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DEVELOPMENT OF COMMUNITY CHARACTERISTICS ASSESSMENT TOOLS FOR SPEED LIMIT USING DECISION-MAKING THEORY: CASE OF THAILAND

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ABSTRACT

The traffic engineering measures for the speed limit in the residential area not only helps with road accident mitigation but also creates a pleasant environment for the residential areas and expands the space for pedestrians. The extensive study of numerous the speed limit measurements of other countries especially in Europe shows that it is important to incorporate other measurements to the existing laws to effectively enforce the speed limit in the residential area. The use of a decision-making support tool to set appropriate speed could lead to further analysis to improve the assessment of the areas that need an appropriate speed limit. The decision tree related theory is used for specific decision tree analysis. Decision tree gives an effective decision structure where the decision and consequence are placed together. In this regard, the manual for the speed limit in the urban and municipality has been compiled by the World Health Organization and Thai Road Foundation by decision-making factors. The purpose of the manual is to ensure the same practice standard throughout Thailand. The development of this assessment tool is the creation of relationship according to the above factors to facilitate decision making and to communicate the involved officers with different knowledge and experience to make decisions with unity.

1. INTRODUCTION

1.1 THE IMPORTANCE OF THE SPEED LIMIT AND ROAD ACCIDENTS IN THAILAND

Road accident statistics from Royal Thai Police during 2008–2013 (Department of Highways, 2014) showed that the first five factors of road accidents were exceeding the speed limit, too close cutting, too close following, drunk driving, and illegal passing. Motorcycles ranked the first of

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affected vehicles followed by personal cars and trucks respectively. According to the Thai Road Traffic Act B.E.2522 and amended B.E.2538, the speed limit on highways shall not exceed 90 km./hr. And 80 km./hr. in the municipality area. This speed limit does not include the areas where highways are connected to cities (transition zone). There were only signs telling drivers to slow down in the city area. It is stated that such signs must be put up not less than 125 meters and not more than 250 meters before entering city zones (Department of Highways, traffic signs manual, 2011). However, there is no specific definition of city zones, i.e. characteristics or number of population, and there is not the clear distance of such a transition zone as well. That is why drivers tend to drive with the same speed they are driving before entering the transition zone and only slow down when they are already in city zones. There are even drivers who still drive with the same speed in city zones which cause severe accidents in transition zones and city zones. In this regard, Road Safety Thailand has issued "People Report 2016" giving a conclusion of accident prevention and mitigation during 2016 new-year holidays. It was revealed that when compared with 2015 new year holidays, number of accidents, deaths, and injured were higher. The cause was drunk driving which was 24.3%; next was exceeding the speed limit which was 17.28%. Consequently, the prevention and reduction measurement of road accidents in 2016 was taken higher than that of 2015. The number of dead and injured during Songkran holidays in 2016 was also increased from 2015, and the first cause was exceeding the speed limit which was up to 32.93% (Department of Disaster Prevention and Mitigation, People Report 2016). Although less than drunk driving, it was even higher than the number during the new year holidays of the same year. This increasing number implies the need for management in city areas as a significant measure to reduce road accidents especially during New Year and Songkran holidays. If drinking is excluded from our parameters, we can see that exceeding the speed limit is the main cause of road accidents. The significant risk when using vehicles includes driving through city areas or city-like areas, the irresponsible use of road-side areas, and people activities in city areas. That's why finding a way to assess a community where the speed limit management is needed is very important to move forward accident prevention and reduction measurement imposed by Road Safety Thailand. Statistical data of highway accidents in 2013 showed that exceeding the speed limit is the main cause of road accident or up to 75% of all causes and it is also the cause of injured pedestrians as shown in Table 1.

Table 1: Causes of highway accidents that lead to injured pedestrians

Causes of accidents	No. of accidents	%	Pedestrians got hit	%
Exceeding the speed limit	8,620	77.5	78	66.1
Too close cutting	853	7.6	26	22.0
Failed to obey traffic lights/signs	128	1.2	2	1.70
Drunk driving	718	6.5	7	5.9
Dozing off	475	4.3	1	0.9
Defective vehicle parts	256	2.3	1	0.9
Others	75	0.6	3	2.5
Total	11,125	100.0	118	100.0

Source: Department of Highways, Thailand, Highway accidents report, 2013.

