Innovative Design of Air-Conditioned Bus Stops Model to Reduce Dust from Traffic, Uthai Tani City, Thailand

Opas Pukklin* and Pajaree Thongsanit

Abstract—**This research aims to study the innovation of a prototype air-conditioned bus waiting stop designed to reduce dust from traffic in the area of the city. Uthai tani Province, Thailand. Objectives are to design a closed air-conditioned bus stop and install a dust filter device and test the effectiveness of reducing the amount of dust generated by traffic in the bus stop area. Data on $PM_{2.5}$ (Particulate Matter of size less than 2.5 micron) and PM_{10} (Particulate Matter of size less than 10 micron) was collected with the air quality sensor model number PMS7003. The study found that the designed air-conditioned bus stop prototype can reduce the amount of particulate matter caused by traffic from the application of engineering knowledge in its design, installation, inspection, and can control dust levels with air pressure systems and air purification systems. It was found that the amount of $PM_{2.5}$ and PM_{10} inside the air-conditioned bus prototype and outside are different. From collecting data on $PM_{2.5}$ and PM_{10} concentrations, it was found that the concentrations outside the air-conditioned bus stops were always higher than inside the prototype air-conditioned bus stops. The innovative design of the prototype air-conditioned bus stop can reduce $PM_{2.5}$ particulate matter of 91.95 to 99.49% and PM_{10} of 89.09 to 96.88%.**

Index Terms—**Innovation design, bus stop, $PM_{2.5}$ and PM_{10}, vehicle emission**

I. Introduction

The $PM_{2.5}$ samples for 2020 were collected at reference points in Uthai tani. The dust data was sampled randomly by the Pollution Control Department (PCD) of Thailand. The dust level was highest at the start of the year, January 2020. In March 2020, the $PM_{2.5}$ concentration was of 37.7 μg/m³. The standard level of $PM_{2.5}$ in the air of Thailand according to PCD is 50 μg/m³. Dust levels higher than the national standard adversely affects people with weaker immune systems [1].

The Uthai tani Province bus interchange has many commuters and passengers, with many minibuses and motorcycles for hire around the vicinity. The number of people using public transportation has increased because it has become an increasingly common mode of transport as compared to private vehicles.

The main air pollutants in Uthai tani would be the chemical compounds nitrogen dioxide, sulfur dioxide, ozone and smog. With reference to the United States if America of Air Quality Index (US AQI) reading, it is found that the air pollution originates from industrial activity, combustion sources and vehicle exhaust.

The various oxides of nitrogen (NO_x) that are also released by cars and combustion sources can undergo a chemical reaction and form ozone under the right conditions (high exposure to sunlight). Other gases and chemical compounds also add to the formation of ozone. Other pollutants include black carbon, which is the main component in soot, and a potent carcinogen when inhaled, making it a very dangerous form of $PM_{2.5}$ that also has climate-changing properties.

Along with black carbon, Volatile Organic Compounds (VOCs) are also formed from the incomplete combustion of both fossil fuels and organic matter. Some examples of VOCs are chemicals such as benzene, formaldehyde, styrene, and toluene, all of which are extremely harmful to one's health.

Air pollution affects the health of people their respiratory systems. Roadside areas are exposed to the highest levels of fine dust. The main objectives of this research are to design a closed air-conditioned bus stop with the installation of a $PM_{2.5}$ dust filter device, along with testing the effectiveness of the air-conditioned bus stop's dust reduction and filtering of $PM_{2.5}$ for commuters waiting for buses.

