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The effects of particulate matter on perceived stress / depression and understanding of stress inequality in Seoul, South Korea

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Summary

Described as “the single greatest environmental health risk”, air pollution shortens our life expectancy by 20 months. Among the air pollutants, nothing is more harmful to our body than fine dust.

However, this is not enough to reveal all of the fine dust (PM). A survey of Statistics Korea in 2018 displayed that the rate of the Koreans complaining ‘stress’ caused by PM constituted 82.5%, as a result of a steady increase from 77.9% in 2014. According to a public survey conducted by a media in 2019, 8 out of 10 respondents in their 20s and 30s exhibited that they have ever desired to emigrate due to fine dust.

In light of this physical and emotional gravity of fine dust, this study sought to explain the effects of fine dust on the formation of negative affectivity such as stress and depression of Seoulites from 2015 to 2018. It also entails the other assumptions that fine dust could play a role in generating a more vulnerable class to negative affectivity (called ‘stress inequality’ in this study) and incurring additional social costs.

In order that the research questions can be answered, both of a secondary quantitative and a primary qualitative analysis were utilized.

Stated briefly as to findings, $PM_{2.5}$ and PM_{10} increase stress and depression et al. of Seoullites during the given period. The index of stress rose by 0.0044 points for each 1 $\mu g/m^3$ increase of $PM_{2.5}$ and depression et al. increased by 0.006 points. Whereas PM_{10} did not exhibit a causal relationship with stress within the significance level, it augmented depression et al. by 0.005 points. $PM_{2.5}$ was more influential on negative affectivity than PM_{10}. In greater detail, stress was more eased in line with the increase of one unit of age - local tax - happiness with financial status - medical cost. In contrast, it was increased by order (of beta): crime rate - $PM_{2.5}$ - traffic accident rate.

Stress inequality is more related to labour conditions than to economic or education levels. Of extraordinary note is that there is a larger increase in stress caused by $PM_{2.5}$ in a group which is not active in social participation such as voting than in the other group.

Fine dust is undermining social trust, too. As the concentration level of $PM_{2.5}$ increased, trust in the public sector decreased by 0.012 points. Among the experts on fine dust, over 9 out of 10 respondents (91.7%) agreed that negative affect led by fine dust can have repercussions on the whole Korean society.

It implies that fine dust impairs not only the physical, psychological health of individuals but also the health of society.

These findings suggest that it is time for the government to take serious consideration of the necessity to move toward a comprehensive policy including an approach to individual stress matters exacerbated by fine dust, beyond focusing on direct measures to reduce PM.

Keywords

Stress, Depression, Fine dust, Particulate matter, Stress inequality, Social cohesion, Seoul

Acknowledgements

1. I had been interested in the Netherlands for years. Personally speaking, Korea has looked a less happy society much competing, conflicting with each other. Why aren't we happier? How come couldn't we be more harmonious except in the World Cup?

It seemed to be due mainly to the structure of labour and education in Korea. So, I thought the Dutch polder model might give a clue on my pessimism.

2. Journalism is in crisis all over the world. Even truth is sometimes disregarded. As a journalist, I come up with that 'micro-journalism' must be strengthened to tackle this crisis. It is because the crisis of media in the 21st century has been partially brought about by old conventional journalism focusing only on the organization and classes of power that already has their voices. I call it 'macro journalism' relying on an agenda of the nation, central government, central congress, the haves, and so on. Micro journalism penetrates deeply into a city, community, the invisible, so that discovers tomorrow’s common sense.

3. For those reasons, I selected the Netherlands first and then decided to study urbanology of IHS at Erasmus University Rotterdam, after winning such a precious opportunity of one year’s leave from my company.

4. I felt unsatisfied and sometimes ashamed that I could not become or behave as what I have been, due mainly to language but I am approaching the finish line of a race thanks to colleagues. It will take time to verify if I attain my goals, but a clear lesson confirmed again is that we are born not to be unhappy and this axiom should be wholly dedicated to by academia and journalism.

5. I will bear a few names in my mind: Alberto Gianoli, Somesh Sharma, Oliver Lah, Veronica Olivotto, Sharon Welsh, Ore Fika, and the young colleagues of F building having shared the windy Dutch nights. And I appreciate her and my family.

Abbreviations

AQG	Air Quality Guideline
CO	Carbon monoxide
EU	European Union
IHS	Institute for Housing and Urban Development
KOSTAT	Statistics Korea
NGO	Non-Governmental Organisation
NO_2	Nitrogen Dioxide
O_3	Ground-level Ozone
OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matter ($PM_{2.5}$, PM_{10})
QOL	The Quality of Life
QOUL	The Quality of Urban life
SO_2	Sulfur dioxide
SOGA	The State of Global Air
SPSS	Statistical Package for Social Sciences
WHO	World Health Organization

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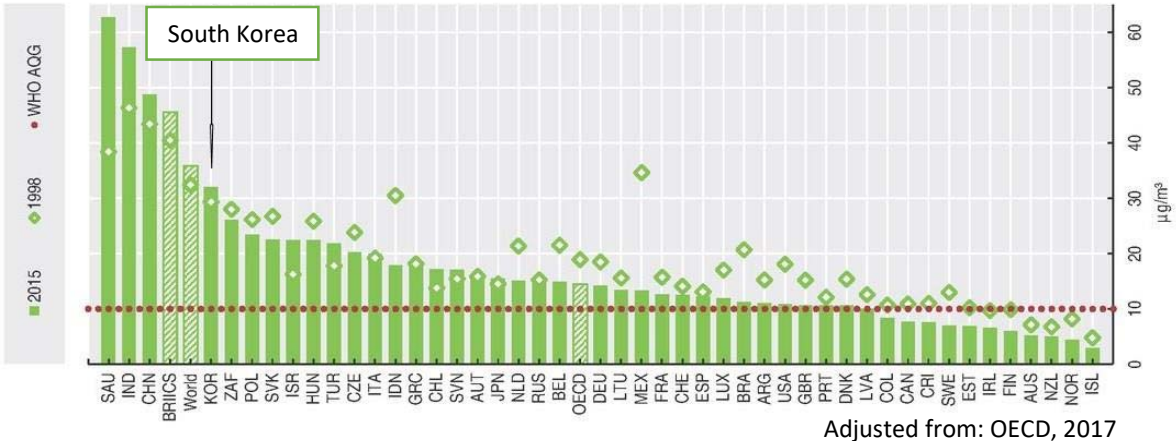
Chapter 1: Introduction

1.1_Background

In April 2019, the State of Global Air released a report that our life expectancy will be shortened by air pollution by 20 months on the global average (as a result of 2016 data analysis). SOGA's report says that the reduced life expectancy in South Asia due to air pollution is 30 months and one in East Asia is 23 months. This is pronouncedly compared to the group of the developed nations, which is estimated less than 5 months (Health Effects Institute, 2019).

The air quality of South Korea is the worst among the OECD members (OECD, 2017) as depicted in **Figure 1**. The yearly concentration average of $PM_{2.5}$ was 28 $\mu g/m^3$, while the average of the OECD groups recorded 14 $\mu g/m^3$. PM is considered the most harmful air pollutants[1] (WHO, 2019, OECD, 2017).

Figure 1. Population exposure to outdoor $PM_{2.5}$



Adjusted from: OECD, 2017

According to a survey conducted by a government-funded research institution in 2017, South Koreans pointed out air pollution (mainly particulate matter) as the most distressing factor in their lives (Jung, Kim et al., 2017). It means the public surveyed felt more anxious by fine dust than all the other given 20 kinds of risks including North Korea's nuclear armament threat[2].

In 2018, Han, Lim et al. came up with the analysis that the number of premature deaths in South Korea caused by $PM_{2.5}$ was up to 11,924 as of the year of 2015, close to 1000 deaths per month.

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[1] Fine dust or PM refers to $PM_{2.5}$ (smaller than 2.5 ㎛ in diameter) and PM_{10} (smaller than 10 ㎛ in diameter). They can penetrate deep into the respiratory system and $PM_{2.5}$ is more harmful because of the smaller size, which width is approximately 30 times less than that of a human hair.

[2] The survey had been conducted at the time when military tension between North Korea and the USA was reaching a crescendo in 2017.

And in the first half of 2019, PM had become one of the most contentious protagonists in the stage of Korean Society. It is because the level of $PM_{2.5}$ concentration had recorded 150 $\mu g/m^3$ (average) per hour, which was the highest one since official observation and PM concentration above 'unhealthy level' (over 35 $\mu g/m^3$, a daily average) had continued for 23 days in Seoul between January and March, which is also the longest record ever. It was when fine dust was in the public gaze as overwhelming anything else.

1.2_Problem statement

According to a public survey (1000 samples, nationwide) conducted by a weekly news magazine in late March 2019[3], 9 out of 10 respondents from the age group in their 20s and 30s presented they have been experiencing difficulty in everyday life due to fine dust, and 8 out of 10 respondents in the same age group said they have ever desired to emigrate. And the survey showed half of all the respondents criticized the government not for taking active policy against fine dust.

In a social survey conducted by Statistics Korea in late 2018, citizens cited crimes (20.6%), national security (18.6%), and environmental pollution (13.5%) as the most worrying societal factor. This is compared to the survey in 2016 that environmental pollution accounted for only 5.8%. Among environmental issues, it was demonstrated that 82.5% of the respondents felt distressed with PM, risen from 79.3% in 2016, 77.9% in 2014 at the national level. And the rate of citizens who think 'the environment has got worse than five years ago' was 36.4% as a result of a rise from 29.7% in the survey of 2016.

In fact, the average of PM concentration in South Korea is not increasing (even though it is not declining.) Nevertheless, the number of those who complain of stress, depression, or anxiety by fine dust seems to be increasing, as observed in the aforementioned and other public surveys. Few studies are offering elaborate explanation or reason concerning this phenomenon of a discrepancy between the perception and the actual PM level.

One of the reasons that it should be explained is that if an individual get stressed more than the level of stressors, and if a few specific groups suffer more from negative affectivity caused by PM, it may be an element of not only threats to individual (mental) health but also of inequality that interferes with social cohesion (Becchetti, Massari et al., 2013, Berger-Schmitt, 2001).

When considering that risk perceptions to the environment like air pollution or climate change are affected by psychological and socio-cultural factors (Leiserowitz, 2006, Bickerstaff, 2004), several assumptions seem to be possible for why citizens look more stressful by PM.

First, media coverage and social attention have increased as the phenomenon of high concentration has become intensified in recent years, even though the annual average of PM concentration is similar since 2012. In reality, the number of articles covering PM issues has increased 4.5 times since 2013 (Kim, 2017) and there was a flood of news regarding the record renewal of PM concentration level in March 2019 as mentioned above. Second, research on PM has been varied and deepened, even revealing and disseminating new health effects triggered by the exposure of low and medium PM level and hence perception of the public can be affected. Third, citizens may have become more sensitively aware of environmental risks threatening the quality of life because of a growing perception of the right to live happily and securely. Lastly, it may be because that distrust on the public sector in charge of dealing with the matter of PM is deepening. Bickerstaff (2004, p. 835) explained individual perception on

[3] https://www.sisapress.com/news/articleView.html?idxno=183004

environmental risk is vehemently affected by concerns about trust on responsible institutions as saying “the meanings people attached to environmental risk were not shaped solely by the distribution of pollution (technical risk) but largely by the distribution of socio-political or economic opportunities to act in an efficacious manner (social risk)”.

Namely depending on the socio-cultural or political-economic factors, Seoul citizens can be generally more susceptible to negative affectivity (such as stress, depression, pessimism, anxiety) caused by PM than people in other cities or countries even under a similar level. Some classes or groups may be more (or less) vulnerable to fine dust even though they are dwelling in the same city. If it is true, why and how could it be so, and what should the government and society, and individual do to respond?

However, most of the studies on fine dust have been engrossed on virtually practical and direct effects analysis, such as an environmental scientific approach to identify measurement methods or pollutants characteristics, a medical approach to explore health effects, and an economic study to estimate damages. Most of the understanding of fine dust impact on perception so far has depended primarily on the findings of the physiological, pathological mechanism by observational, clinical, experimental, epidemiological studies in medical science (Gładka, Rymaszewska et al., 2018).

Therefore, there is a necessity to verify that PM has an effect on the formation of negative affectivity and to measure the extent from a perspective of urban sociology for a sustainable city. It is also required to analyze the characters of classes that are more susceptible to negative affect caused by PM and to understand the impact of these characteristics on a society.

1.3_Research objectives

This research aims not only to verify but also to quantify the effects of fine dust on individual levels of perceived stress or depression in Seoul between the year of 2015 and 2018. Why it places focus on PM is that PM is considered the most dangerous and fatal air pollutant (WHO, 2018) and hence it has been imprinted on most of the Koreans as a culprit of air pollution.

Accordingly, this research will develop a framework to analyze if PM becomes an important factor which amplifies negative affectivity and gives respectively different impacts up to citizens having different backgrounds or assets. The consequence of discriminatory impacts of PM can be rephrased by ‘the effect of stress inequality on a city’, akin to ‘happiness inequality.’

In this respect, of special additional importance is that negative affectivity formed by PM is vehemently related to socio-political aspects; for instance, trust on the public sector affects negative perception (Bickerstaff, 2004) or personal depression becomes a significant factor which undermines social cohesion (Acket, Borsenberger et al., 2011, Helliwell, Layard et al., 2019). In other words, it can be translated into that it is difficult to guarantee the urban quality of life and to enhance social cohesion without proper response or solutions to fine dust.

Stiglitz (2002) argues (economically) sustainable development is more assured by civic participation, which is one of the pivotal elements of social cohesion. This research will examine incidentally the possibility that the social cohesion and nationwide response to fine dust can become a new momentum for sustainable growth finally (Campbell, 1996, Stiglitz, 2002, Gowdy, 2005, Glaeser, 2011, OECD, 2012).

1.4_Provisional research questions

The research questions are the following, based on three assumptions:

1) ***To what extent is perceived stress or depression affected by PM and how is negative affectivity expressed? Is PM more 'significant' than such other predictors as income, job, regional crime rate, and the others for example?***

- Assumption: PM has an effect on the formation of negative emotion of Seoul citizens, such as stress, depression, and so on.

2) ***What are the characteristics of more vulnerable groups to stress or depression caused by PM, in terms of age, gender, marital status, education, income, job, health, and so on?***

- Assumption: There are specific groups who are more susceptible to negative affect even given the same PM concentration level. This is considered symptoms of the so-called 'stress inequality'.

3) ***Why and how is stress inequality meaningful to society?***

- Assumption: Stress, in particular, 'stress inequality', impedes social cohesion and sustainability.

To answer these questions, the study will also focus on statistical analysis to quantify the following basic questions.

When the PM concentration increases by one unit;

1) **How much does self-reported stress increase or decrease, compared to other variables?**

2) **How much does self-reported depression (or other negative emotions) increase or decrease?**

3) **How much do social participation or perceived social cohesion increases or decreases?**

1.5_Significance of this study

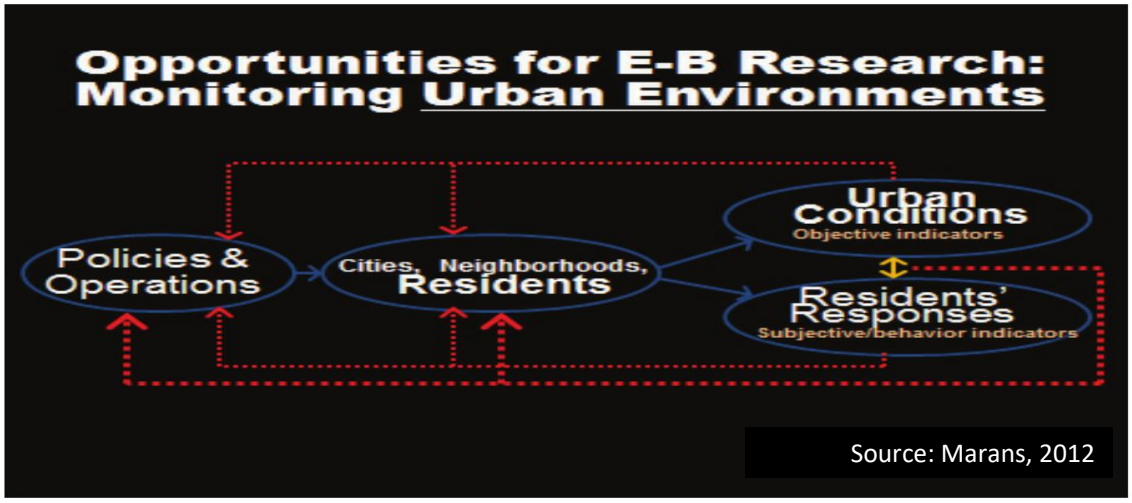
The quality of the urban environment (setting) does not allow to be captured by one single measure and "quality is a subjective phenomenon reflecting the life experiences of the occupants" and "the objective conditions of the setting themselves do not convey the true quality of the setting" (Marans, 2012, p.14)

Several studies have attempted to generalize the relationship between urban environmental factors and subjective perception of citizens. For example, perceived happiness score was utilized to value airport noise which is considered an example of 'environmental bads' (Bernard and Babara, 2005), and was used to evaluate how much people would willingly pay to decrease fine dust (Levinson, 2012, Zhang, Zhang et al., 2017, Kim and Jin, 2017) These are called the Happiness approach in assessing the value or utility of environmental goods or environmental bads. The study of happiness has analyzed the relationship between self-reported happiness and the factors for life by interpreting the essential variables that would affect happiness, basically including income (Frey and Stutzer, 2002, Di Tella and MacCulloch, 2006, Oswald, 1997).

This coincides with the trend that subjective values, such as happiness, quality of life, and life satisfaction, have become the policy goals in various advanced urban or national governments for recent decades. The more urbanized the world becomes, the more important it gets to examine and understand the relationship between the urban geographic environmental characteristics and the residents' perception of their quality of life (Wandersman and Nation, 1998, Marans, 2012).

In this context, a happiness approach can contribute to policymaking for better urban life by capturing urban phenomena that have not been easily revealed by the study focusing mainly on objective conditions (Marans, 2012, Oswald, 1997).

Figure 2. Significance of the studies on subjective perception[4]



This research will borrow the so-called happiness approach in terms of a conceptual framework and hence is likely to inherit part of the significance of happiness research.

In other words, this study can give insight to policy making for better urban life in opposite but similar way with a happiness approach, in the sense that it aims to capture urban geographical environmental characteristics affecting negative perception (such as stress, depression, worries, and anger), contrary to effects on positive perception (including happiness or satisfaction).

Moreover, the findings of for example 'stress approach' may convey a more straightforward message to policymakers and citizens (who have the right to know) rather than a happiness study. This is because the right not to be unhappy has to take precedence over the right to be happy as policy goals.

Nevertheless, of note is that little attempt to assess the value of environmental goods using 'negative affect' data is found in the existing studies based on the perspective of urban sociology.

There have been numerous studies on the effects of PM, but the bulk of them seem to have been engrossed in exploring medical health impacts so that it is not enough to fully explain social pathological characteristics of the Koreans who have reported that they get stressed, depressed, worried, anxious or that they desire to emigrate due to PM. Nor does it explain whether this phenomenon is related to citizens' trust in society or the public sector. This study aims to explain those points by an expanded model employing on happiness approach.

Provided that the framework of this research is robust and a finding of this research is statistically significant, the model can be applied to compare the impact of PM on negative affect on the regional, national, or international basis or to evaluate more various environmental goods other than PM. It is because that "Ability to model the concept" and "to identify

[4] The original title of this figure is "Model showing relationships between E-B research and urban environments." (E: evaluation, B: behaviour)

independent variables that reliably and consistently affect happiness" are considered the strengths of happiness approach (Leyden, Glodberg et al., 2011, p. 864).

While there have been various government policies to deal with fine dust so far, the level of PM concentration has not dropped since 2012. In order for PM measures to succeed, citizens' participation must be prerequisite, considering those measures rely mostly on a reduction of individual cars or old- fashioned energy, an increase of public transportation or bicycle use.

Hence, this study may suggest that policies focusing on environment scientific measures for mitigating PM concentrations alone are not enough and additional approach is needed understanding why people are not participating enough in public policies.

When the coping strategies to stressors are not successful, learned helplessness, exhaustion, mental disorders can be followed to individuals (Pacione, 2003). And green development can be more successful not only with investment, long-term consistency but also with public participation (Maria, Marina et al., 2015, Campbell, 1996, Stiglitz, 2002). In this context, understanding of the relation between stress caused by PM and societal aspects such as social cohesion will be pursued as well.

1.6_Scope and limitation

Despite the seriousness of fine dust, $PM_{2.5}$ has been officially measured at the national level since 2015. It was also from the 2000s that the Seoul Metropolitan government commenced surveying subjective perceptions (such as happiness, stress) of people on the living environments.

Thus, this study will focus on discovering the correlation that to what extent PM had made an effect on 'negative affect' in Seoul from 2015 to 2018.

In doing so, it is inevitable to confront the shortcomings of a happiness approach as long as employing it just as this research seeks to inherit and reinforce the advantages of the happiness approach.

One of the limitations of a happiness study is the reliability of respondents' answers, which may be exaggerated or underrated by personality or unforeseen variables. However, the larger the sample size is, the less the bias effect become (Oswald, 1997, Di Tella and MacCulloch, 2006). This study utilizes the data on negative perception which is collected by the Seoul Metropolitan Government from 2015 will be utilized. No survey is comparable to the Seoul Survey in terms of the sample size of a survey asking subjective perception to the Korean

Second, while quantitative data analysis enables to generalize the correlation between negative affect and PM, there is a limit in explaining directly, for example, how stress is expressed and how it can be reduced. This limit will be supplemented by additional qualitative research.

Whether or not South Koreans are more mentally vulnerable to fine dust (under the same level of PM concentration) may be confirmed through comparative research between nations or cities by the same research model. It should be left for future studies.

Chapter 2: Theory Review

2.1_Air pollution and Particulate matter

According to the WHO's latest report (2018), 7 million people die prematurely a year by the combined effect of indoor and outdoor air pollution. Out of them, 4.2 million people die due solely to ambient air pollution. Out of them again, over a million's deaths are attributable to fine particulate matter ($PM_{2.5}$ and PM_{10}). OECD estimates that the number of deaths by PM will grow 3.5 million by 2050 (Marchal, Dellink et al., 2011).

For this 'invisible killer', WHO defines it as "contamination of the indoor and outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere."[5] Air pollutant is explained in greater detail: "any substance emitted into the air from an anthropogenic, biogenic, or geogenic source, that is either not part of the natural atmosphere or is present in higher concentrations than the natural atmosphere, and may cause a short-term or long-term adverse effect." (Daly and Zannetti, 2007, p. 3)

When it comes to anthropogenic pollutants that we can control, indoor (or household) air pollutants are from domestic combustions such as heating, cooking, while outdoor pollution sources are representatively exemplified by transport, electricity generation, industry, agricultural and domestic sources (WHO, 2006).

