ทางเลือกเพื่อลดการปล่อยคาร์บอนในการตรวจท้องที่ของเจ้าหน้าที่ตำรวจเพื่อป้องกันอาชญากรรมในเขตนครบาล

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบความแตกต่างของพาหนะและการใช้พลังงานในการตรวจท้องที่เพื่อพัฒนาทางเลือกในการจัดทำนโยบายการตรวจท้องที่ในเขตพื้นที่นครบาล โดยใช้เทคนิคการวิจัยเชิงระบบเพื่อหาทางเลือกที่เหมาะสมในการตรวจท้องที่ ทำการจำลองทางเลือก 3 ทาง ซึ่งมีการแทนที่โดยใช้รถจักรยานยนต์ไฟฟ้าและรถจักรยานในร้อยละที่แตกต่างกันเพื่อเปรียบเทียบความแตกต่างกับสภาพการตรวจท้องที่ปกติ สร้างแบบจำลองโดยใช้โปรแกรม STELLA เมื่อวิเคราะห์ผลพบว่าตลอด 5 ปี การตรวจท้องที่ในสภาพปกติจะใช้ต้นทุนถึง 39,059,960 บาทและมีการปล่อยก๊าซคาร์บอนไดออกไซด์ถึง 2,974 ตันคาร์บอน และทางเลือกที่เหมาะสมและทำให้การตรวจท้องที่เกิดความยั่งยืนคือทางเลือกที่ 2 ซึ่งใช้รถจักรยานยนต์ไฟฟ้าร่วมกับรถจักรยานสามารถประหยัดต้นทุนได้ถึง 31,368,212 บาททั้งยังไม่ปล่อยก๊าซคาร์บอนไดออกไซด์ระหว่างการตรวจท้องที่ ส่วนระยะเวลาที่สมควรเปลี่ยนการใช้พาหนะคือตั้งแต่เดือนที่ 31เป็นต้นไป เนื่องจากการเปลี่ยนในช่วงเวลาดังกล่าวไม่ส่งผลกระทบต่อจำนวนการเกิดอาชญากรรม

คำสำคัญ: เทคนิคการวิจัยเชิงระบบ; การตรวจท้องที่; อาชญากรรม; การทำแบบจำลองโปรแกรมสเตลลาร์

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Low Carbon Police Patrolling Options for Crime Prevention in The Bangkok Metropolitan Area

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Abstract

This study aimed to investigate the differences in patrolling vehicle types and their energy use in order to develop alternative patrolling policy in the Bangkok metropolitan area. The Systems Dynamic Approach was used to explore appropriate options for police patrolling. Three scenarios were studied by changing the percentage of vehicle replacements to compare this with the business as usual mode, and then a system dynamics model was created through the use of STELLA software.

The results from the simulation of over five years show that continuing with the initial model would end with a patrolling cost of 39,059,960 baht and carbon emissions of 2,974 tonnes of carbon per five years. A suitable option for sustainable patrolling is scenario II, which uses a mixed patrolling method with electric motorbikes and bicycles. This scenario would reduce patrolling costs up to 31,368,212 baht and would not release CO_2 emissions. The optimum point for changing patrolling vehicles was evident from the 31st month onward since changing vehicles during this time would not affect the number of crimes.

Keywords: System Dynamics Approach; Police Patrolling; Crime; Simulation STELLA

Introduction

In Thailand, the tendency of criminal occurrences such as robbery, burglary, and aggravated assault has significantly increased each year. Thailand has been affected by the world economic crisis, reporting 458,188 criminal files in 2008, 8.25% higher than in 2007 (Dailynews, 2009). In order to suppress crime-related problems and to heighten the community's safety, community policing is required (Grabin, 1993).

Community policing throughout the community ensures a more rapid response to a crime scene as well as its necessity as a proactive approach to both crime prevention and suppression. Officers regularly patrol community neighborhoods in order to make their presence known and to build up relationships with community members (Bureau of Justice Assistance, 1994). Police patrols not only deter crime and reassure residents of the close connection to law enforcement, but also allow police to be aware of community concerns (Petty, 2006).