II. Methods

A. Research Method

1. Study and gather information on engineering, technology and design a bus stop in a translucent enclosed building with dimensions of 1.5 m×6 m×3 m is shown as Fig. 1, made of steel structure, flooring, ceiling, wall paneling, locked glass and sliding glass doors, allowing commuters to see the buses they are waiting for and board them. The air-conditioned system will have air filtering and purifying properties.
2. Minimize external polluted air from entering the building with an air filtration system of $PM_{2.5}$ dust inside incorporated into the establishment.
3. Prevent dust generation inside the bus stop by forbidding activities that generate dust, such as smoking, tracking dust from shoes, etc.
4. Use materials and equipment inside the bus stop that prevent dust accumulation and ensuring the surface of the materials can be easily cleaned.
5. Eliminate dust particles inside bus stops by using an air purifier that can filter dust by filtering with a High Efficiency Particulate Air Filter (HEPA) and Electrostatic precipitators are devices that precipitate particles in a gas stream by inducing an electrostatic charge. Particle's precipitate and then are filtered so that only the desired gas remains. The basic design of an electrostatic precipitator is a row of vertical wires followed by a stack of plates oriented vertically, with a usual separation of 1 cm to 18 cm. The gas stream flows perpendicular to the wires and then passes through the stack of plates, where a negative voltage of several thousand

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volts is applied between the wire and the plate. If this voltage is high enough, an electric discharge ionizes the gas around the electrodes. The negatively charged ions then flow to the plates and charge the particles in the gas. Ionized particles follow the electric field created by the power supply and move to the grounded plates [2].

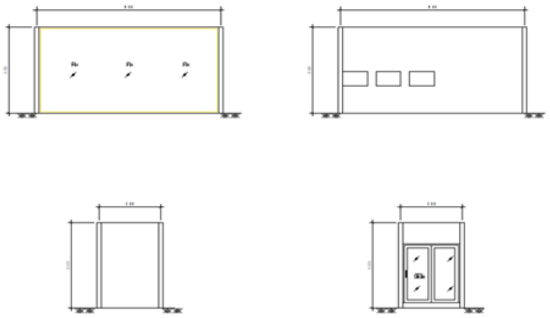


Fig. 1. The bus stop model design.

B. Research Samplings

The dust sampling is based on the buses running from 6:00 a.m. to 6:00 p.m., with sampling every 2 h apart for 7 times, namely 6:00 a.m., 8:00 a.m., 10:00 a.m., 12:00 a.m., 2:00 p.m., 4:00 p.m., 6:00 p.m. Sampling was done for average 30 days, for 3 consecutive months of June, July and August 2022. The sampling compares the dust levels inside and outside the air-conditioned bus stops.

The sampling system contains an air conditioning ventilator and air filter with first sampling at 6:00 a.m. The system ran at 2hour intervals. Indoor and outdoor measurements were taken simultaneously until 6:00 p.m., after which the said electrical appliances were switched off. The last round of data of the day is then collected and compiled. This process is repeated daily.

III. Results

A. Principles and Pattern Design of Bus Stop

The bus stop is designed to be a room that reduces exposure to fine dust show as Fig. 2. This includes $PM_{2.5}$ and dust smaller PM_{10} to reduce the impact on health for people at risk in risky areas. These are areas which must have the average 24-hour particulate matter in the atmosphere not exceeding the standard the amount of $PM_{2.5}$ with more than 50 micrograms per cubic meter (µg/m^3) or the amount PM_{10} not more than 120 mg/m^3.

There are four principles to make the room dust free

1. Prevent dust from the outside from entering the room by closing gaps or leaks of the building in various places where dust can enter [3].

2. Prevent the formation of dust in the room by not doing any activities that generate dust [4].

3. Prevent the accumulation of dust on the walls and equipment in the room and the material of the surfaces of the room [5].

4. Remove dust particles from the room by choosing equipment that can reduce the amount of dust and purify the air inside. For example, using an air purifier that can filter dust by filtering with materials such as High Efficiency Particulate air filters, Air Filter (HEPA) or air purifiers and dust collection systems.

Based on the mentioned four principles, three design styles of the dust-free room models can be proposed

Style 1: Protection against external dust

It is an application of the principle of preventing dust from outside entering the room as a method that is easy to do and has the least cost. This is a way to control the amount of fine dust in the room by closing the doors and windows completely, minimizing the gaps. Performance Dust reduction depends on the airtightness of the room to reduce the permeability of outside air and prevent a high amount of dust from entering the room [6]. The level of dust inside the room must be maintained to not increase as much as possible. This is to reduce the chances of dust levels from outside the room affecting the levels inside the room. If the dust levels outside are not high, and there are no ventilation or dust removal systems inside the room, the levels of dust internally might exceed the levels of dust externally. Therefore, ventilation should be performed from time to time show as Fig. 3.

