Inception Report

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ASIAN TRANSPORTATION RESEARCH SOCIETY

An Optimized Design of Roundabout for Safety Enhancement on Road Users: A Case Study of Suranaree University of Technology

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List of Abbreviations and Acronyms

ATRANS	Asian Transportation Research Society
SUT	Suranaree University of Technology
UAV	Unmanned aerial vehicle
MC	Motorcycle
PC	Passenger car

CHAPTER I INTRODUCTION

1.1 Statement of problems

Nakhon Ratchasima is the biggest third province, in terms of number of populations, in Thailand. The province is a main corridor connecting between the capital of Thailand, Bangkok, and the Northeast provinces. In addition, there are several major trip attractions, for example, universities, schools, hospitals, department stores, located in the urban area. As a result, Nakhon Ratchasima has encountered with either highly traffic movement or traffic congestion problem. This high traffic or congestion problem tends to increase the potential risk of road traffic crashes. Thus, the suitable traffic operational and control is one of the major keys that can be able to improve road safety and traffic congestion problems. Moreover, safety knowledge and awareness of all road users are basic to properly run traffic network safely and securely.

Implementation of roundabout is the concept to move traffic more efficiently through unsignalized intersections which has evolved from conventional traffic circles to modern roundabout. Give way when entering or driving in a roundabout to any vehicle in the roundabout is the international rule and the most important rule. Moreover, the other configurations should also emphasize which are optimization design, traffic sign, pavement markings, regulation, and education of road users.

However, many roundabouts implemented in Nakhon Ratchasima are doubted in either optimization design or well-educated road users. Especially, the roundabout has been installed to reduce the conflicts in front of the Suranaree University of Technology (SUT) main gate, as shown in Figure 1. Most of the road users are students who are beginner or intermediate level in motorcycle riding or car driving. Also, some riders may not be conscious during using the roundabout. Some may not understand how to use the roundabout. Moreover, unappropriated design may lead to misunderstand of the riders and drivers. As a result, road crashes at this roundabout have been happened since the roundabout was implemented.

Figure 1 Overview of existing roundabout at Suranaree University of Technology gate

Figure 2 Vehicle entering in safe area of existing roundabout

1.2 Research objectives

Based on the concept of safe road system (Figure 3), this study aims at fulfilling the gaps of safe road and roadside by improving the physical design of roundabout, and safe road users by educating a basic knowledge of rider safety in roundabouts. The roundabout at SUT main gate is selected as a case study. Two specific objectives of this research are as follows:

1) To optimize the physical design of roundabout based on both traffic safety (low severity) and traffic management (low delay).

2) To educate a basic knowledge of rider safety in roundabouts to the undergraduate SUT students.

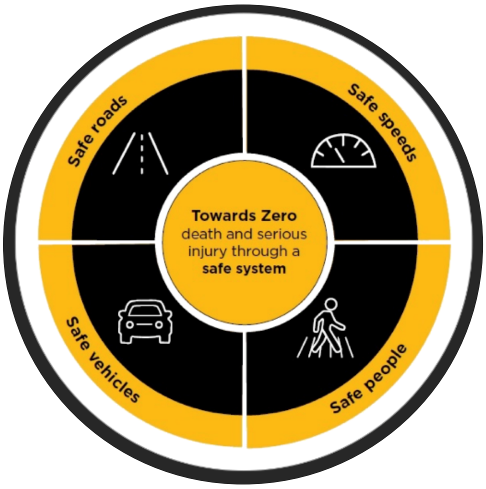


Figure 3 The safe road system
Source: towardszero.nsw.gov.au

1.3 Expected outputs

The expected outcomes are the optimal design of the case study roundabout by integrating both international guidelines and local road users' behavior. Also, this research work will provide the essential international idea of using roundabout or the concept of using roundabout which will be educated to the freshman students. The research results can be evidently useful to not only the SUT area but also other upcoming roundabouts in other areas.

