

**TRANSPORTATION FORECASTING AND EFFECTS ON
THAILAND – LAOS BORDER CROSSING POINTS
AFTER OPENING OF THE ASEAN
ECONOMIC COMMUNITY**

JUANGJAN CHANKRACHANG

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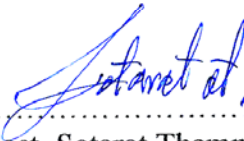
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The author hopes that this work would be beneficial to education personnel and interested individuals for a knowledge enhancement on the Thailand – Laos border in the future.

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ABSTRACT

There are several factors affecting vehicle volumes. When the demand for vehicles increases, transport infrastructure development, such as number of lanes and highway connection, needs to be prepared in advance. It is therefore necessary to plan and predict the traffic flow in the future using existing information. In addition, the opening of the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC) is another major factor that will cause the free movement of populations among the AEC countries, which will result in an increased demand for vehicles. In this study, the amount of vehicles in Thailand and Laos, traffic flow on the border of Thailand-Laos, effects that may occur after the launch of the AEC, and the ability to handle the volume of Thailand-Laos cross-border vehicles were studied. In order to predict traffic flow, a nonlinear auto regressive with exogenous input (NARX) was utilized. The NARX model can forecast the traffic flow on the border with the lowest mean square error (MSE) at the Mukdahan checkpoint at 191,210 and the lowest MSE at the Chiang Khong checkpoint at 12,458. This study can be applied to other Thailand's cross borders by adjusting the relative factors depending on each border's situation.

KEY WORDS: FORECASTING / TRAFFIC / NONLINEAR AUTO REGRESSIVE
WITH EXOGENOUS INPUT (NARX) / BORDER CROSSING
POINTS

99 pages

การพยากรณ์ปริมาณรถยนต์เข้าออกและผลกระทบต่อสภาพการจราจรด่านชายแดนไทย-ลาวหลัง
เปิดประชาคมอาเซียน

TRANSPORTATION FORECASTING AND EFFECTS ON THAILAND – LAOS
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บทคัดย่อ

ปริมาณการใช้งานรถยนต์เกิดจากหลายปัจจัยร่วมกัน เมื่อความต้องการใช้รถยนต์เพิ่มขึ้น
ความจำเป็นในการพัฒนาโครงสร้างพื้นฐาน อาทิเช่น พื้นที่ผิวในการจราจรและช่องทางการจราจรจึง
ต้องเพิ่มประสิทธิภาพตามไปด้วย ดังนั้นการวางแผนพัฒนาจึงมีความจำเป็นที่จะต้องคาดการณ์
ปริมาณรถยนต์ในอนาคตจากแหล่งข้อมูลต่างๆ ที่มีอยู่ในปัจจุบัน นอกจากนั้นการเปิดประชาคม
อาเซียนเป็นอีกปัจจัยหลักปัจจัยหนึ่งที่จะทำให้เกิดการเคลื่อนย้ายของประชากรระหว่างกันง่ายขึ้น
ซึ่งจะส่งผลให้เกิดความต้องการใช้รถยนต์เพิ่มขึ้นตามไปด้วย ในงานวิจัยนี้ได้ศึกษาปริมาณรถยนต์
ในประเทศไทยและลาว การเข้าออกของด่านชายแดนไทย-ลาว ผลกระทบที่อาจจะเกิดขึ้นหลังจาก
การเปิดประชาคมอาเซียน และความสามารถของการรองรับปริมาณรถยนต์ของด่านชายแดนไทย-
ลาว ในการพยากรณ์ปริมาณรถยนต์ของงานวิจัยได้ใช้โครงสร้างแบบถดถอยด้วยตัวเองกับข้อมูล
ป้อนเข้าภายนอกไม่เชิงเส้น (Nonlinear Auto Regressive with exogenous input ; NARX) โดยด่าน
ชายแดนมุกดาหารได้ค่าเฉลี่ยความคลาดเคลื่อนกำลังสองอยู่ที่ 191,210 และ ด่านเชียงของได้ค่าเฉลี่ย
ความคลาดเคลื่อนอยู่ที่ 12,458 แนวทางการศึกษาระหว่างชายแดนไทย-ลาวนี้สามารถนำไป
ประยุกต์ใช้กับการศึกษาด้านชายแดนประเทศไทยกับประเทศอื่นๆได้ โดยจะต้องปรับปัจจัยที่มี
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CHAPTER I

INTRODUCTION

1.1 Statement of Problem

Thailand is regarded as the center of ASEAN with respect to business, tourism, and so forth. The location of the country provides easy access to various countries in ASEAN region. The most popular and convenient means of transportation is ground transportation.

Due to an increase in population and other contributing factors, the current volume of vehicles has increased steadily every year. In addition, the opening of AEC in 2015 will result in more travels among member countries. Therefore, the traffic flow prediction is one of methods that would assist in planning and developing of ground transports as well as traffic routes along the border in the future. The border of Thailand can be classified into three cross border categories, including permanent cross border, temporary cross border, and informal cross border. There is inadequate availability of crossing's infrastructure causing congestion and inflexibilities in logistics, freights, and neighborhood tourism, such as Laos, Myanmar, Cambodia, and Malaysia. This work will be focused on Thailand-Laos border, which is also a pathway to Vietnam and China.

In general, an issue of the use of nonlinear models is inability to accommodate multiple data inputs coupled with its complicated process and impractical results. This is the reason that it is not preferable to use the nonlinear models. However, there is a nonlinear model that can solve this kind of problem, called a nonlinear autoregressive with exogenous Input (NARX).

NARX is utilized in predicting the traffic flows. Mukdahan and Chiang Khong crossing point are chosen as examples in the study as shown in Figure 1.1 [1-2]. The information and references used in this work have been compiling from the Office of Transport and Traffic Policy and Planning, Customs Department, and other trustworthy websites to acquire the most accurate predictions. It issued as a guide in

developing the Thailand borders and has also to accommodate the number of vehicles that will be changing after the AEC in the future.

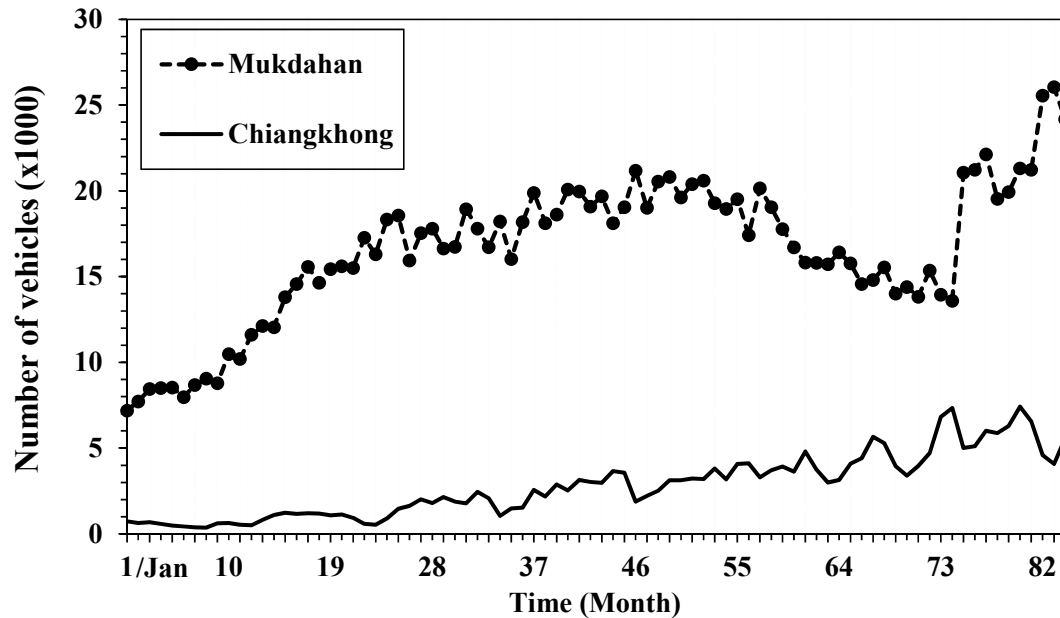


Figure 1.1 Number of vehicles accessing cross-borders during 2008 to 2014.

1.2 Objectives

- 1) To forecast the number of vehicles accessing Thailand - Laos borders.
- 2) To study and apply the NARX in forecasting.
- 3) To analyze the experiment result taken from comparisons between NARX model and Moving Average model.
- 4) To study the effects that may occur to the borders after opening of AEC.

1.3 Scope of Work

- 1) Research in Thailand - Laos borders only with examples taken place in Mukdahan and Chiang Khong checkpoints.
- 2) Information, ranged from 2008 to 2014, is obtained from the Office of Transport and Traffic Policy and Planning, Customs Department, Transport Statistics

Sub Division, Planning Division, The World bank, International Monetary Fund World Economic Outlook, and ASEAN-Japan Transport Partnership.

1.4 Expected Results

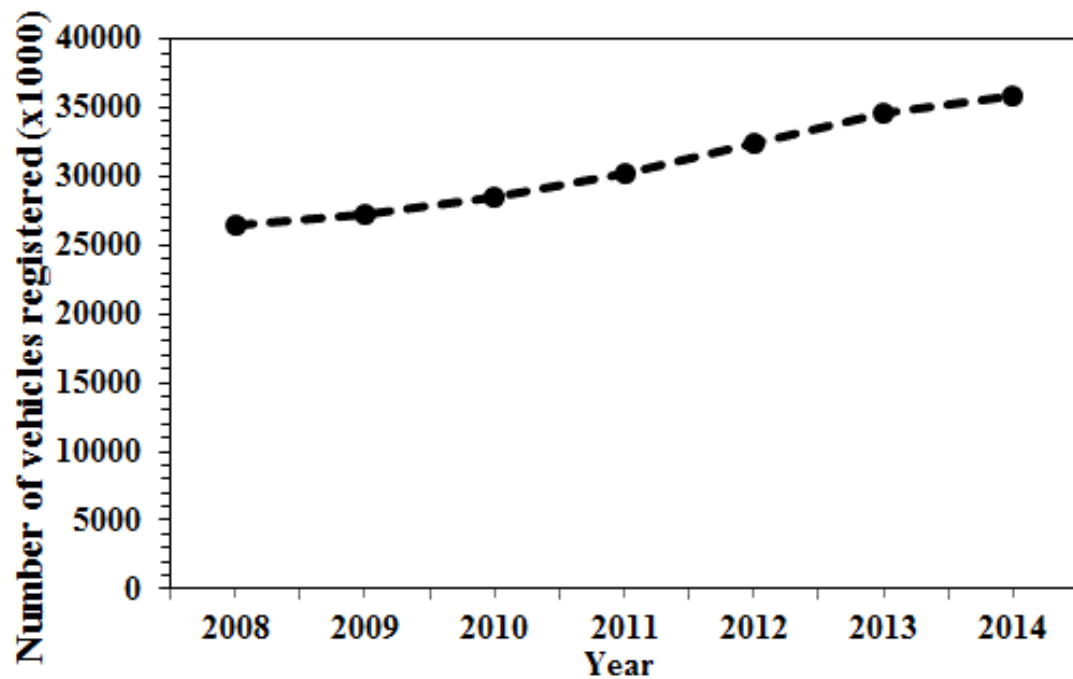
- 1) It is able to forecast the number of vehicles accessing the borders.
- 2) It is able to be used as a guide for further development of the border of Thailand.

CHAPTER II

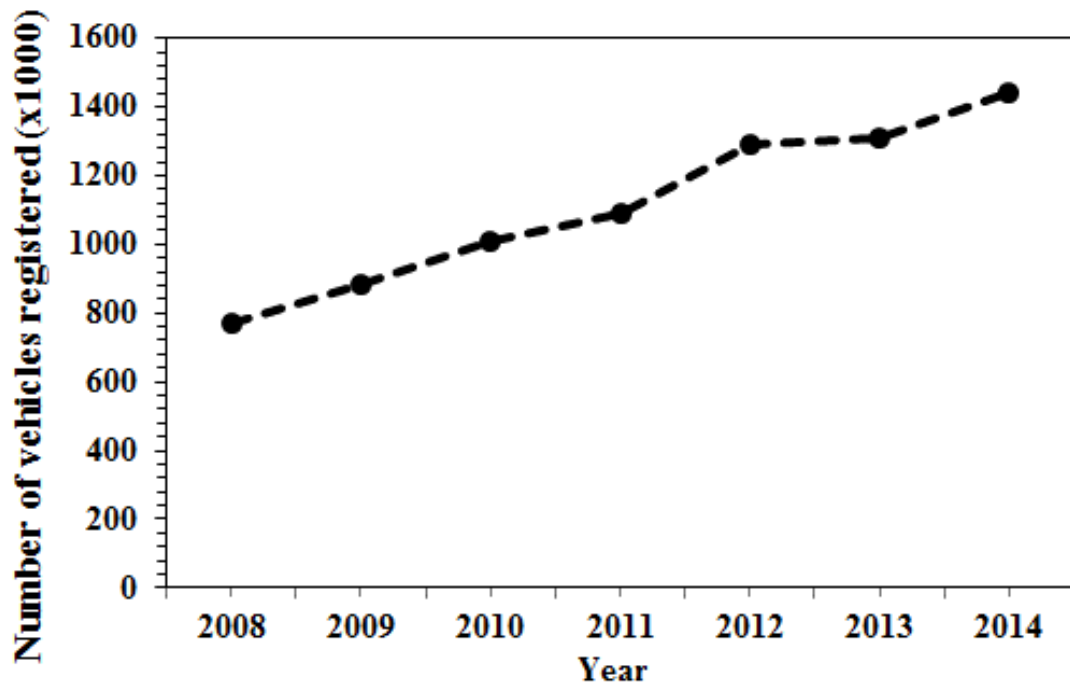
LITERATURE REVIEW

2.1 Traffic flows in Thailand and Laos

Vehicles nowadays are considered to be very important factor in life, because there are more places to go these days. Vehicles prove to be the most effective means of transportation while public transport may not meet the needs of consumers. Statistical data accumulated by vehicle registered in Thailand and Laos from Transport Statistics Sub-Division, Planning Division, and the ASEAN-Japan Transport Partnership [3] are presented in Figures 2.1 and 2.2.



Figures 2.1 Number of vehicles registered in Thailand.



Figures 2.2 Number of vehicles registered in Laos.

As seen from the graphs, the cumulative amount of registered vehicles has steadily increased since 2008-2014 continuously every year, both in Thailand and Laos.

2.2 Asean Economics Community (AEC)

Asean Economics Community (AEC) for short is the integration of 10 countries in ASEAN, including Thailand, Myanmar, Laos, Vietnam, Malaysia, Singapore, Indonesia, Philippines, Cambodia, and Brunei. The objective is to facilitate trade liberalization, investment and labor mobility, increase bargaining power with suppliers as well as alter rules and regulations as Euro Zone.



Figures 2.3 The member countries of AEC.

2.2.1 The important goal of AEC

It can be may be classified into four major characteristics [4], given as:

- To be both single market and single production base which is liberalization of trade, services, investment and labor mobility by reducing the trade tariffs to zero in order to remove the trade barriers or protectionism.
- To standardise the high competitiveness of economic region, such as infrastructure development to facilitate trade and investment.
- An equable of region's economic development refers to reduction of the gap and the disparity of economic development among member countries.
- To link ASEAN to the global economy, such as preparation of a Free Trade Area (FTA) between AEC and various partners.

The ASEAN transport cooperation aims to strengthen transport system in the region, works effectively together, and integrates into the global economy under the ASEAN Transport Action Plan (ATAP) 2005-2010. The cooperation in the transport of ASEAN has focused on strengthening transport links in many forms, which include promoting the mobility of people and goods without boundaries and promoting the liberalization of ground, water, and air transport services to ease movement of goods in the region. ASEAN has established 3 significant Framework Agreements on the facilitation of transport as follows:

- 1) The ASEAN Framework Agreement on the Facilitation of Goods in Transit (AFAFGIT),
- 2) The ASEAN Framework Agreement on Multimodal Transport (AFAMT),
- 3) The ASEAN Framework Agreement on the Facilitation of Inter-State Transport (AFAFIST).

All of these Framework Agreements are intended to reduce steps in the process of trade transport in the region along with harmonizing guidelines and restrictions of the registration of transit transport operators as well as promoting the use of ICT in freight industry.

2.2.2 ASEAN Highway

ASEAN Highway (AH) was one of the Master Plan on ASEAN Connectivity to enhance connectivity among ASEAN members. The Highways Department has been involved in developing international highway. The results of the 2nd meeting of ASEAN Transport Minister (ATM) in Thailand in February 2540 and the 3rd meeting of ASEAN Transport Ministers (ATM) in the Philippines in September 2540, the meeting approved the development principal of Asian Highway by assigning Thailand as the main coordinator of the project.

There are 12 routes in total, accounted for 6,669 kilometers. The first nine routes of Asia and Asian Highway have total distance of 5,129 kilometers and the last three routes of ASEAN Highway have total distance of about 1,540 kilometers. The details of each route is shown in Table 2.1.

Table 2.1 The ASEAN Highway in Thailand.

Number	ASEAN Highway	Distance (km)	National Highway No.
AH 1	Ban Klong Luek (Border of Thailand/Cambodia) - Aranyaprathet - Sa Kaeo - Kabin Buri - Prachin Buri - Nakhon Nayok – Hin Gong - Bangkok - Ang Thong – Singburi- Chainat – Nakhon Sawan - Kamphaeng Phet - Tak - Mae Sot (Border of Thailand/Myanmar)	715.5	33, 32, 1, 12
AH 2	Sadao (Border of Thailand/Malaysia) - Ban Khlong Ngae – Ban Khor Hong – Ban Koo Ha - Phatthalung – Thungsong district - Wiang Sa district - Chaiya district - Lamae district - Chumphon – Thasae district – Bang Saparn Noi district - Prachuap Khiri Khan - Pranburi district – Cha Am district - Phetchaburi – Park Tor district - Nakhon Pathom - Bangkok – Bang Pa In district - Tak - Thoen – Lampang district - Ngao district - Phayao - Chiang Rai - Mae Sai. (Border of Thailand / Myanmar)	1,913.5	4, 41, 338, 9, 34, 32, 1
AH 3	Chiang Khong district (Border Thailand/Laos) – Ban Ta Talard – Ban Hua Doi - Chiang Rai	121.0	1020

Table 2.1 The ASEAN Highway in Thailand (cont.).

Number	ASEAN Highway	Distance (km)	National Highway No.
AH 12	1 st Thai-Lao Friendship Bridge - Nong Khai - Udon Thani – Na Pong district – Khon Kaen – Ban Phai district - Pol district - Nakhon Ratchasima - Si Kiw district – Muak Lhek district - <u>Saraburi</u> – Hin Gong	571.3	2, 204, 1
AH 13	Huay Kon (Border of Thailand/Laos) - Nan - Phrae - Den Chai district - Uttaradit - Phitsanulok – Sam Ngam district – Nakhon Sawan	550.5	1080, 101, 11, 12, 117, 304, 202,
AH 15	Nakhon Phanom (Border Thailand/Laos) – Ban Tart Na Vang(Sakon Nakhon) – Pung Klom district – Sawang Dan Din district – Udon Thani	249.0	22
AH 16	Mukdahan (Border Thailand/Laos) - Nong Sung district – Som Dej district - Kalasin - Yang Talard – Khon Kaen – Nam Nhow district – Lom Sak district - Ban Yaeng – Wang Thong district - Phitsanulok - Sukhothai - Tak	703.0	12, 230
AH 18	Sungai Kolok district (Border of Thailand/Malaysia) - Tak Bai district - Narathiwat - Sai Buri district – Pa Lad district - Pattani - Nongchik district - Tepa district - Chana district - Hat Yai district	311.0	42, 43, 4057, 4084

Table 2.1 The ASEAN Highway in Thailand (cont.).

Number	ASEAN Highway	Distance (km)	National Highway No.
AH 19	Pak Thong Chai district- Kabinburi district – Plang Yao district - Chonburi - Bangkok	364.0	331, 304, 344, 7
AH 112	Klong Loy district - Bang Saphan district	28.00	-
AH 121	Mukdahan - Amnat Charoen - Yasothorn – Suvarnabhumi district - Phayakkhaphum Phisai district - Buriram - Nang Rong district – Sompoi district – Chong Tako district - Sa Kaeo	508.0	212, 202, 214, 219, 218, 348, 3486, 3393, 3485, 3462
AH 123	Ban Phu Nam Ron (Border of Thailand/Myanmar) - Kanchanaburi, Nakhon Pathom - Bangkok - Samut Prakan - Chonburi - Laem Chabang - Map Ta Phut - Rayong - Klang district - Chantaburi - Trat - Hat Lek district	634.0	3, 36, 7, 4, 338, 323, 3512, 3229
Total distances		6,669	

The ASEAN highways linking with eight customs include:

- 1) Sadao Customs, Songkhla connected to ASEAN Highway of AH2.
- 2) Padangbesa Customs, Songkhla connected to Asia railway line.
- 3) Chiang Khong Customs, Chiang Rai Connect with ASEAN Highway of AH3.
- 4) Mae Sai customs, Chiang Rai connected with ASEAN Highway of AH2.
- 5) Mae Sot customs, Tak connected with ASEAN Highway of AH1/AH16.
- 6) Nong Khai Customs Connected with ASEAN Highway of AH12.
- 7) Mukdahan Customs Connected with ASEAN Highway of AH16.
- 8) Aranyaprathet Customs, Sa Kaeo connected with ASEAN Highway of AH1.



Figures 2.4 ASEAN Highway system in Thailand.



Figures 2.5 ASEAN Highway system in Laos.

2.3 Cross-Border

There are approximately 93 crossing points across Thailand connecting neighbor countries. Those can be divided into three categories:

1) Permanent border crossing

The permanent border aims to provide the public of both countries with regard to trades, tourism, and so forth. It has been agreed by the two governments. For Thailand, Minister of Interior acts as a signatory to the Ministry according to the Cabinet's approval, and will be in effect upon its publication. Typically, the crossing will be permanently assigned to a customs.

2) Temporary border crossing

The temporary border opens for specific purposes within a fixed timeframe. It does not affect a country's stability and security. The border will be closed immediately, after the purposes have achieved or the timeframe is over. The Minister of Interior, as a signatory to the Ministry of Interior, announced the opening

of a temporary border crossing in accordance to consent of the subcommittee of the National Security Council.