Style 2: Air purification system

It is an application of the principle of removing dust particles inside the bus stop with an air purifier in conjunction with preventing dust from outside entering the bus stop. The efficiency of reducing dust inside the bus stop depends on the efficiency such air purifiers, so the air purifier used should be of a suitable size for the room [7].

Style 3: Air pressure system with air purification system

It is a highly efficient method. Same to the air purification system in model 2, this is the application of the principle of preventing dust from outside into the room and removing particles that are inside the room as well, but with this design, the fan sucks in air. But with this system, the fan will suck in air from the outside (Intake Fan) that has already been reduced by various methods, such as filtering dust using a filter at MERV 11 (Minimum Efficiency Reporting Value level of 11) higher, supplying it to the bus stop [8].

The inside of the bus stop to have a higher air pressure than the atmosphere outside (Positive Pressure), the air supplied will continuously push the dust out of the room until the dust in the room is lower than the standard. There will be some exhaust fans to direct the air flow inside the bus stop. The suction rate should be less than the air intake rate. This can reduce dust in the room and improve ventilation.

Fig. 2. The bus stop model (No dust bus stop).

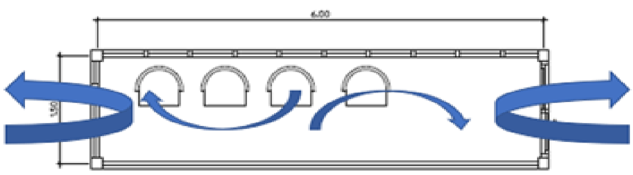


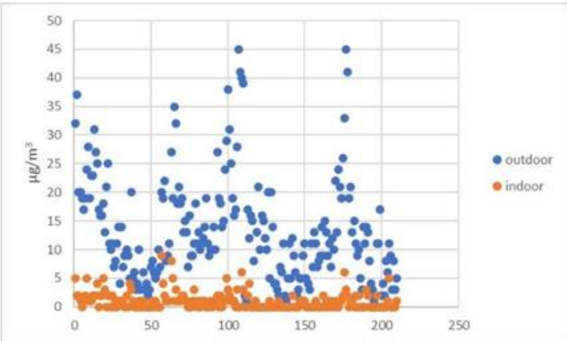
Fig. 3. The ventilation in the bus stop room.

B. Dust Concentrations

Fig. 4 shows the results of the research on $PM_{2.5}$ and PM_{10} dust collection in June 2022.

$PM_{2.5}$ concentration outside the bus stop ranged from 1–45 µg/m^3, with the highest level being at 8:00 a.m. on June 16. Concentrations inside bus stops ranged from 0–9 µg/m^3, with the highest level being at 6:00 a.m. on June 9. From the data, it was found that No Dust Bus Stop is effective in reducing dust. When comparing the dust outside the bus stop and inside the bus stop, it was found that the dust can be reduced by an average of 92.66%.

PM_{10} found that concentrations outside bus stops ranged from 1–57 µg/m^3, with the highest level at 8:00 a.m. on June 16. Concentrations inside bus stops were also found to range from 0–9 µg/m^3, with the highest level being at 6:00 a.m. on June 9. It was found that an average dust reduction of 92.66% was achieved.



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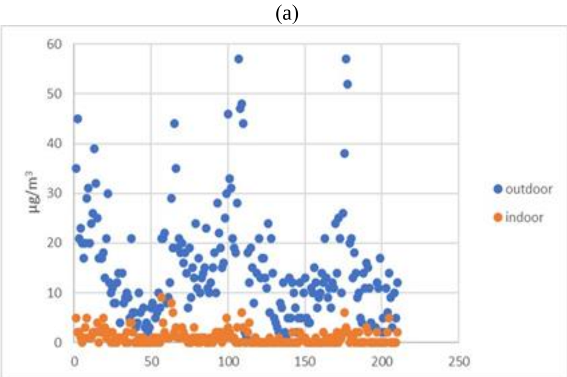


