

**AN EVALUATION OF THE TRUCK BAN REGULATION AND  
SUBURBAN TRUCK TERMINAL IMPLEMENTATION SCHEME IN  
KHON KAEN CITY OF THAILAND**



**A THESIS SUBMITTED IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS FOR THE DEGREE OF  
MASTER OF SCIENCE IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT  
INTERNATIONAL COLLEGE  
KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG  
2017  
KMITL-2017-IC-M-002-001**

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**2017**

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้ภายใน KMITL-2017-IC-M-002-001 อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้



เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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**Thesis Certification**  
**International College**  
**King Mongkut's Institute of Technology Ladkrabang**

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**Thesis Title** An Evaluation of The Truck Ban Regulation and Suburban Truck Terminal Implementation Scheme in Khon Kaen City of Thailand

**Student** Miss. Vuch Lung Chhorn



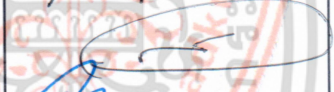


**Student ID** 58610042

**Degree** Master of Science

**Program** Logistics and Supply Chain Management (International Program)


**Thesis Advisor** Dr. Jaruwit Prabnasak

**Thesis Reference Number** KMITL-2017-IC-M-002-001

EXAMINERS	SIGNATURES
Dr. Siradol Siridhara	
Asst. Prof. Dr. Phaophak Sirisuk	
Asst. Prof. Dr. Wichitsawat Suksawat na Ayudhya	
Dr. Jaruwit Prabnasak	
Asst. Prof. Dr. Ronnachai Tiyaratthanachai	

**Date:** May 13<sup>th</sup>, 2017 **Time** 09.00am – 12.00pm  
**Place:** International College, 8<sup>th</sup> floor, 55<sup>th</sup> Anniversary Chalermprakiat Building

KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG

  
(Assoc.Prof.Dr. Supat Kittiratsatcha)  
Dean of International College  
May 13<sup>th</sup>, 2017

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<b>THESIS TITLE</b>	An Evaluation of The Truck Ban Regulation and Suburban Truck Terminal Implementation Scheme in Khon Kaen City of Thailand
<b>STUDENT</b>	Miss.Vuch Lung Chhorn
<b>STUDENT ID</b>	58610042
<b>DEGREE</b>	Master of Science
<b>PROGRAM</b>	Logistics and Supply Chain Management
<b>THESIS ADVISOR</b>	Dr. Jaruwit Prabnasak

## 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 to the destinations. The truck terminal can be expected to come along with implementation of truck ban policy in those cities. Therefore, this study was conducted to examine the potential effects on air pollution of CO<sub>2</sub> 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 policy inside a city where a truck terminal is planned to be invested in Khon Kaen city, one of the biggest city in north-east region, was 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 steps urban transport model developed from household and roadside interviews is employed as a principal analysis tool. As a result, potential of introducing truck ban policy was investigated. The suitable location of truck terminal was identified. Also, the cost of freight transport change due to the policy of truck ban with the truck terminal new location was defined. Some discussions and concerning factors were recommended.

## ACKNOWLEDGEMENTS

The achievement of this research study could not have been successful without those supports and assistants of many people. This immeasurable gratitude is extended to the following people who in one way or another contributed in making this thesis study possible.

My thesis advisor Dr. Jaruwit Prabnasak of International College at King Mongkut Institute of Technology, Ladkrabang, I would like to express my gratitude for the encouraging and supervising from the beginning until the end of my study. If I were in trouble, he would be available helping through email or phone call. I am gratefully indebted to him for his very valuable comments on this thesis.

I also want to express my gratitude to all lecturers. I am grateful for the help and guidance with encouragement extended to me, and to all my friends and classmates who always become part of the help in this study and share the knowledge in part of this research.

Also, I wish to give my sincere thanks to International College for providing me the great opportunity to study and experience with all the facilities as well as the life experience in Thailand for the past two years.

Moreover, I would like to thank to Asian Unit Net Scholarship Program for giving me chance of pursuing my dream with financial support that enable me to pursue my work and study successfully.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Bangkok, May 2017

Vuch Lung Chhorn

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# TABLE OF CONTENTS

	Page
<b>ABSTRACT</b> . . . . .	
<b>ACKNOWLEDGEMENTS</b> . . . . .	i
<b>TABLE OF CONTENTS</b> . . . . .	ii
<b>LIST OF FIGURES</b> . . . . .	iv
<b>LIST OF TABLES</b> . . . . .	v
<b>LIST OF ABBREVIATIONS</b> . . . . .	vi
<b>CHAPTER</b>	
<b>1 Introduction</b> . . . . .	1
1.1 Research Background . . . . .	1
1.2 Problem Statement . . . . .	2
1.3 Objectives of The Study . . . . .	2
1.4 Expected Results . . . . .	2
<b>2 Literature Review</b> . . . . .	4
2.1 Defining Road Freight Transport . . . . .	4
2.2 Truck Classification . . . . .	5
2.3 Policy Implementation . . . . .	7
2.4 Environmental Logistics . . . . .	9
2.5 Modelling in Transportation (Four Steps Modelling) . . . . .	10
2.6 Related Studies . . . . .	14
<b>3 Research Methodology</b> . . . . .	16
3.1 Method for Analysis . . . . .	18
3.2 Suggested Location for Truck Terminal . . . . .	19
3.3 Study Area . . . . .	21

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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# TABLE OF CONTENTS

(Continued)

CHAPTER	Page
<b>4 Results and Discussion</b> . . . . .	25
4.1 Model Estimated Results . . . . .	25
4.2 Overall Traffic Behaviours in The Study Area in Overall . . . . .	25
4.3 Truck Traffic Behaviours in The Study Area . . . . .	27
4.4 Freight Activities Distribution in The City . . . . .	27
4.5 Truck Traffic Behaviours in The Study Area of Base Case Scenario . . . . .	29
4.6 Truck Traffic Behaviours of Case I (Zone71) . . . . .	31
4.7 Truck Traffic Behaviours of Case II (Zone 48) . . . . .	31
4.8 Truck Traffic Behaviours in Case III (Zone 75) . . . . .	33
4.9 Vehicle-Kilometer and Vehicle-Hour Comparison . . . . .	35
4.10 Estimated Results of Vehicle Operating Cost in Study Area . . . . .	37
4.11 Environmental Performance of Trucking Behaviour in The Study Area . . . . .	38
4.12 Discussion on The Potential of Introducing Truck Ban . . . . .	39
4.13 Discussion on Truck Terminal Implementing and Vehicle Handling . . . . .	41
<b>5 CONCLUSIONS AND RECOMMENDATIONS</b> . . . . .	43
5.1 Conclusions . . . . .	43
5.2 Recommendations . . . . .	43
<b>REFERENCES</b> . . . . .	45
<b>APPENDICES</b> . . . . .	49
<b>APPENDIX A</b> . . . . .	49
<b>APPENDIX B</b> . . . . .	50
<b>APPENDIX C</b> . . . . .	51
<b>APPENDIX D</b> . . . . .	52
<b>APPENDIX E</b> . . . . .	53
<b>BIOGRAPHY</b> . . . . .	66

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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## LIST OF FIGURES

Figure	Page
2.1 Vehicle Classification . . . . .	7
3.1 Model network configuration . . . . .	17
3.2 The zoom out with location for truck terminal . . . . .	19
3.3 Out of bound with zone number . . . . .	20
3.4 GIS map application with Zone categorize . . . . .	21
3.5 A comparison of observed and modelled mid-block traffic . . . . .	23
4.1 Traffic flow on links estimated by the model . . . . .	26
4.2 Truck traffic desire lines . . . . .	28
4.3 Truck traffic flow on links estimated by the model . . . . .	28
4.4 Truck traffic flow on links estimated by the GIS application in base case scenario . . . . .	30
4.5 Truck traffic flow on links estimated for Case I of HGV . . . . .	32
4.6 Truck traffic flow on links estimated for Case I of LGV . . . . .	32
4.7 Truck traffic flow on links estimated for Case II of HGV . . . . .	33
4.8 Truck traffic flow on links estimated for Case II of LGV . . . . .	34
4.9 Truck traffic flow on links estimated for Case III of HGV . . . . .	35
4.10 Truck traffic flow on links estimated for Case III of LGV . . . . .	35
4.11 The comparison between vehicle-kilometer with vehicle-hour . . . . .	36
4.12 Total vehicle-operating cost within the study area . . . . .	38
4.13 Total CO <sub>2</sub> emitted to environment within the study area . . . . .	40

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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## LIST OF TABLES

<b>Table</b>	<b>Page</b>
3.1 Model characteristics and current traffic condition . . . . .	17
3.2 A comparison between the data used in this study and a previous dataset . . . . .	22
3.3 Vehicles classification in the study area . . . . .	24
4.1 Model estimation results for overall traffic behaviours in the study area . . . . .	25
4.2 Model estimation results for truck traffic behaviours in the study area . . . . .	27
4.3 Truck traffic activities in outer zone, intermediate zone and inner zone . . . . .	29
4.4 Model estimation results for truck traffic behaviours in base case scenario . . . . .	30
4.5 Model estimation results for truck traffic behaviours in Case I . . . . .	31
4.6 Model estimation results for truck traffic behaviours in Case II . . . . .	33
4.7 Model estimation result for truck traffic behaviours in Case III . . . . .	34
4.8 The total vehicle-kilometers of all cases within study area . . . . .	36
4.9 The total vehicle-hour of all cases within study area . . . . .	36
4.10 Total vehicle operating cost of all cases within study area . . . . .	37
4.11 CO <sub>2</sub> factors and conversion . . . . .	38
4.12 Results of CO <sub>2</sub> estimated for all cases in study area . . . . .	39
A.1 Business Travel Emission Factors . . . . .	49
B.1 Product transport emission factors . . . . .	50
C.1 Monetary value of vehicle equivalent in 2558 hours a year . . . . .	51
D.1 The worth of the travel time of each vehicle category in the year 2558(Time Value (THB/PCU-Hour)) . . . . .	52

เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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## LIST OF ABBREVIATIONS

VK	Vehicle Kilometre
VH	Vehicle Hour
VOC	Vehicle Operating Cost
VOT	Vehicle Operation Time
PCU	Passenger Car Unit
CBD	Central Business District
O-D	Origin - Destination Matric
GIS	Geographic Information System
HGV	Heavy Good Vehicle
LGV	Light Good Vehicle
GHGs	Green House Gases
EPP	Environment + Price+ Performance
EPP	Environmental Preferable Purchasing
FSTDM	Four-step travel demand model
FSM	Four Steps Modelling

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# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

Truck ban regulation is one of several transport policies that have been introduced in many cities around the world and this policy are varied depending on where it is implemented. Policy with the purpose of reducing the impact of freight transport always involves 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 city area as well. Some cities addressed the policy for reducing traffic congestion and accidents from large vehicles, protecting ancient and historical site from vibration and reducing air and noise pollutions (Engel, 2010; EPA, 1992; Fensterer et al., 2014). In Southeast Asia, truck ban has also been addressed in several large cities, such as Bangkok, Manilla, Jakarta, and Kuala Lumpur (Castro et al., 2003; Lidasan, 2011). In Bangkok, truck ban regulation has been introduced since 1989. At the beginning the policy was initially aimed to reduce problems from HGV inside the urban area of the city. However, benefits of truck ban in Bangkok in term of environmental has been concerned (Takahashi and Sirikupanichkul, 2001). However, the impact of the policy should be studied before the implementation. The response from the resident inside the city will cause the policy not to implement. This is because the policy may impact people in the area, as the result, oppose the implementation (Quak and Koster, 2006).

One of the major issues that can cause traffic congestion is the rapidly increase number of vehicles (BBC, 2012). They found that Bangkok has the second top worst traffic, impacts due to the policy of refund tax for first time car buyers. This policy resulted in 5 million vehicles in the city which can only operate with less than 2 million cars on the road. Recently, Metro Manilla also introduced truck ban in some area of the city in morning peak (between 9 am and 12 am) and evening peak (between 5 pm and 9 pm) except Sunday and public holidays targeting vehicles that the gross weight 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 emissions generated in the dense urban area (Fukuda et al., 2013). Vehicle restriction policy is now rapidly applied, especially in developed countries like in Europe and other countries in South-east Asia in the purpose of increasing urban city sustainability. This policy has been involved with the transport infrastructure, freight transport movement, and environmental concern

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(Quak and Koster, 2009).

## 1.2 Problem Statement

Number of vehicles keeps increasing rapidly every year. Traffic situation has been a concern to all developing countries in the world, as many solutions have been proposed to deal with the problem. 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 hours. Khon Kaen city of Thailand has been chosen to study due to the size of population and land scale. However, whether truck ban scheme will be possible for mid-size of city population still remain a question. This study will show that the policy will be possible to examine the truck traffic behaviour and its potential impacts. Introducing the policy in mid-size city as Khon Kaen, which come along with truck terminal as the solution to avoid the conflict with residents living inside city centre. Both concerning factors of environmental problem and city logistics operation will be studied and suggested for a better solution.

## 1.3 Objectives of The Study

The objectives of this study are:

- 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 be located
- To examine how much CO<sub>2</sub> has been emitted from the larger trucks operation in the area compared to the small trucks operation

## 1.4 Expected Results

The expected results of this study are as follows:

- A possibility of introducing truck ban regulation in the study area. A policy will be recommended for future implementation.
- เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า  
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- Truck terminal will be located as a solution for a better city freight transport and also as a support for truck ban policy.
- Assessment of the impact from the evaluation of economics loss and total benefits 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 daily activities of supply chain inside the city and the sustainable improvement.
- Suggestion and recommendation for better future work of similar study with appropriate study area.



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## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Defining Road Freight Transport

National road freight transport is defined as road transport between two places (a place of loading and a place of unloading) located in the same country by a vehicle registered in that country. International road freight transport is defined as the transport by road between two places (a place of loading and a place of unloading) in two different countries irrespective of the country in which the vehicle is registered (Eurostat, 2012). Road freight transport led to many problems around the world including traffic congestion and environmental problem. There is also the lack of understanding of freight transport policies on traffic management. In this study related activities to freight transport are categorised in three different types (Bhuiyan, 2011) These three different types are including 1) Activities, 2) Geography, and 3) Industries Sectors (McKinnon and Piecyk, 2009).

