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Clean Air In, Bad Fumes Out: Benefits and Costs of an Alternative Mode of Public Transportation System in the Baguio City CBD, Philippines

Maria Angeles Catelo, Achilles Costales, Harvey Baldovino, Winona Bolislis, and Dorothy Bantasan

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Front cover photo: Prototype of the automated guideway transit system in Diliman, Quezon City, Philippines. Photo courtesy of the Department of Science and Technology.

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CLEAN AIR IN, BAD FUMES OUT: BENEFITS AND COSTSOF AN ALTERNATIVE MODE OF PUBLIC TRANSPORTATION SYSTEMIN THE BAGUIO CITY CBD, PHILIPPINES

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Winona Bolislis, Dorothy Bantasan

EXECUTIVE SUMMARY

Among the specific locations in major cities in the Philippines where the Environment Management Bureau of the Department of Environment and Natural Resources (EMB-DENR) monitors PM_{10} levels (e.g., Metro Manila, Cebu), the mean annual PM_{10} concentration levels continue to be highest in the Baguio Central Business District (CBD). From 2007 to 2012, the annual mean concentration levels of PM_{10} in the Baguio CBD ranged between 71 and 101 microgram per cubic meter (µg/m^3). The 6-year average for this same period is 83 µg/m^3, which is about 40% higher than the 60 µg/m^3 annual exposure standard set by the Philippine Clean Air Act of 1999 (CAA). Using the World Health Organization (WHO) annual exposure air quality guideline (AQG) of 20 µg/m^3 for PM_{10}, on average, the Baguio CBD population is being subjected to long-term exposure levels that are four times the guideline set by the WHO.

The first phase of this study, conducted by Costales et al. (2016), used the cost of illness (COI) approach to value the economic burden that households bear in terms of having a household member be treated for falling ill due to an air pollution-related disease, or of having a household member die of an air pollution-related disease. Data on the cost of treatment per individual were obtained from a random survey of 398 households living within a 1.5-kilometer radius from the Baguio CBD PM_{10} monitoring station. The cost of premature death was estimated using the loss of productivity approach.

Costales et al. (2016) found that around 157 annual cases of premature nontraumatic adult mortality were attributable to exposure at historical mean concentration levels of 83 µg/m^3. This amounted to around 14% of the total number of premature nontraumatic mortalities in Baguio in 2013, which were valued at PHP 53.3 million per year in terms of lost productivity. In addition, around 4,758 attributable cases of identified cardiovascular and respiratory illnesses per year were estimated, accounting for about 22% of all cases morbidity due to identified cardiovascular and respiratory illnesses in 2013. The direct cost of illness, consisting of costs of hospitalization, physician consultations, and/or medications, and the indirect costs due to work days lost by otherwise productive patients and caregivers, amounted to around PHP 24 million per annum. In sum, the cost of illness due to exposure to the local PM_{10} concentration levels relative to the WHO AQG of 20 µg/m^3 amounted to around PHP 77.4 million per annum.

Because the recorded PM_{10} concentration levels in the Baguio CBD are persistently high, and because the epidemiology literature is consistent in the position that there is no "safe level" of PM_{10} concentrations below which the adverse health impacts of increases in PM_{10} (or $PM_{2.5}$) become negligible or insignificant (Pengelly and Sommerfreund 2004), there is compelling evidence that the local government needs to implement bolder measures that would significantly improve the quality of the air that the Baguio City population breathes. The PM_{10} concentration levels in the Baguio CBD, however, cannot be brought down significantly without a radical change in the type of public mass transport system available to the general public. For decades, the diesel-powered public utility jeepneys (PUJs) and taxis were the only public transport modes available.

Thus, this research was conducted to evaluate the economic merits of a formal proposal by the Department of Science and Technology (DOST)–Cordillera Administrative Region (CAR) to the City Government of Baguio to invest in an electricity-run automated guideway transit system (AGT) for public transportation within the Baguio CBD. The proposed AGT will replace the diesel-powered, aging fleet of PUJs that ply the CBD route. It is recognized, however, that the AGT as a single concrete proposal will not be sufficient to bring down the PM concentration levels.

The study initially considered alternative modes of intervention in the public transportation system for the Baguio CBD to reduce PM_{10} levels. The researchers, however, chose to analyze the DOST-proposed AGT as it was deemed to be a feasible intervention, with the DOST undertaking a pre-feasibility study for the project over the period 2014–2015.

Information on the infrastructural requirements and the cost of building, operating, and maintaining an AGT in Baguio, at a specific scale of operation, were obtained from the DOST Metal Industry Research and Development Center. The size of the potential passenger traffic impact of the proposed AGT was estimated using key informant interviews with an officer or member of each of the identified 40 PUJ operators and drivers associations whose routes pass through the road network identified to be dedicated to the AGT.

The proposed AGT, which covers a 4-kilometer circumferential route traversing the main public transport road network within the Baguio CBD, was estimated to entail an investment cost of PHP 778 million over a 10-year operating period. The bulk of the cost are for the 4-kilometer elevated track, 60 train coaches (which could accommodate up to 60 passengers per coach), 20 AGT stations, and a depot for parking the coaches when not in operation.

The benefits of operating an almost pollution-free AGT public transport system within the Baguio CBD were found to be significant. The class of benefits valued were limited to the following: (1) avoided cost of premature mortality due to air pollution-related illnesses, (2) avoided direct costs due to the treatment of air pollution-related illnesses, (3) value of work days lost due to air pollution-related illnesses, (4) revenue from the AGT operation; (5) shorter travel time (to traverse the 4-kilometer circumferential distance), and (6) residual value of the train coaches after 10 years of service.

Many other benefits had not been monetized, such as (1) the convenience and comfort of riding the air-conditioned coaches instead of smog-filled, open-air PUJs; (2) public health counterpart expenditures avoided to support public hospitals and health centers in the treatment of air pollution-related illnesses and deaths; and (3) the value of improved reputation and image of Baguio as a tourist destination arising from improved air quality.

On a base case scenario, which includes only the monetized benefits and costs and using a discount rate of 12%, the investment in the proposed AGT and its operation over a 10-year period would generate a net present value (NPV) of around PHP 250 million and an internal rate of return (IRR) of 19%.
Various sensitivity analyses that were performed yielded NPV and IRR estimates that were robust to certain adverse changes in revenues and costs in operating the AGT but sensitive in others.

1.0 INTRODUCTION

1.1 Background

The Baguio Central Business District (CBD) has one of the highest air pollution concentrations in the country. In 2007, the DENR began monitoring the levels of finer particulates (PM_{10}) in selected highly urbanized centers, including Baguio. From 2007 to 2012, the annual mean concentration levels ranged between 71 and 101 $\mu g/m^3$, with a 6-year average of 83 $\mu g/m^3$. This figure is almost 40% higher than the annual exposure standard of 60 $\mu g/m^3$ set by the Philippine Clean Air Act of 1999 (CAA). Moreover, using the World Health Organization (WHO) annual exposure air quality guideline (AQG) of 20 $\mu g/m^3$ for PM_{10}, the Baguio CBD population is being subjected, on average, to long-term exposure levels that are four times higher than the guideline set by the WHO.

The main generators of PM_{10} in the CBD have been traced to the predominantly diesel-engine transport vehicles plying the CBD road network. The diesel-powered vehicles traversing the city roads consist mostly of public utility jeepneys (PUJs) and taxi cabs. The PUJs are vehicles assembled from relatively old (but cheap), used engines imported from other countries, with the existing fleet logging an average length of 17 years of operation (as public transport). On the other hand, the taxi fleet consists of a few brand-new vehicles, with the rest being older vehicles with an average length of 11 years of operation.

About 90% of the taxi cabs servicing the city run on diesel engines (based on key informant interview with Mr. Avelino Panayo, President of the Federation of the Taxi Operators in the Cordillera). Combined, there are about 7,300 PUJs and taxi cabs crammed within the CBD's small area, which is densely populated by primary, secondary, and university-level students; school teachers; and other educational institution workers, as well as workers in the various government offices and private business establishments.

The results of the cost of illness (COI) study done by Costales et al. (2016), using a random survey of 398 households living within a 1.5-kilometer radius from the Baguio CBD PM_{10} monitoring station, indicated that around 157 annual cases of premature nontraumatic adult mortality were attributable to exposure at historical mean concentration levels of 83.2 μg/m^3. This amounted to around 14% of the total number of premature nontraumatic mortalities in Baguio in 2013. These attributable cases were valued at PHP 53.3 million per year in terms of lost productivity. In addition, around 4,758 attributable cases per year of identified cardiovascular and respiratory illness were estimated, accounting for about 22% of the total cases of morbidity due to cardiovascular and respiratory diseases in 2013. The direct cost of illness (i.e., costs of hospitalization, physician consultations, and/or medications) and the indirect costs (i.e., lost work days of otherwise productive patients and caregivers) amounted to around PHP 24 million per annum. The overall cost of illness due to exposure to PM_{10} concentration levels relative to the WHO AQG of 20 μg/m^3 was estimated to be PHP 77.4 million per annum.

