การพยากรณ์ปริมาณรถยนต์เข้าออกและผลกระทบต่อสภาพการจราจรด่านชายแดนไทย-ลาวหลังเปิดประชาคมอาเซียน

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

จวงจันทน์ จันทร์กระจ่าง[1*] ทวีศักดิ์ สมานชื่น[2]
[1,2] สาขาวิชาเทคโนโลยีการจัดการระบบสารสนเทศ คณะวิศวกรรมศาสตร์
มหาวิทยาลัยมหิดล อ. พุทธมณฑล จ. นครปฐม 73170
E-mail: juangjan.cha@student.mahidol.ac.th[1*]
E-mail: taweesak.sam@mahidol.ac.th[2]

Juangjan Chankrachang[1*] Taweesak Samanchuen[2]
[1,2]Technology of Information System Management Division, Faculty of Engineering,
Mahidol University, Phutthamonthon, Nakornpathom, 73170
E-mail: juangjan.cha@student.mahidol.ac.th[1*]
E-mail: taweesak.sam@mahidol.ac.th[2]

บทคัดย่อ

การเดินทางสัญจรไปมาระหว่างประเทศต่างๆ ในปัจจุบันมีปริมาณมากขึ้น โดยเฉพาะการเดินทางทางบกโดยรถยนต์เป็นทางเลือกหนึ่งที่สะดวกและง่ายต่อการเดินทางเหมาะสำหรับประเทศที่มีชายแดนติดกัน เมื่อการเดินทางผ่านด่านชายแดนเพิ่มขึ้นความจำเป็นในการพัฒนาโครงสร้างพื้นฐานอาทิเช่น พื้นที่ผิวในการจราจรและช่องทางการจราจรจึงต้องเพิ่มประสิทธิภาพตามไปด้วย ดังนั้นการวางแผนพัฒนาจึงมีความจำเป็นที่จะต้องคาดการณ์ปริมาณรถยนต์ในอนาคต นอกจากนั้นการเปิดประชาคมอาเซียนเป็นอีกปัจจัยหลักปัจจัยหนึ่งที่จะทำให้เกิดการเดินทางไปมาระหว่างประเทศกันง่ายขึ้น ซึ่งจะส่งผลให้เกิดความต้องการเดินทางไปมาระหว่างประเทศเพิ่มขึ้นตามไปด้วย ในงานวิจัยนี้ได้ศึกษาปริมาณรถยนต์เข้าออกของด่านชายแดนไทย-ลาว ผลกระทบที่อาจจะเกิดขึ้นหลังจากการเปิดประชาคมอาเซียนและความสามารถของการรองรับปริมาณรถยนต์ของด่านชายแดนไทย-ลาว โดยวิธีการพยากรณ์ปริมาณรถยนต์ของงานวิจัยได้ใช้โครงสร้างแบบถดถอยด้วยตัวเองกับข้อมูลป้อนเข้าภายนอกไม่เชิงเส้นพยากรณ์รถยนต์เข้าออกด่านชายแดนมุกดาหารและด่านเชียงของ ผลจากการวิจัยพบว่าค่าสัมประสิทธิ์สหสัมพันธ์มีค่าเป็นบวกถือว่าเป็นสหสัมพันธ์ทางบวก และค่าเฉลี่ยความคลาดเคลื่อนกำลังสองที่ได้มีค่าต่ำถือได้ว่าการพยากรณ์มีความแม่นยำและถูกต้อง ดังนั้นสามารถนำข้อมูลการพยากรณ์ไปใช้เป็นแนวทางในการปรับปรุงพัฒนาด่านชายแดนต่างๆ เพื่อเตรียมความพร้อมในอนาคตและการเปิดประชาคมอาเซียน อีกทั้งไปประยุกต์ใช้กับการศึกษาด่านชายแดนประเทศไทยกับประเทศอื่นๆ ได้

คำหลัก การพยากรณ์, การจราจร, โครงสร้างแบบถดถอยตัวเองกับข้อมูลป้อนเข้าภายนอกไม่เชิงเส้น

Abstract

Traveling between countries these days has significantly increased in volume than before. Land transport by cars is regarded as one of the most convenient and suitable for countries with contiguous borders. When traveling through borders becomes in demand, an increase in the need for infrastructure development such as surface area and traffic lanes will therefore have to be optimized. As such, development planning is required to forecast future car volume by using currently available resources. In addition, the opening of the ASEAN Economic Community (AEC) is another major factor that will cause extensive travels between countries. This study examined the volume of vehicles travelling between Thailand - Laos borders, the impact that may arise after the launch of the AEC and the ability to handle the volume of cross-border vehicles. Nonlinear auto regressive with exogenous input (NARX) was utilized for forecasting the traffic volume on the Mukdahan checkpoint and the Chiang Khong checkpoint. The results illustrate that the correlation coefficient is positive and the mean square error (MSE) is relatively low which implies that NARX is an accurate and a precise method. Hence, the forecast information from NARX can be used as a guide to improve cross-border services in order to prepare for the future, the opening of the AEC and applied to any Thailand's borders with other countries.

