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Swot analysis of factors causing air pollution and recommended control efforts in the city of Yogyakarta, Indonesia

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Abstract

Background: Knowing the root causes of air pollution in urban areas will determine the next actions to take. Analyzing the impact caused by air pollution will make it easier to determine the control efforts to be carried out. Determining control objectives makes the efforts more targeted. Air pollution can be controlled through abiotic, biotic, and cultural factors.

Methods: Primary data collection was carried out and used secondary data. This study aimed to find the causes of air pollution in urban areas using the strengths, weaknesses, opportunities, and threats analysis method so that it can see what efforts are appropriate to do.

Results: It was revealed that the government's efforts to control air pollution have been carried out continuously and in multi-sectoral ways, but the socialization of the impact of air pollution has not been conveyed to the community continuously and has not been on target.

Conclusion: Noise and dust are still the main problems affecting air quality in urban areas. Another problem is in human behavior as an affected and interested party. The potential for controlling air pollution can be carried out by combining the strengths and opportunities that are owned optimally and multi-sectorally.

Keywords: Air pollution, Dust, Noise, Transportation

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Introduction

Global warming has changed the climate pattern of the planet so that it leads to an increase in the frequency, intensity, duration of extreme weather events, and natural disasters, including changes in air quality (1). Air pollution based on the data released by the World Health Organization (WHO) shows that 99% of the global population breathes air that exceeds the threshold set by the WHO and contains high levels of pollutants. This confirms that no air pollution is safe for humans (2). The effects of air pollution on health indicate the condition that air pollution has become a multisystemic risk, not only limited to the cardiovascular and respiratory systems, and its effects can be recognized even at low doses (3). Ambient air pollution causes health problems, namely stroke, heart disease, lung cancer, acute and chronic respiratory diseases (4) costs trillions of dollars (5), and affects welfare (6). Ambient air pollution accounts for about 3.7 million premature deaths annually worldwide with a significant threat coming from land transportation in urban areas (7,8). The increase in the number of motorized vehicles and uncontrolled energy consumption worsens the air quality in urban areas. The land transportation sector is one of the most important factors causing air pollution that has a very large role compared to other sectors (9-11). The use of public transportation and energy efficiency has the greatest potential to reduce CO_2 and $PM_{2.5}$ emissions (12,13).

The air quality database in terms of exposure to air pollution on land has been recorded and reported by more than 2 000 cities in the world. Monitoring was carried out for PM_{10} and $PM_{2.5}$ parameters (2). Meanwhile, evidence of the relationship between air quality degradation and human health problems is growing rapidly and shows significant damage. This is because particulates with the size of $PM_{2.5}$ can penetrate deep into the lungs and enter the bloodstream, causing cardiovascular, cerebrovascular, and respiratory effects. In addition, the impact of high concentrations of PM_{10} in the atmosphere can interfere with visibility (14). Air pollution has an impact on a person's behavior, ranging from health risks to emotional changes (15). Long-term exposure to O_3 affects the occurrence

of cardiovascular disease in China (16). Exposure to air pollution and transportation noise increases the risk of arterial inflammation and cardiovascular disease (17). The high absence rate of workers is also estimated to be part of the impact of air pollution that occurs in the worker's environment, related to the mental and mental health of workers (18). Meanwhile, another study showed that about one-fifth of the global burden of type II diabetes was caused by the exposure to $PM_{2.5}$ in Asian, African, and South American countries (19). The potential for death due to inhalation of $PM_{2.5}$ pollutants is 7 million per year (2). Air pollution caused 160 000 deaths by 2020 in the world's five largest cities (2).