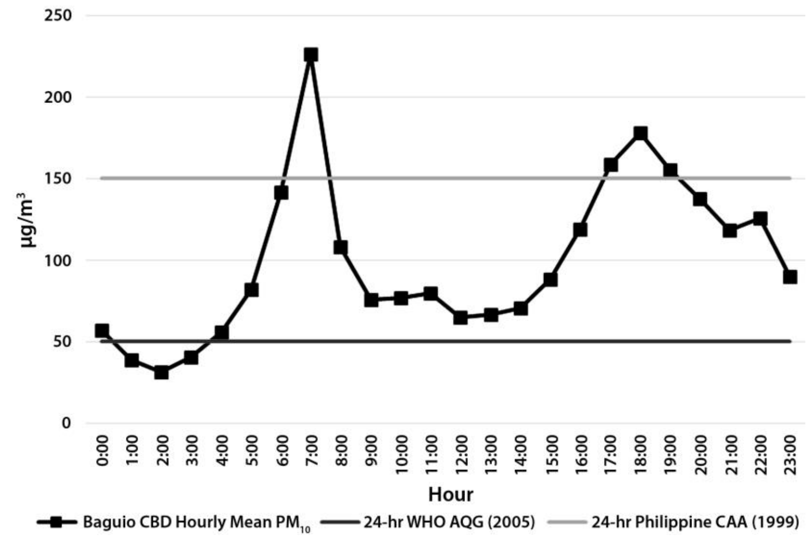
The Baguio City local government is now searching for less-polluting modes of public transport to service the city. The idea of electric jeepneys has been around for the past few years, but it has not gained momentum to be developed into a serious proposal. In early 2014, however, the Department of Science and Technology-Cordillera Administrative Region (DOST-CAR) proposed to the city government for the construction and operation of a Philippine-designed, electric-powered Automated Guideway Transit (AGT) system to operate along a circumferential route within the Baguio CBD. A similar proposal was submitted to the municipal government of La Trinidad, the capital town of Benguet province, to connect La Trinidad with Baguio City. The pre-feasibility study for the La Trinidad-Baguio system was completed in 2015, while the pre-feasibility study of the Baguio CBD system is set to begin.

In support of the local government's search for less-polluting modes of public transport, this study aims to estimate the costs and benefits of implementing the proposed AGT that is designed to operate within the Baguio CBD. The beneficial impact on Baguio City of an improved air quality rests not only on the potential gains of a healthier population but also on the recovery of economic losses stemming from the rapid erosion of its reputation as a high-end tourist destination.

1.2 Research Problem

Over the last two decades, Baguio has lost its title of the "Cleanest and Greenest City" because of the gradual degradation of one of its invaluable environmental assets—its pristine pine-scented cool air. Figure 1 presents the behavior of the short-term exposure of the population to PM_{10} over a 24-hour period, which was taken on 14–20 December 2012. The hourly average of the PM_{10} levels were calculated over a 7-day span. The respective 24-hour standards of 150 μg/m^3 adopted by the CAA and the 50 μg/m^3 guideline set by the WHO are also presented in Figure 1.

The short-term mean PM_{10} levels of the Baguio CBD largely meet the Philippine CAA 1999 short-term standard for the pollutant. However, the average levels fail to meet the more stringent health standard proposed by the WHO. Moreover, the epidemiology literature is consistent in the position that there is no "safe level" of PM_{10} concentrations below which the adverse health impacts of increases in PM_{10} (or $PM_{2.5}$) become negligible or insignificant (Pengelly and Sommerfreund 2004).



Source: Costales et al. (2016)

Figure 1. Mean hourly PM_{10} levels in the Baguio CBD, 14–20 December 2012, relative to 24-hr standards set by the Philippine CAA of 1999 and the WHO AQG of 2005

The city government is searching for more effective policies and measures to continually reduce the concentration levels of air pollution in the CBD. This is on top of the various environmental laws and regulations that Baguio City has enacted such as (1) passing its own Clean Air Ordinance, in accordance with the CAA; (2) implementing a number-coding scheme that bars a certain proportion of motor vehicles from entering the CBD one day a week, according to the ending number of the vehicle registration plate; and (3) conduct of a roadside inspection, testing, and monitoring (RITM) program; and (4) apprehending and penalizing vehicles with emission levels beyond the legal standards. Private emission testing centers (PETCs) also operate in the city in observance of the CAA. PETCs are officially mandated facilities placed in strategic locations to bar the regular registration of vehicles (if these fail to pass emission standards set by the CAA) with the Land Transportation Office (LTO) of the Department of Transportation and Communication (DOTC). However, a glaring anomaly is that all vehicles apprehended by the RITM program for failing to pass their roadside emission testing have duly passed the PETC tests.

With the persistence of high recorded levels of PM_{10} concentrations in the CBD despite the enforcement of local and national environmental regulations, there is compelling evidence that the local government needs to become more decisive and to embark in bolder measures that could yield substantial impacts and significant leaps in improving the air quality in Baguio City.

A longer-term and future-oriented move is to create a regulatory and policy design that would induce a shift from the aging diesel-powered public utility transport units operating within the Baguio CBD to the use of an alternative public transport system. Such system will be designed to

1. reduce the number of PUJs, taxis, and private vehicles traversing the CBD;
2. reduce the aggregate emission and PM_{10} levels from these in the ambient air; and
3. reduce the adverse health impacts of air pollution on the commuting population and households.

This research project hopes to make a significant contribution toward this end.

1.3 Research Objective

This study aimed to evaluate the benefits and costs of an alternative mode of public transportation system that will reduce air pollution concentrations in the Baguio City CBD to levels that meet the national standards and alternative ambient air quality targets.

2.0 LITERATURE REVIEW

Environmental protection, like controlling air pollution from motor vehicles, is an important and serious concern of developed and developing countries. Existing environmental regulations and policies to control pollution from mobile sources are generally classified into traditional command and control regulations (CACs) and market-based instruments or (MBIs) or economic instruments (EIs).

CACs generally include establishing standards for ambient air quality, emissions, technology, product, process, and performance. Standards serve as the legal reference for environmental targets and they set the allowable limits or concentration of certain substances that are discharged into the air. The granting or non-issuance or cancellation of permits, licenses, and franchises to operate motor vehicles is also another form of CAC, since these are usually tied to air quality standards. Despite the criticisms and problems associated with CACs, they remain to be the more dominant form of direct regulation (Field and Olewiler 2005; Markandya et al. 2002).

On the other hand, MBIs or EIs for controlling air pollution from mobile sources that are used in practice include vehicle-related user charges, tax differentiation for leaded and unleaded petrol, and charges on polluting products and inputs. Road pricing for peak-hour use, particularly in large congested cities like Bangkok and Singapore, has also been successful (Markandya et al. 2002).

Financial instruments, such as tax incentives for using motor vehicle-related pollution abatement technology, like buses that run on compressed natural gas (CNG) or taxis that use auto liquefied petroleum gas (LPG) and biofuels or the so-called electric jeepneys and electric tricycles (Francisco 2011) are also used to control air pollution from mobile sources.

Choosing from among policy and regulatory instruments or a combination thereof would necessitate the use of a set of criteria that include, but are not limited to the following: (1) cost effectiveness, (2) dynamic incentives, (3) implementation issues, (4) fairness, and (5) flexibility (Field and Olewiler 2005; Markandya et al. 2002).

2.1 Approaches for Measuring and Estimating the Benefits and Costs of an Alternative Public Transportation System to Reduce Health Impacts of Air Pollution

The benefits of cleaner air through environmental regulation or policy may be derived from aggregating individuals' willingness to pay for the decrease in or avoidance of damages (i.e., air pollution) to the environment or the individuals' willingness to accept compensation to bear or tolerate such environmental damage (Stavins 2009). Policies or programs that are aimed toward reducing air pollution, such as fewer polluting public transportations systems, should result in the decrease in the number of acute illnesses (e.g., cardiovascular diseases, asthma attacks, chronic bronchitis, and other respiratory diseases). These reductions may then be estimated from the avoided costs such as (1) medical costs of treating the illness, (2) loss in productivity due to the illness, (3) amount that the ill person is willing to pay to avoid associated pain and suffering, and (4) loss of leisure time of the ill person or the caretaker (World Bank 2003b).

The cost of illness (COI) approach is generally applied to cases where the change in environmental quality has an impact on human health. Health impacts commonly investigated can be classified as acute and chronic premature mortality and acute and chronic morbidity (or reduced life quality). There is a vast set of epidemiology literature establishing the relationship between short-term (acute) and long-term (chronic) exposure to PM_{10} and $PM_{2.5}$ (and related air pollutants such as CO, SO_2, NO_2, and O_3) and premature nontraumatic mortality, as well as morbidity of populations exposed to the pollutants. The COI approach that uses medical costs and loss in productivity provides a lower bound estimate of the value of avoided illness.

