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Assessing Adaptive Capacity and Climate Change Adaptation Measures for the Building Sector in Bangkok Metropolitan Region

Aumnad Phdungsilp*
Graduate Program in Engineering Management, Dhurakij Pundit University
110/1-4 Prachachuen Road, Laksi, Bangkok, 10210, Thailand
E-mail: aumnad@dpu.ac.th

Abstract

The built environment is likely to be affected by climate change. Building sector represents a significant amount of opportunity for climate change adaptation. The objectives of this paper are to examine the adaptive capacity of cities in Bangkok Metropolitan Region (BMR) and to propose potential climate change adaptation measures for the building sector. BMR is the most important socio-economic center of Thailand, as well as rapid development in the Asia-Pacific. This study contributes to the body of knowledge by assessing adaptive capacity of each city in BMR and analyzing adaptation measures to the projected climate change impacts in the region. The findings indicate that Bangkok has the highest adaptive capacity and followed by Nonthaburi, Pathum Thani, Samut Prakarn, Nakhon Pathom, and Samut Sakhon, respectively. The potential adaptation measures include engineering and non-engineering solutions. This study argues that BMR needs to better integrate strategies for adaptation to climate change along with the mitigation side, revision of building code, and increasing socio-economic parameters under the adaptive capacity framework. In addition, the integration of traditional knowledge and modern scientific methods would offer cost optimum solutions for adaptation to climate change in the building sector. Findings from this study can also provide useful information to policy-makers that implement climate policies and also relevance to other cities having similar impacts of climate change.

Keywords: Adaptive capacity, Building sector, Climate change adaptation, Sustainability

1. Introduction

Climate change plays a major role in the development of our society. Scientific evidence confirms that climate is already changing and the impacts are already observed worldwide [1–3]. Thus, climate change presents a great challenge for all nations. To address this global challenge, society must begin to reduce greenhouse gas (GHG) emissions. The action is referred to climate change mitigation. On the other hand, society must also be adapted to unavoidable climate change or climate change adaptation. The literature has shown that there is a growing concern about the impacts of climate change on urban areas [3]. The building sector is likely to be affected by weather variability and flooding, damage to premises and

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***Corresponding author**
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properties, and problem with subsidence [4]. Globally, the building sector is responsible for 40% of primary energy use and 30% of GHG emissions. It was estimated that the energy demand for buildings will stimulate about half of energy supply investments to 2030 [5].

Building sector represents a significant amount of opportunity for adapting to climate change. Incorporating adaptation measures into new and existing buildings will help to avoid climate-related damages and costs in the long-term. A study by [6] suggested that both climate change adaptation and mitigation should be added to building energy codes and thermal comfort standards. A case study in Australia identified the adaptation pathways by enhancing adaptive capacity to accommodate the impacts of climate change and to maintain energy use and GHG emissions for existing and new residential buildings [7]. In Thailand, a study examined how climate change may influence electricity demand. It was found that the highest change in temperature based on the Hadley Centre Climate Model version 3 (HadCM3) will occur during summertime, which coincides with the demand for electricity [8]. Climate change adaptation has been considered to be an effective strategy to improve the sustainability of existing building stock [9].

Adaptation is necessary to cope with the impacts of climate change due to past emissions. However, the impacts differ from place to place. The adaptive capacity of cities usually depends on various infrastructure and service systems. According to the Intergovernmental Panel on Climate Change (IPCC), the adaptive capacity can be defined as the ability of physical systems to adjust or respond to the consequences of climate change [10]. Adaptation is a way to reduce the negative impacts of climate change. Most of climate change adaptation studies in Thailand focused on water, agriculture, coastal infrastructure, and forestry sectors. Internationally, there has been emerging research on planning for adaptation at both city and local levels. In high-income countries, the urban adaptation became important issue in many city governments [3]. However, few studies have been conducted on the adaptation measures related to the building sector in developing countries, such as Thailand.

Bangkok Metropolitan Region (BMR) is the center of high population density and economic activity of Thailand. BMR consists of Bangkok and five neighboring provinces, namely Nonthaburi, Samut Prakan, Pathum Thani, Samut Sakhon, and Nakhon Pathom. The region is vulnerable to climate change. The World Bank has estimated that the costs associated with climate change in Bangkok under high emission scenario are about 49 billion THB or approximately two percent of GRDP (Gross Regional Domestic Product). Over 70% of flood-related costs are a result of damages to buildings [11]. Previous study has revealed that BMR will require additional adaptation measures to response the adverse impacts of climate change corresponding to different climate scenarios [12]. Buildings are generally expected to have long lifetime. Innovative solutions are required for adapting new and existing buildings. Effective adaptation measures can also bring co-benefits, such as reduction of maintenance and energy costs. Integrating climate change adaptation measures will help to ensure the building stock to cope with climate change.

