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REVIEW

Review Article: Toward Future Particulate Matter Situations in Thailand from Supporting Policy, Network and Economy

Jitiporn Wongwatcharapaiboon

In the era of climate uncertainty in 2019, $PM_{2.5}$ situations in Thailand are considered as big impacts to local livings in terms of health and well-being. This paper aims to investigate policies to decrease $PM_{2.5}$ levels and to examine reliable networking systems. International and domestic policies are literally found for controlling traffic emission, open burning activities, public health and industrial zoning, when strong satellite networks can be proved by the reliability and accuracy of $PM_{2.5}$ data collections, sources and chemicals identifications. Turning to financial loss during the $PM_{2.5}$ situation, cost estimations have been accounted in terms of environmental tax, pollution footprint, health mortality, public air cleaning payment, GDP and uncertainty cost of air pollution. The results related to policy can affect local social interventions, if policies match correctly to suitable techniques in this research series. Also real-time prospective warning of local $PM_{2.5}$ exceeding is required with accuracy, while all applicable methods are financially comparing in different contexts.

Keywords: $PM_{2.5}$ in Thailand; Supporting Policies; Economic Effects; $PM_{2.5}$ Networking; Cost estimation of $PM_{2.5}$

1. Introduction

During the 5-year period of air pollution research in Thailand, Particulate Matter sized 2.5 micron ($PM_{2.5}$) has been studied as environmental threats especially in middle and north land. The components of $PM_{2.5}$ can be various chemical depending on types of source, geographic locations and activity contexts. There are several common sources of $PM_{2.5}$ which include 1) the United State source: secondary sulfate, secondary nitrate, spark-ignition emissions, diesel emissions, road dust, biomass burning, pyrolyzed organic (OP) rich (Squizzato et al, 2018), 2) Asean source: secondary carbon (only in Asia), water soluble transition metals (Cr and Zn) (Park et al, 2018) and 3) European source: potassium (K), brown coal, black coal and oil (Pokorná et al, 2018). Within Thailand context, biomass burning and road dust provide black carbon and transportation chemicals to ambient environment.

Based on $PM_{2.5}$ threats in the middle and north Thailand, there are resulted from the same type of open agricultural burning sources and traffic situations. However, different incidences are showed in receiving locations. For example, Chiang Mai province has a trough location which is blocked ventilation by natural pressure in winter season; while Bangkok has open basin near the coaster which ventilation is somehow blocked from ocean wind. In every winter season, $PM_{2.5}$ concentrations exceed National Ambient Air Quality standards (NAAQs) and World Health Organization (WHO) at 35 and 25 $\mu g/m^3$ respectively. For example, the average intensity of $PM_{2.5}$ levels is higher than 60 $\mu g/m^3$ for nearly a month in 2018 (Pardthaisong et al, 2018). Then the exceeding of $PM_{2.5}$ has returned again in early 2019 (Air Quality and Noise Management Bureau, 2019) which provide serious effects to sensitive group of people in symptoms of bloody cough, respiratory irritation and lung infection.

According to Thai's policies and solutions for seasoning $PM_{2.5}$ situations, there were occasional plans shown in 1) temporary water sprays in city center and traffic junctions, 2) vehicle checks and pollution controls by polish officers, 3) mask protections in public space 4) close temporary academic place and 5) agricultural burning monitor in suburban areas. These policies couldn't show evidentially to reduce $PM_{2.5}$ concentration or protect sensitive groups from $PM_{2.5}$ especially child and elderly people. Also one obstruction was shown in lack of smart technology and holistic analysis to forecast and inform $PM_{2.5}$ situation to people on time.

As a result, brainstorm solutions are called for emergency situations and research suggestions pointed out resilience city and well participants can mitigate $PM_{2.5}$ level. Also well communication to rural residents and higher education organizations possibly protect people

Design Business and Technology Management Program, Faculty of Architecture and Planning, Thammasat University, TH

jjpinx4391@gmail.com

from future exceeding situation. Moreover, air cleaning applications are considered as main tools to purify outdoor and indoor air depended on levels of $PM_{2.5}$ concentration and local climate. One air purifier, for example, integrated by TiO_2 coating on mop and fabric filter was developed within tropical climate and pressure control condition to beneficially support photocatalytic process from high air humidity (Wongwatcharapaiboon, Gan & Riffat, 2019). Another technological solution has shown in case of satellite network to support individual unit, project future situation and analyse relational factor etc. For example, satellite data analysis can find interrelation between $PM_{2.5}$ source and mortality of local people which helps to navigate policy development (Shi et al, 2018). Therefore, this research paper aims to investigate example policies, satellite network systems and financial estimations.