There are six criteria pollutants by US EPA[6]; Particulate matter, O_3 (ground-level ozone), CO (Carbon monoxide), SO_2 (Sulfur dioxide), NO_2 (Nitrogen Dioxide), and Lead.

Air pollutants can also be classified as primary and secondary. Primary pollutants are dispersed into the atmosphere directly from the sources, differently from secondary ones which are emitted after being transformed by precursors (i.e. primary pollutants) in the air. In general, primary pollutants are larger than 2.5 μm (diameter), but secondary ones are less than that (Wilson, Kingham et al., 2005, Seinfeld and Pandis, 2016, Kim, 2017). This classification is significant because their impacts on our health become varied due mainly to the difference in particle size.

This study will pay attention to PM among the main pollutants such as PM, O_3, CO, SO_2, NO_2, and Lead. This is because there are no air pollutants that make the worse effect on our body system than fine particulate. For instance, O_3, NO_2 results in respiratory disease such as bronchitis symptoms, lower lung function (OECD, 2017). However, OECD places emphasis on the point that "fine particulate matter ($PM_{2.5}$), in particular, is the most serious pollutant globally from a human health perspective", on the premise that "air pollution is the single greatest environmental health risk worldwide. Reducing risks to human health from degraded air quality, then, is central for improving people's lives and well-being" (2017, p. 86). It implies there are no air pollutants which deteriorate more seriously the quality of life or happiness than PM. Once we simply look at health impacts of PM, it is well known to cause from respiratory

[5] No page number. World Health Organization, 2019. WHO home page. Available at: http://www.who.int/topics/air_pollution/en [Accessed 25 February 2019]

[6] The United States Environmental Protection Agency, 2019. US EPA home page. [Online] Available at: https://www.epa.gov/environmental-topics/air-topics [Accessed 10 April 2019]

disease and cardiovascular disease to diabetes, Alzheimer's disease, abortion, low birth weight, preterm birth, and affective disorder.

As one of six criteria pollutants, PM is a complex, heterogeneous mixture of various forms (solid, liquid or both) and various sources which are natural or anthropogenic. However, it is known that PM is mainly composed by sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water (WHO, 2016)

PM is also classified as primary and secondary. Secondary PM, as a result of the chemical composition of gaseous precursors, is finer than primary PM. When it comes to a difference on impact, it is noteworthy that while primary particles opt to make a local scaled effect, secondary particles make a regional or broader effect (Blanchard, Carr et al., 1999, Wilson, Kingham et al., 2005).

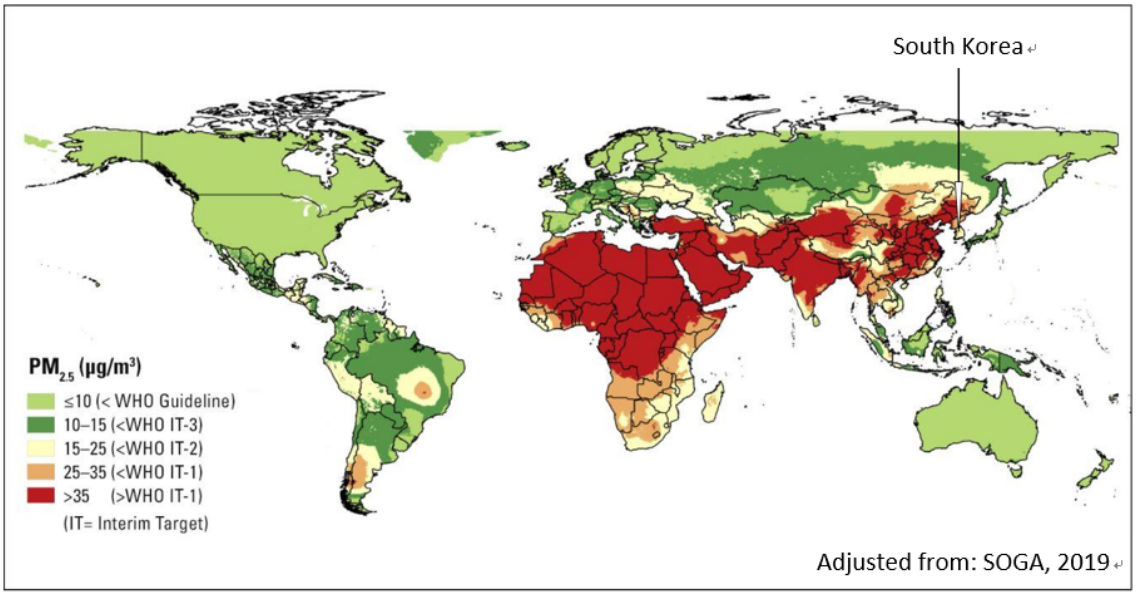
PM_{10} is the particles smaller than 10 μm (diameter) and $PM_{2.5}$ is smaller than 2.5 μm (Wilson, Kingham et al., 2005). Hence $PM_{2.5}$ may penetrate and lodge deep inside lungs, whereas PM_{10} can just impair respiratory system. It does not mean PM_{10} is easy to deal with. Both of them are Group 1 carcinogen (WHO, 2019).

Of note is that the size or chemical composition changes depending not only on precursors but also on the weather, atmospheric conditions, space, even time (Wilson, Kingham et al., 2005, Guerreiro, Foltescu et al., 2014). This is why each city or each nation necessitates tailored policies (OECD, 2017).

2.2_Particulate matter and a City

Most of the air pollutants are also a product of urbanization or industrialization (Cole and Neumayer, 2004). Therefore, the impact of air pollution is very diverse and profound, depending on urbanization or industrialization by a nation or a city (Health Effects Institute, 2019).

Figure 3. The annual average concentration of $PM_{2.5}$ in the world (2017)



Furthermore, due to the inherent nature of PM aforementioned, the solution should be sought differently from cities or regions. In other words, Beijing's solution cannot be the same as Seoul's solution or Seoul would be different from Busan (the second-largest city in South Korea) in terms of solutions. This is why it makes more difficult to deal with PM and air pollution.

Airlabs, a private research institute that put a slogan of "Air pollution is the greatest health problem facing cities" on its webpage, implies that no city in the world is free from air pollution by emphasizing each one sentence's facts per a city; "London breached its annual pollution limit in the first 5 days of 2017"; "The average $PM_{2.5}$ levels are three times over the WHO limit of 25 $\mu g/m^3$ in Beijing"; "Four of the ten most polluted monitoring sites for NO_2 in Europe are in Paris"; "Breathing Delhi's air is equivalent of smoking 20 cigarettes a day."[7]

It is hard for a city to grow without properly countering air pollution. Can we imagine the present prosperity of London or Pittsburgh under dense smog as it had in 1940-1950[8]? South Korea, depicting the rate of urbanization 88% at present, started responding to air pollution from the 1980s mainly by trying to change dirty fuel (from coal or diesel oil) to cleaner ones (LPG or natural gas) and to relocate factories from big cities into other local areas. Consequently, primary air pollutants were remarkably reduced by the early 2000s but $PM_{2.5}$ is hovering at the risky level since 2012 (Kim, 2017). Of note is that no countries with worse air quality than Korea exist in the OECD groups (OECD, 2017). It means the central or major local government policies are not working effectively.

As studied, if the impact of fine dust even in the same country is so diverse by cities, how much more will it vary from person to person? It is not difficult to imagine, nor is the assumption excessive but the existing research models have limitation to measure the holistic effect of PM on a human being.

It is said that "most people are expected to live in cities and metropolitan areas and therefore, it seems important to examine the relationships between the characteristics of these places and the perceived QOL of the residents." (Marans, 2012, p. 10-11)

2.3_Happiness Economy

One of the recent research methods to supplement the limitation of existing research is the evaluation of air pollution effect using happiness data. It is also referred to as a 'happiness approach' (Welsch and Kühling, 2009).

In academia, happiness had been a long subject of psychology. In economics which values 'objective figures' in general, happiness had started to be applied as a means of utility analysis since the late 1970s (Oswald, 1997, Frey and Stutzer, 2002, Welsch and Kühling, 2009).

The meaning of happiness is indeed diversified. But it is clear that the goal of our lives is generally happiness (Frey and Stutzer, 2002). In the academic field, the following definitions by Veenhoven (2000, 2004) are often quoted: 'the overall enjoyment of your life as a whole' and 'the sum of pleasure and pains'.

There seems to be still ambiguity in the definition alone, so happiness may be more specified with its components. World Happiness Report 2019 (Helliwell, Layard et al., 2019, p. 22-23)

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[7] Airlabs, 2019. Airlabs home page. Available at: http://airlabs.com [Accessed 3 April 2019]

[8] London (UK) and Pittsburgh (USA) had been notoriously symbolic cities on smog in 1940-1950s, which killed numerous citizens.

quantifies the happiness index by eight criteria; GDP per capita, healthy Time series of life expectancy at birth, Social support (answer to “If you were in trouble, do you have relatives or friends you can count on?”), Freedom of life choice (answer to “Are you satisfied or dissatisfied with your freedom to choose what you do with your life?”, Generosity (answer to “Have you donated money to a charity in the past month?”), Perception of corruption (of government and business), Positive affect (answer to “Did you experience the following feelings -happiness, laughter, enjoyment- during a lot of the day yesterday? "), Negative affect (answer to “Did you experience the following feelings -worry, sadness, and anger- during a lot of the day yesterday?”)

Veenhoven’s definition (2004) on happiness was also drawn through distinguishing four kinds of satisfaction (pleasure, part-satisfaction, top-experience, life-satisfaction) and four qualities of life (livability of the environment, life-ability of the person, utility of life, satisfaction with life). Diener (2000) modelled components of happiness with Subjective Well-being, Positive affect, and Negative affect, while Seligman (2004) modelled with Experiencing positive emotion, Engaged life, and Meaningful life (Schiffrin and Nelson, 2010). Layard (2005) analyzed that financial situation, family relationships, work, community and friends, health, personal freedom, and personal values determine happiness.

In general, happiness is used with no great difference from *Quality of Life (QOL), Life Satisfaction, and Subjective Well-being*. Happiness in this context enables comprehensive utility evaluation or policy evaluation, even by embracing the concept of *welfare* in Economics and the concept of *health* in Medicine (Veenhoven, 2000, Veenhoven, 2004).

Happiness and QOL seem to be the policy goals in the era of modern welfare states, but it was already officialized in the 18th century by United States Declaration of Independence with the phrase “Life, Liberty and the pursuit of Happiness”.

Easterlin (1974), who first noticeably used happiness data in economics, concluded in his research that economic growth does not always increase happiness. It confirmed the relativity of happiness and raised objections to economic growth priorities. An economist Oswald (1997, p. 1828) suggested that “economic growth should not be a government’s primary concern” but “unemployment application to be the primary concern” by a conclusion that economic growth has little impact on happiness in a developed country through analyzing big happiness data and variables in the U.S. and Europe. Of importance in these existing studies is that after a society’s economic level reaches a certain level, other policy indicators tend to become more crucial for happiness, which is a significant finding by a happiness study.

2.4_Happiness Economy and Air pollution

A happiness approach to analyze the economic utility of air pollution, or any other public goods, which are non-market factors, began to spread in the West from the 2000s (Welsch and Kühling, 2009). In South Korea, it has been introduced from the 2010s but it still seems to be rare and minimal.

It is difficult to estimate the (monetary) value of environmental goods such as parks, clean water, fresh air, and so on. It is due to its invisibility (Welsch and Kühling, 2009). In order to evaluate the value of environmental goods (or related policies), such ways as cost-benefit analysis, travel cost model, hedonic price method, contingent valuation method have been used (Van Praag and Baarsma, 2005, Welsh, 2007, Welsch and Kühling, 2009, Levinson, 2012).

However, with each approach's respective limit[9], happiness approach has been highlighted as a complementary or alternative method mainly from countries where the quality of life and happiness had become policy goals (Welsch and Kühling, 2009, Tella and MacCulloch, 2006).

Especially the happiness studies on environmental goods such as air pollution or noise are consistently suggesting the reverse relationship between them or the possibility that the relationship can be translated into economic value (Van Praag and Baarsma, 2005, Levinson, 2012, Ferreira, Akay et al., 2013, Kim and Jin, 2017, Zhang, Zhang, et al., 2017).

The merits of a happiness approach seem obvious. First, invisible environmental values are relatively easily translated and visualized by monetary values (Van Praag and Baarsma, 2005, Welsch and Kühling, 2009). Second, it is possible to use a consistent happiness equation all over the world (Oswald, 1997), which allows relatively simple applicability and comparison between various factors or between regions. Last but not least, happiness approach encourages society to move toward an environmentally and socially sustainable society by requiring a policy based on the value of happiness and QOL (Gowdy, 2005).

2.5_Stress, Depression, Happiness, and a City

As of 2014, 54% of the world's population lives in cities (UN, D., 2015). Urban life is vulnerable to mental health led by surroundings such as environment, crime, a structure of community including 'toxic neighborhood'[10]. The urban environment has an exclusive social and psychological effect on people (Wandersman and Nation, 1998) and individual perception on environmental risk is affected even by political-economic factors (Bickerstaff, 2004). Hence it is necessary to study the relationship between PM as urban conditions and the resident's perception such as the quality of life or stress, based on Seoul (Marans, 2012).

The fact that urban characteristics and functions affect individual happiness is also a valuable finding drawn from the study of happiness (Leyden, Glodberg et al., 2011) However, there is little research directly explaining how the urban environment affects individual negative perception from a sociological perspective.

Therefore, the happiness approach seems to lead to the following question: As a human being, is the right to become happy is prior to the right not to get distressed or is the right not to get distressed prior to the right to become happy?

The answer will be contingent upon the level of urbanization, advancement of a city (or a nation), or societal structure, individual values, and so on, but we are it looks clearly not possible to expand the right to become happy without securing the right not to get distressed, not to get depressed, not to get worried, not to get anxious unfairly no matter where we are. For instance, in a city under a dispute, which question can make it possible to more precisely understand the subjective perception of the occupants, between "would you say you have been happy for the last week as a whole?" and "would you say you have been stressed for the last week?" Will it be meaningful to measure the value of urban environments by a happiness approach in this city? There may be little difference in the self-reported score of happiness as if saying "unhappy" with one voice.

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[9] For example, a hedonic price method is hard to capture the whole cost of the intangibles (Van Praag and Baarsma, 2005)

[10] It refers to a neighbour to impede children's proper growth in this paper.

Therefore, this study suggests ‘stress approach’ or ‘depression approach’ as an alternative to ‘happiness approach’ in order to assess PM's adverse impact. It rests on an assumption that a stress approach will be more effective in defining the value of the environmental bads (such as pollution of air, noise, water, and so on) rather than environmental goods (such as green space, fresh air, clean water, and so on).

Stress is difficult to be defined as happiness is. According to Evans and Cohen (1984, p. 572), “early definitions varied in the extent to which they emphasized the responses of the individual or the situations that caused disruptions of ongoing behavior and functioning.”

Stress, in general, means ‘the psychological and physical state when exposed to negative circumstances.’ From an environmental standpoint, stress is “a process that occurs when there is an imbalance between environmental demand and response capabilities of the organism” (Evans and Cohen, 1984, p. 573). Stress is a status in which demand exceeds a person’s assets (Lazarus, 1990). Depression is defined as a status all activities, all emotions, and even life becomes pointless, in which ego becomes distorted and people get to live now in foreseeing distress of future (Solomon, 2014).

Stress or depression is more pronounced than happiness in terms of impacts. They affect not only the health of a person or the quality of life but also the health of society (Pacione, 2003, Gładka, Rymaszewska et al., 2018).

Since the principle of ‘stress approach’ will be similar to a happiness approach, this study looks more at whether stress approach can have independent and discriminative meanings apart from a happiness approach. In other words, it is possible to question whether the findings of a stress approach would already be included in the conclusions of a happiness approach. If it is impossible to refute this concern, the independence of a stress approach will be difficult to be ensured.

As regards this, the following three characteristics are considered from the literature review.

1. Some happiness approaches such as World Happiness Report (Helliwell, Layard et al. , 2019) reflect the negative affectivity when assessing happiness but most of the happi ness does not subsume negative affectivity (i.e., sadness, depression, anxiety, stress, e tc) in an explicit way. For example, happiness in the Seoul Survey is assessed by a si mple answer to the question; “Do you think you are happy these days” (1-10 scale). T he famous question model, the Cantril Ladder-of-life Question (Cantril, 1965) also as ks simply “Where would you put yourself on the ladder at the present stage of your lif e in terms of how satisfied or dissatisfied are you with your personal life?” (1-10 scale) Joseph, Linley et al., (2004, p. 464) argued that “Happiness is not just the absence of depression, but also the presence of a number of positive emotional and cognitive sta tes.” Happiness has a limitation in telling what stress could tell.
2. Although there seems to be an inverse relationship between stress and happiness, ther e are also the studies existing that the inverse relationship between both of them is eq uivocal. There are even studies that it is possible to feel happiness and stress at the sa me time (Watson and Tellegen, 1985, Feist, Bodner et al., 1995, Schiffrin and Nelson, 2010) It implies high happiness is possible to be with high stress at the same time. To paraphrase, 0 points of stress does not mean 10 or 1 points of happiness nor 0 points of happiness does mean 10 points of stress.
3. Regardless of No. 1 and 2 issues, there is perception existing that unhappiness (not ha ppiness) is the essence of life. The psychologist Freud (happiness is short-lived orgas mic experience from the release of primitive urges) and the philosopher Adorno (happ iness is a mere temporary mental escape from misery) are considered as examples (Ra

th, 2002a, Rath, 2002b, Veenhoven, 2004).

Of course, more studies support a generally confrontational relationship between stress and happiness (Schiffrin and Nelson, 2010, Layard, 2005). It premises that to reduce stress can increase happiness. Nevertheless, this premise still cannot assure that the outcome of entering the happiness and stress data into each equation will be coincident when assessing environmental goods.

2.6_Stress, Depression, and Particulate matter

The effect of fine dust on a human being (especially on mental, psychological impact) has been analyzed mainly in medicine sector through observation, experiment, clinical and epidemiological studies (Gładka, Rymaszewska et al., 2018).

Scientifically, a relationship between PM and negative affectivity has been tested and found. According to them, air pollutants directly disrupt the nervous system. $PM_{2.5}$ causes degenerative brain changes (Gładka, Rymaszewska et al., 2018). There are also studies experimenting with the causality between stress and depression. First, Mehta et al. (2015) analyzed that aged men reported a higher level of perceived stress by the change of air pollution level ($PM_{2.5}$, Black Carbon, Nitrogen dioxide, Particle number counts), particularly in the colder season as a result of long-term observation of the panel group. Second, stress can cause (certain forms) depression by a change of the 5-hydroxytryptamine and stress hormone affected by repeated stress (Caspi, Sugden et al., 2003, Van Praag and Baarsma, 2005). The scientific effects of air pollutants on negative affectivity are shown in Table 1. It is said that even suicide risk increases when PM concentration is high (Gładka, Rymaszewska et al., 2018, Cho, Choi et al, 2014).

Table 1. The relationship between depression & suicide and air pollution

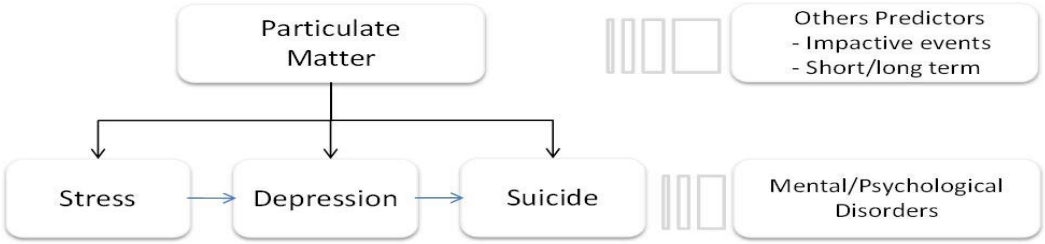
Researcher	Methodology	Pollutants	Main findings
Szyszkowicz et al., 2010	case-crossover	CO, NO_2, SO_2, **PM_{10}**	positive association between air pollution and emergency department (ED) visits for suicide attempts
Fonken et al., 2011	experimental	**PM**	long term exposure alters affective responses and impairs cognition
Lim et al., 2012	cross-sectional	**PM_{10}**, NO_2, O_3	increases in PM_{10}, NO_2, and O_3 levels may increase depressive symptoms among the elderly
Davis et al., 2013	experimental	**nPM**	increased depression-like responses after prenatal exposure to nPM
Cho et al., 2014	time-stratified case-crossover	SO_2, **PM_{10}**, NO_2, CO	significantly increase the risk of ED visits for a depressive episode, esp., among individuals with cardiovascular disease, diabetes mellitus, or asthma
Wang et al., 2014	prospective cohort	**$PM_{2.5}$**, sulfates, black carbon, ultrafine particles	no evidence of a positive association between depressive symptoms

Kim et al., 2015	nationwide study	O_3, **PM**, NO_2, CO, SO_2	O_3, atmospheric PM increased concentrations related to the suicide rate. No significant associations with the others
Lin et al., 2016	case-crossover study	**PM_{10}**, SO_2, NO_2	suicide risk positively associated with ambient air pollution level
Ng et al., 2016	time-stratified case-crossover	**$PM_{2.5}$**, NO_2, SO_2	linked to suicide mortality in certain population subgroups
Zijlema et al., 2016	cross-sectional	**PM_{10}**, NO_2	heterogeneous results of associations of the air pollutants and depressed mood
Szyszkowicz et al., 2016	case-crossover	**$PM_{2.5}$**, NO_2, SO_2	A positive association between exposure to air pollution and visits for depression
Kioumourtzoglou et al., 2017	Prospective cohort	O_3, **$PM_{2.5}$**, **PM_{10}**	association between both long-term O_3 and $PM_{2.5}$ exposure and depression onset, specifically stronger with antidepressant use
Tallon et al., 2017	Observational/ longitudinal/ population-based	**$PM_{2.5}$**	positive associations between recent long-term ambient $PM_{2.5}$ levels and erectile dysfunction, depression, and stress
Casas et al., 2017	time-stratified case-crossover	**PM_{10}**, O_3	PM_{10} or O_3 may trigger suicide, particularly during warm periods; PM_{10} especially among children and elderly population

Edited from: Gładka, Rymaszewska et al., 2018

Based on the literature review, the reciprocal causality between PM and stress, depression, and suicide can be depicted as **Figure 4**.

Figure 4. The relationship between PM and Psychological health



Source: Author (2019)

All these results rest on medical studies. Even though these findings do not enable us to capture in-depth meanings of the relationship between the variables based on the urban sociologic perspective (about societal characteristics of the vulnerable group to negative affect caused by PM or the effect of stress caused by PM on society), they do not have scarcity in providing a consistent rationale to this study.