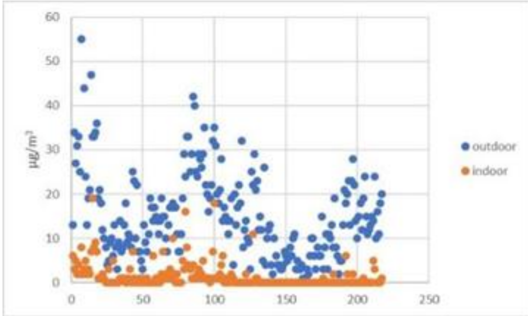
(b)

Fig. 4. $PM_{2.5}$ (a) and PM_{10} (b) concentration in outdoor and indoor of the cabinet in June.

In Fig. 5, the results of the study of $PM_{2.5}$ and PM_{10} dust collection in July 2022.

$PM_{2.5}$ concentration outdoors ranged from 1–55 µg/m^3, with the highest level being at 6:00 p.m. on July 1st. The concentration indoors ranged from 0–19 µg/m^3, with the highest level being at 6:00 a.m. on July 3rd. From the above data, we can conclude that the dust reduction efficiency of this bus stop model can reduce dust. Upon comparing the dust outdoor and indoor the cabinet, results show that the dust can be reduced by an average of 91.95%.

PM_{10} concentration outdoors ranged from 1–69 µg/m^3, with the highest level being at 6:00 p.m. on July 1st. The concentration indoor the cabinet ranged from 0–20 µg/m^3, with the highest level being at 6:00 a.m. on July 3rd. Results conclude that the dust can be reduced to an average of 89.09%.



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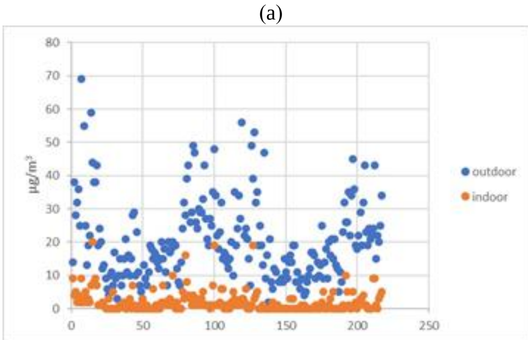
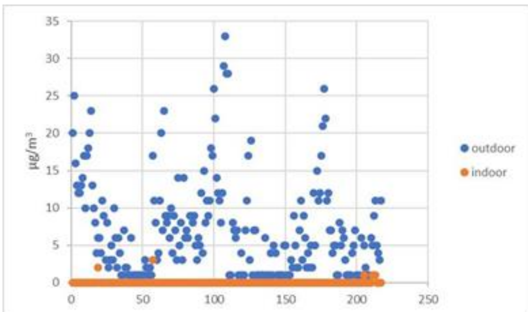


(b)

Fig. 5. $PM_{2.5}$ (A) and PM_{10} (B) concentration in outdoor and indoor of the cabinet in July.

The result of the study of $PM_{2.5}$ and PM_{10} dust collection in August 2022 show as Fig. 6. $PM_{2.5}$ concentration outdoors ranged from 1–33 µg/m^3, with the highest level being at 10:00 a.m. on the August 16. The concentration indoors the cabinet ranged from 0–3 µg/m^3, with the highest level being at 6:00 a.m. on August 9. Results show that the dust reduction efficiency of this bus stop model can reduce dust as when comparing the dust outdoors and indoors, the dust can be reduced was an average of 99.49%.

PM_{10} concentration outdoors ranged from 1–55 µg/m^3, with the highest level being at 10:00 a.m. on August 16. The concentration indoors ranged from 0–8 µg/m^3, with the highest level being at 6:00 a.m. on August 9. Results show that the dust can be reduced an average of 96.88%.



