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INTERNATIONAL DISTRIBUTIONS OF VARIABLES AFFECTING DESIRABLE VEHICLE LIGHTING

Michael Sivak

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Michael Sivak, Ph.D.

The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

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16. Abstract

This study was designed to provide information concerning (1) the desirability of international harmonization of vehicle standards, and (2) the international transferability of field-study findings on vehicle lighting. Toward these goals, data were collected on a variety of factors related to drivers, traffic participants, roadways, and environment in eight major car-producing countries: U.S.A., Japan, Federal Republic of Germany, France, Italy, Spain, Canada, and United Kingdom. The international variability of these factors was contrasted with the correspondent variability among the U.S. states. The findings suggest that, for the examined factors, the within-U.S. variability is generally at least as large as the variability for the eight studied countries. Consequently, it is concluded that the obtained evidence supports (1) the establishment of common lighting specifications, and (2) the international transferability of findings from field studies on vehicle lighting.

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INTRODUCTION

Vehicle lighting standards are substantially different in the various parts of the world. This applies to both headlighting and rear lighting standards. For example, Table 1 presents the current intensity specifications for automobile brake lamps in the U.S. and the ECE countries. It is apparent from the information in Table 1 that there is very little overlap between the two sets of specifications. Only brake lights between 80 and 100 cd would meet both requirements. This is too narrow a region to be of practical benefit. Consequently, the differences in the specification prevent manufacturers from producing the same brake lamps for the U.S. and European markets. This is only one of several instances of photometric differences in rear-lighting specifications. Furthermore, the situation in vehicle headlighting is even worse. The differences in the location and maximum/minimum values of various photometric test points (Olson, 1977) effectively prevent production of a "world" headlamp. (Additional differences are present for headlamp construction and aiming [Olson, 1977].)

TABLE 1
Brake-lamp photometric specifications in the U.S.A. and Europe.

Region	Minimum (cd @HV)	Maximum (cd @HV)
USA (FMVSS/SAE Specifications)	80	300
Europe (ECE specifications)	40	100

Traditional approaches to reconciling these differences in specifications have been to establish, through research, various aspects of "optimal" headlamps (e.g., Olson and Sivak, 1983) and rear lights (e.g., Sivak, Flannagan, Olson, Bender, and Conn, 1986). However, no consensus on the optimum photometrics has yet been achieved in either headlighting or rear lighting. Why is there no agreement? After an extensive review of the headlighting literature, Olson (1978) concluded that, "experimental studies have not produced a consensus on the 'best' low-beam system, partly because the test conditions have not permitted examination of all variables present in real-world night driving (p. 16)." Furthermore, as Olson (1977) has pointed out, "there are a great number of criteria to be considered in the design of low-beam units. Inevitably, no one design can be best measured against all criteria. The weighting of criteria is a subjective process at present and seems likely to remain so for the foreseeable future (p. 54)." The same considerations apply for rear lighting as well.

This state of affairs leads naturally to one of the basic questions underlying the present research: Are the relevant driver, vehicular, roadway, and atmospheric conditions in the various parts of the world similar enough to justify further research toward "world" lighting standards? The implicit assumption is that the answer is "yes." However, no rigorous evaluation of this assumption has ever been performed. Consequently, it is important to establish the similarities and differences in the critical conditions. It is possible that the differences are large enough, so that optimal lighting is likely to be different in various parts of the world.

The degree of worldwide similarity of the relevant conditions also has an impact on the degree of international transfer of field-study results. Should the conditions be generally different, then caution needs to exercised in transferring results from field studies performed in one country to the situation in another country.

To ascertain the feasibility of international harmonization of vehicle-headlighting standards, and the degree of transfer of field-study results, this study examined the differences in a range of relevant conditions for the following eight countries: U.S.A., Japan, West Germany[1], France, Italy, Spain, Canada, and United Kingdom[2]. These countries were selected because they represent the eight largest passenger-car producers in the Western world (see Table 2). While the focus will be on the eight above-mentioned countries, additional comparisons will also occasionally be made with other countries (primarily those that represent the extreme values of the variables under investigation). (These eight countries also represent eight out of the top nine Western countries in the number of registered passenger cars, with Brazil being the eighth and Spain being the ninth [MVMA, 1988].)

