Driver Remarks on Geometric Design Standard of Highways in Thailand

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Abstract: This manuscripts presents driver remarks on geometric design standard of different highway types through questionnaires of car and truck drivers in Thailand. Generally, highway designers in Thailand implement the geometric standards of the Department of Highways that adopted from AASHTO guidelines. They rarely took into account opinions of Thai drivers towards the guideline. This research aims to understand attitudes and opinions of Thai car drivers and truck drivers to this design policy. They were asked to state their remarks on existing design standards as well as suggestions on dimensions of major geometric design elements, i.e., design speed, lane width, shoulder width and vertical clearance, on express, general intercity and urban highways. Survey data are compiled by descriptive statistics and also analyzed to find correlations between driver remarks and their characteristics. Findings from this research yield policymakers ideas on how drivers thought towards the existing highway design standards and their proposed changes that would result in better and more updated design guidelines according to driver views.

Keywords: Highway Design, Highway Safety, Geometric Design Standard, Driver Opinions

1. INTRODUCTION

Geometric design of highways is a crucial stage for highway design. The designers are required to be concerned on efficient mobility, safety and community goals. The first step in highway design is to determine appropriate policies for designed highway. These include functional classification and accommodated traffic volumes. Then, highway elements and design variables are obtained accordingly. To assist highway designers, highway organization generally compiles policy and standards and issues the design guidelines based on topography, society, environment and local policies in each region.

Specifically for Thailand, the Department of Highways (DOH), Ministry of Transport has issued its standards for more than two decades based on United States' AASHTO standards. However these standards have rarely been reviewed locally and have not been based on domestic driver opinions. Moreover, there are very few and not up-to-date studies of geometric design standards in Thailand. Therefore, this research herein intends to review the highway classification policy and geometric design standards for Thai highways according to the opinion survey of Thai drivers. The geometric design standards in this study include major design elements such as design speed, lane width, shoulder width, vertical clearance, etc. Subsequently, the questionnaire data were analyzed statistically to identify how each driver characteristics affect their opinions on highway design standards. This research is expected to be beneficial to highway policymakers and designers to modify highway design standards for better matching drivers' expectation.

The remainder of the paper is organized as follows. Section 2 describes the literature review regarding the standards of highway geometric design and its effect on traffic safety. Next, survey methodology and data collection method are presented in Section 3. Section 4 presents the findings and discussion of survey results. Then, the fifth and final section contains concluding remarks as well as areas of further research

2. LITERATURE REVIEW

2.1 National Standards on Geometric Design of Highways

In each country, its government highway agency generally issues its highway policy along with design element variables to suit the country's geographic, social, environmental conditions. We summarized the geometric design guidelines from seven countries in Table 1. This table below compares four dimensions and scales of major highway design elements that are apparently observable for drivers, i.e., design speed, lane width, shoulder width, vertical clearance, with Thailand standards.

Table 1. Summary of highway design elements for national highways (level terrain only)

Country	Standard	Design Speed (km/hr)	Lane Width (m)	Shoulder Width (m)	Vertical Clearance (m)
United States[(1)]	Maximum	80-130	3.60	3.00-3.60	5.10
	Minimum	50-60	2.70-3.60	0.60-2.40	4.30
United Kingdom[(2)]	Maximum	120	3.65	3.50-4.80	6.45
	Minimum	60-70	3.00	3.50	5.30
People Republic of China[(3)]	Maximum	60-120	3.75	3.75	5.00
	Minimum	20-40	3.50	0.50	4.50
Kazakhstan[(3)]	Maximum	120-150	3.75	3.75	5.00
	Minimum	60	4.50	1.75	4.50
Mongolia[(3)]	Maximum	120-140	3.75	3.75	5.00
	Minimum	60	4.50	-	4.50
Republic of Korea[(3)]	Maximum	100-120	3.50	3.00	4.50
	Minimum	50-60	3.00	-	4.50
Malaysia[(4)]	Maximum	120	3.50	3.00	5.00
	Minimum	40	2.50	1.50	5.00
Thailand[(5)]	Maximum	90-110	3.50	3.00	5.50
	Minimum	60	3.00	-	5.50