The condition of air quality in the city of Yogyakarta is known based on the results of monitoring carried out twice a year in settlements and roads. The value of the PM_{10} parameter is in the medium category, and the value of roadside noise at all sampling locations has exceeded the quality standard (20). The next period shows that the noise measurement results at 80% of the sampling points have qualifications exceeding the specified threshold (21). According to the results of the Driver, Pressure, State, Impact, and Response (DPSIR) analysis in Yogyakarta city, the noise level has exceeded the threshold in 19 locations out of 20 locations whose noise levels were measured (22). In 2021, the noise level at the sampling location is almost close to the quality standard and as much as 65% has exceeded the noise quality standard (23). The SWOT (strengths, weaknesses, opportunities, and threats) analysis is a method that identifies strengths, weaknesses, opportunities, and threats in a condition. In carrying out identification, skills and creativity are needed to compile the results of the SWOT analysis. The SWOT approach limits strategy creation to the interests of strategy alignment and implementation (24). Based on the description of the background that has been submitted, the present study aimed to determine the main factors causing ambient air pollution in urban areas and strategies that can be taken to control air pollution in urban areas.

Materials and Methods

Research design

This is a qualitative research. Researchers made observations and analyses descriptively based on the results of observations and in-depth interviews. Through this research, conditions in the field were observed in a more specific, transparent, and in-depth manner. The results were then formulated in four types of strategies, namely a combination of strengths and opportunities, weaknesses and opportunities, strengths and threats, and weaknesses and threats.

Population and sample research

The population in this study is the entire ambient airspace in Yogyakarta based on the regional administrative boundaries. The sample in this study was taken randomly.

Materials and research tools

The tools and materials used in primary data collection are a list of questions, while secondary data collection is questionnaires, reports, manuscripts of previous research results, and other data sources that are publicly released on websites or stored as archives of an institution or institution.

Collection/research stages

The steps for carrying out a SWOT analysis include determining the purpose of the SWOT analysis, field observations, making a list of strengths, making a list of weaknesses, making a list of opportunities, making a list of threats, and setting priorities from the results of the SWOT analysis. Primary data collection was carried out by in-depth interviews with sources related to the material. While secondary data collection was carried out using questionnaires and reports from institutions or institutions, journals, and research results that have been carried out as references and can be accounted for.

Data analysis

The analysis method uses SWOT analysis, which identifies four aspects, namely strengths, weaknesses, opportunities, and threats. Furthermore, an analysis was carried out to determine strategy formulation, alternative strategy choices, alternative strategy priorities, and the best strategies that can be selected and applied.

Results

The city of Yogyakarta has an area of 32.5 km^2 or 1.02% of the entire territory of the DI Yogyakarta Province. It has a length of 233.21 km of roads. The condition of roads that are categorized as good is 95 km or 40.83% of the entire length of existing roads (25). The population of Yogyakarta city has fluctuated from 2016 to 2020. The highest population density is 11 495 people/km^2. The highest population occurred in 2019. The increase in population is positively correlated with an increase in the number of vehicles to support the mobility of all activities to be more effective and efficient. The number of motorized vehicles in the city of Yogyakarta has increased every year (25), as shown in Table 1.

The development of the number of motorized vehicles in Indonesia from 1950 to 2017 experienced a growth of more than 10% per year. The most dominant number of motorized vehicles is motorcycles, which is 80% of the total operating motorized vehicles. This datum does not represent the real condition of the number of motorized vehicles that take to the streets, because the database used is a vehicle ownership registration sign for tax matters. Conditions in the city of Yogyakarta are also not

Table 1. Distribution of the population and the development of the number of vehicles in the city of Yogyakarta in 2015-2021

Transportation type	Year[a]						
	2015	2016	2017	2018	2019	2020	2021
Passenger car	48.439	50.562	54.346	60.780	66.489	67.078	68.511
Bus	1.094	1.056	1.147	1.230	2.561	2.566	2.544
Freight cars	10.011	10.266	10.623	11.226	2.561	2.566	2.544
Special vehicles	183	656	701	768	161	162	160
Motorcycle	293.843	303.403	309.373	341.986	459.579	465.949	476.212
Total population -Year[b]							
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total population	*	411.282	412.692	412.726	416.049	414.718	415.509

* Description: No data.
Source: [a] Report: Analysis of air monitoring results in 2017, 2018, 2019, 2020, and 2021.
[b] Central Bureau of statistics province of the special region of Yogyakarta, 2021.