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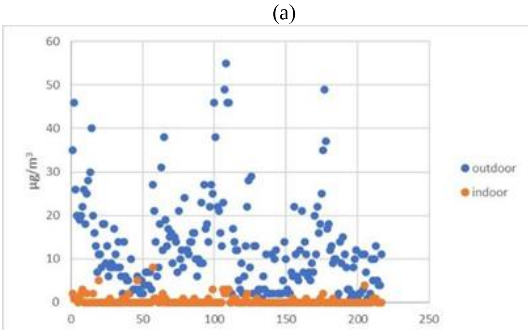

(b)

Fig. 6. $PM_{2.5}$ (a) and PM_{10} (b) concentration in outdoor and indoor of the cabinet in August.

C. Traffic Data

There are two methods of surveying traffic volume that are commonly used today: Automatic Counters and Manual Counters. There are two types of counters in general, namely contact type vehicles (Contact Type) such as Signal detectors and non-contact vehicles (Non-Contact Type) such as video cameras, cameras. This method is expensive and suitable for long and detailed data collection. Storage can be transmitted from the installation in the field via the telephone network to the office [10].

As for the use of the enumerator, it is the easiest way. There is not much cost and information collected is the most accurate and detailed. However, there is a room for error due to boredom and neglect of the counter. The amount of time it takes to count a car depends on your budget and purpose. Use of the information obtained for normal traffic car counting may be studied in many ways, for example: Counting 24 hours, which is the amount of traffic in a day, by doing it on certain days of the week from midnight to midnight of the next day. However, to ascertain the traffic characteristics of business days, data can be selected from noon on Monday to noon on Friday [11].

It is the most ideal to track the traffic for 24 hours a day because during Monday morning and Friday evening, traffic is typically abnormal. During the holidays, tracking will be over a span of 16 hours instead starting from 06:00–22:00. Most of the traffic flows of each day falls between this and the 12-hour count, typically between 7:00 a.m. and 7:00 p.m. This method will cover all traffic during working hours, suitable for roads in community and commercial areas [12]. The traffic survey method in this study was determined with reference to the academic principle. It is a method that is recommended in the academic paper on the traffic volume survey of Department of Rural Roads, namely "How to use enumerators".

The type of vehicles for several consecutive days and as many hours a day as possible must be counted separately to be used to find the average daily traffic volume (Average Daily Traffic: ADT) show as Table I. Regarding the counting of the vehicles separately for each project, the counting should occur for at least 3 days, 8–12 hours per day (7 a.m. to 7 p.m.) and must be 1 weekend (Saturday or Sunday). The area where vehicles pass the most should be selected as the counting and tracking points. The area where the checkpoint is located must consider the width of the road to be the maximum distance that a driver can safely see and be enough to alert the driver of the vehicle that there is a survey point ahead.

TABLE I: CLASSIFICATION OF VEHICLES

Vehicle type	Vehicle type
Motorcycle (MC)	- motorcycle - motor tricycle
Gasoline vehicles (PC)	- 4-wheel passenger cars - car hire (taxi)
Small diesel vehicles (LDT)	- 4-wheel truck - minibus 4 wheels - van
Large diesel vehicles (HDT)	- minibus 6 wheels - medium and large buses - 10 wheels truck - trailers and trailers

Source: The Office of Transport and Traffic Policy and Planning (2003) [9]

The researcher of the traffic volume survey chose to use the method of counting cars in both directions at designated checkpoints within the study area by counting different types of cars cording to the classification of the Pollution Control Department. The method counts the traffic volume for 7 days, Monday to Sunday, for 12 hours a day (6:00 a.m.–6:00 p.m.). The number of different types of cars that can be counted show as Fig. 7. This data is used to calculate the ADT.

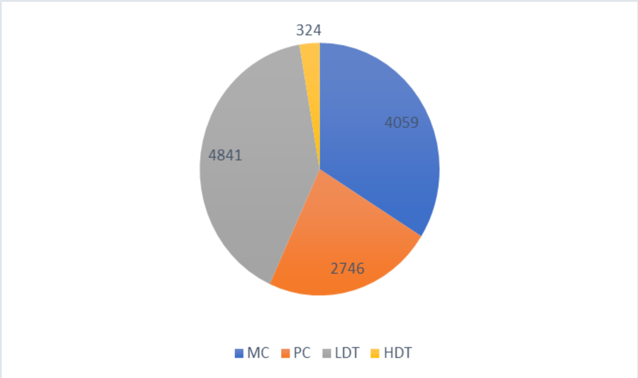

Fig. 7. Pile chart of the vehicle volume at bus stop area.