##### 1. Activities

In most of research studies' interest, there are many concerns about road freight movement of trucks, heavy goods vehicles (HGV), light goods vehicles (LGV) with a gross weight as listed in the Figure 2.1 of vehicle classification. Heavy vehicles are categorised as kind of vehicle with 6-wheels, 8-wheels, and 10-wheels trucks which the limited weight of running on the road (DLT, 2015 ). While lighter vehicles are classified as vans and treated as a separate vehicle type. Partly, sometime they are used for carrying people and equipments as delivery tool which is called city delivery truck (McKinnon and Piecyk, 2009).

##### 2. Industry sector

Trucking is undertaken by companies whose main activity is road freight transport (McKinnon and Piecyk, 2009). As the upcoming agreement of Asian Economic Community (AEC) is approved by last 2015, the industry of freight transport movement is rapidly increased. The logistic and freight movement starting to grow as well as cross trend from one country to another is much easier. These types of growth has increased the activities in both national freight transport and international freight transport. By the rapid growth and need for freight transport, these types of transportation industries are in need of the transportation infrastructure and new investment is also needed in order to support this kind of activities.

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### 3. Geography

Goods movement and freight distribution are widely underrepresented in regional science and geographical researches. This is surprising since a large body of traditional spatial theory has been developed with respect to transportation costs or to trade areas: those aspects were originally closely connected with the exchange of goods (McKinnon and Piecyk, 2009). Rodrigue (2006) found that Freight transport was not interest in the past research, probably because of its concerns. This is always a good idea not to follow the crowds and identify opportunities that are looked over. As such a context, freight appears as the underdog of transport geography in contradiction to its fundamental importance. Large volumes of containers are handled by mostly maritime and rail transportation while trucks are only noticed when linked with congestion problems. It sounds like there is nothing to do with truck transport beside impact to the communities along the journey of trucking. On the other hand, passenger movements is also involved with a large part of activities on the road. Due to the location of recreation, shopping centre, and educational community mostly located inside attraction area such as city centre as per called centre business district (CBD), freight movement has a much more significant variety of geographical conditions (Rodrigue, 2006).

In this regard, there is one study of Wisetjindawat (2011) that provided information on freight transport policies implemented in several countries in Asia, Europe, and North America. It defined objectives for sustainable freight development i.e. reducing energy consumption per ton- kilometres, decreasing ton-kilometres 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 analysed (Wisetjindawat, 2011).

#### 2.2 Truck Classification

In this section, Figure 2.1 shows about all vehicles classification in this study.

- Motorcycles refer to all two or three-wheeled motorized vehicles are including three-wheel motorcycles

- Passengercars refer to type of vehicles, which used for the purpose of carrying passengers.

















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- Other Two-Axle, Four-Tire Single Unit Vehicles, those classification are included pickups, panels, vans, vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses.
- Buses are the traditional passenger vehicles, which includes only traditional buses including school buses.

The detail classes with clear picture is presented in the following Figure ?? with all the 10 classes (FHA, 2014) In reporting information on trucks, the following criteria should be used:

- Truck tractor units traveling without a trailer is considered single-unit trucks
- A truck tractor unit pulling other such units in a saddle mount configuration is be considered one single-unit truck and is defined only by the axles on the pulling unit
- Vehicles are defined by the number of axles in contact with the road; therefore, floating axles are counted only when in the down position
- The term "trailer" includes both semi- and full trailers

### VEHICLE CLASSIFICATION

<b>Class 1</b> Motorcycles		<b>Class 7</b> Four or more axle, single unit	
<b>Class 2</b> Passenger cars		<b>Class 8</b> Four or less axle, single trailer	
			
			
			
<b>Class 3</b> Four tire, single unit		<b>Class 9</b> 5-Axle tractor semitrailer	
			
			

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<b>Class 4</b> Buses		<b>Class 10</b> Six or more axle, single trailer	
			
			<b>Class 11</b> Five or less axle, multi trailer
<b>Class 5</b> Two axle, six tire, single unit		<b>Class 12</b> Six axle, multi- trailer	
			
			<b>Class 13</b> Seven or more axle, multi-trailer
<b>Class 6</b> Three axle, single unit			
			
			

Figure 2.1 Vehicle Classification

Source: Federal Highway Administration (FHA, 2014)

### 2.3 Policy Implementation

Policy restriction on the trucking transportation is now wildly practiced everywhere around the world mostly in large city in the purpose of supporting the city logistics. In each policy implementation, there are always some impact of environment surrounding with city citizen as well as residential nearby. Before any policy can be implemented, there should be some proper studies of overview of public policy and planning in the field of urban freight transport. The meaning of urban freight transport is usually the subject of local or regional and national policies in the purpose of transportation planning, environmental planning, and economic planning (Visser et al., 1999). The research found the reason why policies should be applied. Due to the problems arise and challenges occur, there are usually the combination factors including congestion, air pollution, noise, and safety are considered as the most remarkable negative impacts of freight traffic. These are also the key elements for implementation of freight transport policy. The objective of implementation freight transport policy usually refers to the cost reduction with the improvement of the transport service quality while these will also create the business opportunity for the eco-

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conomic benefit at the same time. The following studies are about the policy implemented in other countries in different perspective and objective with different technique used as the tools for the studies.

These are the related studies of policy implementation focusing not only on the truck ban, but also the impact from the surrounding as the example for this study as the following. Tamagawa, Taniguchi, and Yamada (2010) presented a methodology for evaluating city logistics measures considering the behaviour of several stakeholders associated with urban freight transport using a multi-agent model. The model constructed consists of a learning model and a model for Vehicle Routing and Scheduling Problem with Time Window-Forecasted (VRP-TW-F). They used a method of Q-learning, a technique of reinforcement learning, in constructing a learning model. The authors implemented the model on a test road network representing an urban area. The results indicated that implementing a truck ban directly to environmentally damaged areas and discounting motorway tolls entirely in the urban motorway network together has large environmental effects, and leads to an acceptable environment for all stakeholders (Tamagawa et al., 2010).

In addition, in the study of Amanda et al. (2010) identified Brazilian cities that have traffic restrictions and estimate the odds of implementing certain types of traffic restrictions. The statistical model was used in the present investigation to allow for calculating the odds of whether the cities included in the sample would implement traffic restrictions (Bontempo et al., 2014). For instance, two state capitals, Manaus and Aracaju have probabilities of 72 percent and 75 percent, but they have no truck bans. This means that any shipper or 3PL carriers should plan for such an occurrence. The probabilities of Jaboto dos Guararapes and Gravata implementing traffic restrictive are 5.9 percent and 5.5 percent. In future studies, the logistic regression model should also be applied to the study of variables e.g., the political party that implemented traffic restrictions in a given city, the cities congestion indexes, or the total road network length.

Furthermore, Jess Muuzuri et al. (2010) presented the method for an improvement on other recent works consisting of a demand model for B2B and home deliveries during the morning peak hour that uses only very limited data to estimate the number of delivery vehicles entering and leaving each zone of the city. Then they calculated the trip distribution using an entropy maximisation approach and solve the resulting model using simulated annealing. They applied this model to a case study in the city of Seville, in Spain, and compare its results to those produced by a gravity model and with actual traffic counts. They suggest what should be done in order to determine to what extent the introduction of additional data and complexity produces an equivalent increase in

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the quality of the results (Muñuzuri et al., 2010).

Also, Jos Holgun-Veras et al. (2014) identified and discussed the fundamental tenets that should guide planning and implementation of city logistics projects, and the chief lessons learned from the off-hours delivery project conducted in New York city. They discussed the lessons learned during the off-hour delivery (OHD) project, and the important role cutting-edge research. It identified the most effective paths to achieving the desired goals including building coalitions of agents-of-change involving both private and public sector partners, pilot-testing as an external validation for research concepts, and the importance of defining implementation pathways for promising concepts while also accounting for the complex political realities of modern urban environments. These lessons are framed in the dual contexts of the fundamental tenets that should guide sustainability efforts and the market conditions that influence UFS participants behaviour (Holguín-Veras et al., 2014).

Lastly, 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<sub>x</sub> were the major emission load generated by trucks (61.73 tons per day), followed by CO<sub>2</sub> (37.72 tons per day). The lessons learned should be useful for the proposed regional truck terminals in different parts of the country, 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, in the south at Hat Yai, and Songkhla (Takahashi and Sirikupanichkul, 2001).

## 2.4 Environmental Logistics

To understand the rationale for environmental logistics, the study has to examine current global environmental problems and investigate on how logistic can help to address such problem. First, this review was introduced the majors worldwide environmental issues and current practices in logistics related to environmental management (Liu, 2012).

There are majors environmental concerns in the logistic process, which are under threat from the following sources such as population growth, social issues, environmental degradation (air, land, and water pollution), global warming, and Ozone depletion. As the modern society there are always the needs of development in logistics supports population growth and poverty reduction. Adding to this regard, they always has the natural resources exploitation in the developing countries such as the shrinking of the tropical rainforest, deforestation, and desertification

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which make modern society seeking for further economic development. As the support to global population growth and poverty reduction, the demand of trading by air, sea, and land transport is increasing which required the use of fuels as the energy source. These are the sources of environmental pollutions, which can be defined by two aspects. First, the movement 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 (Golicic et al., 2010). Besides, the emissions from using transport activities has created the problem of air pollution and led to global environmental problems which is global warming. Golicic et al. (2010) has stated that the emission from greenhouse gases (GHGs) is the main cause of CO<sub>2</sub> in the atmosphere and it accounts for 33.6 percent in US. (Golicic et al., 2010).

Moreover, generally transport related activities have been recognised as the principal contributor to the Greenhouse Gas (GHGs) emissions which result in global warming and climate change. Transportation accounts for 26 percent of CO<sub>2</sub> emission. Besides, trucking vehicle is the largest generator of GHG emission in the transport sector (Chapman, 2007). There was a research study which pointed out that the level of the recent Carbon dioxide (CO<sub>2</sub>) 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 (Dulal and Brodnig Onoriose, 2011). There are five main logistics components said by Gonzalez-Benito (2006), they are supply/purchasing, transportation, warehousing and distribution, reverse logistics, and wastes management. Every part of logistics activities had certain undesirable environmental impacts because each process consumed materials and created wastes in every part of operation including manufacturing, transportations, and storage requirement (Gonzalez-Benito, 2016).

## 2.5 Modelling in Transportation (Four Steps Modelling)

The four steps model is the primary tool for forecasting the future demands and performance of the transport system, which was typically defined at a regional or sub regional scale. Smaller scales often apply simplified model (McNally, 2007). This model is suitable for the large project scale running for the new infrastructure with management of the new policies, existing infrastructures, or introducing the policies, which affected the current traffic behaviour. This model is needed of the interview and data collection, which may take years for the period of data collection. This model consists of four different sequential processes of four steps transport as the

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First, trip generation is generally used to define the total trips travelling daily in the system or the study area for various trip activities purposes. Step one of this process is to determine the number of daily trip that took place in the system. Data collection that used in this is origin-destination pairs, which was used to define the relationship of total traveling trip with network system (McNally, 2007). In trip generation procedure, one assumed that each zone results in production and attraction of trips. A trip that is produced in a zone is called a production. A trip which is end at the attraction to a zone is called an attraction (MWCG, 2017). In this step, it estimated the number of trip-ends happened in the zone or attracted to each transport zone in the system of study area.

Second, trip distribution is the second stage of the process to recombine trip ends from trip generation into trips. The objective of this stage is to define the production-attraction pairs but not the origin-destination pair. This stage of trip distribution is very important for a destination choice model and generate the trip table as trip ends (McNally, 2007). The modelling for this process relied on the normal assumption of time spent on travelling. The more distance from the destination, the more trouble for the trip. The general principle is translated into a mathematical procedure known as a gravity model (MWCG, 2017).

Mode choice is the third stage of this four steps model. Mode choice is a factor for trip distribution table in order to produce mode-specific trip table. Mode choice is simply referred to the choice of the travelling transport (McNally, 2007). This step of transport modelling mode choice is used to predict the likely traveling modes of all travellers in the study area or the region. In the decision making of mode choice is based on following factors on the relative availability and the attractiveness of each modes. Those attractiveness are including:

1. Travel time for each mode
2. Travel cost for each mode
3. Accessibility of mass transit
4. Automobile ownership
5. Proximity to carpool lanes

The most important contribution factors in mode choice are the parking cost and time that took to walk to the final destination (MWCG, 2017). Last of all, the last stage is route choice, which is the fourth major steps of the four steps modelling transportation (FSM). An equilibration

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of demands and performance are presented. Model O-D is receiving on the model network as usually under the assumption of user equilibrium (McNally, 2007). Besides, it can be asked with the simple question like what the routes of each trip are. This final step is used to determine the route of the travellers chosen to their destinations in forecasting of travelling behaviour. This can be called as trip assignment (MWCG, 2017). There are many studies that related to trucking and transport have been conducted by using this four steps modelling (FSM) as the following summaries:

Mann and Dawoud (1999) presented a streamlined version of our steps travel demand forecasting model in Washington D.C. region. This proposed model was to have a model that could replicate the regional model, and could be run in a new software that execute the entire four steps process in one execution on a PC. The trip generation and mode split steps resulted in a trip generation rate of 10.0 vehicle trips per detached household for the suburban/rural trip rate. Moreover, this model is now being used for travel forecasts for rural and small communities such as Fauquier County, Virginia on the urban fringe. Furthermore, it also could be adjusted to local area surveys and used for any sized of the area (Mann and Dawoud, 1999).

Also, Kumar and Peeta (2013) proposed to address the aforementioned issues by a post-processing technique incorporated through a feedback mechanism in the four steps travel demand model (FSTDM). In order to apply post-processing technique, SMPA hybrid, perturbation assignment and Origin-Destination (O-D) prioritisation schemes need to be identified. SMPA hybrid is an improved implementation of traffic assignment algorithm labeled Slope-based Multi-Path Algorithm (SMPA) developed . Three methodological contributions are implemented in this paper. First, an enhanced travel demand modelling framework was applied, second, a hybrid approach was formulated by combining the merits of sequential approach and simultaneous approach, and third, it provided a methodology for the O-D prioritisation in TAP. From the results of computational experiments, the SMPA-hybrid had a superior rate of convergence compared to the SMPA (Kumar and Peeta, 2013).