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. The information and references used in this work have been compiling from the Office of Transport and Traffic Policy and Planning, Customs Department, Mukdahan Customs House, Chiang Khong Customs and other trustworthy websites [1-3] 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.

2. Literature Review

2.1 Cross-Border

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

1) Permanent border crossing,

2) Temporary border crossing,

3) Relief border crossing.

The borders of Thailand and Laos are in total of 47 crossing points. From the aforementioned Thailand-Laos cross borders, two main crossing points were chosen for this work, including Mukdaharn and Chiang Khong.

2.1.1 Departure procedures from Thailand to Laos by private vehicles

Figure 1 is a border crossing procedure from Thailand to Laos by cars. There are separated into two steps, departure and arrival steps.

Departure step is the process of private vehicles to depart from Thailand, which can be described as follows.

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 step is the process of private vehicles to arrive in Laos, which process can be described as follows.

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 arrive in Laos.

2.1.2 Departure procedures from Laos to Thailand by private vehicles

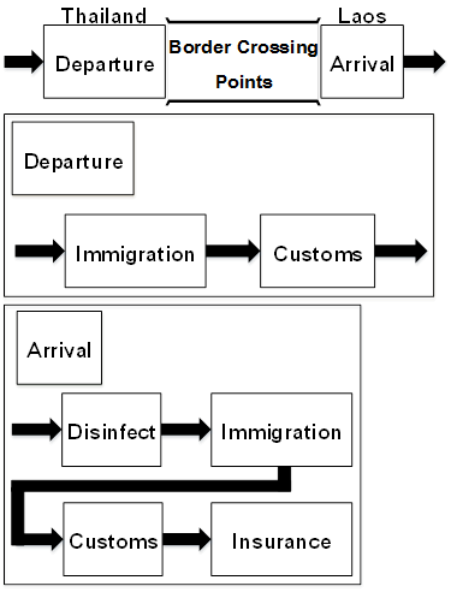

Figure 1 Thailand departure procedures.

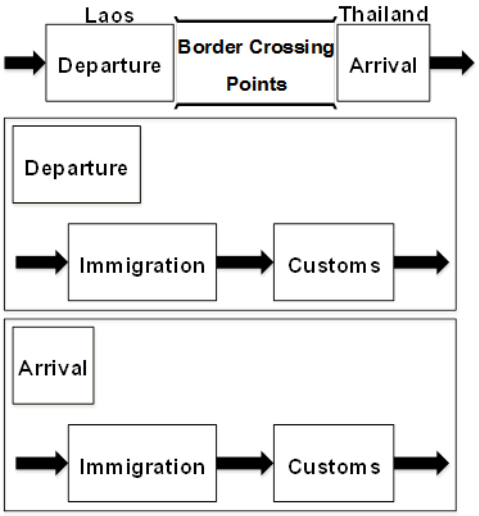

Figure 2 Laos departure procedures.

Figure 2 is a border crossing procedure from Laos to Thailand by cars. There are separated into two steps: departure and arrival steps.

Departure step is the process of private vehicles to depart from Laos:

Table 1 The ASEAN Highway in Thailand.

Number	Route of ASEAN Highway
AH 1	Ban Klong Luek to Mae Sot
AH 2	Sadao to Mae Sai
AH 3	Chiang Khong district to Chiang Rai
AH 12	1st Thai-Lao Friendship Bridge to Hin Gong
AH 13	Huay Kon to Nakhon Sawan
AH 15	Nakhon Phanom to Udon Thani
AH 16	Mukdahan to Tak
AH 18	Sungai Kolok district to Hat Yai district
AH 19	Pak Thong Chai district to Bangkok
AH 112	Klong Loy district to Bang Saphan district
AH 121	Mukdahan to Sa Kaeo
AH 123	Ban Phu Nam Ron to Hat Lek district

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 step is the process of private vehicles to arrive 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.

2.1.3 ASEAN Highway

ASEAN Highway (AH) is one of the Master Plan on ASEAN Connectivity to enhance connectivity among ASEAN members. There are 12 routes in total, accounted for 6,669 kilometers. The details of each route are shown in Table 1.