2. Supporting Policy

From the dynamic of environmental change, all countries have been accounted to predict and avoid harmful situations as well as protecting themselves from $PM_{2.5}$ threats. The difference in economic and social policy can result directly in challenges of sustainable urban development and implementation. Within these challenges, criteria and sustainability indicators should be set up clearly for all contributors and participants (Verma & Raghubanshi, 2018). The effectiveness of air quality policies for the Pacific Islands region was building up collaboration among land users. Also most successful policies resulted from promoting leadership and empower of air quality control by raising awareness, informing more alternatives, financial support and well cooperation from authorities to action facilitating. Noticed awareness of this policy was one-side focus on economic change without balancing of resources, well supports of guideline and facilitating factors. Ambiguous purpose of application and unplanned process of action could lead to misunderstanding and conflicts in government system (Isley & Taylor, 2018). Then clear messages of enforcements will be easy to implement to local people. This section includes all case studies and policies within top-down and bottom-up policies, air quality control and methodology and implementation.

2.1. Top-down and Bottom-up Policies

Throughout the strongest action on environmental concern, Extended Producer Responsibility (EPR) legislations were revealed command and control (CAC) and market-based incentive (MBI). The reactive environmental strategy (RES) responded significantly both side of actions and enterprise economics performance, while the proactive environmental strategy (PES) linked significantly to only MBI action and both economic and environmental performances. Top-down policies should well support the coordination of industrial operation, implementation, monitoring observation and feasible environmental regulations (Peng et al, 2018). It can be seen that top-down policy is suitable for business and government sectors which have organiser or leaders.

Turning to bottom-up policy, social interventions are always from group of users who can point out environmental gap and provide participation for policy improvement. Throughout three case studies from London, Hong Kong and San Francisco, air quality action plans (AQAPs) can reflect how sociotechnical imaginaries affect important air cleaning environment policy by a striking uniformity pattern. Also five planning policies of urban future need to be delimited within the topics of 1) the government up front, 2) economy for cleaning air, 3) technologies for air problems, 4) admiring 'good' citizen, and 5) science policy interaction (Gross, Buchanan & Sané, 2019). Also this example can examines how the requirement of street people can improve direction of policy. According to transportation policy, promoting pathway can support healthy behaviours by increase in physical activities and social interactions. However, these activities allow sensitive group of street people suffering easier from $PM_{2.5}$ exposures (Frank et al, 2019). From 31 representative cities in China, 22 cities have needed policy to improve efficiently air cleaning during the period of 2013–2016 which the study pointed to government supports and industrial cooperation (Li, Chiu & Lu, 2018). The positions of participants and contributors will affect future action of policy. Social intervention is supposed to be more sustainable development since people provides higher willingness of participation.

2.2. Air Quality and Burning Control

Focusing on activities of burning control, outdoor burning is popular throughout rural areas in developing country because it is the lowest cost to eliminate all stuffs even body. Over 40 crematoriums in Mexico are identified being sources of $PM_{2.5}$ exposures. To reduce effects of air pollution, longer times of combustion in 120 minutes is claimed to emit less $PM_{2.5}$ at 11–59 mg/m^3, while those shorter times in 70 minutes provides more than double level of $PM_{2.5}$ at 25–205 mg/m^3 (González-Cardoso et al, 2018). This finding links normally to regulation and policy controlling crematorium burning to have better oxidation of combustion. Oxidation is the same point to coal burning since it cannot reach high quality of combustion. From 2017 to 2030, simulating results of $PM_{2.5}$ concentrations have been projected based on energy saving and adding control technology policies. If applying both policies, polluted areas of Sichuan Basin, Middle Yangtze and North China, it will reduce dramatically $PM_{2.5}$ levels from residential combustion, opening burning and transportation. Coal combustion will be only one activity being threat of air quality in China in 2030 (Cai et al, 2018). This result is supported by research of coal substitution policy evaluation in 2019. The coal replacement policy by gas or electricity is found to still emit high concentrations of air pollutions such as CO_2, SO_2, NO_x and $PM_{2.5}$. Then alternative energy and social welfare policies are recommended to further considerations (Chen & Chen, 2019).