2.7_Stress Inequality and Social cohesion

There is another study flow that air pollution gives a relatively more negative effect on the low-income or minority group in society. For instance, even if you live in the same neighbourhood, the poorer you are or the older/younger you are, the more you are exposed to PM, and the more damage you suffer. According to Miranda (2011), low-income or minority groups tend to experience higher levels of air pollution in the monitored areas in the USA. Under the terminology which is 'environmental injustice', this seems to be an important issue to be addressed more. However, what is as important as understanding the phenomenon of environmental injustice may be the characteristic of a more vulnerable group that gets particularly more stressed or depressed even at the same PM concentration. It is because the factors to determine the gap of stress is not only from physical capitals or visible factors. For example, stress increased by fine dust is likely to be eased by higher social capital such as networking, community membership (Wang, Xue et al., 2018). It implies to the Korean society that the single comprising 25% of the whole households, or the passive class in social activities can be more vulnerable to fine dust. Besides the negative perception about environmental risk can be strengthened by distrust on the public sector or low commitment to a neighbour (Bickerstaff, 2004). These will be examined as a factor resulting in ***'Stress Inequality'*** in this study.

Negative affectivity such as stress or depression and suicide are important factors that make effects on social pathology beyond the individual level. Such negative affectivity as stress or depression is mostly related to an isolated situation which is considered unequal by each individual. So, depression in itself can impede social cohesion (Acket, Borsenberger et al., 2011, Helliwell, Layard et al., 2019) and, by extension, spread to distrust, anger against society or a government (Jung, Kim, et al., 2018).

The definition of social cohesion varies, but mostly includes 'individual voluntary participation' as a key pillar (Campbell, 1996, Stiglitz, 2002, OECD, 2012). Chan, To et al. (2006, p. 290) give a definition that social cohesion is "a state of affairs concerning both the vertical and the horizontal interactions among members of society as characterized by a set of attitudes and norms that subsumes trust, a sense of belonging and the willingness to participate and help, as well as their behavioural manifestations".

The study of social cohesion has developed alongside the perception that a society of high social cohesion displays high well-being (Acket, Borsenberger et al., 2011, Helliwell, Layard et al., 2019). Social tension can be eased by reducing happiness inequality through in particular enhancing education (Becchetti, Massari et al., 2013) and even economic development is possible by active civil participation (Stiglitz, 2002). OECD (2012) compresses these findings as follows: "A cohesive society works towards the well-being of all its members, fights exclusion and marginalization, creates a sense of belonging, promotes trust, and offers its members the opportunity of upward mobility."[11]

From the perspective in South Korea, Lee, Jung et al., (2015) analyzed that while the level of stress, depression, and anxiety are low in the group estimating that "society is stable", thinking of suicide or social deviance is more common in the opposite group. Jung, Kim et al., (2017)

[11] No page number. Organización de Cooperación y Desarrollo Económico, 2011. Perspectives on global development 2012: Social cohesion in a shifting world. OECD: Available at: https://www.oecd.org/site/devpgd2012/49067954.pdf [Accessed 11 April 2019]

explains that those who get stressed have doubts about the functioning of their society (institutional) devices. The bottom line is that the greater the stress or depression is, the lower the perception of social cohesion is. It may be supported by a finding that a citizen would face learned helplessness, severe performance decrements, mental disorders, exhaustion after experiencing failure of coping to stressors as mentioned before (Pacione, 2003).

This study assumes that stress and stress inequality may show an inverse relation with social cohesion based on the existing research including the World Happiness Report (Helliwell, Layard et al., 2019, P. 19) saying that "social trust, often found to be lower where income inequality is greater, is even more closely connected to the inequality of subjective well-being."

2.8_Conceptual Framework

As have seen above, the impact of fine dust is extensive and profound in terms of cutting across both individual and national levels.

Much of what has been discovered so far relies mainly on the findings of the physiological, pathological mechanism by observational, clinical, experimental, epidemiological studies in medical science and they have a limit in providing far-reaching implication to society. In order that it should be overcome, this study intends to employ a happiness approach which shows more gently and flexibly that the overall quality of life is affected by fine dust.

By visualizing the invisible value of public goods (or bads), happiness approach has also played a role in further promoting the quality of life in a government and society. Gowdy (2005) puts emphasis that happiness approach encourages society to move toward an environmentally and socially sustainable society. The problem is, nevertheless, that numerous Korean cities are experiencing more severe PM phenomena than before, and citizens are voicing more complaints and pain entailed by PM and this is not still explained fully by the happiness perspective.

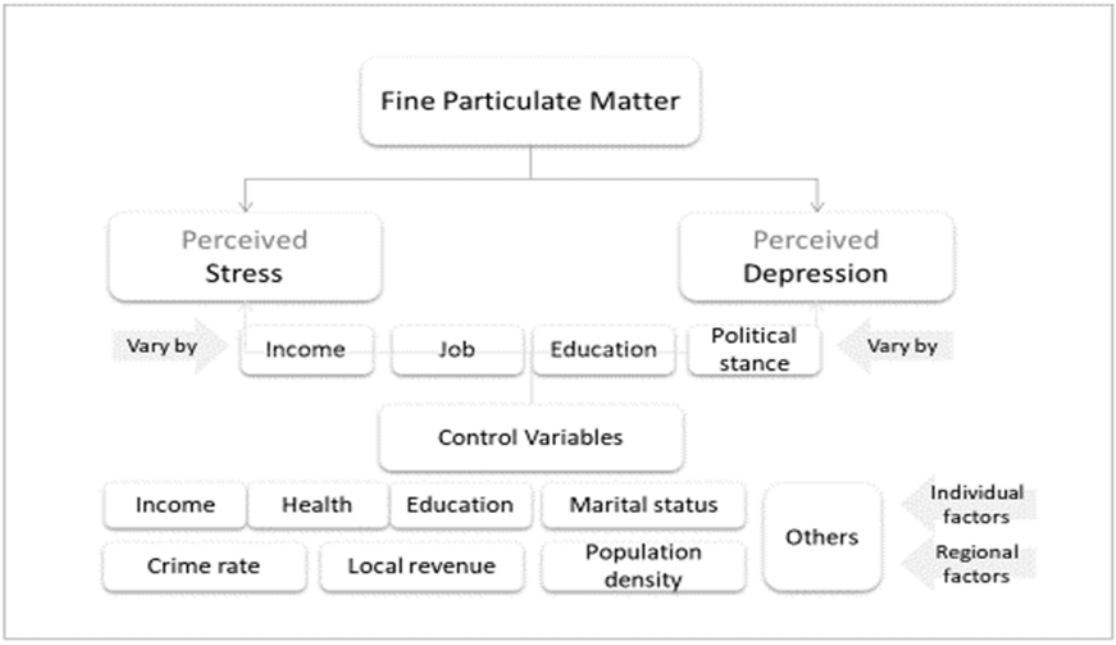
In view of this reality and the aforementioned theoretical review, this study aims to discover the negative effects of PM on the perception of Seoul citizens and society by borrowing the principle of a happiness approach but changing a theoretical framework.

In this study, to be more specific, the change of stress level by PM concentration will be analyzed by inserting perceived stress or depression (or any other negative affectivity) data for years instead of happiness data. The Seoul Metropolitan Government has conducted an annual survey to over 40,000 respondents in Seoul with a structured questionnaire on subjective perception including "would you say you have been stressed as a whole for the last two weeks?", "would you say you have been depressed (or enervated, irritated, pessimistic) for the last two weeks (or for the past month)?" on a 1-5 scale over the last ten years.

Not only objective factors but also subjective perceptual dimension comprise the quality of any entity and "the objective characteristics of society - such as poverty, crime rates, and pollution - contribute predominately to peoples' judgments of their lives" (Marans, 2012, p.10). Hence, general effects of $PM_{2.5}$ and PM_{10} on negative affectivity will be examined under the control variables made up of individual (income, job, education, health, etc) and regional factors (crime rate, fiscal ability of a district, noise conflicts, etc), and furthermore the characteristics of a more vulnerable class under the same level of PM concentration will be additionally explained by a comparative analysis of PM by other variables such as income, job, education, social cohesion.

Stated briefly, this study aims to provide a more straightforward and elaborate interpretation of the invisible impacts of PM on Seoulites, by supplementing the shortcomings of a happiness approach but by reinforcing its advantages.

Figure 5. Conceptual framework



Chapter 3: Research Design and Methods

3.1_Revised research questions

This is the research question which has been refined by a detailed literature review. Although the research goal based on the problem (broadly speaking, examining the correlation between 'Environmental Bads' and perceived Negative Affect) is consistent, the variables become more specified and diversified through main and sub-questions.

The research question is:

What is the relationship between particulate matter and perceived stress or depression?

The research sub-questions are:

1. To what extent is individual stress or depression affected negatively by PM and how is it expressed?
2. Is PM more 'significant' than such other predictors (to stress or depression) as income, health, job, marital status, regional crime rate, regional financial status, and so on?
3. From 2015 to 2018, has PM become more significant or less as a predictor to stress or depression, compared the other variables?
4. Are there specific groups who get in particular more distressed or depressed even by the same level of PM concentration?
5. How is the so-called 'stress inequality' explained in Seoul? What are the characteristics of the vulnerable groups in terms of age, gender, income, education, job, political stance (progressive or conservative), perception of social cohesion, and so on?
6. What is the relation between stress inequality and social cohesion?

3.2_Research Strategy

This study is basically employing the method of secondary quantitative data analysis (the so-called statistical meta-analysis) in order first to explore and generalize the relationship between various variables including PM and perceived score of stress or depression and then to discover the change of the correlation between them since 2015.

This study applies a deductive approach based on the existing theories and research frameworks, and this will try to extend them. Making reference to the studies that various urban environmental aspects influence self-reported happiness, QOL, and satisfaction of citizens differently, this study aims to explain how much stress and depression is caused by not just individual but also collective regional assets or conditions, including PM.

The deductive quantitative data analysis has the advantage of enabling comparison by regional, national, and even international levels and understanding the change over time (Leyden, Glodberg et al., 2011, Van Thiel, 2014). Therefore, this study is expected to function as a prelude to future (provisional) research which will aim to compare the correlations between

negative affectivity and PM among Seoul, Tokyo, Beijing, and other metropolitans, or among any more segmentalized units of residence.

Multi regression analysis (using SPSS) is utilized to analyze the correlation between multiple variables (mainly $PM_{2.5}$ & PM_{10} - Stress, $PM_{2.5}$ & PM_{10} - Depression). R will also contribute to analyzing and visualizing the change of PM concentration level over the last four year since 2015 when $PM_{2.5}$ started to be officially measured at the national level.

The study also conducted a survey through in-depth interviews, one of the qualitative research methods. It is for collecting valuable views or interpretations on the correlation between PM and perceived stress or depression from 30 experts, and also providing insight for betterment in the policy. Although the correlation between PM and for example perceived stress can be discovered by desk research, there are limitations in explaining in detail the causality between the variables, and the meaning of stress inequality in a society.

3.3_Operationalization: Variables and Indicators

Table 2 points to the concepts, variables, indicators, which are translated from the theoretical concept into numeric form. In deductive research, of great importance is to complete proper operationalization for (internal) validity (Van Thiel, 2014) so this study rests on various lessons of 'happiness approach' as a valid existing theoretical framework, and then challenge to expand them.

Table 2. Operationalization (Data: 2015~2018)

Concept		Variable	Indicator	Volume	Source	Original question
Negative Affect	Stress	Y1: Stress Level	Self-reported Stress	Scale 1-5	Secondary data : Seoul Survey	**Would you say that you have been stressed as a whole over the last two weeks?**
	Depression	Y2: Depression level	Self-reported Depression	Scale 1-5	Secondary data : Seoul Survey	**Would you say that you have been depressed over the two weeks?**
Fine dust		X 1: $PM_{2.5}$	Average of concentration level at the time when the survey was conducted ($\mu g/m^3$)	Continuous (Per a district[12])	Secondary data : Ministry of Environment.	Scientific measurement
		X 2: PM_{10}		Continuous (per a district)	Secondary data : Ministry of Environment	Scientific measurement
Control Variables (Urban environments)		Demographic (Individual)	Age (over 15 years old) Gender (female-male)	Continuous Nominal (0-1)	Secondary data : Seoul survey	
		Physical (Individual)	Healthy life Happiness (on health)	Nominal (0-1) Scale 1-11	Secondary data : Seoul Survey	. Do you exercise regularly?

[12] Seoul city consists of 25 districts ("Gu"). All the regional data should be translated and matched at an individual basis.

					. Would you say that you are happy with your health?
	Socio-economic (Individual)	Marital status, education, religion, jobs, Household structure, income Happiness (financial status)	Ordinal Continuous	Secondary data : Seoul survey	. Are you happy with the status of your health overall now?
	Socio-Political (Individual)	Political inclination (progressive-conservative) Social participation (voting)	Scale 1- 11 Nominal (0-1)	Secondary data : Seoul survey	. Would you say that you are progressive or conservative? . Did you vote in this year?
	Regional (By 25 districts, Seoul)	Crime (annual number of cases) Traffic accident (Annual number of cases) Local tax revenue (KRW) Environmental conflicts (annual number of cases) Green space (%) Population density (annual number of persons)	Continuous	Secondary data From Seoul city Statistics Korea Police authority Ministry of Land, Infrastructure and Transport	
Social cohesion	Social cohesion (Individual)	Trust in Public sector	Scale 1-5	Secondary data : Seoul Survey	. Would you say that you trust in the public sector?

Source: Author (2019)

When it comes to depression, it was surveyed only in 2017 by Seoul Metropolitan government. The Seoul survey imposed a question asking enervation, pessimism, or irritation in 2015 and 2016 instead of depression and included only a question about stress in 2018. Accordingly, the indicator of depression will be merged with the other negative emotions of 'being blue' (enervation, pessimism, irritation) into the variable marked 'depression et al.' by respecting the intention of the Seoul survey for comparison with stress.

3.4_Sample Size and Selection

The main results of this study will be derived by analyzing big data primarily collected by Seoul Metropolitan government and the central government.

One of the secondary data is the Seoul Survey's raw data, which is collected by the Seoul Metropolitan Government every year. Seoul City has conducted the Seoul Survey mostly in September or October since 2003. The purpose of the survey is to enhance the quality of life for Seoulites by diagnosing the current state of urban life and exploring provisional policy through time-series monitoring.

In particular, the Seoul government has been conducting household surveys for this purpose. In September or October of each year, approximately 43,000 population (20,000 households) aged 15 and older living in Seoul have been surveyed by Seoul Survey team with almost 50 questionnaires (structured interview) under 12 different indicators including economic level, house owning, education, health, safety, environment, value of life, and so on. The samples of

the survey are selected by the so-called stratified random sampling method, taking account of the number of households by each district and by type of housing. Subjective perception data such as stress, depression, irritation, enervation, pessimism utilized for this research analysis are derived from Seoul Survey raw data too.

The control variables are divided by an individual and regional basis (by 25 districts) in Seoul. While age, gender, income, political orientation, perceived happiness about health or financial status, and voting experience are individual data, the concentration of PM, crime rate, traffic accident rate, the rate of greenness, or the amount of local tax revenue (which refers to financial capacity of each district that is autonomous) are regional ones.

In order to conduct meta-statistical analysis using not only Seoul Survey data but also various data from other sources, it needs to match all kinds of regional data to each respondent's data in Seoul Survey raw data. It is noted that the Seoul Survey raw data has a code to indicate geographical identification of all the respondents. By the courtesy of individualized code of a district where a respondent lives, it is possible to connect such regional data as crime rate, local tax revenue, PM concentration levels with each respondent of the survey by using Excel. Seoul is made of 25 districts and around 424 smaller administrative units, named 'Dong'. If the Seoul survey has more segmentalized code in line with Dong and any local data can be divided by the unit of Dong, it might allow more sophisticated approach on this research topic but the Seoul survey does not have Dong codes and most of the primary local factors including PM are being measured and recorded just at a basis of Gu level.

The concentration levels of PM per district in Seoul, as the independent variable, are acquired from the data collected by the ministry of environment. $PM_{2.5}$ has been officially measured at the national level since 2015, and thereby this research is focusing on analyzing data from 2015 to 2018. Moreover, bearing in mind that Seoul Survey has been conducted in September or October every year, this research intends to compute and utilize the average concentration of PM in keeping with when the survey was conducted.

However, in order that we can understand how PM levels in Korea and Seoul have changed over the years, the daily average of $PM_{2.5,}$ PM_{10} concentration will be holly collected between 2015 and 2018 and be additionally analyzed, visualized by graphs. The government calculates the daily average of PM concentration by province, city, and district through an arithmetic average of the concentration of PM measured on an hourly basis at over 500 measurement points nationwide (over 50 points in Seoul).

3.5_Data Collection and Analysis Methods

This research aims to analyze and generalize the correlation between PM and perceived stress and depression by taking the three steps of analysis.

The first step is to analyze the pattern in PM concentration change since 2015. it is said in chapter 2 that the average nationwide concentration of PM has been stagnant since 2012 in South Korea. However, citizens seem to be more and more frustrated with the increase in the number of days of a high level of PM concentration. Therefore, more specifically, this research will analyze and then visualize the changes in the concentration of $PM_{2.5}$ and PM_{10} in Seoul on a monthly basis to verify the trend of 2015-2018. R is utilized for data analysis and visualization.

Second, in order that the research questions can be answered, data of independent, dependent variables and control variables are collected. The big data collected first by the Seoul Metropolitan Government, the central government, and the police will be rearranged by a form

of data matrix on Microsoft Excel. In this step, the geographic information of individual respondents (approx. 43,000 units every year) of Seoul Survey is verified and matched with data from other sources, especially regional data, as previously stated. Then, analyzing the correlation and causality between variables using multi-level regression (hierarchical regression) among multiple linear regression will be carried out referring to the existing studies. Pacione (2003, p. 24) explained "most geographical research to date has favoured a simple aggregative or linear additive model. This model suggests that somehow individuals 'add up' their joys and sorrows about specific concerns to arrive at a feeling about general wellbeing. A possible approach to the problem of assessing the contribution of each domain to overall wellbeing is by means of step-wise multiple regression analysis."

The equation of multiple linear regression is the following;

$$\gamma_i = \beta_0+\beta_1\chi_1+\beta_2\chi_2 + \beta_3\chi_3 + \beta_4\chi_4+\cdots\cdots+\beta_n\chi_n+\varepsilon_i$$

γ = perceived Stress, perceived Depression (separately)

χ = Independent variable ($PM_{2.5}$, PM_{10})

β = Constant / Intercept

ε = Error term

The variables for hierarchical regression analysis are grouped into largely personal, regional factors including variables having more environmental characteristics.

Hierarchical regression is useful in discovering the change of correlations between variables, namely how much each variable group contributes to explain the relationship with the dependent variable (Bryk and Raudenbush, 1987, Pacione, 2003). For example, hierarchical regression is also being used to analyze how PM affects depression other than individual and collective factors (Wang, Xue et al., 2018). The personal factors making up the first model include relatively objective household income and subjective happiness on their financial status, as well as gender, age, marital status, religion, and perceived overall happiness of Seoul citizens from 2015 to 2018.

The regional factors added in the second model consist of population density, traffic accident rate, crime rate, medical expenses per capita (based on holders of public health insurance), local tax revenue (per capita), and greenness rate, noise conflicts on a district's basis in Seoul[13]. PM is added at the third model. These three models are designed to compare the effects of different variables on the formation of negative emotions, depending on the characteristics of the group of variables and the change of correlation.

Third, a survey of 30 experts will be conducted for supplementary secondary quantitative analysis.

The regression analysis based on numeric data has great advantages in examining correlation or effect between variables, but it has limitations in explaining the causality in greater detail. This is why an additional survey has been conducted.
The group of the interviewee is selected by a cluster sampling method enabling semi-structured

[13] Each characteristic and meaning of the local variables will be explained further in chapter 4.

interview on air pollution matter, out of those who have issued a research paper on the subject, those who have been invited in the governmental committee in charge of responding to PM, or those who have an interview with a media publicly on this issue.

Among the specialist group up to around 100 people, 40 experts were selected in consideration of their majors, gender, workplace, and the possibility of contact, but not sophisticated enough to be called stratified sampling.

The 13 semi-structured questions were emailed, hiring the Google Survey function. Email addresses were searched and gathered mainly from web pages of their organizations single by single. The initial response rate was not high due probably to the short period for the survey and the situation that it was overlapped with the summer holiday season. Accordingly, two or three reminders had to be sent more, and in the final stage, 15 experts got to receive a phone call being asked for a survey response. This process demanded 2 weeks and ended in 60%'s reply.
The questionnaire was designed to make them give their opinion beyond the answer to multiple-choice questions on the relationship between individual negative affectivity caused by PM and the society so as to attain overview and insight beyond what the numeric data demonstrates.

Their answers, as qualitative data collected by email interview (semi-structured), are analyzed and visualized by Google, Excel, or tools of a word cloud.

3.6_Validity and reliability

In general, the validity of desk research may be questioned when the purpose of new research is different from the purpose of collecting the primary data. Reliability can be deteriorated when the raw data collected from the other sources are flawed such as being contradictory or incomplete

In order that this concern can be cleared, this research intends to rely thoroughly on the high quality of data collected by the local and central government which should be precise as much as possible. In particular, data of perceived stress or depression have been primarily collected by the survey of the Seoul Metropolitan Government over 10 years so that they are quite reliable. Accordingly, this research's reliability can be partially assured as well.

As far as validity is concerned, it is noted that the Seoul metropolitan government has collected the data intending to improve the quality of urban life in Seoul. It has implications that it is not quite different from the purpose of this research seeking a way of better urban life through discovering the correlation between stress or depression and PM.

As mentioned before, this research borrows happiness approach. It means this research is exposed to not only the strengths of a happiness study but also weaknesses concerning validity and reliability as well.

Leyden, Goldberg et al. (2011, p. 864) said "if the object of the limitations associated with the happiness research renaissance has been its struggles in definition and meaning, its strengths have rested in its ability to model the concept. Survey research techniques have afforded social scientists the ability to statistically model happiness. Scholars have been able to identify independent variables that reliably and consistently affect happiness." Employing the existing reliable studies of a happiness approach, main variables out of urban environment conditions affecting subjective perception are accepted in this research and even a few more variables are chosen for the purpose of enhancing validity and reliability (Lazarus, 1990).

The limit of using the data of subjective perceptions is the possibility of exaggerated or underrated answers of the respondents just like a happiness study but it is possible to overcome relatively by using a larger size of samples (Rafael, 2006). When it comes to data of perceived stress or depression collected by public sectors, there is no survey having bigger data rather than Seoul Survey in South Korea.

Another limit of this study is the possibility of superficiality, namely lack of depth. Desk research does not fully explain in depth why and how a specific factor makes a different effect on subjective perception, although it can provide a general explanation about the correlation between them.

For instance, perceived stress scores of 'A' and 'B' respondent can be discrepant due to some unforeseen factors, out of the variables chosen in this research, despite the fact that they are in similar urban environments (settings). In this case, an individual deep story may not be enough captured by the net of namely generalization by secondary data analysis. Van Thiel (2014, p. 119) explained: "quantification leads to simplification and a reduction of information, and therefore does not do justice to the complexity of reality." To supplement it, a survey of experts is conducted.