The ASEAN highways linking with Mukdahan and Chiang Khong Customs are AH3 and AH16 [4].

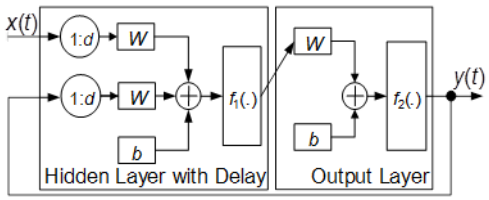

Figure 3 Simple block diagram of NARX.

2.2 Nonlinear Autoregressive with Exogenous Input

Nonlinear Autoregressive with exogenous input (NARX) is a time series forecasting model. NARX model utilizes artificial neural network containing neurons, which model from the work of human brain [5]. The simple block diagram of NARX is illustrated in Figure 3 in order to model time series up. From Figure 3, we can see that NARX consists of two layers, i.e., hidden and output layers. In both 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.

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 output layer, the same process with hidden layer is performed except using the different value of $f_2(\cdot)$, *W*, and *b* [6].

2.3 Related Works

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

Chen D. [7] 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. By analysis on statistics of forecast performance, it is concluded that the ARIMA model is suitable for forecasting monthly demand of China automobile.

Chuanjin J. and Fugen S. [8] used NARX 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.

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 [9-10]. 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 7 input variables, including cumulative 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. 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, as shown in Figure 4.

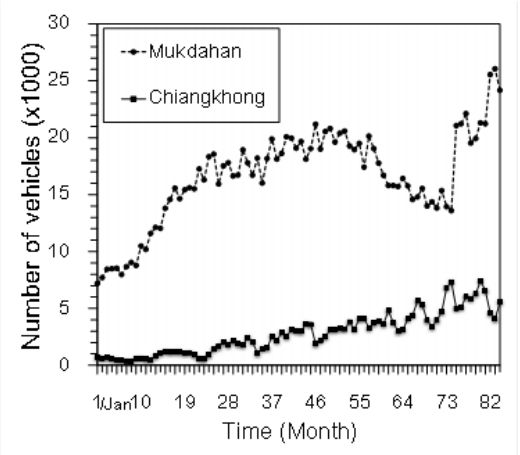

Figure 4 Number of vehicles accessing cross-borders from the year 2008 to 2014.

3.2 Unit Root Test

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.

The hypothesis testing using Augmented Dickey-Fuller (ADF) [11] 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 taken to the next step.

Table 2 Training Conditions.

Parameters	Mukdahan	Chiang Khong
Hidden Neurons	10 to 40	10 to 40
Delays	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%
Testing Round	5	5

Table 3 Results of variables' stationarity.

Variables	ADF test stat.	Critical values
Vehicles in Thailand	-5.421	-4.073
Vehicles in Laos	-8.142	-4.094
Thailand's GDP	-8.841	-4.075
Laos's GDP	-6.819	-4.094
International Driving License	-8.996	-4.073
New driving licenses in Thailand	-3.937	-4.072
New driving licenses in Laos	-2.070	-4.073
No. of Vehicles accessing Mukdahan's checkpoint	-7.328	-4.073
No. of Vehicles accessing Chiang Khong's checkpoint	-6.636	-4.073

3.3 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 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 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 2.

Bayesian regularization [12] 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.

4. Results

4.1 Stationary Testing

Unit root at level, first difference and 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, respectively. It mean that the null hypothesis can be rejected and they are qualified for stationary. The test of stationarity results are shown in Table 3.

4.2 Forecasting results from NARX Neural Network

After training the NARX model with the condition provided in Table 2, the output of the NARX model is obtained as presented in this section.

4.2.1 Selection of Hidden Layer and Delay for NARX

Numbers of hidden layer and delay affect directly to performance of NARX model. The suitable hidden layer and delay will give lower mean square errors (MSE) which can be calculated by (1)

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

where

T_i is traffic volume from the target,

Y_i is amount of vehicles calculated by the model,

N is number of data.

The simulation was setup to search the minimum MSE. The numbers of hidden layer and delay that provide the minimum MSE are applied in next process.

Form the simulation, the lowest MSE of Mukdahan's checkpoint is 191,210 at 10 hidden neurons and 4 delays while the lowest mean square error of Chiang Khong's checkpoint is 12,458 at 10 hidden neurons and 10 delays. The lowest mean square error of NARX models for both Mukdahan and Chiang Khong's checkpoints are shown in Figures 5 and 6, respectively.