much different; the percentage increase in the number of passenger cars over the past five years is 32% while motorcycles are 55.1% (26). An increase in the number of motorized vehicles also increases the number of emissions released into the ambient air. Air quality monitoring in the city of Yogyakarta is carried out manually and automatically. One of the parameters measured is PM_{10}, which is known to be the highest emission load in the Sudirman street, Malioboro street, and Mangkubumi street areas. This condition shows the influence of and relationship between the number of vehicles and the increase in the number of pollutants in the ambient air (26). Motorized vehicles that enter the city of Yogyakarta on weekdays are dominated by vehicles for workers and school students, while on weekends or holiday seasons they are dominated by tourist vehicles (23). Air quality monitoring in Yogyakarta city is carried out using active and passive methods. The air quality monitoring system (AQMS) is an air quality monitoring tool that operates for 24 hours with the monitored parameters being gaseous and particulate pollutants. Monitored data updated every 1 hour (23).

To control air pollution in the city of Yogyakarta, a comprehensive review is needed to investigate the resources that are owned and the possibility of their development while taking into account the pros and cons that might occur (27). The SWOT analysis is often used to propose a better version of decision-making, this is to reduce the arbitrariness of decision-making (28). The results of the SWOT analysis are obtained from the multiplication between the score and the value weight. The results of the SWOT analysis to identify four aspects namely strengths, weaknesses, opportunities, and threats of ambient air conditions in Yogyakarta city are shown in Table 2.

Next, identification of external factors has been carried out as an effort to control air pollution in the city of Yogyakarta which is described in Table 3.

The next process is an overview of the SWOT matrix formulation in Table 4.

According to the calculation of the SWOT analysis, the highest score is obtained from the combination of the Strength-Opportunities strategy with a value of 5.7 that is in Quadrant 1. This condition means that the government as the person in charge in the field has the opportunity and strength to take strategies that support policies that lead to aggressive growth by taking advantages of various existing opportunities and internal strengths. Based on the value of the SWOT analysis matrix, then, the normalization process is carried out. The purpose of normalization is to get a value of 1 in the total weight. The normalization process is used by dividing each number in the strategy divided by the total strategy (30), and shown in Table 5.

The results of the survey conducted with the general public targeting respondents living in the city of Yogyakarta, some information is known, namely:

1. As many as 68% of respondents are not aware of any regulations related to air pollution control in Yogyakarta city.
2. As many as 76% of respondents do not know about the existence of air quality monitoring in the city of Yogyakarta.
3. As many as 92% of respondents know the impact caused by air pollution.
4. As many as 68% of respondents did not know about the air quality monitoring carried out in the city of Yogyakarta.
5. As many as 76% of respondents know the benefits of air quality monitoring that has been carried out.
6. As many as 84% of respondents stated that they had experienced disturbances due to poor air quality.
7. As many as 57% of respondents have experienced health problems due to poor air quality and as many as 76.2% of respondents stated that they have experienced discomfort due to poor air quality.
8. A total of 92.5% of respondents stated that they often experience disturbances due to poor air quality during the dry season.

Table 2. Identification of the internal factors of air pollution control strategies in the city of Yogyakarta