Turning to mobility combustion, for the modeling development purpose, US Environmental Protection Agency's Motor Vehicle Emissions Simulator (MOVES) is used to predict six air pollution emissions in particular CO, CO_2, NO_2, PM_{10}, $PM_{2.5}$, and SO_2. Other factors of morning peak-hour traffic period and rapid growing population in Texas are applied in this model. Dominant finding points to awareness of physical sensitivities resulted from policy decisions relied mostly on regional emission producers. The length of travel is reflecting speed of traffic through overall case simulations (Shah, Nezamuddin & Levin, 2018). It is supported by modelling study of road grade related to vehicle speed, $PM_{2.5}$ emission and dispersion on freeways. 9.5 miles freeway provides impacts on $PM_{2.5}$ dispersions along the road which indicates possible bias from results of the National Ambient Air Quality Standards (NAAQs) ignored different grade of road (Liu, Rodgers & Guensler, 2019). Secondary dust along the street canyon of Krasinski Avenue in the centre of Krakow has been collected from local station to improve Operational Street Pollution Model (OSPM) data since 2019 (Rzeszutek et al, 2019).

Furthermore, from international mega-events in China for examples, the 2008 summer Olympic Games, the 2014 APEC summit, and the G20 summit in 2016, top-down campaign under the name of 'Blue Sky' demonstrated well collaboration between local government enforcement and scientists monitoring air quality over functional region. This could be based – case study for sustainable development in science-policy integration and implementation for air pollution control (Shen & Ahlers, 2019). Then this integrative methodology was promoted again in 2019 because of the returning of air pollution crisis. The conclusion of policy guideline led to integrating technology with the key success of energy, top-down policy initiatives and people engagement (Tilt, 2019). Energy and air pollution crisis suggested to providing feasible and implementable policies, while internet of things (IoTs) is also suggested to share and improve weakness of monitoring, predicting network. The detections of those monitoring were argued to be responded by local contributors in terms of environmental and carbon emission taxes. While, higher value in taxation showed in promoting renewable energy. These aspects of taxation should be applied to modelling policy and policy decision for the future (Wang et al, 2018).

After lunching policies, later situations and feedbacks should be monitored for transforming to more effective policies. For example, due to China's climate change action plans in 2014, there are some aspects needed to be improved in particular urban data, cross disciplinary assessment and policy transformation to develop system mechanism (Ng & Ren, 2018). Another suggestion indicates human behaviour which should be matched to enforcement policies. Theory of Planned Behavior (TPB) was studied the relation to $PM_{2.5}$ controlling policies in China. The study focused on transportation users' behavior to take public transportation and to purchase electronic vehicles in intensive hazardous areas. It was assured that $PM_{2.5}$ intensity was positively affected by attitude, subjective and moral norms, while perceived control affected indirectly intention by subjective norm (Shi, Wang & Zhao, 2017). The development of air pollution control has been mostly exemplified from China because their large industrial developments led them facing widely air pollution before other developing countries.

2.3. Methodology and Implementation

The policy actions related to Internet of things (IoTs) do possibly provide convenient services and facilities, for example, transportations, energy healthcare, education and public safety. This smart transformation can be academically developed in four directions of conducting technological and theoretical studies, integrating implementations and evaluating technologies, focusing current challenges and solutions, expanding existing technological research (Kankanhalli, Charalabidis & Mellouli, 2019).

For the conduction and theory, the comparisons of $PM_{2.5}$ components and emission level were studied from agricultural fuel and coal resources. Biomass fuel provides higher $PM_{2.5}$ level, carbon fraction emission and anionic and cationic chemicals in particular K+, Cl– to atmosphere. The oxidation in charcoal, briquette and wood branches burning can save 775–1,354 kiloton per year, 427–765 kiloton per year and 644–1,155 kiloton per year of $PM_{2.5}$ emission (Sun et al, 2019).