[(1)]AASHTO (2011), [(2)]Dept. of Transport, U.K. (2002, 2005), [(3)]UNESCAP (2001),
[(4)] Public Works Dept., Malaysia (1986), [(5)]Dept. of Highways, Thailand (2010)

By comparing Thailand's highest (maximum) standard to other countries' ones in Table 1, Thailand's maximum design speeds are noticeably lower. However, this is not corresponding with actual Thai driving behaviors nowadays. It led to Department of Highways, Thailand's consideration to modify it. For other design elements, particularly lane width, since Thailand and Malaysian highways are interconnected. It is reasonable to use the same geometric design standards. Also, by excessive widening lane width, it might mislead drivers to use the lane for other objectives such as illegal parking or wrong-side passing.

2.2 Effects of Geometric Design Elements on Highway Safety

Traffic and highway engineers normally evaluated the effects of geometric design elements on traffic safety by using the before & after improvement accident statistics. Although it is acceptable among traffic professionals that human factors are probable the main cause of traffic accidents, roadway condition and highway design aspect are still a significant contributor to traffic accidents. Examples of past researches in each element are as follows:

Total Pavement Width (Lane & Shoulder Width)
Elvik, *et al* (2009) reports that increase in pavement width would decrease traffic accidents on rural roads by 8 percent (for injury rate) and 10 percent (for property damage only) but increase accidents on urban roads by 4 percent (for injury rate) and 10 percent (for property damage only). It argues that wider urban roads cause longer time for crossing the streets while wider rural ones make drivers more comfortable driving.

Lane Width
The effect of lane width on accident rate has been debatable and inconclusive among highway professionals. Lewis-Evans and Charlton (2006) summarizes the evidences and shows that increasing lane width by 0.3-0.5 meters might reduce traffic accidents at horizontal curve section by 8 percent while increase ones at straight section by 19 percent. However, if focusing only on widening substandard or narrow sections, increasing lane width on rural roads has reduced overall accidents by 5 percent but increase injury accident by 9 percent. It also shows that increasing width of existing standard lane would reduce accidents by 19 and 8 percent in urban and rural areas, respectively. However, the increase would not be too wide; otherwise, it might cause driver confusion and likelihood of traffic accidents.

Shoulder Width
The effect of widening shoulder width on accident rate reduction is quite positive among highway professionals. According to Ben-Bassat and Shinar (2011), widening shoulder width on local roads can reduce overall accident rate by 12 percent and reduce injury accident up to 18 percent. The results are more evident on freeways by reducing 27 percent of total accidents. However, Elvik *et al* (2009) argue that excessive shoulder width might lead to higher accident rates if it is shortly built or drivers use it as another driving lane.

Based on literature, we might broadly conclude that highway elements must be designed to suit particular driver expectation for accident reduction and to conform with country's design objectives simultaneously. Therefore, the survey of driver's opinions on highway design elements would be done over time to understand how drivers (or most important road users) perceive existing standards.

3. METHODOLOGY

3.1 Survey of Attitudes and Remarks from Thai Drivers

The main objective of survey is to understand Thai driver opinions towards geometric design elements and highway design policy. The questions include two parts: 1) driver characteristics – age, highest level of education, gender, income, driving experience, vehicle types, frequency of drivers, etc; and 2) opinions towards existing highway geometric designs and suggestions to modify the standards. The second part are separated into express highways, intercity highways (or Highway Class 1-3, according to Department of Highways, Thailand) and urban highway. On each type, they are asked to comment about perceived safe driving speed and dimensions of four major element (design speed, lane width, shoulder width and vertical clearance).

3.2 Data Collection Methods and Analysis

To diversify survey respondents, the data collection team collected 402 survey respondents from rest areas in Central Thailand with high traffic volumes such as express highways rest areas, large gas stations, truck rest areas, etc. The questionnaires include pictures and explanations (as shown in Figure 1) such that drivers without much knowledge in highway design can understand and answer the questions appropriately.

Figure 1: Samples of pictures and description in the questionnaire:
(a) Express highway; (b) General intercity highway

The data from questionnaires are compiled and analyzed by 1) using descriptive statistics to present data in aggregate views; and 2) using regression models to find relationships between driver characteristics and suggestion to changing major design element dimension (from to increase, do nothing, and to decrease). The regression models used in this analysis uses interval-scale dependent variables. The description and findings of these analyzes from 402 respondents are shown in Section 4.

