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EVALUATION OF THE EFFECTIVENESS AND APPROPRIATENESS OF BANGKOK ACTION PLANS ON GLOBAL WARMING MITIGATIONS

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ABSTRACT: Bangkok Metropolitan Administration (BMA) action plans consist of 10 action plans aimed to reduce at least 15% of the total greenhouse gases emissions anticipated in the year 2012 under business as usual projection. In this study, the Multi Criteria Attribute (MCA) analysis was carried out to determine the most appropriate greenhouse gas mitigation measures for implementation in Bangkok, Thailand. Five criteria were used in this analysis included 1) mitigation potential, 2) total costs, 3) feasibility, 4) owner of benefits and 5) environmental benefits. Although, the action plan which focused on improving electricity consumption of the building and promoting electricity conservation campaign for Bangkok resident was expected to the highest reduction of greenhouse gases (2.7 million tons of CO_2 reduction). However, effort on expanding of the park area was evaluated as the most appropriate initiative when consider both of its effectiveness in reducing emissions, and its implementation cost. Carbon removal rate of trees in Bangkok's park was also evaluated through an intensive study at selected parks using data collected over the period of 10 years (2005-2015). It was found that the park in Bangkok could store carbon of about 1.86 tC/y (6.82 tCO_2/y) or 0.58 tC/ha/y. These predicted results were coincided with actual outcomes evaluated from the implementation of each policy in the metropolitan area. Methodology of this study can be applied for further use in analysis and selection of appropriate measures for policy maker in other cities as well as in the national level.

Keywords: Bangkok, action plan, greenhouse gas, mitigation, MCA

1. INTRODUCTION

Climate change is recognized as a global issue concerned the international community. In Asia, the rapid increases in industrialization and urbanization over the past several decades enhance increasing of the emission of greenhouse gases and the impacts of climate change are starting to occur and are predicted to be more severe particularly in some areas of the region. Thus, they are worthy of increased study and vigorous remedial action. Thailand has long been actively participating in the global efforts to prevent or at least ameliorate the effects of climate change. Now its capital city, Bangkok, is starting to participate in these efforts since it is a significant source of greenhouse gases emitted into the atmosphere, and as the nation's economic hub it has a lot to lose [1].

One of the indexes used to evaluate the extent of effect from climate change is changing of ambient temperature. In Bangkok the average maximum temperatures has an increasingly warming trend over the period 1961-2007 (Fig. 1). The same pattern of warming is also observed in the average minimum temperatures measured in Bangkok, as illustrated in Fig. 2. The number of days having the maximum air temperature exceeding 35°C also has an increasing tendency as presented in Fig. 3. The impacts of climate change on Bangkok have thus become increasingly visible and have been the subject of serious concern among residents since 1967, as they experience increasingly hotter weather [2].

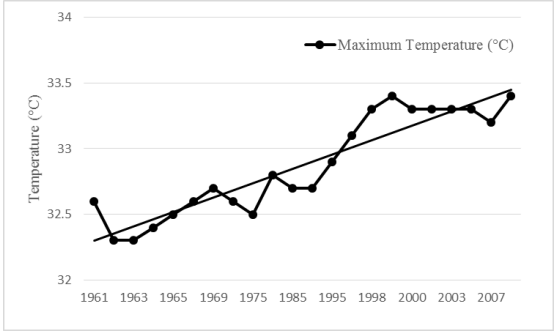

Fig. 1 Average maximum temperature in Bangkok, 1961-2007.

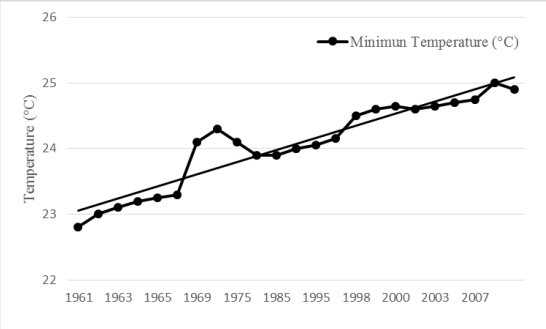

Fig. 2 Average minimum temperatures in Bangkok, 1961-2007.