CHAPTER 2 LITERATURE REVIEW

2.1 Roundabout design standards and guidelines

Implementation of roundabouts is the concept to move traffic more efficiently through un-signalized intersections which has evolved from conventional traffic circles. Giving way when entering or driving in a roundabout to any vehicle in the roundabout is the international rule and most importance. Also taking the collect lane during driving in roundabout must pay attention to eliminate the conflict for safety issues. Designing the geometry of a roundabout involves choosing between trade-offs of safety and capacity. Roundabouts operate most safely when their geometry forces traffic to enter and circulate at slow speeds. Many of the design techniques and parameters are different, depending on the speed environment and desired capacity at individual sites. Additionally, many of the design techniques are substantially different for single-lane roundabouts than for roundabouts with multiple entry lanes. Moreover, the others configurations should also concern emphasize those are optimization design, traffic information sign, pavement marking, regulation policy and educated people. Some existing implemented roundabouts are doubt about the design whether not cover all following standard. Moreover, there is no performance and safety assessment during its operation according to the information guide procedure Figure 4 [1].

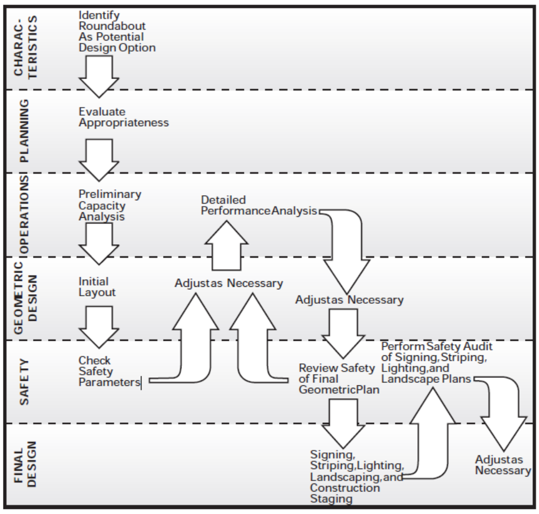


Figure 4 A roundabout information guild procedure

Roundabouts rely upon two basic and important operating principles which are Speed reduction and the yield-at-entry rule. Thus, sight distance is a fundamental consideration for intersection design. There are two types of sight distance that apply to roundabouts: Stopping sight distance must be provided for users approaching the roundabout and for users traveling through the roundabout. Intersection sight distance, sometimes called "sight triangles" must be provided for drivers entering the roundabout Figure 5 [2].

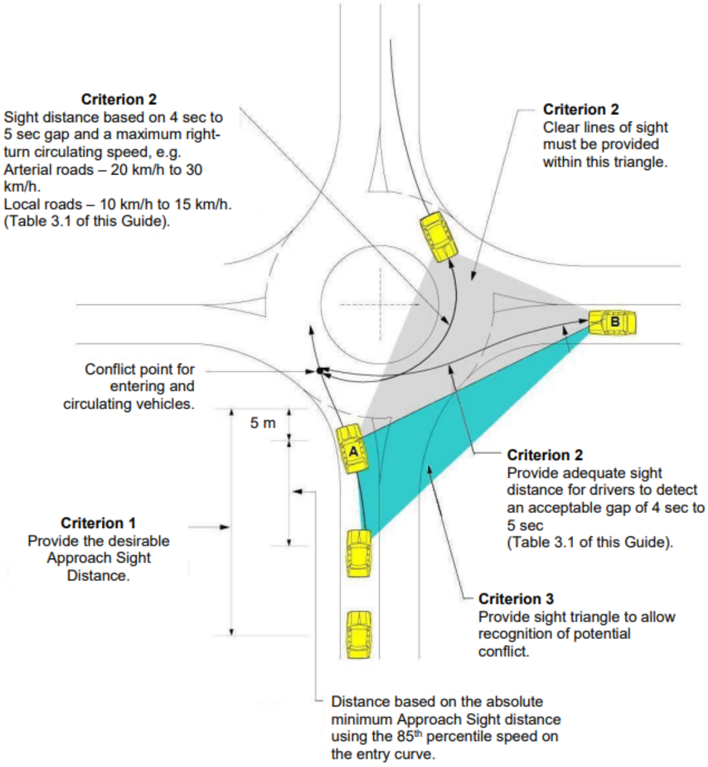


Figure 5 Sight distance criteria for roundabouts

Moreover, the roundabout lane configuration example standard and line marking of multi-lane roundabout are also emphasize concern in Figure 6 [2,3]. Some countries in Europe has proposed the priority lane for bike users as separate the bike lane adjacent the cycle lane, providing some exclusive path separate for bike lanes and providing full exclusive bike lane shown in Figure 7.