3) Relief border crossing

The relief border aims to help neighbor countries in terms of humanity and promoting public relations in local level. Trading of consumer goods and medicines are allowed and have agreed by both local governances. An announcement of the relief border crossing is of power of the governor and must be prior approved by the Ministry of the Interior.

The borders of Thailand and Laos are in total of 47 crossing points, as shown in Tables 2.1-2.2.

Table 2.2 Sixteen permanent border crossing points.

No.	Areas in Thailand		Areas in Laos		Opening Times
	Province	Location of border crossing points	Districts	Location of border crossing points	
1	Chiang Rai	Chiang Khong	Bokeo	Mueang Houayxay	08.00am – 18.00pm
2		Chiang Saen		Mueang Ton Phueng	08.00am – 18.00pm
3	Nan	Huay Kon	Xaignabouli	Ban Nam Ngoen	08.00am – 20.00pm
4	Loei	Ban Park Huay		Mueang Kenthao	08.00am – 18.00pm
5		Nam Hueang Friendship Bridge		Ban Khon Phueng	07.00am – 18.00pm
6		Chiang Khan	Vientiane	Mueang Sanakham	08.00am – 18.00pm
7		Ban Kok Phai		Ban Vang	08.00am – 16.00pm

Table 2.2 Sixteen permanent border crossing points (cont.).

No.	Areas in Thailand		Areas in Laos		Opening Times
	Province	Location of border crossing points	Districts	Location of border crossing points	
8	Nong Khai	Tha Sadet	Vientiane	Tha Duea	08.00am – 18.00pm
9		1 st Thai-Laos Friendship Bridge		Ban Dong Phu Lee	06.00am – 22.00pm
10	Bueng Kan	Bueng Kan	Bolikhamxai	Mueang Paksan	08.00am – 18.00pm
11	Nakhon Phanom	3 rd Thai-Laos Friendship Bridge	Khammouan	Mueang Tha Kael	06.00am – 16.00pm
12		Nai Mueang subdistrict			06.00am – 22.00pm
13	Mukdahan	2 nd Thai-Laos Friendship Bridge	Savannakhet	Mueang Kaysone	06.00am – 22.00pm
14	Mukdahan	Mueang Mukdahan district	Savannakhet	Ban Na Gae	06.00am – 22.00pm
15	Ubon Ratchathani	Chong Mek	Champasak	Ban Pak Ta Parn	08.00am – 18.00pm
16		Ban Park Sang	Salavan	Mueang Phon Thong	06.00am – 22.00pm

Table 2.3 Thirty-one relief border crossing points.

No.	Areas in Thailand		Areas in Laos		Opening Times
	Province	Location of border crossing points	Districts	Location of border crossing points	
1	Chiang Rai	Ban Sop Ruak	Bokeo	Ban Gwarn	08.00am – 18.00pm
2		Ban Suan Dok		Ban See Mueang Ngam	08.00am – 18.00pm
3		Ban Jam Pong		Ban Darn	08.00am – 18.00pm
4		Ban Had Bai		Ban Don Dang	06.00am – 18.00pm
5	Chiang Rai	Ban Rom Pho Thong	Xaignabouli	Ban Pang Hai	08.00am – 18.00pm
6	Chiang Rai	Ban Huay Luek	Xaignabouli	Ban Krok Lhuang	06.00am – 18.00pm
7	Phayao	Ban Huak		Ban Pang Mon	06.00am – 18.00pm
8	Nan	Ban Huay Sa Tang		Ban Pha Warn	09.00am – 16.00pm
9		Ban Mai Chai Dan	Ban Tay Song	08.00am – 16.00pm	
10	Uttaradit	Ban Poo Doo		Ban Pha Kaew	Fri-Sat Daytime
11		Ban Huay Tang		Ban Khon Kaen	Tue-Wed Nighttime

Table 2.3 Thirty-one relief border crossing points (cont.).

No.	Areas in Thailand		Areas in Laos		Opening Times	
	Province	Location of border crossing points	Districts	Location of border crossing points		
12	Loei	Ban Mueang Phrae		Ban Muangphrae	08.00am – 18.00pm Buddhist Holy Day only	
13		Ban Na Kha		Ban Na Kha	08.00am – 18.00pm	
14		Ban Na Ka Seng		Ban Mueang Mhor	07.00am – 18.00pm	
15		Ban Nong Prue		Bolikhamxai	Ban Mueang Kan Tao	07.00am – 18.00pm
16		Ban Ar He			Ban Na Kang Mha	07.00am – 18.00pm
17		Ban Peng Jan			Ban Tuay	08.00am – 18.00pm
18		Ban Boong Klar	Ban Park Kading		08.00am – 18.00pm	
19			Jum Pon	Vientiane	Ban Don Tai	08.00am – 18.00pm
20		Nong Khai	Ban Mhor		Ban Darn Dum	08.00am – 17.00pm
21			Ban Huay Kad		Bolikhamxai	Mueang Tha Prabaht

Table 2.3 Thirty-one relief border crossing points (cont.).

No.	Areas in Thailand		Areas in Laos		Opening Times
	Province	Location of border crossing points	Districts	Location of border crossing points	
22	Nong Khai	Ban Muang	Bolikhamxai	Ban Kok Hae	08.00am – 16.00pm
23	Nakhon Phanom	Ban Nhadtha		Ban Park Peng	08.00am – 14.00pm
24	Nakhon Phanom	Ban Don Pang		Ban Boong Kwang	09.00am – 16.00pm
25		Tart Phanom	Khammouan Savannakhet	Mueang Nong Bok	07.00am – 14.00pm
26		Tha Uthen	Khammouan	Ban Hin Boon	08.00am – 16.00pm
27	Amnat Charoen	Ban Yuk Ku	Savannakhet	Ban Lhao Mahood	06.00am – 18.00pm
28	Ubon Ratchathani	Khemmarat		Mueang Song Kon	08.00am – 15.00pm
29	Ubon Ratchathani	Ban Song Korn	Salavan	Ban Nong Sang	09.00am – 15.00pm
30		Ban Darn Kao	Champasak	Ban Sing Sum Pan	09.00am – 15.00pm
31		Ban Nong Sang		Ban Hieng	08.00am – 15.00pm

From the aforementioned Thailand - Laos cross borders, three main crossing points were chosen for this work, including Mukdaharn, Chiang Khong and Nong Khai.

- Mukdahan

Mukdahan is one of the important crossings. It is home to the Second Thai-Lao Friendship Bridge, which has a total length of 1,600 meters, a width of 12 meters, and two traffic channels. The total construction cost was approximately US \$70 million funded by a low-interest loan of 4,011 million yen from the government of Japan to the Lao PDR and 4,079 million yen to the government of Thailand. The construction was commenced in December 2003 and was completed in December 2006. The Bridge is regarded as gateway of Indochina countries. In other words, it connects Mukdahan district of Thailand with Savannakhet province in Laos, which is a part of the economic routes from west to east starting at Myanmar, Thailand, Laos, and ends in Hanoi, Vietnam.

- Chiang Khong

Chiang Khong has been opened as a new permanent border crossing where a highway bridge over the Mekong River, the Fourth Thai-Lao Friendship Bridge, is located. The bridge links Bandonmahawan, Chiang Khong district in Chiang Rai province of Thailand with Bandon, Ban Houayxay district in Bokeo province of Laos. The bridge is 2.48 km in length and its layout is a segmental concrete box girder with 4-poster width of 14.70 meters. It has two lanes, each lane has width of 3.50 meters. The budget for the construction was approximately 1,624 million Baht by jointly financing between Thailand and China. The construction was completed on 12 December 2012, and was officially opened on 11 December 2013 with Route 3 Asian (R3A) highway linking China, Laos, and Thailand.

- Nong Khai

Nong Khai is the main Thailand-Laos border crossing, where the First Thai-Lao Friendship Bridge is located. It connects Nong Khai with Tha Na Liang in Vientiane, Laos. The bridge has a length of 1,170 meters with two traffic lanes and two rail tracks of 1 meter wide each. The construction budget was US\$30 million with assistance from the government of Australia. The construction period was from October 1991 to April 1994. This Thai-Lao Friendship Bridge plays very important role in supporting economic development of Thailand and Laos and also promotes stronger ties between the two countries.

2.3.1 Conditions and restrictions of the borders

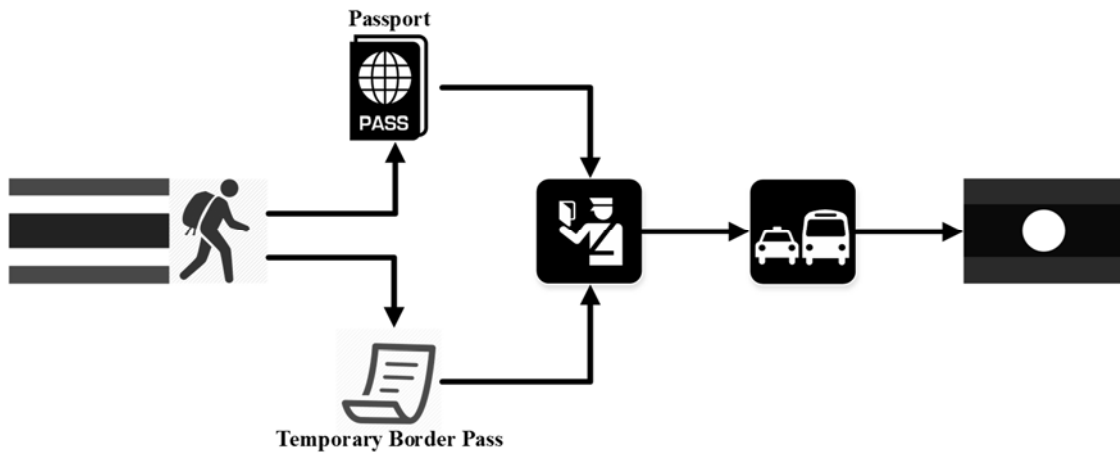
Mukdahan checkpoint is currently short space for truck yard. This results in trucks parking at gas stations around the province. The reason is that truck drivers generally arrive prior to checkpoint's opening hours. There is a risk of goods and fuel being stolen as well. Also, area around the checkpoint is lacking of store or services improvement to support customers.

The operation of Chiang Khong checkpoint has issue in the infrastructure. The customs are in restrictive place, and hence cannot function the technological devices because of limited space.

The current traffic condition within Nong Khai checkpoint is already crowded during rush hours (8:30- 11:00 and 15:00-17:00), because there is only one truck channel, causing congestion at the entrance. The service for exporting-truck including the X-ray standing on the import goods side, as a result, wasting more time for an inspection of export goods.

In addition, the checkpoint has inadequate truck yard space due to a large number of trucks resulting overcrowd track yard in customs area. Apart from the obstacles previously mentioned, Nong Khai's customs area has a limitation regarding availability of the Friendship Bridge; it will not be available during the train running through. Currently, the train will run through bridges 4 times at 9:00 am, 11.00 am, 3.00 pm, and 4.00 pm. It is given that the customs has to be closed for 30 minutes each time. Thereby customs service will lose two hours per day.

2.3.2 Border crossing procedures from Thailand to Laos



Figures 2.6 Border crossing procedures from Thailand to Laos.

Figure 2.6 is a border crossing procedure from Thailand to Laos which can be divided into two categories: a person with a passport and a person with no passport. A person without a passport is required to apply for a temporary pass card to travel across the border. The steps are as follows:

- Passport holder

Steps for passport holder to cross the border from Thailand to Laos:

- 1) An individual fills out Departure form.
- 2) An individual proceeds to immigration and presents the passport with completed Departure form.

- Temporary border pass holder

Steps for temporary border pass holder to cross the border from Thailand to Laos:

- 1) An individual obtains the temporary border pass from border pass agents.
- 2) An individual proceeds to immigration and presents the temporary border pass.

- Required documents for temporary border pass:

- 1) A valid Thai identity card or government identity card.
- 2) 30 Baht fee.

- E-Border Pass process:

1) An applicant for temporary border pass is required to bring either a Thai identity card bearing 13-digit number or government identity card.

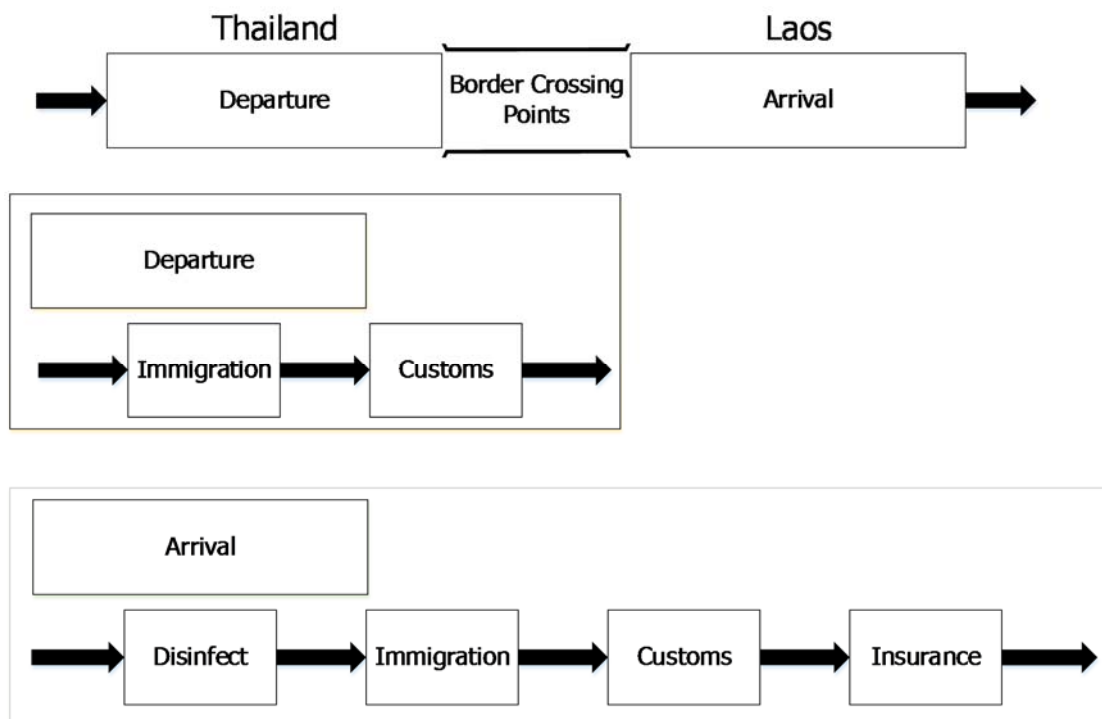
2) The identity card will be read by card reader using 13-digit identification number to retrieve data and face detection from the database.

3) An applicant fills out an issue of e-border pass into the system. Invoice and e-border pass will be issued accordingly.

4) An applicant makes a fee payment.

5) An applicant presents e-border pass to immigration.

2.3.3 Departure procedures from Thailand to Laos by private vehicles



Figures 2.7 Departure procedures from Thailand to Laos by private vehicles.

Figure 2.7 is a border crossing procedure from Thailand to Laos by cars. There are separated into two steps: car travelling from Thailand and car travelling to Laos as follows.

- Departure procedure

Steps for private vehicles to departure from Thailand:

1) A driver proceeds to immigration to lodge an international transport permit, and complete information of conveyance.

2) A driver shows the passport or temporary border pass together with an international transport permit to customs, and receives the simplified customs declaration form to fill out when return to Thailand.

3) After all documents are cleared, a vehicle will be checked by customs officers.

- Arrival procedure

Steps for private vehicles to arrival in Laos:

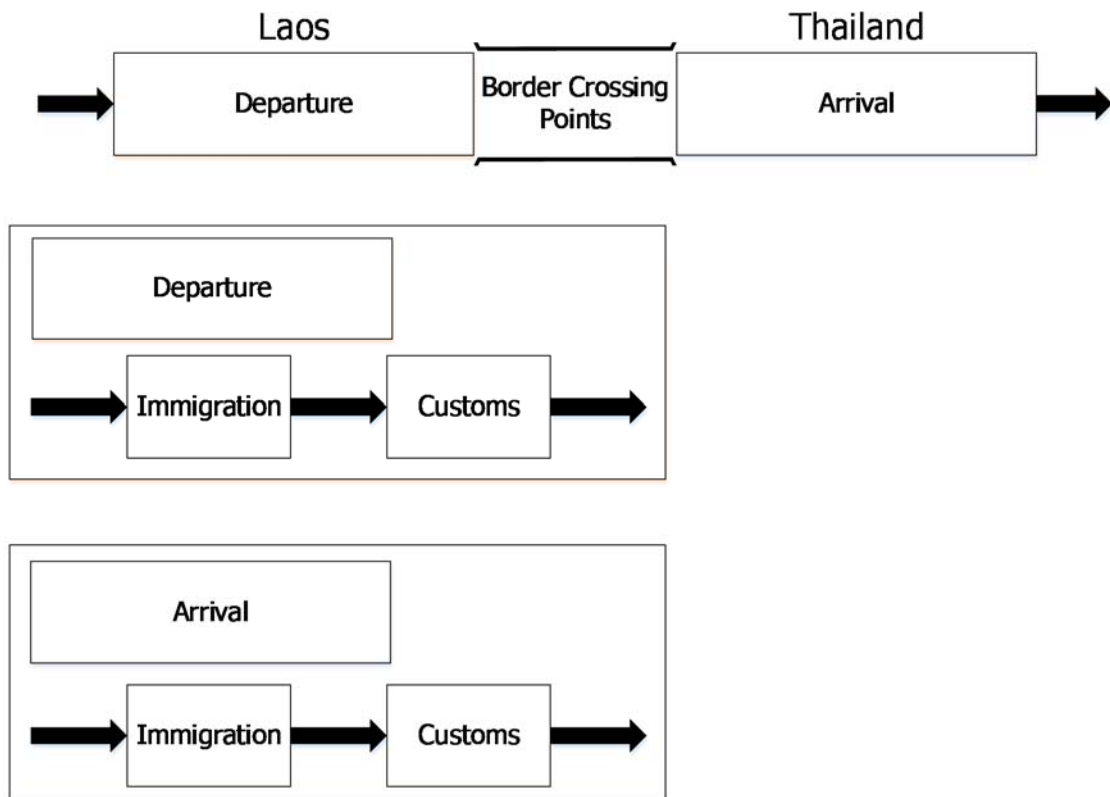
1) Vehicle is sterilised by customs officers.

2) A driver presents travel documents i.e. passport and temporary border pass for checking at immigration.

3) A driver brings simplified customs declaration for checking at customs.

4) Vehicle insurance needs to be purchased prior to departure to Laos.

2.3.4 Departure procedures from Laos to Thailand by private vehicles



Figures 2.8 Departure procedures from Laos to Thailand by private vehicles.

Figure 2.8 is a border crossing procedure from Laos to Thailand by cars. There are separated into two steps: car travelling from Laos and car travelling to Thailand as follows.

- Departure procedure

Steps for private vehicles to departure from Laos:

- 1) A driver presents travel documents i.e. passport and temporary border pass for immigration check.

- 2) A driver brings simplified customs declaration for customs check.

- Arrival procedure

Steps for private vehicles to arrival in Thailand:

- 1) A driver presents travel documents i.e. passport and temporary border pass for immigration check.

- 2) A driver returns the simplified customs declaration to customs officers.

2.3.5 Factors causing congestion in front of the border



Figures 2.9 Congestion in front of the border.

Congestion issue occurred among borders in Figure 2.9 impact the delay in accessing the checkpoint are caused from the following:

- 1) The procedures at the borders are time consuming.
- 2) There are insufficient number of available channels to meet the demand.
- 3) There has been an increase in the number of vehicles traveling between borders.

2.3.6 The ability to accommodate vehicles accessing the borders per day of 2012

According to the daily operating hours, the number of service channels and the amount of time a vehicle spent in the border crossing procedure are derived from the OTP. Information from 2012 of Mukdahan border, Chiang Khong border and Nong Khai border were used to calculate the maximum number of vehicles travelling between the borders are shown in Table 2.4 below.

Table 2.4 The ability to accommodate vehicles accessing the borders per day of 2012.

Border Crossing Points	Hours of service (hours/day)	Number of Service Channels (channels)	Limit of number of vehicles that can be accommodated (vehicles/day)	Actual number of vehicles accessing the borders (vehicles/day)
Mukdahan	16	4	768	580
Chiang Khong	10	1	120	75
Nong Khai	16	6	1,152	1,230

As seen in Table 2.4, a comparison between the maximum number of vehicles travelling between the borders and the actual number of vehicles travelling between the borders shows that vehicle volume in Nong Khai checkpoint exceeds the capacity of the checkpoint.

2.3.7 Required documents for an international transport permit

In order to travel out of the Kingdom, a car will need a vehicle passport or known as international vehicle permission. The car passport can be issued at the Department of Transport and logistics offices nationwide which can be divided into the following two categories.

A vehicle owner:

- 1) An original vehicle registration,
- 2) National identity card,
- 3) Three copies of national identity card.

A legal entity:

- 1) An original vehicle registration,
- 2) Certificate of Incorporation,
- 3) Three copies of certificate of incorporation.

Non-owner vehicle:

- 1) An original vehicle registration,
- 2) An original power of attorney,
- 3) A copy of power of attorney,
- 4) A copy of agent's identity card,
- 5) A copy of appointee's identity card.

A private vehicle passport can be obtained from the Vehicle Registration and Tax Standard Bureau, land transport office, and provincial land transport office where a vehicle was registered. The fee is 55 baht and will receive two T labels which is an initial for Thailand, using by all type of vehicles that entering Laos from Thailand. The T label must be visibly attached at the front and back windshields.

2.4 Variables and Regression Analysis

Regression Analysis is a forecasting technique, widely used in various disciplines, using at least one independent variable (or predictor) to predict/explain the variation of dependent variable. A regression analysis comprising of one independent and one dependent variable is called "Simple Regression". If many independent variables are used, it is called "Multiple Regression".

Variables are classified into two types: the first one is quantitative variable - a variable that can be measured, such as weight and age of student. The second one is qualitative variable - a variable that cannot be measured, such as gender, occupation, teaching method, etc. These variables are influenced by dependent variables for example gender influences costs associated with clothes buying because female would buy more clothes than male. Hence would incur more expenses. When computing a predictive equation, it is important to focus on both quantitative and qualitative variables. However, a regression analysis is generally studied on specific quantitative variables because the data is measurable and easy to analyze.