Kulpa (2014) developed freight truck trip generation equations at regional level using different data sources like secondary data and indirect approaches. There were three methods used in model development i.e. trip generation rates, multiple regression and Artificial Neural Networks (ANN). The presented models were vehicle based and consider two types of trucks: light and heavy. From the experiments, the results of trip generation rates were very suitable. This could be inferred that trip generation rates were the easiest to apply without the commune reflection

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of characteristic. Multiple regression and ANN are more complex and depending on the number of explanatory variables to give better results. Moreover, ANN and multiple regression models resulted with higher errors (Kulpa, 2014).

Lee et al. (2006) proposed a method based on the theories and assumptions of conventional four steps travel demand model. This study developed the model network traffic for planning applications in small and/or medium-sized communities with limited planning resources. The proposed procedure was applied with data from a small community and O-D trip table was estimated from traffic counts. Based on the experience gained from this case study, the proposed approach is applicable for small to medium-sized communities with limited resources. Future work will be required to enhance the proposed approach with the impacts of long-range and area-wide growth that could be modelled within the same framework (Lee et al., 2006).

In Tasic and Porter's study (2016) evaluated the relationship of multimodal transportation infrastructure, multimodal facilities, user exposure, and traffic safety outcomes. Data from Chicago were used for this analysis. Data from a variety of sources were combined to obtain an extensive dataset that includes variables related to multimodal infrastructure and presence of multimodal users. Total and fatal vehicular crashes and total non-motorised crashes were modelled using Negative-Binomial (NB) modelling with fixed and random effects. The results showed strong association between the variables related to multimodal transportation availability and usage, and both motorised and non-motorised crashes. (Tasic and Porter, 2016).

The study of Valentin R. et al. (2015) reviewed the multi-scale traffic models. This study also described the traffic sensor data collected from 25000 sensors along the arterial roads in the Netherlands and discussed the applicability of sensor data to model calibration with the validation of each modelling scale. This study also presented a road networks graph model and the reconstructed Dutch road networks. From the experiments, the study of traffic data analysis during the major power outage in North Holland (27 March 2015) was giving a special attention to one of the most affected locations around the A9/E19 interchange near Amsterdam airport Schiphol (Valentin R. Melnikov, 2015).

Another study found that Karel Martens and Eyal Hurvitz (2006) presented the method that assess the distributive impacts of demand-based modelling and more specifically to the four steps model. This research initially analysed the still-dominant four steps model and formulated the hypothesis that the consecutive application of the model which will widen existing gaps between high-mobile and low-mobile groups in terms of the available transport facilities and accessibility.

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A simplified four-step model is developed to test the hypothesis under the different policy scenarios. The results of the paper provided food for thought on two levels. The first level concerned the distributive implications of the application on transport demand modelling, and more specifically the four-step model. In the second level, the integration of social justice was considered into mainstream transport modelling and planning (Karel Martens and Eyal Hurvitz, 2006)

As well as in the research of Isabelle et al. (2016) had done with the effects of transportation infrastructure on the location behaviour of competing retail firms. First, in a game theoretic framework, which described the location choices made by retailers with respect to each other, the connection between relative firm location and transport demand was outlined. Second, a multivariate point pattern statistic based on this theoretical framework was applied to location patterns of the fast food outlets to measure the effects as major road infrastructure had on firm location behaviour in this sector. The results suggested that transportation infrastructure affects the location behaviour of firms regarding to their location in relation to their competitors. Access to important transportation infrastructure induces competitive outlets to locate next to each other a tendency not necessarily observed among outlets without such access (Nilsson and Smirnov, 2016).

Moreover, the study of Klungboonkrong et al. (2013) presented the analysis and evaluation of transport and land use measurement in reducing Greenhouse Gases (GHG<sub>s</sub>) emissions that generated from the transport sector in the road network of the Khon Kaen University, Khon Kaen, Thailand. This covered approximately 900 hectares and included more than 50,000 residents. This study represented as a prototype example for a small town in other developing countries. In the evaluation process, the study applied the Bottom-Up 2 approach, which can calculate the GHG emissions of all traffic volume running in the transport network. The Bottom-Up 2 approach estimated the baseline GHG emissions for different scenarios by using CDM2, MLIT, and PCD methods in 2011, 2021, and 2031. It was found that the calculation using emission factors from CDM2 (OTP, 2009) project yielded the lowest result approximately 10 percent lower than MLIT (2004) and PCD (2011), which yielded relatively similar results (Klungboonkrong et al., 2017).

## 2.6 Related Studies

Although there are many studies supporting the idea of truck ban policy 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

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truck ban policy in Metro Manila conversely leads to increase in total vehicle- kilometres, total vehicle-hours and total polluted emissions in some cases. Similarly, another research (Liliana et al., 2012) developed a study on the impact of truck ban policy due to public transport development in Mexico City. The study found that the heavy vehicle restriction scheme did not reveal any impact on congestion index and corridors of freight transport, ;however, this practice increased travel time for the heavy vehicles. With these arguments, it seems that one problem of truck ban in large cities is the restriction and the additional distance from avoiding restricted areas. Also, because of massive cargo demands, it is not possible for the government to provide supporting infrastructure such as truck terminal for them. Since truck ban policy has both advantages and disadvantages, intensive study plans 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 as Chiang Mai, Khon Kaen, and Hat Yai, were proposed for the development (DLT, 2015). Although, one main objective of those proposed truck terminals is to serve city logistic activities, the study focused on strategic level (such as, city selection based on city 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 policy might potentially be the answer.

## CHAPTER 3

### RESEARCH METHODOLOGY

As the aim of this study is to preliminarily examining the 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. The scope of the study is to focus on examining policy in strategic level, which is considerably large. The four steps transport modelling technique, which seems to suit the study condition, was 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, this data set included mid-block traffic survey of 24 locations, roadside interview with proximately around 3,500 samples, and household survey with nearly 2,000 samples. These samples are approximately one percent of city population.

In this stage, truck traffic inside the city was the main focused. To calibrate and validate the traffic assignment model using the field data, in the first step the origin-destination demand matrix was acquired by the roadside interview and household survey data, which was adjusted from sample size to the population size. The demand matrix was divided into two sub-matrices, passenger matrix and truck matrix. For the second step, passenger matrix was chosen to assign into the road network. That was because majority of the traffic movements in the city was found to be passenger vehicles. Trucks normally find the route that can avoid massive passenger traffic and congestions. To assign traffic into the network, user-equilibrium with incremental-loading technique was used. The traffic was assigned by 10 percent of total demands 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 were used for calibrating. After passenger traffic is already calibrated and validated, next in the fourth step, truck demand was assigned into the model. Again the truck traffic was 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 were presented in Table 3.1, while the model network configuration and model validating result are presented in Figure 3.1 and Figure 3.5, consecutively.

Futhermore, the environmental sustainability was also focused in this study, as known, trucks behaviour inside the city areas would cause the vibration and affected the historical side within the city area. The pollutions leaded this research to investigate and analyse the different

Table 3.1 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 3.1 Model network configuration

of truck operation with the different CO<sub>2</sub> generated from those two types of HGV and LGV, and compared the difference between them. The source of CO<sub>2</sub> factor received from the website (Climate-Leadership, 2015). Additionally, as the study aims to focus on the suitable location for the truck terminal as the central point of all HGV to stop, and goods transferred to the small and medium vehicle for ongoing operation inside city centre. This was why we have to do the analysis of the vehicle kilometre and vehicle operating time. These two results helped with the decision of the final suggestion with the least financial used in truck terminal implementation project.

The economic analysis of return on financial reliable tool to assess the suitability investment projects is applied. 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

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 ไม่ว่ากรรมใดๆ ทั้งสิ้น อีกทั้งห้ามมีเหตุใดเปลี่ยนแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

scenarios as in Figure 3.3. According to the analysis of the vehicle travel time based on the value of saving vehicle travel time, this value varied according to the objective of the expedition revenue associated with the portion of the vehicle used. In this study, we got the cost of driver and vehicle cost from final report of Expressway project in Thailand for calculating the vehicle operating time (VOT) (DLT, 2015). The calculation included the total of vehicle-kilometre with vehicle-hour in order to find the total vehicle operating cost and compared them among three different scenarios.

Lastly, all possible costs were calculated together. The aim of this finding is the most beneficial case with least operation cost and least CO<sub>2</sub> emitted to the environment. After all the analysis found, discussions on the potential of introducing truck ban is shown in the next section of Chapter 4.

### 3.1 Method for Analysis

The main research tool used in this study was the Four Steps Transport Model (FSM) developed by traffic data collected in 2015. Because in this stage of investigating the current traffic behaviour especially truck traffic inside the city, the four-steps modelling technique that seems to suit the study condition is then selected (McNally, 2007).

First, Origin destination demand matrix is applied for roadside interview and household survey data, which was adjusted from sample size to the population size.

Second, passenger matrix was chosen to assign into the road network. That was because of the majority of the traffic movements in the city was found to be passenger vehicles. Truck demand was also applied with the study of truck behaviour inside the city and the purpose of truck terminal implementation.

Third, CO<sub>2</sub> emission factor was included in the study in order to find the total emissions based on the current base case with the proposed 3 different cases as listed in the next section (Climate, 2015).

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

### 3.2 Suggested Location for Truck Terminal

Below Figure 3.2 and Figure 3.3 are 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 3.2 This suggestion on each location that we have got base on the current situation and land availabilities in google map view. Also, the purpose of introducing this location was based on the accessibility to city centre 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 problems that affects on the logistics activities within this study area. This problem may raise to another issue, which become the conflict with our objectives. Moreover, those issues of congestion, road accessibility, and land availability were considered in our locations' decision. The location of the truck terminal is not possible to locate within city centre 5 kilometres. There are three different options as shown in Figure 3.2 for this study to observe the best location, which benefits to the project the most among other options.

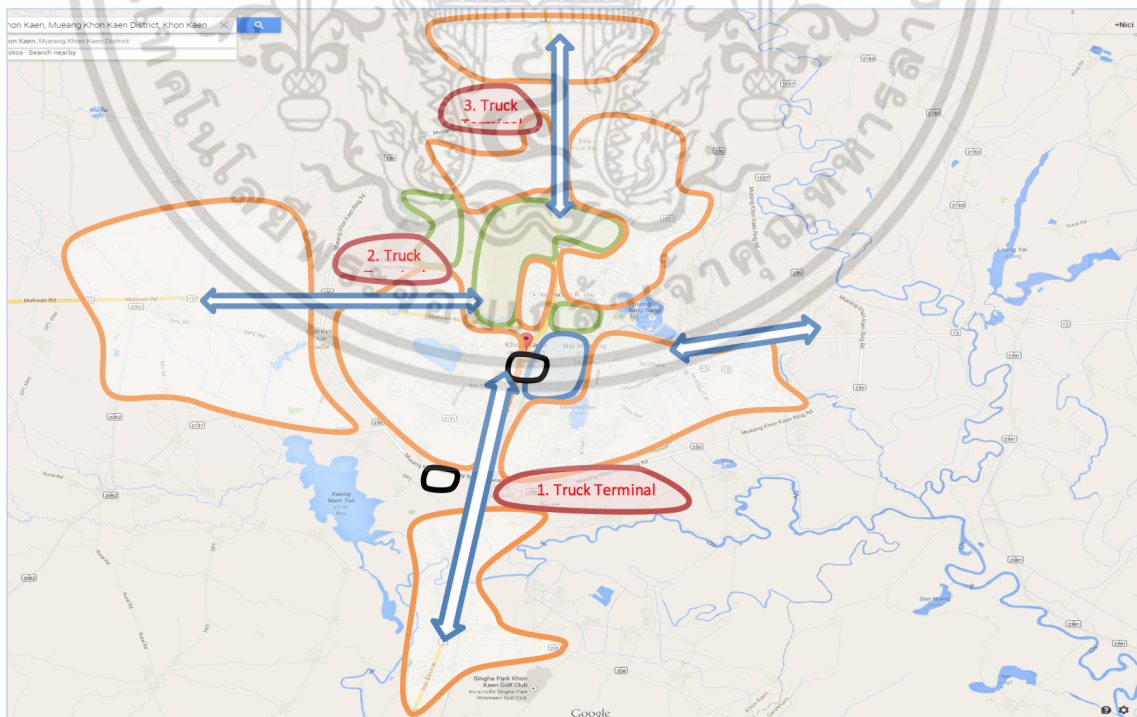


Figure 3.2 The zoom out with location for truck terminal

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

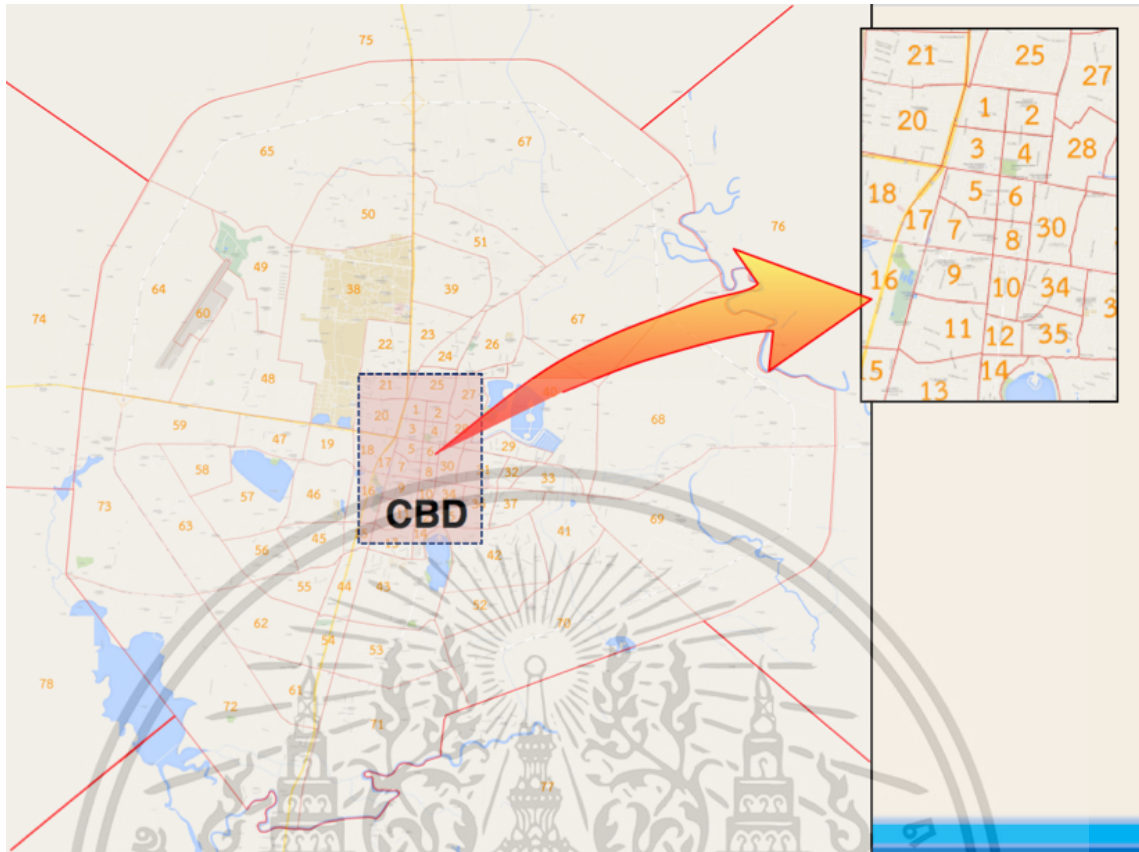


Figure 3.3 Out of bound with zone number

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

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 analysed the current situations of trucks moving inside city centre 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 analysed and discussed, then the study's data sets were used and revised from the original data (DLT, 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 centre, the daily operating

goods, which needed during daytime operation need to get out of city centre 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.