At present automobiles and motorbikes are ubiquitous in police patrol work and are widely used. Although these vehicles have several advantages, the current trend of fuel prices has substantial increased (Energy Information Administration, 2008). Furthermore, CO_2 emissions from motorbike and automobile patrolling are also harmful to the environment and contribute to climate change problems. The Royal Thai Police Department has reviewed that 5,697,016 liters of liquid fuels are consumed by metropolitan police on duty and the cost was 191,748,982 baht in 2008. Hence, there were approximately 13,175 tonnes of carbon emissions are about of carbon when comparing to year 2007 it was found that increased 4.96 percent (Energy Policy and Planning Office, 2008).

As mentioned earlier, patrolling at present partially causes the problems. The climate change phenomenon is getting serious and requires immediate action (Intergovernmental Panel on Climate Change, 2007). Thus, a big change should be made. Bicycles and electric motorbikes are appropriate vehicles for patrolling because they do not release CO_2. That is an alternative to remedy the problems. These patrol alternatives have been expressed explicitly by the police for solving the problems. Furthermore, these vehicles have several advantages (International Police Mountain

Bike Association, 2007), such as saving the cost of patrolling activities since they do not use liquid fuels, and using bicycles can promote health and decrease the cost of medical care (Cavill & Davis, 2007).

This study emphasizes appropriate police patrolling for community policing in the Bangkok metropolitan area. System Dynamics Model (SDM) plays a center role in understanding both CO_2 emissions and the cost of different patrolling vehicle types. The simulation results are compared to find out suitable patrolling alternatives.

Methodology

A System Dynamics Model is one of the larger fields of simulation modelling. This model's approaches are to simulate complex systems and use feedback loops that help to describe baffling nonlinearity. These models are formulated based on the assumption that any change in a system is caused by a feedback structure and interaction between elements in the system (Keeratiwiyaporn, 1998). This methodology is used widely in environmental modelling, including global environmental sustainability, environmental management, and ecological modelling. This study applied the systems dynamics approach to explore appropriate alternatives to patrolling in order to help in decision making for patrol policy planning.

1. Scope of the Study and Data Collection

The inner Bangkok metropolitan area was chosen as a study area, which is a tourist and business district that is suitable for bicycle patrolling. The study area is under the supervision of the 6th metropolitan police division. The study zones, covering a total area of 21.60 km^2, are under the responsibility of seven metropolitan police stations, as follows: Plubplachai 1, Plubplachai 2, Chakkrawat, Bang Rak, Praratchawang, Pathumwan and Yannawa. Documents and information about fuel consumption, the number of patrolling vehicles, crime statistics, fuel prices, population density, and bicycle and electric motorbike prices for the years 2006-2010 were collected (Metropolitan Police Division 6, 2008) and (Administration and Registration Division, 2008). This information was pre-processed and was compatible with model simulation. In this paper, an object-oriented simulation environment, STELLA software version 9, was used as a sophisticated tool to model the police patrolling as a dynamic system.

2. Historical Behavior

Historical behaviours are the patterns over time that are repeated and referred to in the modelling effort. Key variables in this study are fuel consumption, fuel price, crime, population density, and number of patrolling trips. The key variables were chosen under consideration of the relationships between the variables that had possible influential effects on the police patrolling in the study area.

2.1 Fuel Consumption and Its Cost

The influence from raising prices has been documented; as price rises fuel consumption will decline. Officers change their patrolling behavior, and this means that the number of patrolling trips also should decrease accordingly (Metropolitan Police Division 6, 2008).

2.2 The Increasing Trend of Crime and Population Density

Both population density and crime share a similar regression trend. The regression results of population density and crime were adopted because they share a significant correlation (R^2 = 0.78), with a correlation coefficient of 0.88. This means that as population density decreases, so does crime. The mathematical equation of this relationship is

$$\text{Crime} = 0.0792 * \text{population density trend} + 8040.6 \qquad (1)$$

This equation was used to calculate the occurrence of crime in the model structure.

