HEALTH BENEFIT MODELING USING BENMAP FOR AIR POLLUTION IMPACT MEASUREMENTS IN JOHOR BAHRU, MALAYSIA

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ABSTRACT

Recently, Malaysia were experiencing a continuous and transboundary air pollution in cities with increasing economic growth and rapid developments. This resulted in an increasing level PM10 which further led to increase in the respiratory-related health cases. Thus, the exposed population may experience respiratory health effects, lose of working days and increase in medical spending to cure the health effects. This study focused on quantifying health and economic benefits from the PM10 reduction level by applying BenMAP, which is a software measuring the impact of air pollution. Health impact function (HIF) are used to relate between the change of PM10 level and the change in incidence rates of the PM10-related health effects among the exposed population. The HIF was developed based on two Relative Risk (RR) estimates adapted from HKL and HUKM in a similar study in Klang Valley. A 30 percent reduction scenario was implemented in order to exemplify greater health benefits for PM10 level that will be much lower than the current DOE guideline of PM10. From the analysis, the highest PM10 level recorded was 46.88 $\mu g/m^3$ for the baseline scenario and 32.82 $\mu g/m^3$ after the reduction scenario. The second stage analysis for HKL RR estimates resulted in incidence rate of 134.74 during the baseline scenario and 58.69 after reduction scenario. For HUKM's RR estimate, the analysis yielded an incidence rate of 446.45 before the reduction scenario and 202.21 after reduction scenario. The last stage of analysis produced monetized benefits for Johor Bahru by applying Cost of Illness (COI) method. This generated a COI of RM 1,054,000 and RM3,497,000 for HKL and HUKM respectively during the baseline scenario. The COI are reduced to RM459,000 and RM1,584,000 after the reduction scenario for HKL and HUKM respectively. This research further proves that the public health burden could be reduced up to RM1,900,000 if PM10 reduction scenario is applied in Johor Bahru. Policymakers and planners can apply BenMAP in order to check the existing policies and strategies for controlling air pollution and PM10 emission level in Johor Bahru as well as a benchmark to develop a new guideline for PM2.5.

ABSTRAK

Baru-baru ini, Malaysia mengalami isu pencemaran udara yang berterusan terutama di bandar yang mengalami pembangunan pesat dan peningkatan ekonomi. Kesannya, zarah terampai (PM10), iaitu sejenis partikel di dalam udara meningkat naik secara berterusan dan menyebabkan peningkatan kes penyakit berkaitan pernafasan di kalangan penduduk dan seterusnya menyebabkan pengurangan hari bekerja serta peningkatan perbelanjaan perubatan. Matlamat kajian ini adalah untuk mengetahui manfaat kesihatan dan keuntungan dari segi ekonomi apabila tahap PM10 dikurangkan dengan menggunakan *Environmental Benefits Mapping and Analysis Program (BenMAP)*, iaitu program untuk mengukur tahap keuntungan kesihatan daripada pengurangan tahap PM10. *Health impact function (HIF)* digunakan bagi mengaitkan perubahan tahap PM10 dan perubahan kadar insiden penyakit disebabkan oleh PM10 yang dialami penduduk. Bagi menghasilkan *HIF*, nilai *Relative Risk (RR)* bagi simptom berkaitan pernafasan untuk kawasan HKL dan HUKM diadaptasi daripada satu kajian yang serupa di sekitar Lembah Klang. Senario pengurangan sebanyak 30 peratus dilaksanakan bagi menunjukkan manfaat kesihatan yang lebih tinggi untuk tahap PM10 yang dijangka lebih rendah daripada tahap piawaian DOE untuk PM10. Hasil daripada analisis ini, tahap semasa PM10 yang tertinggi adalah 46.88 $\mu g/m^3$ dan 32.82 $\mu g/m^3$ semasa senario pengurangan. Analisis seterusnya adalah bagi mengira kadar insiden kesihatan untuk HKL iaitu sebanyak 134.74 dan 58.69 selepas senario pengurangan. Penggunaan RR bagi HUKM pula menyumbang kepada kadar insiden sebanyak 446.45 dan 202.21 selepas senario pengurangan. Peringkat terakhir analisis menghasilkan keuntungan ekonomi untuk Johor Bahru dengan menggunakan kaedah *Cost of Illness (COI)*. Hasil analisis mendapati jumlah COI sebanyak RM1,054,000 dan RM3,497,000 untuk HKL dan HUKM sewaktu senario semasa. Jumlah COI berkurang kepada RM459,000 dan RM1,584,000 selepas senario pengurangan bagi HKL dan HUKM. Hasil kajian ini membuktikan bahawa sebanyak RM1,900,000 beban kesihatan di kalangan penduduk Johor Bahru boleh dikurangkan jika pengurangan tahap PM10 dilaksanakan dari pelbagai sektor-sektor pembangunan. Ini akan membantu pihak yang berkaitan untuk menggunakan BenMAP bagi memperbaiki polisi dan strategi semasa berkaitan pencemaran udara PM10 di seluruh Malaysia dan juga menjadi tanda aras bagi menghasilkan garis panduan baru untuk PM2.5.