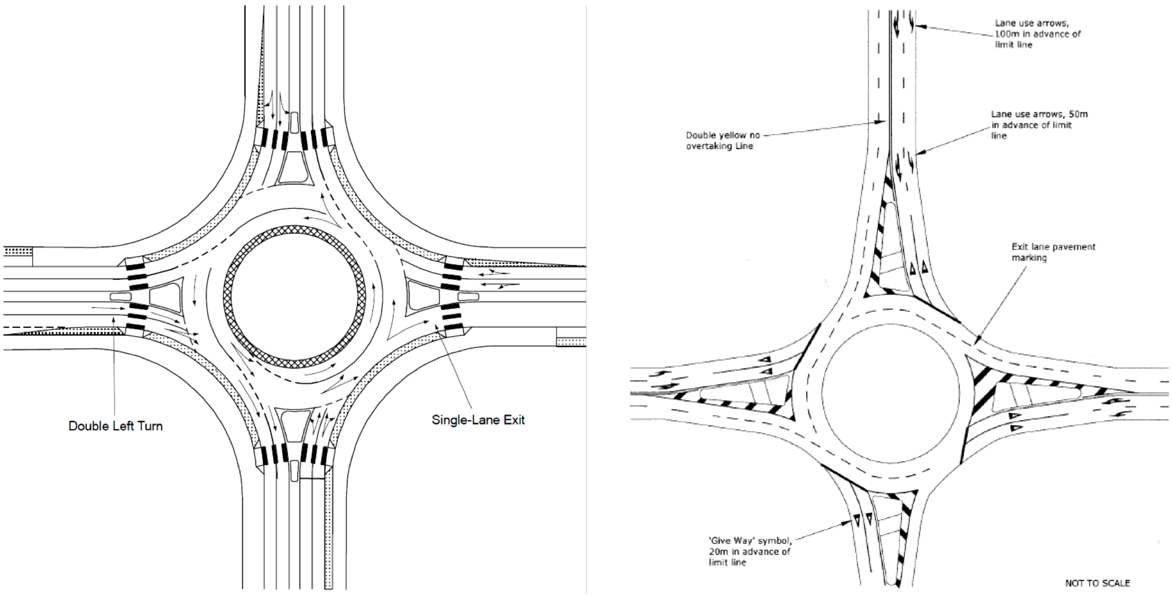


Figure 6 Roundabout lane configuration example standard and line marking of multi-lane roundabout