2.3 The Number of Patrolling Trips and Crime

The relationship between the number of patrolling trips and crime was analyzed by regression and correlation analysis. The correlation (R^2) of this regression was 0.99 and the correlation coefficient was -0.99, which means that as the number of patrols increases, crime also decreases. The mathematical equation of this relationship is

$$\text{Number of patrols (trend)} = -8.47 * \text{Crime} + 268237.1 \qquad (2)$$

This equation was used to calculate the trend of patrolling in the model structure

3. Exploring the Causal Loop Diagrams

Causal loop diagrams (also called influence diagrams) represent a major feedback mechanism, which reinforces (positive feedback loop) or counteracts (negative feedback loop) a given change in the system variable (Sterman, 2000). The causal loop diagrams are helpful in conceptualizing the system structures and understanding how different variables are inter-dependent. Two casual loop diagrams were used in the system under consideration. The first causal loop diagram (Figure 1) represents the interaction among different variables in police patrolling. For example, an increase in police presence in the community is assumed to be caused by an increase in police patrolling on bicycle, and therefore the arrow between these two elements were assigned by a negative sign and this casual loop represented a negative feedback. The interaction between the elements of police patrolling are express by causal loop diagrams throughout the study.

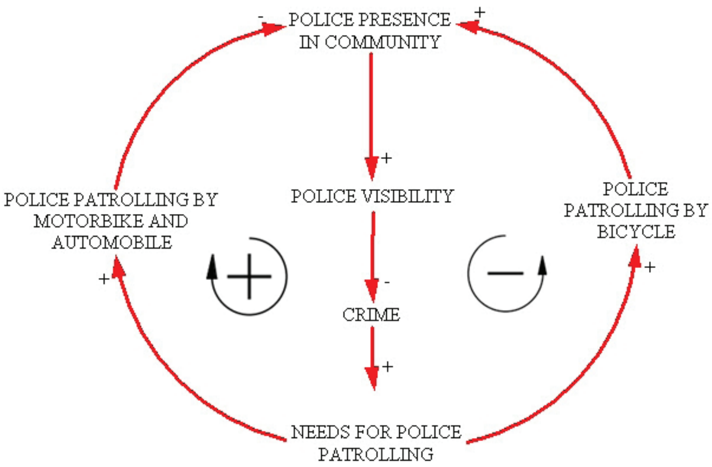

Figure 1 Conceptual loop diagram of police patrolling

There are many reasons why this study desired to employ conceptual causal loop diagrams (Figure 1). First was to focus on the police visibility as it is related to fear of crime. An increase in police visibility affects crime reduction (Salmi, Gronroos & Keskinen, 2004). The second reason was to consider the patrolling vehicle types that are associated with the quality of police visibility (Payne & Trojanowicz, 1985). The speed of vehicle mobilization is determinative—foot and bicycle patrols provide longer police visibility than motorbike and automobile patrols. Since the quality of police visibility is directly related to social contact (interaction between police and public), the bicycle has much more contact with members of the public than car patrols (Menton, 2007). The research of Kansas City Police Department (Kelling & Moore, 1974) found that an increase or decrease in the frequency of car patrols has no significant impact on the level of crime. This was noticed by citizens, but an increase in the time of patrolling at nighttime hours and slow patrol movement were also related to a decrease in the report of crimes (Schnelle, Kirchner, Casey, Uselton & McNees, 1977). The last reason is in respect to the duration of police on street. When the period of time of patrolling is extended, police are present in the community accordingly; people's perception of safety and serenity increases as a result of police visibility in the neighborhood.

Figure 2 presents a causal loop diagram of the variables involved in police patrolling in the study area. The conceptual loop shows the relationship between crime and police visibility that constructs the interrelationships between factors. It showed a negative feedback loop as loop1. The increase in crime will put high pressure on police to suppress it. This pressure is important for crime suppression measures. As the demand to take measures to suppress crime increases, the number of patrolling trips increases, police visibility becomes greater, and the crime will decline. With more patrolling trips, the crime suppression budget increases. This increment applies pressure on the police to make adjustments and crime suppression measures to find suitable patrols. These factors form a positive feedback loop, as shown in loop 2. Typically, whenever crime suppression measures increase, more patrolling trips are required. Not only will there be a higher for the suppression budget according to the intensity of patrolling, but there will also be a negative impact on the environment as well as climate change. CO_2 emissions of patrolling vehicles will increase with the addition of patrolling trips. Although the additional patrolling does not cause CO_2 emissions compared to other activities in the economic sector, an improvement in emissions would be a great contribution to mitigating the climate change situation.