Figure 3.3 indicated the zone number for each location and destination zone within the study area. Figure 3.4 giving a clear picture of how this study defined the location. This idea have been proposed as shown in Figure 3.2. All the colours were defined based on the population density in Khon Kaen city as well as the combination of business community inside CBD. This indicators were shown to help to understand from the different activity within the evaluation.

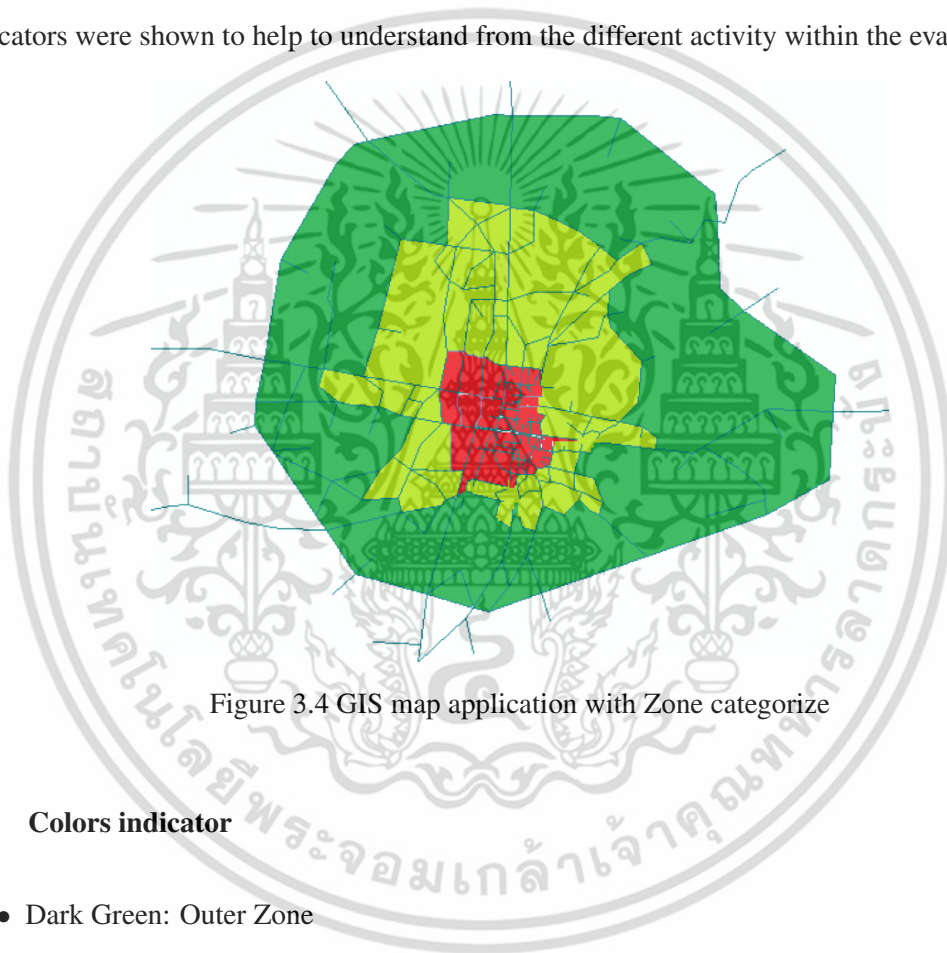


Figure 3.4 GIS map application with Zone categorize

**Colors indicator**

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

**3.3 Study Area**

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

228 square kilometres with approximately 300,000 populations. The data used in this study was collected in March 2015. To observe socio-economic trend in the city in past few years, the 2015 dataset was 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 3.2.

Table 3.2 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%
Load	n/a	9%
Load	n/a	9%
Load	n/a	8%
Full load	n/a	33%

According to Table 3.2, the average household size in 2015 was 3.49 members, which was slightly larger than in 2007. Interestingly, average income in 2015 was 40,319 Thai Baht (approximately US \$1,145) per month, which was about 58 percent higher than that was found in 2007. Looking more closely, in the year 2007, the proportion of households with income more than 30,000 Thai Baht per month significantly rised by half while the proportion of households with income lower than 10,000 Thai Baht decreased by 60 percent in 2015. This could be a result of the

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governments minimum wedge lift up policy in 2011. A variation was also found in working status that in 2015 the proportions of workers and students drop while the proportion of other increased from 16 to 27 percent, relative to the year 2007. That could be explained as a common situation of Thailand, which has turned into ageing-society recently. The majority of populations in category other were retired workers. The household vehicle ownership was found that the proportion of households with motorcycles only dropped by over 40 percent, meanwhile the proportion of households with holding both cars and motorcycles shifted from 52 to 70 percent. However, the proportion of households with cars only remained the same over the time. This could be a result of another government policy introduced in 2011 of first eco-car extra tax deduction. Regarding Table 3.2, basically most common attributes in the 2015 dataset could be fairly comparable to the previous dataset in 2007. Some discrepancies were found but there were reasonable explanations for them. Therefore, it could be fairly confident with the new dataset used in this study.

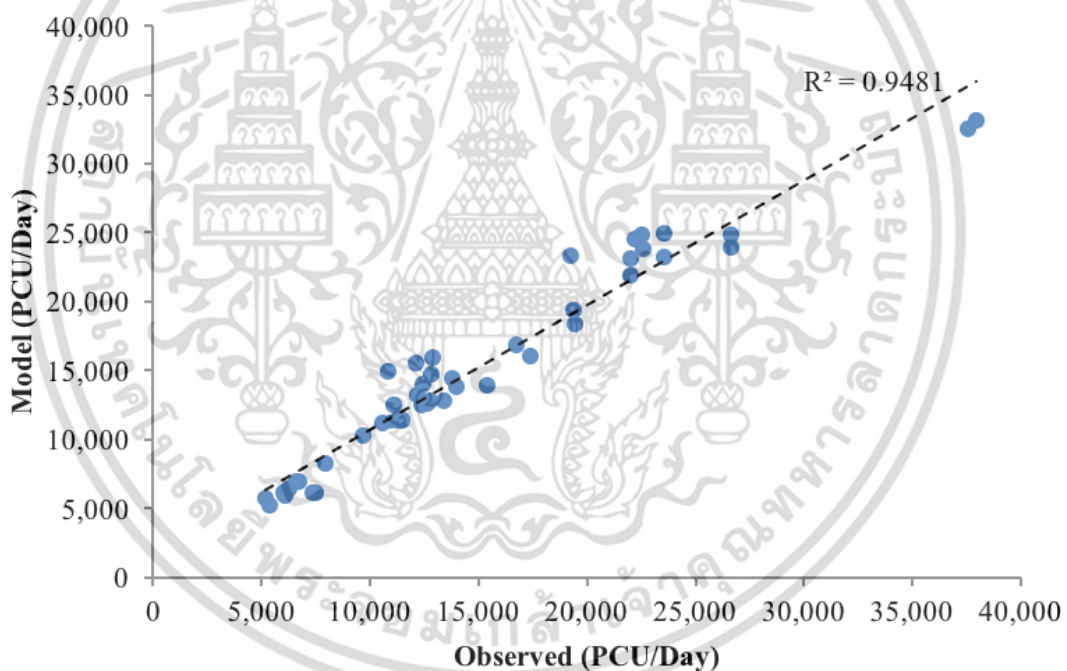


Figure 3.5 A comparison of observed and modelled mid-block traffic

The datas of this study were collected from the traffic survey to compare with the demand on the link in the model as shown in Figure 3.5. To validate the model we plotted the actual demands as the observed against the forecasted demands on that link in the model. As the result, it is not possible that the observed traffic is exactly as the forecasted demands. That was why this study plotted graph and defined the result to find the relativities between the two variables.

This could mean that the observations of this model were quite related. In addition, we have done

the comparison with the model of this study's data collection. The trend line were developed and found that coefficient of determination was (0.9481) in Figure 3.5 were quite high. Then, we could be sure that our model should be fairly accurate enough to use for further study and analysis. After the model calibration and validation were completed, next model was used to determine the truck traffic volume across the networks and also define the behaviour of trucks inside the study area. The analysis was divided into two parts such as to examine overall truck behaviours in the study area and to define impact of truck ban policy in some specific areas of the city.

In this study, the truck classification could different from general classification, as we only focused on below 4 types of truck classification as the following Table 3.3, which reflected from the data that we got from survey (DLT, 2015).

Table 3.3 Vehicles classification in the 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



peak hours were found to be almost similar volume per hour. The average speed in the city was found to be roughly 65 kilometres per hour. However, this average speed accounted outer ring road and some sections of intercity highways, so that could influence the average speed of the model. Figure 4.1 present traffic on links estimated by the model.

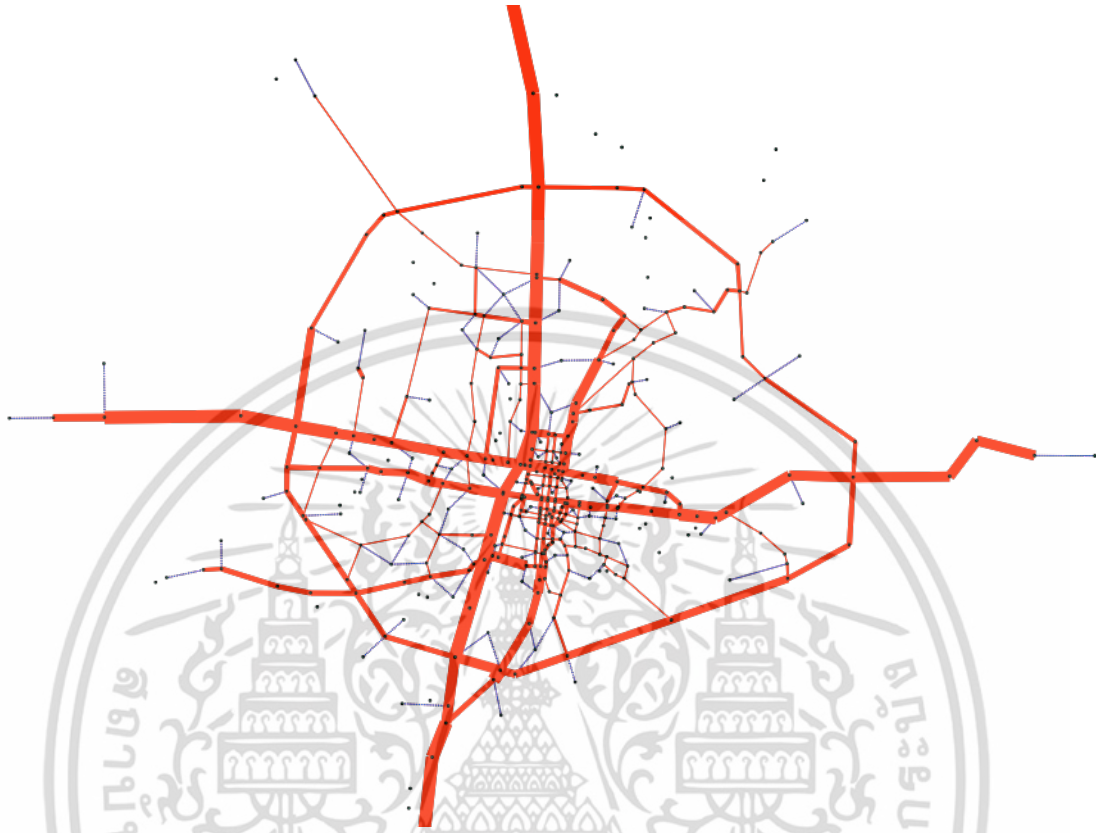


Figure 4.1 Traffic flow on links estimated by the model

According to Figure 4.1, most of the traffics went along north-south and east-west directions. That was because Khon Kaen city is located in the heart of the region. Therefore, not only local traffic generated by inhabitants, but also the city's road network has to handle intercity through trips as well. 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 was found that the main course of traffic congestion in the city is the capacity of traffic signal and intersection.

Another problems found in the city was that there were a large number of intercity vehicles that used Mittraphap and Maliwan roads for crossing the city. That was 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 the daytime. This is the reason why this study has been initiated.

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้ดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

### 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 were presented in Table 4.2.

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

<b>Model estimation results</b>	<b>Comparison to Table 4.1</b>
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 4.2, the daily truck demands in the study area were approximately 40,000 PCU (about 16,000 heavy trucks), which was about 12 percent of total vehicles running in the network each day. However, if considering the total daily travel distances and travel times of trucks, it was found that this took about 20 percent of total travel distances and 17 percent of total times. This implied significance of heavy vehicle traffic in the study area. For the average trip length and trip time, it was found that the trip length was about 66 percent greater while average trip time was over 40 percent longer than the overall traffic. Besides, the truck average speed was 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 4.2 and Figure 4.3.

According to the both Figure 4.2 and Figure 4.3, it could be seen that the majority of the truck origin-destination pairs were through traffic, e.g. north-south, east-west and south-east. Meanwhile, it could be seen that the truck traffics on the ring road were 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 was quite possible that some of traffics through trips, especially truck traffic would use outer ring road to avoid poor traffic condition. This model behaviour was found to match the observations.