A review of the epidemiology literature (Pengelly and Sommerfreund 2004) on estimating health-risk coefficients from concentration-response functions, including those from developing countries in

Latin America and Asia, point toward the robustness of a range of estimates in predicting various health outcomes. Sahsuvaroglu and Jerrett (2007) further qualify that there needs to be keen awareness of the existence of uncertainties in the calculation of the burden of illness (mortality and morbidity) attributable to air pollution as the adopted health risk coefficients rely on statistical estimates and particular assumptions that have inherent impreciseness. For the purpose of using these coefficients in quantifying the burden of illness from exposure to air pollution and deriving policy implications from the results, a range of likely health outcomes should be considered, rather than focusing on single-point predictions.

In the last decade, tools have been developed adopting health risk coefficients in the literature to assess the environmental burden of disease from outdoor pollution. One of these practical tools using PM_{10} and $PM_{2.5}$ as pollutants of focus has been developed by the WHO for application at the national or city level (Ostro 2004; Martuzzi et al. 2002). The tool has been applied in estimating the number of deaths from outdoor air pollution in Bangkok, Thailand (Ostro 2004). Another tool, developed for Canadian cities, is known as the Air Quality Benefits Assessment Tool (AQBAT) (McKeown 2007). The structure of the tool incorporates the basic components of the WHO tool, but also includes the health risk coefficients associated with exposure to other air pollutants from transport vehicles in the model, and moves one step further by estimating the economic costs of the burden of illness from transport pollution. AQBAT uses techniques to assign a monetary value to a health outcome. The value attached to mortality ("value of a statistical life") is based on someone's willingness to pay to reduce mortality risks or willingness to accept compensation for increased mortality risks (i.e., wage premiums for riskier jobs). The morbidity outcomes are valued according to cost of treatment (e.g., medical costs), lost productivity due to illness, pain- and suffering-averting expenditures.

In the Philippine setting, a World Bank study by Arcenas (2009) provided estimates of the economic costs of environmental damage encompassing the value of health effects from indoor air pollution, outdoor air pollution, water pollution, and lack of sanitation and hygiene. The assessment of health outcomes follows the basic procedures outlined above. The economic costs were estimated using human capital value (HCV) and value of statistical life (VSL) methods. Outdoor air pollution mortality outcomes included adult lung cancer, adult cardiopulmonary mortality, and respiratory mortality for children under five years old. Outdoor air pollution morbidity outcomes included acute bronchitis for those under 15 years old; hospital admissions for respiratory diseases (e.g., acute bronchitis or ALRI); and respiratory symptoms for all ages. As would be expected, the VSL estimates of the cost of mortality and morbidity were higher than the HCV estimates. HCV is simply the value of lost income, whereas the VSL i the value that individuals would assign for reducing the risk of premature mortality or the event of falling ill.

3.0 METHODOLOGY

Sections 3.1 and 3.2 of the methodology draw heavily from the study of Costales et al. (2016), which identified the (1) health outcomes and number of cases attributable to exposure to long-term mean level of PM_{10} at 83.2 μg/m^3 and the Philippine CAA PM_{10} target of 60 μg/m^3; and (2) economic value of the mortality and morbidity outcomes attributable to exposure to elevated levels of air pollution. These pieces of information serve as inputs in the cost benefit analysis that follows thereafter.

3.1 Identifying Health Outcomes from Exposure to Air Pollutants from Public Transport

Table 1 shows the health outcomes attributable to exposure to long-term mean level of PM_{10} at 83.2 μg/m^3 using the WHO guideline of 20 μg/m^3 as the base level of PM_{10} exposure. The results of the base incidence rates show that mortality and morbidity rates would have been lower if the PM_{10} concentrations to which the relevant population was exposed were at levels matching the WHO long-term guideline.
The outcomes on the attributable cases of nontraumatic deaths of 157 are to be interpreted as the number of deaths that *would have been avoided* had the actual levels of PM_{10} to which the population had been exposed met the WHO guideline (PM_{10} = 20 μg/m^3) rather than the long-term actual mean of 83.2 μg/m^3. Relative to the actual number of nontraumatic deaths in 2013, the number of preventable deaths translates to about a 14% reduction in the number of cases.

Table 1. Health outcomes attributable to exposure to long-term mean level of PM_{10} at 83.2 μg/m^3, adopting the WHO guideline (PM_{10} at 20 μg/m^3)

Health Outcome	Actual Cases 2013	Actual Incidence Rate	Base Incidence Rate (PM_{10} = 20 μg/m^3)	Attributable Cases	Attributable Percentage (%)
Nontraumatic adult mortality (30+)	1,145	0.0085	0.0073	157	13.8
Hypertension	2,364	0.0068	0.0065	126	5.3
ALRI	4,292	0.0124	0.0113	388	9.0
Bronchitis (< 15 years)	1,212	0.0125	0.0043	612	50.5
Asthma (<15 years)	660	0.0068	0.0052	153	23.2
Asthma (20+ years)	553	0.0026	0.0026	14	2.5
URTI	12,096	0.0350	0.0243	3,465	28.6

Source: Costales et al. (2016)

Note: ALRI = acute lower respiratory infections; URTI = upper respiratory tract infections

Table 1 also shows that the relative magnitude of exposure to high levels of PM_{10} for upper respiratory ailments is also high, with the attributable cases accounting for around 29% of the total. On the other hand, the health outcomes of setting the PM_{10} target at the alternative level of 60 μg/m^3, which is in line with the Philippine CAA of 1999, are presented in Table 2. In this scenario, the attributable cases could be interpreted as the annual number of nontraumatic premature mortalities and the number of specific morbidity cases *avoided* if the PM_{10} concentration levels would be reduced by policy measures and instruments from 83.2 μg/m^3 to 60 μg/m^3, as prescribed in the Philippine CAA. While nominally, the mortality and morbidity numbers of "saved" cases are significant, these figures could be compared to the number of mortality and morbidity cases that could be avoided if public policy pursued measures and instruments that would drive the PM_{10} concentration levels all the way down to the WHO AQG for the pollutant. Such a comparison would show that if the WHO AQG were relentlessly pursued, the number of attributable mortality and morbidity cases avoided would more than double those achievable under the pursuit of a less stringent standard.

Table 2. Health outcomes of setting the PM_{10} target at 60 μg/m^3, adopting CAA standards

Health Outcome	Actual Cases 2013	Actual Incidence Rate	Base Incidence Rate (PM_{10} = 20 μg/m^3)	Attributable Cases	Attributable Percentage (%)
Nontraumatic adult mortality (30+)	1,145	0.0085	0.0080	63	5.5
Hypertension	2,364	0.0068	0.0067	48	2.0
ALRI	4,292	0.0124	0.0120	151	3.5
Bronchitis (< 15 years)	1,212	0.0125	0.0073	385	31.8
Asthma (<15 years)	660	0.0068	0.0061	66	10.1
Asthma (20+ years)	553	0.0026	0.0026	5	0.9
URTI	12,089	0.0350	0.0301	1,578	13.0

Source: Costales et al. (2016)

3.2 The Economic Value of the Mortality and Morbidity Outcomes Attributable to Exposure to Elevated Levels of Air Pollution

3.2.1 The cost of premature mortality

Costales et al. (2016) evaluated the economic value of nontraumatic deaths attributed to elevated levels of air pollution using the opportunity cost of lost years of productive life due to premature mortality of adults aged 30 years and above. The average life expectancy of Filipinos for 2010–2015 is put at 70 years (68 years for males, 73 years for females). The Department of Health projected this average to rise to 75 years for 2030–2035 (DOH 2010). Lost years of remaining productive life, however, is computed only up to 65 years for premature adult mortality. The attributed deaths are also grouped according to the age grouping of total premature adult deaths.

The minimum wage of PHP 280 per day for CAR was adopted as the opportunity cost per day of work loss. A conservative 5-day work week and a 50-week working year were assumed. The unemployment rate in CAR was estimated at 6.5% (DOLE 2014). The unemployed individuals were assumed not to earn income. Furthermore, the underemployment rate, estimated at 14.5% with income assumed to be just 50% of the mean income of the fully employed. After making adjustments for unemployment and underemployment rates, which were assumed to remain constant in the future, the aggregate foregone income of the attributable deaths across age groups was estimated at PHP 53,332,408 per year from 2013 onward. This assumes that the attributable deaths remain at 157 deaths per year, without interventions toward reduction of the PM_{10} mean concentration levels of 83.2 $\mu g/m^3$. On a straight per capita estimation of the opportunity cost of premature mortality for all 157 cases, the estimate was put at an average of PHP 339,697 for each individual.