1.2 THE RELATION OF SPEED AND TRAFFIC ACCIDENTS

When a vehicle moves with speed, kinetic energy has a direct variation with double speed, the braking distance is longer, and impact to any object is higher. The study of Australian Road Safety Bureau regarding breaking distance with various speed before hitting pedestrians in Australia showed

that with the speed of 60 km./hr., cars moving with such speed have normal braking distance on dry road (decision-making time and the time when drivers actually stop the car) at 36 meters while the speed limit in the city area is 50 km./hr. When hitting a pedestrian with such speed, death risk could go up to 80% (Transport Malta, 2012). The braking distance of a car with 50 km./hr. Speed is 28 meter. When speed is increased to 80 km/hr., braking distance becomes 57 meters. When hitting a pedestrian with a braking distance of 60 km/hr., such a vehicle would hit the pedestrian with a speed of 62 km/hr., as shown in Figure 1.

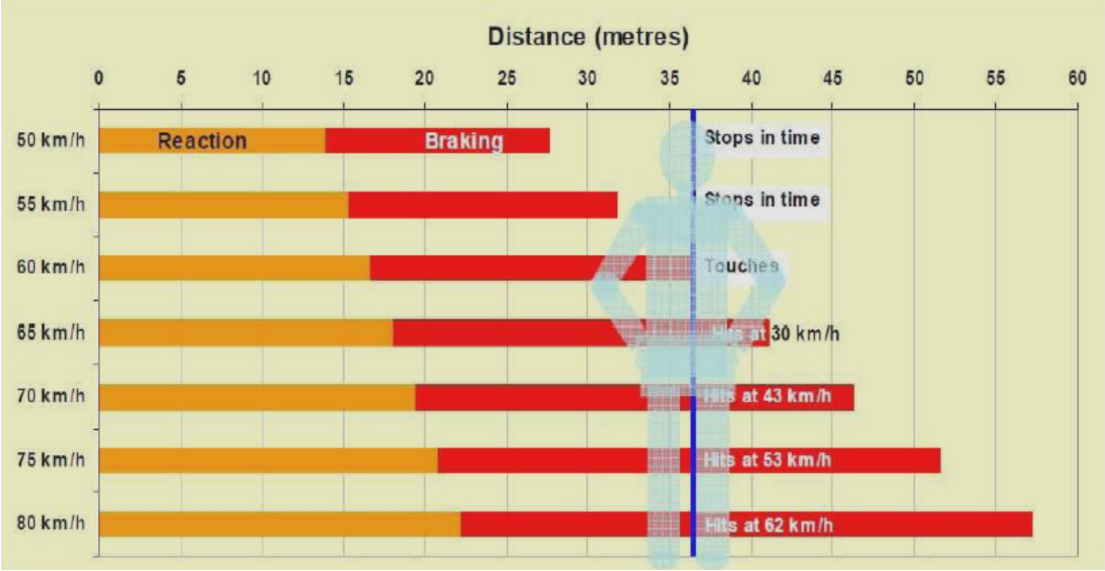

Figure 1: Braking distance of vehicles and speed when hitting pedestrians.
Source: Impact Speed (Road Safety Education Resource) Australian Road Safety Bureau

The Highways the speed limit is 90 km./hr. in Thailand. Geographically residential areas are located along with highways, and population density is perpendicularly distributed from both sides of highways. Characteristics of the community are clear to be seen, i.e. the number of houses, markets, etc. The number of houses is lower away and becoming high in other parts (as shown in figure 2). As such, most drivers tend to enter city zone with the same speed they did on highways despite the signs. Expansion of community leads to population density nearing the signs, and involved units do not move the signs further and that's why drivers are not aware that they are entering areas with population density which might cause serious accidents. Moreover, such involved units do not have a measurement to clearly set the transition zones.

Figure 2 areas of the community located along highways in Thailand

Guidelines to set transition zones for speeding vehicles on highways before who are entering residential areas 2012 by National Cooperative Highway Research Program (NCHRP) under

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Transportation Research Board (TRB) suggested that areas be categorized into 3 zones (as shown in figure 3) which are:

Zone 1 rural zones where there is no speed limit. In the research, speed applied in these zones is 85th percentile before entering transition zones.

Zone 2 transition zones which comprise of 2 areas:

1. Perception – Reaction area: it takes approximately 2.5 seconds to be called perception-reaction area according to the American Association of State Highway and Transportation Officials (AASHTO).
2. Deceleration area: distance from when drivers use break until the speed is decelerated before entering community zones.

