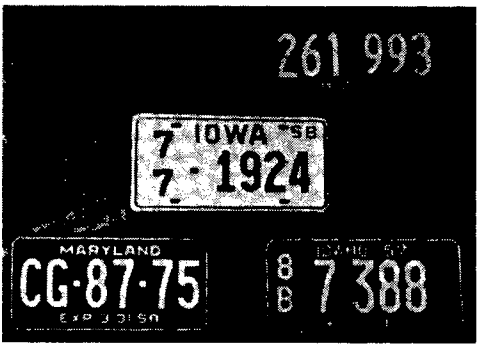

Figure 7. Variations in height of characters used in state names.

Studies of the legibility distance of state names and year numbers of various sizes were conducted with the following objectives:

1. To determine the effect of character size on the legibility distance of the state name and year number.
2. To determine the correct range of character sizes for use in state names and year numbers.
3. To determine the effect of abbreviations on the legibility distance of the state name and year number.

Test plates were constructed with varying sizes of state name and year number. Some plates had slogans, and some had abbreviations for the state name and year number. Pure legibility tests were then conducted using the 6- by 12-in. test plates with white characters on a dark blue background. All plates had a six-numeral registration number, grouped three and three, with a space between the numerals. The registration numbers were the Bureau of Public Roads Series B numbers, 3 in. high and 1¼ in. wide, with ⅜-in. stroke. The numbers were spaced 1¾ in. center-to-center, except the third and fourth numbers which were spaced 2¾ in., center-to-center. One-half of the plates had full state names and half had abbreviations. One-half of the plates in one letter-size group also had abbreviated year numbers.

Ten observers read 30 plates, making a total of 300 observations. The same apparatus (Fig. 5) was used during these tests. The compiled and averaged readings of the observers (Table 9) show the increases in the average legibility distances of the state names and year numbers with an increase in character size. Increasing the height from 0.6 in. to 1.0 in. increased the legibility distance of the state names by 102.5 percent. The increase from 1.0 to 1.5 in. increased the legibility distance an additional 20.5 percent. These increases are significant at the 1 percent level of confidence according to the results of student's "t" tests (Table 10).

TABLE 9

LEGIBILITY DISTANCE OF STATE NAMES AND YEAR NUMBERS

Plate Group	Legibil. Dist. (ft)			
	Reg. No.	State	Year	Slogan
A (0.6 in.)	115	36	35	39
B (1.0 in.)	119	73	66	—
C (1.5 in.)	118	88	81	—

TABLE 10

RESULTS OF "t" TESTS WITH STATE NAME AND YEAR LEGIBILITY DATA

Section	Group	Avg. Legibil. Dist. (ft)	Group	Avg. Legibil. Dist. (ft)	Diff. (ft)	Value of "t"	Means Diff. Signif.	Conf. Level (%)
1	A	36	B	73	37	25.0	Yes	1
(State names)	B	73	C	88	15	6.6	Yes	1
2	A	35	B	66	29	17.4	Yes	1
(Year number)	B	66	C	81	15	6.9	Yes	1

Similarly, the average distance at which the year numbers were legible increased 88.6 percent when height was increased from 0.6 in. to 1.0 in., and 22.8 percent when increased from 1.0 in. to 1.5 in. These increases also were significant at the 1 percent level of confidence according to student's "t" test (Table 10).

Table 9 also gives the average legibility distances of the registration numbers. Basing the required legibility distance for the state and year at one-half the distance at which the registration numbers were read gives a desired distance of approximately 60 ft. This corresponds to a character height of approximately 0.9 in. (Fig. 8). The readings of the observers were compiled and averaged to give the values for abbreviations and full state names. Table 11 shows that the abbreviations had little effect on the legibility distance of the state names. The test results did show, however, that some abbreviations could be read at a greater distance than the full name, and that other abbreviations could not be read as far as the full name. The similarity of the shape of the state name or its abbreviation to other state names or abbreviations is important in determining the legibility. Some abbreviations are distinctive, but many are similar to others and responsible for confusion. For example, during the test, "MD." was frequently mistaken for "MO." and "IND.".