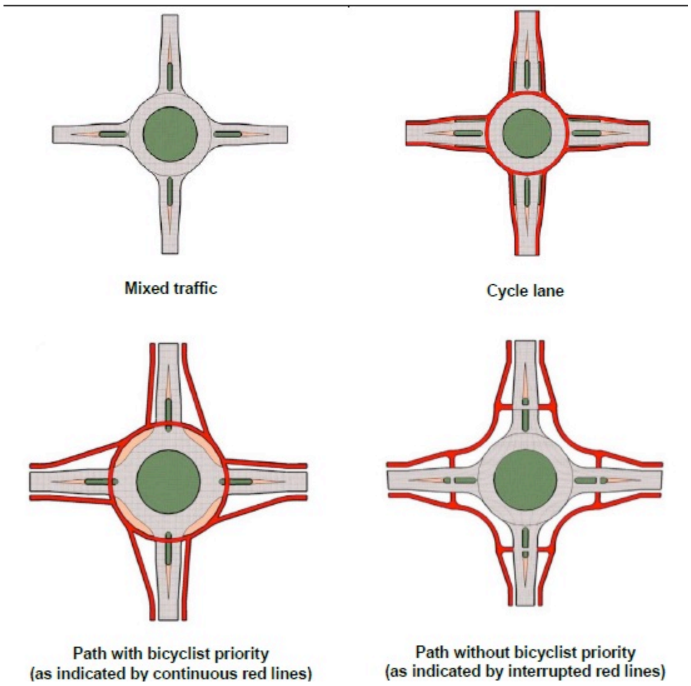


Figure 7 Roundabouts with bike lanes

2.2 Good practices of roundabout from international and national perspectives

In the national press, it was dubbed a "£2.3m 'cyclist killing zone'", while one columnist argued it would "only intensify the war between cyclists and drivers". The Fendon Road roundabout is the UK's first and so-far-only so-called "Dutch-style" roundabout are situated near Addenbrooke's and Papworth hospitals shown in Figure 8. This was built by the county council (opened July 2020) in an attempt to improve the safety of its predecessor, which had seen 12 collisions between cars and cyclists between 2012 and 2017. Cyclists have an outer ring on the Cambridge roundabout, with cycle crossings over each of the four approach roads in a contrasting red surface. There are also zebra crossings over each approach road for pedestrians. Motorists must give way to pedestrians and cyclists when joining and leaving the roundabout. Reduced lane widths on the roundabout and at exit and entry points are designed to encourage drivers to slow down.

Figure 8 Good example of roundabouts with bike lane
Source: BBC news

2.3 New technologies for traffic data collection and analysis

Recently, an unmanned aerial vehicle (UAV) have increasing involve to collect the traffic data. This technology can be benefit seeing from the top view together with image processing analysis, the traffic flow trajectory can be tracked on.

Figure 9 An unmanned aerial vehicle UAV (drone) technology
Source: https://www.youtube.com/watch?v=sswTaiNzKlo

2.4 Artificial intelligence for traffic data analysis

New technologies related to artificial intelligence will be reviewed and applied to develop the algorithm for traffic data analysis.