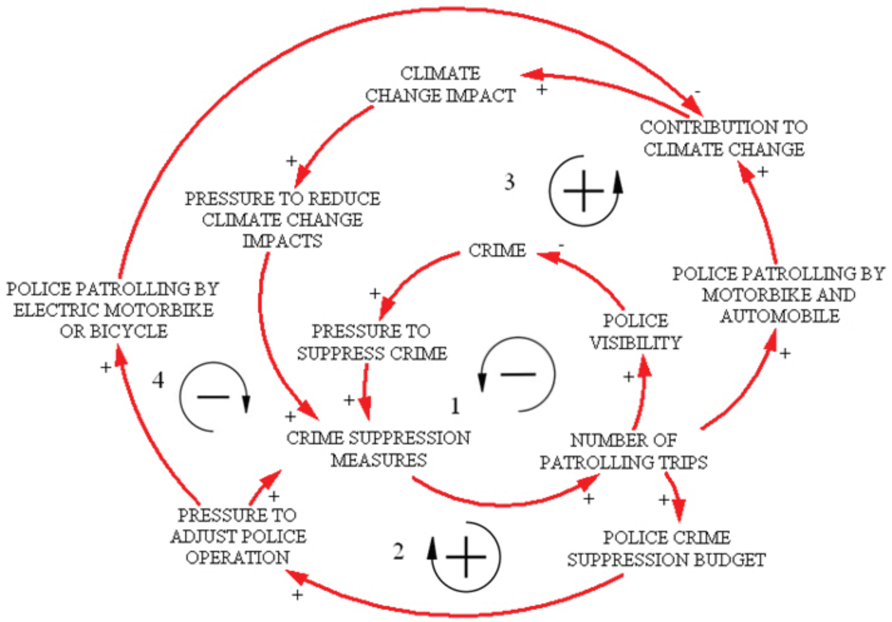

Figure 2 The interrelationships between the factors influencing police patrolling in the study areas

These relations form another positive feedback loop (loop 3). The last loop shows that the interrelationship between the factors. It showed in another negative feedback as loop 4. This is a very important loop since an increase in the number of patrolling trips will significantly affect crime control. As a result, as the police patrols by electric motorbike or bicycle increase, the climate change impact will decrease and this will save money spent on the patrolling budget over time. Although the positive feedback in loop 3 will control crime, as seen with loop 4, patrolling on motorbike and automobile is a costly for of crime suppression and increases the climate change impacts.

4. The System Dynamics Model

The SD approach used in this study to simulate alternative patrolling has four basic building blocks: stock, flow, connector, and converter. Stocks (also called levels) represent anything that accumulates; an example would be cumulative carbon dioxide emissions. Flows (also called rates) represent activities that fill and drain stocks as the simulation proceeds; for example, carbon release or inflow.

Connectors (arrows) are used to establish a relationship between variables in the model; an arrow from A to B indicates that A causes B, i.e., B depends on A. They carry information from one element to another element in the model. Converters are mathematical functions that transform input into output. The causal loop diagrams depict a static picture of the interactions among the model variables, while an SD can be developed to simulate alternatives of patrolling under consideration (Ahmad, Kharn & Rana, 2007).

5. Model Structure

The police patrolling model (Figure 3) was designed under consideration of the interrelationships between the factors influencing police patrolling in the study areas (Figure 2). This model depicts the structural relations of gasoline consumption (GC) from patrolling by motorbike and diesel consumption (DC) from patrolling by automobile, which contribute to fuel consumption (FC). The gasoline price (GP) and diesel price (DP) were simulated over time in order to calculate the value of fuel consumption (VOFC). The carbon dioxide emission (CO2E) derived from the carbon dioxide emission from gasoline consumption (CO2EFG) and carbon dioxide emission from diesel consumption (CO2EFD). The total number of patrolling trips (TNOPT) was composed of the number of patrolling trips by motorbike (NOPTOM) and the number of patrolling trips by automobile (NOPTOA). The population density trend (PDT) was used to calculate crime by putting it in mathematical equation (1), and the result of crime was used to calculate the patrolling trend by using mathematical equation (2). Comparison of the total number of patrolling trips and the number of patrols indicated a suitable period for changing patrolling vehicles in order to save money on the patrol budget and to maintain the occurrence of crime at the usual level. There are three alternative patrolling scenarios (S): scenario I (S I): using electric motorbike replacing 50 percent of the original patrolling vehicles; scenario II (S II): 50 percent replacement of original patrolling vehicles with electric motorbike and the other 50 percent replaced by bicycle; and scenario III (S III): using a bicycle, replacing 50 percent of the original patrolling vehicles. The cost of vehicle replacement from electric motorbike (COEMC) and bicycle (COBC) was used to compare the cost. The value of electricity consumption (VOEC) was calculated in scenario I and II simulation. The results of the simulation in each scenario were compared with the usual patrolling or business as usual (BAU).

