

RESEARCH REPORT

**AN EVALUATION OF THE TRUCK BAN REGULATION AND SUBURBAN TRUCK
TERMINAL IMPLEMENTATION SCHEME IN REGIONAL CITIES OF THAILAND:
A CASE STUDY OF KHON KAEN CITY, THAILAND**



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KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG

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ชื่อโครงการ การประเมินผลกระทบของมาตรการห้ามการจราจรของรถบรรทุกขนาดใหญ่และสถานีกระจายสินค้าในเมืองในชุมชนเมืองภูมิภาคของประเทศไทย

An Evaluation of the Truck Ban Regulation and Suburban Truck Terminal Implementation Scheme in Regional Cities of Thailand: A Case Study of Khon Kaen City, Thailand

แหล่งเงิน งบประมาณรายได้ วิทยาลัยนานาชาติ

ประจำปีงบประมาณ 2560 จำนวนเงินที่ได้รับการสนับสนุน 100,000 บาท

ระยะเวลาทำการวิจัย 1 ปี ตั้งแต่ 1 ตุลาคม 2559 ถึง 30 กันยายน 2560

หัวหน้าโครงการ ดร. จารุวิศว์ ปราบณศักดิ์

หน่วยงานต้นสังกัด วิทยาลัยนานาชาติ
jaruwit.prabnasak@hotmail.com

ABSTRACT

Recently, the Department of Land Transport in Thailand has initiated a plan to develop suburban truck terminals in several cities to support urban logistics by switching from line-haul heavy trucks to small vehicles before distributing into the destinations. The truck terminal can be expected to come along with implementation of truck ban regulation in those cities. Also, the present study is undertaken to examine the potential effects on air pollution of CO₂ emitted to the environment and the traffic flow inside city center with the new proposed truck terminal along with the idea of Truck Ban in Khon Kaen city. This study aims at preliminarily examining potential impacts of truck ban regulation inside a city where a truck terminal is planned to be invested in Khon Kaen city, a capital of the north-eastern region, is chosen as the study area because of its characteristics and availability of data. Besides, this study proposes the location of truck terminal implementation with 3 different locations, which are located outside internal zone, or outside city are. A four-step urban transport model developed from household and roadside interviews is employed as a principal analysis tool. As a result, potential of introducing truck ban regulation together with can be found. The suitable location of truck terminal will be found. Also, the cost of freight transport change due to the policy of truck ban with the truck terminal new location will be defined. Some discussion and the concern factors are provided as recommendation.

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I. INTRODUCTIONS

1.1 Research Background

Truck ban regulation is one of several transport policies that have been known and introduced in many cities around the world, and this seems to be normal practice of large cities. Aim of the regulation is various. Regulation in the purpose of reducing the impact of freight transportation always involved with a heavy truck ban in a particular area and specific time period. This will not only restrict on the truck operation but also the activity of delivery during day time inside cities area as well. However, there should be enough research on the policy impact before any policy implement. The respond from the resident inside the city will cause the policy not to implement due to the impact to their daily support. (Quak & Koster, 2006)

Some cities addressed the regulation for reducing traffic congestion and accidents from large vehicles, protecting ancient and historical site from vibration and to reduce air and noise pollutions. (EPA, 1992; Engel, 2010; Fensterer et al., 2014) In Southeast Asia, truck ban has also been addressed in several large cities, such as Bangkok, Manila, Jakarta, and Kuala Lumpur (Lidasan, 2011). In Bangkok, truck ban regulation has been introduced since 1989. At the time the regulation initially aimed at reducing problems from heavy goods vehicles inside the urban area of the city.

One of the major issue that can cause the traffic congestion become even worse due to the number of vehicle keep increasing rapidly as per BBC news said on the (1st Oct 2012). They found that Bangkok was the Second Top worst traffic due to the policy of refund tax for first time car-buyers, and these has resulted in 5million vehicle in the city which can only operate with less than 2 million cars on the road. However, later the benefit of truck ban in Bangkok in term of environment has been concerned (Takahashi & Sirikupanichkul, 2001). Recently, Metro Manilla also introduced truck ban in some area of the city in morning peak (between 9AM and 9AM) and evening peak (between 5PM and 9PM) except Sunday and public holidays, targeting vehicle that the gross weight is greater than 4,500 kilograms (MMDA, 2015). The aim of the truck ban scheme in Metro Manila is to deal with the issue of insufficient road capacities as well as reducing emission generated in the dense urban area (Fukuda et al., 2013). Vehicle restriction is now rapidly applied, especially in developed countries like in Europe and other cities in South East Asia for the sustainability in the urban area. This policy has been involved with the transport

structure, freight transport improvement, environmental concern and new truck terminal implementation as the solution for the impact of the policies. (Quak & Koster, 2009)

1.2 Problem Statement

Number of vehicles keeps increasing rapidly every year. Traffic situation has been a concern to all developing cities in the world, as many solutions have been offered to implement. A truck ban scheme has been addressed in some developed countries and in larger cities already in order to reduce congestion of the traffic in specific peak hour. However, the truck ban scheme will be possible for this size of city population still be- come-a question. As can be seen that mid-size city has not been introduced due to the size of population and the potential impact that we has never study before; hence the regulation will be possible to examine the truck traffic behavior and its potential impacts of introducing the regulation in mid-size city and come along with truck terminal as the solution to avoid the conflict with residents of daily supply good inside the city as well as the environmental concern will be studied and suggested for a better solution.

1.3 Objective

This study aims at preliminary investigating the potential of following factors:

- To understand the current situation and truck movement in the study area
- To examine potential impacts of truck ban regulation on traffic improvement and understand the change of transport operation cost with the environmental benefit in the study area.
- To define the suitable location of truck terminal
- To examine on how much CO₂ has been emitted from the larger truck compared to the small truck operation

1.4 Expected Results

The expected results of this study are as following:

- A possibility of introducing truck ban regulation in the study area, and a Policy will be recommended for future implementation.
- Truck Terminal will be located as a solution for a better city freight transport and a support for the policy to happen.

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- Seeing the impact toward the feedback in term of economics loss and total benefit of the project gained if this is worth making this project to happen.
- Examining the right location for a better truck terminal which could help both daily activities of supply chain inside the city with the sustainable improvement
- Suggestion and recommendation for better future work of similar study with appropriate study area.

II. LITERATURE REVIEW

Although there are many studies supporting the idea of truck ban in large cities, several arguments have also been given over the time. For example, Takahashi and Sirikupanichkul (2001) mentioned that there are a lot of concern about the freight transport cost for shipping industry after truck ban has been introduced. Besides, Castro *et al.* (2003), found that introducing truck ban regulation in Metro Manila conversely leads to increase in total vehicle-kilometres, total vehicle-hours and total polluted emissions in some cases. Similar to Liliana, *et al.* (2012) who developed a study on the impact of truck ban regulation due to public transport development in Mexico City. According to the study, they found that the heavy vehicle restriction scheme did not reveal any impact on congestion index and corridors of freight transport, however, increased travel time for the heavy vehicle. With these arguments, it seems that one problem of truck ban in large cities is the restriction is the additional distance from avoiding restricted area. Also, because of massive cargo demand, it is not possible for governments to provide supporting infrastructure such as truck terminal for them. Since truck ban regulation has both advantages and disadvantages. Intensive study and well plan are important when the implementation is proposed.

In 2015, the Department of Land Transport (DLT), Thailand, has done a feasibility study on truck terminal development in regional major cities in the country (DLT, 2015). Within the study, some major cities, such Chiang Mai, Khon Kaen and Hat Yai, were proposed for the development. Although, one main objective of those proposed truck terminals is to serve city logistic activities, the study seems to focus on strategic level (such as, city selection based on city's characteristics and economic perspectives) rather than detailed activities inside each city. Another question is that how to induce businesses and cargo owners in those cities to use the truck terminal if there is no restriction on heavy vehicle entering to the business district. Along with the idea of solving traffic related problems, e.g. traffic congestion and road accident,

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noise pollution, vibration, emission and parking deficiency, truck ban regulation might potentially be the answer.

This study aims at preliminary investigating the potential of introducing truck ban regulation along with public city logistics truck terminal in a regional major city of Thailand. Khon Kaen city, a capital city of the north-eastern region of the country is selected as the principal study area because it is the average size of regional major cities in Thailand as well as availability of data. The main research tool used in this study is the four-step transport model developed by traffic data collected in 2015. Overall the model as well as truck traffic behaviour inside the city reveals traffic behaviour. Some findings and concerns regarding the implementation of truck ban regulation and public city logistics truck terminal are discussed. The rest of this paper is organized as follows. Section 2 presents the study methodology. Section 3 reviews some statistics of the study area and data used in this study. Model estimation results are presented in Section 4 while a discussion on potential of truck ban and public city logistics truck terminal is provided in Section 5. Ultimately, the conclusion is given in Section 6.

III. RESEARCH METHODOLOGY

As the aim of this study is to preliminarily examining truck traffic behaviour and its potential of introducing truck ban and truck terminal in a mid-sized city of Thailand, an urban transport model is developed and used as a major tool. Since the scope of the study is to focus on examining policy in strategic level, also the size of the study, which is considerably large, the four-step transport modelling technique, which seems to suit the study condition, is then selected (McNally, 2007). The data used to develop the model was obtained by a traffic survey held in the study area in March 2015. According to the survey, it includes mid-block traffic survey of 24 locations, roadside interview with roughly 3,500 samples and household survey with nearly 2,000 samples, which are approximately one per cent of city populations.

Because in this stage the aim of study is to investigate the current traffic behaviour especially truck traffic inside the city, the fourth step of the model, traffic assignment, is therefore the main focus. To calibrate and validate the traffic assignment model using the field data, in the first step the origin-destination demand matrix is acquired by the roadside interview and household survey data, which is adjusted from sample, size to the population size. The demand matrix is divided into

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two sub-matrices: passenger matrix and truck matrix. For the second step, passenger matrix is chosen to assign into the road network. That is because majority of the traffic movements in the city is found to be passenger vehicles. Truck normally finds the route that can avoid massive passenger traffic and congestions. To assign traffic into the network, user-equilibrium with incremental-loading technique is used. The traffic is assigned by ten per cent of total demand at a time for ten times iteratively. In the third step, passenger model is validated by the mid-block traffic data until satisfying the criteria. Link cost and link restriction are two factors that are used for calibrating. After passenger traffic is already calibrated and validated, next in the fourth step, truck demand is assigned into the model. Again the truck traffic is calibrated and validated using mid-block traffic data until met the expectation. Several characteristics of the model and general indicators of the current traffic condition in the study area are presented in Table 1, while the model network configuration and model validating result are presented in Figures 1 and 2 consecutively. Besides, the environmental sustainability also focused in this study, which cause by the trucks behaviour inside the city areas would cause the vibration and affected the historical side within the city area. While this would lead the city with pollution of noise as well as air pollution. This study will be studied and analysed the different of truck operation with the different CO₂ generated from those types of HGV and LGV then compare the different between them. As by the source of CO₂ factor which receiving from the website (Climate, 2015). Additionally, as the study's aim also focus on the suitable location for the truck terminal in order to be the central point of all heavy good vehicle to stop and having their good transfer to the small and medium vehicle for the ongoing operation inside city centre which is why we have to do the analysis of the vehicle kilometre and vehicle operating time. These two results will help us with the decision of the final suggestion with the less financial used with the truck terminal implement project and the better choice with less cost reduction as well.

The economic analysis of return on financial reliable tool to assess the suitability investment projects is applied. We will present the project with an analysis of return on economic and financial aspects of the project as well as the logistic cost change due to the three different scenarios, which already mentioned from below figure 3. Analysis of the travel time of the vehicle based on the value of saving travel time of the vehicle and the value varies according to the object of the expedition revenue associated with the portion of the vehicle used. In this study, we got the cost

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of driver and vehicle cost from final report of Expressway project in Thailand for calculating the vehicle operating time (VOT). (DLT, 2015). The calculation will be included the total of vehicle-kilometre with vehicle-hour in order to find the total vehicle operating cost and compared with the three different scenario case.

Lastly, all possible cost will be calculated together as the aim of finding the most beneficial case with less operation cost and less CO₂ emitted to the environment. After all the analysis found, discussion on the potential of introducing truck ban will be shown in the next chapter.

3.1 Method

The main research tool used in this study is the four-step transport model (FSM) developed by traffic data collected in 2015. Because in this stage the aim of study is to investigate the current traffic behavior especially truck traffic inside the city, the four- steps modeling technique that seems to suit the study condition is then selected (McNally, 2007).

In the Fourth Steps Transport Modeling (Traffic assignment), first, Origin destination demand matrix is applied for roadside interview and household survey data, which is adjusted from sample size to the population size.

Second, passage matrix is also chosen to assign into the road network. That is because majority of the traffic movements in the city is found to be passenger vehicles. Truck demand will also apply for our purpose of this study with the study of truck behavior inside the city with the purpose of truck terminal implementation.

Thirdly, CO₂ emission factor will be included in the study in order to find the total polluted emission base on the current base case with the proposed 3 different cases as listed in the next section (Climate, 2015).

Lastly, total vehicle-kilometer, total vehicle-hour, and vehicle operating cost (VOT) are then calculated based on GIS application result from O-D table data.

3.2 Study area

In this section, a brief explanation of statistics of the study area and the data used in this study are given. Khon Kaen City is chosen as the study area because its size is the average size of major regional cities in Thailand (DOPA, 2015).

Table 3.1: A comparison between the data used in this study and a previous dataset

| Attribute | Year 2007 | Year 2015 |
|---|-----------|-----------|
| Sample Size | 873 | 2,000 |
| Household size | | |
| Average household size | 3.42 | 3.49 |
| Small (1-2 members) | 28% | 27% |
| Medium (3-4 members) | 53% | 51% |
| Large (5 member and more) | 19% | 22% |
| Household income (THBS) | | |
| Average household income | 25,416 | 40,319 |
| 0-10k | 19% | 8% |
| 10-30k | 54% | 45% |
| 30-50k | 17% | 25% |
| >50k | 10% | 22% |
| Working status | | |
| Working | 64% | 57% |
| Studying | 20% | 16% |
| Other | 16% | 27% |
| Vehicle ownership | | |
| Households with no car and no motorcycle | 4% | 2% |
| Households with motorcycle(s) only | 35% | 19% |
| Households with car(s) only | 9% | 9% |
| Households with car(s) and motorcycle(s) | 52% | 70% |
| Truck load | | |
| Empty load | n/a | 41% |
| ¼ Load | n/a | 9% |
| ½ Load | n/a | 9% |
| ¾ Load | n/a | 8% |
| Full load | n/a | 33% |

Metropolitan area of Khon Kaen City covers 228 square kilometres with approximately 300,000 populations. The data used in this study is collected in March 2015. To observe socio-economic trend in the city in past few years, the 2015 dataset is compared with a previous daily travel survey data obtained in 2007 by (SIRDC, 2008). A comparison of the key attributes between the 2015 dataset and the dataset from 2007 is presented in Table 3.1.

According to Table 3.1, the average household size in 2015 is 3.49 members, which is slightly larger than in 2007. Interestingly, average income in 2015 is 40,319 Thai Baht (approximately US\$1,145) per month, which is about 58 per cent higher than that was found in 2007. Looking more closely, relative to the year 2007, the proportion of households with income more than 30,000 Thai Baht per month significantly rises by half while the proportion of households with income lower than 10,000 Thai Baht decreases by 60 per cent in 2015. This could be a result of the

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government's minimum wage lift up policy in 2011. A variation is also found in working status that in 2015 the proportions of workers and students drop while the proportion of other increases from 16 to 27 per cent, relative to the year 2007. That can be explained as a common situation of Thailand, which has turned into aging-society recently. The majority of populations in category other are retired workers. For the household vehicle ownership, it is found that the proportion of households with motorcycles only drops by over 40 per cent, meanwhile the proportion of households with holding both cars and motorcycles shifts from 52 to 70 per cent. However, the proportion of households with cars only remains the same over the time. This might be a result of another government policy introduced in 2011 – first eco-car extra tax deduction. Regarding Table 2, basically most common attributes in the 2015 dataset seem to be fairly comparable to the previous dataset in 2007. Some discrepancies are found but there are reasonable explanations for them. Therefore, it could be fairly confident with the new dataset used in this study.