2.5 The Correlation Coefficient

A statistical method, commonly used to measure the relationship between interval scale variables and involves quantitative data, is called “Pearson Product Moment” [5]. The letter r is represented as its symbol.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (2.1)$$

where, x_i and y_i are any values of the correlative variables;

\bar{x} and \bar{y} are the mean of each variable;

The Pearson Correlation, r , can have a value from -1 to +1. When r is closer to +1, it indicates that the two variables are perfectly correlated in the same direction meaning that x increases as y increases. When r approaches -1, it means that two variables are perfectly correlated but in reverse direction; if x increases, y will decrease. When r is equal to 0, it implies that there is no correlation between the two variables, in another words, there is a weak correlation, as shown in Figure 2.10.

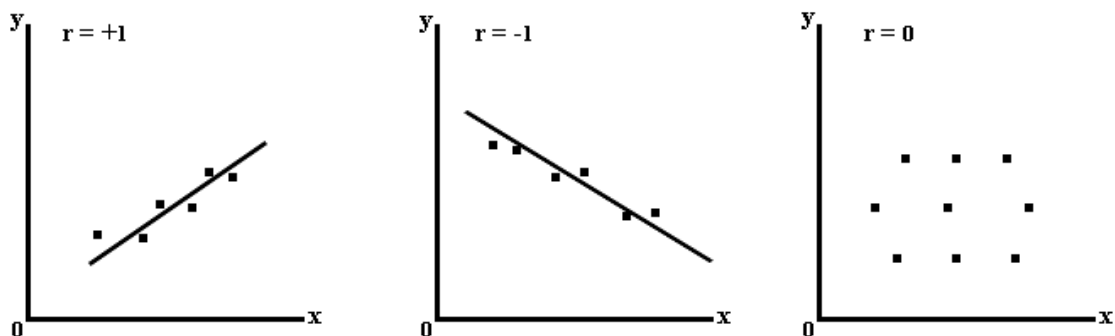


Figure 2.10 The relationships between variables of X and Y.

A lower correlation coefficient or weak correlation will range between -0.29 and -0.10 or 0.10 and 0.29. A medium correlation coefficient or moderate correlation has values between -0.49 and -0.30 or 0.30 and 0.49, and higher correlation coefficient with high correlation falls between -1.00 and -0.50 or 0.50 and 1.00.

This correlation is a measure of linear relationship. So if r is close to 0, it could imply that two variables may have non-linear relationship. To achieve accurate results, plotting a graph to view a form of relationship is recommended [6].

2.6 Time series

Time series is a set of quantitative data collected over time. Time series data is a set of data constantly collected over a period of time, such as sales data collected continuously over a period of many months, information on GDP collected continuously over a period of several years, and so on. Time series data can be categorized as per yearly, quarterly, and monthly depending on its optimum utilization.

2.6.1 Elements of time series

In time series analysis, a separation of various elements is required. The time series will be changes relative to influences, such as changes in production technology, weather conditions, etc. The characteristics of time series model can be used in several ways [7]. A model used by economists is a classical model, which explains the four elements of time series variation as follows:

- 1) Long Term Trend represented by T ,
- 2) Seasonal variation represented by S ,
- 3) Cyclical variation represented by C ,
- 4) Irregular variation represented by I .

Long Term Trend (T) is likely to be a smooth straight line or upward or downward sloping. The data tends to have long-term time frame. The information should be annual and at least of 15 years to show direction of the series.

Seasonal variation (S) is a change with increasing or decreasing trend in one particular period, in other words, seasonal change. The time unit may be measured hourly, daily, weekly, monthly, and quarterly. An annual data has no seasonal variation. Seasonal variation can be predicted the exact period of occurring, for example, monthly sales of one of the shopping malls.

Cyclical variation (C) has a repetitive change and is similar to seasonal variation. The difference is that changes in each cycle take longer than 5 years.

Irregular variation (I) is a change of time series of events that cannot be predicted, such as fire in factory, flooding, earthquake, and strikes of workers. These events happen unexpectedly or it is called random variation because they are not under imposed conditions [8].

However, it is not compulsory to have all of the four elements in one time series depending on type of information. From the aforementioned components, if Y represents a set of time series data, the simulation model can be divided into 2 types:

(1) Additive model: It is a sum of the four components.

$$Y = T + S + C + I. \quad (2.2)$$

(2) Multiplicative model: It is a product of the four component.

$$Y = T \times S \times C \times I. \quad (2.3)$$

2.6.2 Time Series Analysis

Time series analysis is a statistical method used to analyze the historical data for the model, describing relationship between the observations stored in chronological order as a model for predicting the future observations. The relationship between variables involved in the model must be simulated. Variables can be drawn from a model which can be explained by a single relationship or one that is too complex to have relationships [9].

Time series analysis method is categorized into two main groups which are linear approach, such as Box-Jenkins or ARIMA model and Non-Linear approach which is a method that attempts to explain the relationship of non-linear time series. For example, GARCH model has developed from the ARIMA or NARX. Time series' observations are determined at the time, the order takes place or changes of variables during the elapsed time, the changes may/ may not be formed. However, if the time series shows variations over time in the past, this will make it possible to predict future pattern. The time series data analysis is based on the change of time in the past and on assumption that time series data must be stationary. Stationary data has a characteristic

of stochastic process or equilibrium value, which may be temporarily fluctuations from equilibrium but will likely return to its original equilibrium. If such characteristics change over time, the information will be non-stationary. X_t is stationary if mean, variance, and covariance are constant determined from:

$$\text{Mean: } E(X_t) = E(X_{t+x}) = \mu,$$

$$\text{Variance: } \text{VAR}(X_t) = \text{VAR}(X_{t+x}) = \sigma^2, \text{ and}$$

$$\text{Covariance: } \text{COV}(X_t, X_{t+k}) = E (X_t - \mu) (X_{t+k} - \mu) = \sigma_k - \mu,$$

where X_t, X_{t+k} are the time series data.

In analyzing the time series data, the data must be stationary as well as holds the same mean and variance throughout the study because the time series data comes from a random process. Using the time series data without assessing its stationarity can be resulted in non-standard distribution, which makes its use compared to the value in Z-table invalid.

Therefore, it is important to test that the data used are stationary or non-stationary. The most popular method used to test the stationarity is the Unit Root Test.

2.7 Unit Root Tests

For a unit root tests stationarity of data, the time series data is influenced by the change over time in an increasing trend which makes it difficult in modelling because of the time constraint involved. In order to determine any model that requires time series data in the past, it must be assumed that the model does not change with time or whether it has a property of stationary [10].

This study will utilize the method, developed by Dickey et al, namely Dickey-Fuller Test (DF) [10]. Unit Root testing or Order of Integration is a test of variables whether it is stationary or non-stationary. If we cannot reject the hypothesis that the variable is a unit root, it is said that the variable is non-stationary.

Said et al. [11] states that the Augmented Dickey-Fuller test (ADF) tests the stationarity of the data by taken the ADF-test value relative to the MacKinnon crisis value to indicate that the data is static and can reject the null hypothesis. Let the relationship is as follows.

$$Y_t = \alpha + \beta X_t + \varepsilon_t, \quad (2.4)$$

$$X_t = \rho X_{t-1} + \varepsilon_t, \quad (2.5)$$

where, Y_t is dependent variable, X_t, X_{t-1} are independent variable of the time series data at time t and $t-1$, α, β are parameters, ρ is autocorrelation efficient, ε_t is random error.

Let the null hypothesis $H_0: \rho = 1$ and the alternative hypotheses $H_1: |\rho| < 1$.

If H_0 is accepted, it means the data is non-stationary. However if H_0 is accepted, the data is stationary. By comparison, if the t-test is less than the DF-test, we can reject the null hypothesis that variables are stationary.

One of the main issues in time series analysis is stationarity problem. This can be solved by stabilizing the data via finding the difference between data and converting into a Logarithm or co-integration, etc. This is because time series data at time t is associated with time series data at time $t-1$ in both constant and trend. Thereby the DF-test needs to consider three different regression equations whether they have unit root. Accordingly, Equation (2.8) can be converted into the equations as follows.

If there are neither constants nor time trends,

$$\Delta X_t = \theta X_{t-1} + \varepsilon_t. \quad (2.6)$$

If there is a constant,

$$\Delta X_t = \alpha + \theta X_{t-1} + \varepsilon_t. \quad (2.7)$$

If there are both constant and time trends,

$$\Delta X_t = \alpha + \beta t + \theta X_{t-1} + \varepsilon_t. \quad (2.8)$$

Where X_t, X_{t-1} are time series data of the independent variable at time t and $t-1$, respectively;

α, β, θ are parameter;

t is time trends;

ε_t is random error.

Let the null hypothesis $H_0: \theta = 0$, and the alternative hypotheses $H_1: \theta > 0$.

If accepts H_0 , it means that the data is non-stationary. However if rejects H_0 , the data is stationary. Adding autoregressive processes into the equation is a solution to the DF-testing which has low DW (Durbin-Watson Statistic). An increase in autoregressive processes from the ADF test will lead the DW close to two to get a new equation from adding lagged difference terms (l) which depends on the suitability of the information or can be added until the error does not cause an autocorrelation problem [12]. From Equations (2.6), (2.7), and (2.8), the following equation are given as:

If there are neither constants nor time trends,

$$\Delta X_t = \theta X_{t-1} + \sum_{i=1}^l \phi_i \Delta X_{t-i} + \varepsilon_t. \quad (2.9)$$

If there is constant,

$$\Delta X_t = \alpha + \theta X_{t-1} + \sum_{i=1}^l \phi_i \Delta X_{t-i} + \varepsilon_t. \quad (2.10)$$

If there are both constant and time trend,

$$\Delta X_t = \alpha + \beta_t + \theta X_{t-1} + \sum_{i=1}^l \phi_i \Delta X_{t-i} + \varepsilon_t. \quad (2.11)$$

Where X_t, X_{t-1}, X_{t-i} are time series data of an independent variable at time t and $t-1$, ϕ is parameter

From Equations (2.9), (2.10), and (2.11), the number of Lagged Difference Terms (l) added to the equation is based on the suitability of each study, or can be inserted until the error does not cause an autocorrelation problem.

There has to be enough lagged difference terms to allow serially independent error terms. When applied to the previous equations, they are known as ADF-test which statistical values are belong to asymptotic distributions or DF-test, therefore the same critical value can be used. In order to find a suitable number of lag length for testing, this study has proposed the several appropriate methods, such as

setting enough large amount of lag length. For example, setting it at P^* to see, if coefficient of lag length statistically significantly differs from zero. It can be done by testing the statistical t-test, if there is no statistically significant, then the lag length is reduced down one by one until the lag length coefficient is significantly different from zero [13].

From Equations (2.2) and (2.3) for analyzing the time series, the separation of components can be done in several methods, such as autoregressive (AR) models, integrated (I) models, and moving average (MA) models. Moreover, there are also other techniques that do not require a separate component of signal which are nonlinear autoregressive models (NAR) and NARX. These techniques demand the use of computer to facilitate for solving. In this work, NARX is selected as forecasting methods, since it takes into account signal from external factors [14].

2.8 Moving Average (MA)

Moving Average is a forecasting method using historical statistic data (Time-Series Model) by prediction from the average of the last n number of months. Moving Average (MA) can be divided into three categories, given as:

- 1) Simple Moving Average (SMA),
- 2) Weighted Moving Average (WMA),
- 3) Simple Exponential Smoothing (SES).

A Simple Moving Average (SMA) is a forecast of future data from recent n number of observations, given that each observation is equally weighted [15].

After determining number of terms to take average, the value is resulted as the predictive value of subsequent period (at time $t+1$). The value of n can be either even or odd number, but it requires a minimum of 3 periods or more. If the data used covers three periods, thereby the first forecasting value will be the value at time period of 4. In case of $n = 3$, this is referred to a Moving Average of Order 3 or 3 MA Smoother [16].

Generally, there is no restrictions on n value when calculates a simple moving average (MA). However, it is preferable to use n value that is closer to its real value as much as possible by selecting n with overall lowest errors. If a time series

data has slow constant movement, then it should use a smaller n . In contrast, if a time series data has fast constant movement, a larger n should be used. To eliminate seasonal errors, one should find an average of 12 months or let $n = 12$.

A formula for calculating the simple moving average is stated as follows.

Moving Average = sum of the previous data prior n

$$n \text{ or } F_{t+1} = (Y_t + Y_{t-1} + Y_{t-2} + \dots + Y_{t-(n+1)}) \div n, \quad (2.12)$$

where,

Y_t is actual data at time t ;

n is number of terms or duration in calculating an average;

F_{t+1} is forecast value at time $t + 1$.

The predictive value equals to the average at present calculation time.

Disadvantages of moving average:

- Value of n will not affect the result, if n is excessively large.
- Data trend may be unrealistic and does not meet user's needs.
- Moving Average method requires a lot of historical information.

2.9 Nonlinear Autoregressive with Exogenous Input (NARX)

Regression Analysis is a study of the relationship between two variables or factors represented by more than two variables to learn their direction of relationship as well as characteristic between variables.

There are several types of regression analysis based on dependent variables, independent variables and its relationship [17].

The most common types of regression analysis are:

- Linear Regression Analysis is a statistical process used in characteristic relationship inspection of at-least two variables, given as: independent variable and dependent variable. The result informs as follows.

- 1) Size of relationship between independent and dependent variables.
- 2) Model of relationship between independent and dependent variables.

In regression analysis, it often refers the independent variable as predictor or stimulus variable, and calls the dependent variable as response variable or criterion variable.

- Nonlinear Regression is a regression analysis between stimulus variable and response variable. It can be represented by mathematical equation, called nonlinear model.

Nonlinear Autoregressive with exogenous input (NARX) is one of the time series forecasting model. NARX model utilizes artificial neural network containing neurons [18], modeling from the work of human brain. The simple block diagram of nonlinear autoregressive models with exogenous input is illustrated in Figure 2.7 in order to modeling time series up. From Figure 2.11, we can see that NARX consists of two layers, including hidden and output layers. Both of layers contain the transfer functions of $f_1(\cdot)$, $f_2(\cdot)$, weight of W , bias value of b , and tapped delay line with d buffers. These parameters can be any value depending on training process.

When input data $x(t)$, feeding into the tapped delay line with being weighted by becomes an input data of the transfer function $f_1(\cdot)$, the output of transfer function is sent to next layer. In the output layer, the same process with hidden layer is performed except using the different value of $f_1(\cdot)$, $f_2(\cdot)$, W and b [19].

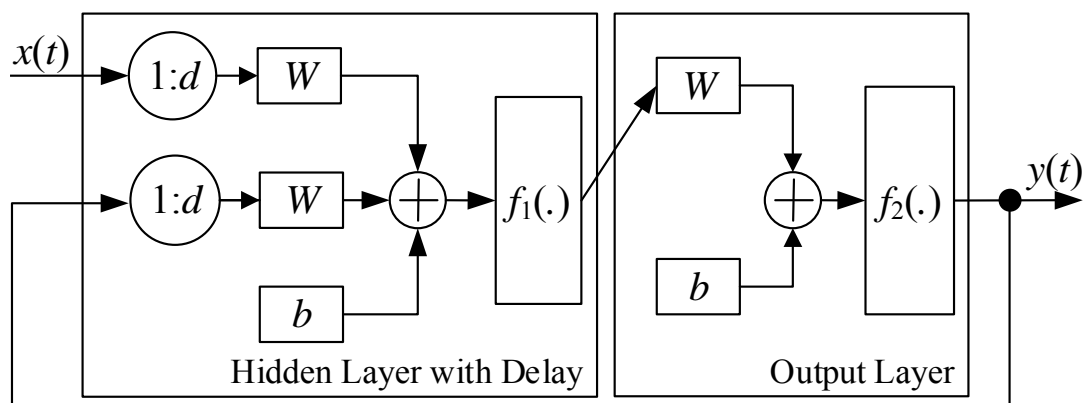


Figure 2.11 Simple block diagram of NARX.

2.10 Mean Square Error (MSE)

Mean Square Error (MSE) is a measurement of the average of the squares of the errors. It will focus on the predictive value which yields large discrepancies from the actual value. The MSE is very sensitive to the size tolerances. If any tolerances are high, when it is squared will be very high. The MSE is suitable for comparing to several forecasting methods with one data set. The error occurred in the mean square error (MSE) is calculated by the Equation 2.13

$$\text{MSE} = \frac{\sum_{i=1}^N (T_i - Y_i)^2}{N} \quad (2.13)$$

where

T_i is volume of traffic flow from the target,

Y_i is amount of vehicles calculated by the model,

N is number of data.

2.11 Related Works

There are a few works that focus on the transportation forecasting and NARX. Those works can be summarized as follows.

Chen D. [20] aimed to build a forecast model of automobile demand of China by using the monthly data of automobile sales from China Association of Automobile Manufactures (CAAM) during January 2001 to June 2011 based on autoregressive integrated moving average (ARIMA) time series model. While monthly data may have seasonal fluctuations, the researcher had calculated the values of autocorrelation and partial autocorrelation function of sample for exploring seasonal fluctuation character. The study showed that the TIC, bias proportion, variance proportion and covariance proportion were closer to one, indicated the model about automobile demand of China has very well forecast effectiveness. By analysis on statistics of forecast performance, it is concluded that the ARIMA model is suitable for forecasting monthly demand of China automobile.

Jiang et al. [21] used nonlinear autoregressive with exogenous input (NARX) and chaotic time series analysis to forecast sunspot. Chaotic time-series is a dynamic nonlinear system whose features can not be fully reflected by Linear Regression Model or Static Neural Network. This paper took 310 sunspot number from 1700 to 2009 as time-series sample, studied its internal chaos, calculated embedding dimension and delay, established model with NARX neural network and conducted prediction. The result showed that NARX network provided the highest prediction accuracy compared with BP network and ARIMA model. The reason being was NARX network reflected the system's dynamic feature better because of network output's feedback.

Lerkmongkolwit. [22] used the nonlinear model application of the NARX and polynomial equation for forecasting the latex volume, by analyzing the relationship of meteorological parameters as inputs to the model such as average temperature, average dew temperature, average pressure and average relative humidity. The result of the model generated polynomial equations for the latex volume's prediction. The size of polynomial equations that caused the least mean square error is the initial six regressions. The error from the equations did not exceed $\pm 5\%$ compared with the actual amount of latex. This model can also be used as a guide in developing models to utilise in other industries for example business services and medical. This research is particularly useful for prediction with high accuracy.

From the aforementioned theory and related work, the issue of congestion at some border checkpoints are caused by an increase in vehicles volume coupled with an inadequate service channels to accommodate the traffic flow. The researcher studied various theories that are used to solve such problems as well as studied forecasting methods in relation to vehicles. As a result, NARX model was applied in forecasting the number of vehicles travelling between borders. The work was carried out in Chapter 3.

CHAPTER III RESEARCH METHODOLOGY

This work has applied the Nonlinear Autoregressive model with exogenous input (NARX) for forecasting the traffic flow in Thailand-Laos border crossing points. NARX training with the Time Series Analysis. Figure 3.1 represents the procedure of the work.

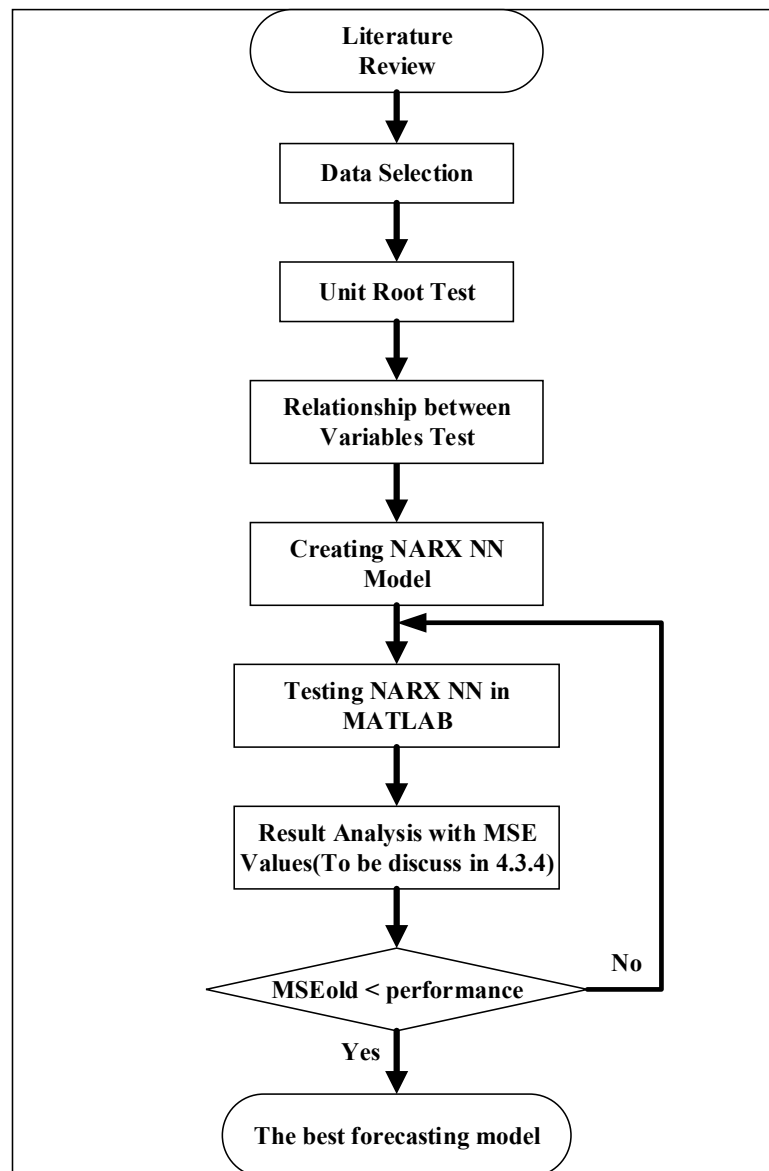


Figure 3.1 The procedure of the work.