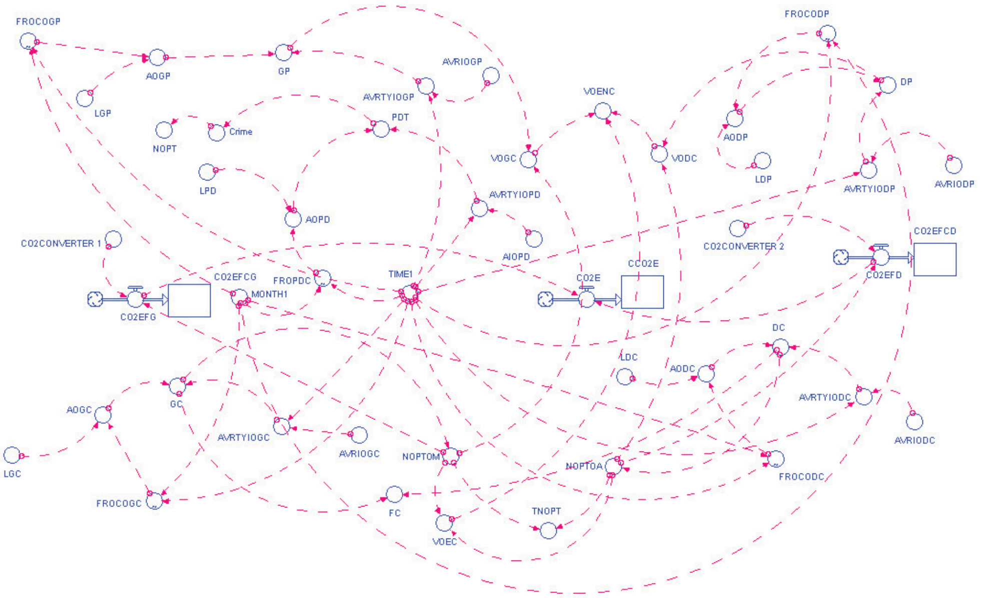

Figure 3 The structure of police patrolling activities

Results and Discussion

1. The Results of the Model Simulation

The total number of patrolling trips (TNOP) per year shows in Table 1 that there was an increase from 204,371 trips in 2010 to 352,883 trips at the end of 2015, representing an average increase of 14.5 percent per annum. The cumulative number of patrolling trips for 5 years was 1,357,667 trips. The number of patrols (trend) (NOPT) per year increased from 262,000 trips in 2010 to 262,249 trips at the end of 2015, representing an average increase of 0.02 percent per annum. The cumulative number of patrols was 1,310,680 trips. The fuel consumption (FC) per year increased from 194,275 liters in 2010 to 321,432 liters at the end of 2015, representing an average increase of 7.9 percent per annum. The cumulative fuel consumption was 1,259,313 liters. The value of energy consumption (VOENC) per year increased from 5,206,583 baht in 2010 to 11,175,614 baht in 2015, and the total value was 39,059,960 baht.

Table 1 Total number of patrolling trips (TNOPT), number of patrols (trend) (NOPT), fuel consumption (FC), and value of energy consumption (VOENC)

YEAR	TNOP (Trip)	NOPT (Trip)	FC (Liter)	VOENC (Baht)
2010/11	204,370.62	262,000.38	194,275.32	5,206,582.87
2011/12	232,179.44	262,076.75	218,076.62	6,202,555.66
2012/13	265,453.10	262,142.81	246,562.15	7,473,571.76
2013/14	302,781.04	262,210.49	278,966.04	9,001,636.10
2014/15	352,882.50	262,249.30	321,432.36	11,175,613.95
Total	**1,357,666.70**	**1,310,679.73**	**1,259,312.49**	**39,059,960.34**

Table 2 shows that the cumulative crime decreased from 8,840 to 8,488 cases, representing an average annual decrease of 0.8 percent. There were 43,241 cases of cumulative crime in five years. Carbon dioxide emissions per year increased from 463 tonnes in 2010 to 753 tonnes in 2015, representing an average increase of 7.7 percent per annum and cumulative emission was at about 2,974 tonnes during the period of five years. The population density (PDT) decreased from 121,081 persons per km^2 in 2010 to 67,664 persons per km^2 at the end of 2015 representing, an average decrease of 15.8 percent per annum.