Zone 3 Community zone: according to the Road Traffic Act B.E.2552 and amended B.E. 2538, it is stated that in general circumstances, the legal speed of vehicles should be:

1. Trucks weighing over 1,200 kilograms or carrying passengers driving in Bangkok, Pattaya, or municipal areas, the speed should not exceed 60 km./hr., and not exceed 60 km./hr. outside the mentioned areas.
2. Other vehicles apart from 1: if they are towing cars, trucks weighing over 1,200 kilograms or auto-rickshaws driving in Bangkok, Pattaya, or municipal areas should drive the speed not exceeding 45 km./hr. or 60 km./hr. outside the mentioned areas.
3. In Bangkok, Pattaya, or municipal areas, speed should not exceed 80 km./hr. or 90 km./hr. outside the mentioned areas.
4. In case that the speed limit signs are available, drivers should not exceed the recommended speed

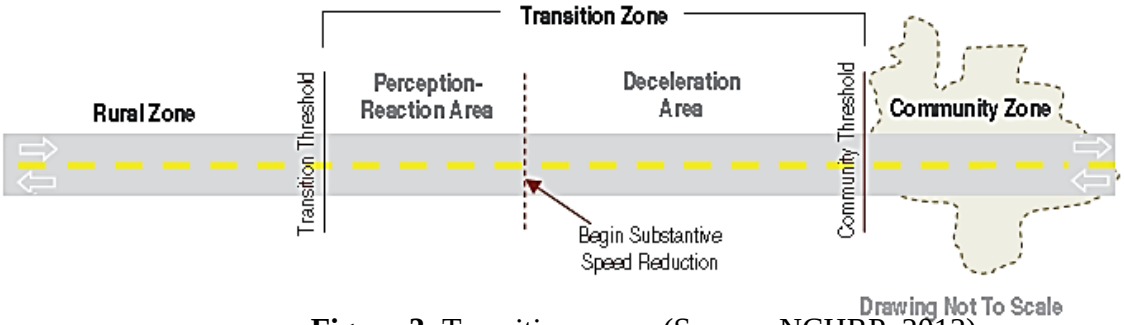

Figure 3: Transition zones (Source: NCHRP, 2012).

The 3Es measurement is recommended for the speed limit in community zones, it includes:

1. Enforcement,
2. Engineering, and
3. Education.

2. DEVELOPMENT OF ASSESSMENT TOOLS FOR SPEED LIMIT

According to traffic engineering, it is found that slowing down in community zones is not only beneficial for accident severity decreasing, but also for creating a pleasant environment and pedestrian walking space increasing. Studies related to deceleration especially those of Europe showed that other measurements should be incorporated into legal ones in order to make efficient

the speed limit in community zones. Appropriate decision making assisting tools could lead to effective analysis for the development of community characteristics assessment tools for the speed limit using decision-making theory. The decision tree is appropriate for decision analysis because it separates decisions into branches. Such branches could then enable us to come up with an efficient structure showing options and consequences of such options. Abstracts are made apparent thus the assessment could be done. Another factor taken into account is decision making factors that World Health Organization (WHO) together with Thai Road Foundation have included in their guideline to the speed limit in city zones and municipal zones i.e. Road Risk Method. This method talks about the speed limit by physical and environmental factors that increase the risk of the accident. This development of assessment tool is thus a way to create relation using the above-mentioned factors in order to facilitate decision making and to communicate with the involved officials who have different knowledge and experience to make sure efficient decision is made together.

The decision to limit speed needs many factors. Each of them reflects the physical characteristics of the community which could lead to an appropriate speed. Decision tree analysis with branches separated gives us a picture of how consequences are linked. Further, decision tree analysis is able to respond to more than one decision-makers. This is because each added criterion means another branch is made. We have studied decision-making factors stated in the guidelines of the speed limit in city zones and municipal areas by World Health Organization (WHO) and Thai Road Foundation and found that this guideline has used decision tree analysis to assess community characteristics for the speed limit. After the literature review, we found a difference in how our targeted vehicles are categorized. In the guideline, vehicles are categorized into 3 types, with a difference of type 1 and type 3. However, the basic principle of the speed limit is similar in order to minimize confusion of decision making when developing the tool using decision tree analysis. We agreed to categorize vehicles according to the ministerial regulations in compliance with the Land Traffic Act B.E.2522 which stated 3 types of vehicles (1) trucks with total weight over 1,200 kilograms or with passengers (2) other vehicles apart from (1) with trailers, cars with total weigh over 1,200 kilograms or auto-rickshaws (3) other vehicles apart from (1) and (2) or motorcycles. Basic the speed limit in community zones should comply with Road Safety Thailand as shown in Table 2 and mentioned in section 1.2 (The Relation of Speed and Traffic Accidents**)** where community expansion results in population nearing the speed limit signs and the involved units do not move the signs causing the unawareness of drivers who drive with certain speed before entering community zones where traffic is heavier which could lead to serious accidents. Moreover, there is still no method to specify transition zones in Thailand. Minimum distance before entering the community zone with specific transition zones would reduce any unnecessary confusion of how fast a driver should drive. The recommended speed should be limited between 30 – 80 km./hr. and distance before changing speed should be between 300 – 800 meters.