CHAPTER 3 METHODOLOGY

3.1 Research framework

The research framework consists of 7 tasks as shown in

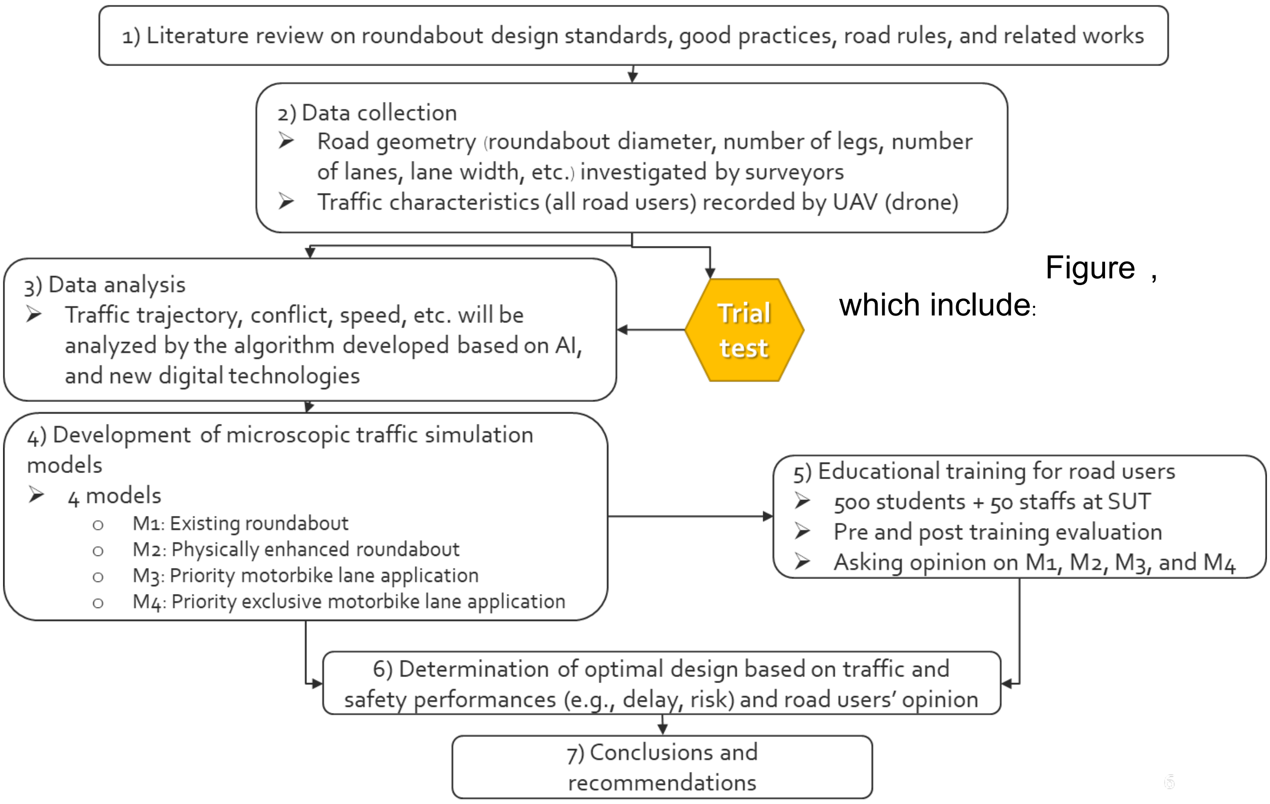


Figure , which include:

Figure 10 Research Framework

3.2 Literature review

Chauhan [4] propose the traffic flow simulation at Malhar circle, India by using VISSIM to recognize zone of influence through acceleration and deceleration activities of vehicle to generate the pollution amount. Unmanned Aerial Vehicle-based Traffic Analysis [5] used to similarly apply once at roundabout to observe the trajectory however, the results determine traffic volume via OD metrics for each leg and analyze driver behavior via gap acceptation analysis. Paul [6] introduces the methodology being developed for the detailed analysis of driving behavior, trajectory interpretation, and conflict measures in modern North American roundabouts. The analysis explores the methods used to prepare microscopic speed maps, compiled speed profiles, lane-change counts, and gap time measures. However, the collection data is based on video data which extracted by means of computer vision. Dinh [7] propose an automated traffic data collection system dedicated to roundabout, resulting vehicle trajectory of each individual vehicle gives the position, size, shape and speed of the vehicle at each time moment. Therefore, this study would like to fill the gap to consider more deeply of direction trajectory angle analysis of lane changing in roundabout by recent popular drone application. Then, using this to further improve the physical element design of roundabout for road user.

Now the drone is popular in the transportation files because its low cost, low maintenance, flexible design, small size, high mobility, and adaptability [8]. The image from the drones are equipped with a camera to collect the visual information of the environment, and then, computer vision techniques have been used to extract the information of the environment as post image analysis. This information can be used to analyze the information of the traffic. Many researchers proposed many methods to analyze the information of the traffic by using the computer vision technique with the image from the drone. An analysis of the images from the drone in transportation field have been implemented in the road safety [9], traffic monitoring and surveying [10], highway infrastructure management [9], etc. [11,12].

The detection algorithm is the main part algorithm for the drone traffic monitoring and surveying systems. The well-known detection algorithms are CNN [13], Fast R-CNN [14], YOLO [15, 16], etc. [17-19]. If the surveying area isn't too large, only one drone can be used for traffic monitoring. Barmpounakis [20] used one drone to measuring the accuracy of the microscopic traffic parameter. In addition, the basic analysis parameter from the drone could be used to analyze the prediction of the traffic. Yu [21] use the traffic data from the drone to predict the trajectory data of freeway high-risk events. In some case, only one drone cannot be use for traffic monitoring because the drone must be survey with very large area. So, the survey drone trajectory management must be developed. Shi [22] proposed a hierarchical DRL approach for multiple drone surveying trajectory management system. Conte [23] used a machine-learning-based prediction for drone planning path. Nguyen [24] proposed an autonomous drone flight trajectory system for a traffic management in smart city. The traffic data from the multiple drone also very useful for traffic monitoring and management. Barmpounakis [25] use 10 to record the 1.3 km2 area with more than 100 km-lanes and around 100 busy intersection of road network. Kumar [26] developed the software for on-road traffic monitoring and management using the traffic data from the multiple drones.