Although Thailand has prepared the National Climate Change Master Plan B.E. 2558–2593 (2015–2050) and Thailand's Second Assessment Report on Climate Change 2016 [13–14]. However, there is little detail on method and measure on climate change adaptation for the building sector. In addition, the literature on building sector and climate change in Thailand focused on mitigation side, with less attention to adaptation. This paper addresses the knowledge gaps and contributes to the area of research by assessing adaptive capacity of cities in BMR and examining adaptation measures for the building sector. Thus, the objectives of this paper are to assess the adaptive capacity and to propose the potential adaptation measures for both new and existing buildings. The building sector covers both residential and commercial buildings.

2. Methodology

Climate change will be impacted on environmental, economic, and social systems. Building adaptive capacity increases the ability of individuals, groups, and organizations to adapt to climate change whereas implementing adaptation measures can be prepared for response to climate change. Research methods in this paper consist of various components, starting from investigating impacts of climate change in Thailand based on available data from literature review on regional climate modeling, assessment of adaptive capacity in the BMR, and identifying adaptation measures with focusing on the building sector. Previous studies on the projections and likely impacts of climate change in Thailand are well documented in [15–19].

2.1 Adaptive Capacity

Assessing adaptive capacity requires a clear conceptual framework. An assessment of adaptive capacity was conducted based on the method developed by [20]. The same method was also used to identify climate change vulnerability for Greater Mekong sub-region [21]. Adaptive capacity can be determined in the following form.

Adaptive capacity = f(socio-economic, technology, institution and infrastructure)

The overall framework of adaptive capacity assessment is shown in Figure 1. Socio-economic parameters include Human Development Index (HDI), poverty incidence, and income inequality. The HDI has greater weigh (0.50) than poverty incidence (0.28) and income inequality (0.22). This is due to the emphasizing people and their capabilities [20–21]. The HDI is an indicator of average achievement of the three key dimensions of human development, including standard of living (GDP per capita), life expectancy (years), and adult literacy rate (%). The calculation of HDI is followed [22]. The income index is based on household income, poverty incidence, and households with consumer debt. The income disparity is measured by the Gini coefficient.

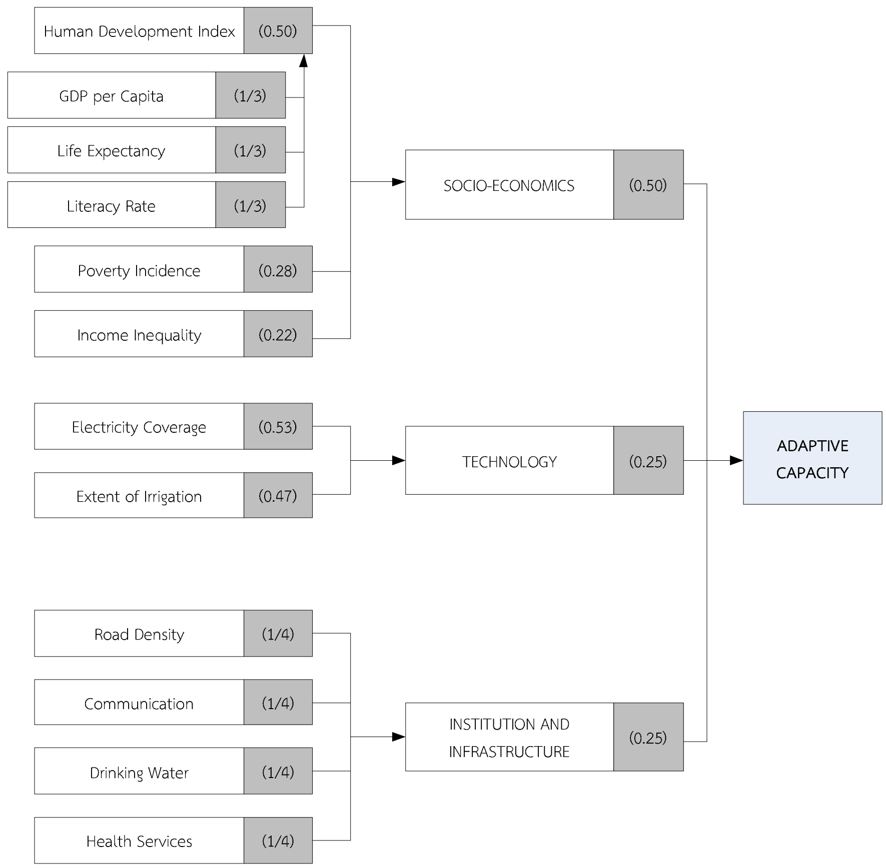

Figure 1 Adaptive capacity assessment (Adapted from [20–21])