3.2.2 The cost of illness of air pollution-related attributed deaths and morbidity

The direct costs of illness are obtained using the mean cost per capita of hospitalization, outpatient consultations, and medicines for treatment of each particular health outcome estimated in the Cost of Illness Household Survey of 2014 (Costales et al. 2016). Table 3 shows the health outcome-specific costs per capita and the aggregate for all attributable cases. Table 3 indicates that the cost of premature mortality dominates (PHP 53.33 million per year), accounting for 69% of total costs. The remaining 31% (PHP 24.04 million per year) is attributed to the direct costs to patients of hospital admission, outpatient consultations, and medication. Thus, the aggregate direct cost of premature mortality and illness attributable to PM_{10} exposure in Baguio City is about PHP 77.37 million per year.

Table 3. Per capita and aggregate direct costs of premature mortality and illness attributable to PM_{10} exposure in Baguio City

Health Outcome	Attributable Cases	Cost per Capita (PHP)	Aggregate Cost per Year (PHP)
Mortality Costs			
Nontraumatic adult mortality (30+)	157	337,550	53,332,408
Morbidity Costs			
Hypertension/cardiovascular disease	126	34,214	4,314,138
ALRI	388	11,159	4,329,061
Bronchitis (< 15 years)	612	5,367	3,283,079
Asthma (<15 years)	153	6,934	1,061,392
Asthma (20+ years)	14	6,934	94,169
URTI	3,465	3,162	10,957,157
Total cost of illness per year			24,038,996
Total opportunity cost of premature adult mortality per year			53,332,408
Total direct costs per year			77,371,404

Source: Costales et al. (2016)

3.3 Benefit-Cost Analysis of Introducing an AGT

The long-term mean PM_{10} concentration level established at the Baguio CBD area was 83.2 $\mu g/m^3$. The questions then are:

1. How far would be the reduction in concentration levels if a policy intervention is introduced that would replace the jeepneys plying the Baguio CBD road networks with a low-polluting public transportation system?
2. What would be the benefits and costs of such an investment?

To achieve the objective of this research, the researchers conducted a benefit-cost analysis (BCA) of introducing an electricity-powered AGT on identified main roads around the Baguio CBD that will replace the current fleet of heavily polluting PUJs plying the same. For this purpose, the following pieces of information were gathered:

1. Infrastructural requirements of the AGT along a 4-kilometer circumferential route
2. Engineering cost (infrastructure, operation and maintenance) estimates of the AGT
3. Estimate of passenger-load capacity of the AGT and the corresponding passenger-traffic flow per day, extrapolated to a per year basis
4. Estimates of the flow of AGT net income, assuming standard fares and capacity utilization
5. Identification of PUJ lines to be adversely affected by the shift to AGT in the CBD; estimates of the number of PUJ units affected per line
6. Estimate of passenger-load capacity of the affected PUJ lines and fleet and passenger-traffic flow per day, extrapolated to a per year basis
7. Estimates of PM_{10} (and $PM_{2.5}$) concentrations reduction resulting from the shift and the resulting health cost savings using COI results
8. Estimates of net jeepney income changes due to replacement of the jeepneys public transport system with the AGT

The sources of data are key informant interviews (KIIs) with the DOST engineers of the AGT, the Baguio City Planning Office, and the officers, operators, and drivers of the PUJ groups federated with the Baguio City Public Transport Organization. A series of KIIs were done between April and August 2014 as appointments and subsequent appointments were difficult to make due to uncontrolled variability in the availability of the key informants. A survey of 40 members of various PUJ associations was also conducted between July and August 2014 to elicit the relevant information as outlined above. The health outcome-specific costs per capita and the aggregate for all attributable cases as estimated by Costales et al. (2016) were also used as inputs in the BCA.

4.0 RESULTS AND ANALYSIS

4.1 Selecting the Portfolio of Projects to Reduce Air Pollution in the Baguio CBD

This study considered a portfolio of other projects that have the potential to reduce air pollution in the Baguio CBD. Unfortunately, as of the time of the study and under the current state of technology, only the AGT seems to be feasible. Nevertheless, the succeeding discussions intend to shed more light as to why only the AGT was given prominence in this research.

4.1.1 The e-jeepney

The authors considered the e-jeepney alternative first when the proposal for an AGT was not yet on the floor. After discussions with the head and members of the PUJ operators and drivers associations, their actual tests with the current generation of e-jeepney models revealed that these lacked the strength and power to traverse the ascending sections of the rolling terrain of Baguio streets, compared to the more powerful diesel-fed regular jeepneys. The current generation of e-jeepneys was asserted to be more fit to the flat terrain of the lowlands.

The Le Monet Hotel in Camp John Hay, Baguio, operated an e-jeepney model within the Camp John Hay area on a pilot basis. The observation of the operator and driver was that the six regular car battery cells that are being used to store electricity tend to overheat and needed distilled water replacements frequently (on a daily basis). The six car batteries were also a heavy load on the e-jeepney unit itself. Thus, at the present time, the current generation of e-jeepneys is not an attractive proposition for local jeepney operators and drivers.

4.1.2 The "bus train"

The "bus train" was also considered by the DOST, but was considered not feasible for the narrow streets of Baguio. The size of the current models of bus train units is about the size of the regular big buses used for provincial operations by bus companies (e.g., Victory Liner), and would need two dedicated lanes along the streets for a two-way traffic service. The requirement of wide streets precluded the use of the technology.

4.1.3 The use of compressed natural gas by PUJs

"Retrofitting" PUJs to convert them into CNG-powered units was also considered. The technology of retrofitting, however, has not yet been perfected for PUJs. There are CNG-powered provincial buses being used by certain bus companies; but these are new buses designed to run on CNG, not converted or retrofitted.

There were taxicab units in Baguio that were retrofitted to run on LPG. Taxi cab operators and drivers, however, stated that the retrofitting was not yet perfect. There have been incidences of LPG leakage, as manifested by the unpleasant odor that consistently plagued the driver and passenger. These initiatives have been discontinued.

4.1.4 Total ban or displacement of PUJs in the CBD without replacement

The total ban of jeepneys in the CBD, without replacement, has not been considered. This idea puts the local government in a very sensitive political position vis-à-vis the jeepney operators and drivers associations.

In view of all the above considerations, this study selected the AGT as the option that holds the most potential in reducing air pollution in Baguio City. As in standard benefit-cost analysis, the status quo, which also means "business as usual" or do no additional measure on top of the existing policies and regulations to reduce air pollution, was also considered as an option. It actually refers to the discussions on the aggregate costs of mortality and illness from exposure to PM_{10} at 83.2 $\mu g/m^3$. Table 3 reflects the base case or the status quo scenario of health outcomes, attributable cases to current level of PM_{10} exposure, and the aggregate costs of PHP 77.4 million per year if no public utility vehicles (PUV) are displaced from the Baguio CBD and the AGT is not introduced.

4.2 The General Features of the Proposed AGT

The AGT was initially developed as a response to the increasing pollution levels and traffic jams, which are known to greatly affect productivity. The AGT is a locally manufactured rapid mass transit system project of the DOST in collaboration with the University of the Philippines Diliman (UP Diliman) and other partners. It is a fully automated, driverless vehicle that is automatically steered along the guide-way and uses an electric drive train without a hanging catenary. It is electric-based and therefore does not emit carbon dioxide and other toxic pollutants on-site.

There are two prototypes that are currently being tested: one in UP Diliman and the other in DOST-Bicutan. For the purposes of this study, the features of the larger-capacity AGT prototype (Figure 2) shall be used in order to meet the daily demand for jeepney rides that the proposed AGT would potentially replace for similar routes to the Baguio CBD.

The proposed AGT train that will be introduced in the Baguio CBD link (CBD-University Belt Loop) has two coaches per train, each coach accommodating 60 passengers for a total of 120 passengers per trip. The current radius of the elevated track is 13 meters. The AGT will operate for 15 hours per day (5 a.m. to 8 p.m.), 30 days a month, 362 days a year to account for 3 national holidays. A total of 20 stations are assumed for the AGT to complete the 4-kilometer circuit, with each station at about 200 meters apart (Figure 3). The detailed features of the proposed AGT are presented in Table 4.

Figure 2. Prototype of the AGT

Source: DOST

Figure 3. Station design of the AGT

Source: DOST

Table 4. General features of the proposed AGT in Baguio CBD

General Features	Value
Elevated tracks	1
No. of coaches per trip	2
Capacity per coach	60
Capacity per trip	120
Distance (km circuit)	4
Number of stations per kilometer (200 m)	5
Total number of stations in circuit	20
One-way traffic	1
Max number of trips for 20 stations at any one time, one-way	15
Max number of coaches for 15 trips at any one time	30
Peak-full capacity at 30 coaches at any one time (number of riders)	1,800
Operating speed of coaches (kilometers per hour)	30
Travel time per station (200 m), in minutes	1
Loading/unloading time per station, in minutes	1
Total travel time per unit station, in minutes	1
Total travel time per km or five stations, in minutes	5
Headway or waiting time for next train, in minutes	2
Total full circuit travel time, in minutes	22
Number of full circuit trips per hour	3
Peak passenger load per hour of service time (per direction)	4,909
Number of hours of operation of AGT per day	15
Peak passenger load per day (15-hour service)	73,636

4.2.1 Investment cost

Based on the results of the KII, the estimated infrastructure cost per kilometer of the elevated track (one direction) is PHP 70 million. Thus, for a 4-kilometer circuit, total infrastructure cost would be PHP 280 million. One 60-passenger AGT coach costs about PHP 15 million. Hence, the investment cost for a fleet of 30 coaches would be PHP 450 million. The other major investment costs are the cost of the depot, which is assumed at 10% of the infrastructure cost or PHP 28 million, and the construction cost of the 20 stations at an estimated total value of PHP 20 million.