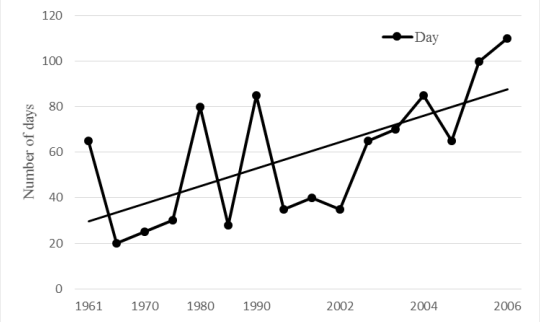

Fig. 3 Number of days exceeding 35°C in Bangkok, 1961-2007.

In 2007, total greenhouse gas emission in Thailand was estimated as 61.23 million tons CO_2e. It was estimated that 43 million tons CO^2e (about 70%) of the country's emission was contributed from Bangkok. Although, these emissions were much greater amount than that of San Francisco (8 million tons), San Diego (13 million tons), and Toronto (24 million tons). However, they were about the same as those of London (44 million tons). The greenhouse gas emissions from Bangkok were reported to be lower than those emissions of New York City (58 million tons) and Tokyo (71 million tons) [1]. Meanwhile, results from the calculation of greenhouse gas emissions per capita reveals that the residents of Bangkok were responsible for producing 7.1 tons of CO_2e per annum which is, the same level of emissions as produced by New Yorkers (7.1 tons per capita). This level was significantly higher than the annual emissions of San Diego (4.5 tons per capita), Tokyo (5.7 tons per capita) and Londoners (5.9 tons per capita) but lower than the levels produced by residents of Toronto (9.6 tons per capita) and San Francisco (11.4). Results are as summarized in Table 1.

Table 1 Greenhouse gas emissions of Bangkok and selected cities

City	Total emission (million tons of CO_2e)	Tons per capita of CO_2e emissions
San Diego	13	4.5
Tokyo	71	5.7
London	44	5.9
Bangkok	43	7.1
New York	58	7.1
Toronto	24	9.6
San Francisco	8	11.4

Comparing greenhouse gases emission in each country determine that San Francisco was the lowest emission of countries but emission per capita was the highest. In converse, Tokyo was the highest greenhouse gas emission but it was the second rank of the lowest emission per capita from the list.

Bangkok Metropolitan Administration (BMA), being aware of the global warming crisis and the necessity to take initial action to be part of the global effort in mitigating the problem. Bangkok Action Plan on Global Warming Mitigation was designated covering the period from the year 2007-2012. The action plan was aimed to reduce at least 15% of the total greenhouse gases (GHG) emissions by using emission amount under business as usual activities of the year 2012 as benchmarking. This action plan comprised of 5 initiatives: 1) Expand the mass transit rail system within Bangkok metropolitan area; 2) Promote the use of renewable energy; 3) Improve building electricity consumption efficiency; 4) Improve solid waste management and wastewater treatment efficiency; and 5) Expand park area. Each initiative consisted of several implementation plans to reach its goal. For the long term management, basic dimensions of sustainability consisted of environmentally, technically, economically, and socially sustainable alternatives should be reliable, adequate, and affordable [3]. Therefore, in order to select and evaluate alternatives, this work proposes the use of the multi-criteria attribute (MCA) which anticipates the three dimensions: environmental, technical, and economic needs. The purpose of this study was to analyze the appropriateness and effectiveness of each mitigation measure in order to prioritize actions under the plan for further implementation of the policy. In addition, the results from MCA analysis was compared with actual outcomes after implementing mitigation actions to validate all criteria of MCA for proposing appropriate mitigation action on

greenhouse gases mitigation.

2. BMA ACTION PLAN

The BMA Action Plan on Global Warming Mitigation was used to serve the Thai policy in reducing emissions of greenhouse gases in Bangkok. Five initiatives have been set under this plan. They were 1) expanding the mass transit rail system within Bangkok Metropolitan area; 2) promoting the use of renewable energy; 3) improving building electricity consumption efficiency; 4) improving solid waste management and wastewater treatment efficiency; and 5) expanding park area. In each initiative had the action plans for implementation.