Figure 4 showed that before entering the community zone, at 85th percentile drivers drive faster than 80 km./her. And at 50th percentile they drive at 70 km./hr. which is considered very high as shown in the area with low density. When considered the continuity in the transition zone when the driver is driving at 80 km/hr, it takes 800 meters. We can see that the transition zone is exactly where

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population density is low. This is helpful and can remove any unnecessary confusion regarding various speed needed on the same road with somewhat short intervals.

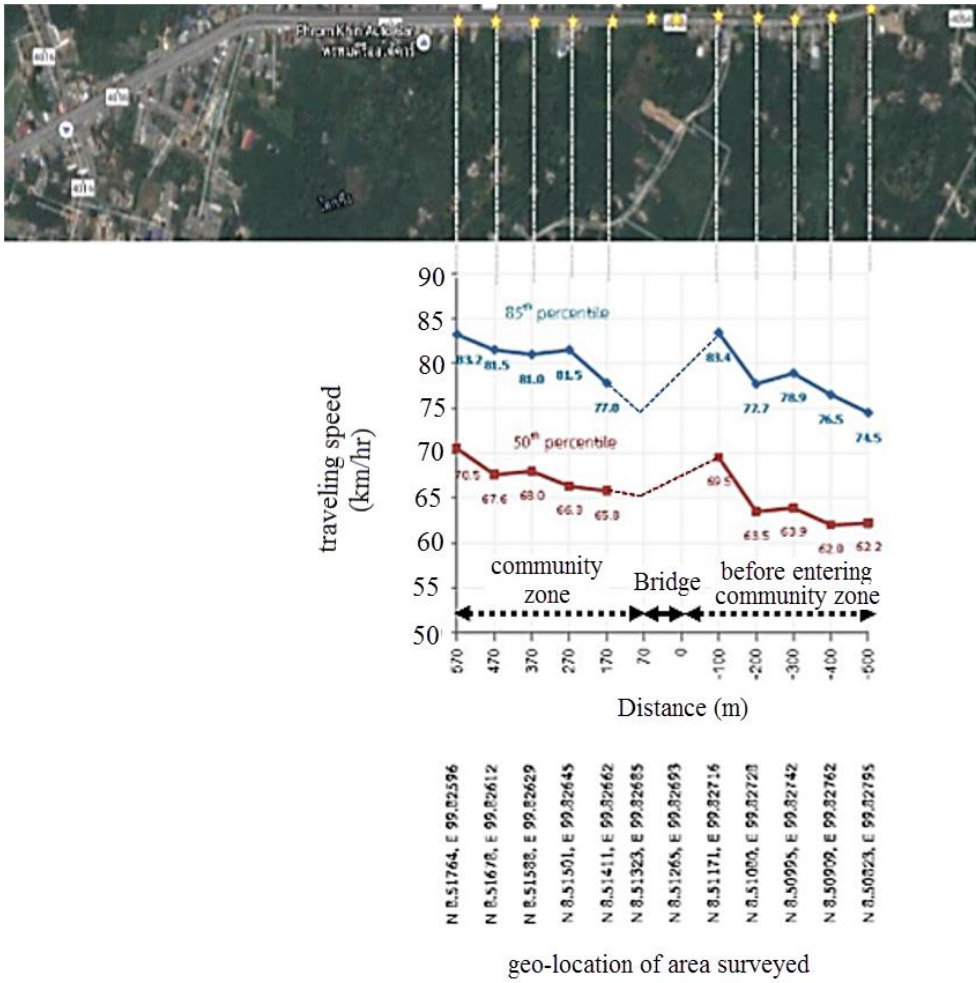

Figure 4 Speed survey on highway no.4016 before entering Nok Tah community, Nakorn Srithammarat (Piti et al, 2016)

3. SPEED LIMIT USING DECISION-MAKING THEORY

Results from the study above showed that this information is relevant. Some minor details need to be amended according to the guideline of Road Safety Thailand. Committees meetings will be held to come up with "a guideline for community zone the speed limit management". According to the guideline of the speed limit in city zones and municipal areas established by WHO and Thai Road Foundation using road risk method, community characteristics assessment tools for the speed limit using decision-making theory can be developed as follow:

3.1 STEP 1: BASIC THE SPEED LIMIT

This is by types of vehicles and physical characteristics of roads. A table with details of such a relationship is created in compliance with "guideline of community zone the speed limit management" established by Road Safety Thailand. According to the said guideline, drivers driving in the low-density area are allowed to use the same speed and the only difference is types of vehicles. Regarding physical characteristics of roads, we used the table as recommended by Safety Road

Thailand with different description but we are still communicating the same messages. Each table consists of 4 characteristics. Basic the speed limit set by the relation of vehicles and physical characteristics of roads is the first speed before using road risk method. The Decision tree is used for better understanding of involved personnel or committees who will be making the decision of appropriate speed in community zones.