4. FINDINGS

4.1 Descriptive Statistics

Table 2 shows the profile of 402 survey respondents. Data show that most drivers are male (86%) at the average age of 37.6 years and with average 12 years of driving experience. The monthly income and level of highest education are pretty much to broader Thais in general. The exemption was the percentage of motorcycles, which are less than Thailand registered vehicle statistics at 30%. This could be due to the reason that most survey places were located on rest areas of major highways. We also found that the expected maximum driving speeds of most drivers are around 80-120 km/hr, with the average of 102.4 km/hr. This is quite fast since Thailand's legal maximum speeds was only 80 km/hr in urban area and 90-110 km/hr otherwise.

Table 2. Profile (socioeconomic and driving behavior) of survey respondents

Characteristics	Details	Count	Percent (%)
Age	Avg = 37.6, Max = 68, Min = 18	402	100.00
Gender	Male	345	85.82
	Female	57	14.18
Level of Highest Education	Junior High School or lower	136	33.83
	High School or Diploma	58	14.43
	Bachelor's	156	38.81
	Master's or Higher	52	12.93
Monthly Income (THB)	Below 10,000	55	13.68
	10,000-20,000	171	42.54
	20,001-40,000	120	29.85
	Higher than 40,000	56	13.93
Driving Experience	Avg = 12, Max = 46, Min = 1	402	100.00
Typical Used Vehicle	Car	240	59.70
	Van	32	7.96
	Bus	29	7.22
	Pick-up Truck	38	9.45
	Truck (6 wheels)	25	6.22
	Trailer	25	6.22
	Motorcycle	13	3.23
Driving Frequency (per week)	One day or less	15	3.73
	1-2 days	31	7.71
	3-5 days	92	22.89
	6-7 days	264	65.67
Area of Driving	Urban Areas only	87	21.64
	Both rural and urban areas	290	72.14
	Rural areas only	25	6.22
Maximum Driving Speed (km/hr)	Avg = 102.44, Max = 200, Min = 40	402	100.00

Drivers expressed their opinions on regarding their satisfaction on existing highway design standards as shown in Figure 2(a) with the geometric design elements that would be improved in Figure 2(b). Clearly, about 80 percent of respondents were not satisfied with existing design standards and almost 20 percent said that they would be totally improved. The elements that would be much improved according to driver opinions are design speed (29.0%), shoulder width (26.1%), lane width (24.5%) and vertical clearance (7.9%), respectively. Other geometric design elements that would be improved are curve, median, U-turn channel and non-geometric ones are pavement condition, traffic signs, lane marking, and lighting.

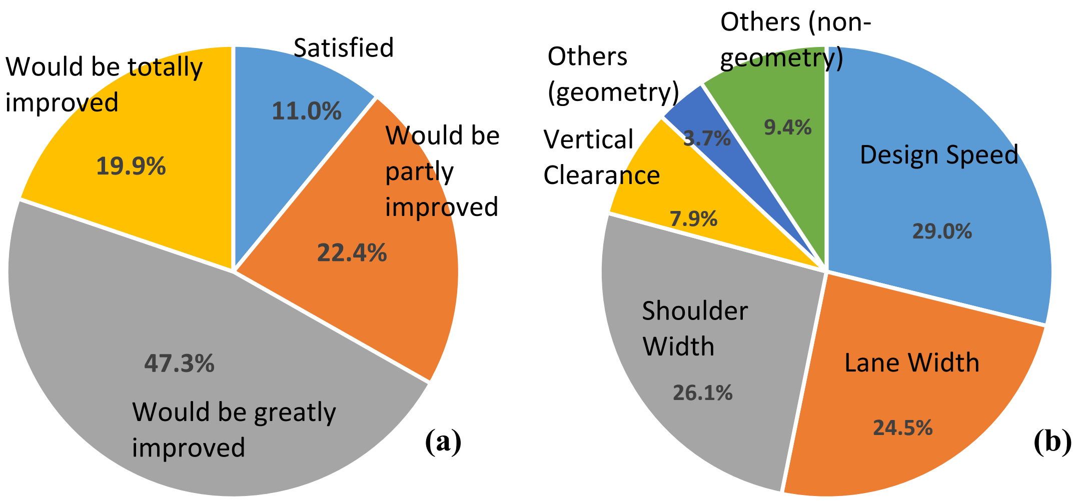

Figure 2. (a) Opinions on existing standards and (b) elements that would be improved