Table 3.2: Model characteristics and current traffic condition

| Model characteristics | |
|--|----------------|
| Number of zones | 83 Zones |
| Number of node | 374 Nodes |
| Number of links (separate direction) | 754 links |
| Total network distance (exclude centroid connectors) | 514 kilometers |

In this study, the truck classification is different from general classes, as we only focus on below 4 types of Truck types as the following Table 3.3, which reflected from the data that we got from survey as presented in table 3.3 (DLT, 2015).

Table 3.3: Vehicles classes in study area

| Vehicle Classification | Weight Capacity | Truck Proportion |
|------------------------|--|------------------|
| Small truck | (4wd approx. 2Tons carrying weight) 11.01% | 53% |
| Medium truck | (6wd 6Tons carrying weight) 5.7% | 28% |
| Large rigid truck | (10wd 15 tons carrying weight) 1.6% | 8% |
| Trailer truck | (18wd 25 tons carrying weight) 2.4% | 12% |

Source: Final Report, Department of Land Transport (DLT), 2016 Thailand

3.3 Location Suggested for Truck Terminal

Below figures are the idea of where to locate the truck terminal in the purpose of dealing with the policy of truck ban implementation which helps to improve the city traffic condition toward city logistics movement. All the locations, which we suggest, is based on the land availability in the study area with the accessibility of road transportation that is used during the operation. All the reasons and pictures we have got base on the current situation and land availabilities in google street view. Also, the purpose of introducing this location is based on the accessibility to city center and outer city link, which make both operation inside and outside city easier after the study found. As some of goods will consider as daily delivery products, .If the location is far away from the city center, these might incur another problems or impacts of logistic activities within this study area, which may lead to another issue, which become the conflict with our objectives. Moreover, as the purpose of making the city center clear from truck traffic jam, this also consider in our location decision which not able to locate the truck terminal less than 5 kilometers around CBD area. There are three different options as shown in Figure 3.1 for this study to observe the best location, which benefit to the project best among other options.

1. Before entering city center around 8km along Mithraphap road
2. Before entering CBD area about 6km along Maliwan road
3. The other option is around 12km from CBD along Mithraphap road

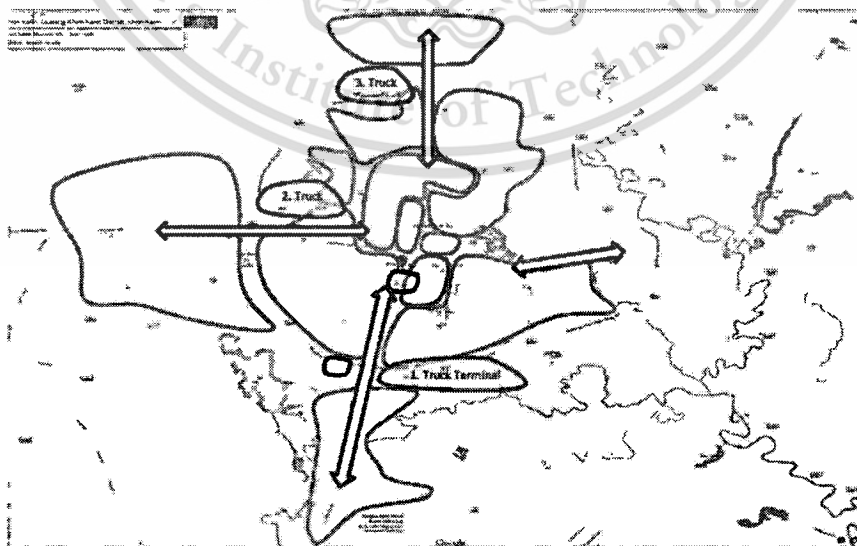


Figure 3.1: The zoom out of bound with location for truck terminal

The option is for the various observations in which location will be more convenient for all truck to left their cargo and exchange with the smaller truck in order to transfer products to city areas. This proposed cased will be studied at the end after the review of all data that we received. First, all data sets will be studied and analyzed the current situa- tion of truck moving inside city center and outside the inner zone such as intermediate and outer zone. Then, we will compare the current situation of truck moving including pas- sage vehicle together and addressing the different of all vehicles moving with the trucks moving traffic on the desire line. After all data sets has been analyzed and discuss; then, we will remodel the secondary data that we received from department of land transport (DLT, 2015) as the other aims of this study are to check and look for the suitable location in order to address new truck terminal as the support of truck ban regulation as well as to investigate the different change within the three different scenarios. Thus, the remodel data will be focus only the truck travelling demand of large truck that operating on the road inside Khon Kaen City while the other data set of passage vehicles will be ignore and cut out from the modeling. All trucks that move directly inside city will be forced to stop at each truck terminal; then, all goods will be transferred to the small trucks instead before getting into city center for the daily operating goods which needed during daytime operation. Same scenario also applied with the goods which need to get out of city center to other zone like intermediate or outer zone is then force to stop at each truck terminal then transfer to larger truck. These will apply to all scenarios, which already proposed.

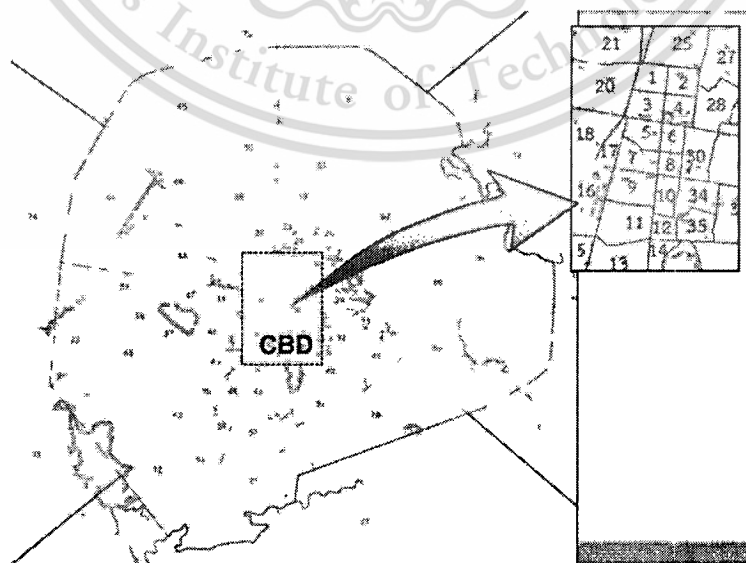


Figure 3.2: Out of bound with zone number

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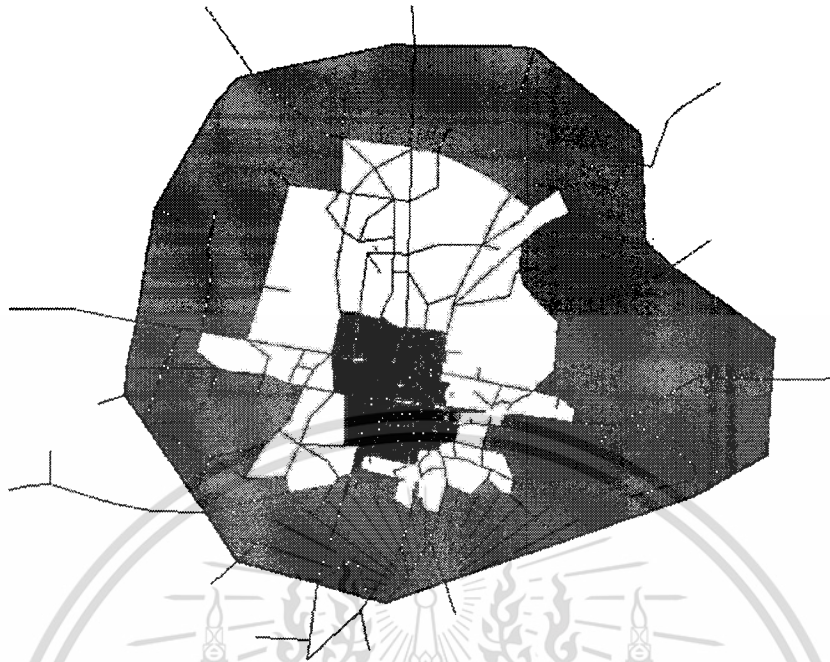


Figure 3.3: GIS map application with Zone categorize

Colors indicator

- Dark Green: Outer Zone
- Light Green: Intermediate Zone
- Red: Inner Zone or CBL

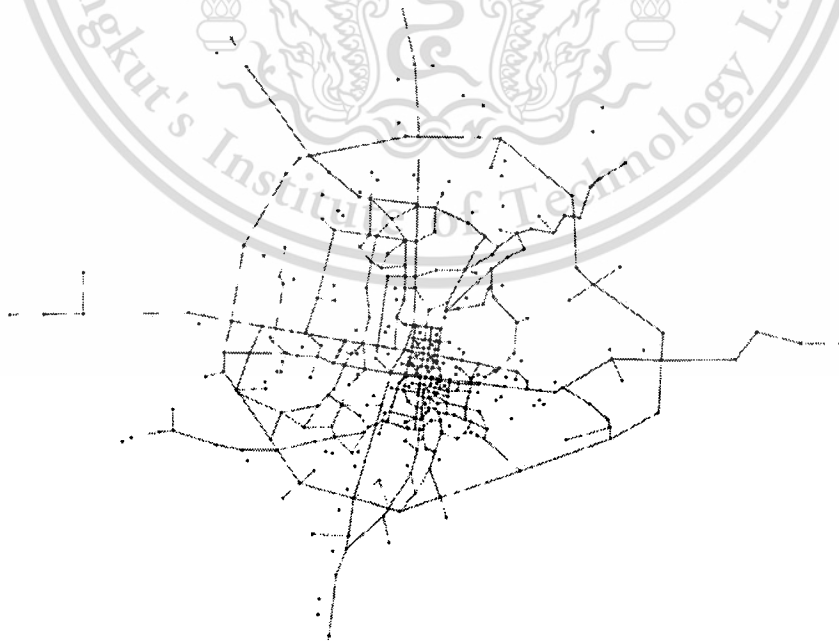


Figure 3.4: Model network configuration

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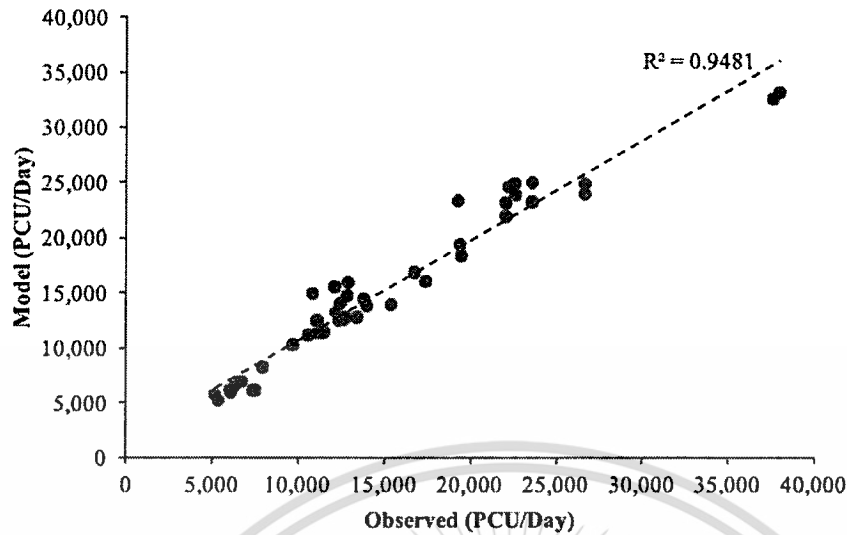


Figure 3.5: A comparison of observed and modelled mid-block traffic

As the graph in Figure 3.5, we used data we collected from the traffic survey to compare with the demand on the link in the model as shown. To validate the model we plot the actual demand as the observed against the forecasted demand on that link in the model. As can be seen, it is not possible that the observed traffic is exactly as the forecasted demand. That is why the plot graph result to find the relativity between the two variable which means that the observe model are quite relative. In addition, the plot, which we have done compare with the model of the data collection location, then the trend line are developed and found as the R Square above, is quite high (0.9481). Then, we can be sure that our model should be fairly accurate enough to use for further study and analysis. After the model calibration and validation are completed, next model is used to determine the truck traffic volume across the network and also define the behaviour of truck inside the study area. The analysis can be divided into two parts: to examine overall truck behaviour in the study area, and to define impact of truck ban in some specific areas of the city.

IV. RESULTS AND DISCUSSIONS

4.1 MODEL ESTIMATED RESULT

This section presents estimation results of the urban transport model developed, which can be divided into two sub-sections: overall traffic behaviours and truck traffic behaviours found in the study area. Besides, this section also presented the remodel- estimated results of truck transport excluding the passenger vehicle

while only large trucks moving will be focus. These remodel-estimated results have been divided into 2 sub- sections as well. First, the overall truck traffic behaviours will be found and compared with the three cases proposed; also, the explanation of each figure from desire link of truck traffic running by model compared with the result after running from GIS program will be provided with each case. Last of all the potential of introducing truck ban policy will be proposed while the benefit of environment is addressed.

4.2 Overall traffic behaviors in the study area in overall

In this section, overall traffic behaviours found in the study (including both passenger and truck traffics) are reviewed and discussed. Some results acquired from the model are presented in Table 4.1

Table 4.1: Model estimation results for overall traffic behaviours in the study area

| Model estimation results | | |
|--|-----------|----------------|
| Daily demand (24 hours) | 340,990 | PCU |
| Daytime demand (12 hours: 7.00AM-7.00PM) | 254,673 | PCU (74.7 %) |
| Peak-hour demand (1 hour: 8.00AM-9.00AM) | 28,416 | PCU/hour |
| Total daily travel distance | 4,463,034 | PCU-kilometer |
| Total daily travel time | 69,007 | PCU-hour |
| Average trip length | 13.1 | Kilometers |
| Average trip time | 12.2 | Minutes |
| Average Speed | 64.6 | Kilometer/hour |

Remark: PCU denotes Private Car Equivalent Unit

According to the model, it is predicted that there are over 340,000 PCUs running in the road network of the study area each day. This does not include traffic in small streets, access road and allays. With this among of traffic, about 75 per cent of them serve daytime activities between 7AM and 7PM. In the study area, morning and evening peak hours are found to be almost similar volume per hour. The average speed in the city is found to be roughly 65 kilometres per hour. However, this average speed accounts outer ring road and some sections of intercity highways, so that can influence the average speed of the model. Figure 4.1 presents link traffic estimated by the model.



Figure 4.1: Traffic flow on links estimated by the model

According to Figure 4.1, most of the traffics go along north-south and east-west directions. That is because Khon Kaen city is located in the heart of the region. Therefore, not only local traffic generated by inhabitants but the city's road network has to handle intercity through trips also. The business corridor is the north-south corridor named Mittraphap road; meanwhile, the second business corridor is the western corridor named Maliwan road. With the business road section on Mittraphap road, each day there are approximately 38,000 PCU per direction. Besides, the business road section on Maliwan road is roughly 27,000 PCU per direction. However; both corridors are three to four lanes divided with frontage road for both side, capacity of the road is yet sufficient in normal situations. It is found that the main course of traffic congestion in the city is the capacity of traffic signal and intersection. Another problem found in the city is that there are a large number of intercity vehicles that used Mittraphap and Maliwan roads for crossing the city. That is because both roads consist of a number of lanes, which are enough to provide a good level of service, especially in off-peak period. The through traffic includes both passenger and truck traffics. For the passenger traffic that is mostly a platoon of private cars, they can easily merge to the local traffic in the city. Nevertheless, in the case of truck through traffic, this would lead to many problems inside the city, for

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instance, noise and air pollutions, vibration and extending severity of traffic congestion along the daytime. This is the reason why this study has been initiated.