1) Expanding the mass transit rail system within Bangkok Metropolitan area: the objective of this initiative was to reduce CO_2 Emission from Vehicle Traffic including three action plans as follow;

- Action Plan 1: Expand the mass transit rail system within the Bangkok Metropolitan area
- Action Plan 2: Improve public bus system
- Action Plan 3: Improve traffic system

2) Promoting the use of renewable energy: the objective of this initiative was to increase the proportion of biofuels usage which had one action plan as follow;

- Action Plan 1: Promote the use of biofuels

3) Improving building electricity consumption efficiency: the objective of this initiative was to reduce electricity usage in Bangkok which include two action plans as follow;

- Action Plan 1: Improve building energy consumption efficiency
- Action Plan 2: Electricity conservation campaign for Bangkok people.

4) Improving solid waste management and wastewater treatment efficiency: the objective of this initiative was to increase efficiencies in solid waste management and wastewater treatment which had two action plans as follow

- Action Plan 1: Increase efficiency in solid waste management
- Action Plan 2: Increase efficiency in wastewater treatment

5) Expanding park area: the objective of this initiative was to increase the number of trees for CO_2 absorption which include two action plans as follow;

- Action Plan 1: Plant trees in the Bangkok Metropolitan area
- Action Plan 2: Plant trees in the neighboring province areas.

3. MULTI-CRITERIA ATTRIBUTE (MCA)

Multi-criteria attribute (MCA) is generally understood as an assessment method that does not try to monetize everything, but to supply an unrefined view on the many different dimensions of the multiple effects of a certain policy or project or investment options. Nevertheless, the MCA can integrate monetary values like investment costs as one of the many dimensions it takes into account. In addition, it is a tool to calculate overall scores and rankings based on the scores given for each criterion for each individual option. Key elements of the MCA are the performance matrix, the weighting and the ranking process. Normally, the scoring of each criterion is from zero (worst) to five (best). And, each criterion weighted across all criteria are 100 [4]. In order to compare alternative options scoring on different criteria scales in different directions (trade-offs), it is necessary to put weights representing the relative importance associated with the respective criteria on the scoring results. Then, the MCA shows the effects of baseline developments and management scenarios on the multiple dimensions of the ecological, economic and social systems. The advantages of MCA, it has ability to deal with complex and unstructured decision problems in the sphere of environmental and natural resources managements, which involve a number of conflicting ecological, environmental, societal and economic objectives, multiple interests groups and different languages of valuation [5]. MCA methods have been used to prioritize urgent and immediate adaptation options during the formulation of National Adaptation Programs of Action (NAPAs) that Least Developed Countries (LDCs) developed under the United Nations Framework Convention on Climate Change (UNFCCC) [6]. Moreover, the use of MCA in the context of agricultural organic food production is sparse, and the relatively few studies that have been published are quite wide-ranging – from ‘narrow’ applications focusing on specific products [7] and it also used for the identification of spatial land-use conflicts in the Bucharest Metropolitan Area [8]. In addition, MCA is a popular tool in Dutch environmental impact assessment [9]. It also can be used for selecting an optimal configuration for an Air Quality Model as well [10].

For each dimension, the criteria was set taking into consideration impact of implementing

activities under each action plan which can be explained as follows:

– The environmental aspect: The amount of greenhouse gas reduction is used to evaluate the extent of environmental benefit in implementing each activity. Reduction of greenhouse gas is expressed as CO_2e/5 years. The environmental benefit also determines by considering whether the project can provide other beneficial beside reduction of greenhouse gases. Examples of these in-direct benefits include potential in reducing water pollution, waste minimization, local air and noise pollution control, etc.

– Economic and social systems: The criteria used to evaluate this aspect included the operation and implementation cost as well as the possessor of benefit occurred from each activity. For example, the energy saving policy will give direct benefit to the implementing agency while forest plantation will provide the benefit to the public, etc.

– Technical and operational feasibility: This item is analyzed by considering the involving of technology involved in implementing measures under each action plan. The complicated technology will require much technical and operational knowledge and efforts. Therefore, higher score is given to the activities which can be implemented base on local or simple technology.