4.2.2 Operation and maintenance cost

The energy consumption for a 15-hour daily operation of the AGT is estimated at 620 kilowatt hours (kWh) per coach. With an assumed price of PHP 10 per kWh, the daily power cost of operating one coach is PHP 6,200, which translates to about PHP 2.24 million per year (operating on 362 days). For a fleet of 30 coaches, the total energy cost per year would be about PHP 67.33 million and is assumed to increase at the rate of 10% per year.

The other major operation and maintenance (O&M) cost items are for the operation and maintenance of the 30 coaches and the depot, which are assumed to be 25% of the total cost of the coaches and 25% of the total depot cost, respectively.

4.2.3 Non-market costs

The introduction of the AGT is assumed to affect PUJ lines operating along the route of the AGT within the Baguio CBD link (Figure 4). As such, there would be a cost on the part of the affected PUJ lines plying similar routes in terms of foregone net income. This is estimated at PHP 29.19 million annually. Details of this foregone income estimation are discussed in the next section.

Figure 4. The Baguio CBD link of the AGT

4.3 Impact of AGT on PUJ Income

To assess the likely impact of the AGT on PUJ drivers, a survey of 40 PUJ association members and officers was carried out. The jeepney drivers and operators identified their respective PUJ lines that traverse the Baguio CBD roads as well as the number of their jeepneys that ply these routes.

Of the 40 PUJ lines identified by the respondents, 22 will not be affected by the AGT, but 12 lines will be partially affected (those who would likely lose about 25% of their net income) and 6 lines will be greatly affected (those who would likely lose about 40% of their net income). Judging from the routes that these PUJ lines take from their points of origin (*paradahan* in the vernacular) to their destination points, which is within the Baguio CBD, and comparing them with the 4-kilometer circumferential route that the AGT will take when it is in operation, Table 5 shows that no PUJ line would be completely displaced since these jeepneys still need to bring passengers from the outskirts (more than 2 km from the Baguio CBD) to the “doorsteps” of the Baguio CBD where the AGT would be making its circular route. It is just that these PUJs can no longer bring their passengers from the outskirts right into the Baguio CBD. For these PUJ units, income will not be totally eliminated.

The six PUJ lines that are classified as “greatly affected” are those which are in danger of dying out since their point of origin is quite near the proposed AGT stations. Although the point of origin is near the station, it is not the end destination of these jeepney lines. For example, PNR-Hillside would still have to go down to Hillside, which is considerably far from the station. The same goes for Military Cut-Off. They might be losing a significant number of passengers but they would still continue to operate.

The 12 PUJ lines that will be partially affected have no paradahan within the CBD, and the end destination per area where most of their passengers get down or get picked-up is a bit far from the AGT stations. For example, for the Aurora Hill line, the passengers that they would most likely be losing would be those who ride and get down at the St. Louis University or Magsaysay Road areas. Table 5 shows that 18 of 40 PUJ lines; 1,718 out of 2,463 jeepney units; and around 1.87 million passengers of the total 2.658 million passengers per week will be affected.

It has to be emphasized that these data on affected PUJ lines and units refer only to the 40 PUJ associations that have been identified in the survey. The DOTC LTFRB estimates that there are around 3,000 PUJ units plying Baguio City and its environs, ferrying passengers from the outskirts of the city to the CBD and back. This number is quite consistent with the estimates of the Baguio Jeepney Operators and Drivers’ Association.

Table 5. PUJ lines affected by the AGT

Affected PUJ Lines	No. of Lines	No. of Jeepney Units	Total No. of Passengers per Week*
Greatly affected	6	1,239	1,228,675
Trancoville, Military Cut-Off			
Sanitary Camp, PNR-Hill Side			
Partially affected	12	479	641,860
Aurora Hill, Tuding Express, Greenwater			
Maria Basa, Mines View Cervantes			
Leonila Hill, Navy Base, Pacdal General Luna			
Not affected	22	745	787,465
TOTAL	**40**	**2,463**	**2,658,000**

Note: *Authors' calculations

Although it is recognized that private vehicles also ply the CBD route and would likewise contribute to the long-term average pollution of 83.2 µg/m^3, they were not considered in this study. The main reason for this exclusion is that private vehicles tend to exhibit a different behavior from PUVs. Private individuals take their vehicles to work at the beginning of the day, park their vehicle, work, and then bring their vehicle home after work; or their drivers bring them to work or school in the morning, and fetch them back in the afternoon. Moreover, most private cars are run by gasoline rather than diesel. Thus, if diesel-run motor vehicles are the main generators of $PM_{2.5}$ and PM_{10}, then there is justification in focusing on the PUVs.

Since there will be PUJs that will be greatly and partially affected when the AGT operates, this implies that these PUJ drivers or operators shall be foregoing some level of net income. For PUJs that are classified as partially affected by the AGT operation, it is assumed that 25% of their net income would be lost; for those that will be severely affected, 40% of their net income is assumed to be foregone. Table 6 shows that the impact of the AGT on affected PUJs would be about PHP 29.19 million of net income foregone per year. On average, for the 1,718 PUJ operators that will be affected, the foregone net income per year due to AGT is estimated at PHP 16,989 per operator.

Table 6. Foregone PUJ net income due to AGT

Impact Level	Net Income per Year	Foregone Income per Year
Not affected	44,898,360	–
Partially affected[1]	14,150,674	3,537,668
Severely affected[2]	64,124,239	25,649,695
Total	**123,173,272**	**29,187,364**

Notes: (1) Only 25% of net income is foregone. (2) Only 40% of net income is foregone.

4.4 Benefit-Cost Analysis (BCA) of using AGT in Baguio CBD

4.4.1 Estimation of benefits and costs

The upper bound values of the benefits that can come with the introduction of the AGT in the Baguio CBD in the ideal case that the pollution level is reduced from PM_{10} = 83 µg/m^3 to PM_{10} = 20 µg/m^3 are presented in Table 7. In particular, the upper bound estimate of benefits from avoided health costs is PHP 77.4 million annually. The actual health benefits will fall within a range depending on the assumed pollution reduction of PM_{10} with the introduction of the AGT which, in the worst case will be only at 60 µg/m^3, with a corresponding lower bound estimate of avoided health costs amounting to PHP 32.4 million per year.

Table 7. Upper bound estimates of benefits of introducing the AGT in the Baguio CBD

Benefit	Estimation
Avoided direct costs due to air pollution-related illnesses	Aggregate of morbidity cost of illness per capita x attributable cases per year (Table 3) at PHP 24,038,996
Avoided premature mortality from air pollution-related illnesses	Total opportunity cost of nontraumatic adult mortality cost (adult 30+) per capita × attributable cases per year (Table 3) at PHP 53,332,408
Revenues from AGT operation	Peak load number of passengers at 15-hour operation at 73,636 × AGT fare at PHP 12 per pax × 362 operating days per year = PHP 319,876,364
Residual value of AGT coaches at10% of total coach value	10% of cost of coach (PHP 15 million) × 30 coaches = PHP 45,000,000
Shorter travel time for distance within system (avoided lost man-hours from PUJ)	The difference in waiting time for the next jeepney ride and next train to reach destination (7 mins) × opportunity cost[1] of waiting time valued at minimum wage[2] of PHP 280 per day for an 8-hour work or PHP 0.30 per minute × 1/3 of total jeepney passengers per year (127,584,000) = PHP 98,303,135

Note: [1] Unemployment rate used to compute opportunity cost taken from Allad-iw (2014)
[2] Minimum wage rate taken from DOLE (2014)

Note that these benefits are underestimated since many other benefits have not been monetized such as (1) the convenience and comfort of riding the air conditioned AGT coaches, (2) lower public health expenditures from avoided illness due to air pollution, and (3) the value of increased reputation and image of Baguio City as a tourist destination.

The estimation of costs follows the cost items identified in the previous section, namely, (1) investment cost for infrastructure, coaches, stations, and depot; (2) operating and maintenance cost for the coaches, depot, and other services; (3) energy cost; and (4) foregone net income of PUV operations. Energy cost is assumed to increase 10% per year.