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[1] For brevity, "West Germany" will be used throughout this report in lieu of "Federal Republic of Germany."

[2] Some of the tables to follow are based on the information that was identified in the original source as pertaining to Great Britain (i.e., excluding Northern Ireland) as opposed to United Kingdom (IRF, 1986, 1987). Nevertheless, in this report the reference will always be made to United Kingdom.

TABLE 2
The eight largest passenger-car producers in the Western world, 1986 (MVMA, 1988).

Country	Production
U.S.A.	7,828,783
Japan	7,809,909
West Germany	4,310,828
France	2,773,094
Italy	1,652,452
Spain	1,281,899
Canada	1,061,365
United Kingdom	1,018,962
U.S.S.R.	1,326,000
All Countries	32,762,338

The international variability in the relevant factors will be contrasted, whenever possible, with the variability within the U.S.A. (i.e., the variability among the states). Such comparisons will serve to qualitatively evaluate whether the within-U.S.A. variability is at least as great as the correspondent international variability. Specifically, the variability of a factor will be estimated from the range of the values for this factor. While examinations of a variety of factors will be reported, this research was limited by the availability and comparability of international data.

METHOD

The information was obtained from two general sources:

- Annual statistics published by national and international organizations.
- Individuals in the respective countries.

The range was used as an indicator of the variability of a distribution. Obviously, there is no one-to-one correspondence between the range and the variability. Nevertheless, the range data, in the absence of more detailed distributional data, provide the first approximation to the variability.

FINDINGS

The findings are being presented in relation to four major categories of factors: drivers, traffic-participants, roadways, and environment.

Driver factors

Age. Associated with aging are changes in a range of visual, perceptual, cognitive, and psychophysical abilities (Birren and Schaie, 1985), with potential consequences for driving performance. For example, because of the increase in light scatter in older persons' eyes (Weale, 1963), the elderly generally are more impaired by glare (Wolf, 1960). This increased susceptibility to disability glare has implications for the photometric maxima of both headlights and brake lights. Consequently, when taking into account older drivers, glare considerations become dominant. As another example, older persons have generally longer reaction times (Welford, 1977). A consequence of this effect is that older drivers need to detect an obstacle at a longer distance in order to make an appropriate decision—again with important consequences for the design of headlamps. (The increased susceptibility to glare and the increased reaction time result in somewhat contradictory requirements on headlighting: When designing for the older driver, glare from the oncoming traffic should be minimized, while light output should be maximized for increasing the seeing distance. Presumably, the only currently reasonably approach to this dilemma is a sharper gradient in the light output.)

The age changes in a variety of potentially relevant functions make it important to evaluate the age distributions of drivers. The data on the percentages of older persons in the general population are shown in Table 3.

The international range of the elderly population in Table 3 should be contrasted with the corresponding range within individual countries. Such within-country distribution for one country—U.S.A.—is shown in Table 4. (Table 4 includes data for the ten most extreme states.)

The data in Tables 3 and 4 are for the total population. The optimal data—percentage of the elderly drivers—is not readily available, with the exception of the U.S.A. The U.S. data (FHWA, 1987a) indicates a good congruence between the percentage of drivers 65 years and older (12.3%), and the corresponding percentage in the general population (12.2% [Table 3]).

TABLE 3
Percentage of the total population that is 65 years of age and older in selected countries; estimates and projections for 1987 (U.S. Bureau of the Census, 1988b).

Country	Percentage ≥65
U.S.A.	12.2
Canada	10.9
France	13.4
Italy	13.7
Spain	12.3
United Kingdom	15.4
West Germany	15.2
Japan	10.8
Sweden	17.8
United Arab Emirates	0.9

TABLE 4
Percentage of the total population that is 65 years of age and older in selected U.S. states, 1986 (U.S. Bureau of the Census, 1988a).