Chapter 4: Research Findings

4.1_Secondary Quantitative Analysis

4.1.1_Descriptive Statistics

The descriptive statistics of all the factors selected as variables that can affect negative affectivity are included in the following **Table 3** along with the values of the independent variable. The total of 178,124 samples of the Seoul survey from 2015 to 2018 is all available as an individual variable in this research. The regional readings are differentiated by 25 districts in Seoul.

Table 3. Descriptive Statistics of the Variables

Variables		N	Minimum	Maximum	Mean	Std. Deviation
Dependent	Stress	178124	1	5	3.515	1.0611
	Depression et al.	135133	1	5	2.546	0.7431
Reference	Happiness (overall)	178124	0	10	6.96	1.1185
	Life Satisfaction (overall)	135133	0	10	7.152	1.5919
Independent	$PM_{2.5}$	178124	9	26.5	17.482	4.5195
	PM_{10}	178124	16	46	30.987	7.6367
Individual	Gender	178124	0	1	0.481	0.4996
	Age	178124	15	102	45.437	16.5309
	Marital Status	178124	0	1	0.663	0.4728
	House Owning	178124	0	1	0.584	0.4929
	Religion	178124	0	1	0.453	0.4978
	Happiness on Health	178124	0	10	7.184	1.4926
	Income (household)	178124	25	1122.9	499.11	237.8711
	Happiness on Financial status	178124	0	10	6.293	1.5074
	College (over 2-years)	178124	0	1	0.541	0.4984
	White-collar Job	178124	0	1	0.298	0.4572
Regional	Population Density	178124	6771	28098	17920.62	4586.646
	Traffic Accidents (per 10K cars)	178124	67.4	222.9	112.435	30.0055
	Crime Rate (per 10K persons)	178124	57.74	383.99	122.743	50.1793
	Medical Cost (1000 won)	178124	863.64	1636.63	1125.052	129.8031
	Local Tax revenue (1000 won)	178124	0.52	10.75	1.76	1.7406
Environment	Greenness Rate	178124	9.31	55.71	22.292	9.0793
	Noise Conflicts (per 10K persons)	178124	11.61	114.9	50.013	24.7038
	Valid N (listwise)	135133				

4.1.2_Individual Factors

In the years from 2015 to 2018, Seoul citizens (178,124 respondents) was 45.4 years old on average, ranging from 15 to 102, and 48.1% (85,708) are male and 51.9% (92,416) are female.

Out of all the respondents, 66.3% are married, 58.4% own their houses, and 45.3% have religion. They reported their happiness on health at 71.8 points out of 100.

54.1% have a two-year college degree or higher, and three out of 10 respondents (29.8%) work in white-collar jobs. The average household income of Seoul citizens in this period is around 3,800 euros (approx. 5 million won) per month. Household income was derived by calculating the median values for each segment instead of the 1-19 category selected by respondents (Levinson, 2012). Those who exceed 6900 euros (the 19th segment) was requested to write the real income, so that made it possible to calculate the average of the highest income group, which is 8600 euros.

Nevertheless, this data does not depict the level of quality of life. Their perceived stress score averaged 3.515 (on a 1-5 scale) for four years, which is equivalent to 70.3 out of 100 and depression et al. (including irritation, enervation, pessimism) was 2.55 points (51 out of 100), while their happiness score was 69.6 points and life satisfaction score was reported 71.5.

Two points need to be noticed. 1) The score of happiness or life satisfaction is greater than the score of happiness on financial status (62.9 points), therewith allowing us to suppose that the quality of life is affected not only by money but also by the other factors additionally. 2) The score of depression et al. is lower than the one of stress. It may be related to a difference in the questions about negative sentiments.

The value of depression et al. was drawn from answers to a question if one had emotional experience of depression (in 2017), or of irritation, enervation, pessimism (in 2015 and 2016), while stress was rated by a general question “would you say you have been stressed in the last 2 weeks?”

In other words, the question concerning depression et al. requires the respondents more sophisticated judgment and assessment. It does not seem simple to say ‘yes’ about depression or irritation or enervation, compared to say ‘yes’ about stress. This pattern of score gap is also observed in the result from income earners’ group (111,534 units, 62.6%)[14], who reported stress score is 71.6 and depression et al. is 51.2

4.1.3_Longitudinal trends of PM

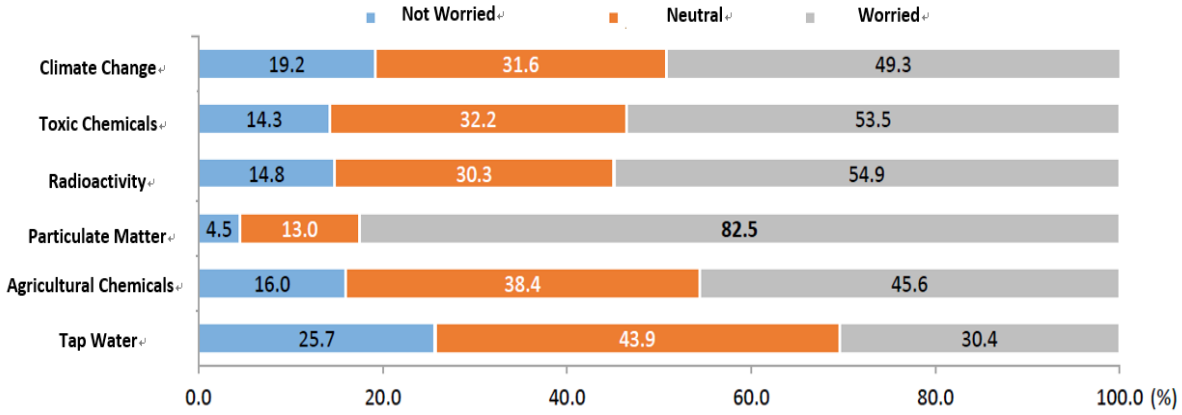
Particulate matter was pointed out as the most anxious environmental issue in 2018 as seen the result of KOSTAT’s survey (**Figure 6**).

82.5% of the respondents at a national level exhibited their anxiety about fine dust, and only 4.5% said: “not worried” with it. The fear with radioactivity, toxic chemicals or climate change was simply overwhelmed by PM.

This result is driven by an annually steady increase in fears of PM, as shown in several public polls.

[14] The group of income earner was sorted out just for comparison, with an assumption that they are more exposed to external stressors. Their score of negative affect is (slightly) higher than the whole group.

Figure 6. The Change of the Public perception about Environmental threats



Adjusted from: KOSTAT, 2018[15]

For instance, the ratio of those who speak out that they are (somewhat or strongly) worried about PM increased from 77.9% in 2014 to 79.3% in 2016 and eventually surpassed the 80% last year (**Table 4**). For Seoulites, the increase is greater and steeper. The level of anxiety, hovering around 81% between 2014 and 2016, jumped over 85% in 2018.

Table 4. Change of the public answer to "Would you say that you are worried about PM?" (%)

Level	Year	Not worried at all	Not very worried	Neutral	Somewhat worried	Strongly worried
Nation	2014	0.5	3.5	18.2	48.6	29.3
	2016	0.8	3.7	16.2	44.7	34.6
	2018	0.6	3.9	13.0	37.2	45.3
Seoul	2014	0.3	2.4	15.4	47.8	34.1
	2016	0.9	3.5	14.4	43.1	38.2
	2018	0.6	3.1	11.0	31.9	53.4

Adjusted from: KOSTAT, 2018

Is it because of the ceaseless increase in fine dust levels in Seoul? Not really. Confirming the average concentration of PM in Seoul, the annual average has been decreasing even slightly since 2016.

Table 5. The Change of PM concentration of Seoul

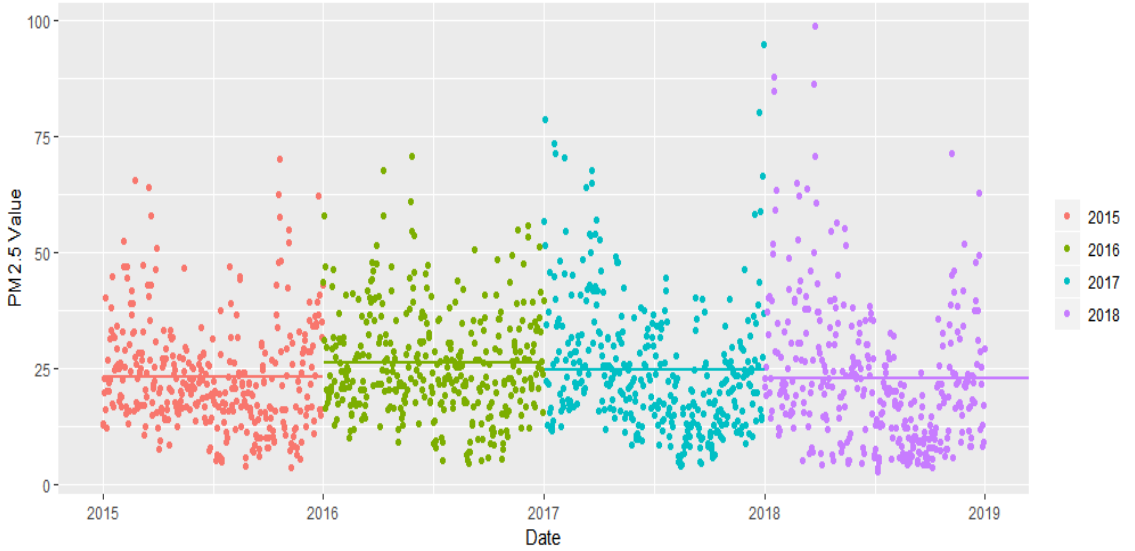
Annual average	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
2015	23	45
2016	26	48
2017	24	44
2018	23	40

Source: Author, based on Seoul Metropolitan government, 2019

[15] Sample: 39,000 respondents over 130year old in May 2018, nationwide.

The actual problem is that, especially in the case of $PM_{2.5,}$ which is considered most serious in terms of health risk, high levels of concentration has steadily risen (as breaking the highest) and the number of days with high concentration has mounted by years in Seoul (**Figure 7**). For this reason, the number of days of warning-alert to citizens according to a public system is increasing, and the PM_{10} alert was issued for the first time in 2018 (**Table 6**).

Figure 7. Daily concentrations of $PM_{2.5}$ from 2015 to 2018 (annual mean: horizontal line)



Source: Author, based on AirKorea, 2019

Figure 8. Daily concentrations of PM_{10} from 2015 to 2018 (annual mean: horizontal line)

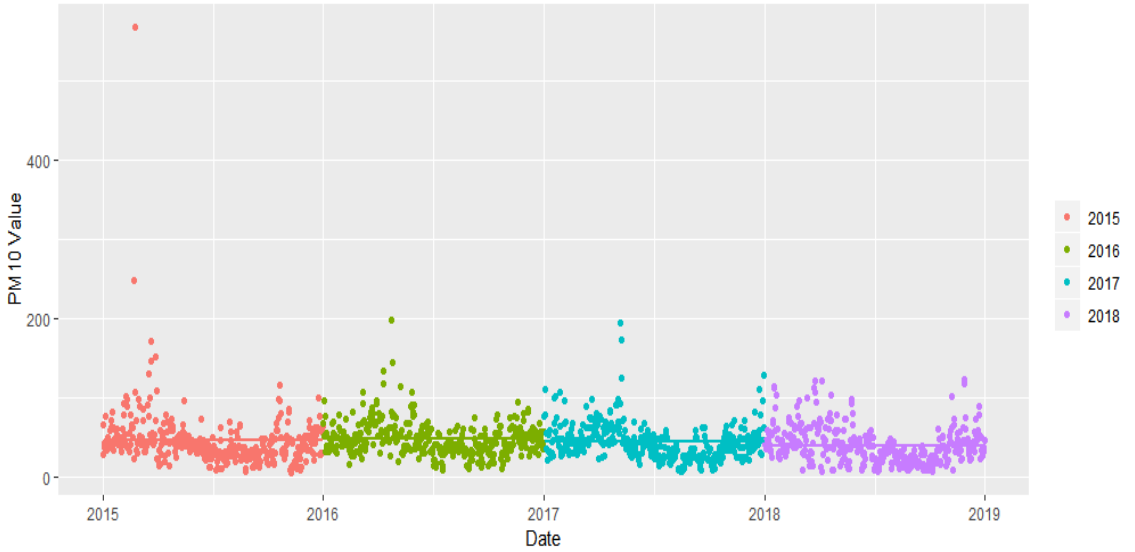


Table 6. The History of warning-alert about the danger of PM in Seoul

	$PM_{2.5}$		PM_{10}	
	Warning	Alert	Warning	Alert

	Number of Issues	Days of Issue	Number of Issues	Days of Issue	Number of Issues	Days of Issue	Number of Issues	Days of Issue
2013	1	1			1	2	0	0
2014	6	13	0	0	2	4	0	0
2015	6	8	0	0	3	5	0	0
2016	-	-	-	-	6	7	0	0
2017	5	10	0	0	6	10	0	0
2018	8	18	0	0	5	6	1	1

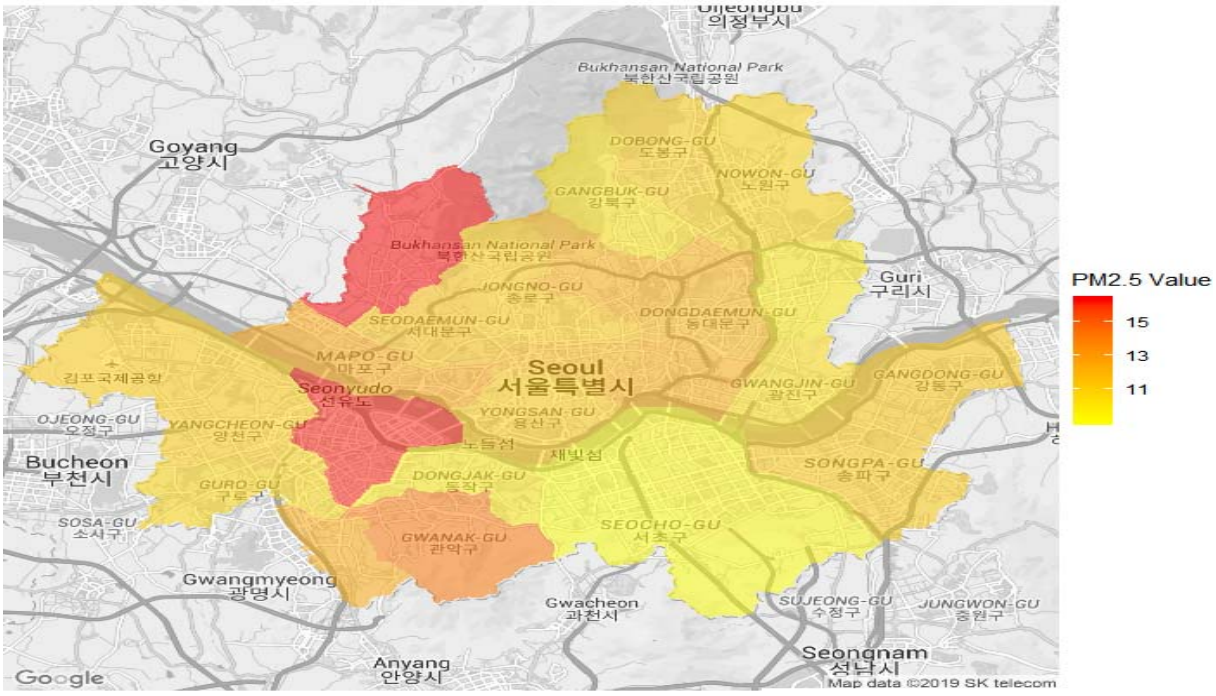
Adjusted from: Seoul metropolitan government

4.1.4_Cross-sectional trends of PM

The concentration of PM in this study is the independent variable that affects the psychological state of Seoulites, and the level of exposure to each individual is inevitably different. However, a district of Seoul (divided into 25 districts) is the most segmented unit having distinguishable readings of PM concentration. This data had to be merged by aligning with each district where each respondent dwells.

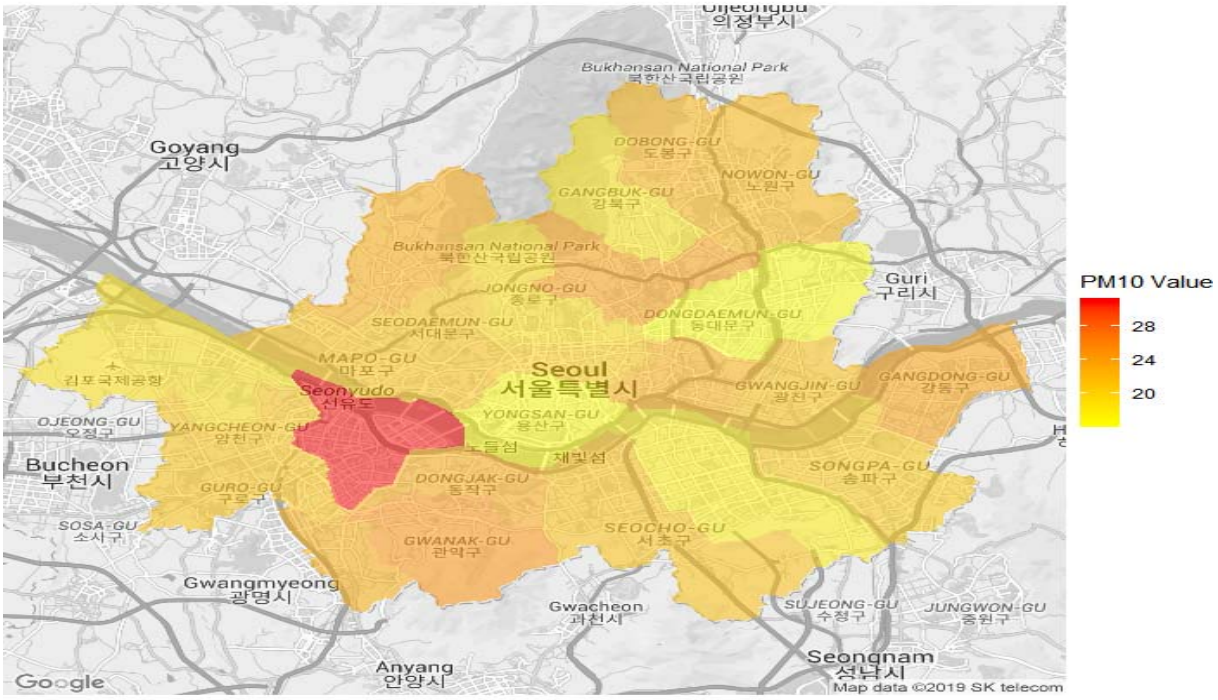
For example, the concentration of PM in Seoul in 2018 varied from 9 to 26.5 (average 17.48 $\mu g/m^3$) in $PM_{2.5}$, and from 16 to 46 (average 30.99 $\mu g/m^3$) in PM_{10}, and can be geographically visualized as depicted below.

Figure 9. $PM_{2.5}$ by 25 districts in Seoul in 2018



Source: Author (2019)

Figure 10. PM_{10} by 25 districts in Seoul in 2018



Source: Author (2019)

According to the average of PM concentration between August and September in 2018 which was used as a variable in line with when the Seoul survey was conducted, the level of $PM_{2.5}$ is high in order of Yeongdeungpo-gu ≒ Eunpyeong-gu (16.5 μg/m^3) > Gwanak-gu (13.5) > Mapo-gu ≒ Geumcheon-gu ≒ Seongbuk-gu ≒ Seongdong-gu (12.5 μg/m^3) and PM_{10} is high in the order of Yeongdeungpo-gu (30.5 μg/m^3) > Gwanak-gu (25) > Gangdong-gu ≒ Seongbuk-gu (24) > Eunpyeong-gu ≒ Geumcheon-gu (23.5 μg/m^3)[16].

In crude terms, the citizens in the districts of Yeongdeungpo, Gwanak, Seongbuk, and Geumcheon are breathing the most unsafe air by PM in Seoul.

4.1.5_Regional factors: the characteristics of Urban Settings in Seoul

As mentioned earlier, a total of seven regional factors are utilized in this analysis as control variables. They subsume population density, traffic accident rate, crime rate, medical expense, local tax revenue, greenness rate, and noise conflict.

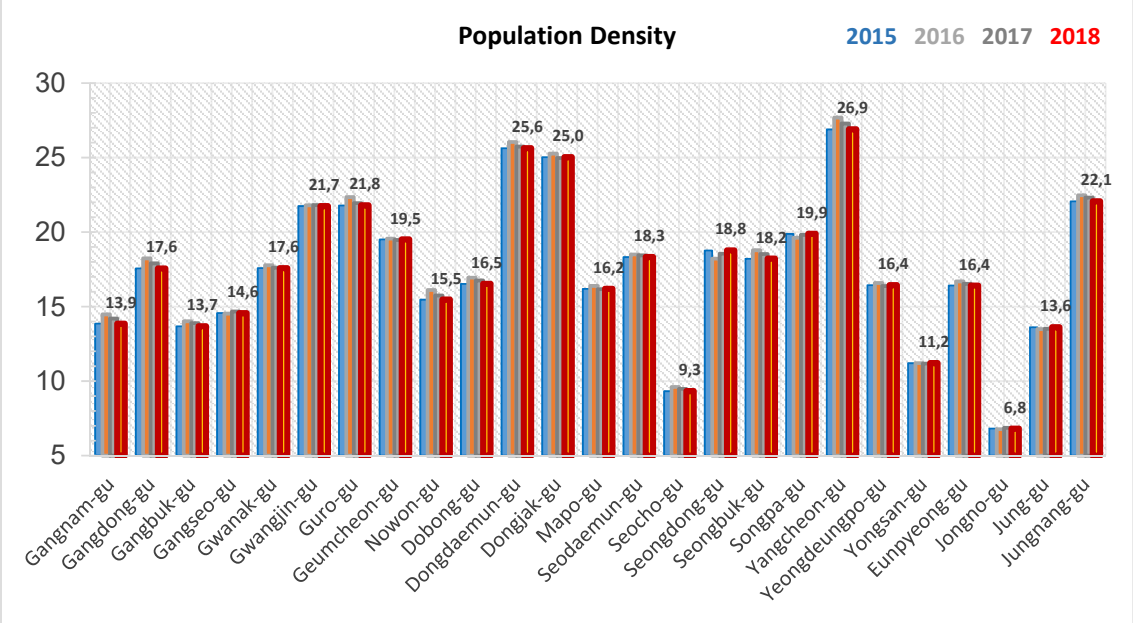
This data, as an indicator of urban environments, allows being compared by years and 25 districts in Seoul between 2015 and 2018. However, if the latest data of a factor is from 2017, the regional factors are set up with data from 2014 to 2017.