3.3 Data collection

All related traffic parameters and physical road data such as roundabout diameter, number of legs, number of lanes, lane width right of way, decision variables, constraints, etc. Also, preliminary survey of the study area will be conducted.

The existing traffic circumstance will be further investigated by surveying on the traffic parameters and the traffic measurement which are the frequency of traffic trajectory violence on lane marking and driving speed. A method for deriving traffic information in the roundabout using a camera installed on the unmanned aircraft vehicle (UAV or shortly called drone) will be proposed. The method will apply a machine-learning-based approach for image processing by vehicle detection, vehicle type classification and trajectory tracking. Then the optimization will be performed.

Aerial video surveillance using a wide field-of-view sensor will be applied to provide new opportunities in traffic monitoring over such extensive areas. In fact, an UAV equipped with automatic position stabilization units and high-resolution cameras could be the most effective choice for data acquisition in sufficient quality. UAVs, unlike satellites or airplanes, can collect visual data from low altitudes, and therefore provide images with adequate spatial resolution for further traffic inspection, i.e., vehicle detection and tracking.

Traffic data were recorded at evening peak hour on Friday in every 15 minute. Figure 11 shown the driving behavior whether drivers concern drive on appropriate lane for safety or not. Several cars and motorcycles are driving on truck apron area which is not their driving lane. This leads the unappropriated directional angle that can be control for approaching speed. The approaching speed will be investigated as one of the factor designing.

Figure 11-1 Driving behavior of passenger cars

Figure 11-1 Driving behavior of motorcycles

Figure 11 Driving behavior approaching to roundabout

3.4 Data analysis

Traffic trajectory which are concerned as tracking multiple vehicles will be investigated to obtain detailed and accurate information about the vehicles' trajectories during their passage through the roundabout. The visual data for the analysis will be captured by a camera mounted on an UAV. The operating time of a UAV is about 15 minutes due to its limitation of battery capacity. The data will be recorded in a memory card and subsequently post-processed on a high-performance computer.

Object detection algorithms will be developed pre-trained models and then fine-tune them as per our requirements. Generally, the object detection task is carried out in two steps:

1) Generates the small segments in the input.

2) Feature extraction is carried out for each segmented rectangular area to predict whether the rectangle contains a valid object.

Analyze the safety level based on the traffic trajectory that vary from the lane marking guideline and the safety distance between adjacent cars are concerned. The conceptual idea is to use the angle collision avoidance and lane-changing base for safety. The Safety Performance Evaluation Standard for Highway Fences (2013) have stated this angle should be less than 20 degrees, which is in accordance with the study of Yang [27] indicated that the angle during lane-changing is less than 23 degree and safety distance between adjacent cars 2 meters. Simultaneously, an education content design based on the current problems and international guidelines (the details will be explained in step 5).

3.5 Development of algorithm for traffic data analysis

The machine learning algorithm can track vehicles in multilevel roads. This can track all the vehicles even when the visual occlusion appears. Also can follow the whole trajectory of the car for the tracked time and collect reliable data which are average speed, acceleration, gap-time, time to follow, heatmaps or dimensions of vehicles. To track those vehicles can link to our research as this can see the directional driving between adjacent vehicles.

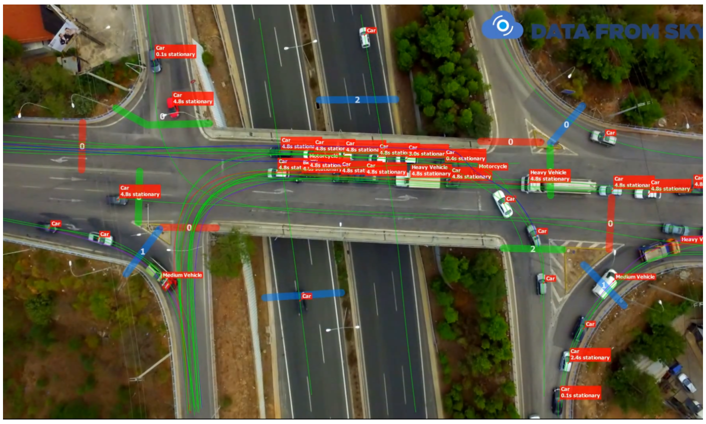
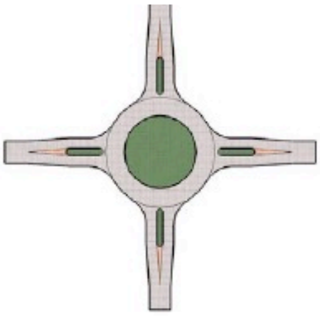