Table 2: Basic the speed limit by the relation of types of vehicles and physical characteristics of roads

The physical characteristic of roads	The speed limit in the community zone (Bangkok, Pattaya, or municipal areas) not exceed (km./hr.)					
	Type 1 Trucks with a total weight over 1,200 kg. or with passengers		Type 2 Other vehicles apart from 1 with trailers, cars with a total weight over 1,200 kg. or auto-rickshaws		Type 3 Other vehicles apart from 1 and 2 or motorcycles	
	Refer to the Road Traffic Act B.E.2522	Basic speed	Refer to the Road Traffic Act B.E.2522	Basic speed	Refer to the Road Traffic Act B.E.2522	Basic speed
2 lanes	60	40	45	40	80	40
4 lanes (without traffic island)	60	50	45	45	80	50
4 lanes (with traffic island)	60	50	45	45	80	50
More than 4 lanes	60	60	45	45	80	60

When considered the relation of basic speed and road physical characteristics according to 3.2.2 in 2) to 4), we found that certain speed is chosen due to on-street parking. For example, the 4 lane road without traffic island and the left lane is occupied is considered two-way 2 lane road as shown in Table 2. For highways with partial traffic control with a frontage road, the consideration is made according to Table 2 as well but the main road and frontage road should be considered separately. Main roads with no more than 3 entrances and exits to frontage road per 1 kilometer are subject to add speed control value at 10 kilometer per hour. This is the consideration made for the transition zone, not the way to increase speed in this study. Therefore, to choose the speed in this step, we can refer to Table 2.

3.2 STEP 2: FINDING AN APPROPRIATE THE SPEED LIMIT

After basic speed is chosen, we then use the road risk method to assess communities that need appropriate the speed limit. This method has been adjusted to fit risk factors of the actual driving environment in order to find appropriate speed. Adjustment is made according to Decision Tree as in Figure 5.

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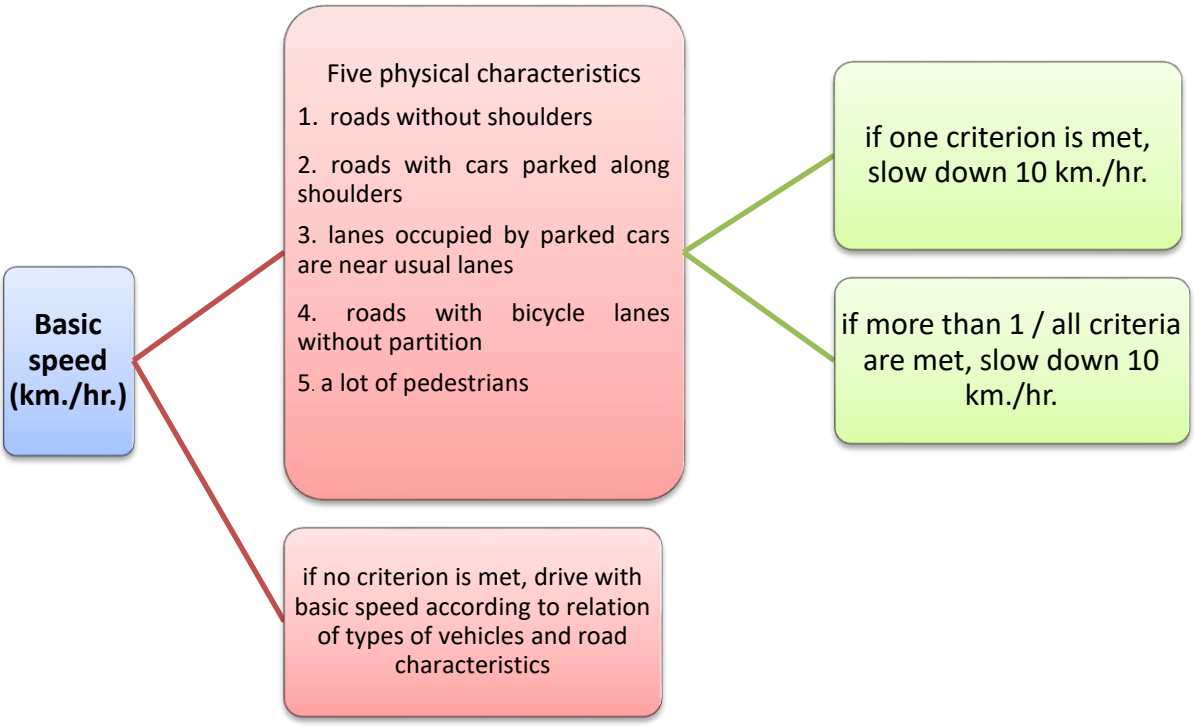

Figure 5 Decision tree to find appropriate speed

In the WHO's "guideline for the speed limit in city zones and municipal areas" Section 3.2.3 in 2) to 4) has been used as the criterion to choose road characteristics in step 1 in order to set basic speed. After that, we assessed the physical characteristics of the roads and the use of road shoulders. If one of the criterions is met, the appropriate speed will be decreased by 10 km./hr. If no criterion is met, the appropriate speed is similar to basic speed.