First of all, when it comes to population density, there has been no significant change since 2015 (**Figure 11**). the density in most of the districts is even slightly shrinking, except for

[16] Rounding off the numbers to the nearest hundredths

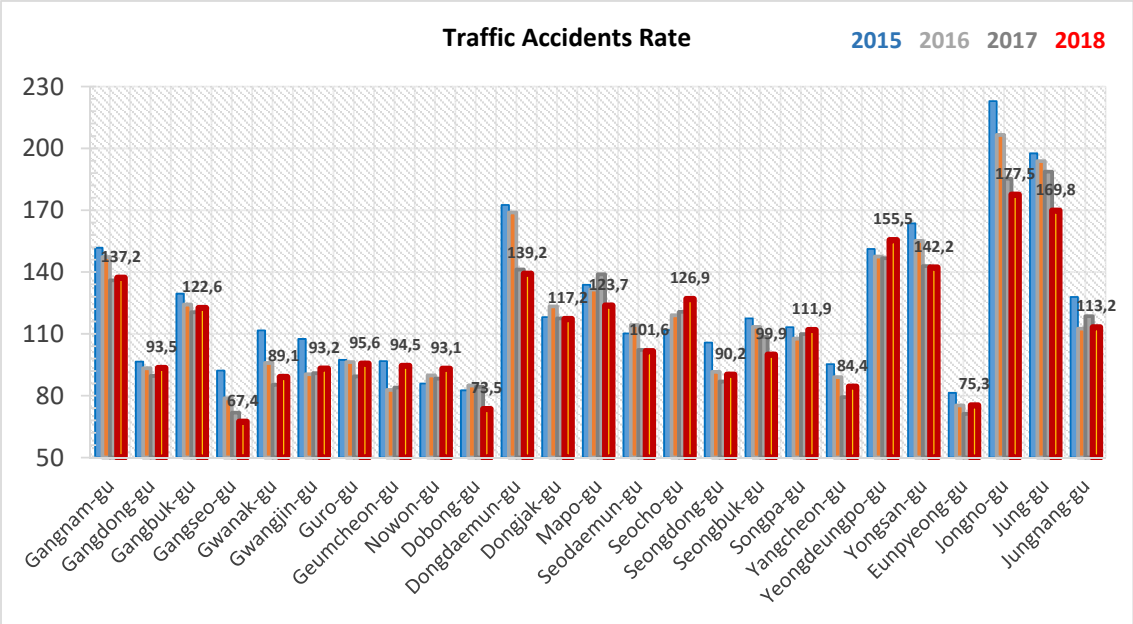
Seongdong-gu. The average of population density in 2018 is 17,920 people per cubic kilometer, which was raised by Yangcheon-gu (26,894) - Dongdaemun-gu (25,630) - Dongjak-gu (25,032), while dragged down by Jongno-gu (6,817), Seocho-gu (9,326) and Yongsan-gu (1,209).

Figure 11. Population density (1000 persons/km^3)



Source: Author (2019), based on the Seoul Metropolitan Government, KOSTAT, 2015-2018

Figure 12. Traffic accident rate (cases per 10,000 cars)

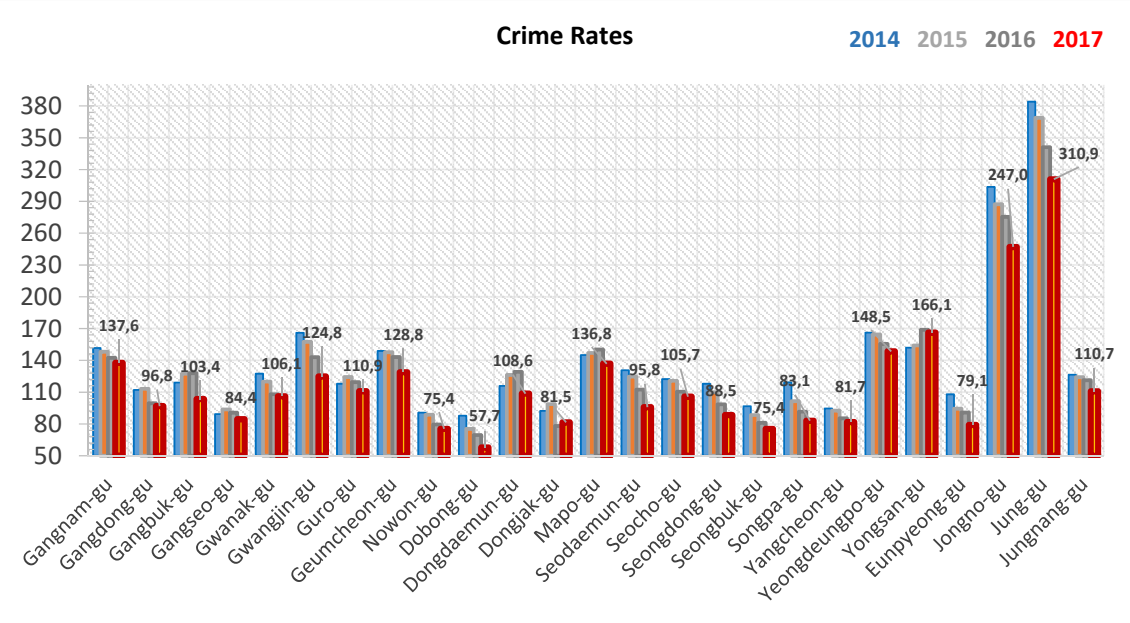


Source: Author (2019), based on the Seoul Metropolitan Police/government, 2015-2018

Although density was the lowest in Jongro-gu, the traffic accident rate was the highest at 177.5 (case per 10,000 cars) in 2018 as observed in **Figure 12**. Jung-gu came next with 169.8 cases and Yeongdeungpo-gu with 155.5 cases. It is 2.8 to 2.4 times higher than the lowest Gangseo-

gu (64.7) and Dobong-gu (73.5), and 1.6 to 1.4 times higher than the four-year average in Seoul (112.4).
The crime rate (cases per 10,000 persons) is the number of five kinds of violent crimes (murder, robbery, rape, larceny, and violence) divided by the population of each district and then multiplied by 10,000 (**Figure 13**).

Figure 13. Crime rate (cases per 10,000 persons)



Source: Author (2019), based on Seoul Metropolitan Police, 2014-2017

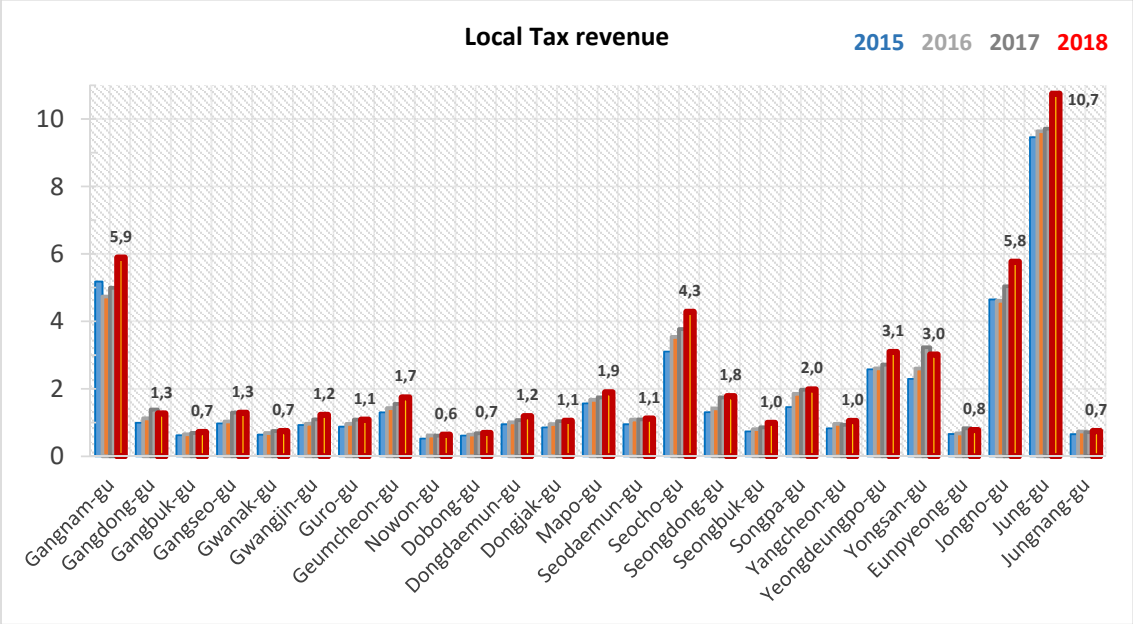
The latest four-year average of all the districts is 122.7 cases, with a total of 10 districts having a higher crime rate in 2017 than the average. Jung-gu (310.9), Jongno (247.0), Yongsan-gu (166.1), and Yeongdeungpo-gu (148.5) constitutes the top group, while Dobong-gu (57.7), Seongbuk-gu (75.4) and Nowon-gu (75.4) position at the bottom. Only Yongsan-gu experienced an increase in the crime rate from 2014, differently from the other districts.

As seen in **Figure 14**, the values of local tax revenue (per capita) is derived from the result that the total revenue of local tax is divided by each district population, geared to compare the level of tax revenue per capita levied by the 25 districts.

It indicates the independent financial capacity of each district, particularly which is proportional to the amount of each district's expenditure for welfare. It also may insinuate the level of citizens' tax burden, but in this context, it does not seem to be appropriate because the sum of local tax is largely dependent on how many corporates do their business in a district.

In the past four years, 25 districts in Seoul had seized 1516 euros (1.97 million won) to each resident on an annual average. In 2018, Jung-gu (10.75 million won), Gangnam-gu (5.89 million won), Jongno-gu (5.77 million won), and Seocho-gu (4.28 million won) is at the top group, while Nowon-gu (0.64 million won), Dobong-gu (0.69 million won), Gangbook-gu (0.72 million won) is at the bottom.

Figure 14. Local tax revenue (million won per person)

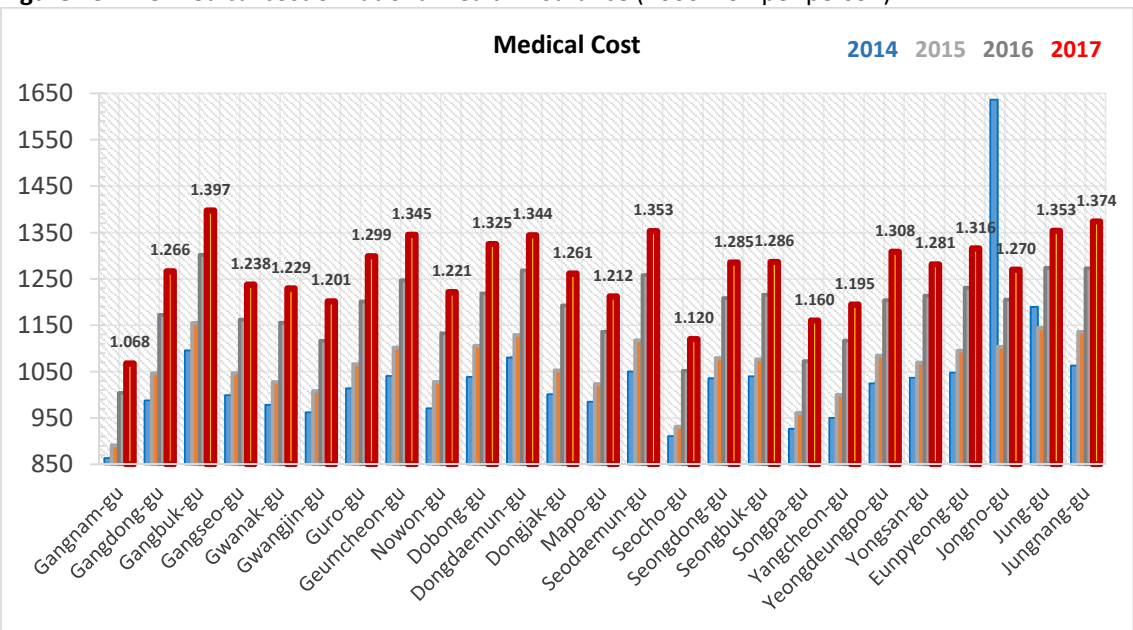


Source: Author (2019), based on the Seoul Metropolitan Government, 2015-2018

Medical cost per capita (**Figure 15**) was drawn from medical expenses every year paid by all the holders of the national health insurance, which can be interpreted that the greater the cost, the greater the demand for medical care, and the bigger the benefits of hospital use with national financial support.

The four-year average was 865.5 euros(1,125,100 won) per person, and in 2017, the latest figure was high in Gangbuk-gu (1,397,300 won), Jungnang-gu (1,373,600 won), Jung-gu (1,353,400 won), and was low in Gangnam-gu (10,67800 won), Seocho-gu (1,120 won), and Songpa-gu (1,160 won). Of note is that the latter three districts are considered representative wealthy regions in Seoul.

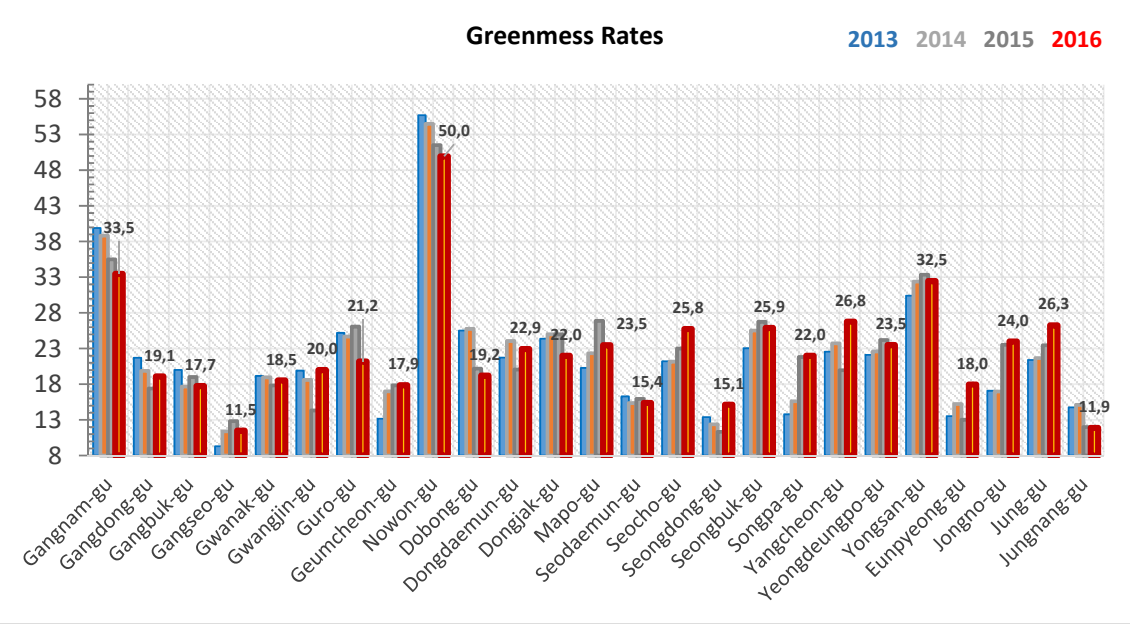
Figure 15. The Medical cost of national health insurance (1000 won per person)



Source: Author (2019), based on National Health Insurance Service, Seoul Metropolitan Government

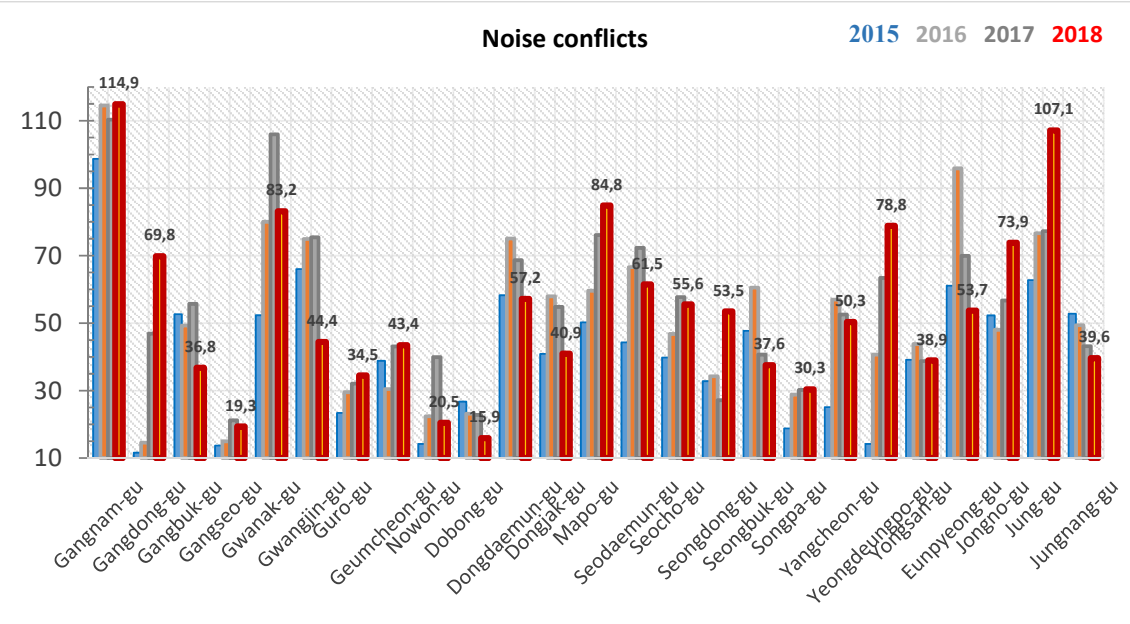
One of the urban settings is greenness rate, having environmental characteristics (**Figure 16**). It implies the rate at which the leaves of a plant are dotted within the visibility of a person standing at a certain point, as one of 'green index'. However, data in 2016 was the latest. The latest four-year average from 2016 was 22.29% in greenness rate. It was high in Nowon-gu (49.95%), Gangnam-gu (33.46%), Yongsan-gu (32.45%) but low in Gangseo-gu (11.5%), Jungnang-gu (11.88%), and Seongdong-gu (15.13%). All but Seocho, Songpa, Yangcheon, Eunpyeong, Jongno, and Jung-gu showed a decline. Nowon-gu and Guro-gu, which lost 5 to 6% points for the period, are examples. The rate of Nowon-gu has been lowered from 55.71% to 49.95% and it decreased from 26.1% to 21.2% Guro-gu.

Figure 16. Greenness rate (%)



Source: Author (2019), based on the Seoul Metropolitan Government, 2013-2016

Figure 17. Noise conflicts (cases per 1000 persons)



Source: Author (2019), based on the Seoul Metropolitan Government, 2015-2018

This variable, 'noise conflicts (per 10,000 persons)', is the number of complaints due to noise filed by the residents by the district (**Figure 17**). The total number of complaints is divided by the population of each district.

Noise, along with light (at night) and smell, has been considered one of the three major urban pollutants by the Seoul Metropolitan government. Among them, noise is the most notorious. If a noise complaint is received, the public workers directly are supposed to visit the site and tackle the conflicts.

The average number of complaints received over the past four years was 50 case (per 10,000 persons) in the whole districts. The number of conflicts caused by noise was high in Gangnam-gu (114.9), followed by Jung-gu (107.1), Mapo-gu (84.8), and Gwanak-gu (83.2). Conversely, Dobong-gu (15.9), Gangseo-gu (19.3), Nowon-gu (20.5), and Songpa-gu (30.3) were relatively free from the conflicts.

In sum, the districts of Gangnam, Seocho, and Songpa were visible, as to its fiscal capacity. These areas also have a commonality that medical costs are low as well.

Jongno-gu or Jung-gu with the least population and size enjoys a high tax revenue per capita (maybe) thanks to the development of business (as areas having many headquarters of global companies) but looks exposed to a high rate of crime or traffic accidents instead. Yeongdeungpo-gu and Yongsan-gu which show a high crime rate are also considered a district having many developed commercial areas. In the condition that the data of individual expenses for health cares are inaccessible, regional medical cost (per capita) was high in the districts of Gangbuk, Geumcheon, Seodaemun, Dongdaemun, Jungnang, Yeongdeungpo, and Eunpyeong. Several districts known to have a relatively high population of the elderly and low-income people were also included in this group. It is noteworthy that this group is also including some districts with high levels of fine dust.

In terms of environment, Nowon-gu and Gangnam-gu show high greenness rate. But Gangnam-gu suffers from noise conflicts, which are likely to result from the commercial areas, traffic volume, or continuous expansion or renovation of buildings.

4.2_General Analysis of Hierarchical Regression: PM and Negative Affectivity

Employing the literature review, the results of hierarchical regression with selected variables are shown in the following Table 6 and Table 7.

$PM_{2.5}$ increases both the level of stress and depression et al. of Seoulites. In the years from 2015 to 2018. The index of stress (on a 1-5 scale) rose by 0.0044 points for each 1 $\mu g/m^3$ increase in $PM_{2.5}$ and depression et al. (on a 1-5 scale) increases by 0.006 points (**Table 7**). By contrast, PM_{10} did not explain causality with stress within the significance level but augmented the score of depression et al. by 0.005 points for every 1 $\mu g/m^3$ increase of PM_{10} (**Table 8**).

Stress

The analysis of **Model 1** applying personal factors says that males have bigger stress than females, and married people get more stressed than those who do not. On the contrary, the result says that the greater happiness on financial status is, the less stress they get, and those

who own a house are less stressful than the group of tenants. Of interesting is that the coefficient of household income is close to zero, meaning little statistical significance and that the older people display lower stress than the younger.

In **Model 2**, where regional characteristics were factored, traffic accidents, crime rates, and medical expenses strengthened stress, while the higher index of local tax and greenness attribute to lower stress. The coefficient of population density was close to zero.

In **Model 3**, one can verify the additional impact of PM on stress beyond all the other control variables. However, unlike having verified the distinguishable increase of the value of the adjusted R^2 from Model 1 to Model 2, Model 3 shows a slight F change from Model 2.

Depression et al.

When it comes to the relation with depression et al., it is found that depression et al. decrease in line with the increase of age, happiness on financial status, and happiness on health. The effect of happiness about health is newly confirmed within the level of significance but the factor of house owning gets eliminated from the list of significant variables, which are different from the correlation between stress and PM.

Household income contributes to decreasing depression et al. but the coefficient was close to zero, which effect is little.

In the analysis of **Model 2**, whereas the index of local tax and greenness rate decrease depression et al., traffic accidents, crime rates, and medical expenses increase them.

It is noticeable that the exclusive influence of $PM_{2.5}$ and PM_{10} on depression et al by **Model 3** analysis is much clearer than the effect on stress, according to not only the coefficient but also the change of adjusted R^2 or F. In detail, Model 3 brings about increased adjusted R^2 by 0.2% ($PM_{2.5}$) and by 0.4% (PM_{10}) respectively from Model 2.