To implement IoTs to local user, they may need to understand and apply all instruction by themselves. One forecast technique from cyberinfrastructure is merged well to international networks in Romania by artificial intelligent algorithms. This adding technical detector can pre-inform people to avoid $PM_{2.5}$ exceeding from their children (Dunea et al, 2017). Also satellite data should be calibrated and validated to the real data collections. Based on Air Quality in Major Incidents (AQinMI) service, Osiris laser light scattering monitors are settled throughout 23 major incident industrial fires for testing accuracies of particulate matter ($PM_{2.5}$ and PM_{10}) collections in different ranges of exposure time (Griffiths et al, 2018).

Moreover, $PM_{2.5}$ level was proved linking to 1.2 million premature deaths (42% higher) during the 10-year satellite observations between 2000 and 2010, while Henan, Anhui and Sichuan in **Figure 1** were monitored to be high population density areas. Then this could be the first rationale to improve air quality in China by relocation of intensive industries. Also government policies should promote emission control technologies in industrial areas (Xie et al, 2016). Then premature mortality in 1 square kilometre was proved to correlate sensing-geostatistical monitoring results of $PM_{2.5}$ concentrations which were possibly parameter to report the trend of air quality in China. For result examples, nearly 20 $\mu g/m^3$ reduction of $PM_{2.5}$ could save approximately 150,000 local people lives and save USD 210 billion in the 5-year period from 2013. From this application test, some second priority locations along with Harbin-Changchun Metropolitan Region, Central Henan City Belt and Yangtze-Huaihe City Belt in **Figure 1** always demonstrate noticed $PM_{2.5}$ exceeding and high rate of mortality over 28,000 people per year (Zou et al, 2019). Premature mortality reduction relied on $PM_{2.5}$ levels has been similar to the Air Pollution Prevention and Control Action Plan in Pearl River Delta region of China in **Figure 1**. The mortality reduction was estimated from four reducing admissions of stroke, ischemic heart disease (IHD), chronic obstructive pulmonary disease and lung cancer which related directly to 13% reduction of ambient $PM_{2.5}$ and could save approximately USD 1300 million between 2013 and 2015 (Lu, 2018). The Action Plan could play important role to reduce $PM_{2.5}$ emissions in top-down authorized country.

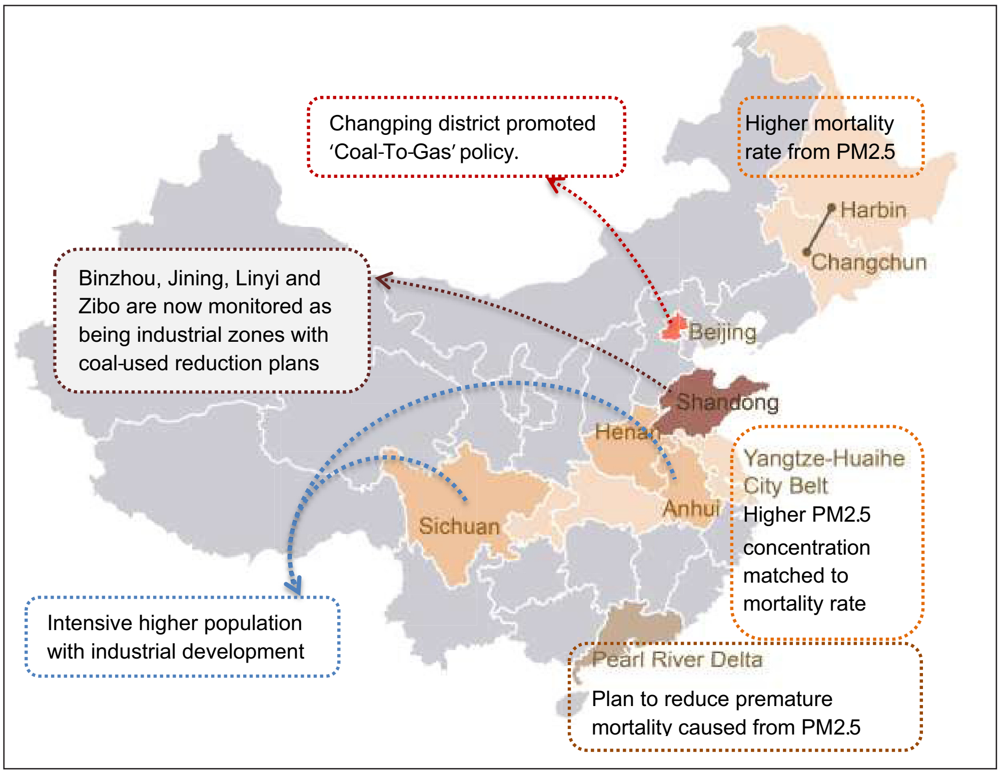

Figure 1: Air pollution controlled zones and solution plans in China.