Technology plays an important role in climate change adaptation. Following [20], the electricity coverage and the extent of irrigation are used as primary indicators in this study. The electricity coverage is weighted as 0.53 and the area equipped for irrigation is weighted as 0.47. Institution and infrastructure are effected the capacity to adapt to climate change. Cities with well-developed institution and infrastructure are expected to have higher adaptive capacity. The parameters in institution and infrastructure are road density, communication, drinking water, and health services.

Due to different types of units in each indicator, a normalization analysis of each indicator is employed to normalize values of units. For the indicators express the higher is better (e.g., income, education, electricity coverage, etc.). Equation 1 was applied for the calculation. Then, Equation 2 was applied for the indicators express the lower is better, such as poverty incidence, income inequality, etc.

$$Normalized_{(Higher\ is\ better)} = \frac{(Actual - Minimum)}{(Maximum - Minimum)} \quad (1)$$

$$Normalized_{(Lower\ is\ better)} = \frac{1-(Actual - Minimum)}{(Maximum - Minimum)} \quad (2)$$

2.2 Data Collection

This study assesses the adaptive capacity in the BMR and analyzes the potential adaptation measures for the building sector in particular. The study relies on the document analysis of both a review of literature and secondary data in addition with consultation with expert interviews. Data were collected from a mixture of published and peer-reviewed literature, grey literature, and information websites. Data sources in this study were taken from: (i) publications and working papers from the United Nations, Asian Development Bank, World Bank, Southeast Asia START Centre, and others; (ii) academic literature (e.g., Climate & Development, Building Research and Information, Building and Environment, Energy and Buildings, and Sustainability); and (iii) government publications.

3. Results and Discussion

3.1 Adaptive Capacity

Climate change adaptation is related to various natural and social aspects that need to be studied from a multi-disciplinary approach. The adaptive capacity was determined to empirically assess vulnerability to climate change. The higher score indicates the less vulnerable to climate change, while lower score reflects greater vulnerability. This study uses BMR as a case study for assessing adaptive capacity of each city for further planning. BMR is the most important socio-economic center of Thailand. BMR is not only the political, administrative, economic, and cultural area of the country but the region is also the focal point for national infrastructure, including roads, railways, and financial and communication services. The administration of BMR comprises of provincial and local administration. The provincial administration comprises of six provinces. Bangkok is a Special Local Administration (SLA), called Bangkok Metropolitan Administration (BMA). Provincial administration consists of district, sub-district and village levels. Local administration divides into municipality and Tambon Administration Organization (TAO) levels. The administration of BMR and average area of each city is shown in Table 1.

Table 1 Administration of BMR [12]

Province	Area (km^2)	Provincial Administration			Local Administration		
		District	Sub-district	Village	Municipality	TAO	SLA
Bangkok	1,569	50	154	-	-	-	1
Samut Prakarn	1,004	6	50	399	16	32	-
Samut Sakhon	872	3	40	290	7	31	-
Nonthaburi	622	6	52	328	10	35	-
Pathum Thani	1,526	7	60	494	14	52	-
Nakhon Pathom	2,168	7	106	930	16	100	-

It was estimated that the projections of population and households in BMR would be 15,680 thousand people and 5,813 thousand households in 2030, and 15,901 thousand people and 7,998 thousand households in 2050. It should be noted that the projections are also included non-registered population [12]. Thus, this region will have large effects of climate change and it will need to adapt to the changes. Adaptive capacity can be used to describe the extent to which natural and human systems will be able to cope with climate change. The assessment of adaptive capacity of each city in BMR is presented in Table 2.

Table 2 Assessment of adaptive capacity in BMR by cities

Province	**Adaptive capacity index**
Bangkok	0.82
Samut Prakarn	0.75
Samut Sakhon	0.68
Nonthaburi	0.77
Pathum Thani	0.75
Nakhon Pathom	0.73

The findings are shown that Bangkok has the highest adaptive capacity in BMR and followed by Nonthaburi, Pathum Thani, Samut Prakarn, Nakhon Pathom, and Samut Sakhon, respectively (Table 2). Based on the adaptive capcity index, Bangkok can improve the adaptive capacity by increasing the HDI similarly to other cities. Samut Sakhon has the lowest adaptive capacity as reflected by low scores on socio-economics, technology, and institution and infrasture dimensions. The main findings were compared with the previous study by [21] to verify the results of this study. It was found that the adaptive capacity index is in the similar range for each city in BMR.