Table 7. Hierarchical regression: Stress

Stress			**Model 1**				**Model 2**				**Model 3** ($PM_{2.5}$)				**Model 3** (PM_{10})			
			B	Beta	t	Sig.	B	Beta	t	Sig.	B	Beta	t	Sig.	B	Beta	t	Sig.
Independent		Particulate Matter									0.0044	0.019	5.042	0	0.001	0.006	1.615	0.1063
Control	Local factors	Population Density					-2.96E-06	-0.013	-4.625	0	-2.83E-06	-0.012	-4.407	0	-2.95E-06	-0.013	-4.594	0
		Traffic Accidents					0.001	0.016	4.317	0	0.0005	0.013	3.425	0.0006	0.0005	0.015	3.964	0.0001
		Crime Rate					0.001	0.067	14.353	0	0.0012	0.057	11.203	0	0.0014	0.065	13.281	0
		Medical Cost					-0.0003	-0.039	-15.762	0	-0.0002	-0.026	-6.985	0	-0.0003	-0.034	-8.737	0
		Local Tax					-0.052	-0.086	-19.27	0	-0.0466	-0.075	-14.992	0	-0.0509	-0.083	-17.598	0
		Greenness Rate					-0.001	-0.005	-2.102	0.0355	-0.0003	-0.003	-1.091	0.2752	-0.0005	-0.004	-1.59	0.1117
		Noise Conflicts					0.0001	0.002	0.901	0.3678	0.0001	0.003	1.108	0.2679	0.0001	0.003	1.154	0.2487
	Individual factors	Gender	0.0232	0.011	4.611	0	0.0222	0.01	4.423	0	0.0221	0.01	4.391	0	0.0222	0.01	4.413	0
		Age	-0.0053	-0.083	-28.727	0	-0.0049	-0.076	-26.177	0	-0.0049	-0.076	-26.066	0	-0.0049	-0.076	-26.146	0
		Marital Status	0.0385	0.017	6.478	0	0.0332	0.015	5.592	0	0.0334	0.015	5.628	0	0.0333	0.015	5.605	0
		House Owning	-0.0239	-0.011	-4.58	0	-0.0175	-0.008	-3.347	0.0008	-0.0183	-0.008	-3.488	0.0005	-0.0178	-0.008	-3.396	0.0007
		Religion	0.0028	0.001	0.554	0.5796	0.0014	0.001	0.278	0.7807	0.0018	0.001	0.322	0.7474	0.0015	0.001	0.293	0.7696
		Happy with Health	0.0009	0.001	0.448	0.6539	0.0024	0.003	1.18	0.2381	0.0024	0.003	1.217	0.2236	0.0024	0.003	1.182	0.2371
		Happy with Finance	-0.0446	-0.063	-23.802	0	-0.0448	-0.064	-23.955	0	-0.0450	-0.064	-24.06	0	-0.0448	-0.064	-23.964	0
		Income (Household)	0.0001	0.022	9.063	0	6.71E-05	0.015	5.946	0	7.05E-05	0.016	6.234	0	6.75E-05	0.015	5.979	0
		(Constant)	3.958		211.97	0	4.22		118.897	0	4.033		78.61	0	4.15		74.138	0
		R Square	0.01				0.014				0.014				0.014			
		Adjusted R Square	0.01				0.014				0.014				0.014			
		R Square Change	0.01				0.004				0				0			
		F Change	232.54				92.889				25.427				2.608			

Green Grey: P < 0.05, P < 0.01, **Dark Grey**: P < 0.001

Source: Author, 2019

Table 8. Hierarchical regression: Depression et al.[17] (including irritation, enervation, pessimism)

Depression et al.			**Model 1**				**Model 2**				**Model 3** ($PM_{2.5}$)				**Model 3** (PM_{10})			
			B	Beta	t	Sig.	B	Beta	t	Sig.	B	Beta	t	Sig.	B	Beta	t	Sig.
Independent		Particulate Matter									0.006	0.06	17.901	0	0.005	0.086	23.73	0
Control	Local factors	Population Density					-4.50E-06	-0.064	-20.307	0	-4.49E-06	-0.064	-20.264	0	-4.59E-06	-0.065	-20.731	0
		Traffic Accidents					0.0005	0.05	11.614	0	0.0004	0.034	7.766	0	0.0003	0.027	6.066	0
		Crime Rate					0.0011	0.167	29.096	0	0.001	0.143	24.249	0	0.001	0.151	26.21	0
		Medical Cost					-0.0005	-0.171	-56.461	0	-0.0004	-0.135	-37.045	0	-0.0003	-0.113	-29.008	0
		Local Tax					-0.038	-0.194	-35.965	0	-0.032	-0.165	-29.41	0	-0.033	-0.173	-31.603	0
		Greenness Rate					-0.002	-0.046	-15.688	0	-0.001	-0.036	-12.25	0	-0.001	-0.025	-8.038	0
		Noise Conflicts					0.0001	-0.008	-2.673	0.0075	-5.31E-05	-0.004	-1.387	0.1655	9.65E-05	0.007	2.469	0.0136
	Individual factors	Gender	-0.002	-0.003	-1.096	0.2732	-0.002	-0.004	-1.337	0.1812	-0.003	-0.004	-1.449	0.1473	-0.003	-0.004	-1.465	0.1429
		Age	-0.001	-0.05	-15.024	0	-0.001	-0.032	-9.852	0	-0.001	-0.03	-9.126	0	-0.001	-0.03	-9.005	0
		Marital Status	0.006	0.009	2.985	0.0028	0.001	0.001	0.451	0.6519	0.001	0.001	0.269	0.7878	0.0005	0.001	0.227	0.8201
		House Owning	-0.003	-0.005	-1.692	0.0907	0.004	0.006	2.063	0.0391	0.003	0.004	1.619	0.1054	0.002	0.004	1.363	0.1728
		Religion	-0.003	-0.004	-1.503	0.1329	-0.004	-0.006	-2.147	0.0318	-0.003	-0.005	-1.805	0.0711	-0.003	-0.005	-1.723	0.0849
		Happy with Health	-0.009	-0.043	-13.562	0	-0.009	-0.042	-13.355	0	-0.009	-0.042	-13.39	0	-0.009	-0.043	-13.617	0
		Happy with Finance	-0.003	-0.015	-4.962	0	-0.002	-0.011	-3.64	0.0003	-0.002	-0.011	-3.67	0.0002	-0.002	-0.01	-3.338	0.0008
		Income (Household)	-2.33E-05	-0.018	-6.268	0	-6.97E-05	-0.053	-18.455	0	-6.65E-05	-0.05	-17.628	0	-6.96E-05	-0.053	-18.485	0
		(Constant)	1.031		158.573	0	1.56		120.422	0	1.35		77.299	0	1.225		63.986	0
		R Square	0.004				0.033				0.035				0.037			
		Adjusted R Square	0.004				0.033				0.035				0.037			
		R Square Change	0.004				0.029				0.002				0.004			
		F Change	64.235				578.098				320.445				563.135			

Green Grey: P < 0.05, P < 0.01, **Dark Grey**: P < 0.001

Source: Author, 2019

[17] Logged values of depression et al. are applied for higher normality.

4.2.1_Discussion of the Result

In summary, in the years between 2015 and 2018, $PM_{2.5}$ and PM_{10} have provided a clear effect on the formation of stress and depression of Seoulites, by increasing the score of those sentiments by 0.004~0.006 points out of 5 for every 1 $\mu g/m^3$ increase of its concentration. PM_{10} was out of the level of significance only in the correlation with stress. And this conclusion is consistently confirmed in the analysis results as well when the original data of depression et al., instead of logged value, is applied as the dependent variable.

Now, it needs to understand the difference of standardized coefficient between variables which can tell each influence of a variable on negative affectivity, as sorted in **Table 9** and **Table 10.**

Table 9. $PM_{2.5}$ and Negative Affects: In order of Beta value of Model 3

Variables		Stress			Depression et al.[18]		
		Stronger	Weaker	Beta (P-value)	Stronger	Weaker	Beta (P-value)
$PM_{2.5}$		Higher	Lower	0.019(<0.001)	Higher	Lower	0.060(<0.001)
Local factors	Local tax	Less	More	-0.075(<0.001)	Less	More	-0.165(<0.001)
	Crime	Higher	Lower	0.057(<0.001)	Higher	Lower	0.143(<0.001)
	Medical cost	Less	Higher	-0.026(<0.001)	Less	More	-0.135(<0.001)
	Greenness	-	-	(p>0.05)	Lower	Higher	-0.036(<0.001)
	Traffic accident	Higher	Lower	0.013(<0.001).	Higher	Lower	0.034(<0.001)
Individual factors	Age	Younger	Older	-0.076(<0.001)	Younger	Older	-0.030(<0.001)
	Financial happiness	Happier	Unhappier	-0.064(<0.001)	Happier	Unhappier	-0.011(<0.001)
	Health happiness	-	-	(p>0.05)	Unhappier	Happier	-0.042(<0.001)
	Marriage	Married	Not Married	0.015(<0.001)	-	-	(p>0.05)
	Gender	Male	Female	0.010(<0.001)	-	-	(p>0.05)
	House	tenants	Owner	-0.008(<0.001)	-	-	(p>0.05)
	Religion	-	-	(P>0.05)			(P>0.05)
	B≒0	Population, Income			Population Income		
	Income	Higher	Lower	B≒0(<0.001)	Lower	Higher	B≒0(<0.001)
	Population	Lower	Higher	B≒0(<0.001)	Lower	Higher	B≒0(<0.001)
	P>0.05	Green, noise, religion, health happiness			Noise, house, gender marriage religion		

Concerning $PM_{2.5}$ (**Table 9**), stress was more decreased in line with the increase of one unit of age > local tax revenue (per capita) > happiness on financial status –medical cost based on the

[18] Logged values of depression et al. are applied for higher normality.

national health insurance (in order). Instead, it was more increased in proportion to the growth of one unit of crime rate > $PM_{2.5}$ > marital status (not married people) > traffic accident (in order).

In case of depression et al., the order of the variables leading to '+' relationship is crime rate > $PM_{2.5}$ > traffic accident, and the order of the variables having '-' relationship is local tax revenue > medical cost > happiness on health > greenness rate > age > happiness on financial status.

When it comes to PM_{10} (**Table 10**), the variables decreasing stress follow the order: local tax revenue > age > happiness on financial status > medical cost > house owning in terms of beta values, while the variables increasing stress are: crime rate > traffic accident > marital status.

Depression et al. were more decreased by the following variables: local tax revenue > medical cost > happiness on health > age > greenness rate > happiness on financial status (in order) but more increased by crime rate > PM_{10} > traffic accident (in order).

Table 10. PM_{10} and Negative Affects: In order of Beta value of Model 3

Variables		Stress			Depression et al.[19]		
		Stronger	Weaker	Beta (P-value)	Stronger	Weaker	Beta (P-value)
PM_{10}		Higher	Lower	(P>0.05)	Higher	Lower	0.086(<0.001)
Local factors	Local tax	Less	More	-0.083(<0.001)	Less	More	-0.173(<0.001)
	Crime	Higher	Lower	0.065(<0.001)	Higher	Lower	0.151(<0.001)
	Medical cost	Less	Higher	-0.034(<0.001)	Less	More	-0.113(<0.001)
	Traffic accident	Higher	Lower	0.015(<0.001).	Higher	Lower	0.027(<0.001)
	green	-	-	(p>0.05)	Lower	Higher	-0.025(<0.001)
	Noise	-	-	(P>0.05)	More	Less	B≒0(<0.05)
Individual factors	Age	Younger	Older	-0.076(<0.001)	Younger	Older	-0.030(<0.001)
	Financial happiness	Unhappier	happier	-0.064(<0.001)	Unhappier	happier	-0.010(<0.001)
	Health happiness			(P>0.05)	unhappier	happier	-0.043(<0.001)
	Marriage	Married	Not Married	0.015(<0.001)	-	-	(p>0.05)
	Gender	Male	Female	0.010(<0.001)	-	-	(p>0.05)
	House	tenants	owner	-0.008<0.001)	-	-	(p>0.05)
	Income	Higher	Lower	B≒0(<0.001)	Lower	Higher	B≒0(<0.001)

[19] Logged values of depression et al. are applied for higher normality.

	B≒0	Population, Income			Population Income		
	Income	Higher	Lower	B≒0(<0.001)	Lower	Higher	B≒0(<0.001)
	Population	Lower	Higher	B≒0(<0.001)	Lower	Higher	B≒0(<0.001)
	P>0.05	Green, noise, religion, health happiness			Noise, gender Marriage House, religion		

Of note is that the impact of $PM_{2.5}$ on stress was stronger than that of PM_{10}. Accordingly, it looks natural to face the result that the effect of the other external variables in the model which PM_{10} is factored becomes relatively greater than that in the model with $PM_{2.5}$. For instance, the standardized coefficient of 'local tax revenue' was 0.083 (crime rate: 0.065) in the model containing PM_{10}, but it decreased to 0.075 (crime rate: 0.057) in the model with $PM_{2.5}$.

Besides, it is also noteworthy; that happiness about health, greenness rate, which was not within the significance level in the correlation with stress, decreases depression et al. within the significance level; that household income eases depression et al., differently from the result of the stress model.

Given the fact that there are even studies that suggest stress develops into depression (Hammen, 2005), it can be assumed that stress is likely to affect the development of more specified negative emotions, such as depression toward some groups. However, it is not examined further in this study, hence the need to be analyzed more in any next studies.

When it comes to R^2 which is considered meaningful in a result of hierarchical regression, it is verified R^2's increases due to PM but the changes are considerably faint in the models of stress and it is relatively clear in the depression models. So, in order that the exclusive influence of PM through multilevel analysis can be verified more closely, it creates a comparison model that PM is treated as a solely external independent variable by removing all the other external factors from the original models in Table 7 and 8.
In this new model for comparison, PM's exclusive influence has been confirmed far more clearly than in the original model, as seen in **Table 11**.

For example, R^2 value has increased from 1% (Model 1' only with personal factors) to 1.3% (Model 3' adding $PM_{2.5}$) and 1.2% (Model 3' adding PM_{10}) in the analysis on stress and it also increases from 0.4% to 2.5% in depression analysis. In other words, PM contributes to exclusively explaining the correlation with negative affectivity regardless of the impacts of the other variables.

Table 11. The Change of adjusted R^2 by models

Variables		Stress			Depression et al.[20]		
		Personal	+Regional	+PM	Personal	+Regional	+PM
$PM_{2.5}$	Original	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	Adjusted R^2	0.010	0.014	0.014	0.004	0.033	0.035

[20] Logged values of depression et al. are applied for higher normality.

	Comparison	Model 1'		Model 3'	Model 1'		Model 3'
	Adjusted R^2	0.010		0.013	0.004		0.025
PM_{10}	Original	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	Adjusted R^2	0.010	0.014	0.014 (P>0.05)[21]	0.004	0.033	0.037
	Comparison	Model 1'		Model 3'	Model 1'		Model 3'
	Adjusted R^2	0.010		0.012 (P<0.001)	0.004		0.025

Source: Author, 2019

4.3_Primary Qualitative Analysis

From 21 July to 8 August, 24 respondents answered a total of 13 questions. The questionnaire was designed to be answered objectively in line with Likert scale, and then to be subjectively written about reasons or any other opinions by respondents. The characteristics of the respondents are as follows.

Table 12. The Traits of the respondents

By field of specialization

Respondents	Number	Ratio
Environment (Engineering)	10	41.7%
Medicine (phychiatry:1)	4	16.7%
Public Health science	3	12.5%
Chemical Engineering	2	8.3%
Lawyer	2	8.3%
Regional study	1	4.2%
Transportation	1	4.2%
Resource Engineering	1	4.2%
Total	24	100.0%

By occupation (workplace)

Respondents	Number	Ratio
Professor of Univ.	7	29.2%
Doctor & Professor	4	16.7%
Researcher of Institute (Local government-funded)	4	16.7%
General Secretary of NGO	4	16.7%
Researcher of Institute (Cent'l government-funded)	3	12.5%
International NPO	1	4.2%
CEO of private enterprise	1	4.2%
Total	24	100.0%

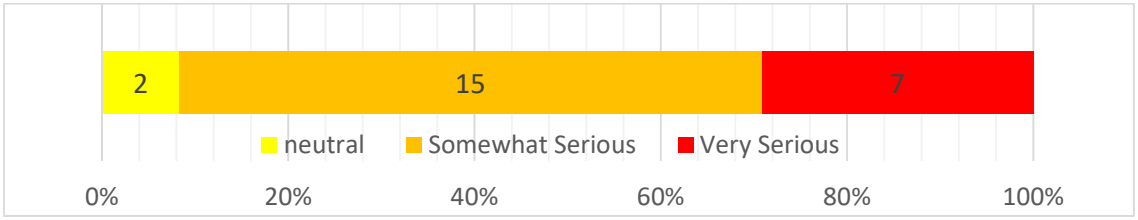
4.3.1_ General Analysis: PM and Negative Affectivity

The first question of the questionnaire was geared to figure out the experts' perception of the general severity of fine dust in Seoul, which allow comparison with the public's perception as following.

As the answer is seen in the bar graph (**Figure 18**), 91.6% of the respondents answered that the problem of PM in South Korea is (somewhat or very) serious, with 29.2% of them mentioning "very serious". Only two respondents (8.3%) take it "neutral". There was no answer with "not very serious" or "not serious at all".

Figure 18. How serious would you say the problem of fine dust in Seoul is?

[21] P value was also changed between the original model and reference model. All the other P values are within the level of significance, as valid as in stress.

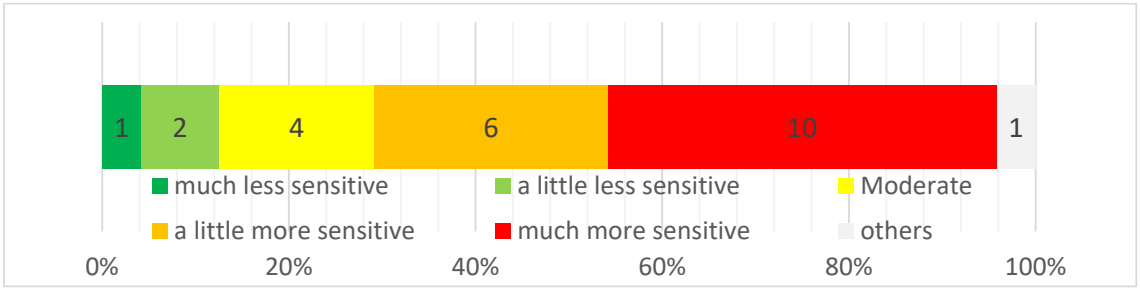


Source: Author, 2019

The ratio of the respondents agreeing "serious" is generally lower than in the surveys for the public. For example, in a survey conducted by a thinktank of a political party in March 2018, 94% answered that it is serious, with 70.8% saying "very serious".

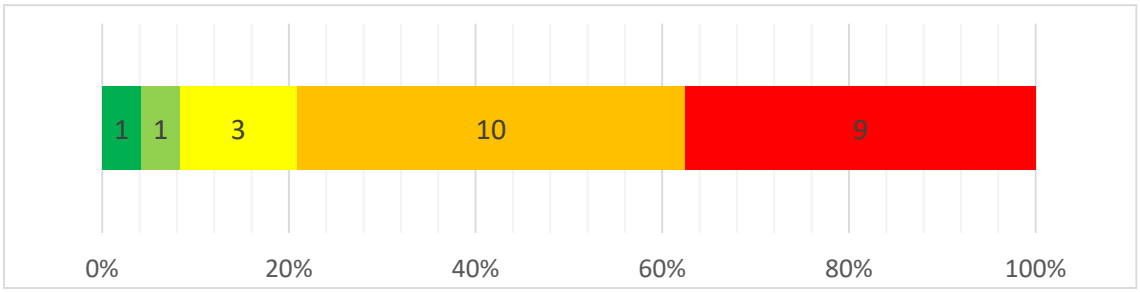
This gap is somewhat met with a pattern of answers to the following question (**Figure 19, 20**).

Figure 19. Would you say that Koreans' reactions to fine dust this year are sensitive or insensitive in comparison to the actual PM level?



Source: Author, 2019

Figure 20. Would you say that Koreans' reactions to fine dust this year in comparison to the actual PM level has become more or less sensitive than 1~2 year ago?[22]



Source: Author, 2019

66.7% of the respondents said that although Korea's PM is serious, Koreans' response to PM is (somewhat or very) excessive compared to the actual severity. And 79.2% of them believe that Koreans' response to PM has become more excessive to the actual severity than 1~2 year ago.

On the other hand, three experts (12.5%) responded that people are insensitive to the PM matter, and two said people became more insensitive than before.

Among the reasons cited by "serious" group, the words such as "distribution of misinformation about PM", "too many reports by media", "information overload on PM compared to other threatening factors", "distrust of the government", "the growing awareness on environment" were frequently or remarkably repeated.

[22] The options for choice are as same as Figure 16.

▷Doctor (male): “much less sensitive”

At first, they are careful, but after a while, they give up or forget about the severity.

“a little more insensitive”: NGO (male)◁

They use cars a lot, don't use bicycles, don't change the cooking recipe causing PM, and don't protest to the government (that doesn’t take enough actions).

▷Professor (public health, male):

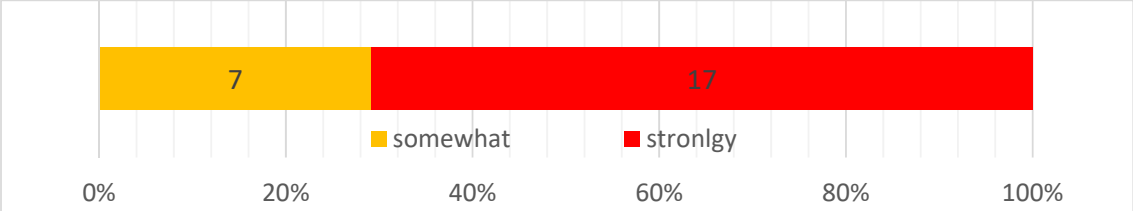
The government should have informed the scientific meaning of PM as a carcinogen but it is not enough. Relying solely on the media, people can be very sensitive. And it is also because we have yet to know the exact reasons on PM's severity and government's measures are not obvious.

“Much more sensitive”

: Professor (doctor, female)◁

People react sensitively because they think it is someone else’s fault rather than theirs. It results partially from that the media emphasizes China's responsibility to our PM matter. Although a considerable amount of PM results from domestic sectors, people don’t want to think about that.

Figure 21. How much would you say fine dust affects the usual happiness of Seoulites, or not?



Source: Author, 2019

Here is no respondent denying the effect of PM on happiness (**Figure 21**). All the experts agree unanimously that PM affects individual happiness, with 7 out of 10 who go for ‘strongly impactive’.

For reasons, “health threats”, “restrictions on activity”, “augmentation of anxiety”, “the cost for health care”, as well as “strengthened interest in PM” were frequently or remarkably mentioned.

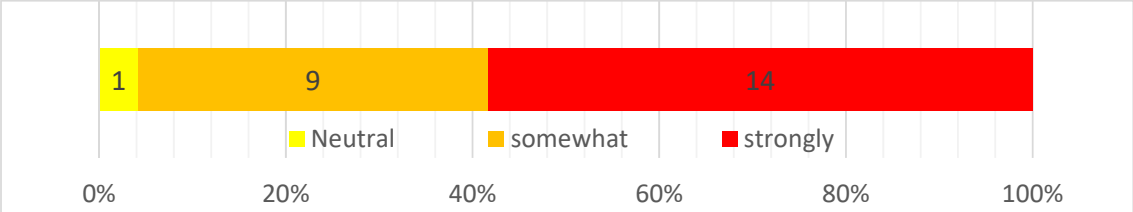
▷NGO (male): “Strongly affect”

The occurrence of health problems and various costs. inconvenient life, a threat to the quality of life.