Table 2. Percentage of survey respondents who expected maximum driving speeds on different highway types

Expected Max. Speed (km/hr)	Express Highway	General Highway	Urban Highway
40	0.0	0.5	2.2
50	0.0	0.3	7.0
60	3.5	7.0	39.8
70	3.7	6.0	10.0
80	12.7	26.1	25.1
90	10.2	13.7	7.5
100	26.4	26.4	5.7
110	7.7	8.2	0.8
120	29.6	11.7	2.0
130	1.3	0.0	0.0
140	3.5	0.3	0.0
150	1.0	0.0	0.0
160	0.5	0.0	0.0
Mean	103.2	91.7	71.0
Median	97.5	87.4	71.0
85th Percentile	117.0	106.2	81.2

Table 2 shows percentages of Thai drivers who expected to drive at particular maximum speed on different highways. The data show that most drivers (at 85th Percentile) expect to drive on express highways, general highways and urban highways at the speed of 117, 106 and 81 km/hr, respectively. Figure 3 shows the opinions on whether to increase, decrease, or do nothing with existing design elements. We will discuss each highway type separately as follows.

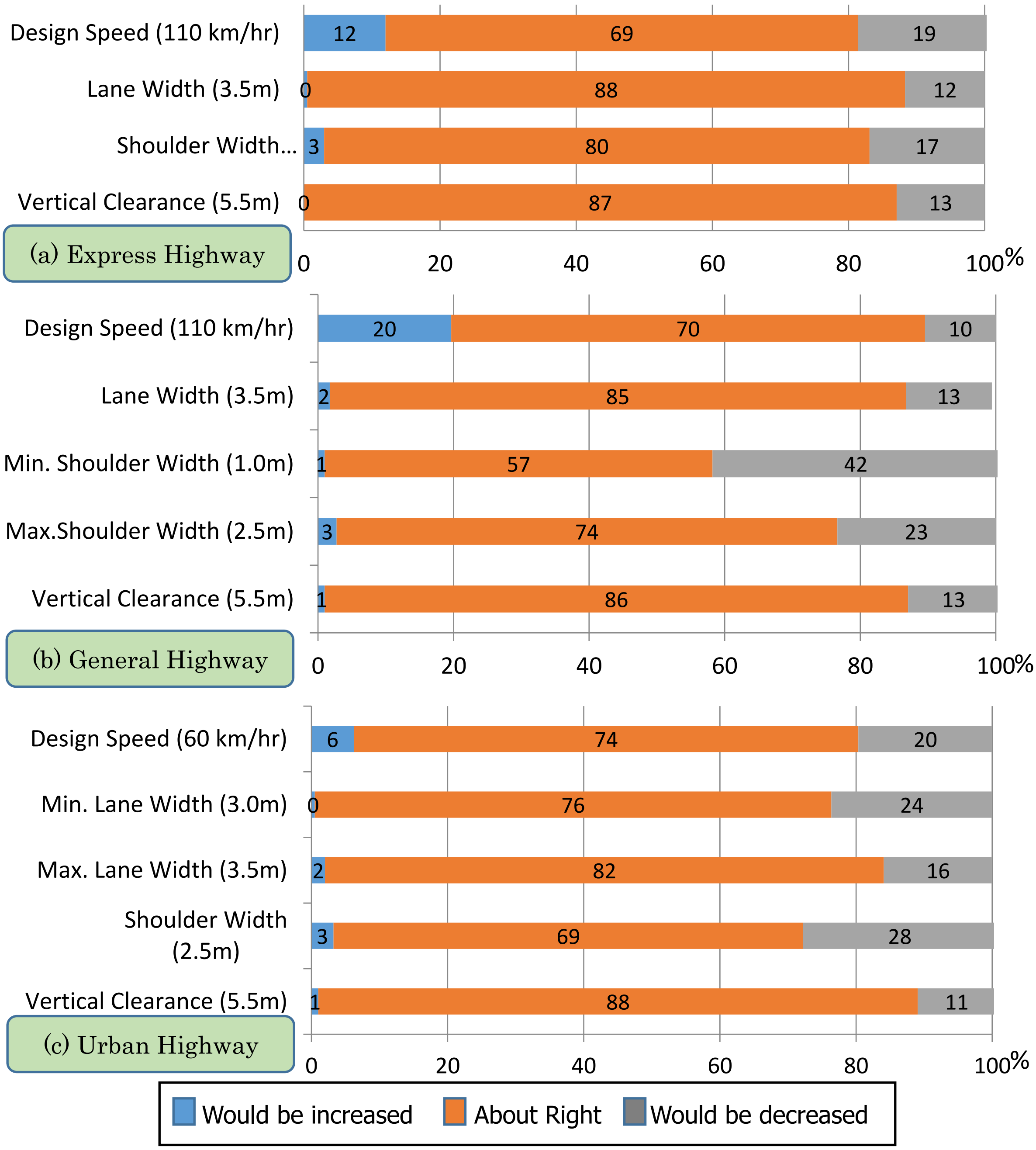

Figure 3. Opinions on different design elements

For express highways, most drivers believe that the safe maximum speed would be between 100-120 km/hr, which is according to existing standard of 110 km/hr. For design element improvement, about 19 percent of drivers said that design speed would be increased. These were among the highest percentage of all elements to be improved.

For general highways, most drivers believe that the safe maximum speed would be between 80-100 km/hr, which is lower than existing standard of 110 km/hr. For design element improvement, 42% of drivers expected decreasing minimum shoulder width. Notably, 20% of drivers expected lower design speed and speed limit.

For urban highways, most drivers believe that the safe maximum speed would be between 60-80 km/hr, which is higher than existing standard of 60 km/hr. For design element improvement, 28% of drivers expected wider shoulder width and 24% of them expected wider lane width as well.

By carefully looking into the data in Figure 3, even the majority of drivers believe that each element has been well designed, more than 10% of drivers in all highway types expected some changes, i.e., drivers on express highways were concerned about design speed, while one on urban highways expected wider lane width. Nevertheless, in all cases, existing vertical clearance is well acceptable to drivers and would not be modified.