4. CRITERIA

4.1 Criteria Identification

To evaluate achievement of the appropriate action plan to mitigate greenhouse gases emissions in Bangkok, five criteria were set with five indicator each. The criteria include

1) Mitigation potential: to determine the potential of each initiative could reduce greenhouse gases consisting of 5 indicators ranging from zero to more than 4 million tons CO_2e.
2) Total costs: to analyze how expensive of each initiative in order to implementing the projects which ranging from zero to more than 8,000 Million Baht.
3) Feasibility of the projects: including both technical and operational feasibility which ranged from not good (not feasible) to very good (feasible).
4) Benefits owner: to make sure that the appropriate initiative provided their benefits to the public.
5) Environmental benefits: the main issues of urban areas were identified including air pollution, water pollution, noise pollution, solid waste, and visualization. To identify the potential of the initiatives to solve these issues, the score of this criteria will be upon the number of potential that it could fulfil.

4.2 Criteria weighting

Two major criteria are mitigation potential and implementation cost. Weighting of these two criteria are 30% each. Meanwhile, environmental benefits is a sensitive criterion which weighted 20%. And, the others criteria were feasibility (both in technical and operational feasibility) and the owner of benefits. Weighting of these criteria were 10% each. Indicators of each criterion were set for appropriated rating system. Summarized of criteria, indicators and score weighting are presented in Table 2.

5. RESULTS AND DISCUSSION

Results from MCA evaluation indicated that the most effective initiative was the 3rd initiative which was improving building electricity consumption efficiency. Given the increasing scientific understanding of the threat of global climate change and the decline of oil production to meet the demand, many countries are now finding ways to make energy consumption efficient and reduce greenhouse gas emissions [11]. This initiative focused on management of energy consumption by improving energy efficiency and promoting electricity conservation campaign in Bangkok. It could mitigate greenhouse gases in the middle level but it was feasible, less investment cost and good for community and environment. Under the energy efficiency program, there are some countries in Asia proposing the mitigation action under Nationally Appropriate Mitigation Actions (NAMA). For instance, China expressed the intension submitted to the UNFCCC to increase the share of non-fossil fuels in primary consumption to around 15% by 2020. Meanwhile, Indonesia proposed to reduce emission 26% by 2020 which would reduce deforestation rate and promote energy efficiency. And, Singapore would begin implementing the mitigation and energy efficiency measures announced under the sustainable Singapore blueprint [12]. As well as, Thailand would reduce emission 7% by 2020 and 20% by 2030 particularly in energy sector.

The second rank of initiatives was the expanding park area, the 5th initiative, which includes planting trees in Bangkok Metropolitan area and the neighboring provinces around Bangkok. Even though, the potential of greenhouse gases mitigation was low but the other benefits were high, such as community benefits, environmental benefits, feasible implementation, and lower implementing cost. Moreover, urban trees also influence air temperatures, use of energy in the building energy, and consequently alter carbon emissions from numerous urban sources (e.g., power plants) [13]. Numerous benefits of urban forests studied in China indicated that urban forests are integral components of urban ecosystems, which could generate significant ecosystem services, such as offsetting carbon emission, removing air pollutants, regulating the microclimate, and recreation [14]. The last three initiatives were expanding mass transit and improving traffic system (the 1st initiative), promoting the use of renewable energy (the 2nd initiative), and improving solid waste management and wastewater treatment efficiency (the 4th initiative), respectively. Total score of each criterion ranking from the lowest to the highest were 66, 61, 57.3, 52, and 48 in improving building electricity consumption efficiency, expanding park area, expanding the mass transit rail system within Bangkok Metropolitan area, promoting the use of renewable energy, and improving solid waste management and wastewater treatment efficiency, respectively (Table 3).