State	Percentage ≥65
Florida	17.7
Pennsylvania	14.6
Rhode Island	14.6
Arkansas	14.5
Iowa	14.5
Texas	9.5
Colorado	9.0
Wyoming	8.4
Utah	8.0
Alaska	3.4

Alcohol consumption. Alcohol is known to have a variety of detrimental effects on vision, decision-making, and psycho-motor performance. For example, in the area of vision, alcohol has negative effects on dynamic visual acuity (Brown, Adams, Haegerstrom-Portnoy, Jones, and Flom, 1975), and on glare sensitivity (Adams, Brown, and Flom, 1976). The impairments in basic skills are known to affect driving-performance and are assumed to contribute to accident overrepresentation of drivers under the influence of alcohol (e.g., Smiley and Brookhuis, 1987).

It is apparent that in the U.S. the enforcement efforts to prevent drunk driving have not been successful. In 1986, for example, 41% of drivers involved in fatal accidents had been drinking (UMTRI, 1988). Thus, the available countermeasures involve taking the drunk driver into account in the design of the driving environment. Areas that have been explored include, for example, optimization of traffic signs (Hicks, 1976) and road markings (Ranney and Gawron, 1986). Optimization of the headlighting pattern, in response to the impaired capabilities of drunk drivers, would fall into the same general category of countermeasures.

Because of the above considerations, the consumption of absolute alcohol per capita in various countries is shown in Table 5. In comparison, the data for the ten most extreme states within the U.S.A. are shown in Table 6.

TABLE 5
Consumption of absolute alcohol per capita in selected countries, 1984 (Horgan, Sparrow, and Brazeau, 1986).

Country	Annual consumption (liters per capita)
U.S.A.	7.90
Canada	7.98
France	14.22
Italy	11.51
Spain	10.86
United Kingdom	7.27
West Germany	11.90
Japan	5.87
Luxembourg	19.33
Norway	3.95

TABLE 6

Consumption of absolute alcohol per capita in selected U.S. states, 1985.

State	Annual consumption (liters per capita)
Nevada	15.60
District of Columbia	15.48
New Hampshire	14.50
Alaska	10.52
Florida	9.80
Kentucky	5.60
Oklahoma	5.53
Arkansas	5.22
West Virginia	5.03
Utah	4.13

Sources: Beer Institute, 1986 (consumption of distilled spirits, beer, and wine), and NIAAA, 1985 (conversions to absolute alcohol).

Traffic participants

The composition of the traffic fleet relates to safety considerations for several reasons. One obvious reason (which is not relevant to the topic under investigation) is the effect of the composition on the variance in the mass of the traffic participants. Another reason is that the nature of the traffic fleet affects the speed distribution. As Solomon (1964) has pointed out, "the greater the differential in speed of a driver and his vehicle from the average speed of all traffic, the greater the chance of that driver being involved in an accident" (p. iii). (A refinement of this statement was offered by Cowley [1987] who concluded, on the basis of a literature review, that this did not apply to single-vehicle accidents.)

Bicycles and mopeds. On one extreme of the speed distribution are the bicyclists. Because of their slow speed, headlighting systems with long seeing distance would be especially desirable in regions with a substantial bicycle usage. With this consideration in mind, Tables 7 and 8 present international data on bicycles. Table 7 list the numbers of bicycles held, and the population per bicycle. The numbers of motor vehicles per bicycle, indicative of the respective speed distributions, are shown in Table 8. (The optimal data—bicycles *in use*—were not available.) The analogous data for mopeds (another class of relatively slow-moving traffic participants) are shown in Table 9.

Trucks and buses. Trucks and buses, because of their generally lower top speed and slower acceleration, also contribute to an increase in the variance of speed distribution. The relevant international truck and bus data are shown in Table 10. In comparison, the analogous U.S. data for the ten most extreme states are shown in Table 11.