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ARI	-	Acute respiratory infection
CAQM	-	Continous air quality monitoring
COI	-	Cost of Illness
C-R	-	Concentration-response function
DOE	-	Department of Environment Malaysia
EGU	-	Electricity generating unit
GBD	-	Global Burden Disease
GDP	-	Gross domestic product
HIF	-	Health impact function
LRI	-	Lower respiratory infection
MAAQG	-	Malaysia Ambient Air Quality Guideline
MOH	-	Ministry of Health
PM10	-	Particulate matter with diameter size of 10 μm or less
PM2.5	-	Pariculate matter with diameter size of 2.5 μm or less
RR	-	Relative risk
UN	-	United Nations
UNEP	-	United Nations Environment Program
UNFCCC	-	United Nations Framework Convention on Climate Change
URTI	-	Upper Respiratory Tract Infection
USEPA	-	United States Environmental Protection Agency
VOC	-	Volatile organic compound
VSL	-	Value of Statistical Life
WHO	-	World Health Organization
WTP	-	Willingness to Pay
CAMx	-	Comprehensive Air Quality Modeling with extensions

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The issue of air pollution has long been discussed globally and had been proven to have impact on the exposed population. Malaysia is one of the developing countries in ASEAN region that is not excluded from experiencing serious issues related to air pollution. Recent activities on major development in Malaysia have led to a growing concern on the ambient air quality, especially with the rate of development increasing significantly throughout the years which was a worrying trend of air pollution scenarios in Malaysia. In recent years, it was reported that the stationary air pollution sources in Johor accounted for about 35 percent of the total air pollution sources in Malaysia (UTM-Low Carbon Asia, 2013).

Johor Bahru as the third conurbation in Malaysia after Kuala Lumpur and Penang has been tremendously developing with new international projects that encompasses of commercials, industries and high rise residentials especially because the city is within the vicinity of Iskandar Malaysia region. With the rapid on-going major developments in Malaysia that contributes to the level of air quality in the ambient surroundings, the population in Johor Bahru city will be exposed to the deteriorating ambient air and will be a potential threat to the current and future health of the population in the metropolitan city.

The purpose of this research is to explore on the increased threat of public health related to the deteriorating air quality level that takes place in the massive development of Iskandar Malaysia. Air particles which has the size of 10µg (PM10) and smaller in aerodynamic diameter have been a recent concern where epidemiological studies proved that continuous exposure on air pollution affects the health of the population exposed. Jimoda (2012) reported that PM10 penetrates into the upper respiratory tract while being inhaled into the lungs and given some period of exposure, it was proven to have adverse health effects on the exposed population. Despite that, many recent studies around the world are now focusing on the adverse health effects of PM2.5, a smaller particle which have the capacity to penetrate deep into the respiratory system because of its smaller particle size. This research is focused on PM10 because of the non-availability of PM2.5 data from the Department of Environment Malaysia for this particular study period.