4.3 Truck traffic behaviours in the study area

In this section, truck traffic behaviours revealed by the model are reviewed and discussed. Some results obtained from the model are presented in Table 4.2

Table 4.2: Model estimation results for truck traffic behaviours in the study area

| Model estimation results | | Comparison to Table 5. |
|-----------------------------------|----------------------|------------------------|
| Daily truck demand (24 hours) | 41,289 PCU | 12.1% of total traffic |
| Total daily truck travel distance | 901,369PCU-kilometre | 20.2% of total traffic |
| Total daily truck travel time | 11,815 PCU-hour | 17.1% of total traffic |
| Average trip length | 21.8 kilometres | 66.4% greater |
| Average trip time | 17.2 minutes | 41.0% longer |
| Average Speed | 76.3 kilometre/hour | 18.1% faster |

In this study, the PCU is referred to code of the Department of Highways (DOH, 2013), which suggests that a unit of heavy vehicles, such as heavy rigid, trailer and semitrailer trucks, is roughly equivalent to 2.5 PCU. Regarding Table 4.2, the daily truck demand in the study area is approximately 40,000 PCU (about 16,000 heavy trucks), which is about 12 per cent of total vehicles running in the network each day. However, if considering the total daily travel distance and travel time of trucks, it is found that this takes about 20 per cent of total travel distance and 17 per cent of total time. This implies significance of heavy vehicle traffic in the study area. For the average trip length and trip time, it is found that the trip length is about 66 per cent greater while average trip time is over 40 per cent longer than the overall traffic. Besides, the truck average speed is 18 per cent greater than average speed across the network. To investigate the reason that the average speed of trucks is greater than the network overall, the desire line and truck traffic volume on links are plotted as presented in Figure 4.2 and Figure 4.3 According to the both figures, it can be seen that the majority of the truck origin-destination pairs are through traffic, e.g. north-south, east-west and east-south. Meanwhile, it can be seen that the truck traffics on the ring road are noticeably high, particularly the southern loop. As mentioned earlier, Khon Kaen city is located in the centre of a region. It is expected that a considerably large amount of intercity traffics that has to cross the city without need for stopping. Since traffic congestion is such common situation in the city for the daytime, it is quite possible that some of through trips, especially truck traffic, would use outer ring

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road to avoid poor traffic condition. This model behaviour is found to match the observation.

4.4 Freight activities distribution in the city

Table 4.3. Truck traffic activities in outer zone, intermediate zone and inner zone.

| Model estimation results | Overall | Outer | Intermediate | Innier |
|---|---------|---------|--------------|--------|
| Network length (kilometre) | 514 | 195 | 189 | 130 |
| Truck demand (PCU/day) | 41,289 | 35,649 | 3,698 | 1,942 |
| Total truck travel distance (PCU-kilometre) | 901,369 | 789,072 | 72,863 | 39,434 |
| Total truck travel time (PCU-hour) | 11,815 | 10,059 | 1,161 | 594 |

After the overall truck behaviours in the study area are investigated and found that there are approximately 41,000 PCU of trucks running in the network each day, which is roughly 20 per cent of total travel distance in the network. The question given here is that how many trucks that actually have their origin or destination in the inner zones of the city. These trucks are likely to be disturbed by truck ban policy in the city Centre. To do so, the study is divided into three zones using urban density: outer zone, intermediate zone and inner zone. Truck traffic activities within each zone are estimated as demonstrated in Table 4.3. The network length in outer zone is 195 kilometres, which is about 38 per cent of the total network distance. Meanwhile, the network length in inner zone is 130 kilometres, which is about 25 per cent of the total network distance. As expected, the outer zone which the ring road and intercity highways are located is the busiest area for truck activities. Approximately, 35,000 PCUs of trucks use road network within the outer zone each day. This is about 86 per cent of total truck traffic in the study area. As a result, majority of truck travel distance and truck travel time are generated in this zone. The intermediate zone accounts nine per cent of total truck traffic in the study area and the inner zone handle the rest of truck activities that is about five per cent.

According to the findings, it seems that there is only small portion of trucks that have some activities inside the city, while majority are through traffic. However, if the PCU is converted to heavy truck unit, the intermediate zone is expected to have about 1,500 trucks entering and exiting the area each day. With this amount of heavy vehicles, they can certainly impact traffic in the zone. Moreover, if focusing on the inner zone, there are about 780 heavy trucks, which have origin or destination in the zone each day. The inner zone is the central business district (CBD) of the city. There

are many activity nodes, such as central market, large shopping centre, schools and government offices. Thus, this is the most traffic-congested area of the city. Hundreds of heavy trucks visiting the district resulting to many problems, such as vibration, congestion, air and noise pollution, accident, and loading and unloading parking problem. Another behaviour that is also found from field survey is that the truck demand profile in outer zone seems to be roughly steady thought out day and night, which is such common situation for intercity highway. However, in the case of intermediate and inner zones, majority of the truck activities occur in the daytime. That is because these trucks are related to local businesses in the city. Thus, most of activities need to be done during business hours.

4.5 Truck traffic behaviours in the study area of base-case scenario

This section, base-case scenario is created base on the previous data set from survey as secondary data obtained from Department of Land Transport. (DLT, 2015) Then, the new O-D matrix is created by deleting all passengers' vehicle and focused only on the trucking transportation within inner zone (CBD). After the new O-D matrix created, we found there are trips, which are operating just within the inner zone by large trucks and as the proposition of trip is only 3% compared to other trips. We decided to take it out from the model in order to avoid the strange value inside the model after the result reveal. Then, we re-run the model and rechecked the O-D result again by GIS application. The base case scenario estimated result on truck traffic behaviors is shown in table 4.4.

Table 4.4. Model estimation results for truck traffic behaviours in base case scenario

| Model estimation results Base Case | | |
|------------------------------------|-----------|-----------------|
| Daily truck demand (24 hours) | 3,521 | PCU |
| Total daily truck travel distance | 58,504.47 | P-kilometer |
| Total daily truck travel time | 1,020.08 | PCU-hour |
| Average trip length | 0.7 | Kilometers |
| Average trip time | 0.81 | Kilometers |
| Average Speed | 49.1 | Kilometers/hour |

As the result from table 4.4 shown that the total demand of truck for the normal operation with large truck is approximately around 3,521 PCU (about 16,671 tons of light truck) moving inside city area in the road network for 24h. In addition, it is consist of 58,504.47 vehicle kilometers as total within the network and 1020 hour

with the average trip length of 0.7 kilometers as well as the average trip time 0.81 with average trip speed 49.1 kilometers per hour.

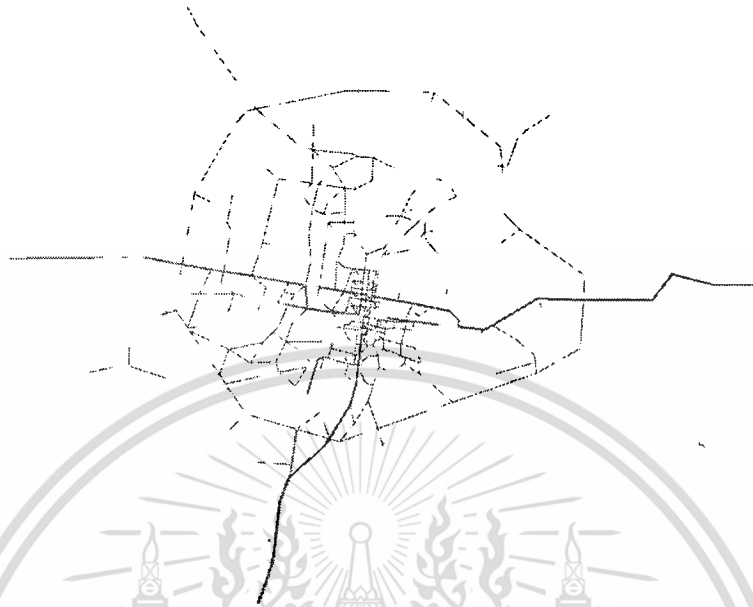


Figure 4.2. Truck traffic flow on links estimated by the GIS application in base case

In Figures 4.2 shown us the truck traffic flow on the links estimated by the GIS application in base case scenario. The figure show that the traffic flow on the link is coming from all side of road within the study area and directly go inside the city area which is the main cause of having the congestion problem on the link road as can be seen the yellow line and read line indicated the heavy traffic on the road. This make our assumption becomes more realizable as we expected the traffic to move from everywhere crossing by the city center and coming to city center. By this figure we can assume that this model is suitable for doing the further study on the 3 different locations of the truck terminal as the solution to avoid the crowded problem and traffic congestion inside CBD area.

4.6 Results comparison for all 3 cases

In this section, the total kilometer and total hours all the three difference cases will be presented and show by figure 4.3. This section will bring the clear pictures of all the cases for the comparison.

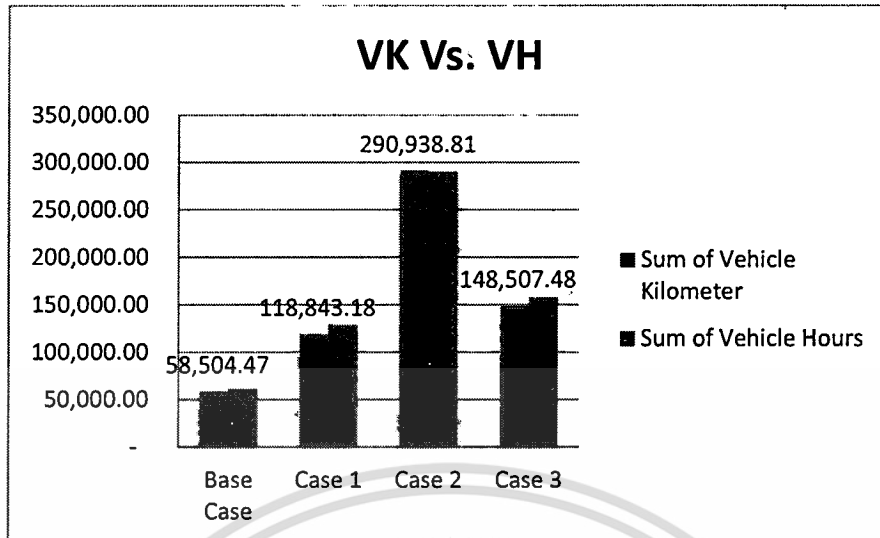


Figure 4.3. The comparison between vehicle-kilometer with vehicle-hour
 VK: Vehicle kilometer VH: Vehicle hour

From the Figure 4.3, the result show that when the number of traveling distance increased, and obviously, the total traveling hours also increased dramatically as well. The total vehicle-kilometer in case I is double if we compared with the base case where vehicle is not yet convert into small truck using in CBD area yet, while case I we already convert very large vehicle to be the small vehicle in order to check the possibility of truck moving inside traffic. Also, by so doing, we will be able to demonstrate the comparison with other two different cases. Thus, base case will be show just to display the difference among the result of original and the proposed result with different three scenarios. After the result is found, results show us that among all the 3 cases the case II is very large number of vehicle-kilometer and vehicle-hour which we can assume that case number 2 is likely not being able to meet our criteria and expectation of cost saving and environmental protection. Then, case II is automatically rejected by our study. By figure 4.3, we found in case I and case III which is quite similar in number however the total value of vehicle kilometer in case I is 25% less than case III. This result is very interesting, we found out that the first case is very favorable toward our study and we will continue to the next section in order to find out the total CO₂ emitted to the environment between all the 3 cases with the base case (original vehicle moving without stopping by the truck terminal in the study area). However, we will continue with the total vehicle operating cost which getting the detail of vehicle-kilometer and vehicle-hour from this section. The result

will find out more about the total cost change which is applying to one of our objection in order to find the different cost change of transposition during the operation within the study area.

4.7 Estimated result of vehicle operating cost in study area

In this section, the total vehicle operation cost is found and make the comparison among all cases in the study area. Below cost is taken directed from the final report study of Express Way implementation of Thailand, Department of land Transportation (DLT, 2015). The purpose of this section is to look for the total cost of both vehicle and driver cost together running on the road. In addition, the longer the vehicle spending on the road of the link in the study area, the more vehicle operating cost is generated base on the total operating time per total trip generated from the model.

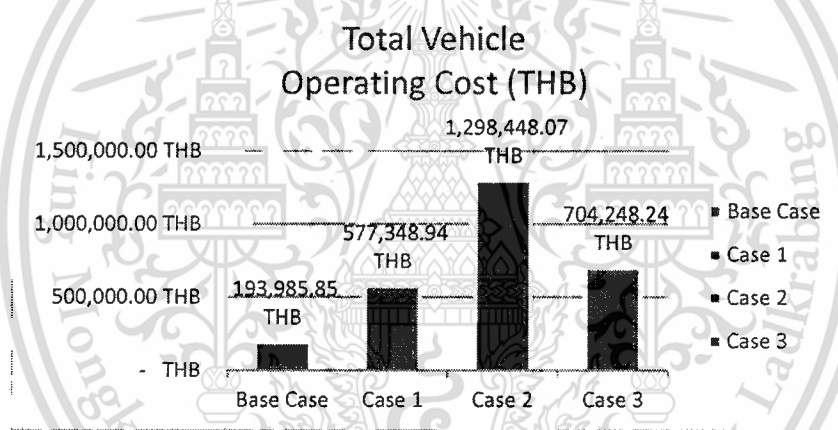


Figure 4.4: Total vehicle-operating cost within the study area

Figure 4.4 show the result of total calculation of all vehicle operation on the link road of the study area from internal zone to truck terminal and from truck terminal to the final destination outside the study area. Results shows that in order to implement new truck terminal large amount of money need to invest as we found that the cost of base case scenario is less than 200,000THB which compared to case I is larger around two time compared to base case. This is very far significant for the change of total cost, as the result from case II show that more than 1 million baht is wasted per hour if truck terminal located in the intermediate zone which mean that in the location case, they generate the longer waiting as the location is quite near the internal zone of CBD where traffic congestion will not be improved but it causes even more serious traffic condition than the normal practice. Additionally, case III is

shower quite better cost of vehicle operation if we compared with case II; however, case I still generated the better result than case III where the total cost will still larger than case I around 21%. By the table result we found that case I still become the most suitable case for the study implementation; however, we are sure that as the number of vehicle is increasing, due to the model purpose of transferring goods to truck terminal before entering city area. That is also the reason why vehicle operation is increased dramatically. That is reasonable enough for this finding.

This shows that forcing large trucks to move toward the truck terminal and transfer to small trucks will cost more time of travelling and more time of vehicle operating on the road as well. Vehicle distance surely increases while the time length also increase at the same time. This cost summary is not included the value adding cost beside the waiting time and distance of vehicle. Value adding cost will be included the warehouse operation cost as the land use for doing truck terminal is operating under the use of labors for doing the storage controlling, loading, unloading, and warehouse management etc. All of the extra cost for the value adding to the total cost that we found will surely increase if we consider of having this case I truck terminal location as per proposed.

4.8 Environmental Performance of Trucking Behaviour

This section, the study of total CO₂ generated to the environment has been conduct and the CO₂ factor that is used is extracting from the source of US environmental protection agency. (Climate, 2015)

Table 4.5. CO₂e factor conversion

| CO ₂ factors | | | In vehicle-kilometer |
|--|-------|------------------------------------|----------------------|
| Light Truck | 0.485 | CO ₂ e per vehicle-mile | 0.30 |
| Heavy Truck | 1.43 | CO ₂ e per vehicle-mile | 0.89 |
| 1Mile = 1.609.Km (www.metricconversions.org) | | | |

Source: Climate leadership (U.S Environmental Protection Agency)

Table 4.5 is the conversion from mileage to kilometer as the original data that we use is used vehicle mile instead of vehicle kilometer as per our study. Kilometer per hour is one type of measurement from speed typically using for metric of transportation. Road speed are given in kilometer are using used for Asian countries, on the other hand, mile per hour is use typically for measurement for speed of transportation as well but it is use in non metric country such as U.S and The United

Kingdom even if officially the metric system has been adopted. Road speed limits are given in miles per hour. (Ltd., 2017)

By the Figure 4.5 shows that factor of CO₂e for trucking transportation for logistic purpose as the whole. Light vehicle good emits less emission around 0.485 in vehicle mile while convert to kilometer it is around 0.30 kg per kilometer. In addition, heavy good vehicle generate greater emission to the atmosphere more than light good vehicle which is around 1.43 in vehicle mile while convert as 0.89 per vehicle kilometer (Climate, 2015).