Pedestrians. Providing sufficient illumination for the detectability of pedestrians is one of the main contemporary criteria of effective headlighting (Perel, Olson, Sivak, and Medlin, 1984). The relative weight that is placed on this performance aspect of headlamps is influenced by the incidence of pedestrians (Bhise, Farber, and McMahan, 1976). Consequently, comparison of international and domestic incidence of encounters with pedestrians would be desirable. The closest available data to this ideal are the data on the population density per km of the roadway. Such international data are shown in Table 12, while the data for the ten most extreme U.S. states are in Table 13.

TABLE 7
Number of bicycles held in selected countries (Cycle Press International, 1987).

Country	Number (in millions)	Persons per bicycle
U.S.A. (1984)	95	2.4
Canada[a] (1987?)	8	3.2
France (1984)	17	3.2
Italy (1984)	20	2.8
Spain	?	?
United Kingdom (1982)	14	4.0
West Germany (1985)	35	1.8
Japan (1986)	58	2.1
India (1980)	42	16.0
Brazil (1981)	12	10.6
China (1985)	210	5.0
The Netherlands (1984)	11	1.3

[a] The information for Canada is based on an estimate of the number of bicycles by the Canadian Cycling Association (Sanderson, 1988).

TABLE 8

Number of motor vehicles per bicycle in selected countries.

Country	Motor vehicles per bicycle
U.S.A.	1.8
Canada	1.8
France	1.4
Italy	1.1
Spain	?
United Kingdom	1.4
West Germany	0.8
Japan	0.8
Brazil	0.9
The Netherlands	0.5
Finland	0.3
China	0.01

Sources: Cycle Press International, 1987 (number of bicycles, with the exception of Canada), Sanderson, 1988 (number of bicycles in Canada), IRF, 1987 (number of motor vehicles with the exception of Brazil and China), IRF, 1986 (number of motor vehicles in Brazil), and CATARC, 1986 (number of motor vehicles in China).

TABLE 9
Number of motor vehicles per moped in selected countries, 1983 (ECMT, 1985).

Country	Motor vehicles per moped
U.S.A.	?
Canada[a]	322.6
France	5.4
Italy	?
Spain	?
United Kingdom	?
West Germany	15.4
Japan[a]	3.5
Sweden	16.6
The Netherlands	8.1
Switzerland	4.0

[a] 1982 data.

TABLE 10
Number and proportion of trucks and buses in selected countries, 1985 (MVMA, 1988).

Country	Number of trucks and buses (in thousands)	Proportion of trucks and buses of all motor vehicles
U.S.A.	39,790	.23
Canada	3,149	.22
France	2,766	.11
Italy	1,824	.08
Spain	1,610	.15
West Germany	1,723	.06
United Kingdom	728	.04
Japan	18,313	.40
China	2,374	.82
Australia	2,132	.24
Bulgaria	27	.03
All countries	113,024	.23

TABLE 11

Number and proportion of trucks and buses in selected U.S. states, 1985 (FHWA, 1986).

State	Number of trucks and buses (in thousands)	Proportion of trucks and buses of all motor vehicles
Wyoming	213	.43
Montana	257	.40
Alaska	133	.38
Idaho	322	.38
South Dakota	246	.38
Hawaii	82	.13
Massachusetts	470	.13
New Jersey	495	.10
Connecticut	158	.06
District of Columbia	18	.06

TABLE 12
Population density per roadway network in selected countries, 1985 (IRF, 1987).

Country	Persons per km of roadway
U.S.A.	38
Canada	30[a]
France	69
Italy	189
Spain	121
United Kingdom	157
West Germany	124
Japan	107
The Netherlands	129
Switzerland	92

[a] Based on the length of the road network provided in RTAC (1987) and the population data in IRF (1987).

TABLE 13
Population density per roadway network in selected U.S. states, 1985.