D. Estimation of Air Pollution Emissions

The estimation of air pollution emissions from vehicles in this study is possible. An equation referenced from the Pollution Control Department (2008) was selected based on traffic volume data and the distance traveled by the car in the study area (road length) [13].

$$Ei,j = Nj \times EFi,j \times D \quad (1)$$

where Ei,j is the discharge rate of pollutant i from category j vehicles (g/day)
Nj is the traffic volume of category j vehicles (cars/day)
EFi,j is the emission factor i from category j vehicles (g/km/vehicle)
D is the distance traveled by the car (km)

The emission factor values for vehicles are based on the Pollution Control Department. to use in the calculation for mobile origin shown in the Table II. Substitute the coefficients in the calculations according to the equation above.

TABLE II: AIR EMISSION FACTOR VALUES FOR THE VEHICLES

Vehicle type	PM (Particulate Matter)
Motorcycle	0.086 [14]
Gasoline vehicles	0.101 [14]
Small diesel vehicles	0.042 [15]
Large diesel vehicles	1.15 [14]

For Table III, calculation of emissions from vehicles the area in front of the bus stop reduces dust and calculated as a percentage as shown in Fig. 8.

TABLE III: PARTICLE EMISSION CONCENTRATION

Pollutants	Emission concentration (g/day)				
	MC	PC	LDT	HDT	Sum
PM	6262.74	4975.86	3647.80	6684.82	21571.22

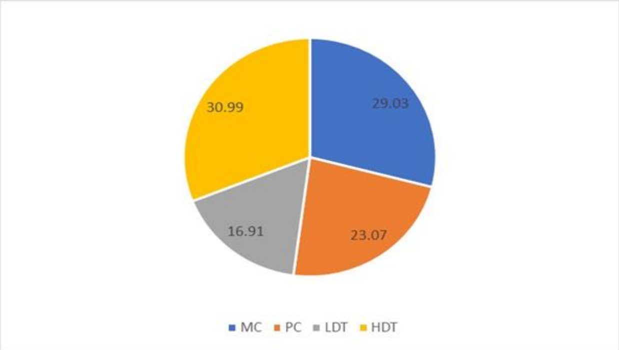

Fig. 8. Proportion of air pollutant emissions from vehicles (%).

IV. Conclusion

This study follows an innovative air-conditioned enclosed bus stop developed to reduce exposure to air pollution in people's daily lives such as while waiting for buses. While standing on the side of a road, the level of particulate matter in the atmosphere is at a level that is detrimental to health. This is the issue that this innovation of enclosed air-conditioned bus stops equipped with a dust filter aims to solve. This innovation reduces the amount of dust and the exposure to dust to a level that is safe for health by using an air purifier that can filter dust.

The usage of High Efficiency Particulate Air Filter (HEPA) air filter can reduce the amount of dust and keep the air inside the bus stop clean. The study found that during June-August, the $PM_{2.5}$ particulate matter was highest outside the bus stop between 33–55 $\mu g/m^3$, while inside the bus station the highest was between 3–19 $\mu g/m^3$. The amount of particulate matter PM_{10} during June–August outside the bus stop had a maximum value in the range of 55–69 $\mu g/m^3$. On the contrary, inside the bus stop, a maximum value of 8–20 $\mu g/m^3$ was found.

Upon collecting the concentrations of both outdoor and indoor $PM_{2.5}$ and PM_{10} simultaneously, the value outside the bus stop is higher than inside the bus stop at all intervals. It can be concluded that this prototype can reduce the amount of $PM_{2.5}$ particulate matter by 91.95%, 92.66% and 99.49% in July, June and August respectively and can reduce the amount of PM_{10}. got 89.09 percent, 92.66 and 96.88 in July, June and August respectively.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Opas Pukklin collected research data, calculated the particle levels, and performed the statistical analysis. Pajaree Thongsanit wrote and supervised the article. All authors had approved the final version

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