Estimating Public Transportation Demand for Nakhon Ratchasima, Thailand

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***Abstract*—Nakhon Ratchasima was one of the two cities selected by German International Cooperation (GIZ) and Thailand's Pollution Control Department (PCD) to develop a draft of activities toward a Clean Air Plan. Identified as one of the most crucial source of pollution, traffic and transportation activities became one of the main focal points in this study. Focusing on promoting the use of public transportation, the study team investigated service characteristics, quality, ridership and trends in mode share in Greater Nakhon Ratchasima. It identified the role of public transport relative to other modes and current trends in mode share. This paper presents survey techniques with limited staff and time resource in survey and rational estimation. Against the operators' low ridership claim, the study team estimated rather promising passenger volume that could support decent quality public transport. The strengths and weaknesses of the current system were highlighted along with data gaps. The study team proposed a comprehensive but indicative range of practical short term public transport improvement and complementary options. Other supplement transportation management plan were also developed including traffic direction and parking regulations. The ending results would be reduction in travel time, pollution and energy consumption.**

***Index Terms*—public transportation, ridership survey, transit priority, transit demand estimation.**

I. Introduction

Nakhon Ratchasima (NR) was selected as one of the three ASEAN (Association of Southeast Asian Nations) Cities for independent expert review of the public transport systems along with Vientiane (PDR Laos) and Phnom Penh (Cambodia). This was a crucial part of a larger scope in an attempt to establish a "Clean Air for Smaller Cities in ASEAN" Program commissioned by German International Cooperation (GIZ) and Thailand's Pollution Control Department (PCD). As transportation demand continued to grow rapidly, it was identified as one of the major source of pollution. This transport study aimed to review existing situations and evaluate options for for public transport improvement, non-motorized priority, traffic management and parking control based on transport demand management concepts.

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A. City's Demographic and Land Use

Nakhon Ratchasima is the largest province of Thailand in term of area [1]. With 2.8 million registered residents, it is the second most populated province after Bangkok. Korat District or "Amphur Muang" has approximately 460,000 population, approximately 160,000 of whom are in the city municipality area, comprising slightly more female than male population. It was estimated that another 30% non-registered population also exist which would bring the total to approximately 220,000. The city municipality population has been fluctuating within the recent years.

NR municipal area comprises a variety of land use raging from old town, new commercial and industrial zones, dense and light residential zones, government offices, green reservation area and small agricultural zone in the north. Nakhon Ratchasima Comprehensive Plan (NRCP) [2] covered 314.30 square kilometers including all municipal area and parts of three other districts. Despite being regularly reviewed and updated, this land use plan usually facilitated horizontal expansion of the city rather than containing it. As a result the city suffered an urban sprawl effect which usually generated unnecessarily long journeys.

B. Transportation Network

The City of Nakhon Ratchasima is in a rectangular shape with its long axis in the East-West direction as shown in Fig. 1. An east-west major highway carried a large amount of internal and through traffic. It is connected with a well developed hierarchy of major and minor arterials, collectors and local streets. A bypass highway is located to the north and appears to be a catalyst land development towards the north and north east.

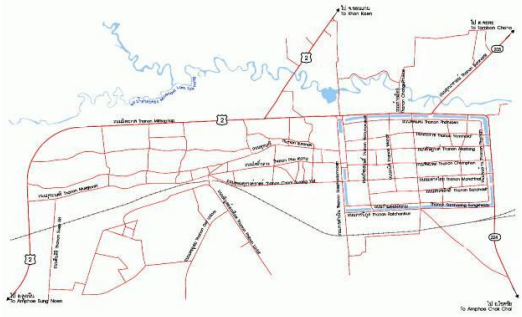

Figure 1. Nakhon ratchasima road network.

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Due to narrow street width, curb parking is allowed every other day alternately on both sides of most streets. On-street parking is always free of charge, contributing to parking overflow problem especially in the commercial area. Parking demand is so overwhelming that double parking, parking in no parking zone and illegal parking near an intersection are common scenes in downtown area. Government-owned and private-own parking lots are available and with minimal hourly charges, yet they cannot accommodate all parking demand.

C. Public Transportation and Paratransit

One can reasonably get around the city of Nakhon Ratchsima without having private motor transport. Major mode of fixed-route public transport is a special type of bus called "Song Thaew" which is practically a modified small pick-up truck for passengers (Fig. 2). Other hired transit including taxi, three-wheeled motorized vehicle or "tuk-tuk", motorcycle taxi and cyclo.