TABLE 11

LEGIBILITY DISTANCES OF STATE NAMES AND ABBREVIATIONS

Plate Group	Legibil. Dist. (ft)	
	Full Name	Abbrev.
A (0.6 in.)	36	36
B (1.0 in.)	77	69
C (1.5 in.)	86	89

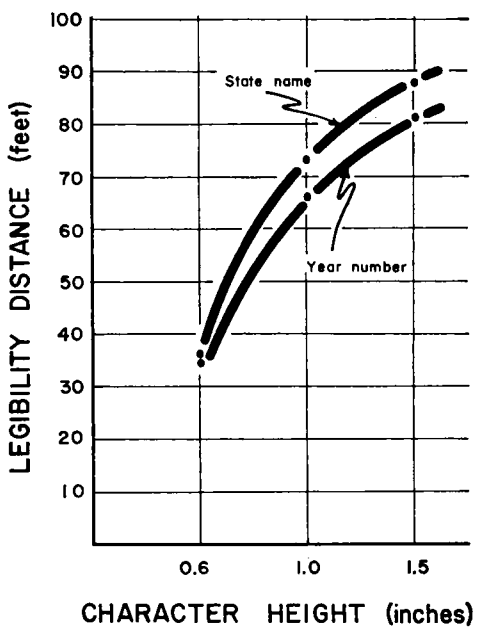

Figure 8. Average legibility distances of state names and year numbers.

Abbreviating the year number did not affect legibility according to the readings taken. The year numbers with the century prefix were read at an average distance 35.0 ft, and the numbers without prefixes were also read at 35.0 ft.

The results of the state and year legibility distance tests form the basis for the following conclusions:

1. The height of characters in the state name and year number should be approximately 1.0 in. if those two items are to be legible at the required distance

of one-half the legibility distance of the identification legend.

2. State names and year numbers on most current designs are too small.

3. The effect of abbreviations on the legibility of the state name varies with different states.

4. Omitting the century prefix before the year does not affect the distance at which the year number is legible, but will relieve the crowded appearance of many plates.

Slogans and Emblems

The placing of slogans, symbols, and emblems on license plates has become a popular practice in recent years. In 1959, 28 states and 7 Canadian provinces carried one or more of these publicizing designations.

Law enforcement officers and motor vehicle administrators were asked to give their opinion of slogans in the initial phase of this project. Seventy-two percent of the law enforcement men and 83 percent of the motor vehicle administrators felt that it would be easier to identify the state if the state slogan was removed and the size of the state name increased. Eighty-five percent of the law enforcement officers and 89 percent of the motor vehicle administrators thought that removing slogans to make room for larger vehicle registration numbers would be advantageous (*5*).

The effect of slogans was observed as part of the legibility study of various state names and year identifications. Table 12 shows that removing slogans and using the increased space for larger state names and year numbers approximately doubles the distance at which these two items of information can be read.

TABLE 12

EFFECT OF SLOGANS ON LEGIBILITY OF THE STATE NAME AND YEAR NUMBER

Height of Char. (in.)	Legibil. Dist. (ft)		
	State Name	Year No.	Slogan
0.6	35	35	39
1.0	73	66	—

The harmful effect that slogans have on plate legibility substantiates the conclusion of the questionnaire respondents that, "It would be easier to identify the state if the state slogan was removed and the size of the state name was increased."

The results of these tests form the basis for the following conclusions:

1. The presence of slogans and emblems reduces the space available for the state name and year number, thus reducing their legibility.

2. The removal of slogans and emblems will permit the use of state names and year numbers large enough to be legible at the distance required for fast and accurate identification.

3. The publicizing of a state by means of a slogan or emblem may have intangible value to the state, but should be done by other means.

Color Combinations

The color of license plates has become an important factor in identification. Color aids in identifying the state or province in which a vehicle is registered, and in most states, is the primary method of identifying the year of issuance. In general, color combinations are chosen so that there is high contrast between legend and background. Occasionally, however, some states adopt a combination such as pink and white, or light blue and white, reducing the contrast and plate legibility.

Studies of the relative legibility of various color combinations are fairly numerous. Preston *et al.* (*14*) reported the results of studies with the following color combinations: (a) black on white, (b) green on white, (c) blue on white, (d) black on yellow, (e) red on yellow, (f) red on white, (g) green on red, (h) orange on black, (i) orange on white, (j) red on green, and (k) black on purple. Results showed that "combinations which rank high in legibility are those which have marked brightness contrast between print and background. Those of poor legibility have comparatively little brightness contrast between

print and background. Blue on white, black on yellow, green on white, and black on white provide good legibility; green on red, red on yellow, and red on white provide fair legibility; and orange on white, and red on green provide poor legibility."

Tests conducted by the Michigan Department of State in 1940 (*9*) produced results (Table 13) which show that the dark green-light green combination did not provide enough contrast for good legibility. There were no important differences between all other combinations except that the brown-cream combination apparently had little contrast under artificial lighting.