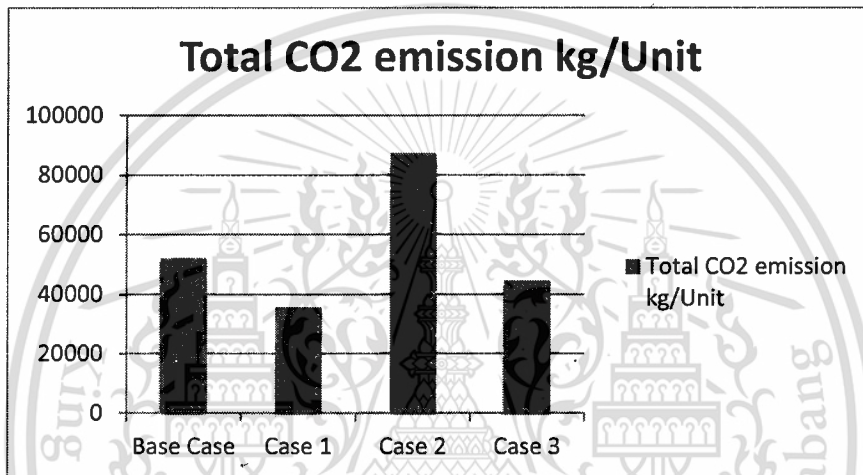


Figure 4.5: Total CO₂ emitted to environment within the study area

Figure 4.5 show the result of CO₂e that has been emitted from all total vehicle operating on the road for each cases within the study area where the original data of base case show the largest amount of CO₂e around 52,000kg per kilometer which generated from the trucking transportation. This result caused by token large truck type as the transportation of goods moving without stopping at truck terminal that we proposed in the study. Moreover, looking to the first case, results show in Figure 4.5 found that case I is significantly the less CO₂e that generated to the environment among all cases including base case. This imply that if we chose case I of truck terminal location, the improvement to the environment will be better than using large truck which cause a lot more emission due to the different of vehicle engine and fuel type. This not only help with the traffic situation inside city center, this will also help with the global warming reduction by 33% if compared with base case scenario. The other two cases will not meet our expectation as case II is generated around 84,661 kg per unit of CO₂e which is even more polluted to the environment than using large

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truck due to the distance of total vehicle moving is far greater than the original data. However, case III is quite similar amount with case I as the total CO₂ emitted to the environment is just around 40,000 which is greater than case I around 15%. After all, results found out that case I will be the most suitable case for this research study.

5. DISCUSSION

A discussion on possibility of introducing truck ban in this study area is given here, divided into two cases. For the first case – considering that truck ban is addressed in the inner zone where the traffic is most critical during the daytime; around 800 trucks are likely visit the zone each day. Among this number, based on the mid-block traffic survey, about 75 per cent of them are daytime activities. Assumed that the regulation is set for 12 hours daytime period – between 7AM and 7PM, thus about 600 trucks are potentially affected. Regarding the data obtained from roadside interview presented in Table 1, it is found that on average truck utilization in the study area is 45.7 per cent. Presumed that the truck utilization is true across the study area, it means that within 12-hours of implementing the truck ban regulation those 600 trucks can be converted into 274 fully loaded trucks, or approximately 4,100 tons of cargo (assumed that one fully loaded truck carries 15 tons of cargo), being enforced by the regulation.

In the second case; if the regulation is assumed to address in both inner and intermediate zones, there are a total of approximately 2,300 trucks associated with both zones. Based on the same assumption, the number of trucks with daytime activities can be roughly 1,700. With similar utilization rate and carrying capacity, within 12-hours of implementing the truck ban regulation there are approximately 1,050 fully loaded trucks, or roughly 15,700 tons of cargo.

Though truck ban regulation might be one solution in relieving traffic condition in the city centre, banning those trucks certainly impacts businesses and cargo owners in the city. Without a reasonable alternative for them, introducing the regulation might not be possible. Referring to a study held by the DLT in 2015 (DLT, 2015); based on the findings of the study, it is suggested that there should be a number of truck terminal investments in large regional cities in Thailand, including Khon Kaen city. The truck terminal project leads to potential for introducing truck ban regulation in the study area. The truck terminal developed can be used as a public terminal for serving city logistics. Businesses and cargo owners inside the city can use

the terminal to tranship cargo from large goods vehicles to small distribution trucks, or temporarily stock at the terminal waiting for delivery in off-peak period.

Considering the estimated total cargo volume of both inner and intermediate zones, which is 15,700 ton per 12-hour period or about 1,300 ton per hour; refer to the designed capacity of the truck terminal given by (JICA, 1988; DLT, 2015), this amount of this cargo is considerable and required quite large space for operation. Besides, introducing the regulation across both inner and intermediate zones is difficult in term of social acceptance and management, which does not seem to be practical in reality. In contrast, focussing on truck ban in the inner zone seems to be more potential. The cargo volume of about 4,000 ton per 12-hour period or about 340 ton per hour is more likely to be managed. Additionally, there is more rational to introduce such regulation in the area where the traffic congestion and roadside parking issue are critical. Thus, it is suggested that the truck ban regulation can potentially be addressed in the inner zone presented in this study. Nevertheless, truck ban regulation could not be successful without the development of public truck terminal for supporting businesses and privates inside the enforced area.

In addition to location of truck terminal is assume to be located around 13 km far away from the city centre, which is right at the outer zone. While all trucks from all outside city in other location, which use to run along Maliwan and Mithraphap road to inside city. By the policy and truck terminal location, most traffic will move to outside link road mostly and we found the traffic inside the city centre is less on road and clean with very less traffic while the operation of truck inside with only the small type of vehicle which capacity of current road traffic is enough for the traffic moving.

Beside, this study aim to examine on how much CO₂ emitted to the environment compared to usual traffic large truck running, we assume that the possibility of CO₂ reduction is 25% comparing to allowing large truck moving inside city as around 17,100 kg per vehicle kilometre, which is consider as a lot. If the pollution is reducing, the city centre environment also become healthier as less noise pollution from large vehicle as well as the rate of accident inside city because of the large truck and it will be reduced. Truck accident is known to be the worst case among all type of vehicle and the result of death and serious injuries are very high. (Y & N, 2014). Regarding our study, as large truck will be move to outside link road, the city sustainability will be possible.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study aims at preliminary investigating the potential of introducing truck ban regulation along with public city logistics truck terminal in a regional major city of Thailand. Khon Kaen city, a capital city of the north-eastern region of the country is selected as the principal study area as its characteristics and availability of data. The main research tool used in this study is the four-step transport model developed by traffic data collected in 2015.

In the study, overall traffic behaviour as well as truck traffic behaviour inside the city is modeled. Some important traffic indexes are demonstrated. Several specific characteristics of the study area, such as the behaviour of intercity through trips, truck preferred routes, proportion of truck activities in different zones of the city, and estimated volume of freight activities, are defined.

According to the key findings of the study, it is found that there is a possibility of introducing truck ban regulation in the study area. The proper area for addressing the regulation is roughly suggested; that is the inner zone. Referring to the assumptions given in the study and without considering the details such as cargo type, it is estimated that there are approximately 274 fully loaded trucks, or about 4,100 ton of cargo, associated within 12-hour period of banning each day. Nevertheless, it is noted that the introducing of truck ban policy in the study area is less likely to achieve if there is no supported infrastructure such as a public truck terminal serving for city logistic activities.

Regarding the truck ban location is chosen to use the first case as the suggested best case among the other two locations due to the less of distance running on the road in the study area with the least of total running time in the study area. With the result of vehicle operating cost is also found to use case I as per suggested due to the total cost of vehicle operation is less than the other case, and looking at the traffic in GIS application the road condition is also very good while they are moving by using outer link road with small of truck that moving to intermediate zone due to the demand of good are located there. Adding to this study results, after all the cost change is found and the location of truck terminal is found to locate in the right location with less cost of operation time and favorable road to use in order to avoid the impact of traffic congestion inside city center, there still has little bit concern of

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value added cost toward the operation within truck terminal as there will be the increase of labor working process, double loading and unloading as for doing the transferring goods from large truck to the smaller one.

5.2 Recommendation

This study aim at preliminarily examines the possibility of the truck ban idea with city logistics truck terminal in the study area. Some technical details and constrains have been left out to simplify the scope of study. For example: type of cargo is not taken into account although this is an important factor and not all of cargo types can be transhipped at a truck terminal; the location of truck terminal which are extensively important; or what is the total economic benefits of introducing the project. These questions have been noted for more intensive works in the next stage of the study.

Even though there is a possibility of introducing truck ban regulation along with urban logistics truck terminal in the study area, a number of additional research questions are given here. For instance: what is an appropriate number, size and location of the truck terminal for the current and future situations; what is the type of cargo that can practically be transhipped or stocked in a truck terminal; how to deal with cargo that cannot be stocked or transshipped at the terminal; is the project feasible in term of economics and what is the total economic benefits of the project; or could this project really improve traffic condition and other problems inside the study area. Regarding the new truck terminal location, what size and the amount of investment needed to support for the operation with the specific amount of land rental and operation cost inside truck terminal should be advise and address clearly. All of the questions listed are the scope of the future works of this study. Eventually, it is believed that the results of this study will be useful information for supporting both central and local governments in Thailand as well as all other Southeast Asian countries in making a decision about introducing truck ban and public city logistics truck terminal in regional cities of the country in the future.

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Introduction

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Due to world trade liberalization and global logistics operation, world cargo volume has been increasing in an unprecedented fashion for the past several decades, especially in the Asia-Pacific region. This exceptional growth path has led to tremendous challenges to logistics professionals. With the development of information and communication technology and the support of data-driven and optimization-based decision making, intelligent logistics plays a crucial role in managing global supply chains. As an excellent platform to facilitate the interaction among the logistics professionals, T-LOG 2016 will be hosted by National Chiao Tung University in Hsinchu, a city known as the Silicon Valley in Taiwan. The conference will serve as a great opportunity for both academics and practitioners to exchange their information and knowledge as well as to work on the issues and problems related to transportation and logistics.



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An Evaluation of the Truck Ban Regulation and Suburban Truck Terminal Implementation Scheme in Regional Cities of Thailand: A Case Study of Khon Kaen City, Thailand

Chhorn VUHLUNG^a, Jaruwit PRABNASAK^{a*}

^a *Logistics and Supply Chain Management Program, International College, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*

Abstract: Recently, the Department of Land Transport in Thailand has initiated a plan to develop suburban truck terminals in several cities to support urban logistics by switching from line-haul heavy trucks to small vehicles before distributing into the destination. The truck terminal can be expected to come along with implementation of truck ban regulation in each city. This study aims at preliminarily examination of potential impacts causing by the regulation inside a city where a truck terminal is planned to be invested. Khon Kaen city, a capital of the north-eastern region, is chosen as the study area because of its characteristics and availability of data. A four-step urban transport model developed from household and roadside interviews is employed. As a result, potential of introducing truck ban regulation together with truck terminal can be found. Some discussions and important concerns are also provided.

Keywords: Truck Ban, Truck Terminal, City Logistics

1. INTRODUCTION

Truck ban regulation is one of several transport policies that have been known and introduced in many cities around the world, and this seems to be a normal practice in large cities. Aim of the regulation is various. Some cities addressed the regulation for reducing traffic congestion and accidents from large vehicles, protecting ancient and historical site from vibration and to reduce air and noise pollutions. (EPA, 1992; Engel, 2010; Fensterer *et al.*, 2014) In Southeast Asia, truck ban has also been addressed in several large cities, such as Bangkok, Manila, Jakarta, and Kuala Lumpur (Lidasan, 2011). In Bangkok, truck ban regulation has been introduced since 1989. At the time, the regulation initially aimed at reducing problems from heavy goods vehicles inside the urban area of the city. However, later the benefit of truck ban in Bangkok in term of environment has been concerned (Takahashi and Sirikupanichkul, 2001). Recently, Metro Manila also introduced truck ban in some area of the city in morning peak (between 9AM and 9AM) and evening peak (between 5PM and 9PM) except Sunday and public holidays, targeting vehicle that the gross weight is greater than 4,500 kilograms (MMDA, 2015). The aim of the truck ban scheme in Metro Manila is to deal with the issue of insufficient road capacities as well as reducing emission generated in the dense urban area (Fukuda *et al.*, 2013).

Although there are many studies supporting the idea of truck ban in large cities, several arguments have also been given over the time. For example, Takahashi and Sirikupanichkul (2001) mentioned that there are a lot of concern over freight transportation cost for shipping industry after truck ban has been introduced. Besides, Castro *et al.* (2003), found that introducing truck ban regulation in Metro Manila conversely leads to the increase in total vehicle-kilometres, total vehicle-hours and total polluted emissions in some cases. Similar to

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* Corresponding author. Tel.: +66-2-329-8261; fax: +66-2-329-8262; E-mail: kjaruwi@staff.kmitl.ac.th

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Liliana, *et al.* (2012) who developed a study on the impact of truck ban regulation due to public transport development in Mexico City. According to the study, they found that heavy vehicle restriction scheme did not reveal any impact on congestion index and corridors of freight transport; however, increased travel time for the heavy vehicle. With these arguments, it seems that one problem of truck ban in large cities is the restriction is the additional distance from avoiding restricted area. Also, because of massive cargo demand, it is not possible for governments to provide supporting infrastructure such as truck terminal for them. Since truck ban regulation has both advantages and disadvantages. Intensive study and well-developed plan are important when the implementation is proposed.

In 2015, the Department of Land Transport (DLT), Thailand, has done a feasibility study on truck terminal development in regional major cities in the country (DLT, 2015). Within the study, some major cities, such Chiang Mai, Khon Kaen and Hat Yai, were proposed for the development. Although, one main objective of those proposed truck terminals is to serve city logistic activities, the study seems to focus on strategic level (such as, city selection based on city's characteristics and economic perspectives) rather than detailed activities inside each city. Another question is how to induce businesses and cargo owners in those cities to use the truck terminal if there is no restriction on heavy vehicle entering to the business district. Along with the idea of solving traffic related problems, e.g. traffic congestion and road accident, noise pollution, vibration, emission and parking deficiency, truck ban regulation might potentially be the answer.

This study aims at preliminary investigating the potential of introducing truck ban regulation along with public city logistics truck terminal in a regional major city of Thailand. Khon Kaen city, a capital city of the north-eastern region of the country is selected as the principal study area because it is the average size of regional major cities in Thailand as well as availability of data. The main research tool used in this study is the four-step transport model developed by traffic data collected in 2015. Overall traffic behaviour as well as truck traffic behaviour inside the city is revealed by the model. Some findings and concerns regarding the implementation of truck ban regulation and public city logistics truck terminal are discussed. The rest of this paper is organized as follows. Section 2 presents the study methodology. Section 3 reviews some statistics of the study area and data used in this study. Model estimation results are presented in Section 4 while a discussion on potential of truck ban and public city logistics truck terminal is provided in Section 5. Ultimately, the conclusion is given in Section 6.