4.4.2 Base case scenario and sensitivity analysis

As discussed in Section 4.1, this study considered the proposal of the DOST submitted to the local government of the City of Baguio to introduce AGT, which will service a circumferential route through the main streets of the Baguio CBD. This system will have the impact of displacing 40 lines of PUJs ferrying daily commuters from the outskirts of the city and beyond into the Baguio CBD, and back, involving a total of 2,463 units of diesel-powered motorized units. Phasing out this number of PUJ units from the Baguio CBD streets and the fully replacing such service through an electric-powered AGT can reduce outdoor air pollution (as measured by PM_{10} concentration levels) by a substantial amount from the pollutant's historical mean of 83.2 μg/m^3.

There are no empirical studies establishing the relationship between the reduction in the number of heavily-polluting diesel-powered PUJs and the reduction in PM_{10} concentrations; a specific number for the reduction in PM_{10} cannot be established. It is asserted, nevertheless, that the magnitude of reduction would be substantial, as the proposed change in the major mode of public transport within the Baguio CBD, from a pollution-heavy PUJ system to an almost "pollution-free" electric-run AGT, is a significant qualitative shift. Moreover, phasing out all 2,463 PUJ units from all the CBD streets constitutes a substantial change in the number of heavy-polluting motorized vehicles. It is also asserted that a certain number of units of taxi cabs ferrying passengers from one point to another along the same circumferential route of the proposed AGT will be eased out by market competition, with the AGT offering a substantially cheaper, traffic-free, commuting alternative. About 90% of these taxi cab units are also diesel-powered. The number of taxi cabs eased out along the route of the AGT, however, cannot yet be ascertained.

Nevertheless, this study made a very crude attempt at estimating the potential reduction in PM_{10} that may result from a specific reduction in the number of PUVs for use in the benefit-cost analysis. Based on the estimated number of PUVs plying the CBD route at 7,300 units and with a long-term mean of PM_{10} at 83 μg/m^3, each PUV unit contributes roughly 0.0114 μg/m^3. Hence, for example, for a target reduction of

PM_{10} from 83 μg/m^3 to 60 μg/m^3, about 2,023 PUV units would need to be replaced. If a further reduction in PM_{10} is desired, say, from 60 μg/m^3 to 50 μg/m^3, then an additional 880 units of PUVs would have to be replaced.

There are four other PM_{10} monitoring stations located outside the CBD that can serve as empirical reference points for alternative levels of PM_{10} concentrations, as discussed in the previous section. One site is closer to a long-term PM_{10} mean of 20 μg/m^3, and the three other sites are closer to the long-term PM_{10} mean of 30 μg/m^3. The reference point of 20 μg/m^3 in one of the sites is consistent with the health standard set by the WHO AQG for long-term level of PM_{10}. The reference point of 30 μg/m^3 in the three other sites are consistent with the third-level WHO interim target (IT-3) as localities progress from their current PM_{10} levels to the AQG of 20 μg/m^3.

This study argues that the proposed replacement of the PUJs by an AGT in the Baguio CBD, as a single independent intervention, will definitely not succeed in bringing down the long-term PM_{10} to the WHO AQG of 20 μg/m^3 registered in one location. Neither will it be able to reach the WHO IT-3 of 30 μg/m^3 registered in the three other locations. The main reason is that the CBD will still have a higher density of motorized vehicles relative to the three other locations, even when the identified substantial number of PUJ services in the CBD would have been removed. With the AGT intervention, the resulting long-term mean of PM_{10} in the CBD would still remain above the WHO IT-3 of 30 μg/m^3.

At what mean level of PM_{10} can the AGT intervention settle? Or what might be the likely range of values?

The study proposes an educated guess, considering the qualitative shift in the nature of public transportation provision in the CBD, and considering the substantial number of PUJ services that would have to be removed and replaced. The more conservative estimate is that PM_{10} will be lowered to 60 μg/m^3. The more optimistic estimate is a mean of 50 μg/m^3. The more conservative estimate of 60 μg/m^3 implies that the achieved level of PM_{10} at the CBD after the AGT intervention will still be double the reference value found in the three other locations outside the CBD (i.e., 30 μg/m^3). This would constitute a 28% reduction from the historical long-term value of 83.2 μg/m^3. In essence, this more conservative estimate asserts that the AGT investment would at least lead to the achievement of the long-term PM_{10} standard set out by the Philippine Clean Air Act of 1999. On the other hand, the more optimistic estimate of 50 μg/m^3 implies that the achieved level of PM_{10} at the CBD after the AGT intervention will still remain to be two-thirds higher than the reference point of 30 μg/m^3 found in the three other locations outside the CBD. This achievement will constitute a 40% reduction of PM_{10} from its historical mean. This more optimistic value asserts that the AGT investment would at most lead to the achievement of the WHO IT-2 for the locality, as a contribution to other complementary interventions that could lead to the achievement of the WHO AQG of 20 μg/m^3.

The cost-benefit analysis of this study uses the achievement of the more conservative mean value of PM_{10} concentration at 60 μg/m^3. Using the benefits and costs estimations in the previous section, Table 8 shows that for a 10-year operation period of the AGT in Baguio CBD and a total investment of about PHP 778 million, the net present value (NPV) using a 12% discount rate would be PHP 250.8 million with a respectable internal rate of return (IRR) of 19%. Note that there are still several unmonetized benefits that can increase the value of the NPV and the IRR.

Thus, at the more conservative achievement in PM_{10} reduction, the proposed AGT intervention comes out to be viable, with a positive value for its NPV and an IRR above the assumed opportunity cost of funds. The above results indicate that if the more optimistic reduction in PM_{10} were achieved, then the estimated societal net benefit attained through the AGT intervention would even be higher, as reflected by a higher NPV and IRR, respectively. The comparative results for conservative and optimistic levels of reduction in PM_{10} are shown in Table 9. Results show that a larger reduction in long-term mean PM_{10} levels (to achieve the WHO IT-2 with the same intervention), all other things being equal, would lead to a slightly lower value of the NPV and IRR, respectively. This relative decline in project performance is traced to the downward pull from the increase in the foregone income of 880 additional PUJ units that need to be replaced in order to achieve higher air quality target.

Table 8. Benefit-cost analysis of introducing AGT in Baguio CBD and PM_{10} is reduced to 60 μg/m^3 (in million PHP)

Item	Y0	Y1	Y2	Y3…	…Y10	Y11	Y12
Benefits							
Avoided direct costs due to air pollution-related illnesses			10.9	10.9	10.9	10.9	10.9
Avoided premature mortality from air pollution-related illnesses			21.52	21.5	21.5	21.5	21.5
Revenues from AGT operation (MRT price of PHP 12)			319.9	319.9	319.9	319.9	319.9
Residual value of AGT coaches at10% of total coach value							45.0
Shorter travel time for distance within system (avoided lost man-hours from PUJ)			98.3	98.3	98.3	98.3	98.3
Total Benefits	–	–	450.6	450.6	450.6	450.6	450.6
Costs							
Infrastructure at PHP 70 million per km x 4 km	280.0						
Coach with 60 passenger x 30 coaches at PHP 15 million	450.0						
Depot	28.0						
Cost of 20 stations at PHP 1 million	20.0						
Energy cost (30 coaches) at 41.33kWh per hour of operation per coach			67.3	74.1	144.3	158.8	174.6
Operations and maintenance of 30 coaches at 25% of total coach value			112.5	112.5	112.5	112.5	112.5
Operations and maintenance (depot)			4.2	4.2	4.2	4.2	4.2
Foregone net income of affected PUJ operations			34.4	34.4	34.4	34.4	34.4
Total Costs	778.0	–	218.4	225.0	227.4	309.8	325.7
Net Benefits	(778.0)	–	232.2	225.4	155.2	140.7	169.8
NPV at 12%	250.8						
IRR	19%						

Table 9. Comparative NPVs and IRRs of introducing AGT in Baguio CBD at alternative reductions in PM_{10} concentrations

PM_{10} Reduction Scenario (μg/m^3)	NPV @ 12% (PHP million)	IRR (%)
60 (Philippine CAA 1999)	251	19
50 (WHO IT-2)	238	18

4.4.3 Sensitivity analysis

Tests on the benefit side. Sensitivity analyses of the BCA results are built around the base case scenario where the introduction of the AGT would bring about the more conservative estimate in the reduction of PM_{10} concentration to a long-term mean of 60 μg/m^3. The sensitivity tests are performed on changes in the assumptions on the benefit side, on the one hand, and changes in the assumptions on the cost side, on the other. The results of the changes in particular assumptions on the benefit side are shown in Table 10.