State	Persons per km of roadway
District of Columbia	351
Hawaii	166
New Jersey	139
Massachusetts	107
Connecticut	100
Idaho	9
Wyoming	8
Montana	7
South Dakota	6
North Dakota	5

Sources: U.S. Bureau of the Census, 1988a (population) and FHWA, 1986 (road network).

Roadway factors

Paved vs. unpaved roadways. There are several aspects of the roadway infrastructure that affect desirable lighting. For example, the extent of paved roads is important for glare control from vehicle headlamps. Specifically, a sharp intensity gradient is likely to be more of a problem on unpaved than paved roads. The available international data on the percentage of paved roads is shown in Table 14. However, the validity of these data is questionable, since they indicate that all roads in Italy and the United Kingdom are paved. This suggests that the roads considered for inclusion by IRF (the source of the data) might have varied from country to country. Consequently, no explicit comparison was attempted between the international data in Table 14 and within-U.S. distributions that could have been derived from the information in FHWA (1987a).

Motorways (limited-access roadways). One of the benefits of motorways is that meetings with oncoming traffic are avoided. Consequently, glare from the opposing lane of traffic is reduced. (Glare from rearview mirrors, however, still remains as a factor.) Thus, the proportion of traffic on motorways is another potentially important consideration. International data on the proportion of motorways and proportion of motorway traffic volume are listed in Table 15. The analogous data (percent vehicle-miles on motorways) for the ten most extreme U.S. states are shown in Table 16.

Traffic density. Traffic density affects the frequency of meeting situations. (Obviously, this does not apply to motorways.) The frequency of meeting opposing vehicles, in turn, contributes to the frequency of occurrence of headlamp glare and affects the degree of dark adaptation. (The degree of dark adaptation influences the detectability of rear lights and of other targets during nighttime driving.) Table 17 presents two sets of international data on the density of traffic: vehicles per km of roadway, and km travelled per km of roadway. The analogous data for the ten most extreme U.S. states are listed in Table 18.

TABLE 14

Percentage of paved roads in selected countries, 1985 (IRF, 1987).

Country	Paved roads (%)
U.S.A.	55
Canada	36[a]
France	92
Italy	100
Spain	56[b]
United Kingdom	100
West Germany	99
Japan	56[c]

[a] From RTAC (1987)—includes "surface treated" roadways.

[b] Includes rural paths and forest trails.

[c] From Road Bureau (1985).

TABLE 15

Motorways and motorway traffic in selected countries.

Country	Motorways	
	% of total roadways[a]	% of total traffic volume[b]
U.S.A.	1.3	20
Canada	0.9[c]	?
France	0.8	16
Italy	2.0	?
Spain	0.6	6
United Kingdom	0.8	12
West Germany	1.7	26
Japan	0.3	6

[a] 1985 data except for Italy (1984) (IRF, 1987).

[b] 1983 data except for the U.S.A. and Japan (1982) (ECMT, 1985).

[c] Based on the length of the road network provided in RTAC (1987).

TABLE 16
Percent of annual vehicle-miles on motorways in selected U.S. states, 1986 (FHWA, 1987a).

State	% of total annual vehicle-miles travelled on motorways
California	39
Connecticut	38
Massachusetts	36
Maryland	33
Washington	31
Maine	17
Nebraska	17
Wisconsin	17
North Dakota	16
Delaware	15
All states	27

TABLE 17
Density of traffic in selected countries, 1985 (IRF, 1987).

Country	Vehicles per km of road	Thousand km travelled per km of road
U.S.A.	28	460
Canada	17[a]	?
France	30	430
Italy	75[b]	922[b]
Spain	72	243[b]
United Kingdom	53	804
West Germany	54[b]	724
Japan	41	456

[a] Based on the length of the road network provided in RTAC (1987).
[b] 1984 data.

TABLE 18
Density of traffic in selected U.S. states, 1985 (FHWA, 1987b).