3.1 Data Collection

The data used in this work have been compiled from the Office of Transport and Traffic Policy and Planning, Customs Department, Transport Statistics Sub-Division, Planning Division, The World bank, and ASEAN-Japan Transport Partnership [23]. These agencies have collected the statistical information on the number of vehicles accumulated within the country, the values of Gross Domestic Product (GDP) of each country in ASEAN region, the number of vehicles access cross-borders as well as infrastructure and transport of Thailand.

This work is primarily focused on Thailand and Laos, where the variables used in the forecast are 7 input variables, including cumulative number of vehicles in Thailand and Laos, Thailand's GDP per Capita, Laos' GDP per Capita [24-25], International Driving License, and Total number of new driving licenses issued for automobiles in Thailand and Laos. The output variable is the number of vehicles access Thailand-Laos border which Mukdahan's checkpoint and Chiang Khong's checkpoint are selected as samples for forecasting. Monthly data during January 2008 to December 2014 are used as shown in Appendix A "The data used for forecasting".

3.2 Testing the properties of variables by Unit Root

Variables tested in this study are times series data. For the study that needs time series data, stationarity is the assumption to be made. Stationarity is based on three pillars: mean, variance, and covariance remain unchanged over time. Unit Root testing that tests the stationarity of times series data is testing the unit root or finding out the order of Integration prior to examination of the relationship between variables. A method of Augment Dickey-Fuller Test (ADF) is utilized by using the following in Equation (2.11)

The hypothesis testing using ADF Test is:

$H_0: \theta = 0$ (variable of X_t qualifies as Non-Stationary)

$H_1: \theta > 0$ (variable of X_t qualifies as Stationary)

The test indicates whether the variable of interest (X_t) is a Unit Root by checking the value of θ . If θ equals to 0, it suggests that a Unit Root X_t data is non-stationary. Therefore a further test needs to be done in a higher difference level. If $\theta >$

0, H_0 can be rejected before a differentiation has been made showing that a variable is stationary. When a variable is stationary, then it can be take to the next step.

3.3 The correlation between variables

After the stationary test of time-series data by using ADF Test, the relationship between two variables is determined. This work has adopted Pearson Product Moment. The correlation coefficient refers to a value indicating a linear relationship, ranging from -1.0 to +1.0, where a value is closer to -1.0 or +1.0 showing the strongest relationship and a value of 0 means the two variables has no relationship at all. The + or – sign indicates that the relationship is in the same or the opposite direction. For example, one variable increases, another variable will also increase or vice versa, this kind of relationship r will be positive. On the other hand, if one variable increases where as another variable decreases, r will be negative, as given in Equation (2.1).

When the relationship between input variable and output variable has been identified, it will be compared and chosen the one that shows the strongest relationship between input and output variables for a further prediction. If a value has very low relationship, it will be eliminated and not be used in the prediction.

3.4 Transportation Forecasting

This work has applied the NARX for forecasting traffic flow in Thailand-Laos border crossing points. The neural networks used in the work will adjust W in accordance to the nodes. The adjustment is based on differences of the output $y(t)$ calculated from seven input variables and one desired variable by predicting one border at a time.

Data as described in Subsection 3.1 are applied to neural training process of NARX model. In this work, there are seven input data sets called “input” and one output data set called “target”. These data sets are randomly separated into 3 parts, i.e., training set, validation set, and test set. The training set indicates the neural network to recognize

a relationship between the input and the output produced by the open-loop model. The validation set is data set for verifying accuracy of the data. The test set is a data set used in neural network testing that have been predicted by neural network. There are various conditions that need to be set beforehand, including number of neurons in the hidden layer, delays, model variations of NARX, number of input, number of target, numbers of training set, validation set, and also test set. The training condition is shown in Table 3.2.

Table 3.1 Training Condition.

Parameter	Mukdahan	Chiang Khong
Hidden Neurons	10 to 40	10 to 40
Delay	2 to 10	2 to 10
NARX Model	Open-loop	Open-loop
Input	84×7	84×7
Target	84×1	84×1
Training Set	80%	80%
Validation Set	0%	0%
Test Set	20%	20%
Round	5	5

NARX training begins with considering variables that will be used, determining the range of Hidden Neurons and the range of Delay then trains to find the best NARX model used to forecast the vehicles volume accessing the border. This work determined that training procedures specify Delays to be started at 2 and increasing by 2 up to 10 and Hidden Neurons starting at 10 until 40 by an incremental value of five. Each training runs for five rounds. The best NARX model is the model that has caused the least error by using MSE. When a training finishes one round, the MSE will be recorded to compare with the next MSE. If the latest MSE is less than the previous MSE, a collection of new MSE will be required as well as Ploting error histogram, function fit, network performance, linear regression, training state values, and Generating MATLAB function for simulating neural network. The training procedures of NARX

Neural Network Time-Series can be found in Appendix B “NARX Modeling Process by using MATLAB”.

Bayesian regularization is an algorithm approach used in this paper. It is suitable for limited amount of data set, noisy data, and free validation data. This method may be time-consuming than other algorithms [26].

CHAPTER IV

RESULTS AND DISCUSSIONS

This chapter would describe the detail as follows:

1. Results of stationary testing in each variable by Unit Root test, called the Augmented Dickey-Fuller Test (ADF test);
2. Results of relationship testing between two variables from seven input data, including the number of vehicles in Thailand and Laos, Thailand's GDP per capita, Laos' GDP per capita, international driving license, and total number of new driving licenses issued for automobiles in Thailand and Laos, as well as two target data which are number of vehicles access Mukdahan's checkpoint and Chiang Khong's checkpoint using Pearson Product Moment;
3. Forecasting results from NARX Neural Network in Matlab;
4. Comparison of NARX and Moving Average results; and
5. Impact on traffic flow after opening of the ASEAN Economic Community.

4.1 Results of Stationary Testing

The test of stationarity results are shown in Tables 4.1 – 4.6 and Figures 4.1 – 4.8 with given description as follows.

Table 4.1 Results of variables' stationarity at level.

Variable	ADF test at level (I(0))					Result
	Lag	ADF test statistics	Test Critical values			
			1%	5%	10%	
Vehicles in Thailand	1	-2.009315	-4.073859	-3.465548	-3.159372	Non-stationary

Table 4.1 Results of variables' stationarity at level (cont.).

Variable	ADF test at level (I(0))					Result
	Lag	ADF test statistics	Test Critical values			
			1%	5%	10%	
Vehicles in Laos	1	-3.64052	-4.073859	-3.465548	-3.159372	Non-stationary
Thailand's GDP	1	-3.04739	-4.07386	-3.46555	-3.15937	Non-stationary
Laos's GDP	1	-2.82819	-4.07386	-3.46555	-3.15937	Non-stationary
International Driving License	0	-2.36246	-4.07242	-3.46487	-3.15897	Non-stationary
New driving licenses in Thailand	0	-3.93797	-4.07242	-3.46487	-3.15897	Non-stationary
New driving licenses in Laos	1	-1.99396	-4.07386	-3.46555	-3.15937	Non-stationary
Number of Vehicles accessing Mukdahan's checkpoint	0	-2.46771	-4.07242	-3.46487	-3.15897	Non-stationary
Number of Vehicles accessing Chiang Khong's checkpoint	1	-6.63698	-4.07386	-3.46555	-3.15937	Stationary

From Table 4.1, a unit root at level testing shows that the number of vehicles access of Chiang Khong's checkpoint has the higher absolute ADF-statistics value than the Mackinnon Critical Value at the level of statistical significance of 1, 5, and 10, respectively. In other words, the null hypothesis can be rejected at significance level of 5 percent.

In contrast, the number of vehicles in both Thailand and Laos, Thailand's GDP per Capita, Laos' GDP per Capita, International Driving License, Total number of new driving licenses issued for automobiles in both Thailand and Laos, and number of vehicles access of Mukdahan's checkpoint have the lower absolute ADF-statistics than the Mackinnon Critical Values at the level of statistical significances of 1, 5, and 10, respectively. It is implied that the null hypothesis can be accepted. The variables are qualified for non-stationary at the significance level of 5 percent. Therefore, it must convert the data in the form of at first difference, and tests a unit root in order to subsequently test for stationary as shown in Table 4.2.

Table 4.2 Results of variables' stationarity at first difference.

Variable	ADF test at level (I(1))					Result
	Lag	ADF test statistics	Test Critical values			
			1%	5%	10%	
Vehicles in Thailand	0	-5.42186	-4.07386	-3.46555	-3.15937	Stationary
Vehicles in Laos	0	-2.45157	-4.07386	-3.46555	-3.15937	Non-stationary
Thailand's GDP	0	-2.79491	-4.07386	-3.465548	-3.15937	Non-stationary
Laos's GDP	0	-2.3391	-4.07386	-3.465548	-3.15937	Non-stationary
International Driving License	0	-8.99616	-4.07386	-3.46555	-3.15937	Stationary

Table 4.2 Results of variables' stationarity at first difference (cont.).

Variable	ADF test at level (I(1))					Result
	Lag	ADF test statistics	Test Critical values			
			1%	5%	10%	
New driving licenses in Thailand	0	-3.93797	-4.07242	-3.46487	-3.15897	Non-stationary
New driving licenses in Laos	0	-2.07003	-4.07386	-3.46555	-3.15937	Non-stationary
Number of Vehicles accessing Mukdahan's checkpoint	0	-7.32829	-4.07386	-3.46555	-3.15937	Stationary
Number of Vehicles accessing Chiang Khong's checkpoint	10	-6.51529	-4.0906	-3.47345	-3.16397	Stationary

From Table 4.2, a unit root at first difference testing indicates that number of vehicles in Thailand, International Driving License, and number of vehicles accessing Thailand-Laos border at Mukdahan's checkpoint and Chiang Khong's checkpoint have higher absolute ADF-statistics values than the Mackinnon Critical Values at the level of statistical significances of 1, 5, and 10, respectively. In other words, the null hypothesis can be rejected at significance level of 5 percent.

On the other hand, number of vehicles in Laos, Thailand's GDP per Capita, Laos' GDP per Capita, and Total number of new driving licenses issued for automobiles

in Thailand and Laos have the lower absolute ADF-statistics than the Mackinnon Critical Values at the level of statistical significances of 1, 5, and 10, respectively. It is evident that the null hypothesis can be accepted. The variables are qualified for non-stationary at the significance level of 5 percent. Therefore, it must convert the data in the form of at second difference, and tests a unit root in order to test for stationary for the final testing as shown in Table 4.3.

Table 4.3 Results of variables' stationarity at second difference.

Variable	ADF test at level (I(2))					Result
	Lag	ADF test statistics	Test Critical values			
			1%	5%	10%	
Vehicles in Thailand	0	-13.8578	-4.07534	-3.46625	-3.15978	Stationary
Vehicles in Laos	11	-8.14273	-4.09455	-3.47531	-3.16505	Stationary
Thailand's GDP	0	-8.84148	-4.07534	-3.46625	-3.15978	Stationary
Laos's GDP	11	-6.81946	-4.09455	-3.47531	-3.16505	Stationary
International Driving License	11	-9.01794	-4.09455	-3.47531	-3.16505	Stationary
New driving licenses in Thailand	0	-3.93797	-4.07242	-3.46487	-3.15897	Stationary
New driving licenses in Laos	0	-2.07003	-4.07386	-3.46555	-3.15937	Stationary

Table 4.3 Results of variables' stationarity at second difference (cont.).

Variable	ADF test at level (I(2))					Result
	Lag	ADF test statistics	Test Critical values			
			1%	5%	10%	
Number of Vehicles accessing Mukdahan's checkpoint	5	-8.57399	-4.08336	-3.47003	-3.16198	Stationary
Number of Vehicles accessing Chiang Khong's checkpoint	11	-5.65163	-4.09455	-3.47531	-3.16505	Stationary

Table 4.3 illustrates a unit root at second difference testing showing that all of the variables have the higher absolute ADF-statistics values than the Mackinnon Critical Values at the level of statistical significance of 1, 5, and 10, respectively. It mean that the null hypothesis can be rejected and they are qualified for stationary at second difference.

4.2 Results of correlation testing between two variables

After all of the variables have been qualified for stationarity, each input will now be tested for correlation with output and will result in the Pearson's Correlation Coefficient (r), as shown in Table 4.4.

Table 4.4 Results of correlation testing between input variable and output variable.

Variable	Pearson' s Correlation Coefficient (r)	
	Mukdahan's checkpoint	Chiang Khong's checkpoint
Vehicles in Thailand	0.557904	0.929083
Vehicles in Laos	0.665628	0.915331
Thailand's GDP	0.537692	0.873403
Laos's GDP	0.612288	0.933246
International Driving License	0.645056	0.941643
New driving licenses in Thailand	0.507712	0.921897
New driving licenses in Laos	0.596195	0.929998

Table 4.4 shows the correlation coefficient between each input variable and an output variable, where the r values of 7 input variables with the number of vehicles accessing both Mukdahan's and Chiang Khong's checkpoint are presented as follows:

- The coefficient of the relationship between the number of vehicles in Thailand and the number of vehicles access Mukdahan's checkpoint is equivalent to 0.557904 meaning that the correlation is large with positive relationship.

- The coefficient of the relationship between the number of vehicles in Thailand and the number of vehicles access Chiang Khong's checkpoint is equivalent to 0.929083 meaning that the correlation is large with positive relationship.

- The coefficient of the relationship between Thailand's GDP per Capita and the number of vehicles accessing Mukdahan's checkpoint is equivalent to 0.665628 showing that the correlation is large with positive relationship.

- The coefficient of the relationship between Laos's GDP per Capita and the number of vehicles accessing Chiang Khong's checkpoint is equivalent to 0.915331 showing that the correlation is large with positive relationship.

- The coefficient of the relationship between the number of international driving licenses and the number of vehicles accessing Mukdahan's checkpoint is equivalent to 0.645056 showing that the correlation is large with positive relationship.

- The coefficient of the relationship between the number of international driving licenses and the number of vehicles accessing Chiang Khong's checkpoint is equivalent to 0.941643. It indicates that the correlation is large with positive relationship.

- The coefficient of the relationship between the total number of new driving licenses issued for automobiles in Thailand and the number of vehicles accessing Mukdahan's checkpoint is equivalent to 0.507712. It indicates that the correlation is large with positive relationship.

- The coefficient of the relationship between the total number of new driving licenses issued for automobiles in Thailand and the number of vehicles accessing Chiang Khong's checkpoint is equivalent to 0.921897. It indicates that the correlation is large with positive relationship.

- The coefficient of the relationship between the total number of new driving licenses issued for automobiles in Laos and the number of vehicles accessing Mukdahan's checkpoint is equivalent to 0.596195. It indicates that the correlation is large with positive relationship.

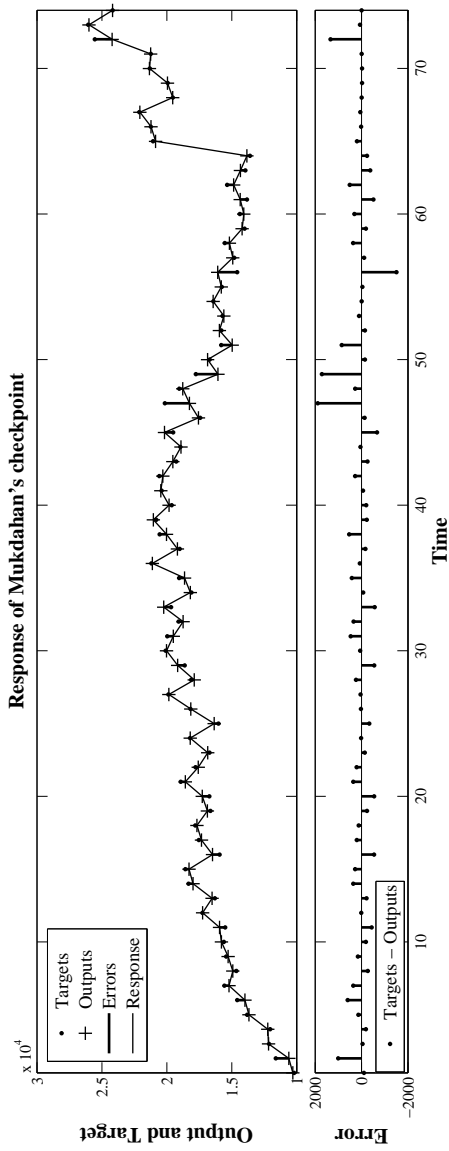
- The coefficient of the relationship between the total number of new driving licenses issued for automobiles in Laos and the number of vehicles accessing Chiang Khong's checkpoint is equivalent to 0.929998. It indicates that the correlation is large with positive relationship.

4.3 Forecasting results from NARX Neural Network

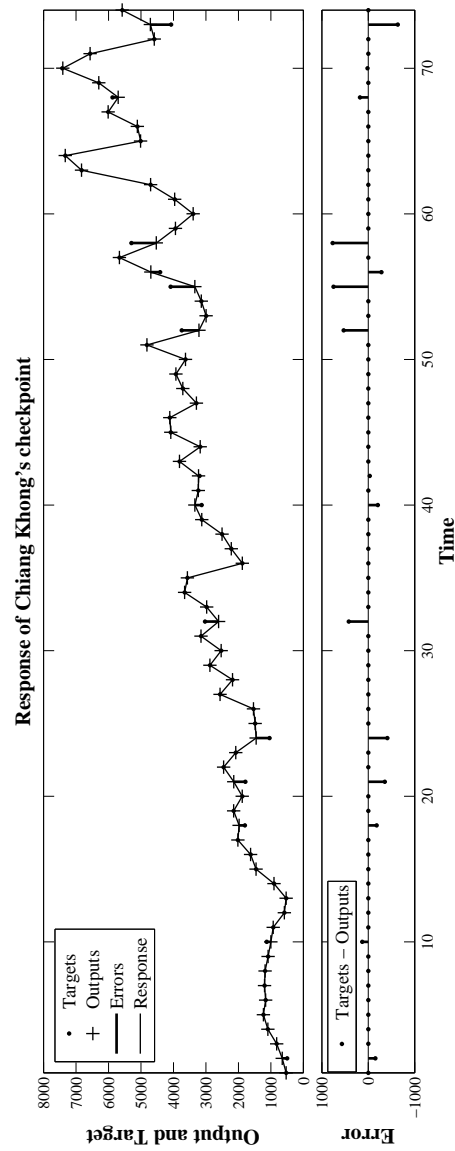
After training the NARX model with the condition provided in Table 3.2, the output of the NARX model is obtained as presented in this section.

4.3.1 Time-Series Response

Graphs respond to the output and target of the training data, and test the data by x-axis representing the number of months of data and y-axis representing the traffic flow by target and output. These values are similar as shown in Figures 4.1 and 4.2.



Figures 4.1 Graph of Time-Series response of Mukdahhan's checkpoint.



Figures 4.2 Graph of Time-Series response of Chiang Khong's checkpoint.

4.3.2 Regression

Correlation coefficient (R) is a measure of linear relationship of two variables referring to Target and Output. The values of Mukdahan and Chiang Khong correlation coefficient are 0.98707 and 0.9944, respectively, as shown in Figures 4.3 and 4.4.

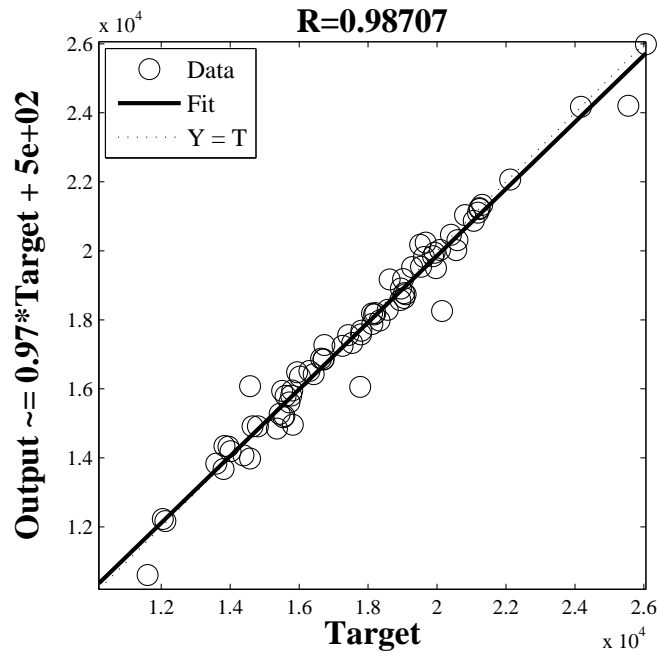


Figure 4.3 Regression graph of Mukdahan's checkpoint.

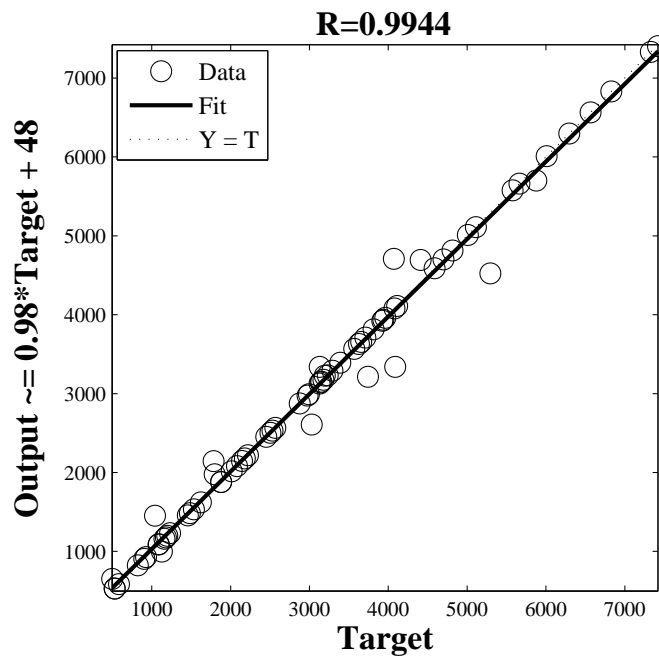


Figure 4.4 Regression graph of Chiang Khong's checkpoint.

4.3.3 Error Autocorrelation

Figures 4.5 and 4.6 illustrate the error autocorrelation, where y-axis represents the lag and x-axis represents the correlation. It illustrates that most of the error autocorrelation values are smaller than the confidence limit value.