Table 10. Effects of alternative assumptions on the benefit side, at the conservative reduction in PM_{10} to 60 µg/m^3

Scenario	NPV at 12% (PHP million)	IRR (%)
(A) Base Scenario at PM_{10} = 60 µg/m^3	250.8	19
(B) Avoided costs only on 50% of attributable cases	174.1	17
(C) Price per trip decreases from PHP 12 to PHP 10 per trip	(1.6)	12
(D)Only 50% of passengers have opportunity cost of transport waiting time	18.1	13
Both (B) and (D) occur	(58.5)	10
Both (C) and (D) occur	(234.3)	4

The avoided costs of premature death and illness pertain to only 50% of the attributable cases in the base case scenario. This change in this assumption on the scope of the health benefit of reducing air pollution concentration to 60 µg/m^3 arises from the observation in the household survey that there is a tobacco smoker in 50% of the households. Tobacco smoking has its own health impacts in terms of the incidence of cardiovascular and respiratory illnesses and premature death. These impacts were not considered in the study.

Although the health risk coefficients adopted for the study referred only to PM_{10} from outdoor air pollution, the change in the assumption about the scope of the impact of the reduction in PM_{10} to apply to only half of the original attributable cases in the base scenario is an attempt to test what happens to the BCA results when a possible confounding effect arises because of the prevalence of tobacco smoking among households in the locality. Essentially, the impact of this change in the assumption is a reduction by half of the aggregated avoided costs of illness and premature mortality. The observed effect is a reduction in the NPV of the intervention by 44% to PHP 174.1 million. Correspondingly, the IRR falls by two-percentage points to 17%. In general, even at half the magnitude of health benefits arising from the introduction of the AGT, the intervention still proves to be socially beneficial.

The price per trip is reduced from PHP 12 to PHP 10. The original price per trip of PHP 12 was based on the minimum fare of a similar, but not identical, facility in Metro Manila, which is the Metro Rail Transit (MRT). The basic fare is applicable up to a 5-kilometer distance, after which the fare is adjusted after every kilometer. In the case of the MRT, however, the fare does not reflect the true cost of operating the train. The MRT system involves huge capital investments in elevated rails and coaches imported from abroad. For example, for the MRT-3 line, at the said fares, the government still subsidizes 75% of the MRT-3 operations.

In the case of the AGT, with significantly lower infrastructure costs and cheaper locally-made coaches, the PHP 12 fare per passenger is asserted to more or less approach a rate that allows for an internal recovery of the investment from passenger revenues.

The PHP 12 per trip fare is higher than the minimum fare of a PUJ ride at PHP 8.50. This rate, however, is much lower than the alternative minimum flag-down rate of a taxi cab at PHP 35, increasing to about PHP 40 for a 1-kilometer trip, to about PHP 50 for a 2-kilometer distance within the Baguio CBD. For a more efficient, faster, and less-polluting ride via the AGT, it is asserted that the passengers are willing to pay the difference of PHP 3.50 per trip above the PUJ fare for the same distance. The AGT is also a much cheaper alternative than taking a taxi cab for a similar origin and destination.

The assumption of a lower AGT fare at PHP 10 per trip is done to test whether the system can absorb such a shock. Table 10 shows that a reduction in the fare to PHP 10 would drastically reduce the NPV to a negative value, and drive the IRR to just the 12% breakeven value. The result reveals that the social viability of the proposed intervention is extremely sensitive to the fare per trip.

Only 50% of the working (employed) passengers of the AGT have an opportunity cost of transportation waiting time. The base case scenario assumes that one-third of all the passengers of the AGT have an opportunity cost of transportation waiting time. This segment of the daily commuters would represent the working population as separate from students. Opportunity cost of time is pro-rated with the minimum daily wage rate. With a more efficient and faster AGT, the travel time (which includes waiting time plus actual travel time) from origin to destination is substantially reduced with the absence of unpredictable traffic congestion along the streets of the CBD when either the PUJ or taxi cab is used.

In essence, this scenario tests what would happen to the project viability if only one-sixth of the daily commuters would have opportunity cost of transportation travel time. Table 10 shows that the proportion of the passengers that have an opportunity cost of transportation travel time substantially impacts on the magnitudes of the NPV and the IRR, respectively. NPV falls by a large 128% to only PHP 18 million. IRR falls to 13%, barely above the adopted opportunity cost of funds. Thus, the viability of the proposed intervention is sensitive to the value of the opportunity cost of time that a proportion of the riding public truly has.

Both avoided health costs apply to only 50% of the attributable cases and only 50% of the working (employed) passengers of the AGT have opportunity cost of transportation waiting time. The sensitivity test combining the occurrence of a reduced proportion of attributable cases of illness and deaths to air pollution with a reduced proportion of the riding public having opportunity cost of transportation waiting time drives the proposed intervention into the region of unviability at the adopted opportunity cost of funds. The negative value of the NPV in this case, however, is not very large (–PHP 58.5 million), and the IRR at 10% is just 2-percentage points lower than that of the opportunity cost of funds.

Both the price per trip is reduced from PHP 12 to PHP 10 and only 50% of the working (employed) passengers of the AGT have opportunity cost of transportation waiting time. The combination of the adverse conditions of a fare reduction and a reduced proportion of the riding public having an opportunity cost of transportation waiting time would drive the proposed intervention into a deeper region of unviability. This is traceable to the high sensitivity of the project viability to each of the two assumptions taken independently.

Tests on the costs side. The sensitivity of project performance can also be tested for changes in the assumption about particular components on the costs side of the proposed intervention. The tests conducted in this section pertain to changes in the assumptions of the following: (1) investment costs, (2) energy costs on which the system will run, and (3) maintenance and other operating expenses (MOOE). Table 11 shows the changes in the values of the NPV and IRR for each of the changes in the values of the above items.

An increase in investment costs by 20%. An increase in the investment costs by 20% has the impact of substantially reducing the NPV to a –PHP 7.3 million. The increase in investment cost also drives down the IRR to just 12%, making it just at par with the opportunity cost of funds. The proposed intervention is very sensitive to costs that are made up front.

An increase in energy costs by 18%. Energy is a necessary component in running the innovative public transportation system. The cost of energy is crucial to the viability of the proposed intervention. An increase in energy cost up to a high 20% already drives the proposed intervention into the unviable region. The assumption on the increase in energy cost is thus purposely scaled down to the level in which positive NPV could be realized. As shown in Table 11, to maintain viability, the proposed intervention could absorb an 18% increase in energy costs. Suffice to say, the viability of the proposed project is very sensitive also to the primary input that would run the transportation system.

Table 11. Effects of changes in the assumptions on the cost of investment or operation of the AGT, at the conservative reduction in PM_{10} to 60 $\mu g/m^3$

Scenario	NPV at 12% (PHP million)	IRR
Base Scenario	250.8	19%
20% increase in investment costs	(7.3)	12%
18% increase in energy costs	39.6	13%
10% Increase in MOOE	(23.0)	11%

Note: MOOE = maintenance and other operating expenses

An increase in MOOE by 10%. The sensitivity test results as shown in Table 11 also indicate that the viability of the proposed intervention is also very sensitive to changes in the level of the MOOE. A mere 10% increase in MOOE already drives the NPV to a negative value and IRR down to 1-percentage point lower than the breakeven level of 12%.

Summary of sensitivity analyses. The base case scenario in standard BCA assumes the status quo or "business as usual" situation where no additional measure to reduce air pollution in the Baguio CBD is done and, thus, PM_{10} is at the long-term average level of 83 µg/m^3 and the corresponding aggregate health costs amount to about PHP 77.4 million.

The alternative scenario is to introduce the AGT as the mode of public transportation system, replacing PUJs, within the Baguio CBD. At the more conservative reduction in PM_{10} to 60 µg/m^3, the BCA shows that the proposed intervention to reduce PM_{10} is viable. The viability of the proposed intervention has been shown to be quite stable to changes in the magnitude of attributable cases of air pollution-related illnesses and deaths. However, the proposed intervention is quite sensitive to changes in price charged per trip for the AGT, as well as to the proportion of passengers to which the opportunity cost of transportation travel time matters. In the operation of the AGT, the viability of the proposed intervention has been shown to be quite sensitive to all the potential sources of shocks that have been identified: increases in the investment cost, energy cost, or MOOE.

Although sensitivity tests were not conducted for the assumption that the introduction of the AGT would result in the more optimistic extent of PM_{10} reduction to 50 µg/m^3, it can be deduced that the viability of the proposed intervention will still be sensitive to the various shocks assumed above.

4.5 Caution in the Use of PM_{10} Concentrations as Indicator in Estimating Health Impacts and Cost of Illness of Exposure to Outdoor Air Pollution when Diesel Emissions are the Main Generators of Particulate Matter in a Particular Location

As defined, PM_{10} refers to particulates of an aerodynamic diameter of less than 10 µm. Thus, PM_{10} monitoring machines are capturing not only coarse particulates, but in terms of health impacts, also the more hazardous fine and ultrafine particulates, although their respective concentration levels are not known. The finer particulates are defined as follows:

- $PM_{2.5}$ – fine particles with diameters below 2.5 µm
- Ultrafine particles – particles with diameters below 0.1 µm or 100 nanometers (nm)
- Nanoparticles – particles characterized by diameters of less than 50 nm.