The challenges and solutions are depended on current pain points. For example, the policy to reduce air nitrogen pollution under the project of Ten Cities, Ten Thousand New Energy Vehicles (NEVs) has been reduced its important action to be optional plan because improvement of modern car could emit less nitrogen level (Tan, Tang & Lin, 2018). What's more, for the purpose of urban mobility, Sustainable Urban Mobility Plans (SUMPs) frameworks were applied among 642 cities in Europe which pointed out first priority to reduce $PM_{2.5}$ and NO_2 emissions. The effectiveness is positive when promoting low-cost measures of energy consumption and greenhouse gas emission. While introducing electro-mobility would increase the impact of air quality (Pisoni et al, 2019). Or even specific challenge subject can be met the requirement of people or standard. One methodology of the National Health Interview Survey, suitable compulsory in European countries, is following the input information of air pollution ($PM_{2.5}$ and NO_2) exposure values and the outcomes are monitored within mortality and hospital admissions rate. These promoting values provide well networking of air quality modelling data within environmental and system diversities (Gandini et al, 2019).

In case of expanding research, it could be a part of policy or large project. For example, at Changping district in Beijing in **Figure 1**, the policy of 'Coal-To-Gas' has been promoted to respond $PM_{2.5}$ situation since 2015 which premature death could be one of criteria. Increase by 40% of premature death needed 1.2 billion CNY affording before those death reduced to 13.3% and 26% in two years later. This is because $PM_{2.5}$ level dropped continually to 2015 (Xi et al, 2019). With regard to air pollution concern, the Long-Range Energy Alternatives Planning System (LEAP) model was used to project total coal consumption in Shandong province in **Figure 1**. Coal substitution and used efficiency are dominant actions from three optional plans which could reduce coal consumption by 37 and 36 million tons respectively. Air quality improvement can decrease only 3.4 million ton of coal consumption. Four industrial areas of Binzhou, Jining, Linyi and Zibo need to be mainly monitored coal consumption (Zhang et al, 2018b). It is more clear and well understanding in this kind of research because it was shaped by the scope of main project.

3. Network

To follow timeline of $PM_{2.5}$ satellite monitor, the first period in 1998–2016 focused on improving higher quality of data resolution. Then during the period of 2015–2017, data collection and processing system were affected to rely on the Chinese "Air Pollution Prevention and Control Action Plan" launched in 2014. After well enforced policy, $PM_{2.5}$ concentrations decreased by 6.5 $\mu g/m^3$ especially in Central, North, Northeast and East China (Bai et al, 2019). On the other hand, in the same period, there was $PM_{2.5}$ satellite monitor development by navigation following the urban Sustainable Development Goal which concerned mainly the effects of long-term pollution exposure on human health and environmental ecosystem (Beloconi et al, 2018) and the accuracy of data (Bhardwaj & Pruthi, 2019). While European countries concentrated firstly a multi-objective problems and solutions from air quality control policies within different motors plan depended on location (Carnevale et al, 2018a).

One of networking improvement is mapping data by adding specific approaches to the main model. For example, after applying a random forests-based geo-statistical approach, the accuracy and effectiveness of dataset increased and supported more real situation by providing brightness and night-time lights data (Liu et al, 2018). Dark target and deep blue (DB_DT) in **Figure 2** in aerosol optical depth (AOD) and Multi-Angle Implementation of Atmospheric Correction (MAIAC) in AOD could develop $PM_{2.5}$ prediction model in Tehran, Iran. Data set of DB_DT model with random forest (RF) is similar to real time monitor of ambient $PM_{2.5}$ (Nabavi, Haimberger & Abbasi, 2018). In developing country, low-cost sensors have been developed for the purpose of air quality monitoring (AQM) network and pollution policy and regulation developments. Only awareness of using low cost development is reliability and creditability of data collection process (Amegah, 2018).