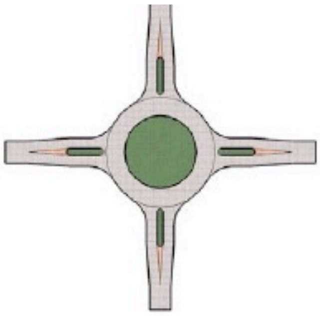
Figure 12 A vehicle tracking algorithm

3.6 Development of microscopic traffic simulation models

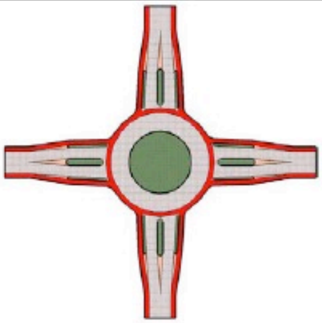
There are 4 potential models will be developed covering for all vehicles. Firstly, the existing roundabout will be simulated as the based model, Model 1. Secondly, the physically enhanced roundabout will be developed as Model 2. Lastly, the concept of giving the priority lane to separate the mixed traffic will be applied as Model 3 and Model 4. Both models provide the priority lane for motorbike however, one provides the same level separate and another one provide the exclusive motorbike lane.



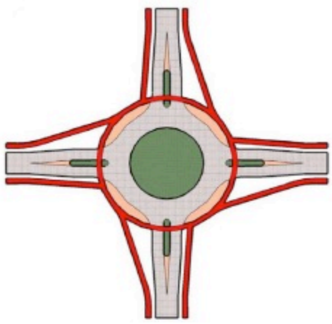
Model 1
Existing roundabout



Model 2
Physically enhanced roundabout



Model 3
Priority motorbike lane application



Model 4
Priority exclusive motorbike lane application

Figure 13 Microscopic traffic simulation potential models

Each of potential model will be simulated according to the different traffic flow rates between MC and PC (Figure 14) to investigate the traffic and safety performances (e.g., delay, conflicts, speeds)

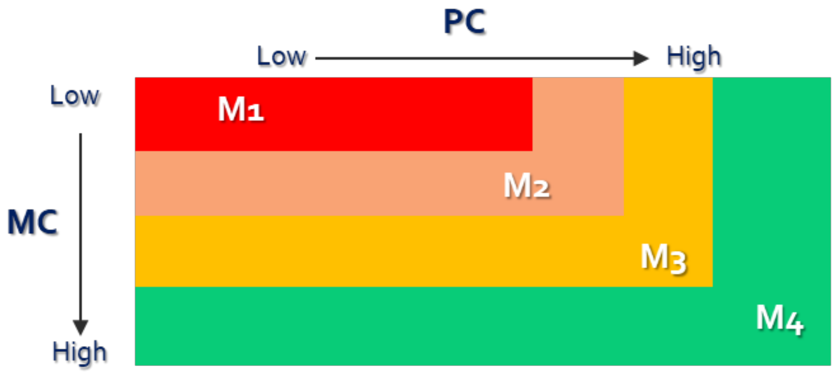


Figure 14 Varying traffic flow rate between MC and PC

3.7 Roundabout Education training

This section will be started after the simulation models are performed. This training aims to educate the roundabout users to improve their driving in the international ways and rising their driving skills. First step is to promote the public relation to SUT students and staffs who using the roundabout at SUT. The Pre-test is introduced to evaluate their basic knowledge of using roundabout before training process is started. Roundabout training program consist of reviewing on the existing situation whether how crash risks can be possible occurred. Next, the overview of international rules using roundabout and the safety parameters are demonstrated to all road users. Then, discussion on the existing roundabout and possible solutions for safer roundabout are presented. Post-test to evaluate the knowledge after the training is operated after finish training. Provide the training and instructions for safe roundabout using to at least 500 SUT undergraduate students. Students' basic knowledge on using roundabout before and after the training will be evaluated using the paper-based test. Finally, asking the road users' opinion on different types of roundabout (M1, M2, M3, M4) will be operated.