Figure 2. Nakhon ratchasima song thaew.

A total of 19 Urban "Type 1" routes are registered with the Provincial Office of Land Transport (POLT). All routes charge a flat rate of 8 baht, except two long routes which charge 15 baht. There are also a large number of longer distance "Type 4" services linking rural areas and smaller towns with NR Municipality.

The main focus of this study is on Type 1 bus services. Most route run on unifocal transit network [3] with Suranaree Monument as the center. It appears that some routes are operating with good profit and some are not. Main competitors other than private vehicles are Type 4 buses. Although their main purpose is to serve commuters between the city and rural area, their routes extend to serve the intracity trips. Passengers may choose to go with these 4xxx buses as an alternative if their "more appropriate" Type 1 bus services do not come. This presents challenges to Type 1 routes and fleet management in order to maintain their level of service.

Another concerned on operation problems is the internal management and control among permit holders and their "subcontractors". Most permit holders lease out their vehicles for individuals to drive and collect fares themselves. Several others even let third parties bring their own vehicle and run the operation, and some routes operate in the form of a loose co-op. Therefore the level of control authority among drivers is low and service quality (i.e., headway, running time and reliability) goes down as a result. In an attempt to solve this problem, POLT sets additional evaluation criteria that favors vehicle owners over leasers.

POLT's enforcement has always been relaxed nonetheless. Cancellation of any route is preferably avoided, as given groups of people may suffer from lack of public transport. POLT tries to encourage the operators to keep on operating unprofitable routes by allowing route or headway adjustment to match true demand, or via cross-subsidy from other routes. The last option is to truncate the route and keep only the profitable section. Despite such effort, recently two routes have been temporary out of operation. A few other lines have altered their routes, adopted split-route operation or cut their operation into sections to increase the benefit-cost ratio. Several studies from elsewhere showed headway variation [4] and punctuality [5] should be main measures to evaluate traffic performance

Public transport vehicles are required to go through inspection twice a year. However, the result of inspection primarily depends on an officer's judgment. There is no vehicle age specification in the permit or any other official documents. The vehicle standard tends to go down as the price of gasoline/diesel goes up.

The Provincial Department of Land Transport has, for the time being put a limit on the number of taxis at 80. This is presumably to ensure that there is a reasonable amount of business for each taxi, and, in the longer term, to encourage further investment in the taxi business. Most of them do not roam but station at taxi stands, intercity bus terminals and a shopping mall. Passengers starting a journey from other places must call to a dispatch centre to schedule a pick up. However, the system has a low reliability as taxis often fail to pick up passengers at the scheduled time.

Motorized three-wheelers or Tuk-Tuks are more plentiful. They gather around markets, bus terminals, train stations, shopping malls and communities. They charge on a lump sum price which is comparable or sometimes more expensive than the taxi fare. Their passengers' willingness-to-pay is the result from low taxi system reliability.

Motorcycle taxis are found mostly at the same places as tuk-tuks. They provide individual transport with faster and slightly cheaper service. They are known to be aggressive and sometimes dangerous, but are normally the quickest mode for those who are in a hurry.

Non-motorized tricycles or "cyclos" are available around the moat. Their customers are from the market and the vicinity who make short trips which sometimes can be as short as across the street. The fare ranges from 10 to 40 baht. Tricycles will not generally go far beyond the city centre.

D. Vehicle Ownership

Vehicle ownership in Nakhon Ratchasima has continually increased over the years. A 6-year historical

data from Nakhon Ratchasima Provincial Office of Land Transport shows a constant growth rate of 3% with an exception of 2006, the year where the motorcycle taxis were introduced, in which the growth rate skyrocketed to more than 13%. Table I shows cumulative registration record by the Provincial Office of Land Transport [6], and Fig. 3 shows the share of registered vehicle types in 2010.