This study focuses on characterizing PM10–related health benefits and monetized benefits of the emission reduction scenarios in the vicinity of Johor Bahru city. This is beneficial in relating the effects of built environment developments with the decrease of air quality level, exposed population's health level and the economic benefits that are obtain from air pollution managament in the surrounding environment. The health benefits and monetized benefits can be measured by applying BenMAP program (Environmental Benefits Mapping and Analysis) that was developed by U.S. Environmental Protection Agency (US EPA). BenMAP application aids in performing the analysis of PM10 emission reduction and to obtain the monetized benefits in terms of reduced health cases. The analysis is further focus on the reduction of health effects that contributed to the economy of the study region such as the decrease number of lost work days, decrease number of hospital admissions related to respiratory and cardiovascular symptoms and decrease in emergency room visits.

To date, previous studies regarding air pollution were mainly associated with PM10 health effects but less studies were done in Malaysia regarding PM10 health effects that applied BenMAP to obtain the related health benefits and monetized benefits, not to mention studies for PM2.5. Although similar researches has been done in other Asian countries like Thailand and China, but the characteristics of the

population's background and environment were different from Malaysia. This resulted in the formation of this research whereby specific considerations of various data in the background context are taken into account.

1.2 Problem Statement

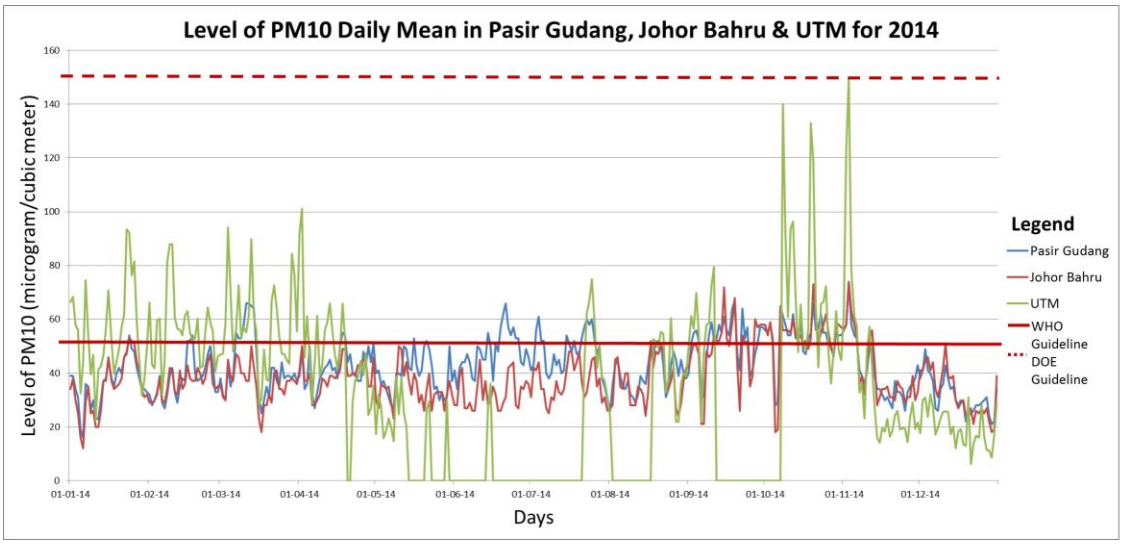
Recently, the emission per capita for Malaysia was approximately 5.9 million tons which were triple when compared to the levels recorded for the whole of South East Asia region. Malaysia which has a population of 28.318 million (UN, 2010), were indicated as the country with the third greatest emission released which was about 194.48 million tones when compared to Indonesia and Thailand which released about 397 and 278 millions tones respectively (Nizam et al., 2013). This worrying values of emission released for Malaysia is an indicator that emissions released from industries and transportation sector needs to be dealt early, even with a small step that could result in a greater impact for the country.