Moreover, the Multi-angle Imaging Spectro Radiometer (MISR) from NASA's satellite is another approach supporting $PM_{2.5}$ data to aerosol optical depth (AOD) approach. This provided more convenient for validation and reliability with allow other special data linking common collected data (Meng et al, 2018a). To observe $PM_{2.5}$ level by real data collections in three different Chinese areas, AOD approach is used to investigate high correlation coefficient between those areas. This means ambient $PM_{2.5}$ level affected other nearly region by suspension exposure (Kong et al, 2016). The comparison of mortalities between short-term and long-term exposure of $PM_{2.5}$ pointed to those $PM_{2.5}$ level in long-term condition provided stronger effects to Beijing people (Liang et al, 2018).

Then, in the period of 2005–2015, US estimation of $PM_{2.5}$ has become error and machine learning approach called spatio-temporal distributions of $PM_{2.5}$ constituents. This approach provided beneficial estimated outcome as assessment of economic cost of exposure, degradation and regional people health (Meng et al, 2018b). This spatio-temporal distribution has been developed in Southwest China within the random–forest sub models. The result shows more complete data set which helps reducing more than 30% of old error (Zhang et al, 2018a). This distribution is suitable for transportation assumption with chemical transport model (CTMs). It was found that population density could affect $PM_{2.5}$ concentration to increase by 2.10 μg/m3/year during 2000–2007 (Xue et al, 2019). Throughout 178 network stations n Yangtze River Delta (YRD) of China, a weight of mobility in clustering algorithm of simulation was suggested to be higher ranking referred to meteorological conditions of local wind speed and direction, geographic distance and $PM_{2.5}$ concentrations (Wang, Wang & Zhang, 2018). From the study of traffic density and smog pollution, traffic registrations and policies should be more restrict in high traffic density city; while household registration and restriction should be more flexible because of insignificant relation to ambient $PM_{2.5}$ concentrations (Xie et al, 2018).

For the purpose of predicting open burning spot in China, the spots are normally higher and expand wider in winter and autumn season in Northeast part from 2014 to 2015. Middle-east parts' spot are high during summer season; however, those are less than spot number in Northeast. The number of crop burning spot correlates significantly to $PM_{2.5}$ situation in each region (Yin et al, 2017). In case of uncertainty context of $PM_{2.5}$ sources, an uncertain Gaussian diffusion model (UGD) should be applied to production-emission system (PES) for mitigating pressure on atmospheric control and managing multiplex data from industries, emission and period context (Zhu et al, 2019). The main purpose of network is sharing techniques and data to complete well policy simulation. To reach highest benefit, main standardised program and platform should be internationally agreed to apply for all users.

4. Economy

Throughout the period of 11-year (2005–2016) data collection, public investment in environmental awareness in low developed country has more beneficial effects

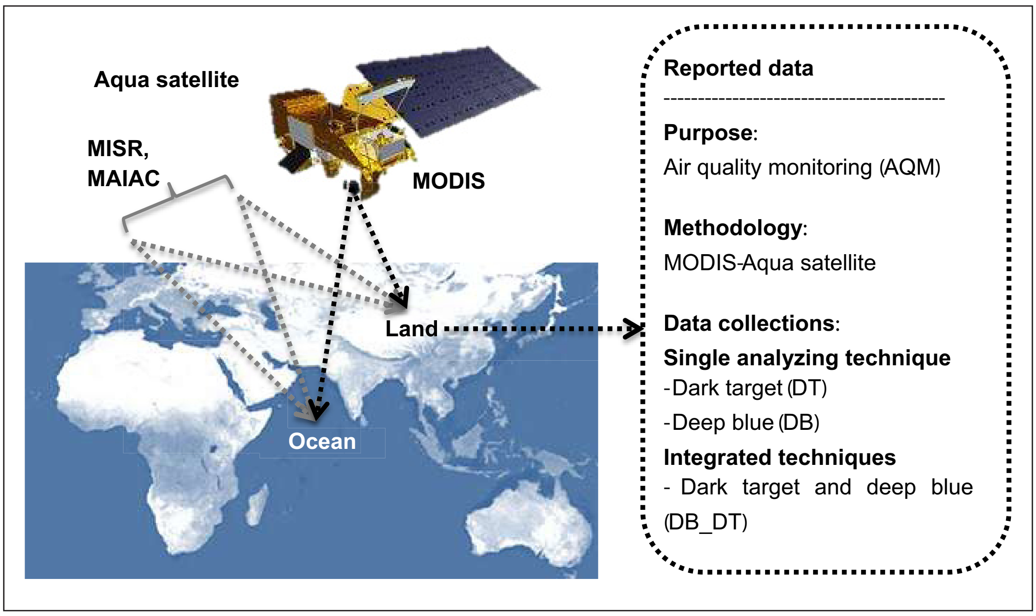

Figure 2: Data collections diagram from MODIS-Aqua satellite.