3.8 Optimized design of roundabout

Select the parameters and variables to generate the objective function of optimal roundabout design problem. The evolutionary algorithm (EA) will be applied to develop the algorithm for solving the proposed optimal design problem.

Evolutionary algorithm was proposed by Goldberg and Holland (1988). This algorithm technic has been widely used to solve optimization problems. It can solve a wide range of problems, including some that no other existing optimization methods can solve. Initially, several feasible solutions are randomly selected. Then, the number of solutions is selected by the user, and the random solutions are called the first generation. Candidate solutions can be created for the second generation using the following three steps:

1) Evaluation: The first generation is evaluated using an objective function.

2) Crossover: Based on an evaluation process, two of its solutions in the generation are selected as parents. We create two new solutions by combining these choices. We continue this crossover process until we obtain as

many solutions as in the first generation.

3) Mutation: We randomly select a small portion of the solutions obtained by the crossover process and slightly modify them.

This study particularly focuses on finding the optimal roundabout design based on traffic trajectory which can be related to the existing design, driving behavior and speed. The traffic controls and roundabout elements will be designed to maximize the traffic safety level in the roundabout. The optimal features of the roundabout obtained from step 6) will be used to estimate the traffic characteristics (e.g., traffic flow, travel time, delay) and safety issues (conflicting movement, speeding) by applying traffic micro-simulation model.

CHAPTER 4 RESEARCH PLAN AND BUDGET

4.1 Research plan

The research consists of 12 months and the details of research plan can be summarized in Table 1.

Table 1 The research work plan

Work process	Month											
	04	05	06	07	08	09	10	11	12	01	02	03
1. Reviewing on the existing studies of roundabout optimization design elements	■											
2. Surveying and Investigating the existing traffic circumstance on the traffic parameters and the traffic measurement		■	■	■								
3. Performing the model and applying the proposed roundabout design to the simulation model				■	■	■	■	■				
4. Providing the training and instructions of roundabout to the undergraduate students.							■	■	■			
5. Evaluating the students' knowledge of using roundabout pre- and post- trainings										■		
6. Report writing and presentation												
6.1 Inception report submission	■											
6.2 Progress report presentation			■									
6.3 Interim report presentation						■						
Interim report submission						■						
Final report presentation												■

4.2 Research budget

The research budget is mainly consisting of data collecting part and roundabout education training which describe in Table 2.

Table 2 The research budget notations

No	Description	Amount (Baht)
1	Project leader	36,000
2	Roundabout optimization activity	
	2.1 Expense for equipment calibration and data collection (200 baht/hour x 50 hours x 3 persons)	30,000
	2.2 Expense for export and fill with data in the form (200 baht/hour x 50 hours x 2 persons)	20,000
	2.3 Expense for data analysis, model simulation and optimization (200 baht/hour x 150 hours x 3 persons)	90,000
	2.4 Research assistance for roundabout model report (200 baht/hour x 50 hours x 3 persons)	10,000
3	Safety riding in roundabout training	
	3.1 Participant meal (60 baht/person x 500 students)	30,000
	3.2 Education training poster and materials	20,000
	3.3 Questionnaire material (20 baht/copy x 500 copies)	10,000
	3.4 Expense of pre-educating questionnaire survey (100 baht/sample x 500 students)	50,000
	3.5 Expense of post-educating questionnaire surveying (100 baht/sample x 500 students)	50,000
	3.6 Research assistance during the training (200 baht/hour x 80 hours x 1 persons)	16,000
	3.7 Research assistance for evaluating the student's knowledge pre- and post- education (200 baht/hour x 100 hours x 2 person)	40,000
4	Travel expenses for research meeting and site investigation	25,000
5	Stationery and office supply	10,000
6	Secretariat's participation portion	10,000
7	Publishing proportion of the report book	50,000
Total	**Four hundred ninety-seven thousand Baht**	**497,000**

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