Table 2 Crime, population density trend (PDT), and carbon dioxide emission (CO2E)

YEAR	Crime (Case)	PDT (Person)	CO2E (Tonnes of carbon)
2010/11	8,840.34	121,081.12	462.87
2011/12	8,732.06	104,687.79	518.46
2012/13	8,638.44	90,513.97	583.01
2013/14	8,542.55	75,994.16	656.90
2014/15	8,487.52	67,663.56	752.69
Total	**43,240.91**	**459,940.60**	**2973.93**

2. Comparison of Simulation Results

Table 3 presents a comparison of the simulation results, including of cost of vehicle replacement, fuel consumption, value of energy consumption, CO_2

emissions, and the cost of patrolling. The S II cost of vehicle replacement was the highest because the original vehicles were replaced by 50 percent electric motorbikes and the rest were replaced by bicycles. The cost of the vehicle change in S II was 4,329,000 baht. For S III the cost of vehicle replacement was lowest since 50 percent of the current patrolling vehicles were replaced by using 50 percent bicycles and the cost per unit of bicycle was the lowest. The value of vehicle replacement in S III was cheaper than S I and S II, at 1,665,000 baht and 2,664,000 baht respectively. Although the cost of vehicle replacement from S II was very high in the beginning period, in the long term patrolling S II saved the most on fuel consumption. S II fuels were not used and therefore the fuel consumption throughout the five years was zero. S I and S III showed similar results of fuel consumption—the volume of consumption was 629,660 liters which was a half of the fuel consumption for the business as usual scenario (BAU).

Table 3 Comparison of simulation results

Comparison of Simulation Results	BAU	S I	S II	S III
Cost of vehicle replacement (baht/five years)	0	2,664,000	4,329,000	1,665,000
Fuel consumption (liters/five years)	1,259,313	629,660	0	629,660
Value of energy consumption (baht/five years)	39,059,960	22,892,848	3,362,748	19,530,099
CO_2 emission (tonnes of carbon/five years)	2,974	1,487	0	1,487
Cost of patrolling (baht/five years)	39,059,960	25,556,848	7,691,748	21,195,099

The value of energy consumption of the business as usual scenario (BAU) was highest, with a cumulative value of 39,059,960 baht, and the S II showed the lowest cumulative energy consumptions value (3,362,748 baht). It was found that scenario I - III could reduce the value of energy consumption up to 16,167,112 baht, 35,697,212, baht and 19,529,861 baht respectively. S II showed the most energy-efficient approach and could be chosen for a future patrolling strategy.

BAU emitted the highest level of carbon dioxide and cumulative emission was 2,974 tonnes. S I and S III emitted a lower level than BAU. The values of total emissions were 1,487 tonnes. Since fuels were not used in scenario II, the carbon emission in this scenario was zero. S I and S III could reduce carbon emissions up to 1,487 tonnes. In terms of ecology, S II was the most ecologically friendly because it did not release carbon dioxide (CO_2). Scenario II was the most appropriate option for police patrolling; not only is it energy efficient but also environmentally friendly.

The costs of patrolling BAU and under the conditions of scenario I, II, III were 39,059,960 baht, 25,556,848 baht, 7,691748 baht, and 21,195,099 baht respectively. The result indicates that S II used the lowest patrolling budget. When compared with BAU, it was found that scenario I-III could reduce patrolling costs up to 13,503,112 baht, 31,368,212 baht, and 17,864,861 baht respectively.

3. The Optimum Point to Changing Patrolling Vehicle

A comparison between the number of patrols (trend) (NOPT) and the total number of patrolling trips (TNOPT) could be find an optimum point to change patrolling vehicle since NOPT indicated the usual level of crime suppression , as TNOPT is more than NOPT these mean excess number of patrolling has no effect on crime occurrence.