TABLE I. CUMULATIVE VEHICLE REGISTRATION 2005-2010

Year	Total
2005	714,830
2006	810,675
2007	838,474
2008	867,182
2009	895,196
2010	938,180

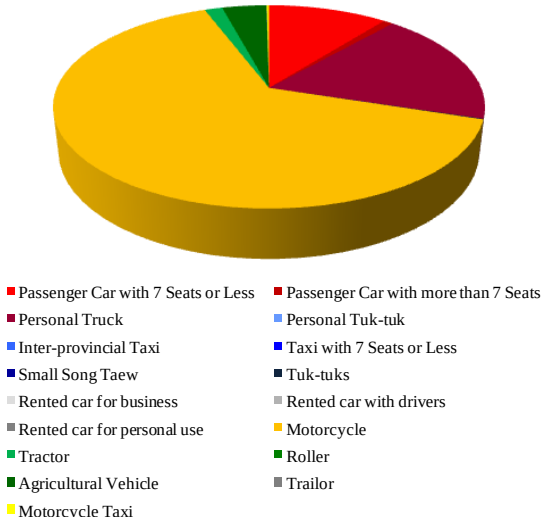

Figure 3. Distribution of registered vehicle types (year 2010)

Outnumbering all other vehicle types combined, Motorcycles have become a popular mode of transportation in most major provincial areas due to its fierce market competition with low down payments and affordable payment plans. These motorcycles give freedom and reliability of commuting to places at preferred time. Personal "pick up" trucks are simply utility vehicles that can transport more passengers and goods, especially local agricultural products. Such pick ups are an appropriate vehicle for making a living in rural areas, in addition to providing for private passenger transport. This makes the investment seem rational.

E. Previous Study

The Office of Transport Policy and Planning (OTP) [7] conducted a traffic and transportation master plan for Nakhon Ratchasima with aim to identify problems and causes after the first study and propose of countermeasures and preventive plans. The study also focused on establishing a traffic and transport management plan in order to maintain city growth inconsistence with city's vision on tourism enhancement and as a liveable city.

The proposals of the study covered short term (2004-2005), medium term (2006-2009) and long term (2010-2013) timeframes. Urgent attention was paid to traffic calming and traffic safety improvement in the study area. Short-term solutions with limit budget were proposed to reduce speed and enhance sight distance thus improve safety at these locations. For medium and long term solutions, the study team summarized details of problems and proposed rectifying approaches in nine development plans corresponding to the province's vision. These included strategies on current traffic management, road infrastructure development, public transport system development, safety and environment, traffic device maintenance, institutional building and public relation, safe driving training and campaign sustainable transportation, land use plan, and environmental and landscape improvement.

II. PUBLIC TRANPORT SURVEY AND ANALYSIS

The study team considered some limited additional demand surveys essential to reflect in the analysis true transportation demand and supply characteristics of the city. Two types of survey were carried out, namely roadside occupancy surveys (point check) and on-bus boarding and alighting survey (ride check) [8]. In addition, a separate parallel "Clean Air Plan" technical study, conducted classified traffic counts at several locations within Nakhon Ratchasima. These data was incorporated in the analysis to estimate the transit demand for specific routes.

A. Roadside Occupancy Surveys

Roadside occupancy surveys were conducted to estimate the local public transport demand at several locations around the city. The number of passengers at strategic points was obtained to appreciate the general public transport usage and its pattern associate with the area or land use. Spin-off results include a number of service characteristics namely average headway and its variation and number of buses in service during peak and off-peak periods of each route These data can help measure the overall level of service and service reliability of the bus service.

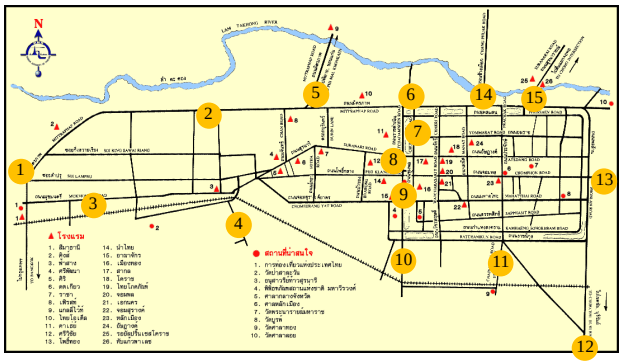

Figure 4. Survey locations

Fifteen locations were selected as representatives for occupancy survey. Twelve of these locations cover key entry/exit points to and from the city in all directions. The other three represent city centre locations where most routes have to pass or terminate. All stations were

surveyed on both sides of the street representing inbound and outbound trips. Fig. 4 shows the roadside occupancy survey locations. Table II shows observed all-day ridership.

TABLE II. PASSENGERS BY ROUTE TYPE AT EACH SURVEY SITE.