The WHO advocates that countries should have measures of $PM_{2.5}$ at the local level so that local authorities can take measures to control the levels of this pollutant when actual levels exceed certain health standards. In the absence of $PM_{2.5}$ machines, particularly in many localities in developing countries, measures of PM_{10} are accepted as the indicator of the behavior of pollutants that have known adverse impacts on human health. Thus across countries, measures of PM_{10} are more widely available than those of $PM_{2.5}$. However, $PM_{2.5}$ is the more crucial indicator in predicting health impacts; thus, the WHO employs particular conversion factors to obtain "converted $PM_{2.5}$ values" derived from actual data obtained from PM_{10} measures. The conversion factors are obtained from observed regular relationships between concentrations in PM_{10} and $PM_{2.5}$, respectively, in particular locations where both data types are available. In large urban centers in European countries, the conversion factor revolves around a relatively high mean value of 0.67 since the main generators of particulates are motor vehicles. For such a value, if PM_{10} data is registered at 100 µg/m^3, then $PM_{2.5}$ concentration would be around 67 µg/m^3.

In developing countries where PM_{10} data are available but not $PM_{2.5}$, the conversion factors are generally lower. Taking a sample of groups of countries in the *WHO Air Quality Report of 2014*, the various conversion factors used for designated cities are the following:

- 0.44 for Indonesia, Maldives, Myanmar, Nepal, and Sri Lanka
- 0.46 for China, Malaysia, Mongolia, the Philippines, and Viet Nam
- 0.53 for Thailand

In the *WHO Air Quality Report of 2014*, all three cities of Baguio, Metro Manila, and Cebu had converted $PM_{2.5}$ values using a uniform conversion factor of 0.46. With the recent installation of a $PM_{2.5}$ monitoring machine at the Baguio Burnham Lake (Park) area in May 2014, the 13-month mean ratio of $PM_{2.5}$ to PM_{10} was computed to be 0.67. This relatively high figure approximates the relationship between $PM_{2.5}$ and PM_{10} in the European countries referred to in the 2014 WHO report. This high ratio is also consistent with the WHO observation when the main generators of particulate matter are motor vehicles.

The recently available data on $PM_{2.5}$ concentrations in the Baguio Burnham Lake monitoring station reveals that previous estimates of $PM_{2.5}$ concentrations for the Baguio CBD area, given the known values of PM_{10} over the years, grossly understates the gravity of the public's exposure to concentrations of the finer particulates; these are more hazardous to human health than the coarser particulates that are captured in the PM_{10} readings.

The previous section describes the PUJs plying Baguio CBD routes—all run by old, used diesel-powered engines imported from abroad. In addition, a high proportion of the taxi cab units used as public transportation also use diesel fuel. The above information is significant. Studies show that in diesel engine emissions, the nanoparticles, ultrafine particles, and fine particles ($PM_{2.5}$) dominate in terms of particle numbers and particle mass as compared to the coarse particles (Hall et al. 2001). Thus, this implies that the public is put at a greater health risk due to exposure to diesel emissions in the Baguio CBD than what the initial study has predicted. It also implies that the benefits in terms of avoided mortality and morbidity costs of attributable cases of investing in a less polluting public transport system such as the AGT system would be much higher.

5.0 CONCLUSIONS AND AREAS FOR FUTURE RESEARCH

The long-term mean concentration level of air pollution in the Baguio CBD covering the years 2007–2012 was measured at 83.2 $\mu g/m^3$ of the PM_{10} pollutant. This average level exceeds the national and international health standards. It is almost 40% higher than the long-term standard of 60 $\mu g/m^3$ set by the Philippine Clean Air Act of 1999, and it is more than four times the WHO Air Quality Guideline (AQG) for PM_{10} at 20 $\mu g/m^3$.

The annual economic value of the magnitudes of reduction in attributable cases of premature nontraumatic deaths and morbidity via policies and measures that could bring down the long-term PM_{10} concentration levels in the Baguio CBD to a level that meets the WHO health guideline is quite significant. In premature deaths avoided, the economic value saved is estimated at about PHP 53.3 million per annum. In attributable morbidity cases avoided, the monetary value saved is about PHP 24.0 million per annum. Hence, the total cost of illness that could be avoided is estimated at PHP 77.3 million per year.

The PM_{10} concentration levels in the Baguio CBD, however, cannot be brought down significantly without a radical change in the type of public mass transport system available to the general public. For decades, the diesel-powered PUJs and taxis have been the only public transport modes available.

In early 2014, the DOST presented a proposal to the Baguio local government for the construction and operation of an electric-powered AGT system that would service the Baguio CBD, and another system that would connect Baguio with the adjacent municipality, La Trinidad, the capital town of the province of Benguet. The pre-feasibility study for the La Trinidad-Baguio line has just been completed; whereas that for the Baguio CBD system is still ongoing.

The results of the BCA conducted on the investment in an AGT covering a 4-kilometer circumferential route within the CBD , with a fleet size that can meet a substantial proportion of the total transport demand, showed that with the inclusion of benefits from the reduction in the cost of illness (COI) of around PHP 77.8 million per annum, due to death and morbidity cases attributable to high concentration levels of PM_{10} in the Baguio CBD, the proposed investment would generate substantial positive social net benefits. The net social benefits will even be much higher if a social discount rate of 6% will be used instead of the 12% discount rate adopted in the study in view of the possibility of the AGT being sourced from public funds. On economic efficiency grounds, it is worthwhile for the Baguio local government and the citizenry to pursue and support this novel proposal.

Actual data on $PM_{2.5}$ is now being generated by the new Continuous Air Monitoring System by the Environmental Management Bureau monitoring station at the Baguio Burnham Park area; thus, the long-term mean value of $PM_{2.5}$ exposure of the population could soon be determined. It is recommended that a new study be made to obtain new estimates of attributable cases of mortality and morbidity, using $PM_{2.5}$-specific health risk coefficients for a more expanded and more specific set of health outcomes. These data can then be used to further determine the benefits and costs of investing in a less-polluting alternative public transport system such as the AGT.

Although this study focused on analyzing only the single concrete proposal of the investment in an AGT to replace the aging and heavily polluting diesel-fueled fleet of PUJs (and taxi cabs) operating within the Baguio CBD, there could be complementary (or even alternative) policy and investment measures that could help bring the PM_{10} concentration levels in the Baguio CBD. Pursuing this lead could serve as extensions and refinements to this preliminary study.

6.0 LIMITATIONS OF THE STUDY

Ideally, $PM_{2.5}$ is the more preferred measure of concentration level for predicting the particular adverse health impacts of air pollution. $PM_{2.5}$, which measures the more dangerous fine particulates of less than 2.5 micrometers in aerodynamic diameter, is more effective than PM_{10} as the latter only the coarse particulates measuring less than 10 micrometers in aerodynamic diameter. However, the available historical data for the city and for the particular location in the CBD was only data on PM_{10}. For this reason, the health risk coefficients for PM_{10} associated with mortalities and particular cardiovascular and respiratory illnesses in the epidemiology literature were adopted by Costales et al. (2016).

The EMB-CAR finally set up a $PM_{2.5}$ monitoring machine in the city in May 2014, but it was not possible to obtain long-term (annual) concentration levels of the pollutant to make observations about chronic exposure of the population to the pollutant. Furthermore, the $PM_{2.5}$ monitoring machine was set up at a site in Burnham Park (in the lake), where PUJs do not traverse. Thus, the PM_{10} readings cannot be taken to represent those for the Baguio CBD. So far the $PM_{2.5}$ and PM_{10} data over a 13-month period, on a monthly mean basis, move in the same direction. In general, $PM_{2.5}$ movements "mimics" the PM_{10} movement. At the mean, the ratio of $PM_{2.5}$ to PM_{10} concentrations is 0.67. This relatively high ratio is consistent with the assertion that the main generator of particulates, as measured by PM_{10} in the locality, are the motor vehicles rather than dust particles from nearby construction activities (Costales et al. 2016).

On another note, the study of Costales et al. (2016) did not explicitly take into account the independent adverse health impacts of the incidence of tobacco smoking among the population exposed to air pollution. It is known that tobacco smoking is associated with particular health risks that are also cardiovascular and respiratory in nature. The study also did not explicitly take into account the adverse health impacts of households using fuel wood or charcoal for cooking food. The household survey, nevertheless, obtained information on these aspects of household behavior to temper interpretation of the quantitative values obtained in estimating health impacts expressed in terms of incidence of particular health outcomes. The BCA of this study, however, made sensitivity analysis to capture this uncertainty.

Many other benefits had not been monetized, such as (1) the convenience and comfort of riding the air-conditioned coaches instead of smog-filled, open PUJ motor vehicles; (2) lower public health counterpart expenditures avoided (to support public hospital and public health centers in the treatment of air pollution-related morbidity and mortality cases); and (3) the value of improved reputation and image of Baguio as a tourist destination arising from improved air quality. All these can be areas for future research.

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