on the quality and policy related to environment (Chen, Huang & Lin, 2019). By statistical analysis model in the period of 1999–2011, there were 6 socioeconomic factors studied influencing $PM_{2.5}$ concentrations in 12 regions of China. It can be seen that proportion of secondary economic sector influences first priority to $PM_{2.5}$ increase. GDP and other economic calculations are negatively affected from air pollution within specific case. Urbanization can support or obstruct $PM_{2.5}$ reduction depending on regions, weather and local people (Luo et al, 2018). According to promote $PM_{2.5}$ policy to multi-region in China, it is found that main self-generated areas of $PM_{2.5}$ indicate Central, Northwest, Northeast and Southwest China which loss amount of economic benefit and environmental cost (Etchie et al, 2018). Structural equation model (SEM) in 2014 and 2015 indicated industrial area caused mainly to $PM_{2.5}$ pollution level and other supporting socioeconomic factors affected significantly air pollution especially city size, weather condition, outdoor situation of $PM_{2.5}$ and people activities (Jiang et al, 2018). However $PM_{2.5}$ level was negligibly concerned when customers made their decision to buy residences in Shanghai (Lu, 2018).

One commuting policy promoting active mobility was calculated financial cost based on different travels. By bike, users may reduce 3,000–3,800 million kilometer per year and may save institutional communication costs by 48–76 thousand Euro per year compared to travel by urban diesel car. Also this affects directly to 80% reduction of air pollution from gasoline and diesel combustions in Europe (Carnevale et al, 2018b). Between 1991 and 2014, the transformation of biomass energy to commercial energy is significant reduced because of high price and poor mechanic function. To limit residential energy consumption per capita (RECPC), national energy strategy should be included rural energy and improved in facilitating transition process of energy and educating local residents (Han & Wu, 2018).

Within the condition of high population, health impact from $PM_{2.5}$ situation in China could be summarized to consume 0.3% of GDP from $PM_{2.5}$ protection as external cost and the impact could count economic loss from premature deaths equal 80% of overall external cost (Yin, Pizzol & Xu, 2017). In 2005, it was proved that ambient $PM_{2.5}$ reduction in only one unit (microgram per cubic meter) could call up to USD 8.83 billion from all residences in China (Freeman et al, 2019). Form these cost and taxation, it is evident that high society people are willingness to pay for environmental protection, while increasing people income can reduce that willingness. Also people, who live in more polluted cities, have strong willingness to pay for environment (Shao, Tian & Fan, 2018). Last but not least, throughout 9 Japanese cities in the period of 2002–2008, it was found that only 10 $\mu g/m^3$ increase in $PM_{2.5}$ could lead to 0.52% increase in risk of mortality or possibly loss profit at YEN 0.4–1.5 trillion (Seposo et al, 2018). According to $PM_{2.5}$ suffering experiences, people are now willing to participate and pay for air quality improvement.

5. Conclusion and Suggestion

In summary, air pollution has become more severe in industrial developing Asean countries. There are two directions solving $PM_{2.5}$ situations in Thailand which one is technological purifier and another methodology focuses on policy making. This research paper aims to review systematically literatures related to $PM_{2.5}$ controlling plans which can be top-down or bottom-up policy. Top-down plan seems to be suitable for business and governmental organisations which have a few leaders to take action, while bottom-up policy is appropriated for sustainable social interventions. Then burning controls should be considered separately depended on activities such as open burning, mobility or industrial burning. The main purpose of open burning points suitably to better oxidation combustion linked directly to engine combustion too. For traffic and industrial activities, it is suitable to plan their zoning and monitor effectively $PM_{2.5}$ in density zone. Also policy reflection and feedback are important for future transformations. The implementations of policy can divided into 4 states of 1) conducting application and theoretical study, 2) integrating and evaluating implementation, 3) focusing current challenges and solutions and 4) expanding research as shown in **Table 1**.