Site No	Direction	Number of Observed Daily Passengers by Bus Route Type		
		Type 1 "Urban"	Type 4 "Rural"	Total
1	Inbound	256	0	256
1	Outbound	266	0	266
2	Inbound	3288	4323	7611
2	Outbound	4081	4638	8719
3	Inbound	2377	0	2377
3	Outbound	1791	0	1791
4	Inbound	2163	0	2163
4	Outbound	2416	0	2416
5	Inbound	2373	1844	4217
5	Outbound	2486	2413	4899
6	Inbound	0	923	923
6	Outbound	40	1510	1550
7	One-way	9728	413	10141
8	Inbound	2417	3054	5471
8	Outbound	4984	99	5083
9	One-way	8056	636	8692
10	Inbound	1105	0	1105
10	Outbound	1117	0	1117
11	Inbound	1440	115	1555
11	Outbound	615	113	728
12	Inbound	2469	698	3167
12	Outbound	2000	407	4207
13	Inbound	475	0	475
13	Outbound	400	0	400
14	Inbound	935	0	935
14	Outbound	938	0	938
15	Inbound	2827	1953	4780
15	Outbound	3176	1999	5175
Total		64219	25138	89357

At each location, the records were separated by route numbers. The analysis considered three key periods, morning, midday and evening peaks as well as all-day performance. The average number of passengers at each point by time period was the first useful data directly retrieved from the survey. In addition, the number of buses during morning, midday and evening peaks was obtained for each route. Then average, maximum and minimum headways were determined at different peak periods.

Most routes were observed at more than one survey point and in more than one direction. The average observed headways are the average of all sites, and the maximum headway is the maximum observed at all sites through which the route passed.

It was found that the actual peak period headways provided are generally similar to or better than the official scheduled headways with only few exceptions. Most routes have average peak period headways less than 10 minutes. On the other hand there is generally a very large difference between the average headway and maximum observed headway on most routes. It should be pointed out however that in many cases the maximum headway occurs prior to 7.00 am, when demand is generally rather low.

Headway Variation Index (HVI) was introduced as a measure of overall reliability of the bus service. HVI is a measure of headway regularity defined as:

$$HVI = \left(\frac{\sum h_i^2}{\sum h_i}\right) / \bar{h} \quad (1)$$

This HVI represents a particular route's headway variation which impacts on the average waiting times experienced by passengers. Typically HVI values less than 1.3 are considered acceptable.

In addition, the average headway itself should be considered in the analysis as it affects differently how a passenger perceives headway variation. For example a passenger would not feel much different if he or she has to wait for 6 minutes for a bus route with an advertised average 3 minute headway. It would be much more disappointing to wait for 30 minutes for a bus that is scheduled to come every 15 minutes. Table III shows average headways and HVI for Song Thaew routes.

TABLE III. NAKHON RATCHASIMA BUS AVERAGE HEADWAY AND HEADWAY VARIATION INDEX

Site No	Morning Peak			Evening Peak		
	Avg headway (min)	Avg HVI	Avg Pass-engers	Avg headway (min)	Avg HVI	Avge Pass-engers
1	8.39	1.24	4.97	9.68	1.28	5.00
2	7.10	1.47	7.80	7.32	1.65	9.32
3	6.10	1.71	7.31	6.17	1.49	8.59
4	5.66	1.42	8.04	5.16	1.79	11.23
5	8.36	1.34	6.13	9.44	1.31	9.09
6	7.80	1.68	6.42	19.63	1.50	3.72
7	6.56	1.45	5.87	7.25	1.63	7.00
8	8.36	1.48	5.63	9.55	1.50	6.97
9	7.19	1.55	5.34	7.77	1.71	7.81
10	8.85	1.28	6.13	9.65	1.33	6.04
11	18.73	1.19	8.64	8.10	2.26	9.07
12	11.04	1.30	8.93	11.77	1.47	9.19
13	6.86	1.86	4.34	6.62	1.45	5.53
14	5.78	1.32	12.24	6.29	1.33	12.27
15	6.61	1.44	8.43	7.53	1.40	8.94

However, in case of Nakhon Ratchasima public transport, ridership showed virtually no correlation to average headway or HVI.

A clear pattern of peak periods can be observed. Morning peak demands are slightly lower than those in the evening for most of the locations. The midday period is noticeably lower. Unfortunately no significant correlation was found among headway variation index, average headway and number of passengers-on-board. In other words, transit demand elasticity with respect to reliability was low. This could indicate that existing public transportation users are generally captive riders who have limited choices of travel.