The development of assessment tools is made by guideline established by Road Safety Thailand and WHO. We adjusted basic speed according to the Road Traffic Act B.E. 2522. We incorporated the road risk method to assess the communities that need the appropriate speed limit. However, regarding the distance needed to change speed, we have adapted our past studies in the area with low population density, i.e. the transition zones are assigned before community zones. Regarding the development of the speed limit guideline to be submitted to Road Traffic Management Sub-committee, a certain adjustment is needed to accommodate guideline of Road Safety Thailand. This includes 1) needs of people or community leaders 2) data from private organizations or academic offices that identify the needs of the speed limit in community 3) suggestions from Provincial Road Safety 4) needs of landowners where signs must be put up. All these would bring success to the speed limit in a concrete way.

4. IMPLEMENTATION AND COMMUNITY ASSESSMENT FOR APPROPRIATE SPEED LIMIT

The development of community assessment tools is to adopt the established guideline by Road Safety Thailand the suggestions from WHO. Basic speed is adjusted under the Road Traffic Act B.E.2522. We incorporated the road risk method to assess communities that need an appropriate speed limit. Transition zones in the past studies have been adopted in areas with low population

density, i.e. these areas are assigned as transition zones. The development of guideline to be submitted to the sub-committee needs additional guideline to comply with Road Safety Thailand which includes 1) needs of people or community leaders 2) data from private organizations or academic offices that identify the needs of the speed limit in community 3) suggestions from Provincial Road Safety 4) needs of landowners where signs must be put up as shown in the appendix.