### 4.4 Freight Activities Distribution in The City

After the overall truck behaviours in the study area were investigated and found. There were approximately 41,000 PCU of trucks running in the network each day, which is roughly 20 percent of total travel distance in the networks. The question given here was that how many trucks that actually have their origin or destination in the inner zones of the city. These trucks were likely to be disturbed by truck ban policy in the city centre. To do so, the study was divided into three zones using urban density such as outer zone, intermediate zone, and inner zone. Truck traffic activities within each zone was estimated and demonstrated in Table 4.3

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Regarding Table 4.3, the network length in outer zone was about 195 kilometres, which was about 38 percent  
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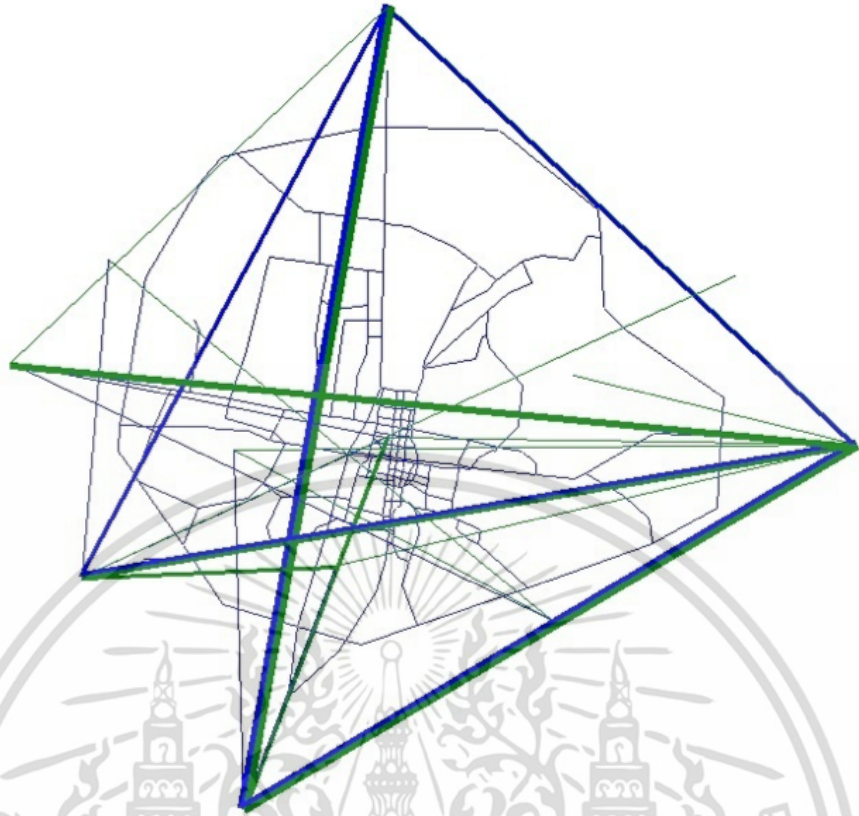


Figure 4.2 Truck traffic desire lines

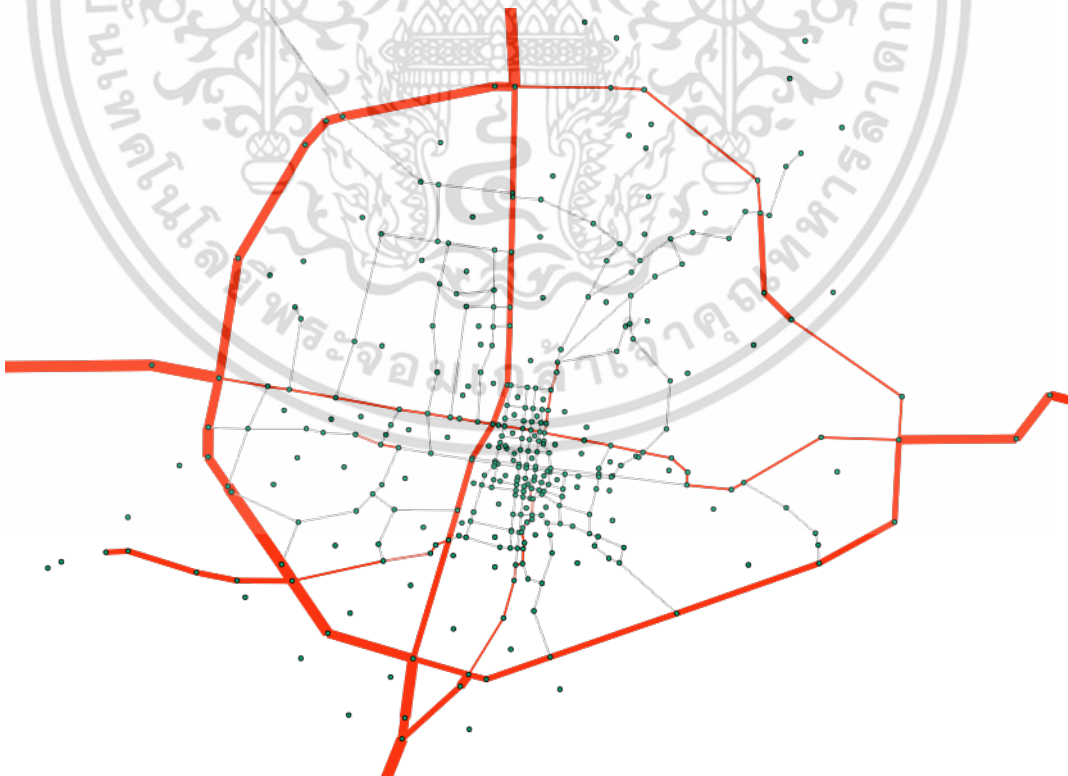


Figure 4.3 Truck traffic flow on links estimated by the model

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

<b>Model estimation results</b>	<b>Overall</b>	<b>Outer</b>	<b>Intermediate</b>	<b>Inner</b>
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

of the total network distance. Meanwhile, the network length in inner zone was 130 kilometres, which was about 25 percent of the total network distance. As expected, the outer zone including ring road and intercity highways are located is the busiest area for truck activities. Approximately, 35,000 PCUs of trucks used road network within the outer zone each day. This was about 86 percent of total truck traffic in the study area. As a result, majority of truck travel distance and truck travel time was generated in this zone. The intermediate zone accounted 9 percent of total truck traffic in the study area and the inner zone handle the rest of truck activities that was about 5 percent.

According to the findings, there was only small portion of trucks that had some activities inside the city while majority were through traffic. However, if the PCU is converted to heavy truck unit, the intermediate zone was expected to have about 1,500 trucks entering and exiting the area each day. With this amount of heavy vehicles, they could certainly impact traffic in the zone. Moreover, if focusing on the inner zone, there were about 780 heavy trucks, which had 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 resulted in many problems such as vibration, congestion, air and noise pollution, accident, and loading/unloading parking problems.

Another behaviour found from field survey was the truck demand profile in outer zone which was roughly steady thought out day and night. This was such a common situation for intercity highway. However, in the case of intermediate and inner zones, majority of the truck activities occurred in the daytime. That was because these trucks were related to local businesses in the city. Thus, most of activities were done during business hours.

#### 4.5 Truck Traffic Behaviours in The Study Area of Base Case Scenario

This section, base case scenario was created based on the previous data sets from survey as secondary data obtained from DLT (2015). Then, the new O-D matrix was created by deleting all passengers vehicle and focusing only on the trucking transportation within inner zone (CBD). After the new O-D matrix created the result 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 the results revealed. Then, this data sets were remodelled and rechecked results by GIS application. The base case scenario estimated result on truck traffic behaviours were shown in Table 4.4.

As the results from Table 4.4 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. อย่างไรก็ตาม การดำเนินการครั้งนี้จำเป็นต้องมีการนำข้อมูลจากแบบจำลองการจราจรที่สร้างขึ้นใหม่มาใช้ในการประเมินผลกระทบของการจราจรที่หนาแน่นในเขตเมือง โดยเฉพาะอย่างยิ่งในเขต CBD ซึ่งมีการจราจรที่หนาแน่นอยู่แล้ว การดำเนินการครั้งนี้จะช่วยลดผลกระทบจากการจราจรที่หนาแน่นในเขตเมืองได้บ้าง อย่างไรก็ตาม การดำเนินการครั้งนี้จำเป็นต้องมีการนำข้อมูลจากแบบจำลองการจราจรที่สร้างขึ้นใหม่มาใช้ในการประเมินผลกระทบของการจราจรที่หนาแน่นในเขตเมือง โดยเฉพาะอย่างยิ่งในเขต CBD ซึ่งมีการจราจรที่หนาแน่นอยู่แล้ว การดำเนินการครั้งนี้จะช่วยลดผลกระทบจากการจราจรที่หนาแน่นในเขตเมืองได้บ้าง

hours. In addition, it consisted of 58,504.47 vehicle-kilometres within the networks. This results accounted for 1,020 hours with the average trip length of 0.7 kilometres as well as the average trip time around 0.81 hour with average trip speed 49.1 kilometres/hour.

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

Model estimation result 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

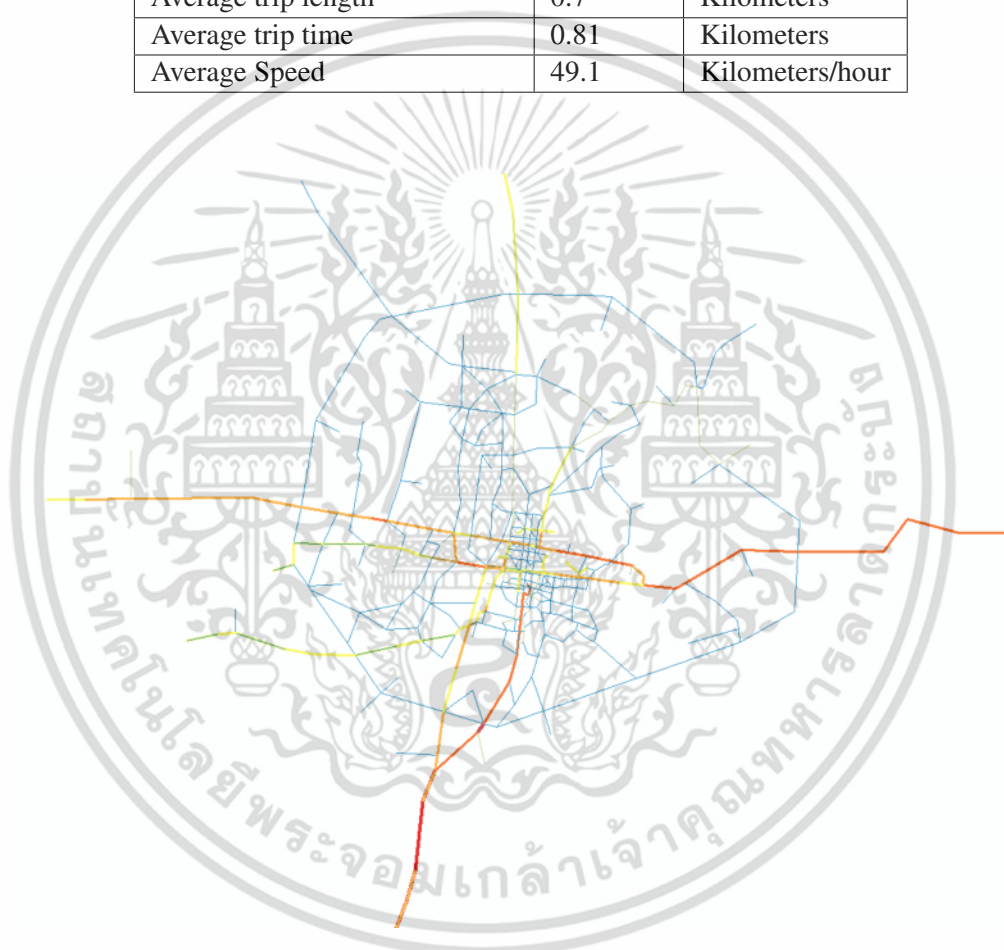


Figure 4.4 Truck traffic flow on links estimated by the GIS application in base case scenario

Figure 4.4 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 realisable due to the movement of traffic from everywhere crossing city centre or coming from city centre, so that this study is useful to deal with this kind of current traffic behaviour in the study area. By Figure 4.4, the result of this study was assumed that this model was suitable for doing the further study on the 3 different locations of the truck terminal as suggested to avoid the truck traffic on the main road and truck traffic inside CBD.

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ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมิให้คัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

#### 4.6 Truck Traffic Behaviours of Case I (Zone71)

In this section, truck traffic behaviours of case I (zone 71) revealed by the model were reviewed and discussed. Results obtained from the model were presented in Table 4.5

Table 4.5 Model estimation results for truck traffic behaviours in Case I

Model estimation result Case I		
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
Average trip length	0.7	Kilometers
Average trip time	0.81	Kilometers
Average Speed	49.1	Kilometers/hour

As the result from Table 4.5 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 same average trip length, average trip time, and average speed of vehicles with the same study area.

Figure 4.5 showed that after having the truck terminal in Zone 71 trucks that moved from outer zone using the Mithraphab road and city road has to switch to use the outer link road instead due to the policy of truck ban. Then all large trucks that moved from outside city turned to used Tambon Ban Pet road which was shown as the yellow line and orange line through circle around map in Figure 4.5.

Figure 4.6 indicated the traffic flow on link road within CBD area with the LGV moving within 24 hours operation. As has been set in the Case I in Zone 71, the result found that traffic moving desire line is as per expected with 8,337 PCU (about 16,674 tons), which already mentioned in previous section of Figure 4.5. 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. The road was able to handle this amount of demands quite well without any problems.