B. On-board Surveys

The purpose of the "on bus" boarding and alighting route surveys was to learn the load profile and load factor-of selected bus routes. Load factor measures the effectiveness of the route and service frequency as compared to demand. This survey also aimed to check actual service route and service frequencies compared to the details registered at the POLT.

Five routes were selected to represent bus routes that travel between city centre and all five major directions out of the city. A surveyor would ride the bus for the whole length of service route and noted down a number of boarding and alighting passengers at each stop, and the number of passengers on board on leaving each stop. Load factor, defined as the actual passenger-km served divided by the "capacity-km" could be calculated based on this simple survey.

By law, a Songthaew bus should carry a maximum of 12 passengers. However, it was not uncommon to see double that number on some routes at a given time of the day. The Load Factor, by the aforementioned definition would only take into account theoretical maximum occupancy, but fail to represent actual capacity when the bus is overloaded. Another indicator called Route Efficiency Index (REI) was introduced to compensate this shortcoming. REI was a ratio between actual passenger-km and the capacity in passenger-km based on the maximum number of passengers at any point on the route.

Journey time and resulting average speed could also be retrieved from the survey. The travel time and speed could be assessed on each interval providing a ballpark estimate of traffic conditions. Travel time could also be divided into running time and stop time in order to evaluate appropriate and excessive dwell time at some key locations. However it should be noted that passenger loading profiles and travel time data were obtained from only one roundtrip in each period (morning, midday and evening).

Maximum number of passengers, load factor, and REI of the five routes were determined from the survey result. Table IV shows these key indicators during the morning, midday and evening peak periods.

TABLE IV. EXAMPLE OF NAKHON RATCHASIMA BUS ROUTE SURVEY

Route	Peak	Direction	Max Passen-gers	Load Factor	REI
1	Morning	Inbound	10	34.46%	41.35%
		Outbound	10	30.47%	36.56%
	Midday	Inbound	9	19.58%	26.11%
		Outbound	8	41.77%	62.65%
	Evening	Inbound	9	15.85%	21.13%
		Outbound	15	81.80%	65.44%
2	Morning	Inbound	31	196.41%	76.03%
		Outbound	4	15.89%	47.66%
	Midday	Inbound	4	25.23%	75.69%
		Outbound	16	84.53%	63.40%
	Evening	Inbound	21	83.05%	47.46%
		Outbound	19	93.17%	58.84%

This survey shows a wide range of load factor and route efficiency indices. This is partly because the survey was conducted on a small sample size. Load factors range from just under 20% to almost 200% (which indicates that the bus was overloaded most of the time). Route efficiency indices range from under 20% to 75% while most of which are in a 40-50% range. These indices are reasonably efficient in comparison to other urban public bus systems

The fluctuation of the survey result could not be interpreted to very precise conclusions. However, it is a foundation for estimating overall route demand when considered together with the roadside bus occupancy surveys. The next section addresses the method and result of demand estimation.

C. Fixed Route PT Demand and Modal Share Estimates

Public transportation demand on each of the 5 surveyed bus routes was estimated using a combination of results from the occupancy and route surveys. The total number of passengers per day passing through a location on a given bus route was calculated from the occupancy survey. This number was extrapolated by multiplying by a ratio between the number of total passengers boarding for the whole route and the number of passenger on board at the occupancy survey locations., obtained from the on-bus surveys.

This methodology is quite approximate, but it helps understand the demand comparatively among different locations in the city. Table V shows demand estimation for the five survey routes.

TABLE V. DAILY RIDERSHIP DEMAND ESTIMATE

Route	Estimates Daily Passengers			Observed No. of Buses Deployed	Passengers per Bus Deployed
	Inbound	Outbound	Total		
1	5,231	4,805	10,036	44	228
2	1,061	1,292	2,353	13	181
4	3,018	2,231	5,249	17	308
6	5,994	4,962	10,956	43	254
11	2,355	2,975	5,330	28	190
Total			33,924	145	233

The average estimated daily passenger boarding per bus deployed on the five routes surveyed was 233. Taking that a passenger paid a flate rate 8 baht per ride, a song thaew bus should make averagely 1,865 baht per day before expenses.