The network is a part of policy modelling which can be shared tactic and error to more complete simulation. The popular model is aerosol optical depth (AOD) which can be applied variety of algorithm included spatiotemporal approach, specific meteorological data, geographic data and specific existing situation of $PM_{2.5}$. Last concern of economy, big amount of government loss in the past for reducing $PM_{2.5}$ level leads us to improve well policy and social intervention to predict and avoid air pollution and to protect themselves from $PM_{2.5}$ threats. Also suffering people have well known $PM_{2.5}$ situation and they are willing to pay for environmental cost and taxation.

Future suggestions in **Table 1** are based on example policies, deficiency implementation and possible potentials to relief $PM_{2.5}$ situations in Thailand. Firstly, real-time $PM_{2.5}$ situation should be open accessed for well understanding, public discussion and solution findings together. Then optional finding solutions should be supported financial part to implement actual plan or technology to local community. Moreover, to avoid other sources of $PM_{2.5}$, clean energy and eco-friendly mobility should be promoted to Thais. Whereas regional collaborations and agreements are necessary to control emigrated $PM_{2.5}$ from neighborhood agricultural area.

This research is one part of review article of concerning $PM_{2.5}$ situations in Thailand. Optional policies and networking plan can provide firstly basic information to all participating sectors such as governmental, private business, public organization and academic institutes. More basic information related to $PM_{2.5}$ controlling in building scale will be continually offered as the next research series.

Table 1: Summaries of methodology and implementation linked to Thailand's customizations.

Implementation	Descriptions	Outcomes	Thailand	
			Existing policies	**Future suggestions**
Conducting technological and theoretical studies	2.3. Chemical results of burning agricultural fuel, coal resources and biomass fuel.	2.3. Oxidation results can multiple-save $PM_{2.5}$ emission.	1. Control open burning in local agriculture	- Informing people to understand well $PM_{2.5}$ impacts and set up public hearing to discuss seriously and find out agreement together, - Investing brainstorm process to find out optional implements or technological solutions for reducing $PM_{2.5}$
	4. Statistical analysis GDP based on environmental policy	4. $PM_{2.5}$ affected negatively GDP, while urbanization in middle-east china concerned slightly $PM_{2.5}$ situation	N/A	
	4. Health impacts, economic loss and human suffering from $PM_{2.5}$ situation	4. Social interchanges to increase willingness to pay taxation for environmental protection and air quality improvement	1. Closing tempo-rally academic place affected from high $PM_{2.5}$ level	
Integrations and evaluating tech-nologies	2.3. Smart technology and IoTs to forecast $PM_{2.5}$ situation	2.3. Satellite with calibration and validation	1. There were some individual satellite analysis of $PM_{2.5}$ situation, but all analyzers haven't been linked or shared platform together.	Setting up sharing networks for updating meteorological data
	3. Mapping data to satellite collection	3. Traffic density monitor-ing and motor controls		
	3. Increasing accuracy of satellite's analysis	3. Data multi-analysis from DB_DT, MAIAC, MISR		
	3. Meteorological conditions affected to $PM_{2.5}$ levels	3. Sharing data to complete information		
Focusing current challenges and solutions	2.3. Increasing population and industrial zones in China resulted to higher $PM_{2.5}$ level	2.3. Action plans to control industrial $PM_{2.5}$ emissions for saving lives and money	1. Vehicles' motor and traffic controls policy in city center	Focusing to main causes of $PM_{2.5}$ in Thailand and providing action plans to discuss and collaborate to regional countries for agricultural burning controls
	2.3. Challenging to reduce $PM_{2.5}$ and NO_2 emissions by new energy mobility	2.3. Campaign with electronic vehicle can be applied to 642 European countries	N/A	
Expanding exist-ing technological research	2.3. Long-running air quality controls to reduce $PM_{2.5}$ in industrial areas and changing coal to optional oxidations	2.3. Reducing coal burning emissions by 36–37 million tons	1. Open burning control policy in dry and winter seasons	
	4. Transportation transformation by concerning quality of energy resources	4. Promoting electronic car and bicycle to replace diesel and fuel uses	N/A	Providing public alterna-tives for clean energy and eco-mobility

Competing Interests

The author has no competing interests to declare.

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