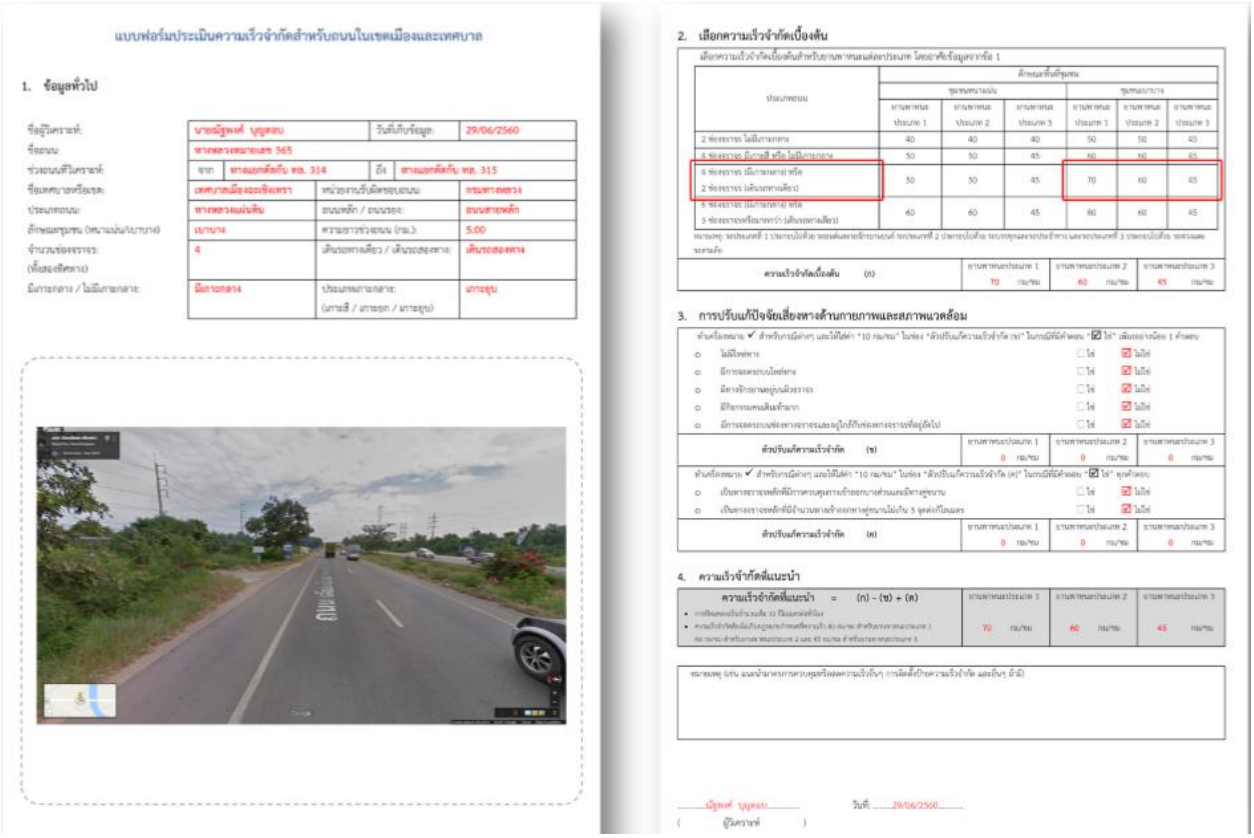

Figure 6 speed evaluation for Highway no.356, Thailand.

To fill out the form, start first with part 1 which is general information of the analyzing person, date, responsible office, population density, distance, and traffic characteristics. These data will be used for the speed limit according to physical characteristics of roads and to make sure the limited speed is in accordance with basic speed table. Basic speed according to types of vehicle will then be filled out. Please note that types of vehicles categorized by the speed limit in city zones and municipal areas manual are different from that stated in the Road Traffic Act B.E.2522. After part 2 of the form is filled out, adjust the speed lower according to the five criteria of road characteristics as you can see in part 3. Highway 356 does not have any characteristics that meet the criterion, so drivers here are allowed to use basic speed as shown in figure 6. Thai Road Foundation has analyzed characteristics of communities and roads and now they have come up with a network of municipal roads. Characteristics of roads can be defined by how the land is used, but we all know that in a community there exist many buildings such as government offices, houses, business areas, shopping malls, all of which need a road network. The speed limiting using this network could lead

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to appropriate speed despite the intervals.