Table 2 Criteria, indicators and score of criteria for BMA action plan

Criteria	Indicators	Score
Mitigation Potential	0-1 million tons CO_2e	1
	1-2million tons CO_2e	2
	2-3million tons CO_2e	3
	3-4million tons CO_2e	4
	More than 4 million tons CO_2e	5
Total Costs[1]	0-2,000 Million Baht	1
	2,001-4,000Million Baht	2
	4,001-6,000Million Baht	3
	6,001-8,000Million Baht	4
	More than 8,000 Million Baht	5
Feasibility	Not Good	1
	Bad	2
	Fair	3
	Good	4
	Very Good	5
Owner of Benefits	To implementing authority	1
	To public	5
Environmental Benefits[2]	having1 potential benefit	1
	having 2 potential benefits	2
	having 3 potential benefits	3
	having 4 potential benefits	4
	having 5 potential benefit	5

Note: [1] ref. [15], [16], [17], [18], [19], [20], [21]

[2] selected from 1) Potential for reducing air pollution, 2) Potential for reducing water pollution, 3) Potential for reducing noise pollution, 4) Potential for reducing solid waste, and 5) Potential for increasing visualization

The result was compared with an analyzing of each measure conducted by BMA [22]. Results of mitigation measures of BMA action plan in 2007-2012 indicated that the most effective action was the improvement of building electricity consumption efficient. It could achieve reduction target which reduce emission 2.70 million tons CO_2. Likewise, the result of MCA analysis, energy efficiency in the building was the most appropriate measure to implement. Subsequently, expanding park area was another appropriate mitigation measure both from MCA and BMA results which could remove GHG 1.69 million tons CO_2. The other three initiatives were expanding mass transit and improving traffic system, promoting use of renewable energy, and improving solid waste management and wastewater treatment efficiency which reduced GHG 1.01, 0.88, and 0.70 million tons CO_2, respectively. Table 4 shows the result of BMA and MCA analysis.

Meanwhile, mitigation of each action was higher than their targets, which had been set up when proposed the action plan, except the 1st initiative. Even if it had the potential to reduce emission, it was still costly nor minor contributed to the environment benefits. Besides, it was inadequate opportunity to develop as well.

Table 3 Scoring of each initiative for GHG reduction mitigation in BMA and other benefit

Criteria	Criteria weight	Initiative				
		1th	2nd	3rd	4th	5th
Mitigation Potential	30	30	6	18	6	6
Total Costs	30	6	30	24	18	24
Feasibility	10	6	10	10	4	9
Owner of Benefits	10	10	2	6	6	10
Environmental Benefits	20	5.3	4	8	14	12
Total	100	57.3	52	66	48	61
Ranking	-	3	4	1	5	2

Table 4 Result of greenhouse gas emission reduction after implementing BMA action plan and prioritize action using MCA analysis

Initiative	BMA*			MCA
	CO_2 emission reduction	Compare to target	Ranking	Ranking
1st	1.01	under	3	3
2nd	0.88	over	4	4
3rd	2.70	over	1	1
4th	0.70	over	5	5
5th	1.69	over	2	2

Note: the 1st Initiative: expanding the mass transit rail system within Bangkok Metropolitan area; the 2nd Initiative: promoting the use of renewable energy; the 3rd Initiative: improving building electricity consumption efficiency; the 4th Initiative: improving solid waste management and wastewater treatment efficiency; and the 5th Initiative 5 expanding park area.

6. CARBON SEQUESTRATION OF URBAN PARK

From the MCA result, expanding urban park area was the second rank of all initiatives which had less investment cost and a lot of benefits for people and environments. Therefore we further study on carbon sequestration on urban park in order to elucidate its benefit in carbon sequestration. To serve this objective, relevant data used for calculation of carbon sequestration rate were collected over the period of 10 years (2005-2015) at the Santipab Park located in the central of Bangkok. In 2015, there were 46 tree species with the total number of 330 trees or about 101 trees per hectare. Back in 2005, there were 45 species with total number of 357 trees or about 111 trees per hectare. The total carbon storage of trees in this park were 26.71 tC (97.94 tCO_2) and 45.32 tC (159.57 tCO_2) in 2005 and 2015, respectively (Table 5).

In a decade, trees in Santipab Park could store carbon of about 18.61 tC (61.63 tCO_2). Therefore, the sequestration rate of trees in this urban park was estimated as 1.86 tC/y (6.82 tCO_2/y) or 0.58 tC/ha/y. It should be note that the amount of carbon storage and sequestration are depend on an area of estimation. Larger areas could result to higher amount of carbon storage and sequestration. Furthermore, the potential of carbon sequestration were also depend on density of trees in the areas as well. Low carbon sequestration rate of urban park in this study could be resulted from low density of trees planted in the park as compared with other studies.