“Strongly affect”: Professor (doctor, male)◁

First of all, it has become a top environmental issue felt by citizens, as seen in many polls. And although it is said that PM levels have been improved over the last 20 years, the number of days of high concentrations has increased in recent years.

Figure 22. How much would you say fine dust affects negative affectivity of Seoulites, such as stress, depression, or not?



Source: Author, 2019

95.8% of them agreed that PM affects the development of stress and depression and 6 out of 10 experts (58.3%) said it makes a greatly serious impact (**Figure 22**). Only one respondent (researcher, male) went for 'neutral' as explaining that it is hard to generalize because of different effect by time.

While the reasons quoted are quite akin to No.4 such as "stress from activity constraints" "health concerns" and so on, more political and social viewpoints were added, "complaints about government policies (efficacy on measures)", "lethargy from lack of solutions", "excessive media news reports", and "fear amplified by false information or excessive information on PM's severity".

▷Researcher (female): "somewhat affect"

Stress by a restriction of activity, exaggerated anxiety regarding PM's health effects. A misconception that PM level is the worst nowadays, or that there is nothing that I can do but to blame China.

"strongly affect": Professor (health science, male)◁

The lethargy that they think fine dust cannot be solved with individual competence. limitations on how to respond to the PM issue.

▷Professor (public health, male): "Strongly affect"

Fine dust acts as a significant amplifier to stresses caused by other social and economic problems.

"Strongly affect": Researcher (male)◁

carcinogens, heavy metal pollution, personal cost, incompetence of the government, bias, no obvious solutions.

4.4_Specific Analysis of Stress Inequality caused by PM

4.4.1_Qualitative Analysis: the expert group

Despite the highly perceived severity of PM as a specialist, only half (54.2 percent) of experts reported their 'actual' experience of stress or depression caused by PM in last six months[23].

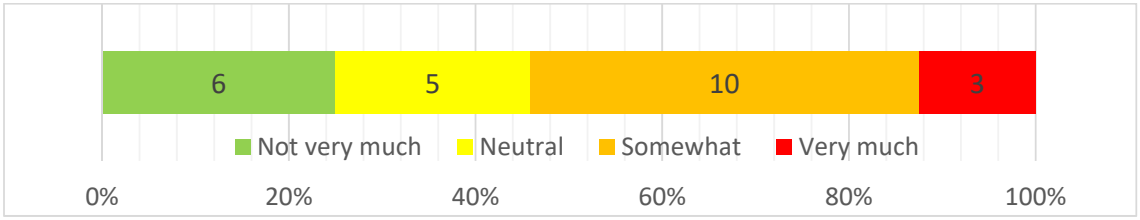
Of course, it is not confirmed whether this rate is higher or lower than the ordinary group. As examined in chapter 2, PM is likely to be more threatening to the health of the vulnerable, mostly economic or ethnic minorities, in society (Miranda, 2011).

However, the meanings of 'the vulnerable' in terms of mental or psychological health seem to be more diverse. This is because how well to be resilient to negative affect caused by exterior threats will be varied by not only physical assets but also psychological and cognitive assets, even under the same atmospheric environment. Moreover, risk perception is affected by socio-political or economic opportunities (Bickerstaff, 2004).

This is why and how so-called 'stress inequality' occurs, and it is empirically supported by how the expert respondents are explaining their own experiences in **Figure 23**.

Figure 23. Have you experienced any stress or depression due to Particulate Matter in the last six months?

[23] It includes March and April in 2019 when setting various new records about the highest PM concentration.



Source: Author, 2019

▷Professor (environment, female): "Not very much"

I have not been affected in recent years because I have been aware of the harmfulness of PM by long study.

"Neutral": NGO (transport, male)◁

I know that there is a low possibility of acute health deterioration except when a high concentration of PM is quite maintained.

▷Professor (public health, male): "Not very much"

Personally, I think it has a small health impact on me.

"Neutral": Professor (doctor, male)◁

I am in the position of objectively looking at and studying fine dust problems.

▷Lawyer (female): "Somewhat"

I feel depressed with doubt whether the problem of PM can be improved since experiencing high concentration in March.

"Somewhat": Professor (doctor, male)◁

Worries about deteriorating health, concerns about child health.

Three respondents who have reported a strong experience with negative affectivity caused by fine dust give explanation such as "being depressed because it gets blurred outside and because I should stay inside, being worried about respiratory illnesses" (Doctor, male), "uncomfortable to breathe freely, health anxiety, having a sense of despair because fine dust seems to be a daily life's stressor"(International NPO, female), "health deterioration, difficulty breathing, (low) visibility, (threat to) quality of life" (NGO, male).

Despite a relatively low rate of experience of stress caused by fine dust, 21 respondents of them (87.5%) answered that there would be the particularly vulnerable groups existing to negative affectivity triggered by fine dust. Analyzing the frequency of keywords (based on morpheme) from their answers, it comes out with this form of a word cloud **(Figure 24, 25).**

Who are particularly vulnerable? **(Figure 24)**

Their answers are disassembled by these words: Children (8 times repeated) = elderly (8) > people (5) > patients (5) > respiratory (4) > vulnerable (4) > sensitive (3) > infirm (3) > existing (2) > family (2) > socioeconomically = environmentalist = cardiovascular = low-income = underlying (disease) = resentment = housewife = question = respond = outside workers = parents = problem = without = Mother = policy makers = taking = strong = social = mental = little asset = member = female = asset = study = group = find = dust = care = know (1)

Why are they vulnerable? **(Figure 25)**

Their answers are disassembled by these words: Disease = health = vulnerable = children (4 times repeated) = measures = sense = fine dust = sensitive (3) > proper = affordable =

susceptible = deprivation = experience = exposure = damage = fact = lack = concerns (2) > responsibilities = disease-causing = concentrations = socioeconomic deterioration = psychological = non-judgmental = desperation = respiratory = carcinogens = possibility = information = substances = protection = hazardous = expensive = pollution = emotional = conflict = purchase = solution = research = physical = response = question = existing = worsened = general = foetuses = elderly = reality = improve = threats = limited = already = becomes = chronic = causing = medical = outdoor worker = without = fear = effect = little = masks = avoid = media = poor (1)[24]

Figure 24. Who is particularly vulnerable to negative affectivity caused by PM?

Figure 25. Why are they vulnerable to negative affectivity caused by PM?

[24] A few morphemes for the group mentioned one time have been omitted.

Many of the experts pointed out that the elderly and children, or their families, as the most vulnerable group. And those who are already suffering from basal diseases, an outdoor worker, mothers and women raising children were also mentioned.

Of note is that answers in a way of tautology are frequent. In other words, an answer like "those who are particularly sensitive to fine dust will be vulnerable to stress caused by PM" is the case, which seems to emphasize that the vulnerability to PM may vary not only depending on physical assets but also psychological assets or resilience to external stressors.

This pattern is also confirmed in the answer to reasons. But to this question, the experts tended to additionally point out stress or worries about practical and specific health impact such as cancer, respiratory disease. Moreover, some experts added invisible social-psychological causes such as social deprivation (e.g., “people who cannot afford to purchase high-priced fine dust protection masks”), or a kind of learned helplessness in tandem with frustration or fear (e.g., “people who think there seems no solution to PM”).

▷Professor (Doctor, male)

Little study existing for this question, but maybe the sensitive people to fine dust.

NGO (public health, male)◁

An outdoor worker who can't avoid fine dust or people without measures.

▷Professor (doctor, female)

The poor people experience not only a general sense of socioeconomic deprivation but also a sense of deprivation that they cannot afford to purchase expensive fine dust protection masks.

Professor (doctor, male)◁

Children, fetuses, and the elderly are more vulnerable to damage of PM, but they are not well aware of it.

4.5_Quantitative Analysis: Stress inequality

As the experts pointed out, does it exist, namely those who are particularly vulnerable to negative affect caused by fine dust?

In order that ‘stress inequality’ can be explored -in other words, if it exists and then how it is exhibited in society, and so on-, a setup of conditions including grouping for comparison is required.

In this study, stress inequality will be examined only by analyzing the relationship between $PM_{2.5}$ and stress. It is for better simplicity of comparison but it took into consideration that $PM_{2.5}$ is more serious pollutant than PM_{10} and depression can be affected by stress as following the relation with a parameter.

Over 170,000 samples in this data matrix are regrouped by household income, education level, and job.

4.5.1_Description of Samples

Household Income

Household income was intended to be classified by a bottom, mid, top group with equal 33% respectively. In reality, due to a thick mid-income bracket, it was classified into a bottom group of 35.2%, mid group of 36.4%, the top group of 28.4%. According to a 1-19 category that the

respondents were supposed to choose at the primary survey, the bottom group covers 1-8, the mid group of 9-12, and the top takes 13-19.

The bottom group reveals the average income with 2073 euros (269.5 million won), compared with the mid group of 3755 euros (488.1 million won) and the top group with 6136 euros (797.7 million won).

Table 13. Descriptive statistics of subgroups

	Frequency	Percent	Cumulative Percent	Minimum	Maximum	Mean
Low-income (Bottom)	62692	35.2	35.2	25.00	375.00	269.4897
Mid-income (Mid)	64832	36.4	71.6	425.00	575.00	488.0784
High-income (Top)	50600	28.4	100.0	625.00	1122.90	797.7363
Total	178124	100.0				

Source: Author, 2019

Education

The Seoul Survey has categorized its citizens into groups of no education, the graduation of primary school, middle school, high school, 2-year college, 4-year university, master's and doctorate degrees. Based on this classification, two groups are formed with a college group of 44.1% (from a 2-year college graduate to a holder of Ph.D.) and non-college group of 45.9%.

Occupation

The Seoul Survey has identified citizens' jobs by managerial position, professionals, office workers, services, sales, farmer/fishermen, mechanics, student, housewife, and so on. All the respondents are categorized by white-collar workers (managerial position, professionals, office workers) and the other group (i.e., non-white collar workers). As a result, 29.8% is identified as white-collar jobs. While the group of white-collar workers usually works inside of a pleasant office, the other group is more likely to face outdoor activities.

Table 14. The Detailed description of statistics of subgroups

	New variables	N	Minimum	Maximum	Mean	Std. Deviation
Low-income (Bottom)	College	62692	0.00	1.00	.4192	.49344
	White collar Jobs	62692	0.00	1.00	.1907	.39289
	Valid N (listwise)	62692				
Mid-income (Middle)	College	64832	0.00	1.00	.5898	.49186
	White collar Jobs	64832	0.00	1.00	.3175	.46550
	Valid N (listwise)	64832				
High income (Top)	College	50600	0.00	1.00	.6278	.48340
	White collar Jobs	50600	0.00	1.00	.4048	.49086
	Valid N (listwise)	50600				

Source: Author, 2019

As seen in **Table 14**, the rate of a college group takes up 41.9% in the bottom group of household income, and 59.0% in the mid group and 62.8% in the top group.

The rate of white-collar workers is up to 19.1% in the low-income group but it increases to 31.8% in the mid group, 40.5% in the top group, displaying a steady and relatively uniform increase of around 10% by each group.

Whether they are a white-collar worker or not entails the gap of 21.4% between the top and bottom group of income, while the factor of college generates 20.9%'s difference between the two income groups.

4.5.2_Analysis of Hierarchical Regression by subgroups

By income, $PM_{2.5}$ further contributes to increasing of the stress of high-income group as seen in **Table 15**. With 0.003 of the coefficients (B value) in the low-income bracket, 0.005 in the mid-income group and 0.006 in the high-income bracket, the influence of PM on stress drew a consistent upward curve by income group.

There must be a variety of reasons for this, but based on this analysis alone, it allows to assume that there are more sensitive stressors than $PM_{2.5}$ in the low-income group in terms of achieving a certain standard of living. For example, homeowners in this group reported lower stress score than tenants (B:-031, $P<0.001$) but the same factor, home-owning, did not give a statistically significant effect on the formation of stress ($P>0.0863$, $P>0.6625$) in the mid or high-income groups. Happiness on health has also contributed to reducing stress only in the low-income group (B:-0.008, $P<0.05$).

Education also followed a similar trend with income. The college group has a greater increase in stress caused by $PM_{2.5}$ (B:0.007, $P<0.001$) than the counterpart group. According to the opinions of experts analyzed before, it may be due partially to the relatively high awareness of the environment and a large amount of information acquired.

In this group, happiness about financial status played a greater role in reducing stress than any other factors including household income (beta:-0.083, $P<0.001$), followed by local tax revenue (beta:-0.059), crime rate (0.051), age (-0.031), and then $PM_{2.5}$ (0.028). In the low-educated group, age (-0.095), local tax revenue (-0.088), crime (0.062), and happiness on financial status (-0.042) affected stress in order of beta (standardized coefficient)

The non-white-collar group was much more vulnerable to stress caused by $PM_{2.5}$ than the white-collar workers categorized from the Seoul survey raw data.

While significance has not been found in the relationship between variables in the white-collar workers' group, the stress of the non-white collar group has increased by 0.005 points within the level of significance as $PM_{2.5}$ increases by 1 $\mu g/m^3$. This implies that those who are more likely to be exposed to outdoor activities have greater stress levels triggered by $PM_{2.5}$ in the same condition.

Table 15. Hierarchical regression result of model 3 by subgroups: $PM_{2.5}$ and Stress

Variables	Low income			Mid income			High income			Low-educated			High-educated			Non-White collar			White collar		
	B	beta	Sig.	B	beta	Sig.	B	beta	Sig.	B	beta	Sig.	B	beta	Sig.	B	beta	Sig.	B	beta	Sig.
(constant)	4.423		0.000	3.916		0.000	3.750		0.000	4.272		0.000	3.805		0.000	4.064		0.000	3.935		0.000
Gender	.029	.013	.001	.018	.008	.031	.018	.008	.064	.029	.013	.000	.007	.003	.338	.031	.014	.000	-.033	-.015	.001
Age	-.005	-.089	.000	-.004	-.059	.000	-.004	-.053	.000	-.005	-.095	.000	-.003	-.031	.000	-.005	-.080	.000	-.003	-.032	.000
Marital status	-.022	-.010	.023	.046	.020	.000	.048	.021	.000	.012	.005	.187	.030	.014	.000	.022	.010	.001	.046	.020	.000
House Owning	-.031	-.014	.001	-.015	-.007	.086	-.004	-.002	.662	-.020	-.009	.011	-.018	-.009	.011	-.021	-.010	.001	-.009	-.004	.350
Religion	-.006	-.003	.468	.008	.004	.312	.004	.002	.643	-.003	-.002	.668	.005	.002	.484	.001	.000	.909	.003	.002	.726
Happiness with Health	-.008	-.012	.012	.011	.015	.001	.002	.003	.603	-.002	-.003	.544	.004	.005	.145	.001	.001	.741	.005	.007	.168
Happiness with Financial status	-.043	-.063	.000	-.052	-.072	.000	-.045	-.061	.000	-.029	-.042	.000	-.061	-.083	.000	-.041	-.060	.000	-.058	-.077	.000
Income Household	.000	.024	.000	4.080E-05	.002	.590	-1.079E-05	-.002	.701	3.646E-05	.008	.031	6.039E-05	.013	.000	7.827E-05	.017	.000	2.980E-06	.001	.884
Population Density	-6.502E-06	-.028	.000	-4.813E-06	-.021	.000	5.513E-06	.024	.000	-5.963E-06	-.026	.000	4.009E-07	.002	.650	-4.337E-06	-.019	.000	1.533E-06	.007	.201
Traffic accidents	.001	.016	.013	.001	.016	.013	.000	.008	.278	.001	.015	.006	.000	.009	.095	.000	.012	.008	.001	.015	.041
Crime rates	.002	.081	.000	.001	.040	.000	.001	.047	.000	.001	.062	.000	.001	.051	.000	.001	.064	.000	.001	.039	.000
Medical cost	.000	-.050	.000	-9.158E-05	-.011	.068	-9.895E-05	-.013	.064	.000	-.040	.000	-7.572E-05	-.009	.063	.000	-.029	.000	.000	-.013	.060
Local Tax	-.059	-.098	.000	-.043	-.068	.000	-.029	-.048	.000	-.054	-.088	.000	-.036	-.059	.000	-.053	-.086	.000	-.027	-.044	.000
Greenness rates	-.001	-.011	.016	.000	.001	.778	.000	.002	.723	-.002	-.018	.000	.001	.011	.003	-.001	-.008	.014	.001	.009	.071
Noise conflicts	.000	.004	.307	5.077E-06	.000	.978	-1.198E-05	.000	.957	.001	.012	.002	.000	-.005	.190	.000	.005	.087	.000	-.004	.376
$PM_{2.5}$	.003	.011	.074	.005	.022	.000	.006	.023	.001	.002	.007	.223	.007	.028	.000	.005	.023	.000	.002	.008	.226

Green Grey: P < 0.05, P < 0.01, **Dark Grey: P < 0.001** Source: Author, 2019

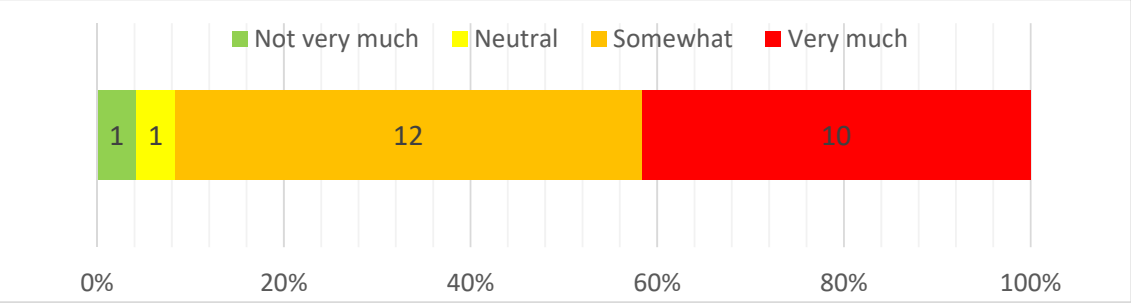
4.6_The Effects of PM on the Korean Society

4.6.1_Social cohesion and PM

However, fine dust does not seem to be limited to individual problems that depend on their environments and resources.

In fact, 91.7% of the respondents agree that the stress or depression caused by fine dust will make a negative impact on the whole Korean society. 41.7% goes for “very much” as seen in the below graph.

Figure 26. Would you say that individual stress or compression caused by Particulate Matter has negative effects on Korean society?



Source: Author, 2019

For the reasons or results, “distrust in society and government”, “anger over government (incompetence)”, “the threat to trust in the nation”, “relative deprivation of the socially vulnerable”, “socioeconomic costs”, and “decrease of social activities” were frequently or remarkably pointed out. There was no reason given by the respondent, who denied the possibility of a negative effect of stress or depression on society.

▷Researcher (female): “Very much”

dissatisfaction with the whole society, a threat to trust in the nation.

“Very much”: Professor (male)◁

Increasing suicide or antisocial behavior

▷NGO (female): “Somewhat”

Social hostility due to the low efficacy of public measures, negative social perception.

“Neutral”: NGO (male)◁

People may express one’s helplessness or complaints to society.

▷ Researcher (male): “Somewhat”

Vague social fear, health concerns such as lung cancer, anger over government incompetence, (excessive) hostility to China, and decrease of social activities.

4.6.2_Political inclination and PM

Through the survey for this research, 9 out of 10 experts predict that stress or depression caused by fine dust can make an adverse effect on the whole Korean society.

In particular, it may raise social discontent and hostility, and reduce trust in the nation or governments, they point out. This is also verified via regression analysis of big data collected and sorted out at the variable level.

While the existing model and regression formula is applied, the dependent variable is replaced by self-reported trust in the public sector instead of stress or depression.

Index of trust in the public sector has been collected by the question "How much you trust the public sector" on a 1-5 scale in the Seoul survey in the last consecutive 4 years.

As displayed in **Table 16**, it comes up with the result that $PM_{2.5}$ and PM_{10} consistently diminish trust in the public sector. As $PM_{2.5}$ increases by one unit, it reduces the score of trust in the public sector by 0.012 points, while PM_{10} curtails trust by 0.005 points

Table 16. Hierarchical regression result: Trust in the public sector and PM

	Variables	$PM_{2.5}$				PM_{10}			
Model		B	beta	t	Sig.	B	beta	t	Sig.
1	(constant)	2.487		158.092	0.000	2.487		158.092	0.000
	Gender	-.022	-.012	-5.248	.000	-.022	-.012	-5.248	.000
	Age	.004	.076	26.397	.000	.004	.076	26.397	.000
	Marital status	-.035	-.018	-6.988	.000	-.035	-.018	-6.988	.000
	House owning	.017	.009	3.909	.000	.017	.009	3.909	.000
	Religion	.014	.008	3.220	.001	.014	.008	3.220	.001
	Happiness with Health	.038	.063	22.432	.000	.038	.063	22.432	.000
	Happiness with Financial status	.026	.044	16.464	.000	.026	.044	16.464	.000
	Income (household)	-5.043E-05	-.013	-5.420	.000	-5.043E-05	-.013	-5.420	.000
2	(constant)	2.292		76.627	0.000	2.292		76.627	0.000
	Gender	-.021	-.012	-5.048	.000	-.021	-.012	-5.048	.000
	Age	.004	.073	25.003	.000	.004	.073	25.003	.000
	Marital status	-.033	-.017	-6.505	.000	-.033	-.017	-6.505	.000
	House owning	.012	.007	2.727	.006	.012	.007	2.727	.006
	Religion	.018	.010	4.181	.000	.018	.010	4.181	.000
	Happiness with Health	.036	.060	21.443	.000	.036	.060	21.443	.000
	Happiness with Financial status	.026	.044	16.660	.000	.026	.044	16.660	.000
	Income (household)	-9.696E-06	-.003	-1.019	.308	-9.696E-06	-.003	-1.019	.308
	Population Density	-3.023E-06	-.016	-5.598	.000	-3.023E-06	-.016	-5.598	.000
	Traffic accidents	-.002	-.051	-13.508	.000	-.002	-.051	-13.508	.000
	Crimes rates	.000	.009	1.993	.046	.000	.009	1.993	.046
	Medical cost	.000	.041	16.364	.000	.000	.041	16.364	.000
	Local Tax revenue	.000	.001	.112	.910	.000	.001	.112	.910
	Greenness Rates	.001	.012	4.764	.000	.001	.012	4.764	.000
	Noise conflicts	.001	.032	12.168	.000	.001	.032	12.168	.000
3	(constant)	2.783		64.400	0.000	2.650		56.193	0.000
	Gender	-.021	-.012	-4.951	.000	-.021	-.012	-4.994	.000
	Age	.004	.072	24.681	.000	.004	.072	24.837	.000
	Marital status	-.033	-.017	-6.621	.000	-.033	-.017	-6.586	.000
	House owning	.014	.008	3.173	.002	.013	.007	3.035	.002
	Religion	.017	.010	4.047	.000	.017	.010	4.093	.000

	Happiness with Health	.036	.060	21.342	.000	.036	.060	21.434	.000
	Happiness with Financial status	.027	.045	17.006	.000	.026	.044	16.717	.000
	Income (household)	-1.855E-05	-.005	-1.948	.051	-1.171E-05	-.003	-1.231	.218
	Population Density	-3.384E-06	-.017	-6.265	.000	-3.121E-06	-.016	-5.779	.000
	Traffic accidents	-.001	-.041	-10.732	.000	-.001	-.045	-11.563	.000
	Crime rates	.001	.041	8.033	.000	.000	.023	4.736	.000
	Medical cost	-1.137E-05	-.002	-.451	.652	7.478E-05	.011	2.773	.006
	Local Tax revenue	-.018	-.035	-6.921	.000	-.008	-.015	-3.205	.001
	Greenness Rates	.000	.004	1.646	.100	.001	.005	1.947	.052
	Noise conflicts	.001	.030	11.518	.000	.001	.028	10.395	.000
	Particulate Matter	-.012	-.059	-15.727	.000	-.005	-.039	-9.822	.000

Green Grey: P < 0.05, P < 0.01, **Dark Grey: P < 0.001** Source: Author, 2019

Trust in society is an element for social cohesion and happiness, as social capital (Layard, 2005, Berger-Schmitt, 2000, Leyden, Goldberg et al., 2011). However, it is worth noting that the trust in the public sector is supposed to vary depending on whether the government is conservative or progressive. In other words, the trust score of citizens may change according to their political inclination and attitude. It seems difficult for conservative citizens to give high trust in the progressive government, and vice versa.