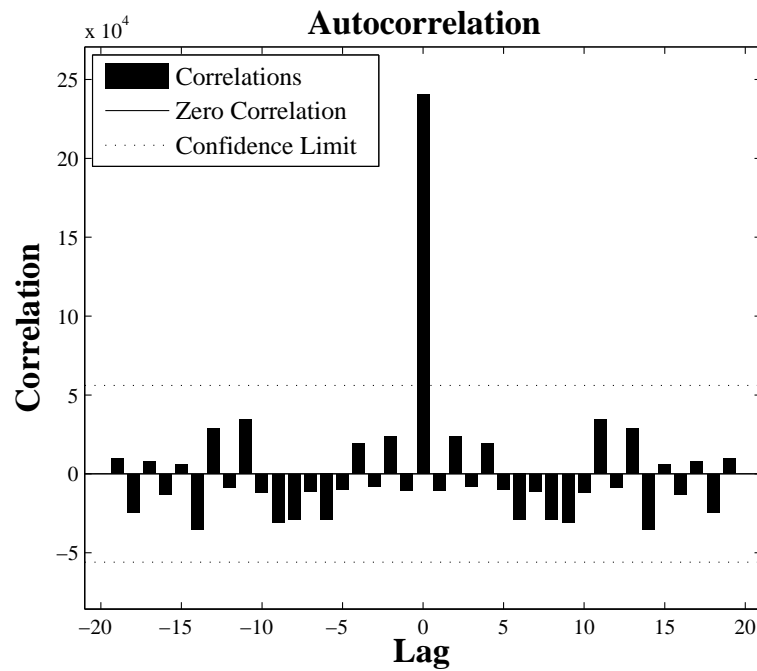


Figure 4.5 Error autocorrelation function of Mukdahan’s checkpoint.

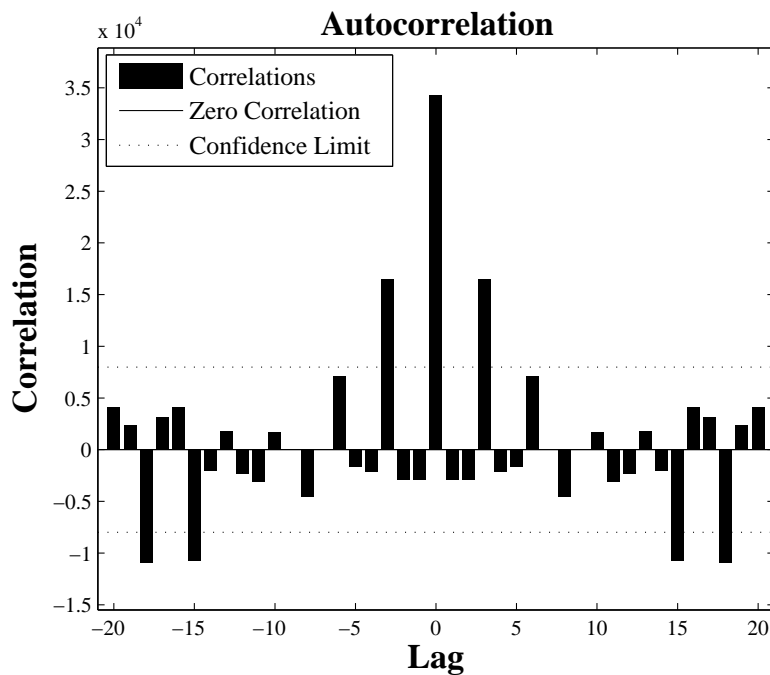


Figure 4.6 Error autocorrelation function of Chiang Khong’s checkpoint.

4.3.4 Mean Square Error

The error occurred in the mean square error (MSE) is calculated by the Equation 4.1

$$MSE = \frac{\sum_{i=1}^N (T_i - Y_i)^2}{N} \quad (4.1)$$

Where,

T_i is volume of traffic flow from the target,

Y_i is amount of vehicles calculated by the model,

N is number of data.

The lowest mean square error of Mukdahan’s checkpoint is 191,210 while the lowest mean square error of Chiang Khong’s checkpoint is 12,458. The lowest mean square error of NARX models for both Mukdahan and Chiang Khong’s checkpoints are shown in Figures 4.7 and 4.8, respectively.

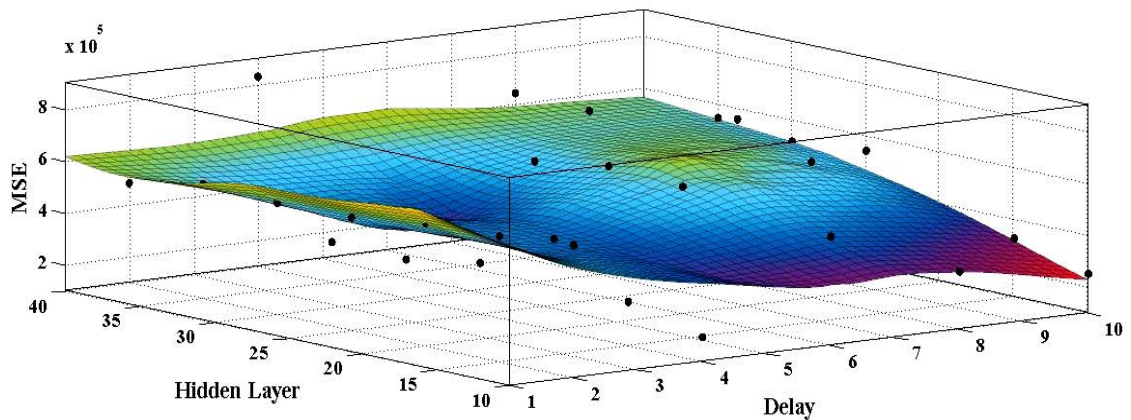


Figure 4.7 The lowest MSE of Mukdahan’s checkpoint.

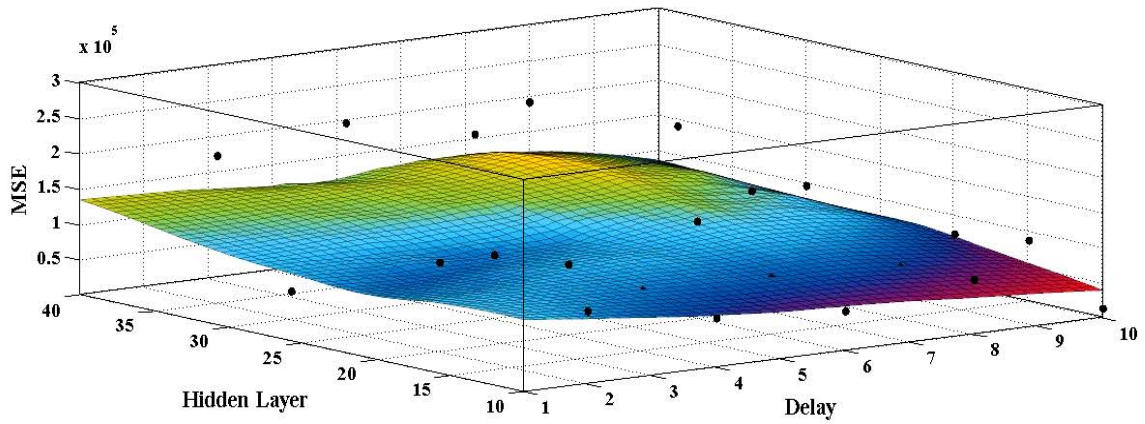


Figure 4.8 The lowest MSE of Chiang Khong’s checkpoint.

4.4 Comparison of NARX and Moving Average results

The mean square error of number of vehicles access Mukdahan checkpoint calculated by the Moving Average is equal to 2,616,725 and the mean square error of number of vehicles accessing Chiang Khong checkpoint calculated by the Moving Average is equal to 18,855. The results obtained from NARX and Moving Average are compared in Table 4.5.

Table 4.5 The MSEs data of vehicles access number for both Mukdahan and Chiang Khong checkpoints calculated by NARX and Moving Average.

Method	Mean Square Error	
	Mukdahan’s checkpoint	Chiang Khong’s checkpoint
Nonlinear Autoregressive with exogenous input (NARX)	191210	12458
Moving Average (MA)	2616725	18855

From the Table 4.5, it is shown that MSE using NARX is less than MSE using Moving Average for both Mukdahan and Chiang Khong. Hence, NARX forecast is more accurate than that of Moving Average.

4.5 Impact on traffic flow after opening of the ASEAN Economic Community (AEC)

Thailand is a member of AEC. The objective is to establish a single market with the same rules/regulations. Compared with other members of the AEC, Thailand has advantages in many ways, for example, the location becoming the center of transportation, bordering the most countries in the region, and becoming a production base of industrial and agricultural products. These strengths make Thailand have a high potential for the AEC economic, i.e., trade and investment. Thus, it is significant to be prepared in opening of the AEC in December 31, 2015.

The opening of the ASEAN Economic Community will cause an increase in traffic flow at the borders. According to the IMF World Economic Outlook (WEO), economic growth rate of ASEAN indicates that the economy of ASEAN will rise eight-fold in 20 years [27], representing an average 9.2% per year and over the next four years the ASEAN's economy will increase on an average of 7% per year, as shown in Table 4.6 and Figure 4.9.

Table 4.6 ASEAN's GDP data during 1995-2018.

Year	GDP of ASEAN (USD)
1995	0.659
1996	0.732
1997	0.695
1998	0.480
1999	0.558
2000	0.610
2001	0.584
2002	0.650
2003	0.732
2004	0.824
2005	0.924
2006	1.108
2007	1.326

Table 4.6 ASEAN’s GDP data during 1995-2018 (cont.).

Year	GDP of ASEAN (USD)
2008	1.541
2009	1.530
2010	1.902
2011	2.205
2012	2.335
2013	2.406
2014	2.465
2015	2.640
2016	2.867
2017	3.087
2018	3.335

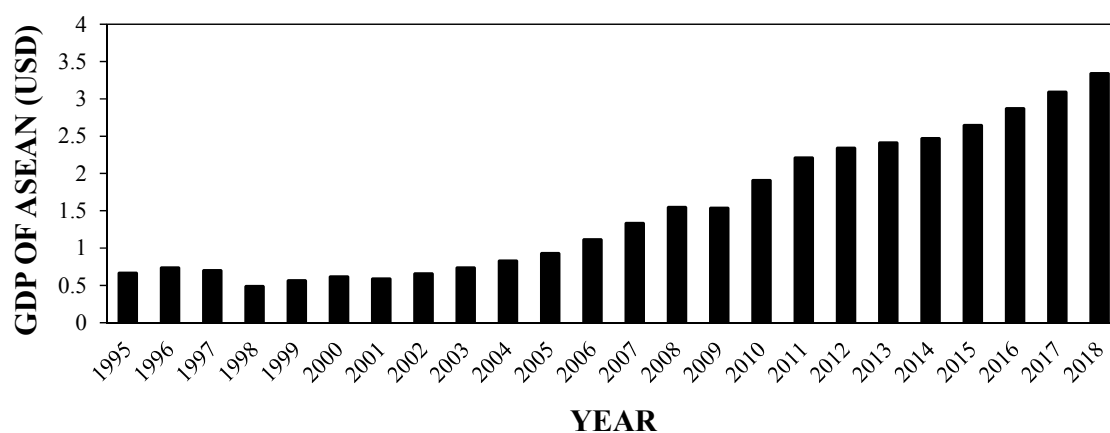


Figure 4.9 ASEAN’s GDP data during 1995-2018.

The information on number of international driving licenses from Transport Statistics Sub-Division, Planning Division shows that the popularity in acquiring an international driving license has gradually increased each year as shown in Table 4.7 and Figure 4.10.

Table 4.7 Number of international driving licenses.

Year	International Driving License (licenses)
2002	158,079
2003	160,134
2004	162,210
2005	164,308
2006	166,406
2007	215,250
2008	264,833
2009	315,713
2010	368,741
2011	421,683
2012	476,962
2013	537,697
2014	604,038

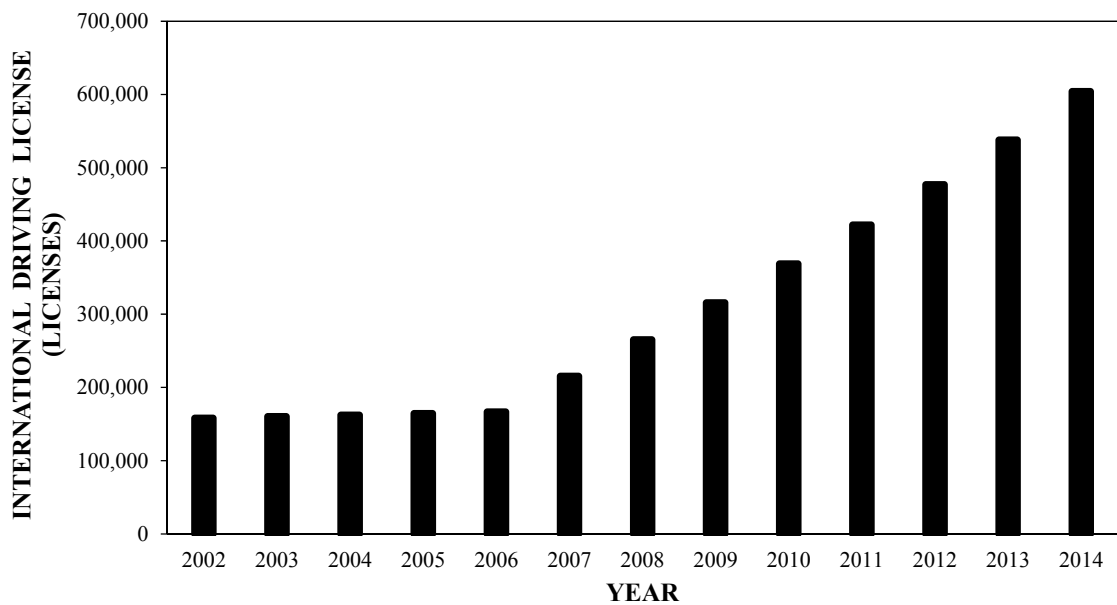


Figure 4.10 Number of international driving licenses.

A growth in GDP and international driving licenses will lead to an increase in travels between countries, coupled with the “International Visa” policy introduced by ASEAN countries, allowing the people in the ASEAN region to freely travel among member countries, using only a passport and visa which is no longer required.

This section presents the examples of impact place on Thailand-Laos borders after opening of the AEC. Based on the information collected from Nong Khai checkpoint which is a permanent checkpoint with the first Thai-Lao Friendship Bridge connecting to Vientiane, the passport holders can pass through the immigration. However, those who do not have either passport or border pass must obtain the border pass at another office away from the border checkpoint. Nong Khai checkpoint is divided into immigration section and customs vehicles check section. The vehicles check point has three channels for personal vehicle, one channel for bus and coach, and one channel for diplomacy. The immigration procedure takes about 5 minutes per person. The customs vehicles check will take about 15 minutes to inspect one vehicle. Upon completion of these procedures, travelers are now able to cross to the Laos side.

From the foregoing, it is observed that Nong Khai checkpoint is experiencing the following issues:

1. People without passport will be required to obtain border pass at another place, border pass cannot be issued right away at the checkpoint.
2. Customs vehicles checking channels are not enough. It may cause the delayed process, if there is a large number of vehicles crossing.
3. People without vehicles have to queue in order to buy the bus tickets.

The opening of AEC will increase a number of vehicles crossing the borders according to the forecast of Mukdahan’s and Chiang Khong’s checkpoints affecting the traffic flow at border crossing points, and may be further delayed in procedures. Potential of border today may not be sufficient to accommodate more vehicles rising. Therefore, it is necessary to properly study and improve the border of Thailand for the near future.

CHAPTER V

CONCLUSIONS

This work aims to use NARX to forecast the traffic flow of Mukdahan and Chiang Khong checkpoints, predict the effect that may occur after the launch of the AEC, and compare the accuracy of a prediction using NARX and Moving Average. The process of the work commenced from collection of relevant data and tested for stationarity by Unit Root method. The static data were tested for relationship between each input and output variable. The variables with high level of correlation were subsequently forecasted by NARX method using MATLAB program. Then the prediction of NARX method was compared with MA method using MSE as a measurement of accuracy in forecasting. For Mukdahan's checkpoint results, it illustrates that graph pattern consists of only trend signal, whereas the results of Chiang Khong's checkpoint consists of trend and seasonal signals. The correlation coefficients (R) of Mukdahan's checkpoint equal 0.98707 and Chiang Khong's checkpoint equal 0.9944. This can imply that the target and output has a positive relationship. In addition, MSE using NARX is as low as 191,210 and 12,458. MSE using MA is as low as 2,616,725 and 18,855. Therefore NARX is a more accurate forecasting tool compared with MA and holding that the forecast is accurate and correct.

The aggregated data on ASEAN's GDP and international driving licenses are implied that an increase in the GDP rate of ASEAN and number of international driving licenses form important factors will cause higher traffic flow at the borders as evident by the strong relationship and the positive correlation coefficient. Another factor affecting the traffic flow car is an introduction of international visa policy among ASEAN members as well as free trade policy. These will result in a lot more trips among countries in ASEAN.

The traffic flow forecasting could be a model to support the benefits of country in order to greatly improve and develop the border of Thailand when AEC is coming. Furthermore, the application of NARX is a novel method which can be used to forecast with other constraints.

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APPENDICES

APPENDIX A
INPUT DATA SETS AND OUTPUT DATA ARE USED FOR FORECASTING

Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Inter- national Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahan's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Jan/2008	25,618,447	651,667	3,905	718	215,250	434,022	1,343,411	7,195	729
Feb/2008	25,631,288	662,333	3,905	733	219,758	436,784	1,340,603	7,721	624
Mar/2008	25,645,309	673,000	3,905	748	224,265	439,546	1,337,794	8,445	675
Apr/2008	25,657,812	683,667	3,978	764	228,773	442,308	1,334,986	8,501	580
May/2008	25,670,435	694,333	4,051	779	233,280	445,070	1,332,177	8,536	488
Jun/2008	25,980,143	705,000	4,124	795	237,788	447,832	1,329,369	7,976	437
Jul/2008	26,039,682	715,667	4,181	810	242,295	450,593	1,326,560	8,680	390
Aug/2008	26,145,384	726,333	4,238	825	246,803	453,355	1,323,752	9,044	364

Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Internatio nal Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahan's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Sep/2008	26,226,915	737,000	4,295	841	251,310	456,117	1,320,943	8,792	610
Oct/2008	26,285,481	747,667	4,236	856	255,818	458,879	1,318,135	10,488	636
Nov/2008	26,336,806	758,333	4,177	871	260,325	461,641	1,315,326	10,192	530
Dec/2008	26,417,353	769,000	4,118	887	264,833	464,403	1,312,518	11,605	498
Jan/2009	26,423,876	778,750	4,021	890	269,073	467,499	1,312,058	12,122	823
Feb/2009	26,507,638	788,500	3,923	894	273,313	470,595	1,311,598	12,042	1,091
Mar/2009	26,592,045	798,250	3,826	898	277,553	473,691	1,311,138	13,810	1,231
Apr/2009	26,659,322	808,000	3,764	901	281,793	476,787	1,310,678	14,578	1,161
May/2009	26,708,201	817,750	3,701	905	286,033	479,883	1,310,218	15,570	1,197
Jun/2009	26,790,326	827,500	3,639	909	290,273	482,979	1,309,758	14,646	1,178
Jul/2009	26,853,357	837,250	3,605	912	294,513	486,075	1,309,298	15,434	1,086
Aug/2009	26,901,395	847,000	3,571	916	298,753	489,171	1,308,838	15,606	1,129
Sep/2009	26,992,674	856,750	3,537	920	302,993	492,267	1,308,378	15,505	927

Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Internatio nal Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahana's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Oct/2009	27,005,284	866,500	3,684	923	307,233	495,363	1,307,918	17,261	585
Nov/2009	27,042,860	876,250	3,831	927	311,473	498,459	1,307,458	16,298	529
Dec/2009	27,184,577	886,000	3,979	931	315,713	501,555	1,306,998	18,333	905
Jan/2010	27,197,302	896,250	4,138	947	320,132	504,481	1,315,104	18,569	1,457
Feb/2010	27,204,376	906,500	4,297	963	324,551	507,406	1,323,209	15,943	1,623
Mar/2010	27,368,966	916,750	4,456	979	328,970	510,332	1,331,315	17,537	2,015
Apr/2010	27,519,420	927,000	4,532	995	333,389	513,258	1,339,421	17,806	1,798
May/2010	27,604,916	937,250	4,608	1,011	337,808	516,183	1,347,526	16,640	2,145
Jun/2010	27,721,862	947,500	4,684	1,027	342,227	519,109	1,355,632	16,728	1,880
Jul/2010	27,893,518	957,750	4,710	1,043	346,646	522,035	1,363,738	18,933	1,785
Aug/2010	28,032,741	968,000	4,737	1,059	351,065	524,960	1,371,843	17,793	2,453
Sep/2010	28,190,268	978,250	4,763	1,075	355,484	527,886	1,379,949	16,711	2,081
Oct/2010	28,268,904	988,500	4,776	1,091	359,903	530,812	1,388,055	18,211	1,042

Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Internatio nal Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahan's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Nov/2010	28,361,932	998,750	4,790	1,107	364,322	533,737	1,396,160	16,022	1,484
Dec/2010	28,484,829	1,009,000	4,803	1,123	368,741	536,663	1,404,266	18,176	1,534
Jan/2011	28,496,381	1,015,750	4,851	1,135	373,153	539,777	1,415,176	19,883	2,566
Feb/2011	28,506,732	1,022,500	4,899	1,147	377,565	542,891	1,426,087	18,125	2,180
Mar/2011	28,654,295	1,029,250	4,947	1,159	381,977	546,005	1,436,997	18,622	2,876
Apr/2011	28,743,914	1,036,000	4,990	1,170	386,388	549,118	1,447,908	20,086	2,531
May/2011	28,943,672	1,042,750	5,032	1,182	390,800	552,232	1,458,818	19,970	3,151
Jun/2011	29,247,903	1,049,500	5,075	1,194	395,212	555,346	1,469,729	19,089	3,029
Jul/2011	29,543,327	1,056,250	5,135	1,206	399,624	558,460	1,480,639	19,673	2,975
Aug/2011	29,946,042	1,063,000	5,194	1,218	404,036	561,574	1,491,549	18,113	3,656
Sep/2011	29,950,682	1,069,750	5,253	1,230	408,448	564,688	1,502,460	19,051	3,568
Oct/2011	30,053,680	1,076,500	5,233	1,242	412,859	567,801	1,513,370	21,186	1,879
Nov/2011	30,145,318	1,083,250	5,212	1,254	417,271	570,915	1,524,281	19,011	2,219

Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Internatio nal Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahhan's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Dec/2011	30,194,937	1,090,000	5,192	1,266	421,683	574,029	1,535,191	20,553	2,504
Jan/2012	30,322,761	1,106,500	5,197	1,278	426,290	577,378	1,546,101	20,811	3,128
Feb/2012	30,483,912	1,123,000	5,203	1,289	430,896	580,726	1,557,012	19,620	3,131
Mar/2012	30,667,049	1,139,500	5,208	1,301	435,503	584,075	1,567,922	20,402	3,232
Apr/2012	30,813,731	1,156,000	5,281	1,313	440,109	587,423	1,578,833	20,588	3,195
May/2012	31,037,272	1,172,500	5,354	1,325	444,716	590,772	1,589,743	19,277	3,814
Jun/2012	31,257,709	1,189,000	5,426	1,337	449,323	594,120	1,600,654	18,954	3,176
Jul/2012	31,466,422	1,205,500	5,481	1,349	453,929	597,469	1,611,564	19,507	4,079
Aug/2012	31,655,543	1,222,000	5,535	1,361	458,536	600,817	1,622,474	17,422	4,111
Sep/2012	31,849,203	1,238,500	5,589	1,373	463,142	604,166	1,633,385	20,146	3,291
Oct/2012	32,056,367	1,255,000	5,586	1,385	467,749	607,514	1,644,295	19,046	3,710
Nov/2012	32,277,695	1,271,500	5,583	1,396	472,355	610,863	1,655,206	17,769	3,924
Dec/2012	32,476,977	1,288,000	5,580	1,408	476,962	614,211	1,627,897	16,706	3,629

Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Internatio nal Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahan's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Jan/2013	32,719,090	1,289,917	5,649	1,429	482,023	622,863	1,643,475	15,814	4,814
Feb/2013	32,928,635	1,291,833	5,717	1,450	487,085	631,515	1,659,053	15,800	3,743
Mar/2013	33,167,625	1,293,750	5,786	1,471	492,146	640,168	1,674,632	15,717	2,993
Apr/2013	33,363,765	1,295,667	5,840	1,492	497,207	648,820	1,690,210	16,419	3,142
May/2013	33,582,039	1,297,583	5,894	1,513	502,268	657,472	1,705,788	15,771	4,087
Jun/2013	33,781,957	1,299,500	5,948	1,534	507,330	666,124	1,721,366	14,574	4,410
Jul/2013	33,960,792	1,301,417	5,903	1,556	512,391	674,776	1,736,944	14,803	5,663
Aug/2013	34,127,381	1,303,333	5,859	1,577	517,452	683,428	1,752,522	15,543	5,294
Sep/2013	34,272,176	1,305,250	5,814	1,598	522,513	692,081	1,768,101	14,008	3,937
Oct/2013	34,419,174	1,307,167	5,802	1,619	527,575	700,733	1,783,679	14,382	3,392
Nov/2013	34,536,935	1,309,083	5,791	1,640	532,636	709,385	1,799,257	13,831	3,961
Dec/2013	34,624,406	1,311,000	5,779	1,661	537,697	718,037	1,814,835	15,356	4,701
Jan/2014	34,718,448	1,321,667	5,767	1,671	598,628	722,226	1,823,858	13,948	6,829

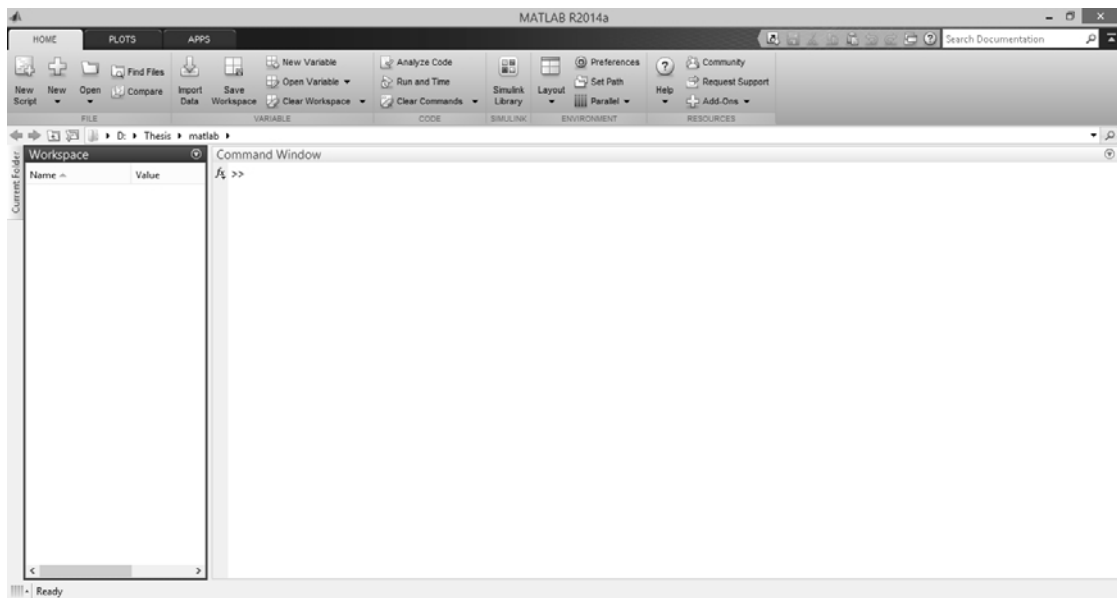
Month/ Year	Vehicles in Thailand (cars)	Vehicles in Laos (cars)	Thai- land's GDP (USD)	Laos's GDP (USD)	Internatio nal Driving License (licenses)	New driving licenses in Thailand (licenses)	New driving licenses in Laos (licenses)	Vehicles access Mukdahan's checkpoint (cars)	Vehicles access Chiang Khong's checkpoint (cars)
Feb/2014	34,860,724	1,332,333	5,756	1,682	598,891	726,414	1,837,984	13,597	7,331
Mar/2014	34,997,233	1,343,000	5,744	1,693	599,595	730,603	1,840,921	21,066	5,010
Apr/2014	35,111,217	1,353,667	5,752	1,703	599,960	734,791	1,858,644	21,232	5,111
May/2014	35,238,776	1,364,333	5,760	1,714	600,557	738,980	1,864,290	22,121	6,009
Jun/2014	35,352,660	1,375,000	5,767	1,725	601,454	743,169	1,870,064	19,533	5,878
Jul/2014	35,466,555	1,385,667	5,779	1,735	601,743	747,357	1,884,326	19,928	6,296
Aug/2014	35,560,860	1,396,333	5,790	1,746	601,756	751,546	1,896,489	21,307	7,421
Sep/2014	35,650,355	1,407,000	5,802	1,757	602,402	755,734	1,907,535	21,232	6,565
Oct/2014	35,737,232	1,417,667	5,794	1,767	602,513	759,923	1,913,489	25,547	4,588
Nov/2014	35,797,893	1,428,333	5,787	1,778	602,813	764,111	1,928,665	26,056	4,071
Dec/2014	35,835,180	1,439,000	5,779	1,789	604,038	768,300	1,938,943	24,171	5,577

APPENDIX B

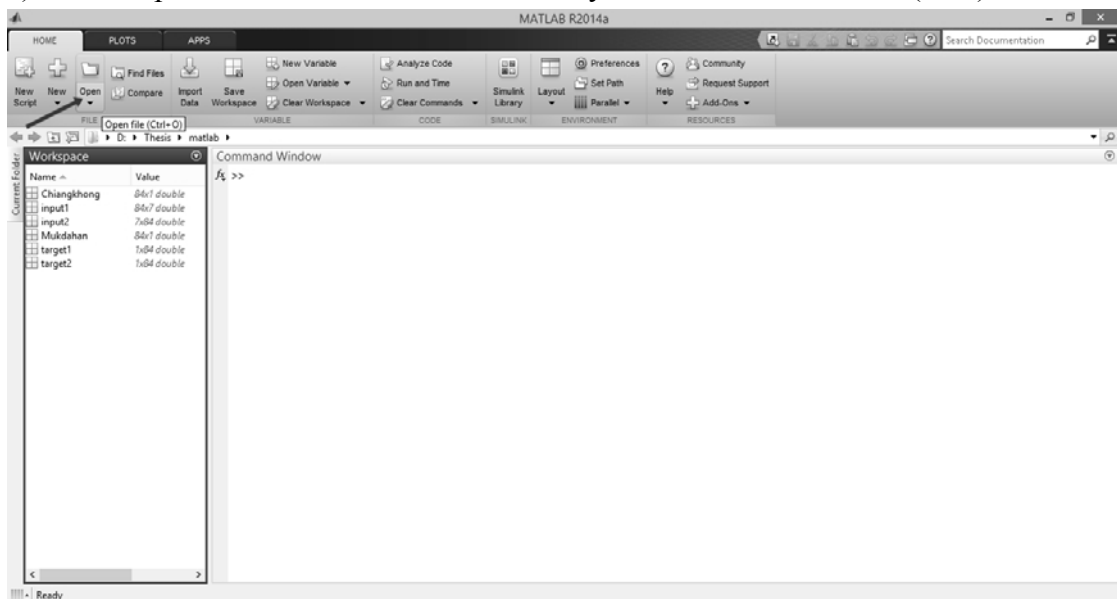
NARX MODELING PROCESS BY USING MATLAB

The training procedures of NARX Neural Network Time-Series as follows:

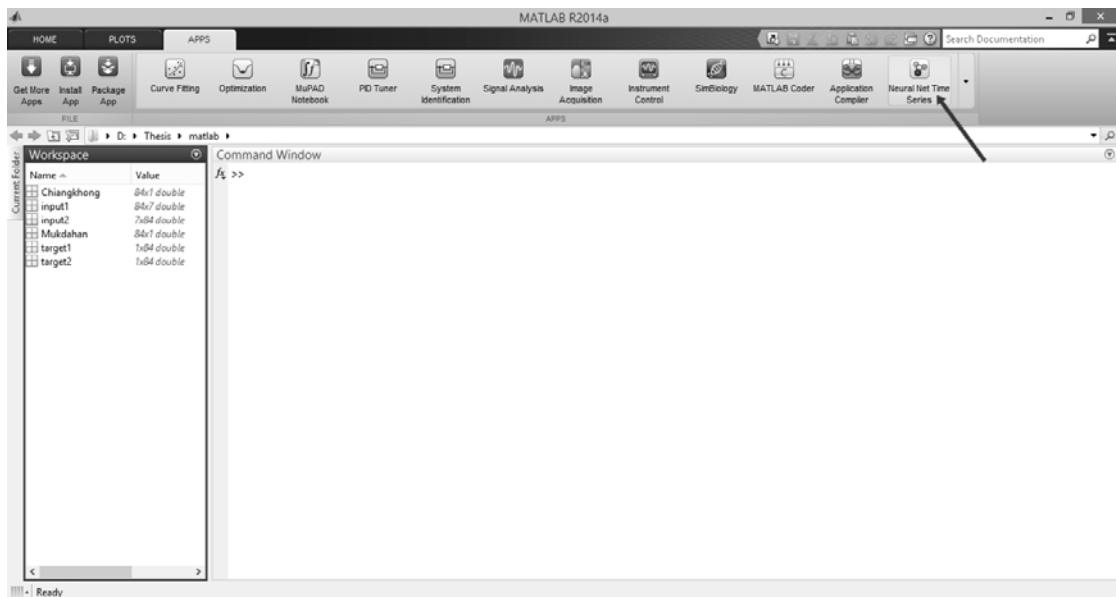
1) Open MATLAB program.



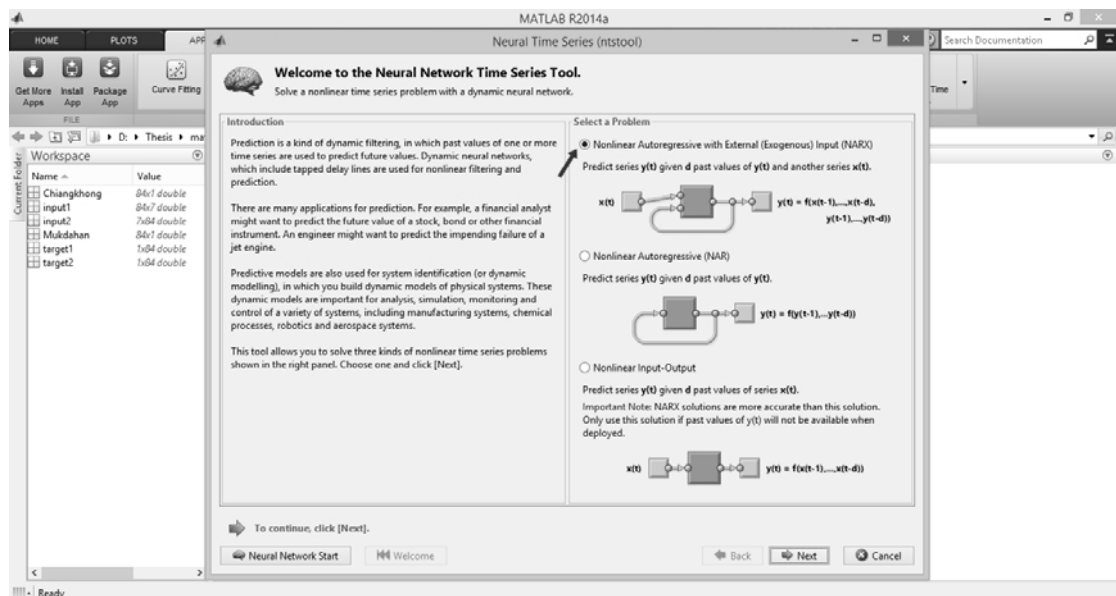
2) Click “Open” in HOME menu and choose your MATLAB data file (.mat).



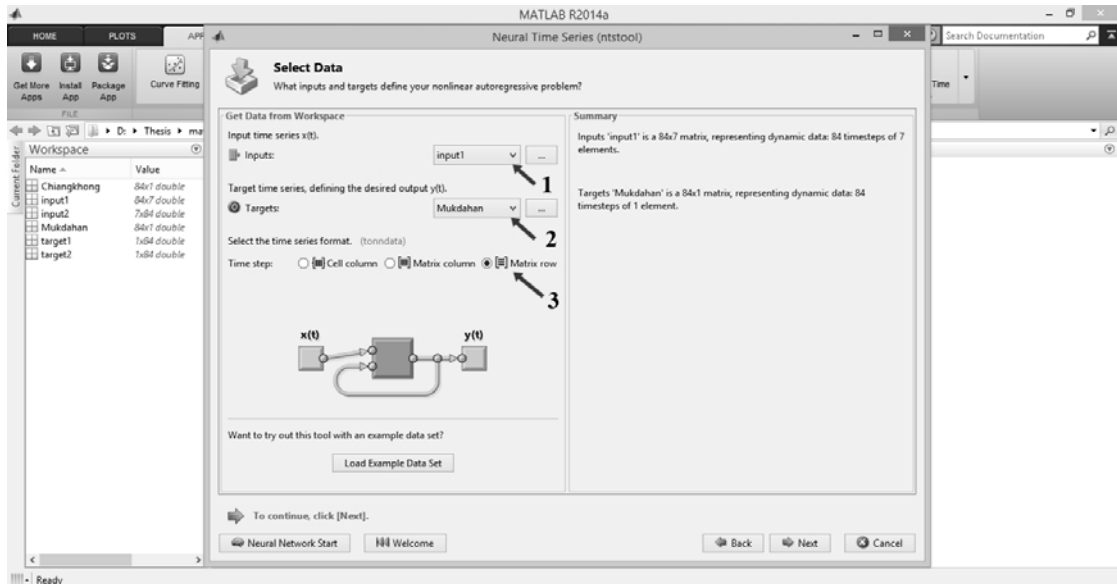
3) Click “Neural Net Time Series” in APPS menu.



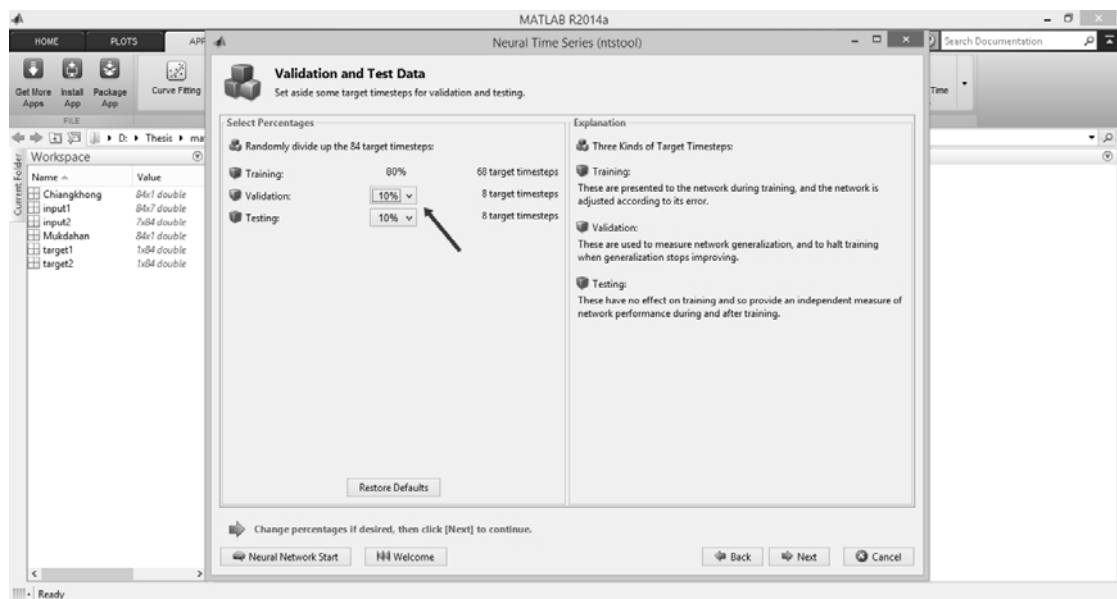
4) In Select a Problem box, choose Nonlinear Autoregressive with External (Exogenous) Input (NARX) and click Next button.



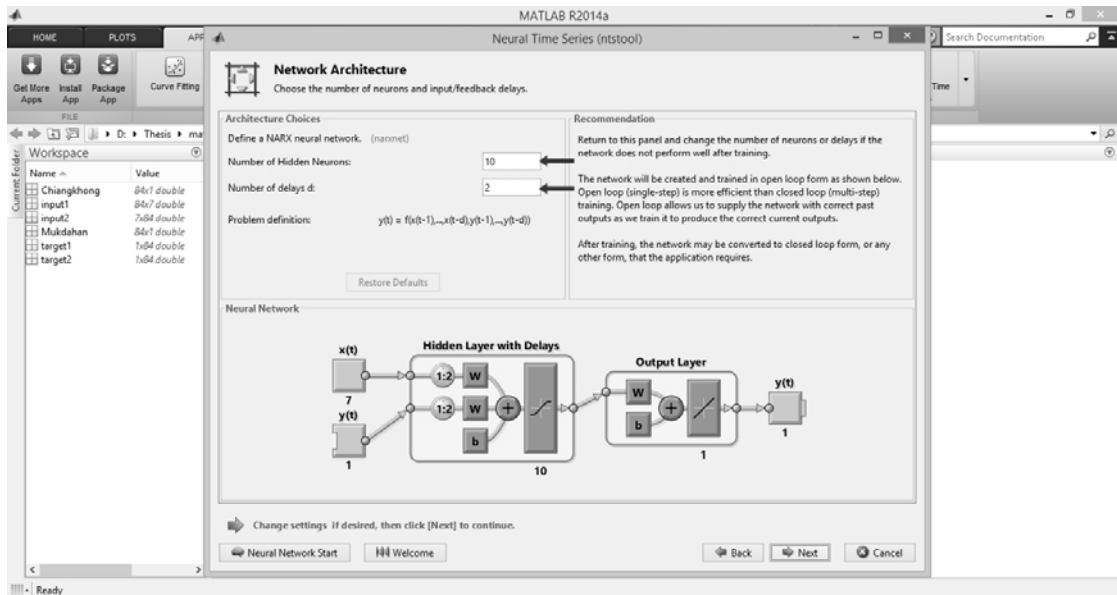
5) In Get Data from Workspace box, choose your input and target data for forecasting, select a time step format, and click Next.



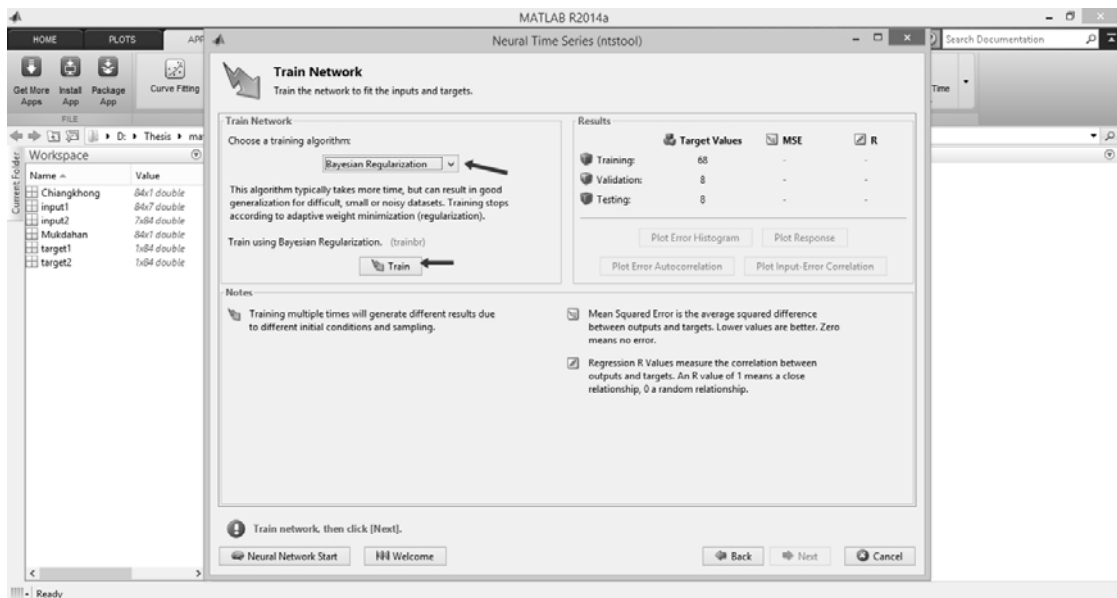
6) Set Training, Validation and Testing percentage as required. Then click Next.