2. METHODOLOGY

As the aim of this study is to preliminarily examining truck traffic behaviour and its potential of introducing truck ban and truck terminal in a mid-sized city of Thailand, an urban transport model is developed and used as a major tool. Since the scope of the study is to focuses on examining policy in strategic level, also the size of the study which is considerably large, the four-step transport modelling technique which seems to suit the study condition is then selected (McNally, 2007). The data used to develop the model was obtained by a traffic survey held in the study area in March 2015. According to the survey, it includes mid-block traffic survey of 24 locations, roadside interview with roughly 3,500 samples and household survey with nearly 2,000 samples, which are approximately one per cent of city populations.

Because in this stage the aim of study is to investigate the current traffic behaviour especially truck traffic inside the city, the fourth step of the model, traffic assignment, is therefore the main focus. To calibrate and validate the traffic assignment model using the field data, in the first step, the origin-destination demand matrix is acquired by the roadside

interview and household survey data which is adjusted from sample size to the population size. The demand matrix is divided into two sub-matrices: passenger matrix and truck matrix. For the second step, passenger matrix is chosen to assign into the road network. That is because the majority of the traffic movements in the city is found to be passenger vehicles. Truck normally finds the route that can avoid massive passenger traffic and congestions. To assign traffic into the network, user-equilibrium with incremental-loading technique is used. The traffic is assigned by ten per cent of total demand at a time for ten times iteratively. In the third step, passenger model is validated by the mid-block traffic data until satisfying the criteria. Link cost and link restriction are two factors that are used for calibrating. After passenger traffic is already calibrated and validated, next in the fourth step, truck demand is assigned into the model. Again, the truck traffic is calibrated and validated using mid-block traffic data until meeting the expectation. Several characteristics of the model and general indicators of the current traffic condition in the study area are presented in Table 1, while the model network configuration and model validating result are presented in Figures 1 and 2 consecutively.

Table 1. Model characteristics and current traffic condition

| Model characteristics | |
|--|----------------|
| Number of zones | 83 Zones |
| Number of node | 374 Nodes |
| Number of links (separate direction) | 754 links |
| Total network distance (exclude centroid connectors) | 514 kilometres |



Figure 1. Model network configuration

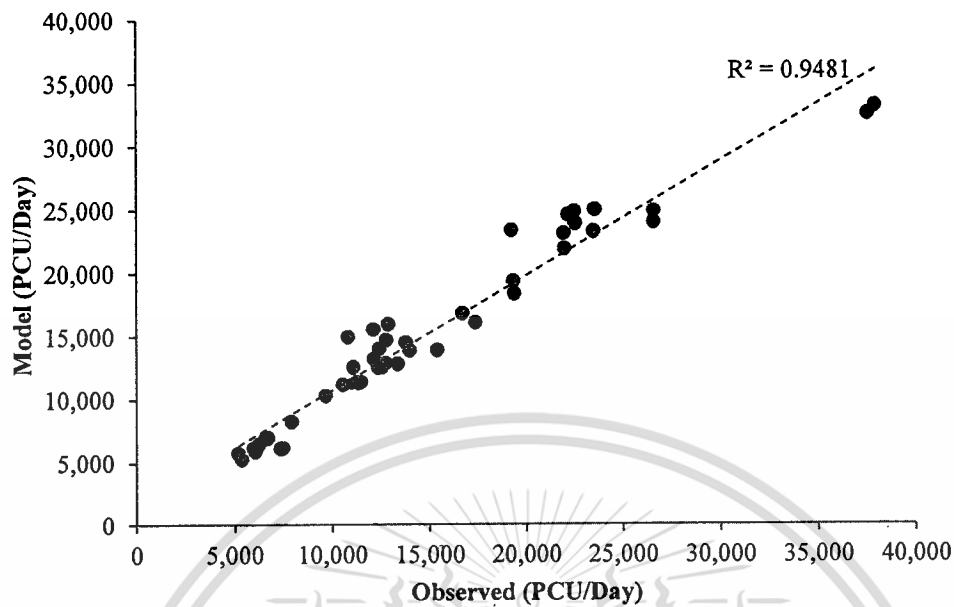


Figure 2. A comparison of observed and modelled mid-block traffic

After the model calibration and validation are completed, next model is used to determine the truck traffic volume across the network and also define the behaviour of truck inside the study area. The analysis can be divided into two parts: to examine overall truck behaviour in the study area, and to define impact of truck ban in some specific areas of the city.

3. STUDY AREA

In this section, a brief explanation of statistics of the study area and the data used in this study are given. Khon Kaen City is chosen as the study area because its size is the average size of major regional cities in Thailand (DOPA, 2015). Metropolitan area of Khon Kaen City covers 228 square kilometres with approximately 300,000 populations. The data used in this study is collected in March 2015. To observe socio-economic trend in the city in past few years, the 2015 dataset is compared with a previous daily travel survey data obtained in 2007 by (SIRDC, 2008). A comparison of the key attributes between the 2015 dataset and the dataset from 2007 is presented in Table 2.

According to Table 2, the average household size in 2015 is 3.49 members, which is slightly larger than in 2007. Interestingly, average income in 2015 is 40,319 Thai Baht (approximately US\$1,145) per month which is about 58 percent higher than that was found in 2007. Looking more closely, relative to the year 2007, the proportion of households with income more than 30,000 Thai Baht per month significantly rises by half while the proportion of households with income lower than 10,000 Thai Baht decreases by 60 per cent in 2015. This could be a result of the government's minimum wage lift up policy in 2011. A variation is also found in working status that in 2015 the proportions of workers and students drop out while the proportion of other increases from 16 to 27 per cent, relative to the year 2007. That can be explained as a common situation in Thailand which has turned into aging-society recently. Majority of populations in category other are retired workers. For the household vehicle ownership, it is found that the proportion of households with motorcycles only drops by over 40 percent, meanwhile the proportion of households with both cars and motorcycles shifts from 52 to 70 percent. However, the proportion of households with cars only remains

the same. This might be a result of another government policy introduced in 2011 – first eco-car extra tax deduction. Regarding Table 2, basically most common attributes in the 2015 dataset seem to be fairly comparable to the previous dataset in 2007. Some discrepancies are found but there are reasonable explanations for them. Therefore, it could be fairly confident with the new dataset used in this study.

Table 2. A comparison between the data used in this study and a previous dataset

| Attribute | Year 2007 | Year 2015 |
|--|-----------|-----------|
| Sample Size | 873 | 2,000 |
| Household size | | |
| Average household size | 3.42 | 3.49 |
| Small (1-2 members) | 28% | 27% |
| Medium (3-4 members) | 53% | 51% |
| Large (5 member and more) | 19% | 22% |
| Household income (THB\$) | | |
| Average household income | 25,416 | 40,319 |
| 0-10k | 19% | 8% |
| 10-30k | 54% | 45% |
| 30-50k | 17% | 25% |
| >50k | 10% | 22% |
| Working status | | |
| working | 64% | 57% |
| studying | 20% | 16% |
| other | 16% | 27% |
| Vehicle ownership | | |
| Households with no car and no motorcycle | 4% | 2% |
| Households with motorcycle(s) only | 35% | 19% |
| Households with car(s) only | 9% | 9% |
| Households with car(s) and motorcycle(s) | 52% | 70% |
| Truck load | | |
| Empty load | n/a | 41% |
| ¼ Load | n/a | 9% |
| ½ Load | n/a | 9% |
| ¾ Load | n/a | 8% |
| Full load | n/a | 33% |

4. MODEL ESTIMATION RESULTS

This section presents estimation results of the urban transport model developed, which can be divided into two sub-sections: overall traffic behaviours and truck traffic behaviours found in the study area, and the potential of introducing truck ban policy.

4.1 Overall traffic behaviours in the study area

In this section, overall traffic behaviours found in the study (including both passenger and truck traffics) are reviewed and discussed. Some results acquired from the model are presented in Table 3.

Table 3. Model estimation results for overall traffic behaviours in the study area

| Model estimation results | | |
|--|-----------|----------------|
| Daily demand (24 hours) | 340,990 | PCU |
| Daytime demand (12 hours: 7.00AM-7.00PM) | 254,673 | PCU (74.7%) |
| Peak-hour demand (1 hour: 8.00AM-9.00AM) | 28,416 | PCU/hour |
| Total daily travel distance | 4,463,034 | PCU-kilometre |
| Total daily travel time | 69,007 | PCU-hour |
| Average trip length | 13.1 | kilometres |
| Average trip time | 12.2 | minutes |
| Average Speed | 64.6 | kilometre/hour |

Remark: PCU denotes Private Car Equivalent Unit

According to the model, it is predicted that there are over 340,000 PCUs running in the road network of the study area each day. This does not include traffic in small streets, access road and alleys. With this amount of traffic, about 75 per cent of them serve daytime activities – between 7AM and 7PM. In the study area, morning and evening peak hours are found to be almost similar volume per hour. The average speed in the city is found to be roughly 65 kilometres per hour. However, this average speed accounts for outer ring road and some sections of intercity highways which can influence the average speed of the model. Figure 3 presents link traffic estimated by the model.



Figure 3. Traffic flow on links estimated by the model

According to Figure 3, most of the traffics go along north-south and east-west directions. That is because Khon Kaen city is located in the heart of the region. Therefore, not only local traffic generated by inhabitants but the city's road network has to handle intercity through trips also. The business corridor is the north-south corridor named Mittraphap road;

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meanwhile, the second business corridor is the western corridor named Maliwan road. With the business road section on Mittraphap road, each day there are approximately 38,000 PCU per direction. Besides, the business road section on Maliwan road is roughly 27,000 PCU per direction. However; both corridors are three to four lanes divided with frontage road for both side, capacity of the road is yet sufficient in normal situations – It is found that the main course of traffic congestion in the city is the capacity of traffic signal and intersection.

Another problem found in the city is that there are a large number of intercity vehicles that used Mittraphap and Maliwan roads for crossing the city. That is because both roads consist of a number of lanes which are enough to provide a good level of service, especially in off-peak period. The through traffic includes both passenger and truck traffics. For the passenger traffic that is mostly a platoon of private cars, they can easily merge to the local traffic in the city. Nevertheless, in the case of truck through traffic, this would lead to many problems inside the city, for instance, noise and air pollutions, vibration and extending severity of traffic congestion along daytime. This is a reason why this study has been initiated.

4.2 Truck traffic behaviours in the study area

In this section, truck traffic behaviours revealed by the model are reviewed and discussed. Some results obtained from the model are presented in Table 4.

Table 4. Model estimation results for truck traffic behaviours in the study area

| Model estimation results | | | Comparison to Table 3. |
|-----------------------------------|---------|----------------|------------------------|
| Daily truck demand (24 hours) | 41,289 | PCU | 12.1% of total traffic |
| Total daily truck travel distance | 901,369 | PCU-kilometre | 20.2% of total traffic |
| Total daily truck travel time | 11,815 | PCU-hour | 17.1% of total traffic |
| Average trip length | 21.8 | kilometres | 66.4% greater |
| Average trip time | 17.2 | minutes | 41.0% longer |
| Average Speed | 76.3 | kilometre/hour | 18.1% faster |

In this study, the PCU is referred to code of the Department of Highways (DOH, 2013), which suggests that a unit of heavy vehicles, such as heavy rigid, trailer and semi-trailer trucks, is roughly equivalent to 2.5 PCU. Regarding Table 4, the daily truck demand in the study area is approximately 40,000 PCU (about 16,000 heavy trucks), which is about 12 percent of total vehicles running in the network each day. However, if considering the total daily travel distance and travel time of trucks, it is found that this takes about 20 per cent of total travel distance and 17 per cent of total time. This implies the significance of heavy vehicle traffic in the study area. For the average trip length and trip time, it is found that the trip length is about 66 percent greater, while average trip time is over 40 percent longer than the overall traffic. Besides, the truck average speed is 18 percent greater than average speed across the network.

To investigate the reason that the average speed of trucks is greater than the network overall, the desire line and truck traffic volume on links are plotted as presented in Figure 4 and Figure 5. According to the figures, it can be seen that the majority of the truck origin-destination pairs are through traffic, e.g. north-south, east-west and east-south. Meanwhile, it can be seen that the truck traffics on the ring road are noticeably high, particularly the southern loop. As mentioned earlier, Khon Kaen city is located in the centre of a region. It is expected that a considerably large amount of intercity traffics has to cross the city without need for stopping. Since traffic congestion is such a common problem in the city for the daytime, it is quite possible that some of through trips, especially truck traffic, would use

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outer ring road to avoid poor traffic condition. This model behaviour is found to match the observation.

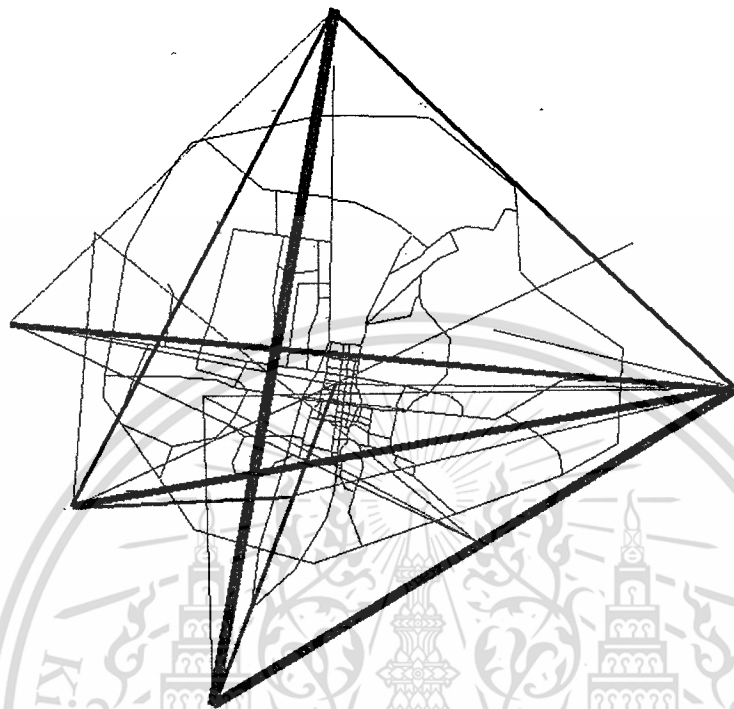


Figure 4. Truck traffic desire lines

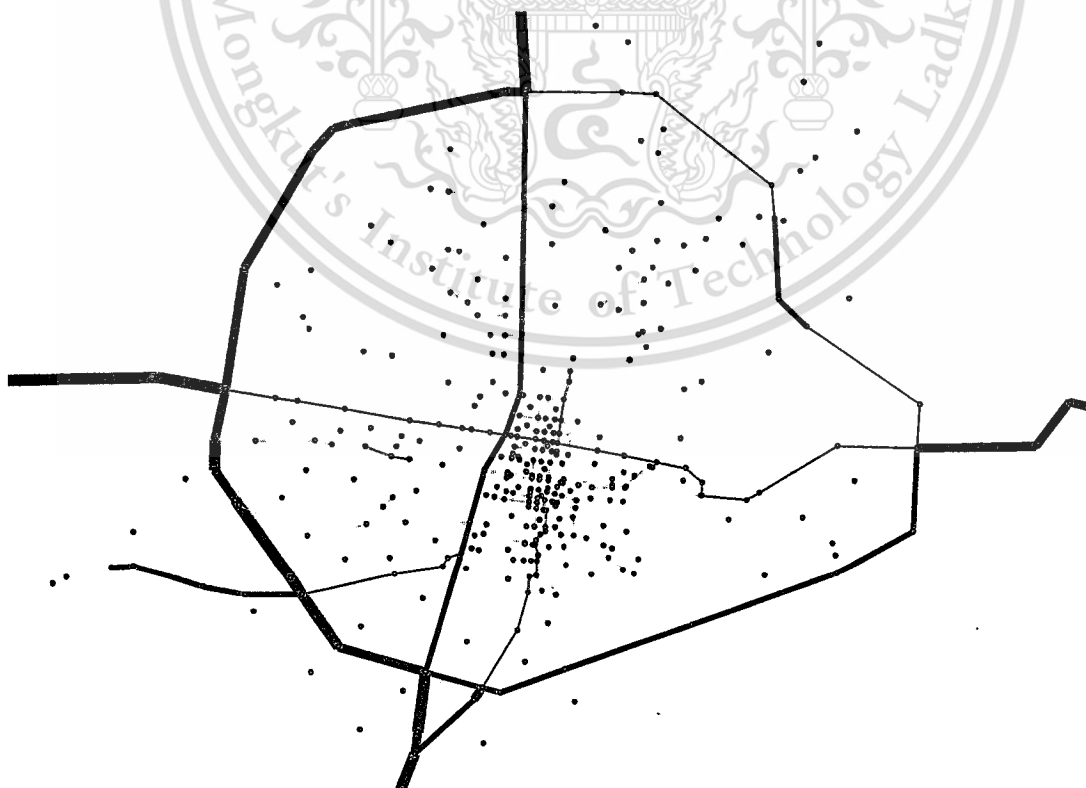


Figure 5. Truck traffic flow on links estimated by the model

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4.3 Freight activities distribution in the city

After the overall truck behaviours in the study area are investigated and found that there are approximately 41,000 PCU of trucks running in the network each day, which is roughly 20 per cent of total travel distance in the network. The question given here is that how many trucks that actually have their origin or destination in the inner zones of the city. These trucks are likely to be disturbed by truck ban policy in the city centre. To do so, the study is divided into three zones using urban density: outer zone, intermediate zone and inner zone. Truck traffic activities within each zone are estimated as demonstrated in Table 5.