4.2 Relationship between driver characteristics and their opinions

To understand the effects of each driver characteristics towards their opinions quantitatively, an ordinal probit model of how drivers suggest the improvement on particular design element are done. The analysis was done through the assumption of standard three-level probit model (from +1 = to increase, 0 = to do nothing (be satisfied with existing standards) and -1 = to decrease) and STATA software package with maximum likelihood algorithm was used. The independent driver characteristic variables include age, gender, level of highest education, monthly income, years of driving experience, their typical used vehicle, driving frequency, area of driving, and maximum driving speed. The description of these variables are shown in Figure 3. The analysis was separately done for each highway type and each highway element. The regression results for design speed and lane width are shown in Table 4 and the two others are shown in Table 5. Note that the analysis was assumed statistically signifiant by using the 90% confidence interval (p-value < 0.1). The discussions of results are as follows.

Table 3. List of independent variables in the ordinal probit model

Variable	Type	Description (or Unit)
Age	Continuous	In Year
Gender	Nominal	0 = Female; 1 = Male
Level of Highest Education	Nominal	0 = below Bachelor's Degree; 1 = Bachelor's Degree or Higher
Monthly Income (THB)	Ordinal	1 = below 10,000; 2 = 10,000-20,000; 3 = 20,000-40,000; 4 = > 40,000 or above
Driving Experience	Continuous	In Year
Typical Used Vehicle	Nominal	1 = Heavy Vehicle (truck, bus, etc); 0 = Others
Driving Frequency (per week)	Ordinal	1 = One day or less; 2 = 1-2 days; 3 = 3-5 days; 4 = 6-7 days
Area of Driving	Nominal	1 = Urban only; 2 = Both urban and rural; 3 = Rural only
Maximum Driving Speed (km/hr)	Continuous	In Kilometer per hour

For design speed, Table 4 shows that vehicle type significantly affects driver opinions on design speed only for general highways, while gender affects ones only for urban highways. Notably and unsurprisingly, maximum driving speed affects driver opinions on all highway types.