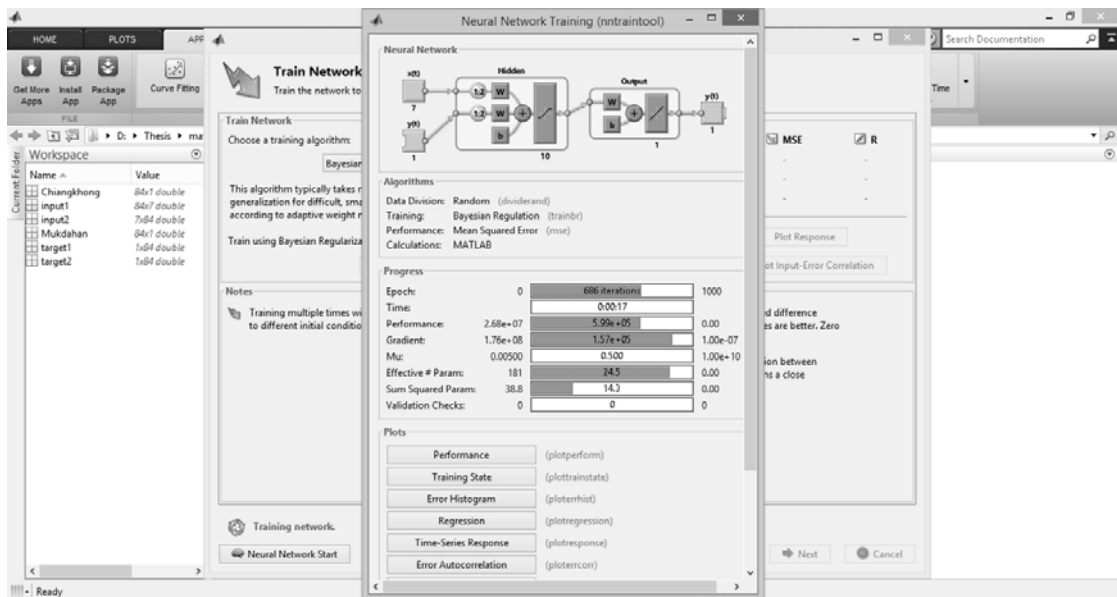
7) Set Number of Hidden Neurons and Number of delays d for create NARX neural network model.



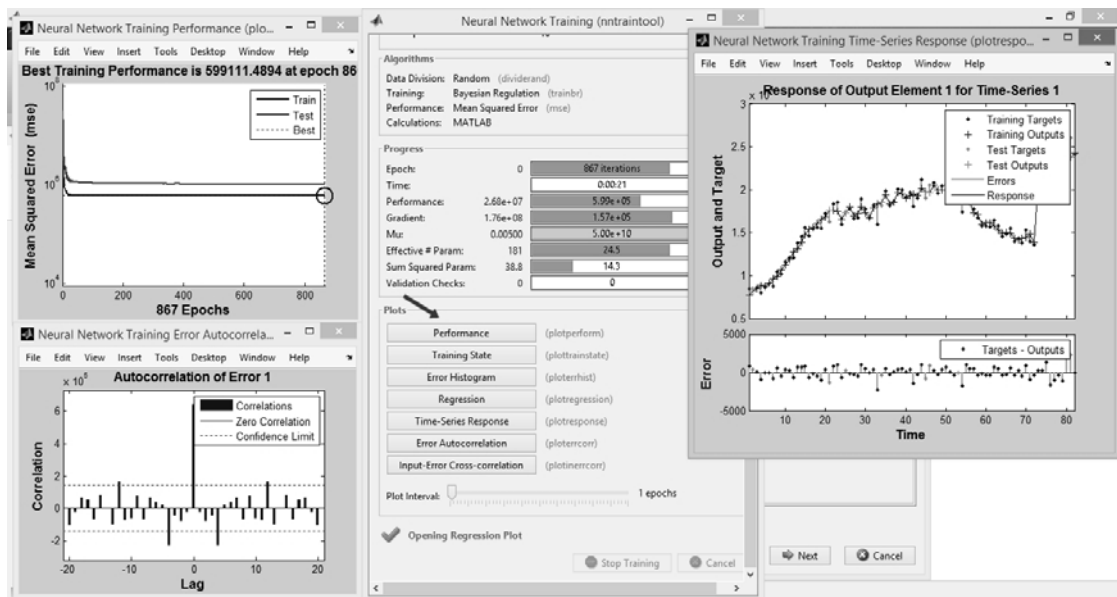
8) Choose a training algorithm to forecasting (This work uses Bayesian Regularization Algorithm) and click Train button.



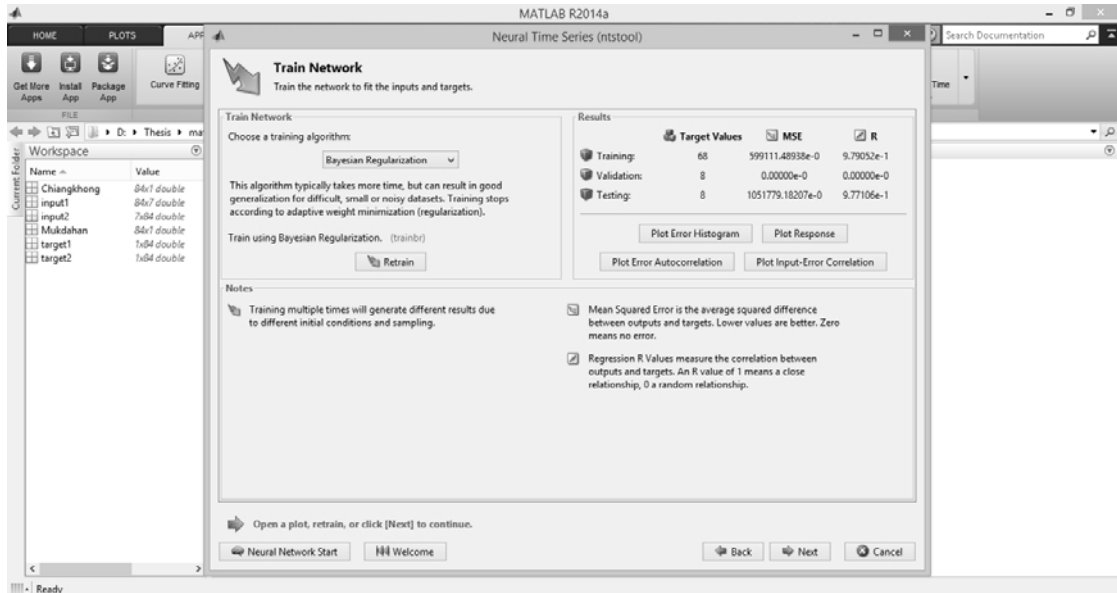
9) MATLAB shows the neural network training GUI (ntraintool).



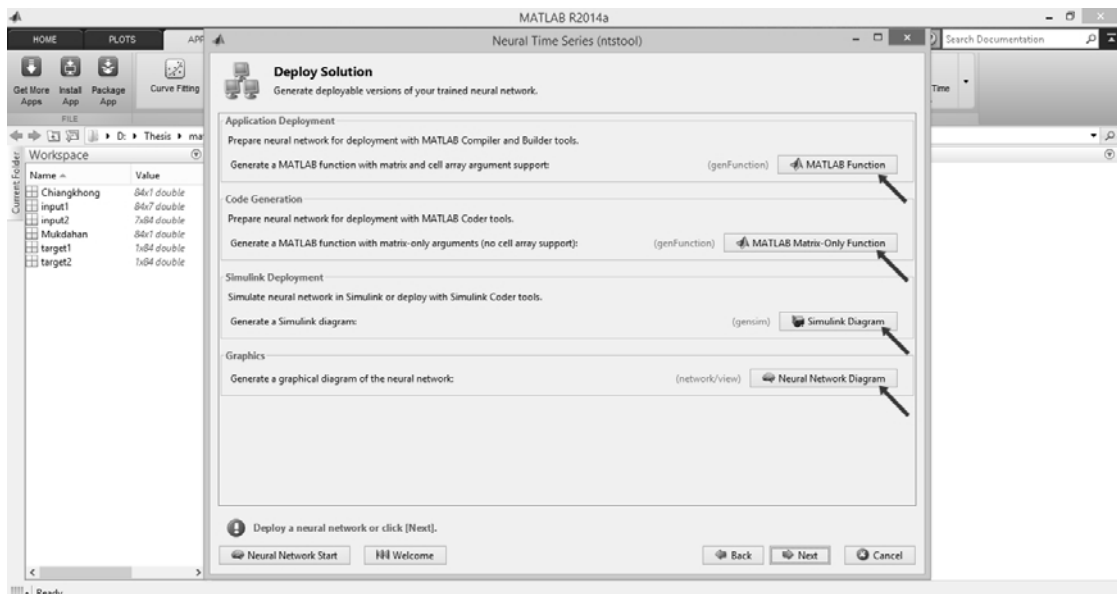
10) When the processing is finished, you can view a graphs. For example, Performance graph, Regression graph or Error Autocorrelation.



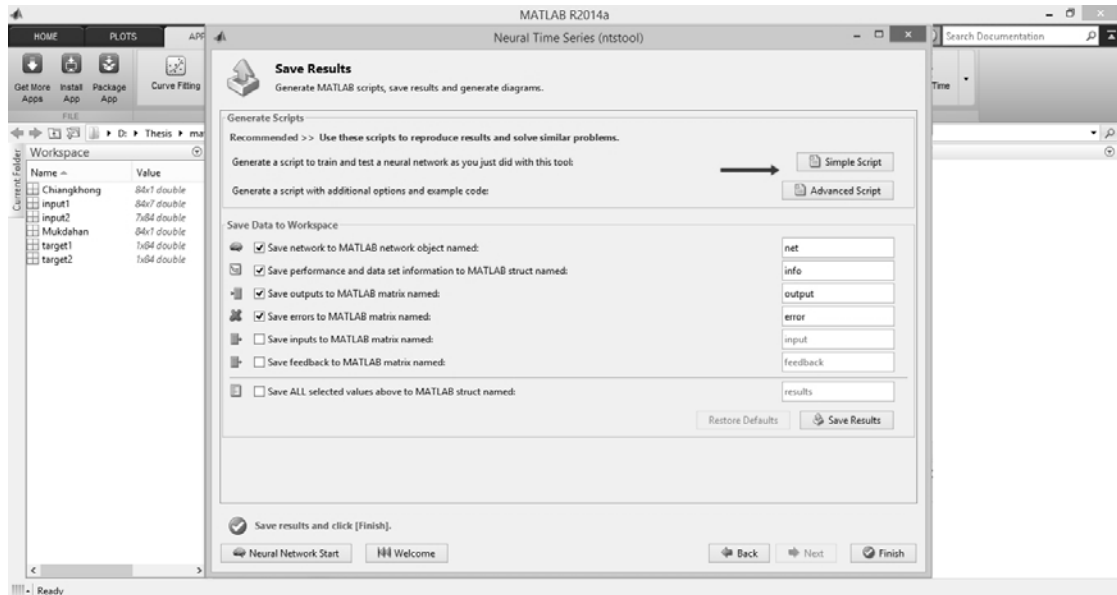
11) Close the neural network training GUI. If a training result is not desirable, you can train again by click Retrain button.



12) Later, you can generate a MATLAB function, a Simulink diagram, and a graphical diagram in Deploy Solution window.



13) The final is Save Results process. For example, save performance data set information, save outputs, and errors to MATLAB matrix named.



APPENDIX C

SOURCE CODE

The NARX model coding of Mukdahan's checkpoint

```
% Solve an Autoregression Problem with External Input with a NARX Neural Network
% Script generated by Neural Time Series app
% Created Wed Jul 08 11:26:40 ICT 2015
%
% This script assumes these variables are defined:
%
% input1 - input time series.
% Mukdahan - feedback time series.
X = tonndata(input1,false,false);
T = tonndata(Mukdahan,false,false);
% Choose a Training Function
% For a list of all training functions type: help ntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. NTSTOOL falls back to this in low memory situations.
trainFcn = 'trainbr'; % Bayesian Regularization
% Create a Nonlinear Autoregressive Network with External Input
for i = 2:2:10;
for j = 10:5:40;
for k = 1:5;
inputDelays = 1:i;
feedbackDelays = 1:i;
hiddenLayerSize = j;
net = narxnet(inputDelays,feedbackDelays,hiddenLayerSize,'open',trainFcn);
% Choose Input and Feedback Pre/Post-Processing Functions
```

```
% Settings for feedback input are automatically applied to feedback output
% For a list of all processing functions type: help nnprocess
% Customize input parameters at: net.inputs{i}.processParam
% Customize output parameters at: net.outputs{i}.processParam
net.inputs{1}.processFcns = {'removeconstantrows','mapminmax'};
net.inputs{2}.processFcns = {'removeconstantrows','mapminmax'};
% Prepare the Data for Training and Simulation
% The function PREPARETS prepares timeseries data for a particular network,
% shifting time by the minimum amount to fill input states and layer states.
% Using PREPARETS allows you to keep your original time series data unchanged,
while
% easily customizing it for networks with differing numbers of delays, with
% open loop or closed loop feedback modes.
[x,xi,ai,t] = preparets(net,X,{},T);
% Setup Division of Data for Training, Validation, Testing
% The function DIVIDERAND randomly assigns target values to training,
% validation and test sets during training.
% For a list of all data division functions type: help nndivide
net.divideFcn = 'dividerand'; % Divide data randomly
% The property DIVIDEMODE set to TIMESTEP means that targets are divided
% into training, validation and test sets according to timesteps.
% For a list of data division modes type: help nntype_data_division_mode
net.divideMode = 'value'; % Divide up every value
net.divideParam.trainRatio = 80/100;
net.divideParam.valRatio = 0/100;
net.divideParam.testRatio = 20/100;
% Choose a Performance Function
% For a list of all performance functions type: help nnperformance
% Customize performance parameters at: net.performParam
net.performFcn = 'mse'; % Mean squared error
% Choose Plot Functions
% For a list of all plot functions type: help nnplot
```

```
% Customize plot parameters at: net.plotParam
net.plotFcns = {'plotperform','plottrainstate','plotresponse','plotregression', ...
    'ploterrcorr', 'plotinerrcorr'};
% Train the Network
[net,tr] = train(net,x,t,xi,ai);
% Test the Network
y = net(x,xi,ai);
e = gsubtract(t,y);
performance = perform(net,t,y)
% Recalculate Training, Validation and Test Performance
trainTargets = gmultiply(t,tr.trainMask);
valTargets = gmultiply(t,tr.valMask);
testTargets = gmultiply(t,tr.testMask);
trainPerformance = perform(net,trainTargets,y)
valPerformance = perform(net,valTargets,y)
testPerformance = perform(net,testTargets,y)
% View the Network
view(net)
if (i==4)&&(j==10)&&(k==1);
    MSEold = performance;
    genFunction(net,'WeightandBias');
    y = WeightandBias(x,xi,ai);
n = plotperform(tr);
saveas(n,'Performance.fig')
m = plottrainstate(tr);
saveas(m,'Train.fig')
o = plotregression(t,y);
saveas(o,'Regression.fig')
p = plotresponse(t,y);
saveas(p,'Response.fig')
q = ploterrcorr(e);
saveas(q,'Autocorrelation.fig')
```

```
r = plotinerrcorr(x,e);
saveas(r,'Crosscorrelation.fig')
end
if MSEold < performance ;
else
    MSEold = performance
    genFunction(net,'WeightandBias');
y = WeightandBias(x,xi,ai);
n = plotperform(tr);
saveas(n,'Performance.fig')
m = plottrainstate(tr);
saveas(m,'Train.fig')
o = plotregression(t,y);
saveas(o,'Regression.fig')
p = plotresponse(t,y);
saveas(p,'Response.fig')
q = ploterrcorr(e);
saveas(q,'Autocorrelation.fig')
r = plotinerrcorr(x,e);
saveas(r,'Crosscorrelation.fig')
end
% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, plotregression(t,y)
%figure, plotresponse(t,y)
%figure, ploterrcorr(e)
%figure, plotinerrcorr(x,e)
% Closed Loop Network
% Use this network to do multi-step prediction.
% The function CLOSELOOP replaces the feedback input with a direct
```

```

% connection from the outout layer.
netc = closeloop(net);
netc.name = [net.name ' - Closed Loop'];
view(netc)
[xc,xic,aic,tc] = preparets(netc,X, {},T);
yc = netc(xc,xic,aic);
closedLoopPerformance = perform(netc,tc,yc)
% Multi-step Prediction
% long as there is known output data, and then switch to closed-loop form
% to perform multistep prediction while providing only the external input.
% Here all but 5 timesteps of the input series and target series are used to
% simulate the network in open-loop form, taking advantage of the higher
% accuracy that providing the target series produces:
numTimesteps = size(x,2);
knownOutputTimesteps = 1:(numTimesteps-5);
predictOutputTimesteps = (numTimesteps-4):numTimesteps;
X1 = X(:,knownOutputTimesteps);
T1 = T(:,knownOutputTimesteps);
[x1,xio,aio] = preparets(net,X1, {},T1);
[y1,xfo,afo] = net(x1,xio,aio);
% Next the the network and its final states will be converted to closed-loop
% form to make five predictions with only the five inputs provided.
x2 = X(1,predictOutputTimesteps);
[netc,xic,aic] = closeloop(net,xfo,afo);
[y2,xfc,afc] = netc(x2,xic,aic);
multiStepPerformance = perform(net,T(1,predictOutputTimesteps),y2)
% Alternate predictions can be made for different values of x2, or further
% predictions can be made by continuing simulation with additional external
% inputs and the last closed-loop states xfc and afc.
% Step-Ahead Prediction Network
% For some applications it helps to get the prediction a timestep early.
% The original network returns predicted y(t+1) at the same time it is given y(t+1).

```

```
nets = removedelay(net);
nets.name = [net.name ' - Predict One Step Ahead'];
view(nets)
[xs,xis,ais,ts] = preparets(nets,X, {},T);
ys = nets(xs,xis,ais);
stepAheadPerformance = perform(nets,ts,ys)
if (false)
% in MATLAB scripts or with MATLAB Compiler and Builder tools, or simply
  genFunction(net,' WeightandBias');
  y = WeightandBias(x,xi,ai);
end
if (false)
  % Generate a matrix-only MATLAB function for neural network code
  % generation with MATLAB Coder tools.
  genFunction(net,'WeightandBias','MatrixOnly','yes');
  x1 = cell2mat(x(1,:));
  x2 = cell2mat(x(2,:));
  xi1 = cell2mat(xi(1,:));
  xi2 = cell2mat(xi(2,:));
  y = WeightandBias(x1,x2,xi1,xi2);
end
if (false)
  % Generate a Simulink diagram for simulation or deployment with.
  % Simulink Coder tools.
  gensim(net);
end
i
j
k
end
end
end
```