#### 4.7 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 as following Figure 4.7 and Figure 4.8.

Results from Table 4.6 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 showed that Case II were not satisfied our research objective as the aims of the cost saving location with the



Figure 4.5 Truck traffic flow on links estimated for Case I of HGV

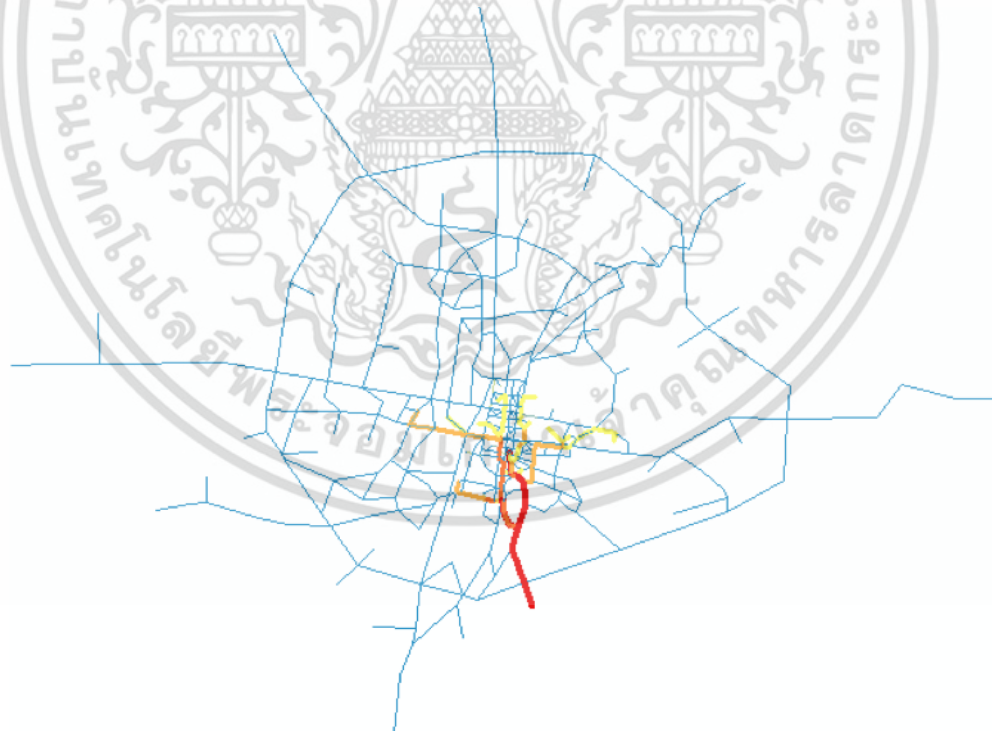


Figure 4.6 Truck traffic flow on links estimated for Case I of LGV

least cost in the transportation operation.

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 Figure 4.7 and Figure 4.8 indicated the flow on the desire link within Case II as the result from GIS application.  
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Table 4.6 Model estimation results for truck traffic behaviours in Case II

Model estimation result 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
Average trip length	0.7	Kilometers
Average trip time	0.81	Kilometers
Average Speed	49.1	Kilometers/hour

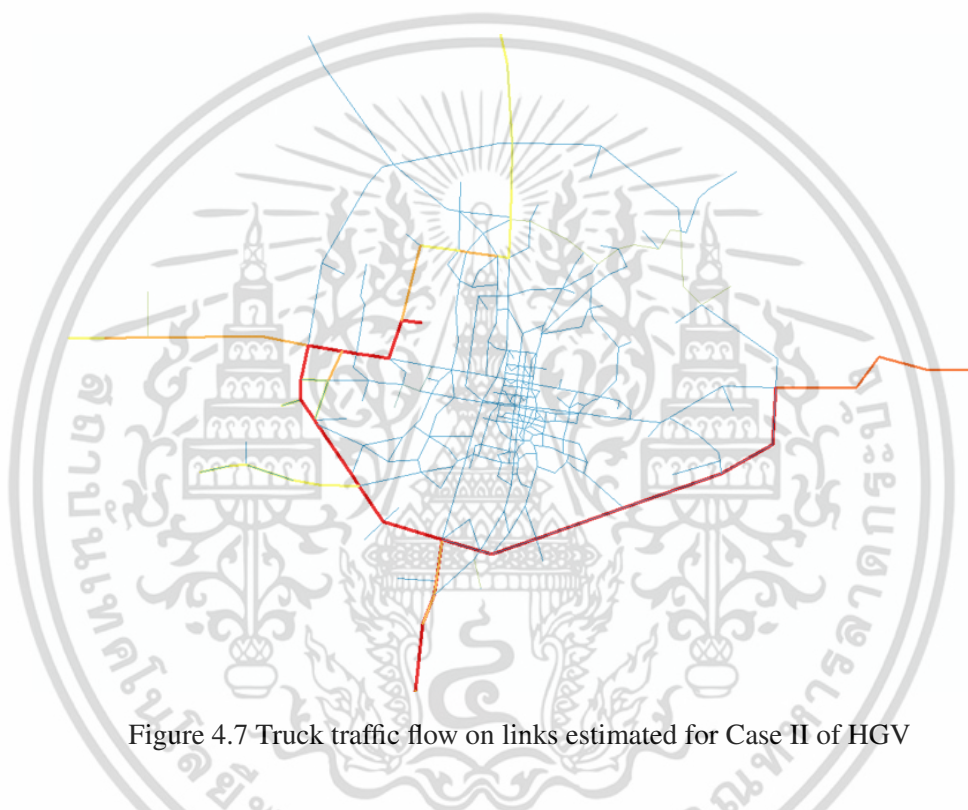


Figure 4.7 Truck traffic flow on links estimated for Case II of HGV

Figure 4.7 showed that the location condition in intermediate zone in Case II which was longer in distance and number of traveling time was greater comparing to Case I. This location condition has forced all the large vehicles to change and avoid using city road. All large trucks will move to use outer link road instead, which is even further away. While the distance increased the travel time also increased. Then, goods, which used Mithraphep road continued using same road as truck could stop by truck terminal along that road. As in Figure 4.8, same method applied on the truck movement so most goods turned to use Maliwan 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.

#### 4.8 Truck Traffic Behaviours in Case III (Zone 75)

This section calibrated the result of model estimated from Case III compared to Case II as the following Table 4.7. Comparing between Table 4.7 and Table 4.6, the results showed that truck traveling distances were 148,507 PCU-kilometres which was about 50 percent less than Case II in Table 4.6; however, it was still greater than Case I in Table 4.6. This result showed that the location condition in Case III was better than Case II. The location condition in Case III was better than Case II because the location condition in Case III was better than Case II. The location condition in Case III was better than Case II because the location condition in Case III was better than Case II. The location condition in Case III was better than Case II because the location condition in Case III was better than Case II.

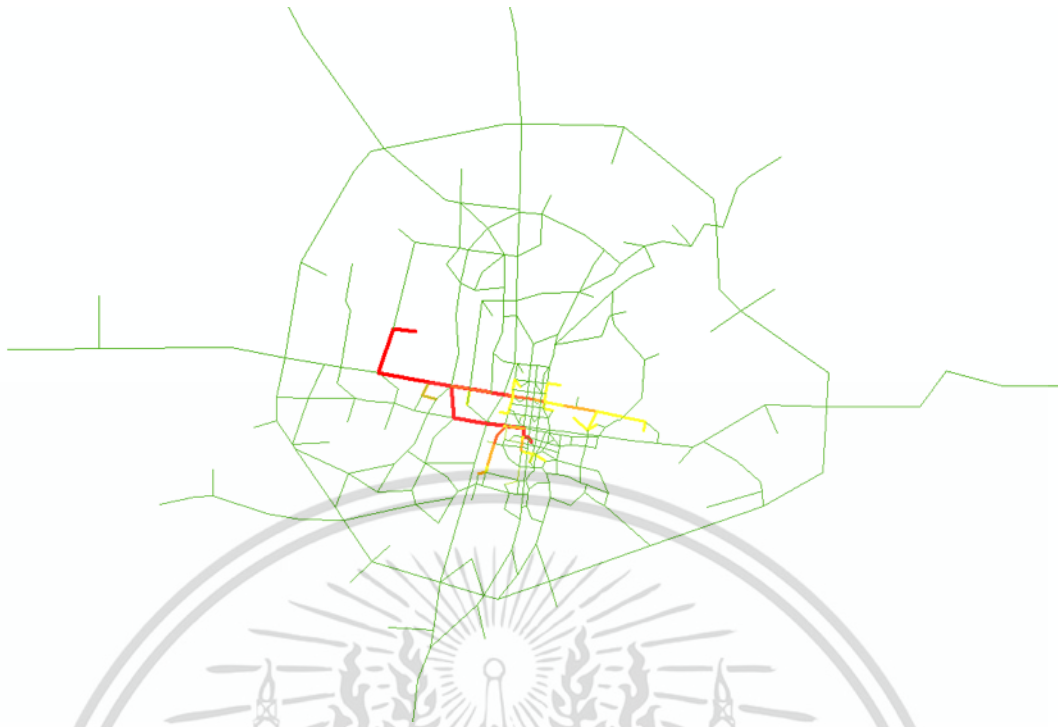


Figure 4.8 Truck traffic flow on links estimated for Case II of LGV

4.5 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. By the last result of Case III, the result assumed that among all the three cases, Case I was quite favourable with less total traveling distance and total traveling time.

Table 4.7 Model estimation result for truck traffic behaviours in Case III

Model estimation results 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
Average trip length	0.7	Kilometers
Average trip time	0.81	Kilometers
Average Speed	49.1	Kilometers/hour

Moreover, Figure 4.9 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 centre 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 colour and orange colour. This indicated the heavy truck traffic moving on the link. In addition, Figure 4.10 presented the heavy traffic of small vehicles moving from CBD to truck terminal by using Mithraphap road. This was significantly crowded and lot of traffic increased in intermediate zones road as appeared in red colour.

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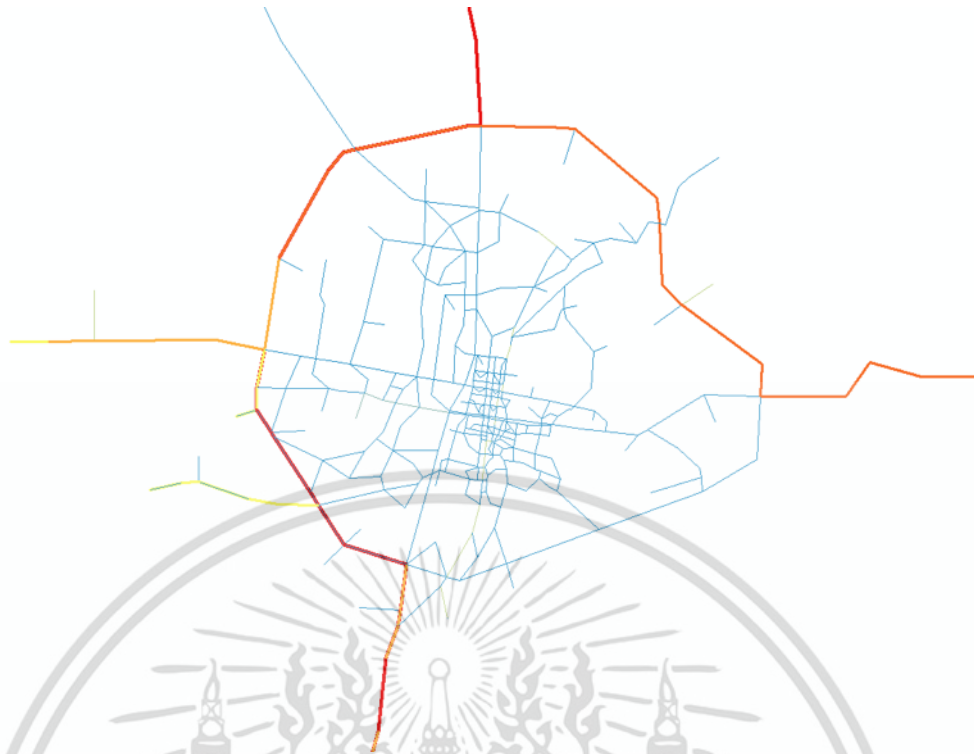


Figure 4.9 Truck traffic flow on links estimated for Case III of HGV

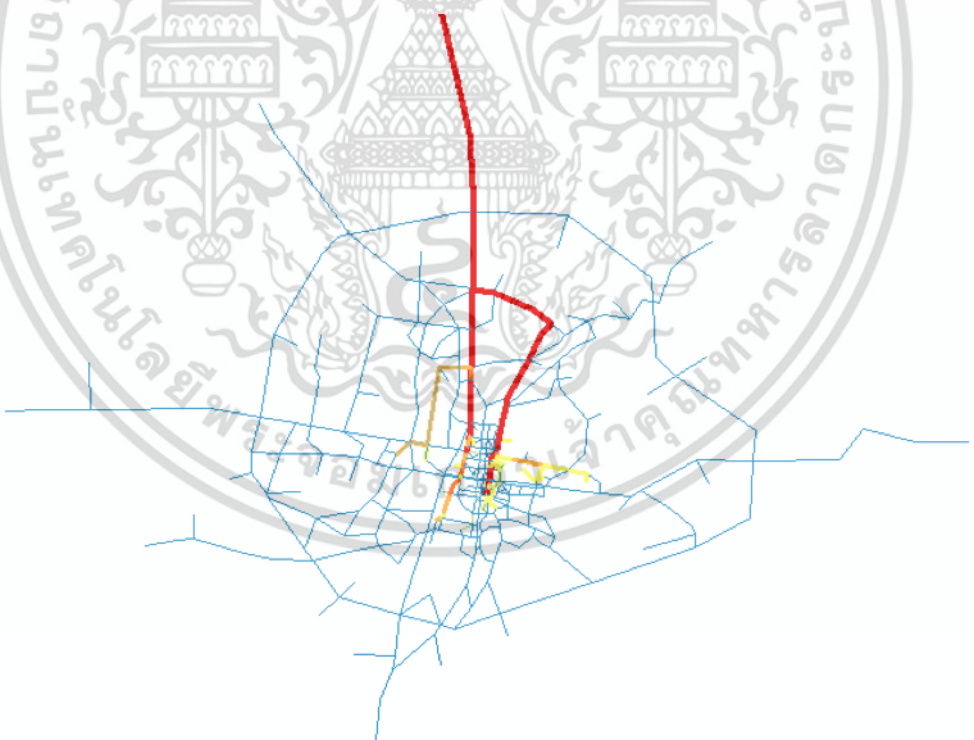


Figure 4.10 Truck traffic flow on links estimated for Case III of LGV

#### 4.9 Vehicle-Kilometer and Vehicle-Hour Comparison

In this section, the total kilometres and total hours of all the three difference cases were evaluated and showed เอกสารนี้เป็นเอกสารที่สงวนไว้สำหรับการใช้งานเพื่อการศึกษาเท่านั้น ไม่อนุญาตให้นำไปใช้ประโยชน์ด้านการค้า by Figure 4.9. This section would bring the clear pictures of all the cases for the purpose of comparison.