Table 5. Truck traffic activities in outer zone, intermediate zone and inner zone

| Model estimation results | Overall | Outer | Intermediate | Inner |
|---|---------|---------|--------------|--------|
| Network length (kilometre) | 514 | 195 | 189 | 130 |
| Truck demand (PCU/day) | 41,289 | 35,649 | 3,698 | 1,942 |
| Total truck travel distance (PCU-kilometre) | 901,369 | 789,072 | 72,863 | 39,434 |
| Total truck travel time (PCU-hour) | 11,815 | 10,059 | 1,161 | 594 |

Regarding Table 5, the network length in outer zone is 195 kilometres, which is about 38 per cent of the total network distance. Meanwhile, the network length in inner zone is 130 kilometres, which is about 25 per cent of the total network distance. As expected, the outer zone which the ring road and intercity highways are located is the busiest area for truck activities. Approximately, 35,000 PCUs of trucks use road network within the outer zone each day. This is about 86 per cent of total truck traffic in the study area. As a result, majority of truck travel distance and truck travel time are generated in this zone. The intermediate zone accounts nine per cent of total truck traffic in the study area and the inner zone handle the rest of truck activities which is about five per cent.

According to the findings, it seems that there is only a small portion of trucks that have some activities inside the city, while majority are through traffic. However, if the PCU is converted to heavy truck unit, the intermediate zone is expected to have about 1,500 trucks entering and exiting the area each day. With this amount of heavy vehicles, they can certainly impact traffic in the zone. Moreover, if focusing on the inner zone, there are about 780 heavy trucks which have origin or destination in the zone each day. The inner zone is the central business district (CBD) of the city. There are many activity nodes, such as central market, large shopping centre, schools and government offices. Thus, this is the most traffic congested area of the city. Hundreds of heavy trucks visiting the district resulting in many problems, such as vibration, congestion, air and noise pollution, accident, and loading and unloading parking problem.

Another behaviour that is also found from field survey is that the truck demand profile in outer zone seems to be roughly steady throughout day and night, which is such a common situation for intercity highway. However, in the case of intermediate and inner zones, majority of the truck activities occur in the daytime. That is because these trucks are related to local businesses in the city. Thus, most of activities need to be done during business hours.

5. DISCUSSION ON THE POTENTIAL OF INTRODUCING TRUCK BAN

A discussion on possibility of introducing truck ban in this study area is given here, divided into two cases. For the first case – considering that truck ban is addressed in the inner zone where the traffic is most critical during the daytime; around 800 trucks are likely to visit the zone each day. Among this number, based on the mid-block traffic survey, about 75 per cent of them are daytime activities. Assumed that the regulation is set for 12 hours daytime period

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– between 7AM and 7PM, thus about 600 trucks are potentially affected. Regarding the data obtained from roadside interview presented in Table 1, it is found that on average truck utilization in the study area is 45.7 per cent. Presumed that the truck utilization is true across the study area, it means that within 12-hours of implementing the truck ban regulation those 600 trucks can be converted into 274 fully loaded trucks, or approximately 4,100 tons of cargo (assumed that one fully loaded truck carries 15 tons of cargo), being enforced by the regulation.

In the second case; if the regulation is assumed to address in both inner and intermediate zones, there are a total of approximately 2,300 trucks associated with both zones. Based on the same assumption, the number of trucks with daytime activities can be roughly 1,700. With similar utilization rate and carrying capacity, within 12-hours of implementing the truck ban regulation there are approximately 1,050 fully loaded trucks, or roughly 15,700 tons of cargo.

Though truck ban regulation might be one solution in relieving traffic condition in the city centre, banning those trucks certainly impacts businesses and cargo owners in the city. Without a reasonable alternative for them, introducing the regulation might not be possible. Referring to a study held by the DLT in 2015 (DLT, 2015); based on the findings of the study, it is suggested that there should be a number of truck terminal investments in large regional cities in Thailand, including Khon Kaen city. The truck terminal project leads to potential for introducing truck ban regulation in the study area. The truck terminal developed can be used as a public terminal for serving city logistics. Businesses and cargo owners inside the city can use the terminal to tranship cargo from large goods vehicles to small distribution trucks, or temporarily stock at the terminal waiting for delivery in off-peak period.

Considering the estimated total cargo volume of both inner and intermediate zones, which is 15,700 ton per 12-hour period or about 1,300 ton per hour; refer to the designed capacity of the truck terminal given by (JICA, 1988; DLT, 2015), this amount in a cargo is considerable and required quite large space for operation. Besides, introducing the regulation across both inner and intermediate zones is difficult in term of social acceptance and management, which does not seem to be practical in reality. In contrast, focussing on truck ban in the inner zone seems to be more potential. The cargo volume of about 4,000 ton per 12-hour period or about 340 ton per hour is more likely to be managed. Additionally, there is more rational to introduce such regulation in the area where the traffic congestion and roadside parking issue are critical. Thus, it is suggested that the truck ban regulation can potentially be addressed in the inner zone presented in this study. Nevertheless, truck ban regulation could not be successful without the development of public truck terminal for supporting businesses and privates inside the enforced area.

Incidentally, this study aim at preliminarily examine the possibility of the truck ban idea with city logistics truck terminal in the study area. Some technical details and constrains have been left out to simplify the scope of study. For example: type of cargo is not taken into account although this is an important factor and not all of cargo types can be transhipped at a truck terminal; the location of truck terminal which are extensively important; or what is the total economic benefits of introducing the project. These questions have been noted for more intensive works in the next stage of the study.

6. CONCLUSION

This study aims at preliminary investigating the potential of introducing truck ban regulation along with public city logistics truck terminal in a regional major city of Thailand. Khon Kaen city, a capital city of the north-eastern region of the country is selected as the principal study

area as its characteristics and availability of data. The main research tool used in this study is the four-step transport model developed by traffic data collected in 2015.

In the study, overall traffic behaviour as well as truck traffic behaviour inside the city is modelled. Some important traffic indexes are demonstrated. Several specific characteristics of the study area, such as the behaviour of intercity through trips, truck preferred routes, proportion of truck activities in different zones of the city, and estimated volume of freight activities, are defined.

According to the key findings of the study, it is found that there is a possibility of introducing truck ban regulation in the study area. The proper area for addressing the regulation is roughly suggested; that is the inner zone. Referring to the assumptions given in the study and without considering the details such as cargo type, it is estimated that there are approximately 274 fully loaded trucks, or about 4,100 ton of cargo, associated within 12-hour period of banning each day. Nevertheless, it is noted that the introducing of truck ban policy in the study area is less likely to achieve if there is no supported infrastructure such as a public truck terminal serving for city logistic activities.

Even though there is a possibility of introducing truck ban regulation along with urban logistics truck terminal in the study area, a number of additional research questions are given here. For instance: what is an appropriate number, size and location of the truck terminal for the current and future situations; what is the type of cargo that can practically be transhipped or stocked in a truck terminal; how to deal with cargo that cannot be stocked or transhipped at the terminal; is the project feasible in term of economics and what is the total economic benefits of the project; or could this project really improve traffic condition and other problems inside the study area. All of the questions listed are the scope of the future works of this study. Eventually, it is believed that the results of this study will be useful information for supporting both central and local governments in Thailand as well as all other Southeast Asian countries in making a decision about introducing truck ban and public city logistics truck terminal in regional cities of the country in the future.

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THE EVALUATION OF TRUCK BAN REGULATION AND TRUCK TERMINAL IMPLEMENTATION IN THE PURPOSE OF URBAN FREIGHT TRANSPORT EVALUATION, A CASE STUDY OF KHON KAEN CITY, THAILAND

Vuchlung CHHORN ^a, Jaruwit PRABNASAK ^{a*}

^a *Logistics and Supply Chain Management Program,*

International College, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

Email ^a : *Vuchlung@gmail.com*

Email ^{a*} : *jaruwit.prabnasak@hotmail.com*

ABSTRACT

This study is undertaken to examine the advantages and disadvantages of introducing truck ban policy along with the development of public urban truck terminal in a mid-sized city of Thailand. Khon Kaen City is chosen as a principal study area because of its importance as well as availability of data. Three potential locations for developing a public truck terminal are evaluated using an urban transport model developed in this study. As the results, the suitable location of truck terminal will be found. Also, the cost of freight transport change due to the policy of truck ban with the truck terminal new location will be defined. Some discussion and the concern factors are provided as recommendation.

Keyword: City logistic, Freight Transport, Truck ban, Truck Terminal

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^a *Logistics and Supply Chain Management Program,
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Keyword: City logistic, Freight Transport, Truck ban, Truck Terminal

1. Introduction

In most countries around the world, there are problems happening everyday as the concern to city operation. As such, truck congestion has been address as one of the major issue due to the amount of large vehicle operation inside city area which causes the traffic getting worse. Many studies have already conducted similar study about this kind of policy to help with the movement in the city. Freight distribution process with the truck terminal implementation also has been a concern (Vuchlung & Prabnasak, 2016). In major cities of most developed countries as well as the South-east Asia countries also have focused on this policy to improve their freight operations and the city traffic situation. Most countries in Europe have already implemented such policy in order to improve the traffic condition as well as the freight distribution among city logistics. (Amanda et al, 2010). A study of Wisetjindawat (2011) provided information on freight transport policies implemented in several countries in Asia, Europe, and North America. The study defined objectives for sustainable freight development, i.e. reducing energy consumption per ton-kilometers, decreasing ton-kilometers of less sustainable transportation modes such as road transport, and increasing usage of more environmentally friendly transport modes such as rail and water transports. Implemented policies and measures in each of the categories was discussed based on their contribution to achieving the stated objectives, and their practicality is analyzed (Wisetjindawat, 2011). The evaluation of freight distribution process is the effective way for the implementation purpose in city (Suksri & Raicu, 2012). Road freight transport led to many problems around the word including traffic congestion and environmental problem. There is also the lack of understanding of freight transport policies on traffic management. On the other hand, passenger movements also involved with a large part of activities on the road. Due to the location of recreation, shopping center, and educational community mostly located inside attraction area such as city center as per called center business district (Rodrigue, 2006).

Also, there was a study conducted on the city freight transportation helping to improve the city sustainability. That study stated that the moment of goods and products will lead to the use of fuel, which is a non-renewable energy resource. In 2007, there are about 28.4 percent of US energy consumption, which were used. Besides, the emissions from using transport activities have created the problem of air pollution and led to a great global environmental problem which is the global warming. The study also stated that the emission from greenhouse gases (GHGs) is the main cause of

CO₂ in the atmosphere and it is account for 33.6 percent in US (Golici, Boerstler, & Ellram, 2010). Besides, trucking vehicle is the largest generator of GHG emission in the transport sector. In addition, Dulal and Brodnig Onoriose, (2011) pointed out that the level of the recent Carbon dioxide (CO₂) concentration in the atmosphere has been considerably increased than the normal natural ranges and this concentration is estimated to be double by the end of this century. Also, Takahashi and Sirikupanichkul (2001) examined the effects of the new public truck terminals on air pollution in Bangkok. An estimation of the emission loads from truck transport was made by using empirical models and the geographic information system. The study showed that NO_x were the major emission load generated by trucks (61.73 tons per day), followed by CO₂ (37.72 tons per day). This lesson learnt should be very useful for future used of the next implementation, which included truck terminals in the north at Chiang Mai, in central Thailand at Nakhon Sawan, in the north-east at Khon Kaen in Nakhon Ratchasima which is mainly this study, also in the south at Hat Yai, and Songkhla (Takahashi and Sirikupanichkul, 2001).

Even the study on truck ban is for the improvement of the city freight mention as well as the comparison of cost change within the study area. This study is mainly focus on the truck which is moving from outside the city area until the CBD area rather than the detail activity of truck movement from the origin to the final destination. This is still the hard project as we need the support from other industries sector to support the idea of truck ban along with truck terminal implementation to avoid the distribution problem and daily cargoes operation. This purpose of truck ban is to help with the current and future congestion of truck traffic with the possibility of city sustainability. Thus, this truck policy could be the answer to all of these questions.

2. Methodology

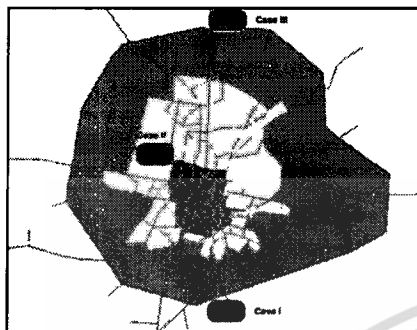
As the purpose of this study is to evaluate the truck traffic inside the city as well as the truck behavior with the trucking cost comparison with the possibility of introducing truck ban and truck terminal implementation, the four-step urban transportation modelling technique is employed as the main tool. The model is chosen due to the suitability of the population size of Khon Kaen city and study condition (McNally, 2007) and the type and pattern of available data on site. According to this, data set used in developing the model was collected in Khon Kaen in 2015.

Since one of the key purposes of this study is to define the variation in cost among three different scenarios of installing an urban truck terminal in the study area. This study presented the project with an analysis of return on economic and financial aspects of the project as well as the logistic cost changed due to the three different scenarios as in Figure 3.1. According to the analysis of the vehicle travel time based on the value of time saving, this value varied according to the objective of the expedition revenue associated with the portion of the vehicle used. In this study, in this study the cost of driver and vehicle operating cost, also called vehicle operating cost (VOC), is obtained from a study conducted by the Expressway Authority of Thailand in Khon Kaen in 2015 (EXAT, 2015). The calculation included the total of vehicle-kilometer-travelled (VKT) and vehicle-hour-travelled (VHT) on the daily basis. These two parameters are used to evaluate and compare among three different scenarios.

3. Three Scenario setting and Suggested Location for Truck Terminal

Figure 3.1 is the ideas of the truck terminal location in the purpose of dealing with the policy of truck ban implementation. This truck terminal would help to improve the city traffic condition toward city logistics movement. All the suggested locations were based on the land availability with the accessibility of road transport that is used during the operation in the study area. The study came up with the sufficient locations as shown in Figure 3.1. Suggested location for each scenario is defined by land availabilities, the official land-use and town master plan, as well as refer to a study on urban truck terminal implementation in Khon Kaen City (EXAT, 2015). Also, the purpose of introducing this location was based on the accessibility to city center and outer city link, which make both operation inside and outside city easier after the investigate. As some of goods considered as daily delivery products, the distance from the city might lead to another problem that affects on the logistics

activities within this study area. This problem may rise to another issue, which become the conflict with our objectives. Moreover, those issues of congestion, road accessibility, and land availability were considered in the locations' decision. The location of the truck terminal is not possible to locate within city center five kilometers. There are three different options as shown in the following for this study to observe the best location, which benefits to the project the most among other options.