The increased rate of development in Johor Bahru city resulted in the increased level of air pollution where this scenario will further lead to the increase in PM10-related health incidences in the urban area. However, limited studies have been done on the related health effects of increased air pollution in Malaysia especially during the scenario of the peak period of smoke haze in 1997 and 1998. World Health Organization reported that, in 1998, there are about two and three times of increased cases for the number of outpatient visits in Kuching and an increase about 250 to 800 visits per day for respiratory diseases to Kuala Lumpur General Hospital. In a recent study, Latif et al. (2014) have reported a positive upward trend of seven pollutants (NO, NO_2, O_3, PM_{10}, THC and CH_4) over the 15-years period in Peninsular Malaysia which affects the level of PM10 in Johor Bahru city. Choong (2012) reported that drawing from available data on PM10 in Petaling Jaya, the mean for PM10 is 36.2 $\mu g/m^3$ which failed to meet WHO guidelines for annual mean of PM10 which is about 20 $\mu g/m^3$. This shows an alarming trend for the levels of PM10 in Malaysia where it is crucial to improve the current PM10 standards and formulate policies with regards to control the pollutants. Therefore,

early steps on controlling the rate of air pollution especially PM10 can be an indicator to start focusing on PM2.5 in the future.

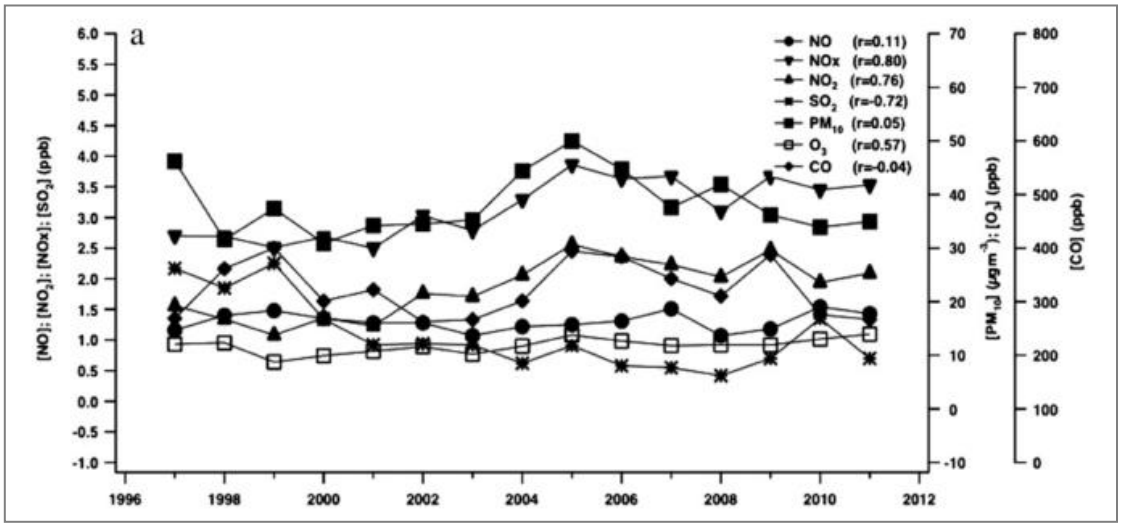
The focus is on Johor Bahru city, which is the third conurbation of Malaysia situated in the state of Johor. It is forecast that Johor will be the second state in Malaysia that will contribute to the country's air quality where the number of industries are fast approaching along with the formation of the Iskandar Malaysia region. Comprehensive policies and guidelines for controlling the level of air pollution which is specifically focused on PM10 is currently being prepared by the Low Carbon Society group in UTM to achieve a Low Carbon Society status with an improve ambient air quality for this current developing region. Despite this, less focus is being done on the health effects and monetized benefits resulting from high level of PM10 in Johor Bahru city.

Figure 1.1 shows the level of PM10 daily mean level in Pasir Gudang, Johor Bahru and UTM area for the year 2014. It can be seen that the level of PM10 in UTM is much higher than the rest and tend to reach the specified guideline of PM10 formulated by DOE during certain period of the year. Most of PM10 level reaches or are higher than the PM10 guideline specified by WHO and this became an issue whether the current Malaysia guideline should be re-evaluated according to the relevant guidelines so that this problem will not escalate further in the future. Overall, the trend of PM10 does not show significant levels due to the fact that during most of the days in 2014, it does not yet exceed the current DOE guideline. But, according to Figure 1.2 shown below, the yearly trend of PM10 are the highest compared to other air pollutants whereby it exceeded the specified guidelines of WHO. With the fast rate of development, it is not surprising that PM10 levels will continue to increase in the future.