State	Vehicles per km of road	State	Thousand km travelled per km of road
District of Columbia	184	District of Columbia	2,925
Hawaii	103	Hawaii	1,717
New Jersey	90	New Jersey	1,567
Connecticut	78	Maryland	1,209
Maryland	74	California	1,192
Wyoming	8	Nebraska	131
Idaho	8	Idaho	111
Montana	6	Montana	106
South Dakota	6	South Dakota	86
North Dakota	5	North Dakota	63

Speed limits. Speed influences the desirable preview distance, since the stopping distance is a monotonic function of initial speed. Consequently, greater speed calls for longer visibility distance. Recent international speed limits are listed in Table 19.

TABLE 19
Speed limits in selected countries, 1984 (adapted from Fieldwick and Brown, 1987).

Country	General speed limit (km)			
		Rural		
	Urban	Limited-access (freeways)	Major arterials	Other
U.S.A.	48	88[a]	88	88
Canada[b]	50–60	100	80–90	80
France	60	130	110	90
Italy	50	140	110	110
Spain	60	100	90	80
United Kingdom	48	112	112	97
West Germany	50	130[c]	130[c]	100
Japan	?	80–100[d]	50[e]	40[e]
Austria	50	130	100	100
Ireland	48	97	97	97
Switzerland	50	120	80	80

[a] 105 since 1987.
[b] From Birch (1988).
[c] Advisory limit only.
[d] From IATSS (1985).
[e] From Koshi (1985).

Lane/road width. The lane/road widths influence the desirable spread of the headlamp beam and the need for tight control of headlamp glare. Unfortunately, international data in a common format were not available, as illustrated in Tables 20 through 22. Table 20 shows the U.S. data for the percentages of roads with different lane widths. (The analogous breakdown by the individual U.S. states can be computed from from the data in FHWA [1987a].) Table 21 presents the Japanese data for the width of the whole roadway. The analogous data for a subset of West German roads is shown in Table 22.

TABLE 20
Distribution of U.S. roadways by lane width, 1986
(computed from the data in FHWA, 1987a).

Lane width (feet)	Percent of all roadways
<9	4.8
9	11.6
10	24.1
11	16.9[a]
12	37.4
>12	5.1

[a] Includes 301 miles (484 km) of interstate highways classified as having a lane width of less than 12 feet.

TABLE 21
Distribution of Japanese roadways by total width, 1984
(computed from the data in Road Bureau, 1985).

Road width (m)	Percent of roadways
<5.5	74.3
5.5–13	24.0
>13	1.7

TABLE 22
Distribution of West German roadways by total width, 1986 (computed from the information in Bundesminister für Verkehr, 1987). (Urban roads not included.)

Road width (m)	Percent of roadways
<5	11.7
5–6	27.6
6–7	29.2
7–9	19.6
9–12	4.1
≥12	7.8

Road surface. Different road surfaces, because of their different reflectivities, influence the effective contrast between targets and roadway. Indicative of the practical range is the data of Bhise, Farber, Saundby, Troell, Walunas, and Bernstein (1977), who have found (using a representative sample of U.S. roadways) that the majority of dry pavement had reflectivity of 2% to 11%. The only international information available—for Japan—is presented in Table 23.

TABLE 23
Distribution of roadways in Japan by surface type, 1984
(computed from the information in Road Bureau, 1985).

Surface	Percent of roadways
Gravel	44.3
Cement	3.7
Asphalt	51.9

Fixed illumination. Illumination from fixed sources influences the optimal aspects of vehicle lighting. A survey conducted by Bhise et al. (1977) indicates that the percentage of roads with fixed illumination varied from 1% to 8% for rural roads and 55% to 91% for urban roads (the actual percentage depending on the road type). However, no comparable international data were available.