Truck Terminal Location Choices

Case I. Before entering city center around 8 km

Case II. Before entering CBD area about 6 km

Case III. The other option is around 12 km from CBD

Colors indicator

Dark Green: Outer Zone

Light Green: Intermediate Zone

Red: Inner Zone or CBD

Figure 2.1 Map for colors categorize and location for truck terminal

The option is for various observations. The location became more convenient for all trucks to drop their cargos and exchange with smaller trucks in order to transfer products to city areas. This proposed case was studied at the end after the reviews of all data that we received. First, all data sets were studied and analyzed the current situations of trucks moving inside city center and outside the inner city areas such as intermediate and outer zones. Then, this study compared the current situation of truck moving including passenger vehicles that addressed the different operation of all vehicles moving on the desire lines. After all data sets had been analyzed and discussed, then the study's data sets were used and revised from the original data (EXAT, 2015). The remodel data focused only on the truck travelling demand of large trucks that operated on the road inside Khon Kaen City while the other data sets of passenger vehicles were ignored. All trucks that moved directly inside city were forced to stop at each truck terminal; then, all goods were transferred to the small trucks instead. Before getting into city center, the daily operating goods, which needed during daytime operation need to get out of city center to other zone like intermediate or outer zone in small trucks. Trucks were forced to stop at each truck terminal for consolidation and transferred to larger trucks. These were applied to all scenarios, which were already proposed. All the colors were defined based on the population density in Khon Kaen city as well as the combination of business community inside CBD. These indicators were shown to help to understand from the different activity within the evaluation.

4. Results and Discussion

This section presents estimated results of the urban transport model development, which can be divided into two sub-sections such as overall traffic behaviors and truck traffic behaviors. Besides, this section also presented the remodel-estimated results of truck transport excluding the passenger vehicle while only large truck movements were focused. These model-estimated results have been divided into two sub-sections as well. First, the overall truck traffic behaviors were found and compared with the three cases. Also, the explanation of each figure from desire link of truck traffic running by model compared with the result after running from GIS program was provided within each in case. Last of all, the potential of introducing truck ban policy was proposed while the benefit of environment was also investigated.

4.1 Truck Traffic Behaviors in the Study Area of Base Case Scenario

This section, base case scenario was created based on the original data sets from survey as secondary data obtained from EXAT (2015). Then, the new O-D matrix was created by deleting all passenger vehicles and focusing only on the trucking transportation within inner zone (CBD). After the new O-D matrix created the result, we found there were trips, which were operated just within the inner zone by large trucks with proposition of trip about 3 percent compared to the whole trip within study area. This study decided to take it out from the model in order to avoid the strange value inside the model during

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the results revealed. Then, these data sets were remodelled and rechecked results by GIS application. The base case scenario estimated result on truck traffic behaviors were shown in Table 4.1.

Table 4.1 Model estimation results for truck traffic behaviors in base case scenario

| | | |
|-----------------------------------|-----------|-------------|
| Daily truck demand (24 hours) | 3,521 | PCU |
| Total daily truck travel distance | 58,504.47 | P-kilometer |
| Total daily truck travel time | 1,020.08 | PCU-hour |

Table 4.1 showed that the total demand of trucks for the normal operation with large trucks were approximately 3,521 PCU (about 16,671 tons of light trucks) moving inside city area in the road networks for 24 hours. In addition, it consisted of 58,504.47 vehicle-kilometers within the networks. This results in accounting for 1,020 hours with the average trip length of 0.7 kilometers as well as the average trip time around 0.81 hour with average trip speed 49.1 km/hour.

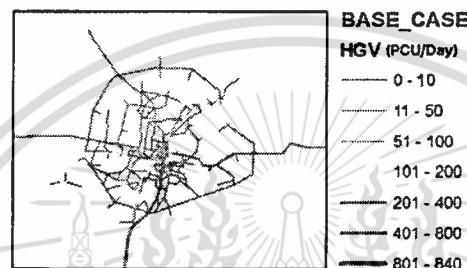


Figure 4.1 Truck traffic flow on links estimated by the GIS application in base case scenario

In Figure 4.1 showed the truck traffic flow on the links estimated by the GIS application in base case scenario. This Figure showed that the traffic flow on the link was arriving from all direction of the street within the study area. All trucks directly went inside the city area which lead to the heavy congestion problem on the link road as could be seen the yellow line and red line. The red line indicated the heavy traffic on the road. This result made this assumption became more realizable due to the movement of traffic from everywhere crossing city center or coming from city center, so that this study is useful to deal with this kind of current traffic behavior in the study area. By Figure 4.1, the result of this study was assumed that this model was suitable for doing the further study on the three different locations of the truck terminal as suggested in Figure 4.1 to avoid the truck traffic on the main road and truck traffic inside CBD.

4.2 Truck Traffic Behaviors of Case I (Zone 71)

In this section, truck traffic behaviors of case I (zone 71) revealed by the model were reviewed and discussed.

Table 4.2 Model estimated result of Case I in Zone 71

| | | |
|-----------------------------------|------------|-------------|
| Daily truck demand HGV | 3,521 | PCU |
| Daily truck demand LGV | 8,337 | PCU |
| Total daily truck travel distance | 118,843.18 | P-kilometer |
| Total daily truck travel time | 2,152.60 | PCU-hour |



Figure 4.2 (Left) Traffic flow on links in Case I(HGV) (Right) Traffic flow on links in Case I of(LGV)

Table 4.2 showed that the truck demands moving in outer zone are about 3,521 PCU which approximately around 8,802.2 Ton for large trucks which is moving outside to truck terminal Zone 71 and the truck demands which need to move inside city is about 8,337 PCU which approximately around 16,674 tons. This was double differences of the existing demands with the total vehicle hours around 2,152 hours with the same study area.

Figure 4.2 (left) showed that after having the truck terminal in Zone 71 trucks that moved from outer zone has to switch to use the outer link road instead of inner city road. Then all large trucks that moved from outside city turned to used outer link road which was shown as the yellow line and orange line through circle around map. While Figure 4.2 (right) indicated that the traffic flows on link road within CBD area with the LGV moving within 24hrs operation. The result found that traffic moving desire line is as per expected with 8,337 PCU (about 16,674 tons). The red colour indicated the traffic along the small block from intermediate zone. The traffic was partly crowded until the truck terminal zone. However, as the truck movements were already converted from larger trucks to the small trucks, this was assumed that the traffic flow on the link was normal with small demand of large trucks on link.

4.3 Truck Traffic Behaviours of Case II (Zone 48)

This section was the description of model estimated results in Case II, which was calibrated with the GIS map showing the traffic flow both outside link road and inside inner city area. Results from Table 4.3 showed the same demand of HGV and LGV as Case I, however the differences found between total truck traveling distances about 290,938.81 PCU-Kilometres which was 144 percent greater than Case I and truck traveling time about 4841.17 PCU-hours which was about 125 percent greater than Case I. This could obviously have showed that Case II were not satisfied our research objective as the aims of the cost saving location with the least cost in the transportation operation.

Table 4.3 Model estimation results for truck traffic behaviors in Case II

| | | |
|-----------------------------------|------------|-------------|
| Daily truck demand HGV | 3,521 | PCU |
| Daily truck demand LGV | 8,337 | PCU |
| Total daily truck travel distance | 290,938.81 | P-kilometer |
| Total daily truck travel time | 4,841.17 | PCU-hour |

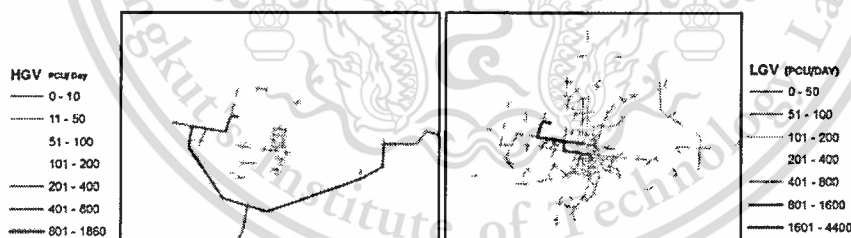


Figure 4.3 (left) Truck traffic flow in Case II of HGV (Right) Truck traffic flow in Case II of LGV

Figure 4.3 (left) indicated the flow on the desire link within Case II as the result from GIS map. Result showed that the location condition in intermediate zone is quite far from the terminal location if we compared with case I. This location condition has forced all the large vehicles to use outer link road instead which make the distance and traveling time increase as well. As in Figure 4.3 (right), same method applied on the truck movement so most goods turned to use inside city road and other roads along with intermediate zone. This result made the road along intermediate zone became significantly red. This indicated the heavy traffic on the link of small kind of vehicle.

4.4 Truck Traffic Behaviors of Case II (Zone 75)

This section calibrated the result of model estimated from Case III compared to Case II as the following Table 4.4. The results showed that truck traveling distances were 148,507 PCU-kilometres which was about 50 percent less than Case II; however, it was still greater than Case I by 25 percent. Total traveling distance was 2,625 hours greater than case I about 22 percent but it was 45 percent better than Case II.

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Table 4.4 Model estimation result for truck traffic behaviors in Case III

| | | |
|-----------------------------------|------------|-------------|
| Daily truck demand HGV | 3,521 | PCU |
| Daily truck demand LGV | 8,337 | PCU |
| Total daily truck travel distance | 148,507.48 | P-kilometer |
| Total daily truck travel time | 2,625.74 | PCU-hour |

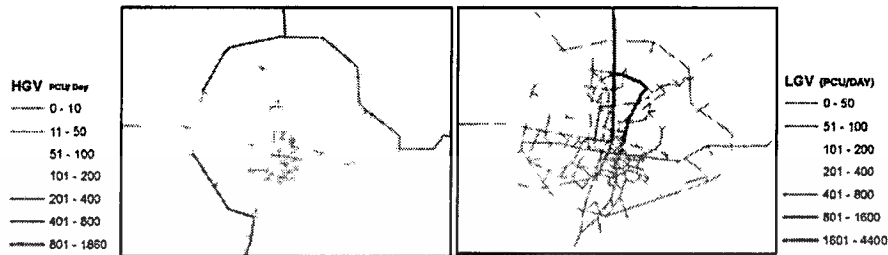
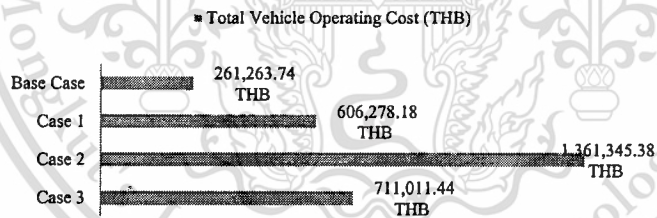


Figure 4.4(left) Truck traffic flow in Case III of HGV **(Right)** Truck traffic flow in Case III of LGV

Figure 4.4(right) showed traffic flow of large trucks. After the road that used for goods delivery has been changed, all large trucks that moved goods to city center had to drop those goods at the third location of truck terminal in Zone 75 instead. The desire link road was outside city as showed in the red color and orange color. This indicated the heavy truck traffic moving on the link. This was significantly crowded and lot of traffic increased in intermediate zones road as appeared in red color.

4.5 Vehicle-Kilometer and Vehicle-Hour Comparison

In this section, the total kilometers and total hours of all the three difference cases were evaluated and showed by Figure 4.5. This section would bring the clear pictures of all the cases for the purpose of comparison. The purpose of this section was to look for the total cost of both vehicles cost and driver costs together running on the road. In addition, the longer the vehicle spending on the road of the link in the study area, the more vehicle operating cost generated base on the total operating time per total trip generated from the model.



Note: THB exchange rate (35THB=1USD) **Figure 4.5** Total vehicle-operating cost of the study area

As Figure 4.5 showed the result of total calculation of all vehicle operation cost per day on the link road from internal zone to truck terminal as well as from truck terminal to the final destination outside the study area. Results showed that in order to implement new truck terminal large amount of money would need to invest in the project as being found that the cost of base case scenario was less than 200,000 Thai baht if compared with Case I. However, comparing to base case, it would be two times greater. This is very significant due to the change of total cost. As the result from Case II showed that more than 1 million Thai baht was wasted per hour if truck terminal located in the intermediate zone. This could mean that in the location Case II they generate the longest waiting time due to the geography of the zone was quite near the internal zone of CBD, where traffic condition need to be improved. Truck terminal located in Zone 48 would cause even more serious traffic congestion than current situation.

Additionally, Case III showed a better result of vehicle operation cost comparing with Case II; however, Case I still generated the most satisfied result than Case III because the total cost in Case III will still larger than Case I around 21 percent. By the result in Figure 4.5 found that Case I still became the most suitable case of this research study; however, the result of this study would expected

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the increase of vehicle kilometer and vehicle hour as the number of vehicle would be increasing due to the model purpose of transferring goods to truck terminal before entering city area. That is also the reason why vehicle operation was increased dramatically. That is reasonable enough for this finding. Vehicle distance surely increased while the time length also increased at the same time. This cost summary was not included the value adding cost beside the waiting time and distance of vehicle. Assuming that all value adding cost is set to be zero, all costs from three different scenarios still greater than the base case scenario in the study area.

4.6 Discussion on Truck Terminal Implementing and Vehicle Handling

From the first discussion, in order to support the policy of truck ban inside city center, the truck terminal would be needed in this case as to support the logistic operation as daily service and delivery during peak hour as well as for the storage purpose. In this case, as the truck terminal is implemented, the study has to discussion about the operation processing inside the terminal with trucking cycle procedure and below concern also need to take into account as well.

In addition to location of truck terminal is assume to be located around 13 km far away from the city center, which is right at the outer zone as per showed in case I (Zone71). While all trucks from everywhere outside city in other location use to run along intermediate road to inside city by the policy and truck terminal location, most traffic will move to use the outside ring road instead. As result, traffic inside the city center will be less on road and clear from congestion with very less traffic. While the operation of truck in the CBD with only the small type of vehicle, with capacity of current road traffic, this will be enough for the traffic operating on the current road size. However, value adding cost is not included. As the land use for doing truck terminal is operating under the use of labors for doing the storage controlling, loading, unloading, and warehouse management etc. All of these operations will surely cost extra handling. Considering those value adding service to the total cost, this will found that adding on the vehicle operating cost that showed in Figure 4.5. The vehicle operating cost sum up with handling cost surely increased if considering of having truck terminal location as per proposed in Case I.

Adding on the above discussion, in this study activities of truck evaluation found out that our analysis of transportation cost is called last mile delivery which mean that was analysed only the last activities of transportation in the study area while not included with the other up-size cargo from other provinces. By this regard, this can assume that having truck terminal will not help with cost reduction but creating even more cost added into the study analysis if comparing with base case scenario (do nothing) in this finding. However, this have not taken into account for the line-haul activities which could be the best benefit to the truck terminal due to the cargo truck upsize from other provide together with the same truck that are going to same direction. The transportation cost and environmental cost of his activities in the chain might be even cheaper than the base case scenario. This will be recommenced for further study for the clearer analysis and understanding.

5. Conclusion

As the aim of this study is primarily evaluate the truck ban policy and truck terminal location in the purpose of urban freight transport, GIS application has been used to check the flow on each link of the three different cases with three different location zones. The total cost has been found and evaluated from the existing O-D table that we generate from GIS attribution table. The location is chosen to use the first location zone 71 which considered as the best case among the other two locations due to the distance of the road with the minimal of total running time in the study area. As the result, vehicle operating costs were also found that using the location in case I is the most suitable choice. As the total cost of vehicle operation was less than the other cases as well as checking in the traffic flow in GIS application. The road condition was also very good while most trucks were moving by using outer link road and only small trucks operated by intermediate zone roads due to the demand of goods were mostly located there.