For lane width, the main characteristics that significantly affect driver opinions are driver's level of highest education (for express highway), years of driving experience (for general highways. It can be explained that drivers with less experiences are inclined to believe that wider lane width is required for better vehicle control.

Table 4. Coefficients of driver characteristic variables and design speed/lane width

Driver Characteristics	Design Speed (Km/hr)			Lane Width			
	Express Hwy	General Hwy	Urban Hwy	Express Hwy	General Hwy	Urban Hwy (Low)	Urban Hwy (High)
Age (Year)	-0.007 (0.405)	-0.001 (0.907)	-0.003 (0.721)	-0.002 (0.845)	0.009 (0.384)	-0.009 (0.337)	-0.009 (0.352)
Gender	-0.292 (0.131)	0.02 (0.914)	**-0.408** **(0.035)**	0.315 (0.201)	-0.315 (0.157)	0.046 (0.826)	0.168 (0.438)
Highest Education Level	-0.101 (0.545)	-0.216 (0.184)	0.027 (0.874)	**0.443** **(0.044)**	0.242 (0.233)	0.259 (0.162)	0.242 (0.199)
Monthly Income (THB)	-0.025 (0.755)	0.016 (0.837)	0.04 (0.615)	-0.016 (0.874)	0.044 (0.641)	0.091 (0.294)	-0.045 (0.611)
Driving Exp. (Year)	-0.003 (0.783)	-0.005 (0.625)	-0.005 (0.623)	-0.005 (0.702)	**-0.024** **(0.043)**	0.000 (0.994)	0.000 (0.978)
Vehicle	-0.314 (0.112)	**-0.41** **(0.032)**	-0.142 (0.476)	-0.391 (0.159)	0.206 (0.388)	0.253 (0.245)	0.079 (0.720)
Driving Freq. (Days/Week)	0.078 (0.349)	0.036 (0.657)	-0.062 (0.465)	-0.02 (0.851)	0.132 (0.194)	0.034 (0.710)	0.073 (0.435)
Driving Area	0.06 (0.640)	0.084 (0.499)	0.197 (0.130)	0.097 (0.557)	0.177 (0.254)	-0.051 (0.716)	0.116 (0.423)
Maximum Driving Speed (km/hr)	**0.023** **(0.000)**	**0.01** **(0.001)**	**0.008** **(0.018)**	-0.004 (0.349)	0.006 (0.146)	-0.001 (0.819)	-0.002 (0.583)
Equation Boundary	**μ1= 0.56** **μ2= 2.99**	**μ1= 0.21** **μ2= 2.42**	**μ1=-1.09** **μ2= 1.41**	**μ1=-2.72** **μ2= 1.18**	**μ1=-0.78** **μ2= 2.60**	**μ1=-2.57** **μ2= 0.77**	**μ1=-1.99** **μ2= 1.11**
-2 Log Likelihood	569.083	620.041	547.313	301.977	359.839	455.758	422.437

*Numbers in parentheses represent p-values of above coefficients

For shoulder width in Table 5, the main characteristics that significantly affect driver opinions are driver ages (for all highway types), vehicle type (for general highway), driver's level of highest education (for urban highways and minimum limit of express highways), driving area (for urban highways) and maximum driving speed (for urban highways and maximum limit of express highways). It can be explained that more matured and more educated drivers in urban area are inclined to believe that widening shoulder width is necessary.

For vertical clearance, the main characteristics that significantly affect driver opinions are driver ages (for urban highways), vehicle type (for urban highways) and driving area (for general highways). It can be argued that drivers who usually drove in the rural area might require higher vertical clearance due to presently larger size of vehicles.

In summary, by considering all driver characteristics that might influence their opinions on highway geometric design elements. We found that driving area (especially the ones who regularly drive in a rural area) and ages are two main characteristics that affect their opinions. These are followed by their vehicle type and selected maximum driving speed. Nevertheless, the effects of each characteristics greatly varied on different types of highways.