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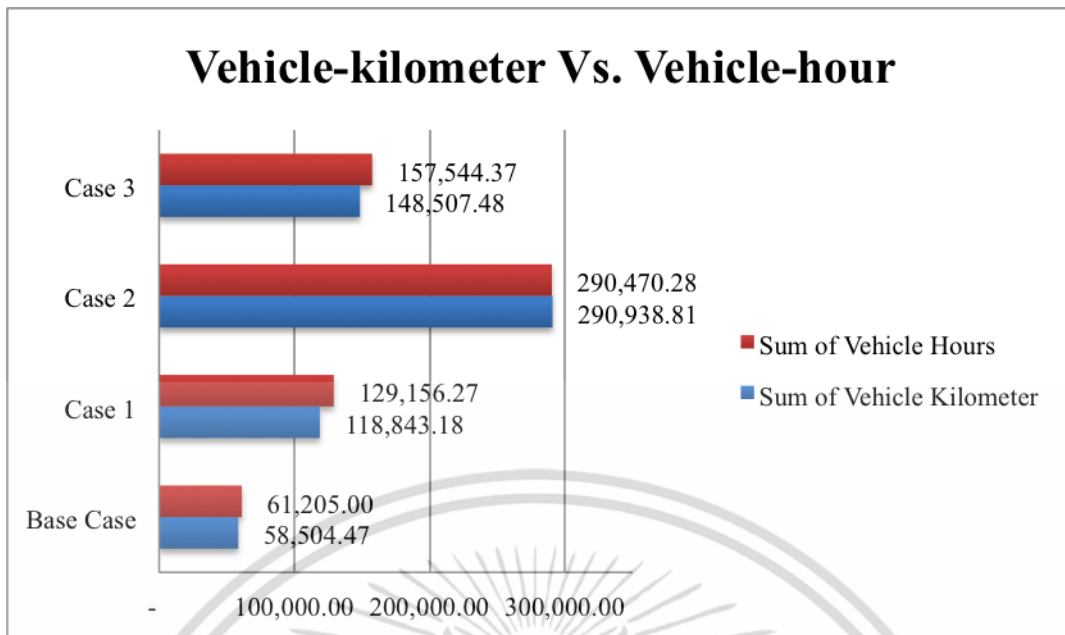


Figure 4.11 The comparison between vehicle-kilometer with vehicle-hour

Remark: VK: Vehicle kilometer VH: Vehicle hour

Table 4.8 The total vehicle-kilometers of all cases within study area

Vehicle-Kilometers	Base Case	Case 1	Case 2	Case 3
HGV	58,504.47	63,370.94	118,030.70	82,849.20
LGV		55,472.24	172,908.11	65,658.28
Sum of vehicle-kilometers	58,504.47	118,843.18	290,938.81	148,507.48

Table 4.9 The total vehicle-hour of all cases within study area

Vehicle-hour	Base Case	Case 1	Case 2	Case 3
HGV	61,205	59,986.21	10,9063.6	79,715.8
LGV		69,170.06	181,406.68	77,828.57
Sum vehicle-minute	61,205	129,156.27	290,470.28	157,544.37
Sum of vehicle-hour	1,020.083	2,152.60	4,841.17	2,625.73

From Figure 4.9, the result showed when the number of traveling distance increased. Obviously, the total traveling hours also increased dramatically as well. From Table 4.8, the total vehicle-kilometres in Case I was double compared with base case, where vehicles were not yet converted into small trucks that used in CBD area yet. While Case I already converted from large vehicle to be the small vehicle in order to check the possibility of truck moving inside traffic, This would be able to demonstrate the comparison among other two different cases. Thus, base case were shown just to display the difference among the results of original and the proposed results with different scenarios.

After the results were found, results showed that, among all the 3 cases, Case II was increased in number of vehicle-kilometres and vehicle-hour. This result could implied that location in Case II was not able to meet our criteria and

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expectations of cost saving with environmental protection. Then, location in Case II was automatically rejected by our study.

Figure 4.9 showed the results of both Case I and Case III which was quite similar in number. However, the total value of vehicle kilometres in Case I was about 25 percent less than Case III. This result look really interesting. The result was finally found that the location in Case I was very favourable toward our study. However, the study continued with the total vehicle operating cost which getting the detail of vehicle-kilometres and vehicle-hours from this section. The result would 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 transport cost during the operation within the study area. Furthermore, the study moved on to the next section in order to find out the total CO<sub>2</sub> emitted to the environment between all the 3 cases comparing with base case scenario (original vehicle moving without stopping by the truck terminal in the study area).

#### 4.10 Estimated Results of Vehicle Operating Cost in Study Area

In this section, the total vehicle operation cost was found and made the comparison among all cases in the study area. Below cost was taken directed from the final report study of Express Way implementation of Thailand (DLT, 2015).

The purpose of this section was to look for the total cost of both vehicle 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.

Table 4.10 Total vehicle operating cost of all cases within study area

Scenario	Total Vehicle Hour	Time Value Cost	Driver Cost	Total VOC (THB)
Base Case	1,020.08	119,237.54	142,026.20	261,263.74 THB
Case 1	2,152.60	415,825.53	190,452.65	606,278.18 THB
Case 2	4,841.17	933,700.37	427,645.01	1,361,345.38 THB
Case 3	2,625.74	487,658.50	223,352.94	711,011.43 THB

Table 4.10 and Figure 4.12 showed the result of total calculation of all vehicle operation cost 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

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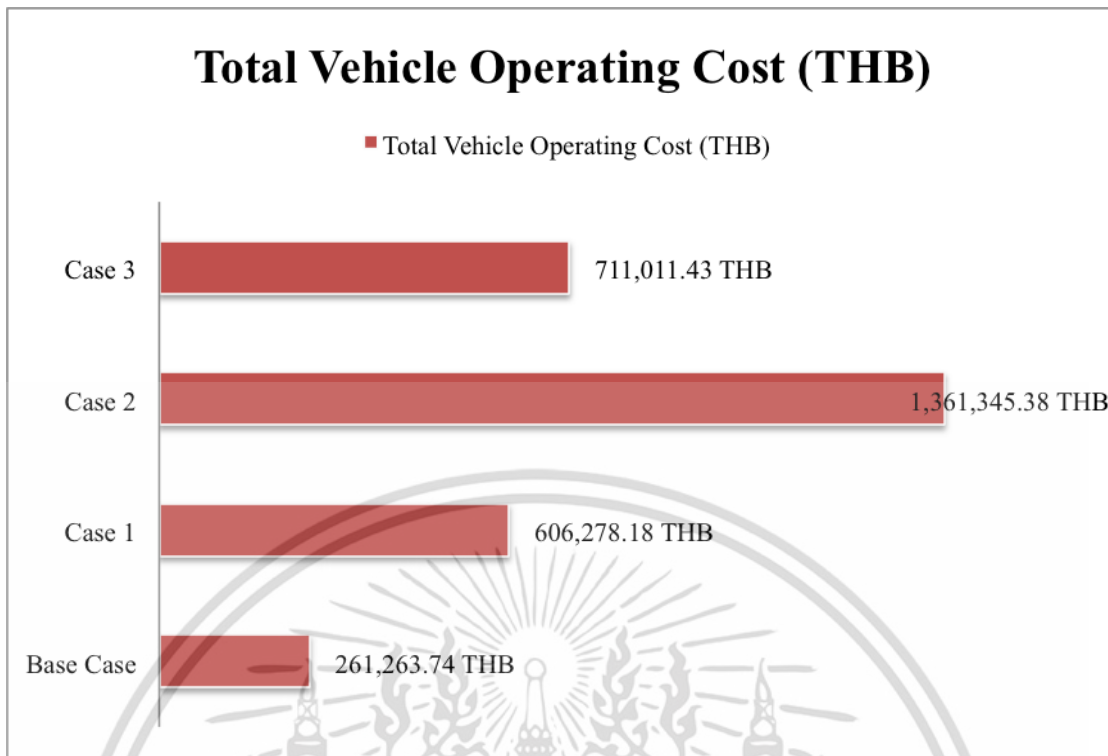


Figure 4.12 Total vehicle-operating cost within the study area

21 percent. By the result in Table 4.10, the result found that Case I still became the most suitable case of this research study; however, the result of this study would expected the increase of vehicle kilometre 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 were increased dramatically. That is reasonable enough for this finding. Figure 4.12 showed 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 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 equal zero, all costs from three different scenarios still greater than current cost of not having any truck terminal in the study area.

#### 4.11 Environmental Performance of Trucking Behaviour in The Study Area

In this section, the study of total CO<sub>2</sub> emitted to the environment has been conducted and the CO<sub>2</sub> factors that was used were extracting from the source of US environmental protection agency. (Climate-Leadership, 2015)

Table 4.11 CO<sub>2</sub> factors and conversion

Light Truck	0.485	CO <sub>2</sub> per vehicle-mile	0.30	CO <sub>2</sub> per vehicle-kilometer
Heavy Truck	1.43	CO <sub>2</sub> per vehicle-mile	0.89	CO <sub>2</sub> per vehicle-kilometer

Source: Climate leadership, 2015 (U.S Environmental Protection Agency)

Remark: 1Mile = 1.609.Km (www.metricconversions.org)

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 Table 4.11 is the conversion from mileage to kilometre from the original data that was received. Our study  
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used vehicle-kilometre instead of vehicle-mile. Kilometre per hour is one type of measurement from speed typically used for matrix of transportation. Road speed are given in kilometre are used for Asian countries, on the other hand, mile per hour is used typically for measurement for speed of transportation as well. However, it is used in non-matrix 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. In Table 4.11 showed factor of CO<sub>2</sub> for trucking transportation in logistic purpose as the whole. Light vehicle good emits less emission around 0.485 in vehicle mile while convert to kilometre it is around 0.30 kg/vk. In addition, heavy good vehicles generated greater emissions to the atmosphere more than light good vehicles which were around 1.43 in vehicle-mile while equal to 0.89 per vehicle kilometre. (Climate-Leadership, 2015)

In Table 4.12 showed the result of CO<sub>2</sub> that has been emitted from all total vehicle operating on the road for each cases within the study area. The data from base case generated the largest amount of CO<sub>2</sub> around 52,000kg per kilometre from trucks transport. This result caused by token large truck type as the transport tool of goods delivery without having to stop at truck terminal.

Table 4.12 Results of CO<sub>2</sub> estimated for all cases in study area

Scenario	Total Kilometer	CO <sub>2</sub> Factor/Unit	Total CO <sub>2</sub> emission kg/Unit
Base Case	58504.47	0.89	52,068.98
Case 1	118843.18	0.30	<b>34,965.87</b>
Case 2	290938.81	0.30	84,661.50
Case 3	148507.48	0.30	40,445.45

Moreover, looking to the first case, results showed in Figure 4.13 found that Case I was significantly the less CO<sub>2</sub> that generated the amount of CO<sub>2</sub> to the environment among all cases including base case. This implied that if Case I of truck terminal location was chosen, the purpose of city sustainability could be possible. This also mean that using small trucks would be better than using large trucks which cause a lot more emissions due to the different of vehicle engine and fuel type. This not only helped with the traffic situation inside city centre, this would also help with the global warming reduction by 33 percent comparing with base case scenario. The other two cases of Zone 48 and Zone 75 would not meet our expectation. As case II generated around 84,661 kg per vehicle-kilometre of CO<sub>2</sub> which generate even more emissions to the environment than using large truck in base case due to the further distance of total vehicle moving. However, case III generated similar amount of CO<sub>2</sub> compared to case I as the total CO<sub>2</sub> emitted to the environment is just around 40,000 kg/vehicle-kilometre which is greater than case I around 15 percent only. After all, results found out that case I considered as the most suitable case for this research study as can be easily seen in Figure 4.13.

#### 4.12 Discussion on The Potential of Introducing Truck Ban

A discussion on possibility of introducing truck ban in this study area is 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 percent of them are daytime activities. Assumed that the regulation is set for 12 hours daytime period between 07:00-19:00. This regulation is not only to reduce the number of trucks but also to reduce the amount of trucks that are allowed to enter the zone during the daytime. This regulation is not only to reduce the number of trucks but also to reduce the amount of trucks that are allowed to enter the zone during the daytime. This regulation is not only to reduce the number of trucks but also to reduce the amount of trucks that are allowed to enter the zone during the daytime.

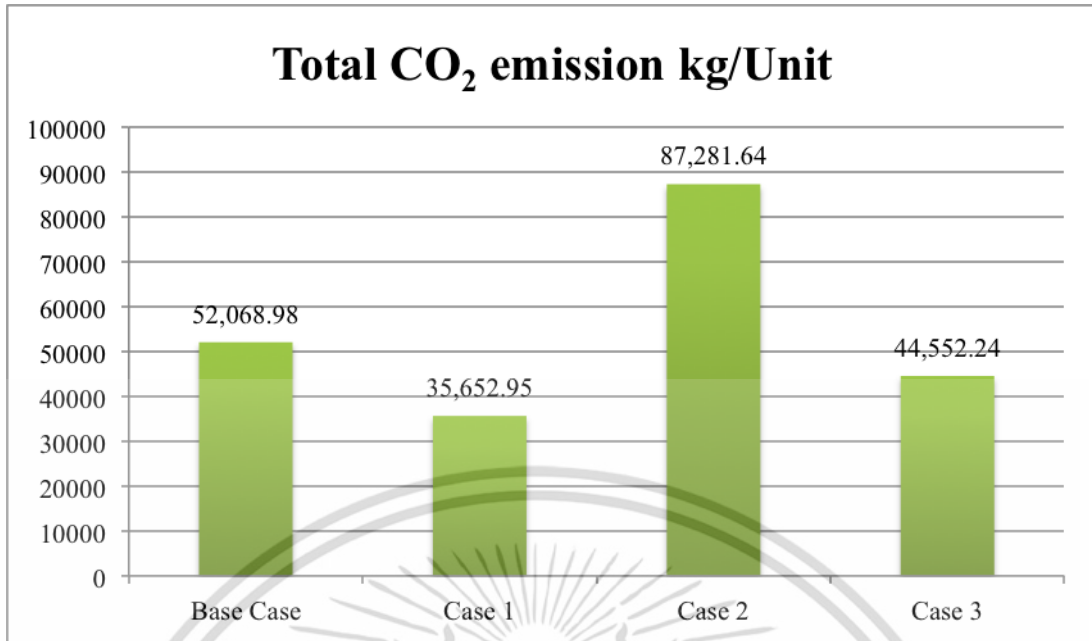


Figure 4.13 Total CO<sub>2</sub> emitted to environment within the study area

7 am and 7 pm, thus about 600 trucks are potentially affected. Regarding the data obtained from roadside interview presented in Table 3.2, it is found that on average truck utilisation in the study area is 45.7 percent. Presumed that the truck utilisation 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 utilisation 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), 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,

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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.