Further analysis compared the volume of local PT passengers with the traffic counts from the EIS, with assumptions made about the average occupancy of various private vehicle types. It was found that public transportation receives its highest share in the city centre, as expected. Public transport received roughly about 30% share of downtown trips as compared to less than 15% in the suburb. An interesting finding from this figure is that the shares from the south and west entrances are significantly higher than that of the east. The share from the north is relatively low as compared to other parts of the city.

The numbers of daily passengers and public transportation market share derived from the survey routes appear promising. There is still sufficient demand for the fixed route that a reasonably well-managed and

well regulated public transportation system is available to be further improved to form a foundation for improved city development.

III. Conclusion and Recommendations

The following main conclusions have been identified. The major public transport flow occurred east-west and northwards on the main highway of the city. Public transport suffered significant delays on this highway and city centre roads due to on-street parking and traffic congestion. The fixed route public transport system, whilst capable of much further improvement, is substantial and professionally organized and run , and provides a sound basis for improving the quality of the services provided.

Uncontrolled on-street parking and the related lack of off street parking capacity were major causes of traffic delays, particularly for fixed route public transport services. Pedestrian facilities including road crossings had considerable room for improvements, while facilities for safe bicycle transport were virtually non-existent.

It was found that the city's main mode of public transportation was run with more than sufficient demand. However, its market share was being threat by cheaper price of motorcycle and its lenient program of payments. It was then necessary to improve the service quality to increase its attractiveness. Policy should include improve vehicle quality and headways, expand coverage, provide bus priority and bus stops. Improve passenger information and install park and ride facilities.

Fares on most routes were 8 Baht flat rate which was reasonable, particularly as compared to the ridership. Transfers between routes were often required to complete a journey. Ideally discounted or "free" transfers should be available. This might be possible by selling discounted "transfer tickets" which are date and time stamped and available to be used on any service within given period of time. Revenue sharing agreements for discounted transfers were required between the operators concerned, and eventually a small increase in the basic fare.

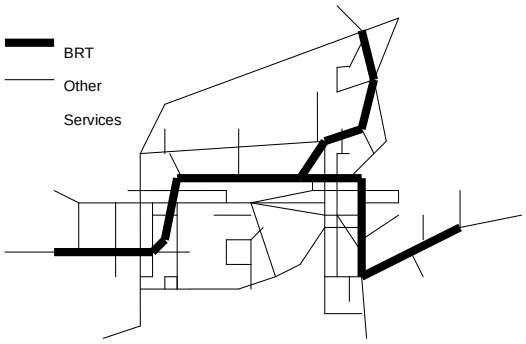

Figure 5. Conceptual bus rapid transit network for nakhon ratchasima

The possibility of implementing Bus Rapid Transit (BRT) was suggested by various stakeholders. This would appear to be an appropriate technology for Nakhon Ratchasima, which has insufficient foreseeable PT demand levels to justify any rail-based system. The eventual BRT network was recommended as shown in in Fig. 5. As recently as last year, the Municipality commissioned a master plan and pre-feasibility project of the BRT line.

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References

[1] National Statistics Office (2014). Provincial Population. [Online]. Available http://www.nso.go.th/
[2] The Association of Siamese Architects. (2014). Nakhon Ratchsima Comprehensive Plan. [Online]. Available http://download.asa.or.th/03media/04law/cpa/mr47-nrs.pdf
[3] V. R. Vuchic, *Urban Transit: Operations, Planning and Economics*, John Wiley & Sons Inc., Hoboken, New Jersey, 2005.
[4] Provincial Office of Land Transport Nakhon Ratchasima. (2013). Accumulated Vehicle Registration. [Online]. Avaiable http://www.dltkorat.go.th/statistic.php
[5] Y. Ding amd S. Chien, "Improving transit service quality and headway regularity with real-time control," *Transportation Research Record: Journal of the Transportation Research Board*, 80th, Annual Meeting Washington, D.C., pp. 161-170, 2001.
[6] S. Y. Kho, J. S. Park, Y. H. Kim, and E. H. Kim, "A development of punctuality index for bus operation," *Journal of the Eastern Asia Society for Transportation Studies*, vol. 6, pp. 492–504, 2005.
[7] Office of Traffic and Tansport Planning and Policy, Nakhon Ratchsima Traffic and Transportation Master Plan, 2004.
[8] Institute of Transportation Engineers, *Manual of Transportation Engineering Studies*, 2nd Edition, Washington, D.C., 2010

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