Source: Department of Environment (2015)

Figure 1.1: Level of PM10 Daily Mean in Pasir Gudang, Johor Bahru & UTM for 2014



Source: Latif et al. (2014)

Figure 1.2: Yearly trends of various air pollutants in Malaysia for 1997-2011

To date, Malaysia is still using PM10 as a parameter to measure particulate pollution as other developed countries is shifting their focused on measures for PM2.5 since the effects are greater. The establishment of monitoring stations maintained by Department of Environment Malaysia are focused majorly to the common five greenhouse gases which are carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3) and particulate matters.

Many policies have not been able to mitigate the impacts of rapid developments on public health prior to the increasing concern about sustainability in Malaysia's national development plans as early as 1990s (Ho et. al., 2013). Furthermore, there has been little study on the impact of other built environment features in air pollution severity in Malaysia. The impact of emerging new economic development corridors, such as Multimedia Super Corridor and Iskandar Malaysia should be investigated to measure its ambient air pollution and carbon footprint. These measurements will quantify the environmental, health, and economic benefits (co-benefit) and provide a clear insight for decision making process for the future developments.

The utilization of the current technology such as the application of the Environmental Benefits Mapping and Analysis Program (BenMAP) developed by US EPA needs close attention in our country and is still not widely used in Malaysia. Currently, there are no studies being done yet on utilizing BenMAP to simulate the benefits from an air pollution reduction scenario in Malaysia. But, it is popular among developed countries such as U.S., Japan and China whereby these countries have a thorough and comprehensive air monitoring data collected over the years. The application of this program is important because it includes analyzing health incidences for a scenario of increased PM10 level when exposed to a population as well as quantifying the monetized benefits for reducing the PM10 level and health incidences. Malaysia needs to adapt more studies related on PM10 by using the application of BenMAP program in order to improve on localized ambient air quality by showcasing the benefits obtained from the reduction scenarios such as increased health benefits, reduced in health expenditure spendings for PM10-related health symptoms as well as attaining a better quality of the ambient environment.

1.3 Research Questions

The specific research questions are:

1.3.1 How much are the economic costs caused by PM10-related health incidences among the existing population during the baseline scenario in Johor Bahru city?

1.3.2 How much PM10-related health incidence rate are reduced when a PM10 reduction scenario is applied in Johor Bahru city?

1.3.3 How much are the monetized benefits obtained when a PM10 reduction scenario is applied in Johor Bahru city?

1.4 Research Objectives

The aim of this research is to quantify health and economic benefits from the reduction of PM10 level by utilizing BenMAP in a more localized scenario for the purpose of future community's usage. This will eventually help in improving the policies and strategies for controlling PM10 and may help policymakers to re-structure guidelines for PM2.5 in the future. To achieve this aim, the following objectives are formulated:

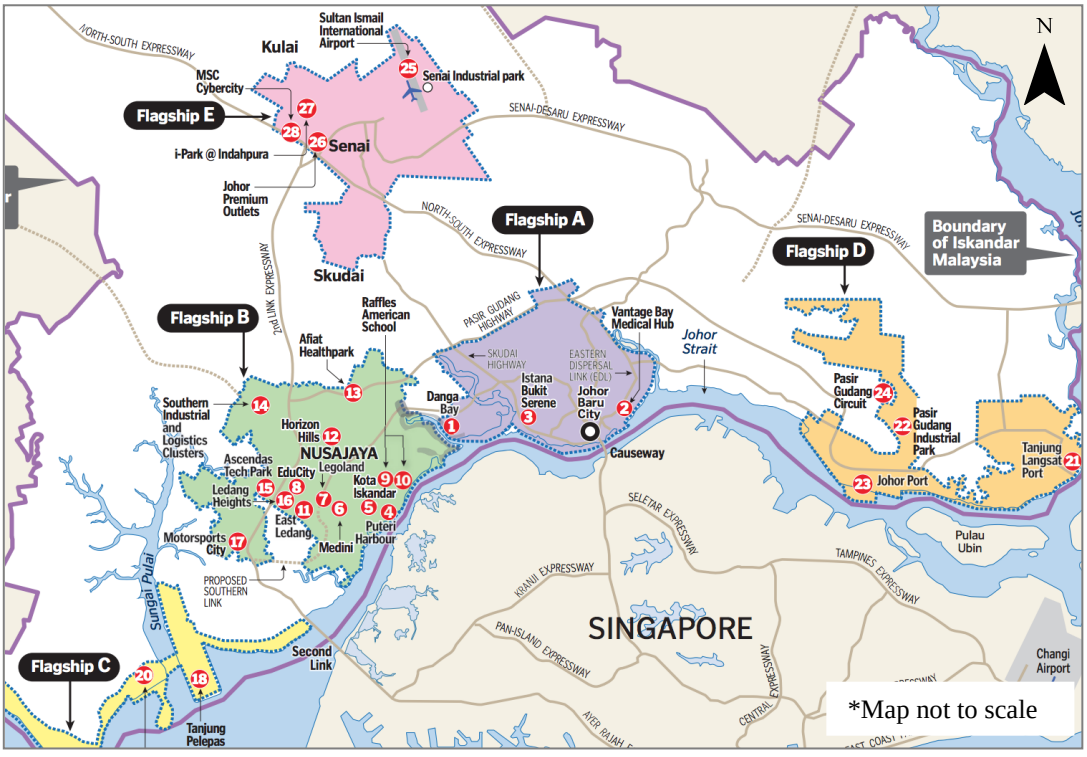
1.4.1 To identify the economic costs due to PM10-related health cases during the baseline scenario in Johor Bahru city.

1.4.2 To quantify the reduction of PM10-related health incidence rate when a PM10 reduction scenario is applied in Johor Bahru city.

1.4.3 To obtain the monetized benefits of a PM10 reduction scenario in Johor Bahru city.

1.5 Research Area

The chosen research area is Johor Bahru city which is located roughly at the centre of Iskandar Malaysia region designated as Flagship A as shown in Figure 1.3. It is the Central Business District (CBD) and the State Capital of Johor and also the main getaway to Malaysia in the south. Johor Bahru has a population of about 1,386,569 people as of 2010 Malaysian Census and is projected to increase to 4.4 million in 2020. As the third conurbation state in Malaysia, generally its population is relatively young where about 1.5 million people are between 15 to 44 years old during 2004. The main keyplayers of Johor Bahru which is situated in Flagship A are financial services, commerce and retail, arts and culture, hospitality, urban tourism, plastic manufacturing, electrical and electronics (E & E) and food processing. The main existing land uses within Johor Bahru's Flagship A are residential, commercial, industrial and manufacturing, recreational open spaces, infrastructures and institutions.



Source: Hoe (2015)

Figure 1.3: Location of Johor Bahru Flagship A within Iskandar Malaysia boundaries

1.6 Expected Findings

The expected findings of this research are the health benefits and economic benefits of a PM10 reduction scenario using BenMAP. The health benefits are obtained in terms of reduced number of PM10-related health incidence cases and the economic benefits are obtained in terms of reduced spending costs for the treatment of PM10-related health incidence cases. The expected findings of this research can help local authorities and planners to plan for reduced emission scenarios in every sectors of land use in the current or future district and local plans. PM10 emission can be reduced through extensive transportation planning and carbon reduction measures, planning of residential land use and control in household activities, energy production, building works, (inland) shipping and large and small scale industries (Keuken et al., 2013). From this, it can contribute to the increase in public health quality at the local level where the population affected in the Johor Bahru area can experience a more cleaner air quality. Furthermore, economic benefits in terms of hospital admissions and monetized benefits can also be reduced which can contribute to the improvement of ambient air quality in Johor Bahru area.