#### 4.13 Discussion on Truck Terminal Implementing and Vehicle Handling

From the first discussion, in order to support the policy of truck ban inside city centre, 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 centre, 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 Maliwan and Mithraphap road to inside city ,by the policy and truck terminal location, most traffic will move to use the outside ring road in stead. As result, traffic inside the city centre 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 labours for doing the storage controlling, loading, unloading, and warehouse management etc. All of these operation 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 Table 4.10. 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 doing nothing scenario (base case) 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 recommended for further study for the clearer analysis and understanding.

Beside, this study aims to examine on how much CO<sub>2</sub> emitted to the environment compared to usual traffic with large truck running. The results assumed that the possibility of CO<sub>2</sub> reduction is 25 percent comparing to having large truck moving inside city as around 17,100 kg per vehicle kilometre, which is considered as quite a lot in number. If the pollution is reduced, the city environment also become healthier as less noise pollution from large vehicle as well as the rate of accident inside city will also 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 and N, 2014). Regarding our study, as large truck will be move to outside link road, the city sustainability will be possible. Thus, having truck terminal will not help in reducing the cost benefit however, this could help with the environmental problem which is the most concern topic for

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every country and for almost every sectors around the world. These could be the positive results of this study even if the results may not satisfied for the economic benefit of this investment.

Incidentally, this study aims 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. 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 was not found. These questions have been noted for more intensive works in the next stage of the study.



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## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

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.

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 labor working process, double loading and unloading, the requirement of some specific kind of cargo, storage requirement, and cargo transshipment process as well.

#### 5.2 Recommendations

Eventhough 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,

1. What is an appropriate number?

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2. What is the size and location of the truck terminal for the current and future situations?

ไม่ว่ากรณีใดๆ ทั้งสิ้น อีกทั้งห้ามมีเหตุดัดแปลงเนื้อหา และต้องอ้างอิงถึงเจ้าของเอกสารทุกครั้งที่มีการนำไปใช้

3. What is the type of cargo that can practically be transhipped or stocked in a truck terminal?
4. How to deal with cargo that cannot be stocked or transhipped at the terminal?
5. Is the project feasible in term of economics
6. What is the total economic benefits of the project
7. Could this project really improve traffic condition and other problems inside the study area

Regarding the new truck terminal location, there are still concerns and the following factors should be addressed clearly.

1. The size of the investment needed
2. The support for the operation
3. The size of land rental needed
4. 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 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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## APPENDIX A

Table A.1 Business Travel Emission Factors

Vehicle Type	CO2 Factor (kg/unit)	CH4 Factor (g/unit)	N2O Factor (kg/unit)	Units
Passenger Car	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck	0.485	0.02	0.022	vehicle-mile
Motorcycle	0.191	0.07	0.007	vehicle-mile
Intercity Rail (i.e. Amtrak)	0.136	0.0083	0.003	Passenger-mile
Commuter Rail	0.169	0.0085	0.0034	Passenger-mile
Transit Rail (i.e. Subway, Tram)	0.12	0.0025	0.0017	Passenger-mile
Bus	0.055	0.0006	0.0005	Passenger-mile
Air Travel - Short Haul (< 300 miles)	0.251	0.0039	0.0083	Passenger-mile
Air Travel - Medium Haul ( $\geq$ 300 miles, < 2300 miles)	0.143	0	0.0047	Passenger-mile
Air Travel - Long Haul ( $\geq$ 2300 miles)	0.167	0.0006	0.0056	Passenger-mile

**Source** U.S. Greenhouse Gas Emissions and Sinks: 1990-2013 Vehicle-miles and passenger-miles data from Federal Highway Administration Highway Statistics 2013

## APPENDIX B

Table B.1 Product transport emission factors

Vehicle Type	CO2 Factor (kg/unit)	CH4 Factor(g/unit)	N2O Factor(kg/unit)	Units
Medium - and Heavy-duty Truck	1.43	0.015	0.013	vehicle-mile
Passenger Car	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck	0.485	0.02	0.022	vehicle-mile
Medium- and Heavy-Duty Truck	0.146	0.0015	0.0014	ton-mile
Rail	0.024	0.0019	0.0006	ton-mile
Waterborne Craft	0.059	0.0005	0.004	ton-mile
Aircraft	1.307	0	0.0402	ton-mile

**Source** U.S. Greenhouse Gas Emissions and Sinks: 1990-2013 Vehicle-miles and passenger-miles data from Federal Highway Administration Highway Statistics 2013

## APPENDIX C

Table C.1 Monetary value of vehicle equivalent in 2558 hours a year

Vehicle Type	Average revenue (Baht /Month)	People/Vehicle	Revenue Vehicle(Baht/Month)	Revenue/Vehicle/Hour
Small Truck	13,362	1.9	25,387.8	139.23
Medium truck	10,555	1.32	13,932.6	76.41
Large trucks	14,492.25	1.23	17,825.47	97.75
Trucks, trailers and semi-trailers	14,909	1.15	17,145.35	94.02

**Source**A feasibility and Management of Provincial Truck Terminals (2015), Final Report, Department of Land Transport, Thailand

## APPENDIX D

Table D.1 The worth of the travel time of each vehicle category in the year 2558(Time Value (THB/PCU-Hour))

Vehicle type	Vehicle Propotion	Traveling proportion by object (%)		Worth the travel time	PCU	Time Value(THB)
		Work/Business (%)	Part time jobs (%)			
Small Truck	0.11	0.63	0.37	116.89	1	116.89
Medium truck	0.06	0.87	0.13	76.84	1.5	115.26
Large trucks	0.02	0.82	0.18	95.21	2.5	238.03
Trucks, trailers and semi-trailers	0.02	0.84	0.16	92.89	2.5	232.23

**Source:** A feasibility and Management of Provincial Truck Terminals (2015), Final Report, Department of Land Transport, Thailand

## APPENDIX E



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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 <sup>a</sup>, Jaruwit PRABNASAK <sup>a\*</sup>

<sup>a</sup> *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 examining potential impacts of truck ban 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 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 normal practice of 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 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

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

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, 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 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.

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

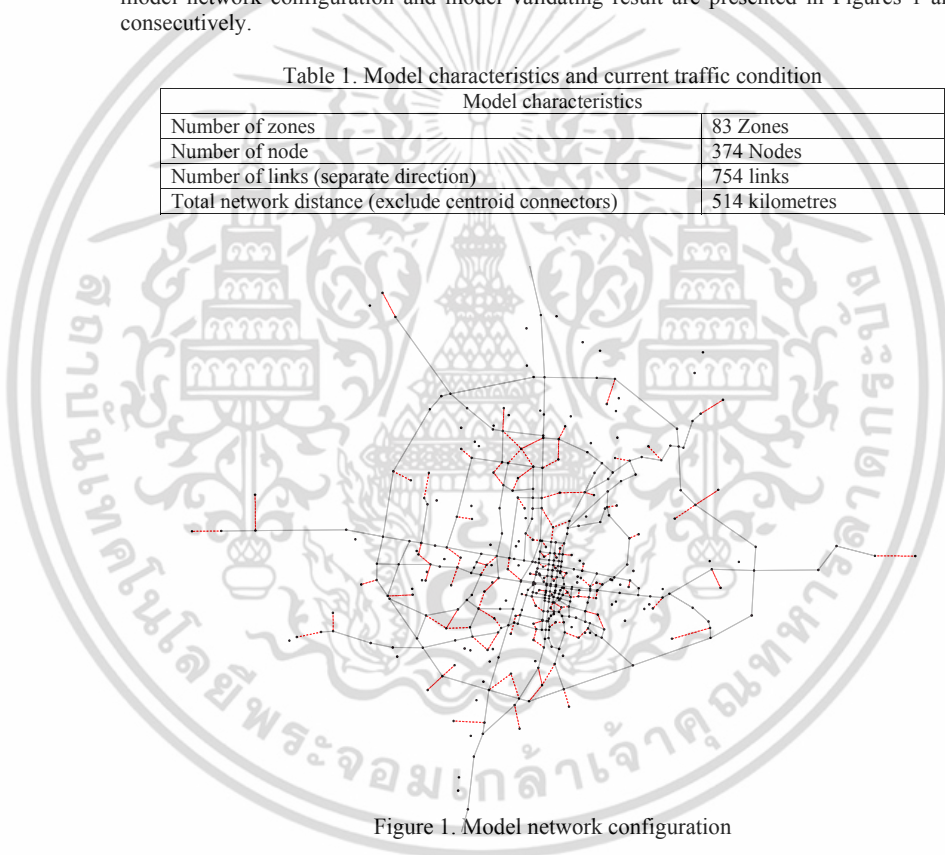


Figure 1. Model network configuration

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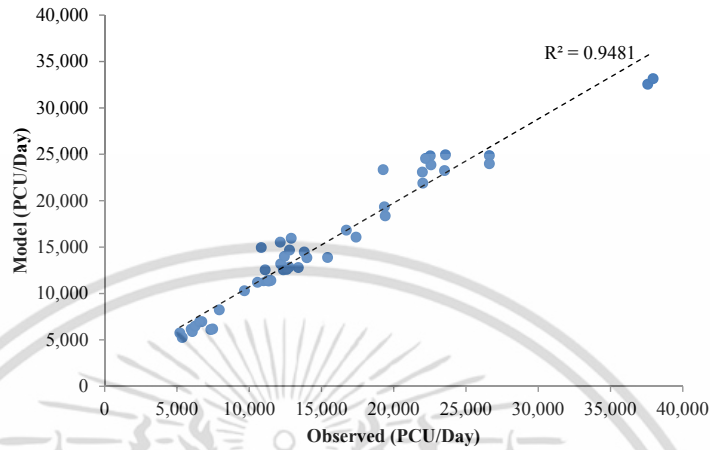


Figure 2. A comparison of observed and modelled mid-block traffic

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 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 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. Majority of populations in category other are then 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

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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 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 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.

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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 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 3 presents link traffic estimated by the model.

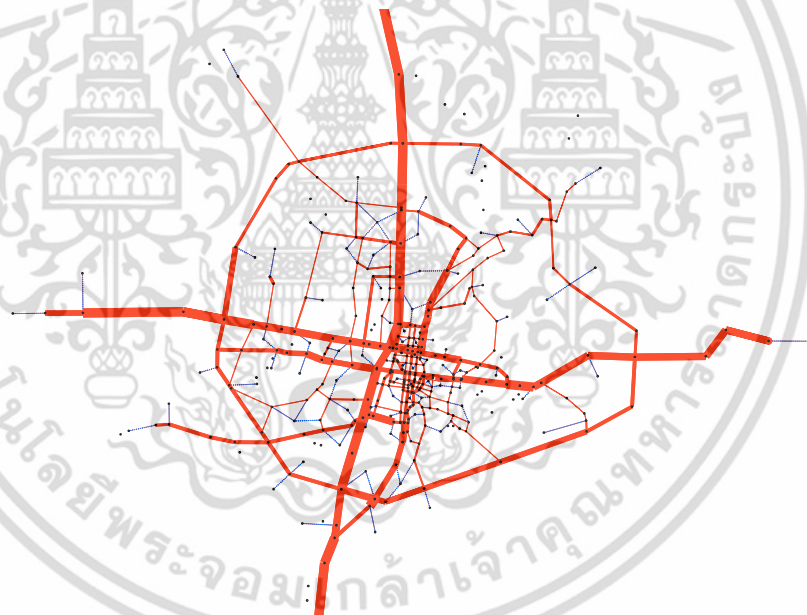


Figure 3. Traffic flow on links estimated by the model

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

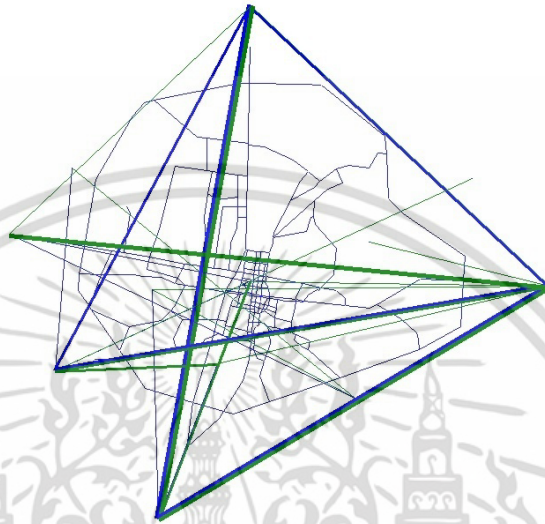


Figure 4. Truck traffic desire lines



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 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.

#### 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 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.

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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# BIOGRAPHY

**Author:** Vuch Lung Chhorn  
**Degree:** Master of Science  
**Defense Date:** May 13<sup>th</sup> , 2017  
**Date of Birth:** Nov 11<sup>th</sup> , 1990  
**Place of Birth:** Phnom Penh, Cambodia

## Undergraduate and Graduate Education:

1. Master of Science in Logistics and Supply Chain Management,  
King Mongkut's Institute of Technology Ladkrabang,  
International College, Bangkok, 2017
2. Bachelor degree in Education in English as foreings languages,  
Royal University of Phnom Penh, Institute of Foreings Languages, 2013
3. Bachelor degree in Banking and Finance,  
Royal University of Laws and Economics, 2012

**Major:** Logisitics and Supply Chain Management

## Presentation and Publication

Vuchlung Chhorn and Jaruwith Prabnasak, "An evaluation of Truck Ban Regulation and Suburban Truck Terminal Implementation Scheme in Khon Kaen City of Thailand,"  
*The 6<sup>th</sup> International Conference on Transportation and Logistics* ,2016.

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