The NARX model coding of Chiang Khong's checkpoint

```
% Solve an Autoregression Problem with External Input with a NARX Neural Network
% Script generated by Neural Time Series app
% Created Wed Jul 08 11:26:40 ICT 2015
%
% This script assumes these variables are defined:
%
% input1 - input time series.
% Mukdahan - feedback time series.
X = tonndata(input1,false,false);
T = tonndata(Chiangkhong,false,false);
% Choose a Training Function
% For a list of all training functions type: help ntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. NTSTOOL falls back to this in low memory situations.
trainFcn = 'trainbr'; % Bayesian Regularization
% Create a Nonlinear Autoregressive Network with External Input
for i = 2:2:10;
for j = 10:5:40;
for k = 1:5;
inputDelays = 1:i;
feedbackDelays = 1:i;
hiddenLayerSize = j;
net = narxnet(inputDelays,feedbackDelays,hiddenLayerSize,'open',trainFcn);
% Choose Input and Feedback Pre/Post-Processing Functions
% Settings for feedback input are automatically applied to feedback output
% For a list of all processing functions type: help nnprocess
% Customize input parameters at: net.inputs{i}.processParam
% Customize output parameters at: net.outputs{i}.processParam
net.inputs{1}.processFcns = {'removeconstantrows','mapminmax'};
net.inputs{2}.processFcns = {'removeconstantrows','mapminmax'};
```

```
% Prepare the Data for Training and Simulation
% The function PREPARETS prepares timeseries data for a particular network,
% shifting time by the minimum amount to fill input states and layer states.
% Using PREPARETS allows you to keep your original time series data unchanged,
while
% easily customizing it for networks with differing numbers of delays, with
% open loop or closed loop feedback modes.
[x,xi,ai,t] = preparets(net,X, {},T);
% Setup Division of Data for Training, Validation, Testing
% The function DIVIDERAND randomly assigns target values to training,
% validation and test sets during training.
% For a list of all data division functions type: help nndivide
net.divideFcn = 'dividerand'; % Divide data randomly
% The property DIVIDEMODE set to TIMESTEP means that targets are divided
% into training, validation and test sets according to timesteps.
% For a list of data division modes type: help nntype_data_division_mode
net.divideMode = 'value'; % Divide up every value
net.divideParam.trainRatio = 80/100;
net.divideParam.valRatio = 0/100;
net.divideParam.testRatio = 20/100;
% Choose a Performance Function
% For a list of all performance functions type: help nnperformance
% Customize performance parameters at: net.performParam
net.performFcn = 'mse'; % Mean squared error
% Choose Plot Functions
% For a list of all plot functions type: help nnplot
% Customize plot parameters at: net.plotParam
net.plotFcns = {'plotperform','plottrainstate','plotresponse','plotregression', ...
    'ploterrcorr', 'plotinerrcorr'};
% Train the Network
[net,tr] = train(net,x,t,xi,ai);
% Test the Network
```

```
y = net(x,xi,ai);
e = gsubtract(t,y);
performance = perform(net,t,y)
% Recalculate Training, Validation and Test Performance
trainTargets = gmultiply(t,tr.trainMask);
valTargets = gmultiply(t,tr.valMask);
testTargets = gmultiply(t,tr.testMask);
trainPerformance = perform(net,trainTargets,y)
valPerformance = perform(net,valTargets,y)
testPerformance = perform(net,testTargets,y)
% View the Network
view(net)
if (i==4)&&(j==10)&&(k==1);
    MSEold = performance;
    genFunction(net,'WeightandBias');
    y = WeightandBias(x,xi,ai);
    n = plotperform(tr);
    saveas(n,'Performance.fig')
    m = plottrainstate(tr);
    saveas(m,'Train.fig')
    o = plotregression(t,y);
    saveas(o,'Regression.fig')
    p = plotresponse(t,y);
    saveas(p,'Response.fig')
    q = ploterrcorr(e);
    saveas(q,'Autocorrelation.fig')
    r = plotinerrcorr(x,e);
    saveas(r,'Crosscorrelation.fig')
end
if MSEold < performance ;
else
    MSEold = performance
```

```
genFunction(net,'WeightandBias');
y = WeightandBias(x,xi,ai);
n = plotperform(tr);
saveas(n,'Performance.fig')
m = plottrainstate(tr);
saveas(m,'Train.fig')
o = plotregression(t,y);
saveas(o,'Regression.fig')
p = plotresponse(t,y);
saveas(p,'Response.fig')
q = ploterrcorr(e);
saveas(q,'Autocorrelation.fig')
r = plotinerrcorr(x,e);
saveas(r,'Crosscorrelation.fig')
end
% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, plotregression(t,y)
%figure, plotresponse(t,y)
%figure, ploterrcorr(e)
%figure, plotinerrcorr(x,e)
% Closed Loop Network
% Use this network to do multi-step prediction.
% The function CLOSELOOP replaces the feedback input with a direct
% connection from the outout layer.
netc = closeloop(net);
netc.name = [net.name ' - Closed Loop'];
view(netc)
[xc,xic,aic,tc] = preparets(netc,X,{},T);
yc = netc(xc,xic,aic);
```

```

closedLoopPerformance = perform(netc,tc,yc)
% Multi-step Prediction
% Sometimes it is useful to simulate a network in open-loop form for as
% long as there is known output data, and then switch to closed-loop form
% to perform multistep prediction while providing only the external input.
% Here all but 5 timesteps of the input series and target series are used to
% simulate the network in open-loop form, taking advantage of the higher
% accuracy that providing the target series produces:
numTimesteps = size(x,2);
knownOutputTimesteps = 1:(numTimesteps-5);
predictOutputTimesteps = (numTimesteps-4):numTimesteps;
X1 = X(:,knownOutputTimesteps);
T1 = T(:,knownOutputTimesteps);
[x1,xio,aio] = preparets(net,X1, {},T1);
[y1,xfo,afo] = net(x1,xio,aio);
% Next the the network and its final states will be converted to closed-loop
% form to make five predictions with only the five inputs provided.
x2 = X(1,predictOutputTimesteps);
[netc,xic,aic] = closeloop(net,xfo,afo);
[y2,xfc,afc] = netc(x2,xic,aic);
multiStepPerformance = perform(net,T(1,predictOutputTimesteps),y2)
% Alternate predictions can be made for different values of x2, or further
% predictions can be made by continuing simulation with additional external
% inputs and the last closed-loop states xfc and afc.
% Step-Ahead Prediction Network
% For some applications it helps to get the prediction a timestep early.
% The original network returns predicted  $y(t+1)$  at the same time it is given  $y(t+1)$ .
% For some applications such as decision making, it would help to have predicted
%  $y(t+1)$  once  $y(t)$  is available, but before the actual  $y(t+1)$  occurs.
% The network can be made to return its output a timestep early by removing one delay
% so that its minimal tap delay is now 0 instead of 1. The new network returns the
% same outputs as the original network, but outputs are shifted left one timestep.

```

```
nets = removedelay(net);
nets.name = [net.name ' - Predict One Step Ahead'];
view(nets)
[xs,xis,ais,ts] = preparets(nets,X, {},T);
ys = nets(xs,xis,ais);
stepAheadPerformance = perform(nets,ts,ys)
if (false)
    % Generate MATLAB function for neural network for application deployment
    % in MATLAB scripts or with MATLAB Compiler and Builder tools, or simply
    % to examine the calculations your trained neural network performs.
    genFunction(net,' WeightandBias');
    y = WeightandBias(x,xi,ai);
end
if (false)
    genFunction(net,'WeightandBias','MatrixOnly','yes');
    x1 = cell2mat(x(1,:));
    x2 = cell2mat(x(2,:));
    xi1 = cell2mat(xi(1,:));
    xi2 = cell2mat(xi(2,:));
    y = WeightandBias(x1,x2,xi1,xi2);
end
if (false)
    % Generate a Simulink diagram for simulation or deployment with.
    % Simulink Coder tools.
    gensim(net);
end
i
j
k
end
end
end
```

APPENDIX D

TRANSPORTATION FORECASTING AND EFFECTS ON THAILAND – LAOS BORDER CROSSING POINTS AFTER OPENING OF THE ASEAN ECONOMIC COMMUNITY



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Transportation Forecasting and Effects on Thailand-Laos Border Crossing Points after Opening of The ASEAN Economic Community

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Abstract

There are several factors affecting vehicle volumes. When the demand for vehicle increases, transport infrastructure development, such as number of lanes, and highway connection, needs to be prepared in advance. It is necessary to plan and predict traffic flow in the future using existing information. In addition, the opening of the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC) is another major factor that will cause free movement of population among the AEC countries which will result in an increased demand of vehicles. In this work, the amount of vehicles in Thailand and Laos, traffic flow on the border of Thailand-Laos, effects that may occur after the launch of the AEC, and the ability to handle the volume of Thailand-Laos cross-border vehicles are studied. In order to predict traffic flow, a nonlinear auto regressive with exogenous input (NARX) is utilized. The NARX model can forecast the traffic flow on the border with the lowest mean square error (MSE) of Mukdahan's checkpoint at 1.0724 and the lowest MSE of Chiang Khong's checkpoint at 0.2351. This study can be applied to other Thailand's cross border by adjusting the relative factors depending on each border situation.

Keywords: Forecasting, Traffic, Nonlinear auto regressive with exogenous input

1. Introduction

Thailand is regarded as the center of ASEAN with respect to business, tourism, and so forth. The location of the country provides easy access to various countries in the ASEAN region. The most popular and convenient means of transportation is ground transportation.

Due to an increase in population and other contributing factors, current volume of vehicles has increased steadily every year. In addition, the opening of AEC in 2015 will result in more travels among member countries. Therefore, traffic flow prediction is one of methods that would assist in planning and developing of ground transports as well as traffic routes along the border in the future. The border of Thailand can be classified into three cross border categories, including permanent cross border, temporary cross border and informal cross border. There is inadequate

availability of crossing's infrastructure causing congestion and inflexibilities in logistics, freights, and neighborhood tourism, such as Laos, Myanmar, Cambodia, and Malaysia. This work will be focused on Thailand-Laos border, which is also a pathway to Vietnam and China.

NARX is utilized in predicting the traffic flows. Mukdahan and Chiang Khong crossing point are chosen as examples in the study as shown in Figure 1. The information and references used in this work have been compiling from the Office of Transport and Traffic Policy and Planning, Customs Department and other trustworthy websites [1] to acquire the most accurate predictions. It issued as a guide in developing the Thailand borders and also to accommodate the number of vehicles that will be changing after the AEC in the future.

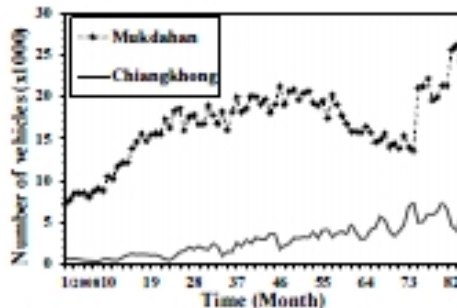


Figure 1 Number of vehicles accessing cross-border from the year 2008 to 2014

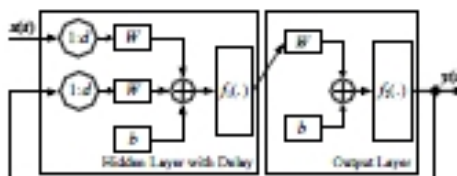


Figure 2 Simple block diagram of NARX

2. Literature Review

2.1 Theory of Time Series Forecasting

Time series refers to information that shows the movement which changes over time as part of an ongoing basis, may be collected monthly, quarterly or annually depending on benefits that will be used. Four components of time series are as follows:

1. Long term trend (*T*) represents movement or change of information in long-term period for example Thailand's electricity consumption, imports of crude oil, etc.
2. Seasonal variation (*S*) refers to seasonal changes which occurred repeatedly in the past one year and have become a pattern, such as rice yield is higher in the first quarter of the year, sales of shopping mall tend to increase at the end of the year. Seasonal variation is measured in the form of seasonal index.
3. Cyclical variation (*C*) refers to movement that follows the cycle. This movement cycles are said to be similar to seasonal variation, but have a longer period of life.
4. Irregular variation (*I*) is a variation of uncertainty which cannot be predicted in advance, such as natural disasters, wars, strikes [2-3].

From the aforementioned components, if *Y* represents a set of time series data, the simulation model can be divided into 2 types:

1. Additive model is a sum of the four components

$$Y = T + S + C + I \quad (1)$$

2. Multiplicative model is a product of the four components

$$Y = T \times S \times C \times I \quad (2)$$

From equations (1) and (2), separation of components can be done in several methods such as autoregressive (AR) models, integrated (*I*) models, and moving average (MA) models. Moreover, there are also other techniques that do not require a separate component of the signal which are nonlinear autoregressive models (NAR) and NARX. These techniques demand the use of computer to facilitate in solving. In this work, NARX is selected as forecasting methods because external factors are utilized.

2.2 Nonlinear Autoregressive with Exogenous Input

Nonlinear Autoregressive with exogenous input (NARX) is one of the time series forecasting model. NARX model utilizes artificial neural network containing neurons, which model from the work of human brain. The simple block diagram of nonlinear autoregressive models with exogenous input is illustrated in Figure 2 in order to model time series up. From Figure 2, we can see that NARX consists of two layers, i.e., hidden and output layers. In both layers, i.e., hidden and output layers, contain transfer functions $f_1(\cdot)$, $f_2(\cdot)$, weight *W*, bias value *b*, and tapped delay line with *d* buffers. These parameters can be any value depending on training process [4].

In the hidden layer with delay, input data *x(t)* feeds into the tapped delay line and the output of the tapped delay line is weighted with *W* and becomes an input data of the transfer function $f_1(\cdot)$. The output of transfer function is sent to next layer. In the



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output layer, the same process with hidden layer is performed except using the different value of $f_2(\cdot)$, W , and b .

2.3 Related Work

There are a few works that focus on the transportation forecasting and NARX. Those works can be summarized as follows.

Wen D. and Siji H. [5] used the grey Verhulst model to describe the development tendency of vehicle population and to forecast the vehicle population in the next 20 years in China. A nonlinear combination forecasting model is backpropagation (BP) neural network. Result of the vehicle population of China is growing up in the next 20 years.

Chuanjin J. and Fugen S. [6] used nonlinear autoregressive with exogenous input and chaotic time series analysis to forecast sunspot. It is compared with BP neural network and ARIMA. This work takes the sunspot number in 310 years from 1700 to 2009 as time series sample. The result shows that forecasting with NARX network is more accurate than BP neural network and ARIMA model.

Teerachai L. [7] used the nonlinear model applies the NARX and polynomial equation for forecasting the latex volume. The model uses correlation of meteorological parameter data such as mean air temperature, mean dew point temperature, and etc. The results are found that the errors are not over $\pm 5\%$ compared with the real volume of latex.

3. Implementation

3.1 Data Collection

The data used in this work have been compiled from the Office of Transport and Traffic Policy and Planning, Customs Department, Transport Statistics Sub-Division, Planning Division, The World bank, and ASEAN-Japan Transport Partnership. These agencies have collected statistical information on number of vehicles accumulated within the country, values of Gross Domestic Product (GDP) of each country in ASEAN region, number of

vehicles access cross-borders as well as infrastructure and transport of Thailand.

This work is primarily focused on Thailand and Laos, where the variables used in the forecast are 4 input variables, including cumulative number of vehicles in Thailand and Laos, Thailand's GDP per Capita, and Laos' GDP per Capita. The output variable is the number of vehicles access Thailand-Laos border which Mukdahan's checkpoint and Chiang Khong's checkpoint are selected as samples for forecasting. Monthly data from January 2008 to December 2014 are used.

3.2 Transportation Forecasting

This work has applied the NARX for forecasting traffic flow in Thailand-Laos border crossing points. The neural networks which is used in the work will adjust W in accordance to the nodes. The adjustment is based on differences of the output $y(t)$ that was calculated from four input variables and one desired variable by predicting one border at a time.

Data as described in Subsection 3.1 are applied to neural training process of NARX model. In this work, there are four input data sets called "input" and one output data set called "target". These data sets are randomly separated into 3 parts, i.e., training set, validation set, and test set. The training set indicates the neural network to recognize a relationship between the input and output produced by the open-loop model. The validation set is data set for verifying accuracy of the data. The test set is a data set used in neural network testing that have been predicted by neural network. There are various conditions that need to be set beforehand, including number of neurons in the hidden layer, delays, model variations of NARX, number of input, number of target, numbers of training set, validation set, and also test set. The training condition is shown in Table 1. Bayesian regularization is an algorithm approach used in this paper. It is suitable for limited amount of data set, noisy data, and free validation data. This method may be time-consuming than other algorithms [8].



Table 1 Training Conditions

Conditions	Mukdahan	Chiang Khong
Hidden Neurons	10	10
Delay	2	2
NARX Model	Open-loop	Open-loop
Input	84 × 4	84 × 4
Target	84 × 1	84 × 1
Training Set	80%	80%
Validation Set	0%	0%
Test Set	20%	20%

4. Results

After training the NARX model with the condition provided in Table 1, the output of the NARX model is obtained as presented in this section.

4.1 Time-Series Response

Graphs respond to the output and target of the training data and test data by the x-axis represents the number of months of data and the y-axis represents the traffic flow by target and output. These values are similar as seen in Figures 3 and 4.

4.2 Regression

Correlation coefficient (R) is a measure of linear relationship of two variables in this case refers to Target and Output. The value of Mukdahan and Chiang Khong correlation coefficient are 0.96428 and 0.96432, respectively, as shown in Figures 5 and 6.

4.3 Error Autocorrelation

Figures 7 and 8 illustrate error autocorrelation where the y-axis represents the lag and the x-axis represents the correlation. We can see that most of the error autocorrelation values are smaller than the confidence limit value.

4.4 Mean Square Error

The error occurred in the mean square error (MSE) is calculated by the equation 3

$$MSE = \frac{\sum_{i=1}^N (T_i - I_i)^2}{N}, \quad (3)$$

where

T_i is volume of traffic flow from the target,
 I_i is amount of vehicles calculated by the model,
 N is number of data.

The lowest mean square error of Mukdahan's checkpoint is 1.0724 while the lowest mean square error of Chiang Khong's checkpoint is 0.2351.

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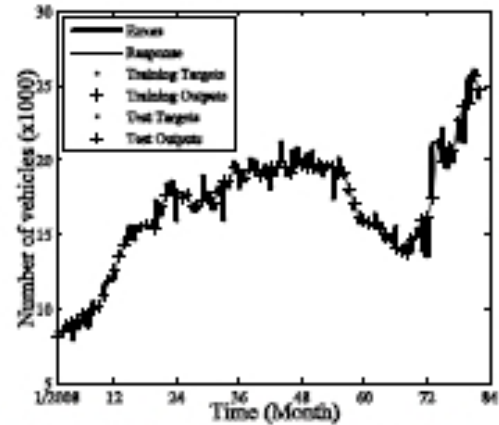


Figure 3 Time-Series response graph of Mukdahan border crossing point

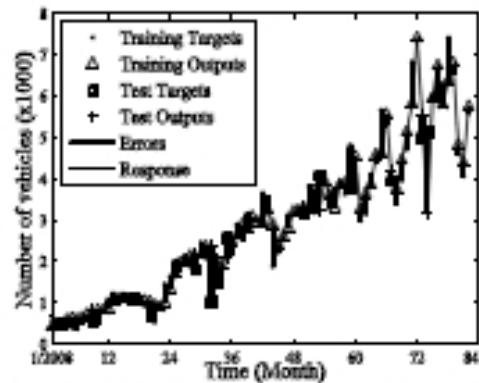


Figure 4 Time-Series response graph of Chiang Khong border crossing point

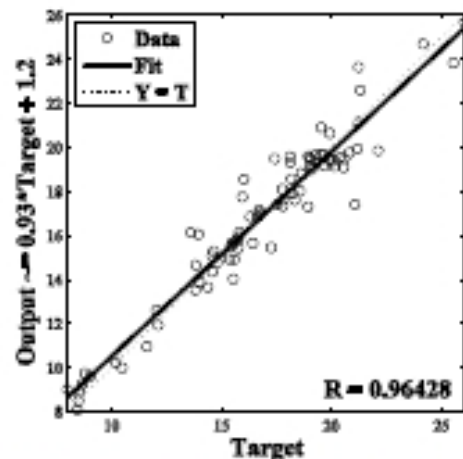


Figure 5 Regression graph of Mukdahan border crossing point



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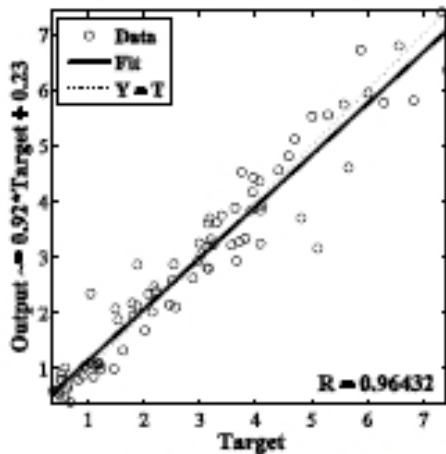


Figure 6 Regression graph of Chiang Khong border crossing point

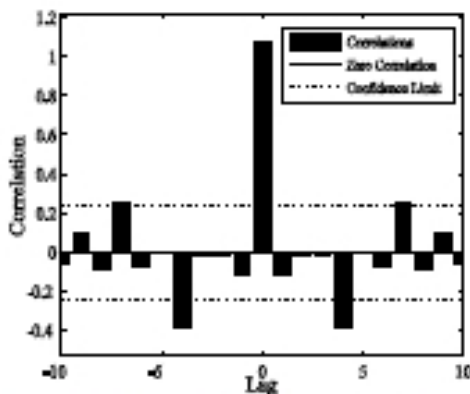


Figure 7 Error autocorrelation function of Mukdahan border crossing point

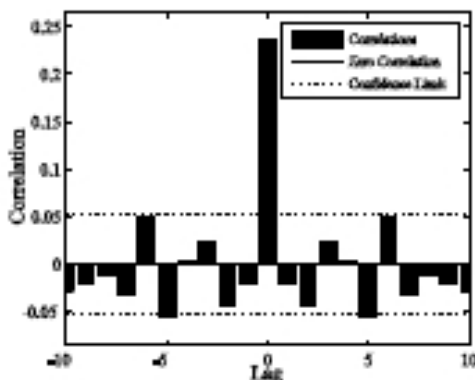


Figure 8 Error autocorrelation function of Chiang Khong border crossing point

5. Effects of AEC to Border Crossing Points

Thailand is a member of AEC. The objective is to establish a single market by having the same rules and regulations. Compared with other members of the AEC, Thailand has advantages in many ways, for example, the location where we are becoming the center of transportation; bordering the most countries in the region as well as becoming a production base of industrial and agricultural products. These strengths make Thailand have a high potential for the AEC economic, i.e., trade and investment. Thus, it is significant to be prepared in opening of the AEC in December 31, 2015.

This section presents examples of impact place on Thailand-Laos borders after opening of the AEC. Based on the information collected from Nong Khai checkpoint, which is a permanent checkpoint with the first Thai-Lao Friendship Bridge connecting to Vientiane, passport holders can pass the immigration. However, those who do not have passport or border pass must be obtained at another office away from the border checkpoint. Nong Khai checkpoint is divided into immigration section and customs vehicles check section. The vehicles check point has three channels for personal vehicle, one channel for bus and coach, and one channel for diplomatic. The immigration procedure takes about 5 minutes per person. The customs vehicles check will take about 15 minutes to inspect one vehicle. Upon completion of these procedures, travelers are now able to cross to the Laos side.

From the foregoing, it is observed that Nong Khai checkpoint is experiencing the following issues:

1. People without passport will be required to obtain border pass at another place; border pass cannot be issued right away at the checkpoint.
2. Customs vehicles check channels are not enough. It may cause delays process if there is a large number of vehicles crossing.



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3. People without vehicles will have to queue to buy bus tickets.

The opening of AEC will increase a number of vehicles crossing the borders according to the forecast in Mukdahan's and Chiang Khong's checkpoints which will affect the traffic flow at border crossing points and may be further delay in procedures. Potential of the border today may not be sufficient to accommodate more vehicles that are rising. Therefore, it is necessary to study and improve the border of Thailand to be ready for the near future.

6. Conclusion

This work uses NARX to forecast the traffic flow of Mukdahan and Chiang Khong checkpoints. For Mukdahan's checkpoint results, we can see that graph pattern is consisted only of trend signal. While result of Chiang Khong's checkpoint consisted of trend and seasonal signals.

The correlation coefficient R is equal to 0.96428 and 0.96432. This implies that the target and output has a positive relationship. In addition, the MSE is as low as 1.0724 and 0.2351, holding that the forecast is accurate and correct.

Forecasting of the traffic flow could be the prophet to give benefits to the country to prepare for the improvement and development of the border of Thailand to better devoted in the AEC to come. The forecast using NARX is a new and interesting methodology which can be used to forecasting other constraints.

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Points after Opening of The ASEAN Economic Community*

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