TABLE 13

LEGIBILITY OF VARIOUS COLOR COMBINATIONS

Color Comb.	Legibil. Dist. (ft) Day	Night
White on maroon	158.4	114.0
Maroon on white	145.4	102.7
Brown on cream	152.5	89.2
Cream on brown	147.8	101.4
White on dark green	152.7	102.8
Black on white	146.9	107.1
Dark blue on maize	153.7	102.8
Maize on dark blue	142.3	110.5
Dark green on light green	139.2	88.6

Wiley (*17*) in his 1937 report stated:

a. For dark colors, use black and the darker shades of red, blue and green. Avoid the more brilliant shades.
b. For light colors use white, the more brilliant shades of yellow and light chrome orange, and perhaps the light tints of green and blue.
c. Avoid grays, browns, and other neutral shades. Do not put colors of similar reflecting power or wave length in combination. Thus, red on black is decidedly bad. Yellow on green is not good unless the green is very dark, etc.
d. Dark symbols on light backgrounds appear preferable to the reverse, but, with well chosen colors, the difference is not so marked as to be objectionable.

A brochure (*10*) lists the strongest, most readable combinations for outdoor advertising. The ranking of color combinations is as follows:

1. Black on yellow
2. Black on white
3. Yellow on black
4. White on black
5. Blue on white
6. White on blue
7. Blue on yellow
8. Yellow on blue
9. Green on white
10. White on green
11. Brown on white
12. White on brown
13. Brown on yellow
14. Yellow on brown
15. Red on white
16. White on red
17. Red on yellow
18. Yellow on red

This is one of the most comprehensive rankings available, and is an excellent guide for the choice of color combinations for license plates.

A report (*15*) gives the reflectance values for 48 different shades of paints (Table 14). These reflectance values can be used in choosing color combinations having a high degree of contrast.

Lauer (*8*) has suggested that the differences between the reflectance values of colors used for legend and background should be no less than 45 percent. Following this recommendation, the following color combinations are suitable for use on license plates:

TABLE 14

REFLECTANCE VALUES FOR DIFFERENT SHADES OF PAINT[1]

Color	Reflectance (%)
Black	0
Dark blue	8
Dark green	8
Dark brown	15
Red	22
Orange	36
Light blue	40
Light green	41
Tan	41
Light orange	53
Light pink	62
Yellow	66
Ivory	79
White	82

[1] Source: General Electric Co.

Color Combination	Diff. Bet. Reflect. Values (%)
1. Black and white	82
2. Black and ivory	79
3. Dark blue and white	74
4. Dark green and white	74
5. Dark blue and ivory	71
6. Dark green and ivory	71
7. Dark brown and white	67
8. Black and yellow	66
9. Dark brown and ivory	64

10.	Black and light pink	62
11.	Red and white	60
12.	Dark blue and yellow	58
13.	Dark green and yellow	58
14.	Red and ivory	57
15.	Dark blue and light pink	54
16.	Dark green and light pink	54
17.	Black and light orange	53
18.	Dark brown and yellow	51
19.	Dark brown and light pink	47
20.	Orange and white	46
21.	Dark blue and light orange	45
22.	Dark green and light orange	45

The information obtained from previous studies and reports provides the information necessary for choosing color combinations which provide a high amount of contrast. Legibility studies were conducted to compare the legibility of dark legends on light backgrounds and light legends on dark backgrounds.

The test was conducted in a large indoor area. Plates were illuminated with low beams of a standard 12-volt headlamp system and were drawn toward the observer at a constant speed of about 1 ft per sec. All plates carried four numbers, spaced 2½ in. center-to-center, 3 in. high, 1¼ in. wide, with varying stroke width. The distance at which each of the four numbers was read correctly was recorded and averaged to give the legibility distance of the plate. The average legibility distances for 30 observers (Table 15)

TABLE 15

EFFECT OF STROKE WIDTH ON LEGIBILITY DISTANCE

Stroke Width (in.)	Legibil. Dist. (ft)	
	White on Blue	Blue on White
14/32	112.4	107.3
12/32	109.8	103.1
10/32	110.2	100.1
8/32	109.5	98.4

show that, at this spacing, the light colored legends were, on the average, 5.5 percent more legible than the dark on light. This is significant at the 1 percent level of confidence.

Seventeen states have adopted color combinations which they use every year, generally reversing the colors of the legend and background from year to year. This plan has two advantages: after a satisfactory combination has been selected there is assurance that plates will always have a color combination providing good legibility, and color becomes more important in state identification as police officers and the general public become familiar with the state colors.

States which adopt permanent color combinations must cooperate with nearby states to eliminate confusion which might result from the issuance of plates with the same legend and background colors. Vermont and New Hampshire, for example, both use green and white; but in years when Vermont uses a green background New Hampshire uses a white background.