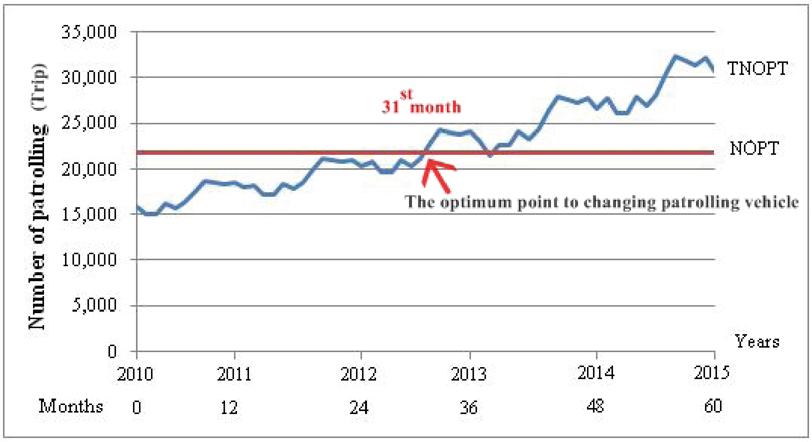

Figure 4 The optimum point to change patrolling vehicle

Figure 4 shows, from the first month to the thirtieth month, the patrolling trips from the TNOPT (15,974-20,423 trips/month) was less than that from the NOPT (21,830-21,840 trips/month); then the situation was changed from the 31st month to the 60th month, where the TNOPT (from 22,941 to 30,702 trips/month) increased more than the NOPT (from 21,844 to 21,860 trips/month). This means that an increase in the number of patrolling trips would require more fuel consumption and increase patrolling expense. Indeed, increasing patrolling trips during this period of time had no effect on crime suppression. The officer could change patrolling vehicle from motorbike and automobile to electric motorbike or bicycle during this period of time.

4. Implementation of Results

Carbon emission and patrolling costs were used to support the decision making at the Royal Thai Police to develop alternative patrolling plans in the Bangkok metropolitan area. Moreover, this result was clearly expressed in energy usage and the environmental effect from patrolling, where both factors were indicators of the measurement of the work of the Office of the Public Sector Development Commission (OPDC). The officers have to pass an annual evaluation (Office of the Public Sector Development Commission, 2008). The simulation of fuel consumption mode found that all of the scenarios could save energy when compared with the usual patrolling mode (BAU mode). Another important indicator in this case was the quality of operation, since the number of patrolling trips in this study was maintained constant and the three scenarios attained the same quality of public service. The replacement vehicles offered an improvement in police patrolling quality since both electric motorbikes and bicycles extended police visibility in the community. In addition, bicycle patrolling also strengthened the police-community relationship and promoted police health. These factors were seen as a co-benefit of successful community policing.

5. Obstacles and Solutions to Police Patrolling under the Condition of Scenario II

- Thailand is a tropical climate; not only is the weather hot but it is also very humid. These are unpleasant factors for patrolling on bicycle. Outfits or uniforms should be appropriately designed for patrolling on bicycle in a hot climate.

- Before patrolling, the officers have to be trained in safety use of a bicycle. Proper training is essential to the performance of officers on the job, for safety as well as liability. Certified and well-trained police would create confidence in the performing patrols in the study area.

- The constraints regarding appropriate bike lanes and road safety are among the important issues of concern. The Bangkok administration areas and big cities do not have or rarely have bicycle lanes, and the footpath conditions do not offer an alternative, as their condition seems to of poor quality.

Conclusion

Simulation through the five years (2010-2015) of the business as usual scenario shows increasing burdens on the Royal Thai Police and on the environment. The high increase of fuel consumption is bringing about higher costs of fuel consumption. Since the budget for police patrolling is limited, in the future, traditional patrolling would add a high burden to the Royal Thai Police. Additionally, in terms of environmental consequences, the rise of carbon emissions will contribute to climate change.

The comparison of simulation results in this study indicated that scenario II was the appropriate option for sustainable patrolling because patrols on electric motorbike in conjunction with bicycle can reduce CO_2 emissions and the cost of patrolling. More importantly, the officer must consider the crime cycle, crime prevention through environmental design (CPTED), and the socio-economic situations that may change over time. Analyzing all of these will help officers to plan proper patrol methods.

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