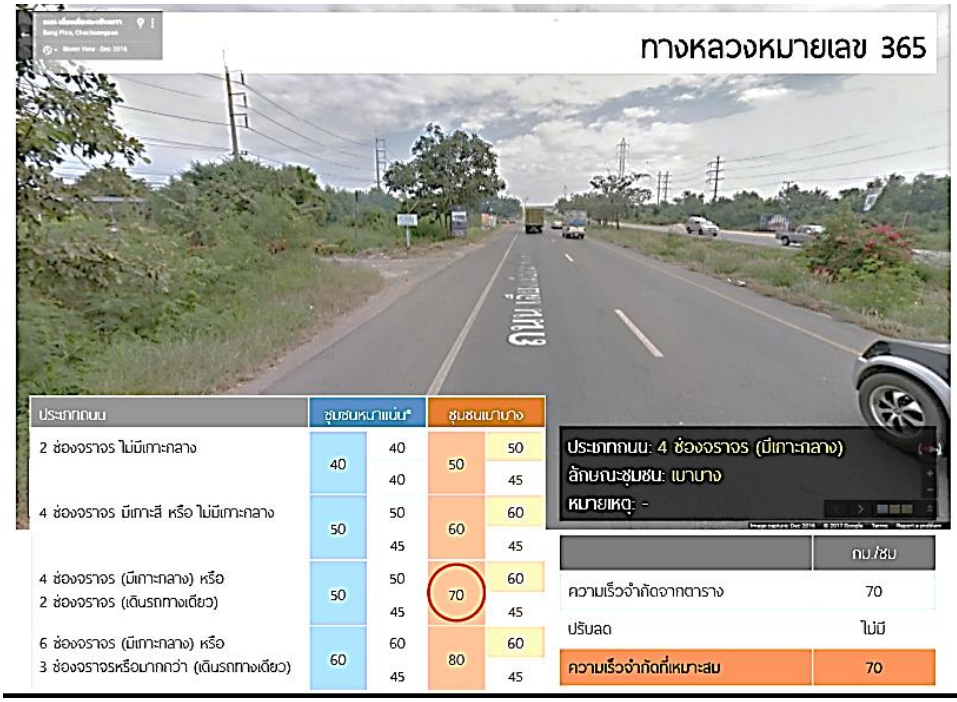

Figure 7 the last step of the speed limit of highway no.356

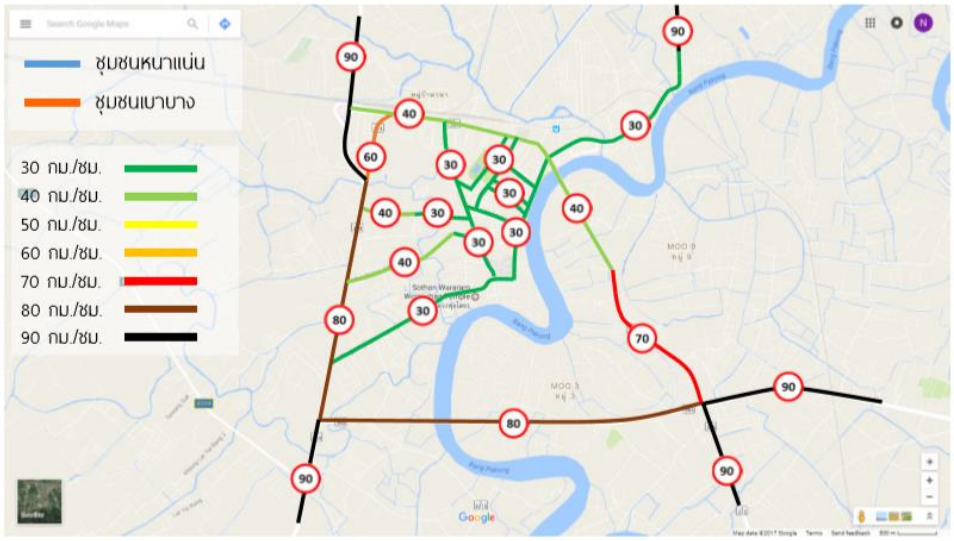

Figure 8 last result of the appropriate speed limit of a road network

Characteristics of communities and roads could help us choose the appropriate speed as shown in figure 8 which shows a road network.

The operation of the Provincial Disaster Prevention and Mitigation to present data and needs that will be submitted to the land traffic management sub-committee is a part of how Road Safety Thailand is moving forward. The Development of Community Characteristics Assessment Tools for The speed limit using Decision Making Theory. The development of this assessment tool was also discussed in the meeting of the Road Safety Thailand committee in order to come up with a "guideline of community areas the speed limit management". The development of this tool is also by

"guideline of the speed limit in city zones and municipal areas" established by WHO and Thai Road Safety where road risk method is incorporated. The decision tree has been chosen as a way to make a systematic decision.

5. CONCLUSION

The Study, review, and implementation have been done in Chachoengsao province. We have developed a community assessment for the speed limit using decision-making theory. Our study will be submitted to road traffic sub-committee for further consideration. This then will become a procedure taken by traffic police to limit vehicle speed in community zones. However, 4 points to be considered include 1) needs of people or community leaders 2) data from private organizations or academic offices that identify the needs of the speed limit in community 3) suggestions from Provincial Road Safety 4) needs of the landowners where signs must be put up such as within the industrial estate area.

Certain adjustments have been made within the frame of the established guideline such as "the speed limit management in community zones" and "guideline for the speed limit in city zones and municipal areas" established by WHO and Thai Road Foundation. Road risk method has been incorporated to develop the community assessment tool. The adjustment results in some differences as follow:

- Categorization of vehicle types that lead to the basic speed limit but still within the regulation of Road Safety Thailand and Road Traffic Act B.E.2552
- Speed table has been adjusted according to the basic speed but still within the regulation of guideline for the speed limit in city zones and municipal areas established by WHO and Thai Road Foundation
- Certain areas with less population density have been assigned as transition zones. This is done by researches and facts.
- Deceleration adjustment using the road risk method is helpful when developing a community assessment tool. We also used the decision tree as a tool for deceleration criterion until the appropriate speed is reached.

Our operation includes another 4 points to be considered which is important for decision making. Furthermore, another step we have taken is to organize a training program regarding the speed limit. This is a way to support the work of Disaster Prevention and Mitigation where the secretary of Road Safety Thailand can take part.

No matter what the cause is, the severity of road accidents always involves speeding. Solving the speeding problem is very important to minimize the number of deaths from road accidents. Road Safety Thailand pays so much attention to this matter and the implementation of such a solution should be done as soon as possible. We have studied, reviewed academic literature, and with our past professional experience and found that problems of road accidents cannot be solved by each party separately and there is no specific step of operation due to the total difference of each area and

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management of each province. Road accidents problems should be solved by the utility. What has been done is beneficial to what will be done next. To limit speed in community zones, we should pay attention to various areas not only the highways as stated in Highway Act B.E. 2535. We should keep in mind that big villages, industrial estates, or some government offices take up a lot of space such as military camps or hospitals. The areas where these offices are located should be included also when considering the speed limit.

Lastly, communities, people, and leaders of the community should be aware of the speed limit within their communities, not only traffic officers. Paying attention to the speed limit management is important to minimize the number of accidents in their severity in community zones.

6. AVAILABILITY OF DATA AND MATERIAL

Data is used or generated from this study is available upon request to the corresponding author.

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