Environmental factors

Atmospheric conditions have substantial effects on the effectiveness of vehicle headlighting and rear lighting. For example, rain can increase glare and affect the contrast of critical objects illuminated by headlamps (Perel, Olson, Sivak, and Medlin, 1984). Similarly, fog will reduce the levels of contrast (such as between a brake light and its background), with the effect being greater during nighttime than during daytime (OECD, 1976). Consistent with the above are the findings of increased accidents (primarily at night) during rain (Haghighi-Talab, 1973) and fog (Koth, McCunney, Duerk, Janoff, and Freeman, 1978). (Visibility during and after snowfall is a more complex issue. While there might be reduced visibility during falling or blowing snow, there might be cases of improved visibility because of high contrast between dark road/objects and white snow on the sides [OECD, 1976].)

For a meaningful comparison of international differences in exposure to adverse weather, map data showing the average annual amount of rain, snow and, fog would be desirable. However, such data (in a relatively comparable format) were available only for total precipitation. Table 24 presents a summary of the precipitation data contained originally in a map form. Localized extreme values are not included in Table 24.

As was pointed out by an *ad hoc* OECD research group, “in most countries data on the occurrence and duration of fog is collected at meteorological centers and airports which do not provide the level of detail or extent of coverage sufficient for statistical analysis” (OECD, 1976, p. 11). The only readily available recent data in map form were for Canada (Environment Canada, 1984). (Relatively old U.S. data that might not be representative of the current conditions are contained in Visher [1954].)

TABLE 24
Mean annual precipitation in selected countries.
(Isolated extreme values are not included.)

Country	Annual precipitation (mm)	
	Minimum	Maximum
U.S.A.	100	2,500
Canada		
rainfall	100	2,400
snowfall	1,000	10,000
France	600	1,600
Italy	600	1,600
Spain	400	1,600
United Kingdom	600	2,000
West Germany	600	1,600
Japan	800	2,400

Sources: U.S. Environmental Data Service, 1983 (U.S.A.), Environment Canada, 1984 (Canada), WMO, 1970 (France, Italy, Spain, United Kingdom, West Germany), and Chiriin, 1977 (Japan).

DISCUSSION

Are the ranges of the values of the lighting-related factors for the eight dominant car-producing countries at least as large as the corresponding ranges for the U.S. states? The answer to this question was sought in attempt to answer the basic question underlying this research: Are the international conditions sufficiently similar for harmonization of vehicle-lighting standards, and for international applicability of findings from field studies? Table 25 provides qualitative answers concerning the comparisons of the ranges that were examined.

The information in Table 25 indicates that the available evidence suggests that the within-U.S. ranges are generally at least as large as the corresponding ranges for the eight countries of interest. Consequently, the present study did not find any evidence in support of unique U.S. lighting specifications. Conversely, the obtained evidence supports the establishment of international lighting specifications.

The obtained information also indicates that field studies that are performed under representative conditions (for that particular country) have a relatively high degree of general applicability to other countries. (Obviously, a study performed under very specific, localized conditions would not necessarily have international applicability. Furthermore, such study might not even have a country-wide applicability.)

The present findings apply most directly to the eight countries under investigation. However, they are likely to also apply to all West European countries, and most likely to all developed countries. (Differences between developed and developing countries in some important aspects [e.g., proportion of older persons, motorway traffic, etc.] might be substantially greater than the corresponding within-U.S. values.)

TABLE 25
Comparison of the ranges of the relevant factors for the countries of interest and for the U.S. states.

Variable	Were international data available?	Were U.S. data by states available?	Is the range for the U.S. states at least as large as the corresponding international range?
Older population	Yes	Yes	Yes
Alcohol consumption	Yes	Yes	Yes
Bicycles	Yes	No	?
Mopeds	Yes	No	?
Trucks and buses	Yes	Yes	Yes
Population density	Yes	Yes	Yes
Paved roads	Yes[a]	Yes[b]	?
Motorways	Yes	Yes	Yes(?)
Traffic density	Yes	Yes	Yes
Speed limits	Yes	No	Yes(?)
Lane width	No	Yes	?
Road surface	No	No	?
Fixed illumination	No	No	?
Precipitation	Yes	Yes	Yes

[a] Of questionable validity.

[b] Available in FHWA (1987a), but not presented in this report.

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