Increasing adaptive capacity can be done through participation of local governments and other stakeholders. It will also create opportunity for co-benefits with other development goals, for example the adopted 17 Sustainable Development Goals (SDGs) [23]. The building sector plays an important role towards achieving the SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). A study of the interactions between SDGs and climate change adaptation in cities reported the multidimensional approaches in SDGs and climate change planning that can help bridge the gap between adaptation planning and implementation [24]. However, increasing adaptive capacity often results from improvement in governance system. This includes the improvement of availability and access to economic resources and technologies. A study in Korea has shown that the adaptation governance can be more effective through grass root activities at both metropolitan and local government levels [25]. BMR can also learn and share information from other cities in terms of multilevel governance for climate change adaptation.

3.2 Climate Change Adaptation Measures for the Building Sector

The building sector is vulnerable to the impacts of climate change in a number of ways. According to previous studies [11,14,19,21,26], BMR will be challenged by increasing temperatures, changes in precipitation patterns, sea level rise, and more intense and frequent extreme events. There are consequences for various impacts of climate change on building design, retrofitting, structural durability, and operation and maintenance. Increases in air temperature are likely to increase energy use for space cooling. Changes in precipitation lead to higher relative humidity. Intensity of floods adversely affects the life span of buildings and maintenance costs. Sea level rise can also affect some local areas in the BMR. Climate change may also be affected the competitiveness of commercial buildings, especially in Bangkok.

Most existing studies related to climate change adaptation in BMR focused on flooding protection and adaptation processes. The plans are included structural measures (e.g., large storage dam, coastal erosion and wave protection, and crest elevations of dikes) and non-structural measures (e.g., reservoir operation, flood forecasting and warning system, and financial response) [12,21]. The important of building sector is due to new buildings both residential and commercial buildings will be constructed in the future and existing buildings will also needed to retrofit to meet the new standard related to energy and environmental performance. Climate change can significantly increase the total energy use and energy-related CO_2 emissions from building sector. Thus, adaptation to climate change is an important issue for new and existing buildings.

However, climate change will not be constant and the variable and extreme weather conditions will have a major impact on the buildings. Climate change can cause paint staining, movements in building structures, cracks in concrete, and corrosion to building materials. These consequences are from temperature variations, changes in humidity, solar radiation, and precipitation patterns [27]. Adaptation for the building sector can be taken in various forms. Adaptation measures should be designed to support economic and social aspects with environmental objective.

Adaptation measures can improve the building services, such as thermal comfort and indoor air quality. The buildings in Thailand have been built to deal with the present climatic conditions. The uncertainty about climate change has not widely considered in building design or retrofit. Adaptation measures would respond to the consequences associated with climate change. Engineering solutions represent the options that can lead to improved outcomes under conditions of climate change [28]. Feasible adaptation measures for the building sector include: (i) creating new regulations or guidelines; (ii) taking climate change into consideration in the new construction; and (iii) using innovative technologies.

Several climate change adaptation frameworks have been developed worldwide for conducting adaptation assessment at both national and local levels or project focused, for example [29–31]. These frameworks can help to prioritize the adaptation activities and to identify the required resources, such as financial technology and human capacity. This paper proposes the potential adaptation measures for the building sector in BMR in particular, as shown in Table 3. Climate change is expected to affect the entire life-cycle of building from construction, operation, and demolition phases. Strategies for adaptation can also be applied to retrofitting buildings. However, adaptation measures taken at the design stage are often cheaper and easier to incorporate than during subsequent adaptation schemes.