Legibility studies, reflectance values, and experience with colors provide information for the following conclusions concerning color combinations for license plates:

1. Color combinations used on license plates must have a high degree of contrast between legend and background. This contrast must be maintained under both natural and artificial lighting.
2. The relative effectiveness of dark backgrounds as compared to light backgrounds is dependent on conditions such as illumination, spacing, stroke width, and color. It is not possible to conclude that either light or dark backgrounds are preferable under all conditions.
3. Dark colors used on license plates should consist of black and the darker shades of blue, green, brown, and red.
4. Light colors used should be white, ivory, yellow or light orange.
5. Grey, pink, light blue or green, and other neutral shades, should not be used on license plates.
6. It would appear advantageous for states to adopt permanent color combinations, reversing the color of legend and background with each issue of plates.

Effect of Other Factors

The design of license plates is affected by a number of factors which vary from state to state. In most states, motor ve-

hicle laws or administrative procedures have required that additional items of information be placed on the plate, or that the plate be manufactured in a certain manner.

The principal registration procedure affecting the design of license plates is the term of issuance of the plate. Some states use plates for two or more years, revalidating them by issuing small metal tabs or adhesive stickers. This procedure requires that the plate be designed so that the revalidating tabs or stickers can be applied readily.

The value of county or area identification was studied in the first phase of this study (*5*). On the basis of the replies and comments received in a questionnaire distribution, and in consideration of the many phases of license plate design, it was concluded that;

> The designation of the vehicle owner's county or area of residence is not a true function of license plates. In cases where distribution is on a county or local level, county or area designation may help in the enforcement of registration laws. In cases where identification is difficult due to the type of numbering system in use, the number of vehicle registrations, and other design considerations, county or area designations may facilitate the accomplishment of the function of identifying the vehicle quickly and accurately.

Various methods for showing an area identification are shown in Figure 9.

State motor vehicle laws specify the requirements for displaying and mounting license plates. Generally, these laws state that plates shall be clearly visible, in a condition to be clearly legible, kept free from dirt and foreign materials, and securely fastened. Most states specify that plates must be mounted a certain distance above the ground.

The materials used for license plates must be chosen on the basis of performance requirements and costs. Specific information regarding performance characteristics and costs of steel, aluminum, and other material is available from manufacturers and metals research laboratories. An extensive treatment of the advantages and disadvantages of various materials is beyond the scope of this

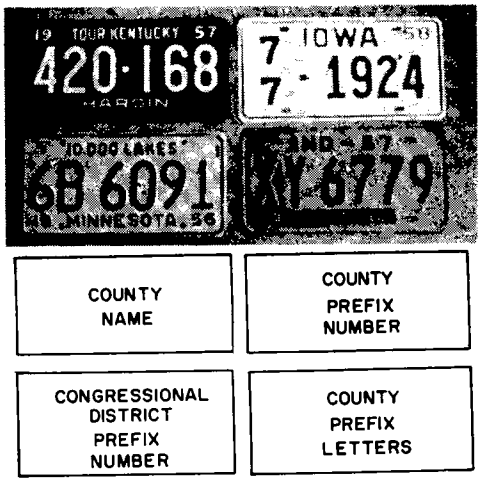

Figure 9. Methods of designating county or area of registration.

report. Whatever materials are used, the principal requirement is that they have sufficient durability so that the plate remains legible throughout the time that it is in use.

DESIGN OF REFLECTORIZED LICENSE PLATES

During the past few years, several states have adopted reflectorized motor vehicle license plates or reflectorized revalidation stickers primarily as an additional safety device in an effort to reduce nighttime traffic accidents. Of secondary concern was the effect on the legibility of the registration number at night.

As stated previously, the principal function of a license plate is to display the information necessary for fast and accurate identification of a vehicle under actual traffic conditions. The legibility of the information on the plate should then be the primary concern of plate designers. The added safety aspect of a reflectorized plate should be considered if it does not impair the readability of the plate.

Investigations were conducted to reveal the basic factors concerning the legibility of reflectorized plates and to make accurate evaluations of these components for an optimum plate design. The use of a reflectorized plate as a safety feature

to reduce nighttime traffic accidents was also studied by analyzing extensive accident statistics maintained by a state that has been using reflectorized plates for several years.

Several variables were considered in the study. Each variable was studied individually and its effect on legibility analyzed. Interactions of the variables were also considered.

The variables studied were as follows:

1. Types of reflectorized and nonreflectorized materials:
   (a) Flat sheeting (Type A).
   (b) Exposed lens sheeting (Type B).
   (c) Beads on paint (Type C).
   (d) Semi-gloss paint (Type D).
   (e) Aluminum paint (Type E).
2. Systems of reflectorization:
   (a) Background only reflectorized.
   (b) Legend only reflectorized.
   (c) Both background and legend reflectorized.
3. Stroke width of characters.
4. Spacing of characters.
5. Reflectorized borders.
6. Color combinations.

Because the legibility experiments on reflectorized license plates are described in a companion paper (*4*), they are not discussed herein.

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