Table 5 Data of trees planted in 2005 and 2015 in Santiphap Park, Bangkok

Data	2005	2015
Numbers of trees	357 trees	330 trees
Numbers of species	45 species	46 species
Density	111 trees/ha	101 trees/ha
The dominant tree species	*Lagerstroemia floribunda* Jack	*Lagerstroemia floribunda* Jack
Total carbon storage	26.71 tC 97.94 tCO_2	45.32 tC 159.57 tCO_2

This value is similar with tree's sequestration rate in Barcelona, Spain reported as 0.54 tC/ha/y [23]. A study in 28 cities in the U.S. reported that carbon sequestration rate were in the range between 0.81-4.01 tC/ha/y [24]. These values were even much higher in the Chinese's studies which estimated in Hangzhou as about 1.66 tC/ha/y [25]. In Beijing, the tree's sequestration rate was calculated as about 2.31 tC/ha/y [26]. Comparisons of carbon sequestration rate from each urban park is as showed in Fig. 4. Annual sequestration rate of a single tree in this study was estimated about 20.98 $kgCO_2$. This value was similar with value of previous reported which was about 21.77 $kgCO_2$ annually [27].

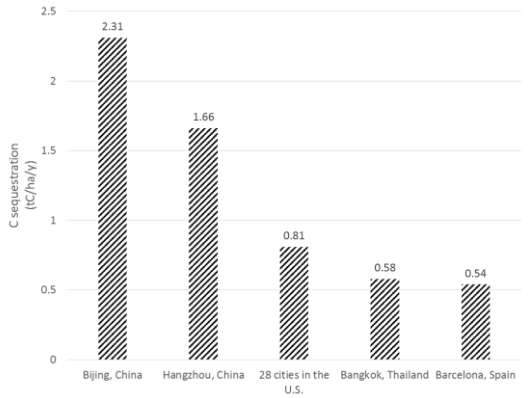

Fig. 4 Comparison of carbon sequestration in study area and previous research

Moreover, urban parks are not just established for the improving of environmental pollution but also for the aesthetic perspective. Number of tree planted in the park might effect to the potential of carbon storage but management of an area within urban park also require space to serve for outdoor activity. The key factors influenced to increasing of the amount of carbon storage and gross sequestrations are not only the density of tree but also increasing in the proportion of big trees with large diameters. Therefore, effort to keep and maintain large healthy trees might be an appropriate measure which can serve for both aesthetic and environmental aspects for the management of urban park.

7. CONCLUSIONS

The consideration of action plan and initiatives for GHG reduction mitigation in Bangkok Metropolitan Administration (BMA) by using five criteria including mitigation potential, total costs, feasibility, community benefits and environmental benefits indicated that the appropriate action plan was the 3rd initiative (Improve Building Electricity Consumption Efficiency). The example activities are a campaign for efficient use of electrical appliance, a campaign for reduced use of air-conditioning, supporting energy efficiency labeling, and proper maintenance schemes for electrical appliance, promoting the use of energy-saving appliances, and promoting the use of energy-saving light bulbs. The second one was the 5th initiative, expanding park areas. There was the intensive study at urban parks in Bangkok using data collected over the period of 10 years (2005-2015). It was found that the park in Bangkok could store carbon of about 1.86 tC/y (6.82 tCO_2/y) or 0.58 tC/ha/y. The sequestration rate of urban tree in Bangkok can be increased by proper maintenance of large healthy trees existed in the parks. These data were valuable for analysis of the appropriate mitigation measures used for management of greenhouse gases in an urban environment. In contrast, promoting the use of biofuels of the 2nd initiative included promoting the use of gasohol and bio-diesel was the lowest score which is less appropriate than the others. The result from actual implementation showed the same direction to the result from MCA of this study. Hence, it could imply that this methodology can be applied to preliminary assess greenhouse gases mitigation measures to reduce for policy making decision.

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