1.7 Research Significance

In Malaysia, the major air pollutants being monitored by the Department of Environment (DOE) are CO, O_3, NO_2, SO_2 and PM10. PM10 is chosen as the specified pollutant because less research has been done on quantifying the monetized benefits from a reduced PM10 emission scenario by using BenMAP in Malaysia. The usual trend of research that has been done in Malaysia mainly focused on the relationship between population that are exposed to PM10 and their health effects by analysing using a generalized additive model procedure (UKM Pakarunding, 2004). The urban population in the vicinity of housing are much closer to experience traffic emissions of particulate matter. The needs to conduct this research are so important prior to the future health effects that will affect the exposed population in Johor Bahru city. Hence, this research is significant in providing the benchmark for further

studies in the future to use BenMAP as the method of health benefit reduction analysis for other air pollutants.

Moreover, this research is significant because epidemiological studies that addressed the relationship between PM10 and adverse health effects were mainly conducted in American and European cities and the background environment may not be applicable to Malaysia. The difference between this research and other researches is the intervention between different geographical areas where this research will only focus in the Johor Bahru city area. The expected findings would be different because most of the characteristics of the study context such as the level of PM10 concentrations, health incidence rates and the health impact functions that will be use in BenMAP analysis would be different in the research area's ambient surrounding which is located in a developing country in the Asian region. Geographical features, population, number of health incidences for respiratory diseases, economic trend and current development are several factors which will affect the results of the analysis later on.

Iskandar Malaysia region was recognized as the second Low Carbon Society (LCS) region in Malaysia so the significance of Johor Bahru city as the research area can provide an example of a successful concept of LCS to the surrounding region and countries. Thus, based on the results of the analysis in the future, this research can help policymakers and decisionmakers to propose a comprehensive framework to improve on the air quality control measures for minimizing costs and maximizing benefits in the health and economy aspects in Malaysian cities. Evaluation on the current air quality strategies and policies can be further done to measure the effectiveness of government initiatives as well as the efficacy of the National Ambient Air Quality Standard (NAAQS) for other cities and regions in Malaysia. The outcome of this research can further improve the policy framework for ambient air quality in Malaysia in the present time as well as in the future.

1.8 Structure Organization of Thesis

The thesis comprises of six chapters and was organized in the following order. **Chapter 1** presents the research background, problem statement, research questions, research objectives, research area, significance of the study, expected findings and a brief introduction on the research method.

Chapter 2 presents a literature review discussing on other studies related to air pollution studies in Asian countries and discussion on the vital relationship of urban sprawl in the built environment that can impact the level of air quality through various sectors of land uses. This chapter further discusses on the monetized benefits of PM10 analysis reduction air pollution and management control strategies around the world and in Malaysia.

Chapter 3 discusses on the related air quality modeling that were frequently used and applied in air pollution studies as well as an introduction on health impact assessment and how it is reflected through the application of BenMAP. This chapter also explores more on existing studies on the relationships between air pollutions and health benefits conducted in other countries.

Chapter 4 presents the methodology used in this research, specifically explaining more on how BenMAP works, the data inputs and formats needed, and the specific guides for each stages of analysis in BenMAP.

Chapter 5 comprises of outcomes from each stages of analysis and its descriptions. Data analysis has been categorized into four stages. Stage 1 prepares all the related data input needed into BenMAP. Stage 2 involves producing air quality grid creation when the population exposure grid is obtain according to the format that BenMAP recognizes. Stage 3 discusses on obtaining the health impact incidence estimation for the overall analysis and Stage 4 involves applying monetary values to the health impact incidence estimation obtained. This chapter later on will present the discussion and justification of findings for all the expected outcomes.

Chapter 6 presents the overall research conclusion, discussion on each of the research questions outcomes and the future recommendations such as how to improve the air quality management and control strategy in Malaysia as well as the suitability of applying BenMAP in cities in Malaysia. This chapter ends with the needs to conduct future researches.

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