Table 5. Coefficients of driver characteristic variables and shoulder width/vertical clearance

Driver Characteristics	Shoulder Width				Vertical Clearance		
	Express Hwy	General Hwy	Urban Hwy (Low)	Urban Hwy (High)	Express Hwy	General Hwy	Urban Hwy
Age (Year)	**-0.018 (0.060)**	**0.02 (0.027)**	**-0.016 (0.081)**	**-0.023 (0.010)**	-0.017 (0.152)	-0.008 (0.456)	**-0.042 (0.001)**
Gender	0.1 (0.632)	0.171 (0.386)	0.068 (0.732)	0.039 (0.840)	-0.167 (0.482)	-0.033 (0.888)	0.142 (0.569)
Highest Education Level	-0.045 (0.805)	0.251 (0.144)	**0.364 (0.038)**	**0.337 (0.045)**	-0.063 (0.771)	0.037 (0.859)	-0.19 (0.377)
Monthly Income (THB)	0.043 (0.620)	-0.01 (0.907)	**0.183 (0.027)**	0.056 (0.483)	-0.031 (0.767)	-0.058 (0.558)	-0.019 (0.858)
Driving Exp. (Year)	0.007 (0.501)	-0.015 (0.145)	0.009 (0.406)	0.008 (0.405)	0.002 (0.873)	-0.003 (0.831)	0.022 (0.127)
Vehicle	0.133 (0.529)	**0.753 (0.000)**	0.087 (0.673)	-0.26 (0.191)	-0.37 (0.173)	-0.134 (0.584)	**-0.476 (0.085)**
Driving Freq. (Days/Week)	0.096 (0.292)	-0.017 (0.840)	0.006 (0.945)	0.051 (0.542)	0.125 (0.259)	0.067 (0.516)	0.103 (0.345)
Driving Area	-0.093 (0.505)	-0.213 (0.106)	0.094 (0.482)	**0.24 (0.065)**	0.183 (0.283)	0.336 (0.039)	0.025 (0.883)
Max. Driving Speed (km/hr)	-0.001 (0.786)	0.003 (0.378)	**-0.006 (0.066)**	**-0.007 (0.047)**	-0.003 (0.469)	-0.003 (0.427)	-0.003 (0.465)
Equation Boundary	**μ1=-2.23 μ2= 0.65**	**μ1=-1.90 μ2= 1.01**	**μ1=-2.24 μ2= 0.53**	**μ1= -2.42 μ2= 0.10**	**μ1= N/A μ2=0.69**	**μ1= –2.62 μ2=1.14**	**μ1=–4.12 μ2=–0.07**
-2 Log Likelihood	462.753	546.298	512.426	558.68	301.459	335.033	293.2

*Numbers in parentheses represent p-values of above coefficients

5. CONCLUDING REMARKS

Based on survey data analysis, we found that most drivers are still satisfied with the existing geometric highway design standards used in Thailand. However, more than 10% of drivers expect some changes especially on increasing design speed on express highways, widening lane width and on urban highways. In addition, by considering all driver characteristics that might influence their opinions on highway geometric design elements. Driving area (especially the ones who regularly drive in a rural area) and ages are two main characteristics that affect their opinions and they are followed by their vehicle type and selected maximum driving speed. Therefore, if there are some modifications on geometric design standards of highways in Thailand, the authorities would need to consider these factors. This manuscript might be served as a guideline to survey drivers in every decade such as the authorities might realize that the expectation of drivers on different geometric design elements could be changed over time.

This research has some limitations, i.e., highway design standards in different countries might not be comparable due to different highway classification. Also, for driver survey, many drivers might not realize the effect of geometric design element change. For example, some might not perceive how a highway with 3-m lane width is more difficult to navigate than a highway with 3.5-m lane width.

For future research, this study could be extended to other geometric elements such as slope, median width, curve design, etc. In addition, since major highway design stakeholders include designers, policymakers, and even pedestrians, it is reasonable to get the opinions from all stakeholders before modifying the guidelines or standards. This type of research would increase the understanding of how each stakeholder perceives on highway design elements and make the guidelines more practical and efficient for all highway users

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