No.	Strength	Score	Value weight	Total (score × value weight)
1	**2**	**3**	**4**	**5**
1.	Abiotic			
a.	Manual and automatic air quality monitoring. Manual with residential and roadside targets, automatically using AQMS whose results can be monitored for 24 hours (26).	0.05	3	0.15
2.	Biotic			
a.	Data about the ISPU condition from DLH have been linked to the transportation service website, so it can also be monitored on the website.	0.05	3	0.15
3.	Culture			
a.	The city of Yogyakarta as a student city, the center of economic activity, the center of government, and a city of cultural tourism, attracts various components of society to come and visit (23).	0.25	5	1.25
b.	Having an integrated parking location as a parking bag reduces the number of illegal parking which causes one of the factors causing congestion. The condition of parking facilities and infrastructure is fulfilled by 92.44%.	0.15	4	0.6
c.	The Yogyakarta city Transportation Service has a monitoring camera to monitor traffic conditions in the city of Yogyakarta. This CCTV is located at a strategic point (29).	0.05	3	0.15
d.	Traffic smoothness and safety increased with the 2021 level of service indicator reaching 0.53. The percentage of public transportation and roadworthy goods reached 84.24% (29).	0.05	3	0.15
e.	The Department of Transportation has conducted emission tests. Emission testing is one of the services provided by the Yogyakarta city Government through the Technical Implementation Unit for Motor Vehicle Testing at the Yogyakarta city Transportation Service. If the vehicle meets the exhaust gas emission quality standard by the provisions of the Regulation of the Minister of the Environment No. 05 of 2006 concerning Exhaust Emission Threshold for Old Motorized Vehicles, the applicant will receive an Emission Test Result Letter and a Sticker.	0.05	3	0.15
f.	Activities that have been carried out by the Department of Transportation include vehicle emission testing, traffic safety socialization, APILL repair, VMS repair, APILL maintenance, and traffic monitoring through ATCS.	0.1	4	0.4
Sub-total		**0.75**		**3**
No.	**Weakness**	**Score**	**Value Weight**	**Total (score × value weight)**
1	**2**	**3**	**4**	**5**
1.	Abiotic			
a.	Measurement of dust and noise has been done manually and automatically. Manually started being done in 2018 until now. The measurement results are conveyed to stakeholders and other interested parties, but the follow-up of the monitoring results has not been maximized.	0.05	4	0.2
2.	Biotic			
a.	Data on the impact or consequences of air pollution on various health problems have not become a major issue in handling health problems in the city of Yogyakarta. Health promotion activities that are carried out are more about material about health and its impact on indoor pollution	0.075	4	0.3
3.	Culture			
a.	Noise measurements in 2018 were 100% of the measurement point locations exceeding the NAV. In 2019, 50% of the measurement point locations exceeded the NAV. In 2020, according to the DPSIR analysis, the noise level exceeded the threshold. In 2021, 66.5% of the locations measured also have noise levels exceeding the quality standard.	0.05	3	0.15
b.	The effectiveness of the socialization that has been carried out has not been measured properly, the public still does not understand much about air pollution, its impacts, and other related matters. There needs to be more detailed socialization with appropriate targets.	0.075	4	0.3
Sub-total		**0.25**		**0.95**
Final score		**1**		**3.95**

CCTV, Closed-Circuit Television; APILL, Traffic Signaling Device; VMS, Virtual Message Sign; ATCS, Area Traffic Control System; DPSIR, Driving Force-Pressure-State-Impact-Respon; NAV, Threshold value : quality stnadard

Table 3. Identification of external factors for air pollution control strategies in Yogyakarta city

No.	Opportunities	Score	Value weight	Total (score x value weight)
1	**2**	**3**	**4**	**5**
1.	Abiotic			
a.	Technology development and research through assessment of dominant pollutant sources and periodic monitoring by conducting motor vehicle emission tests. The purpose of the activity is to evaluate urban air quality and find out basic data regarding the number and percentage of vehicle eligibility used by the community.	0.20	4	0.80
2.	Biotic			
a.	Green Open Space Development: Gajah Wong park and gunungketur as an effort to develop the environment and increase the area of green open space in the city of Yogyakarta (23).	0.15	3	0.45
b.	Periodic monitoring uses the AQMS and performs direct measurements in the field according to the parameters required at each location. The data are time series and stored in a complete database as a basis for setting policies to make them more targeted.	0.15	3	0.45
3.	Culture			
a.	Local government regulations that support the prevention of air pollution and efforts to reduce various potential air pollution in the environment.	0.20	4	0.80
b.	Increasing the number of public transportation by improving the quality to maintain passenger comfort and expand the range of services. This effort is made to reduce the number of private vehicle used in a short and affordable distance (23).	0.05	4	0.2
Sub-total		**0.75**		**2.7**
No.	**Threats**	**Score**	**Value Weight**	**Total (Score x Value Weight)**
1	**2**	**3**	**4**	**5**
1.	Abiotic			
a.	Diversification of land use results in changes in the use of vacant and undeveloped land into residences (64%) and places of business (19.97%) thereby reducing the total area of Green Open Space.	0.04	4	0.16
b.	Parameters for dust content have not been carried out for 24 hours, but have shown "moderate" conditions.	0.05	4	0.2
c.	Data regarding the impact or consequences of air pollution on various health disorders has not become a major issue in handling health problems in the city of Yogyakarta.	0.05	4	0.2
2.	Biotic			
a.	The increase in population has implications for the increasing number of motorized vehicles. This condition also has an impact on increasing the amount of fuel consumption and the number of emissions produced.	0.05	4	0.2
b.	People began to feel the disturbance of comfort from the environment in the form of noise. Health problems are also felt, allegedly due to increased levels of dust, especially during the dry season.	0.05	4	0.2
3.	Culture			
a	The pressure that comes from the environment with an increase in the number of hotels, restaurants, and shopping centers that pay less attention to environmental aspects.	0.01	3	0.03
Sub-total		**0.25**		**0.99**
Final score		**1**		**3.69**