4.2.2 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 depicted in Figures 7 and 8.

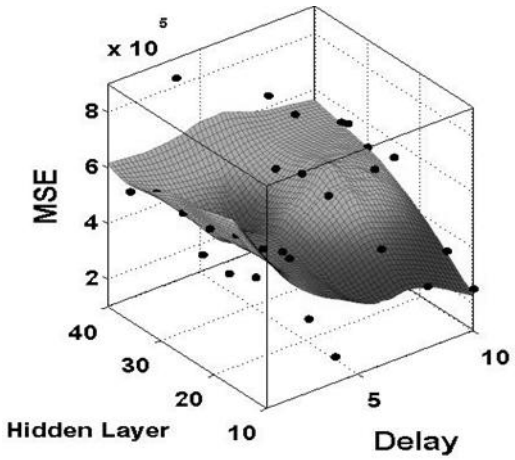

Figure 5 The lowest MSE of Mukdahan.

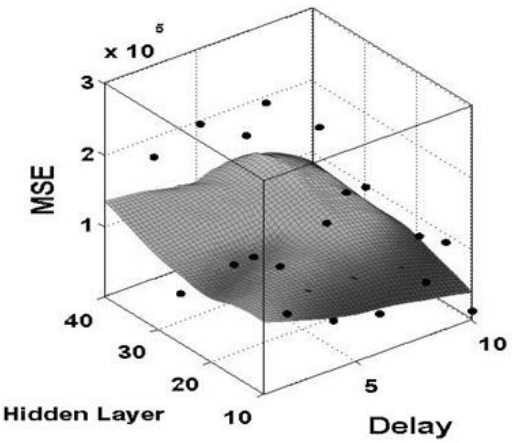

Figure 6 The lowest MSE of Chiang Khong.

4.2.3 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 0.987 and 0.994, respectively, as shown in Figures 9 and 10.

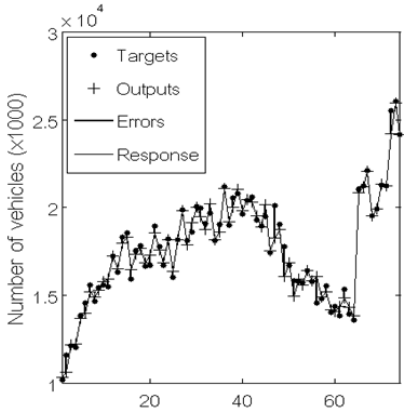

Figure 7 Mukdahan's response graph.

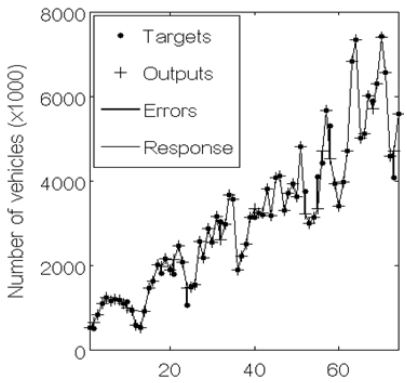

Figure 8 Chiang Khong's response graph.

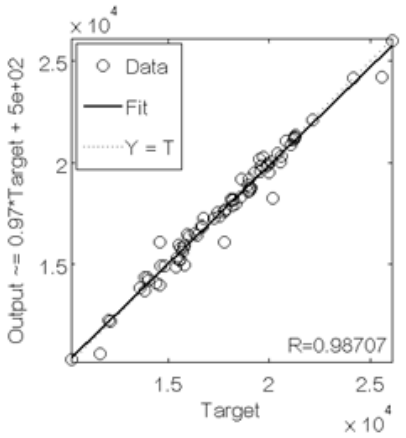

Figure 9 Mukdahan's Regression graph.

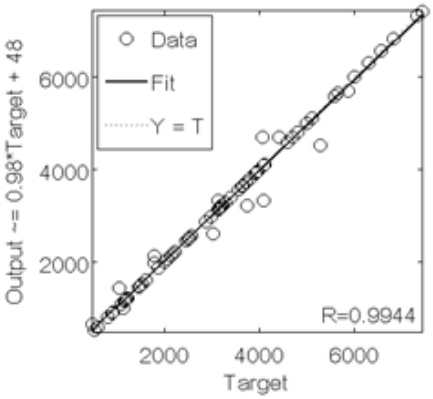

Figure 10 Chiang Khong's Regression graph.

5. Effects of AEC to Border Crossing Points

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.
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 0.98707 and 0.9944 This implies that the target and output has a positive relationship. In addition, the MSE is as low as 191,210 and 12,458, 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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