Adding to this study results, after all the logistics operating costs were found and the locations of truck terminal were evaluated to locate in the right location with favourable road to use in order to avoid the

impact of traffic congestion inside city centre. There were still concerns of value added cost toward the operation within truck terminal as there will be the increase of labour working process, double loading and unloading, the requirement of some specific kind of cargo, storage requirement, and cargo transshipment process as well.

Incidentally, this study aims to preliminarily examine the possibility of the truck ban idea with city logistics truck terminal in the study area. Some technical details and constraints have been left out to simplify the scope of study. For example, type of cargo is not taken into account although this is an important factor. Not all of cargo types can be transhipped at a truck terminal as the location of truck terminal which are extensively important. Also, the total economic benefits of introducing the project and the total cost of value adding service were not found. These questions have been noted for more intensive works in the next stage of the study.

Even though there is a possibility of introducing truck ban regulation along with urban logistics truck terminal in the study area, a number of additional research questions are given here. For instance, what is an appropriate number, what is the size and location of the truck terminal for the current and future situations, and what is the type of cargo that can practically be transhipped or stocked in a truck terminal? Regarding the new truck terminal location, there are still concerns and the following factors should be addressed clearly such as size of the investment needed, the support for the operation, the size of land rental needed, and the extra cost operation inside truck terminal. All of the questions listed are the scope of the future works of this study. Eventually, it is believed that the results of this study will be useful information for supporting the future project for local investor and local government in Thailand as well as in other neighbour countries in making the decision before considering on create such policy for the city freight logistic evolution.

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Dr. JARUWIT PRABNASAK

Personal Information:

Employment: A lecturer at the International College, King Monkut Institute of Technology Ladkrabang

Address: Charong Krung Road, Ladkrabang, Bangkok

Contact number: +66-8-1632-0735 (Mobile), +66-2-329-8261 (International College)

E-mail: kpiaruwi@kmitl.ac.th
Jaruwit.Prabnasak@hotmail.com

Education:

2008 - 2012: University of South Australia, Adelaide, Australia.

Degree: *PhD in Transport Systems Engineering*

Thesis Topic: A Study on Household Vehicle Ownership in Mid-Sized Cities of South East Asia: A Case Study of Khon Kaen City, Thailand

2004 - 2005: University of South Australia, Adelaide, Australia.

Degree: *Master of Transport Systems Engineering (M.Eng)*

Award: AITPM Prize – the highest GPA of the program in 2005

Thesis Topic: Using aaSIDRA 2.1 and PARAMICS 5.1 in Development of a Traffic Signal Coordination on Sri-Jan Road, Khon Kaen, Thailand

1996 - 2000: King Monkut Institute of Technology Ladkrabang, Bangkok, Thailand.

Degree: *Bachelor of Civil Engineering (B.Eng)*

Thesis Topic: Comparison among Several Types of Lateral Load Resistance Structure for High Rise Buildings

Research interests and expert:

- Transport and logistics management
- Urban transport policy planning
- Travel demand modelling: Vehicle ownership and model choice behaviour under motorcycle dominant environments
- Discrete choice modelling approach: Revealed and Stated Preference (RP and SP)
- Traffic modelling and traffic micro-simulation
- Traffic impact analysis

- Road accident investigation and road safety assessment
- Forbidden to modify the content, and cite the document when use.

Awards and honours:

- 2006: Awarded the *Prize for Excellence in Transport System Engineering 2005* from Australian Institute of Traffic Planning and Management (AITPM), Australia
- 1999: Grant an exchange student summer training program at Tokai University (Japan) scholarship from King Monkut Institute of Technology Landkrabang

Academic publications:

- 2011: Prabnasak, J, Taylor, MAP & Yue, WL 2011, 'An Investigation of Vehicle Ownership and the Effects of Income and Vehicle Expenses in Mid-Sized City of Thailand', *Journal of the Eastern Asia Society for Transport Studies*, vol.9, 2011
- 2011: Prabnasak, J, Taylor, MAP & Yue, WL 2011, 'Modelling Household Vehicle Ownership in Asian Medium-Sized Urban Area: A Case Study of Khon Kaen City, Thailand', *Journal of the Eastern Asia Society for Transport Studies*, vol.9, 2011
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- 2008: Prabnasak, J & Taylor, MAP 2008, 'A Critical Review of Travel Demand Studies in Motorcycle Dominant Environments', *The 5th National Transport Conference Proceedings (NTC5 Proceedings)*, King Monkut University of Technology Thonburi, Bangkok, Thailand
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Trainings

- 2006: Senior Road Safety Auditor (officially certified by Thailand Ministry of Transport)
- 2006: Road Safety Auditor (officially certified by Thailand Ministry of Transport)

University activities:

- 1999: Joined Thailand Coke Music Award Contest 1999
- 1998: Took a position of the Deputy Director of the King Monkut Institute of Technology Ladkrabang Robot Club
- 1997: Joined Thailand Robot Contest'97
- 1996: Joined Thailand Robot Contest'96

Professional experiences:

July 2012 - Current: International College, King Monkut Institute of Technology Ladkrabang, Thailand

Position: Lecturer

Job description: Lecturer in Transport Management, Logistics Infrastructure and Facility Planning, Engineering Economics and Geographical Information System

Research experience:

- A Study in Enhancing Performance of Border Weigh Stations, under Department of Highway, Ministry of Transport funding, 2012 (ชื่อภาษาไทย: โครงการศึกษาเพื่อพัฒนาระบบขีดสมรรถนะการบริหารจัดการงานตรวจสอบขนาดและพิกัดน้ำหนักบรรทุก ณ จุดผ่านทางชายแดน, งบประมาณของกรมทางหลวง กระทรวงคมนาคม พ.ศ.2555)

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Forbidden to modify the content, and cite the document when use.

October 2011 - May 2012: Sustainable Infrastructure Research and Development Centre (SIRDC), School of Civil Engineering, Khon Kaen University, Thailand

Position: Senior Research Fellow

Job description: As a senior research fellow, I have been a part of several research and academic service activities of the centre; including being research and technical support staff, invited lecturer and also administrative support staff

Research experience:

- A Study in Developing Green House Gas Baseline and Clean Development Mechanism in Transport Sector of Thai Regional Cities, under Thailand Greenhouse Gas Management Organization (TGO), 2012 (ชื่อภาษาไทย: โครงการศึกษาและจัดทำ Baseline การปล่อยก๊าซเรือนกระจกจากภาคขนส่งในจังหวัดน่านรองและการศึกษาแนวทางในการส่งเสริมกิจกรรมลดการปล่อยก๊าซเรือนกระจกจากภาคขนส่ง, องค์การบริหารจัดการก๊าซเรือนกระจก (อบก.), พ.ศ.2555)
- A Feasibility Study and Preliminary Design for Bus Rapid Transit Prototype in Regional Cities of Thailand: A Case Study of Khon Kaen City, under Road Safe Fund, Department of Land Transport, Ministry of Transport, 2012 (ชื่อภาษาไทย: โครงการศึกษาระบบรถโดยสารด่วนพิเศษ (BRT) ต้นแบบในเมืองภูมิภาค เพื่อการจราจรปลอดภัยอย่างยั่งยืน: กรณีศึกษาจังหวัดขอนแก่น, สำนักงานกองทุนเพื่อความปลอดภัยในการใช้รถใช้ถนน (สปถ.), กรมการขนส่งทางบก, กรุงเทพมหานคร, พ.ศ.2555)
- Traffic and Transportation Master Plan Survey and Study for Northern Strategic Sub-Region II (Chiang Rai, Prayao, Pae and Nan), under Office of Transport and Traffic Policy and Planning (OTP), 2012 (ชื่อภาษาไทย: โครงการศึกษาสำรวจการจัดทำฐานข้อมูลเพื่อพัฒนาระบบโครงข่ายด้านการขนส่งและจราจรในเขตพื้นที่กลุ่มยุทธศาสตร์ชายแดนจังหวัดภาคเหนือตอนบน 2, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) (จ.เชียงราย พะเยา แพร่ และน่าน), พ.ศ.2555)

April 2006 - February 2008: Sustainable Infrastructure Research and Development Centre (SIRDC), School of Civil Engineering, Khon Kaen University, Thailand

Position: Senior Research Fellow

Job description: As a senior research fellow, I have been a part of several research and academic service activities of the centre; including being research and technical support staff, invited lecturer and also administrative support staff

Research experience:

- Traffic and Transportation Master Plan Study for Regional Cities: Kalasin Province, under Office of Transport and Traffic Policy and Planning (OTP), 2006 (ชื่อภาษาไทย: โครงการศึกษาสำรวจข้อมูลด้านการขนส่งและจราจรเพื่อจัดทำแผนแม่บทในเมือง

ภูมิภาค: จังหวัดกาฬสินธุ์, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2549)

- Traffic and Transportation Master Plan Study for Regional Cities: Srisaket Province, under Office of Transport and Traffic Policy and Planning (OTP), 2006 (ชื่อภาษาไทย: โครงการศึกษาสำรวจข้อมูลด้านการขนส่งและจราจรเพื่อจัดทำแผนแม่บทในเมืองภูมิภาค: จังหวัดศรีสะเกษ, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2549)
- Road Accident Investigation Unit Development Project: A case study of Khon Kaen Province, under Office of Transport and Traffic Policy and Planning (OTP), 2007 (ชื่อภาษาไทย: โครงการค่าจ้างศึกษาและพัฒนาตัวแบบหน่วยสืบสวนอุบัติเหตุจากการขนส่งและจราจร พื้นที่ศึกษา : จังหวัดขอนแก่น, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2550)
- Road Safety Audit and Black-Spot Treatment in Khon Kaen University, under Commission on Higher Education, 2006 (ชื่อภาษาไทย: โครงการถนนปลอดภัย มหาวิทยาลัยขอนแก่น, งบประมาณของสำนักงานคณะกรรมการการอุดมศึกษา (สกอ.) พ.ศ. 2549)
- Road Safety Auditor Training Program 2006, under Office of Transport and Traffic Policy and Planning (OTP), 2006 (ชื่อภาษาไทย: โครงการฝึกอบรมด้านการตรวจสอบความปลอดภัยทางถนน, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2549)
- Traffic Signal Coordination Implementation on Sri-Jan Road, Khon Kaen, Project, under Khon Kaen University, 2006 (ชื่อภาษาไทย: โครงการศึกษาวิเคราะห์และออกแบบระบบไฟจราจรแบบต่อเนื่องบนถนนศรีจันทร์ จังหวัดขอนแก่น, งบประมาณของเทศบาลนครขอนแก่น พ.ศ.2549)
- Five-Legs Roundabout Design and Traffic Management Project, under Khon Kaen Municipality Council, 2006 (ชื่อภาษาไทย: โครงการศึกษาวิเคราะห์และออกแบบเพื่อจัดระบบการจราจรบริเวณห้าแยกศาลเจ้าพ่อหลักเมือง จังหวัดขอนแก่น, งบประมาณของเทศบาลนครขอนแก่น พ.ศ.2549)
- Research on Aggressive Identification of Black Spots Through Public Participation Approach (Hiyari Hatto): A Case Study in Khon Kaen University, organized by Transport System Laboratory, Nihon University, Japan, and Khon Kaen University 2006 (ชื่อภาษาไทย: โครงการศึกษาการใช้หลักการ Hiyari-Hatto เพื่อกระตุ้นการมีส่วนร่วมของประชาชนในการระบุจุดเสี่ยงอันตรายในชุมชนเมือง พื้นที่ศึกษาจังหวัดขอนแก่น, มหาวิทยาลัย Nihon University ประเทศญี่ปุ่นร่วมกับมหาวิทยาลัยขอนแก่น พ.ศ.2549)

- Khon Kaen University Land-Use and Traffic Master Plan Development, under Khon Kaen University, 2006-2007 (*ชื่อภาษาไทย: โครงการศึกษาวิจัยและออกแบบผังแม่บทมหาวิทยาลัยขอนแก่น, งบประมาณของมหาวิทยาลัยขอนแก่น พ.ศ.2549-2550*)
- Khon Kaen University Health-Science Centre Land-Use and Traffic Master Plan Development, under Khon Kaen University, 2006-2007 (*ชื่อภาษาไทย: โครงการจัดทำผังแม่บทการใช้พื้นที่และการจัดการระบบจราจรในศูนย์วิทยาศาสตร์สุขภาพมหาวิทยาลัยขอนแก่น, งบประมาณของมหาวิทยาลัยขอนแก่น พ.ศ.2549-2550*)
- Traffic and Transportation Master Plan Study for Regional Cities: Mahasarakarm Province, under Office of Transport and Traffic Policy and Planning (OTP), 2007 (*ชื่อภาษาไทย: โครงการศึกษาสำรวจข้อมูลด้านการขนส่งและจราจรเพื่อจัดทำแผนแม่บทในเมืองภูมิภาค: จังหวัดมหาสารคาม, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2550*)
- Traffic and Transportation Master Plan Study for Regional Cities : Amnat-Charoen Province, under Office of Transport and Traffic Policy and Planning (OTP), 2007 (*ชื่อภาษาไทย: โครงการศึกษาสำรวจข้อมูลด้านการขนส่งและจราจรเพื่อจัดทำแผนแม่บทในเมืองภูมิภาค: จังหวัดอำนาจเจริญ, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2550*)
- Road Safety Auditor Training 2007 (under Office of Transport and Traffic Policy and Planning (OTP), 2007 (*ชื่อภาษาไทย: โครงการฝึกอบรมด้านการตรวจสอบความปลอดภัยทางถนน, งบประมาณของสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) พ.ศ.2550*)

January 2001 - July 2003: CH. Karnchang Public Co, Ltd, Thailand

Position: Civil engineer

Job description: As an office/administrative engineer, drawing supervisor, site engineer and construction inspector

Projects involved:

- January - May 2001: CH. Karnchang's head office,
- June 2001 - February 2002: Bangkok International Airport Development Project (site), Bangkok, budget 3,800 million Baht, (*ชื่อภาษาไทย: โครงการขยายขีดความสามารถท่าอากาศยานกรุงเทพฯ (ดอนเมือง), กรุงเทพมหานคร, งบประมาณโครงการ 3,800 ล้านบาท*)
- February 2002 - July 2003: Mae Fah Lung University Construction Project (site), Chiang-Rai, budget 2,350 million Baht, (*ชื่อภาษาไทย: โครงการก่อสร้างมหาวิทยาลัยแม่ฟ้าหลวง, จังหวัดเชียงราย, งบประมาณโครงการ 2,350 ล้านบาท*)

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Experiences:

- Quantity and cost estimation
- Planning and schedule planning
- Payment and budget control
- Structural and road-geometric design
- Drawing improvement
- Site engineer and inspector responsible for landscape structure, road work, water plant, water treatment plant and other infrastructures
- Testing and materials approving (construction materials and soil testing)
- ISO9000:ver.2000 internal auditor

June - December 2000: MAA Consultant Co, Ltd, Thailand

Position: Civil engineer

Project involved: June - December 2000: Queen Sirikit Heart Centre Construction Project (site), Khon Kaen University, Khon Kaen, budget 300 million Baht, (ชื่อภาษาไทย: โครงการก่อสร้างศูนย์หัวใจสิริกิติ์ มหาวิทยาลัยขอนแก่น, จังหวัดขอนแก่น, งบประมาณโครงการ 300 ล้านบาท)

Experiences: Quantity estimator, construction engineer and site inspector responsible for structural and architectural works

Specialized software packaging:

The list of all transport and traffic specialized software packages which I have been in-depth experiencing is presented as follows:

- Limdep NLOGIT 3 and 4 (econometric model estimator)
- PARAMICS 3, 5 and 6 (traffic micro-simulation)
- aaSIDRA 2.1 (intersection analysis and traffic signal design)
- SIDRA Intersection 3 (intersection analysis and traffic signal design)
- M-SMAC (crash analysis and simulation)
- Cube version 3.0 and version 3.2 (traffic macro-simulation)
- Cube Dynasim (traffic micro-simulation)
- ArcGIS 10.1 (geographic information system)
- ArcView 3.3 (geographic information system)