Table 3 Adaptation measures and climate change impacts for the building sector in BMR

Climate variable	Impacts on building	Adaptation measures
Increased temperature	• Greater cooling demand and operating hours • Thermal comfort level affected • Increased energy use and energy-related CO_2 emissions • Urban heat island effect	• Passive cooling strategies, such as natural ventilation, daylighting and green roofs and walls • High efficiency air-conditioners and high performance buildings • Bioclimatic architectural design, such as building orientation • Building certification, such as green building
Increased precipitation	• Penetration into buildings • Higher relative humidity • Flooding • Corrosion	• Improved building envelope and construction materials • Relocation of buildings • Green spaces • Vernacular architecture, such as traditional buildings
Extreme events (flood or drought) and sea level rise	• Damage to buildings • Lower the loading strength and liquefaction resistance of the subsoil • Destruction of foundations	• Flood protection infrastructure in flood-affected areas • Reinforcement of design strength, such as flood-proof buildings • Legislation related to land use planning and zoning • Climate-proof infrastructure • Education and capacity building
Reduction in air quality	• Greater use of air-conditioning and mechanical ventilation • Increased energy use • Increased emissions • Sick building syndrome	• High efficiency natural ventilation • Green infrastructure • Integrated renewable energy systems • Reconsideration of outdoor design temperature and quality for indoor environment • Legislation to control outdoor air quality

Adaptation measures include engineering and non-engineering solutions. Engineering adaptation measures could be more robust design or retrofitting that provides the buildings with the ability to cope with higher air temperatures and more extreme conditions. This is also included the improvement of the robustness of the engineering designs and operations of installations. In some cases, it may also necessary to consider relocating vulnerable existing buildings. BMR is expected to temperature rises. Adaptation measures (see Table 3) to cope with increased temperature are: (i) passive cooling strategies; (ii) improving building energy performance; and (iii) improving end-use efficiency for buildings. The measures will lead to reduce the energy demand in buildings.

For non-engineering adaptation measures, it could be appropriate to develop and improve the adaptive capacity of local areas or for districts or even sub-districts. It should be noted that currently there is no legislative or strategic planning to guide climate change adaptation for buildings in Thailand. Thus, it would be highly beneficial to develop either a national or city level building adaptability and resilience assessment system for existing and new buildings. Other measures under non-engineering measures include better coordinated land use planning, new policies and regulations on climate-friendly building, integration of climate change adaptation and mitigation planning, building site elevation, and flood management.

Implementing adaptation measures include some costs and can be a huge challenge for cities in developing nations like Thailand. Traditional knowledge (TK) has been increasing interest in climate change adaptation. TK refers to the knowledge, innovations, and practices of local peoples. TK is also a foundation of the modern science and providing ideas, inspiration and designs for sustainable solutions. TK has high potential to help society addressing the impacts of climate change in cross-cutting areas [32–33]. The integration of TK and modern scientific method would offer low cost and effective solutions. In addition, vernacular architecture can deliver adaptation measures without being constrained by intellectual property (IP) restriction. The IP is one of the barriers in transferring climate change technologies. Traditional buildings are usually well-adapted to local conditions. They are built based on passive design and local available materials. Traditional buildings also use less energy and emit less pollution compared to modern buildings [34]. There are some examples of traditional buildings in BMR that enable them to withstand extreme weather, such as flooding.

4. Conclusion

There is a strong scientific consensus that climate change is happening. The building sector in BMR is likely to be affected by increased temperature, changes in precipitation, flooding, and reduction in air quality. Climate change is also expected to affect the entire life-cycle of building. BMR is the most important socio-economic center of Thailand. The region is also the focal point for national infrastructure and financial and communication services. The assessment is shown that Bangkok has the highest adaptive capacity and followed by Nonthaburi, Pathum Thani, Samut Prakarn, Nakhon Pathom, and Samut Sakhon, respectively. There is a large opportunity to increase the adaptive capacity in Bangkok and its vicinity. The first priority would be improved the performance of socio-economic parameters according to the adaptive capacity framework, such as HDI, poverty incidence, and income inequality. Developing appropriate adaptation measures will be critical in reducing the impacts of climate change on buildings. A variety of adaptation measures have been identified. The potential climate change adaptation measures for the building sector include engineering and non-engineering solutions. Some engineering adaptation measures, such as passive design strategies, simultaneously contribute to mitigating energy-related CO_2 emissions. The measures described in this paper provide guidance regarding possible adaptation measures for various climate sensitivities. However, detailed local assessments (such as district, sub-district, and village levels) are necessary to provide greater confidence in adaptation to climate change at the level of specific local areas. This study argues that BMR and other cities in Thailand need to better integrate strategies for adaptation to climate change along with the mitigation side. Future work should deal with the subject of the performance of adaptation measures, including vernacular architecture in both quantitative and qualitative ways. The quantitative approach is based on the measurements of different parameters whereas the qualitative approach involves the investigating and compiling relevant adaptation measures for the building sector. Further work is needed to provide detailed analysis of adaptation measures that are grouped and tested as packages to identify the optimal solution.

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