AQMS, air quality monitoring system.

Table 4. Formulation of the SWOT Matrix strategy combination

	Strength	Weakness
Opportunities	Strategy S-O 3 + 2.7 = 5.7	StrategyW-O 0.95 + 2.7 = 3.65
Threats	Strategy S-T 3 + 0.99 = 3.99	Strategy W-T 0.95 + 0.99 = 1.94

Table 5. Normalization results

	Strength	Weakness
Opportunities	Strategy S-O ⟶ 5.7/15.8 = 0.37 ⟶ 37%	Strategy W-O ⟶ 3.65/15.8 = 0.23 ⟶ 24%
Threats	Strategy S-T ⟶ 3.99/15.8 = 0.25 ⟶ 26%	Strategy W-T ⟶ 1.94/15.8 = 0.12 ⟶ 13%

Discussion

SWOT strategy priority setting can be used to develop policy hierarchies that will help decision-makers to take the right policy steps (31). An integrated approach can be used to evaluate actions that have been taken and holistically able to investigate existing weaknesses so that priority activities can be selected for air pollution control in the future (32). Optimizing the strengths and opportunities possessed is expected to be one of the efforts to control air pollution that occurs in the city of Yogyakarta. Collaboration from multi-sectors by looking at the abiotic, biotic, and cultural perspectives is expected to continue to be pursued for synergies by the objectives to be achieved. The city of Yogyakarta already has various

rules, policies, and activities for air pollution control issues, but the results are not significant.

Air pollution control is urgently needed in developing countries (16). Air pollution mitigation has an important role in reducing the global burden of disease caused by poor air quality (19) Air pollution control guidelines that have been updated by the WHO are estimated to reduce 80% of $PM_{2.5}$-related deaths if WHO rules are adhered to by all countries (2). Efforts to monitor air quality, adjust energy structures, and reduce pollutant emissions from the industrial, transport, and household sectors can reduce pollutants, thereby improving air quality and avoiding premature deaths associated with exposure to air pollution (32). Socialization in the form of promotive and preventive is important to do in the community. The target and level of information delivery are also adjusted to the material to be delivered. Cooperation between the government and the community needs to be carried out more intensively, this is because without cooperation any program implemented to improve air quality in the environment will not be successful. The people's desire to get good air quality must be balanced with the government providing supporting infrastructure to support its success (33).

Conclusion

Based on the results of the analysis, the efforts made can increase the strengths, improve weaknesses, maintain and take advantage of existing opportunities, and avoid potential threats. Handling air pollution control cannot be done only on one aspect of the review, but requires collaboration and concrete actions from various components. Interventions without improving behavior and increasing the understanding of various stakeholders will be actions that are less than optimal in results. The problem of noise and dust is still a problem that affects the air quality in the city of Yogyakarta. The problem lies in the environment, and also, human behavior as parties who have an interest in it. The city of Yogyakarta has a potential strategy to be able to control air pollution in its environment, by combining its strengths and opportunities in a more optimal and multi-sectoral manner

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Authors' contribution

Conceptualization: Naris Dyah Prasetyawati.
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Funding acquisition: Naris Dyah Prasetyawati.
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Supervision: Suranto Tjiptowibisono, Pranoto Pranoto, Sunarto Sunarto.
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Competing interests

The authors declare that they have no competing interests.

Ethical issues

The authors state that some of the data collected during the research are presented in this manuscript, and several parts have been and will be published elsewhere separately, each with its own perspective and discussion. The data are mutually supportive.

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