In light of these points, the effects of $PM_{2.5}$ on stress by political inclination (progressive, conservative and neutral groups) will be analyzed. Furthermore, comparative analysis between a voting group and a non-voting group (of those who have never had voted in the past 4 years), and between the group of active social participation and the non-active group will be added.

According to the hierarchical regression results of the same model (**Table 17**), the coefficient of $PM_{2.5}$ on stress over the past four years was slightly greater in the conservative group than in the progressive.

While it may somewhat surprise when taking into account that progressive citizens seem generally more sensitive to environmental issues, it also requires to consider the fact that the progressive mayor, named Park, Won-soon, has held the reigns of the Seoul local government since 2010, and also the progressive president, Moon, Jae-in, has taken power since 2017.

The non-voting group is facing much greater stress formed by $PM_{2.5}$ than the voting group. In the voting group, stress grows by 0.002 when $PM_{2.5}$ increase by 1 $\mu g/m^3$ (although outside the level of significance), while the non-voting group experiences the rise of 0.011 points in stress score within the significance level. This seems to be related to the finding that a group[25] who are passive in social participation is also more exposed to stress caused by $PM_{2.5}$, compared to the opposite group who are active because voting is one of the basic social participation (**Table 17**).

[25] Seoul citizens have been questioned whether they experienced seven criteria, including civil complaints, the expression of political/social opinions in the (cyber) public sphere, participation in public policies of the Seoul local government, policy proposals, protest/demonstration, and votes through the Seoul survey. In this study, all the answers of the respondents are aggregated into 7 points according to the number of 'yes' and then those who got 1-3 points were categorized into a lower participation group.

Table 17. Hierarchical regression result: Stress and $PM_{2.5}$ by Political-Social subgroups

Subgroups	Stress			
	B	Beta	t	Sig.
Progressive	.004	.016	2.597	0.0094
Conservative	.005	.020	3.088	0.0020
Neutral	.005	.021	3.097	0.0020
Vote	.002	.007	1.289	0.1973
Non-Vote	.011	.048	5.221	0.0000
Social participation	-.012	-.044	-5.032	0.0000
Low social participation	.005	.022	5.503	0.0000

Green Grey: P < 0.05, P < 0.01, **Dark Grey: P < 0.001** Source: Author, 2019

Why stress caused by PM is high in the group of being passive in social activities can give several connotations not only to a government but also to academia. Not much can be known of why this takes place and it allows only a few assumptions behind that as of now. Roughly speaking, lower participation group looks intentional or enforced bystanders on political society. In fact, the possibility that the poor may be more indifferent or passive in voting because of lower expectations that their lives can be changed by politics has been raised by media in South Korea[26]. And it is pointed out that alienation from the decision-making process or political-economic opportunity lead to concern, distrust, cynicism towards the government when dealing with air pollution or a social hazard. (Walker, Simmons et al., 1998, Bickerstaff, 2004). Nevertheless, a closer analysis in this issue will be needed in the future for want of better understanding of social cohesion.

The most salient result in this part is that as $PM_{2.5}$ concentration increases, citizens' trust in public sector declines. This gives implications of the possibility of a vicious circle that the distrust in policies against fine dust can undermine citizens' participation (or engagement) in any future policies against fine dust, and in turn, it can amplify complaint about the public sector along with increased stress.

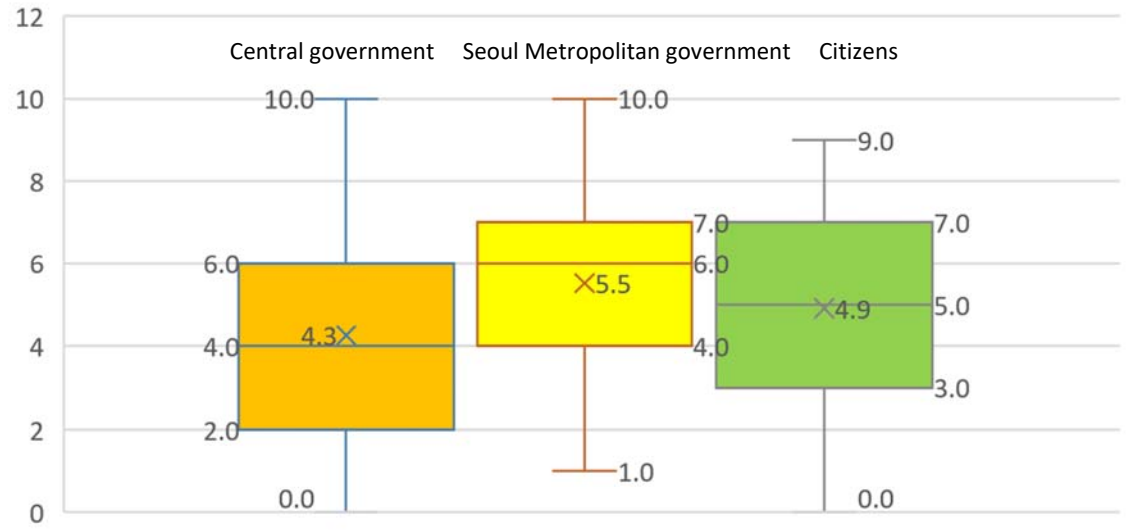
4.7_Evalutation and Suggestions

How well have the government and citizens responded to such a serious fine dust problem? The scores given by experts were not very high.

As seen in **Figure 27**, while the central government scored 4.38 points, the Seoul Metropolitan government got 5.58 points to the question “How well would you say the national government (or the Seoul metropolitan government) is responding to the problem of Particulate Matter?” Citizens scored 4.92, as being positioned between the Seoul local government and the national government. Of note is that all the sectors but the Seoul local government scored less than 5 points.

Figure 27. The evaluation of the three sectors

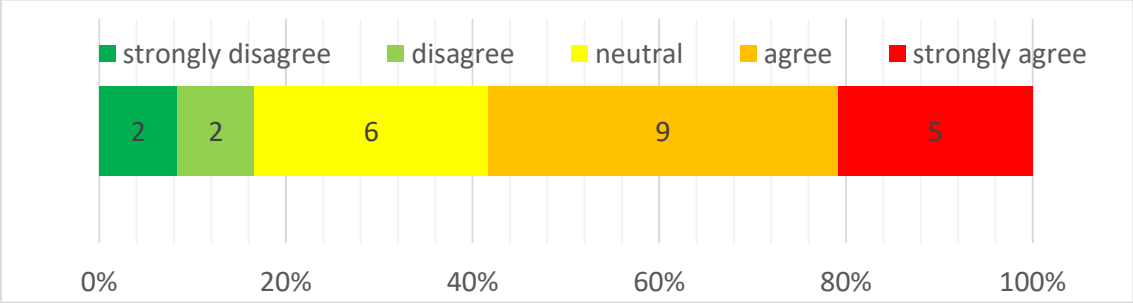
[26] http://www.hani.co.kr/arti/society/society_general/532939.html



Source: Author, 2019

From this perspective, it is noteworthy that 6 out of 10 experts (58.3%) agree that there is a need for measures to reduce fine dust and at the same time, a policy to respond to individual negative affect caused by fine dust

Figure 28. Do you agree there is a need for measures to address individual stress or depression caused by Particulate Matter at the same time when the government tries to reduce the level of PM concentration?



Source: Author, 2019

They suggest the following measures: “Transparent disclosure of policies and simulation effects.”, “To strengthen communication channels.”, “Say ‘don’t know’ about what the government doesn't know and share all the information openly.”, “It needs to inform that the government is endeavouring to solve this matter and to ask for the public's cooperation.”

Some respondents suggest “expansion of welfare (support of consultation, treatment), especially for the patient of respiratory, mental health, and children and the elderly, establishment.”

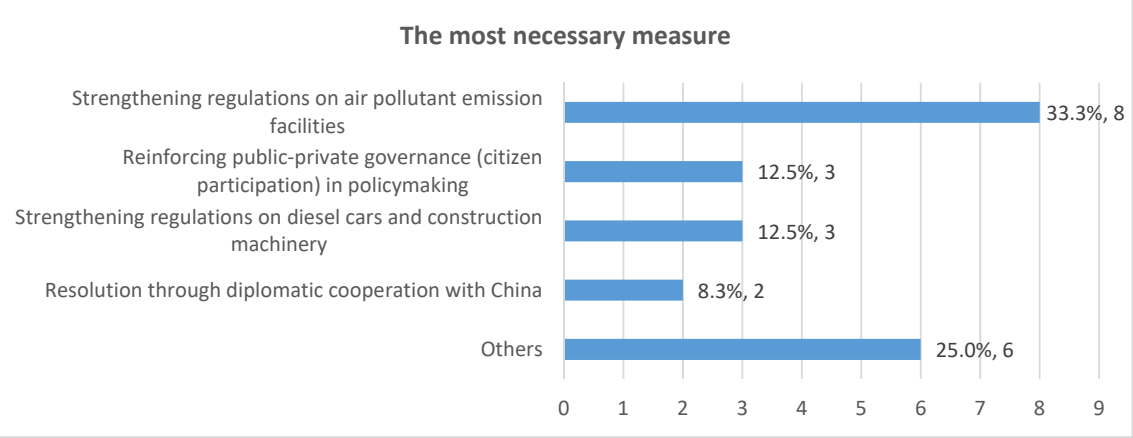
Experts have also appealed for a change in perception among citizens themselves, mentioning such as; “We need to realize that we are the key holder to resolving the fine dust problem, not by the others"; "we need to recognize that fine dust is an artificial social problem and make efforts to solve it by ourselves first”; “it needs citizens’ awareness to support and monitor

public policy by expressing an active interest in efforts to introduce and implement innovative policies".

Some media's incendiary reporting (with lack of veracity) on fine dust issues has also been blamed as one of the reasons to amplify individual negative affect caused by fine dust. As refraining from news reports that magnify anxious inaccurately or excessively or that politicize issues, the experts suggest that "the media needs to spread the new perception that individuals are not only a victim but also an assailant (in terms of the fact that PM is derived from human activities), and to introduce good examples of citizen's efforts resolving fine dust matter in other countries" or "media should focus on informing measures to be taken by individuals, trying to diminish excessive anxiety with news based on 'fact', and monitoring and encouraging government measures to be carried out without interruption".

From the general points of view, the top priority measure proposed by the experts to reduce fine dust is shown as follows:[27]

Figure 29. Recommendation of the most necessary measure for the government



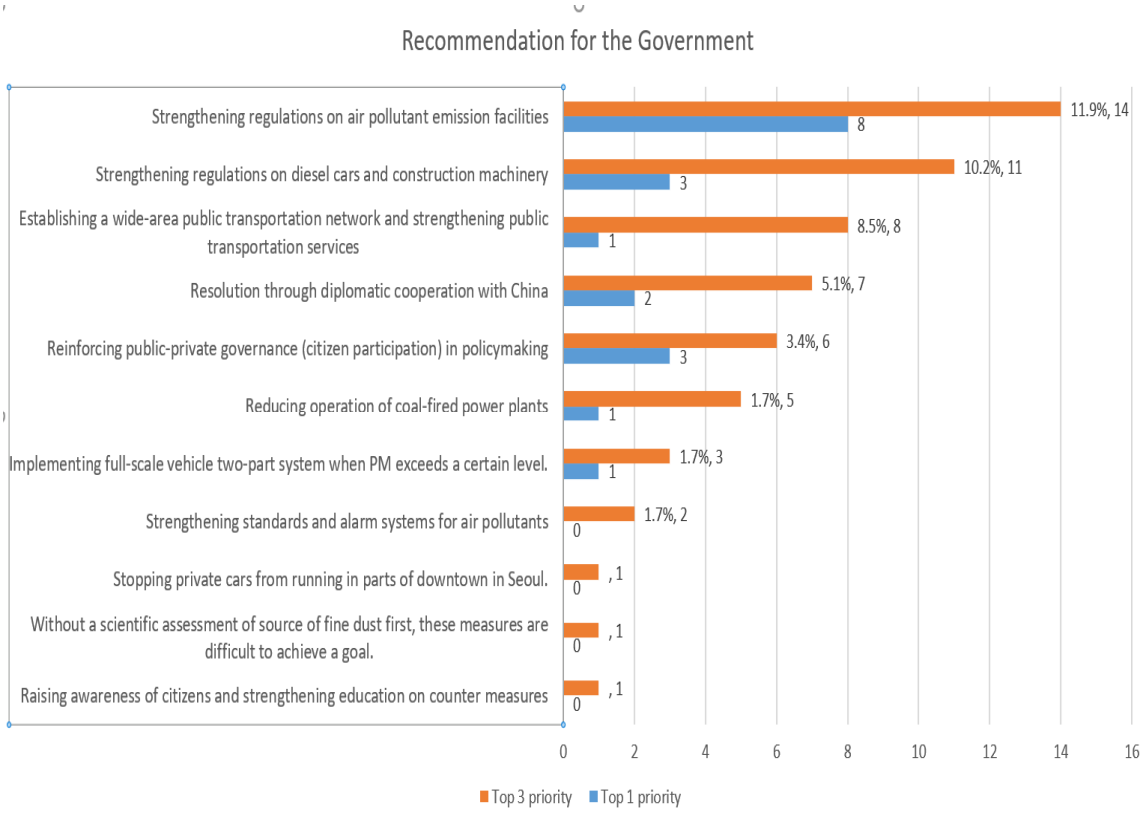
Source: Author, 2019

Others: Implementing a full-scale vehicle two-part system when PM exceeds a certain level (1), Establishing a wide-area public transportation network and strengthening public transportation services (1), Reducing the operation of coal-fired power plants (1), "the prohibition of all cars when PM exceeds a certain level -collection of operation fee from those who drive, and use of the revenue for public transportation service –" (1, the other opinion), "currently, the source of fine dust pollutants is estimated by the Ministry of Environment using statistics and indirect mathematical models. But the contribution of foreign and domestic pollutants and scientific contribution to fine dust pollution of domestic vehicles, coal-fired power plants, and other pollutants should be evaluated so that the government's policy and long-term strategy can be effective" (1, the other opinion). "the need to prioritize the measures that have the most practical effect among the numerous measures. But this is not being proceeded by the government" (1, own opinion).

[27] This is a little far from this study topic but it is contained for a better solution of the government and society against fine dust as a reference.

And Top 3 priorities chosen by the experts' group are merged as follows:

Figure 30. Recommendation of the most necessary measures for the government



Source: Author, 2019

Chapter 5: Conclusions and recommendations

5.1_Conclusions and discussion

This study, along with the following main question, sought to examine and explain the effects of fine dust on the stress and depression formation in Seoulites, where PM has risen top environmental issue from 2015 to 2018.

What is the relationship between particulate matter and perceived stress or depression?

This question was deduced to demonstrate the hypothesis that fine dust affects not only physical health but also mental health on the basis of the social scientific perspective, and to analyze whether this results in additional social costs. It assumed that fine dust could play a role in creating a more vulnerable class to negative affect and hindering social cohesion in the long run.

Stated briefly, $PM_{2.5}$ and PM_{10} have contributed to strengthening Seoulites' negative affectivity (stress, depression, etc.) during the period.

According to hierarchical regression analysis, when $PM_{2.5}$ increases 1 $\mu g/m^3$, the score of perceived stress on a 1-5 scale was increased by 0.0044 and depression et al. was pulled up by 0.006 points. While the correlation between PM_{10} and stress was not confirmed within the significance level, depression et al. was risen by 0.005 points for every 1 $\mu g/m^3$ increase of PM_{10}.

Moreover the increase of F change served to verify the exclusive influence of PM on depression et al. and stress, beyond the impacts of the other variables within the categorization of individual factors (income, age, gender, religion, house owning, happiness with health, happiness with financial status) and collective regional factors (population density, traffic accident rate, crime rate, medical cost, greenness rate, local tax revenue, noise conflicts, at the level of 25 districts in Seoul).

As the results of the analysis of sociological statistics, this finding comes into line with the existing medical studies stating that negative affectivity such as depression increases due to fine dust (Gładka, Rymaszewska et al., 201, Mehta et al, 2015) and sociological studies that fine dust reduces happiness (Welsh, 2007, Levinson 2012, Kim and Jin, 2017, Zhang, Zhang, et al., 2017).

This finding is also vehemently supported by the results of the survey of the experts on fine dust which was conducted on its own since 95.8% of the experts agreed that PM affects the development of stress and depression and 58.3% said it has a very serious impact.

When it comes to reasons between negative emotion and PM, the experts pointed out health concerns, restrictions on activities, social-economic costs incurred through them, helplessness in resolving the matter of fine dust, social deprivation, distrust and discontent about policy or government.

It enables us to guess that fine dust affects not only the (physical and psychological) health of individuals but also the health of society. It is because that distrust on state may be more augmented in the group of political-economic marginalization (Walker, Simmons et al., 1998, Bickerstaff, 2004), negative affectivity like depression in itself can impede social cohesion (Acket, Borsenberger et al., 2011, Helliwell, Layard et al., 2019), and again increase distrust, anger against society or a government (Jung, Kim et al., 2018).

The main question entails six sub-questions as follows.

1) ***To what extent is individual stress or depression affected negatively by PM and how is it expressed?***

$PM_{2.5}$ increases both the level of stress and depression et al. of Seoulites. The index of stress rose by 0.0044 points for each 1μg/m3 increase in $PM_{2.5}$ and depression et al. increased by 0.006 points. PM_{10}, on the other hand, did not explain causality within the significance level, but depression et al. was augmented by 0.005 points for every 1 $\mu g/m^3$ increase.

2) ***Is PM more 'significant' than such other predictors (to stress or depression) as income, health, job, marital status, regional crime rate, regional financial status, and so on?***

There was a slight difference depending on stress and depression.

In case of stress, age, financial happiness among individual variables had a greater beta value than $PM_{2.5}$, and local tax revenue per capita, crime rate, and medical cost as the regional variables were higher than $PM_{2.5}$ in terms of the beta readings. In other words, these were the variables that had a bigger influence than PM on the stress of Seoulites in 2015~2018 but it confirmed as well that PM is a powerful stressor than most of the other variables like income, religion, happiness on health, or traffic accident, the population density of a district where they dwell,

When it comes to depression et al., there were no individual variables that exerted more influence than PM, and among the regional variables, local tax revenue, crime rate, and medical cost were more influential, regardless of '+' or '-' relationships.

The effect of actual household income on negative perception has not been identified. This may be in part in line with a study stating that U.S. economic growth did not play a major role in preventing Americans from feeling depressed (Layard, 2005). However, this study found that the higher the perceived happiness about financial status was, the more 'clearly' the negative affectivity was lessened. It may refer that subjective satisfaction on an economic level is more influential than the amount of tangible money in general.

To sum up, in case of $PM_{2.5}$, stress was decreased in line with the increase of one unit of age – local tax revenue - happiness with financial status – medical cost (based on a holder of health insurance), while it was increased in proportion to the increase of one unit of crime rate – $PM_{2.5}$ – traffic accident rate - marital status (married > not married). And depression et al. establishes a 'plus' relationship with such variables as crime rates – $PM_{2.5}$ – traffic accidents, a 'minus' relationship with such variables as local tax - medical cost – happiness on health – the greenness rate – age – happiness with financial status (in order of influence).

3) ***From 2015 to 2018, has PM become more significant or less as a predictor to stress or depression, compared the other variables?***

Depression et al. were difficult to be compared since it was not surveyed in 2018, and in case of stress, there was no certain tendency.

But this study found that 8 out of 10 experts (79.2%) agreed that Koreans' response to fine dust in 2018 has become more sensitive than 1~2 years ago. They elaborated the reasons with such keywords as "distribution of misinformation about PM", "too many reports of media", "information overload on PM compared to other threatening factors", "distrust of the

government", "the growing awareness on the environmental value". Notwithstanding, it was difficult to determine whether stress or depression by PM was increasing during the given period through numerical analysis.

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4) ***Are there specific groups who get in particular more distressed or depressed even by the same level of PM concentration?***
5) ***How is the so-called 'stress inequality' explained in Seoul? What are the characteristics of the vulnerable groups in terms of age, gender, income, education, job, political stance (progressive or conservative), perception of social cohesion, and so on?***

It is worth recalling that the increase of stress caused by $PM_{2.5}$ was greater among people with higher income and higher education rather than the low-income, the low-educated group respectively.

The low income and low education group are likely to be exposed to more practical stressors than $PM_{2.5}$, compared to the other groups. For example, whether or not to own a house is far more influential than $PM_{2.5}$ in terms of factors that would enhance stress for the low-income group. On the other hand, the factor of house ownership was not statistically significant in the high income, high education group.

This is somewhat understandable, in light of a happiness study that increases in income do not pull up happiness any more after income reaches a certain level (Easterlin, 1974). It implies that still for low-income people, physical assets such as food, clothing, and shelter are more essential for survival and happiness.

A more noticeable picture emerges when the form of labour (or activity) is factored. The growth of stress caused by $PM_{2.5}$ in the non-white collar group, who is likely to have more outdoor work or activity than in the white-collar group, was quite obvious.

If the characteristics of the urban environment where they dwell or lifestyles can be more understood, it enables this study to provide a richer interpretation of why a non-white collar group is more susceptible to stress caused by PM. It should be left for the next studies.

And over the past four years, the conservative group has been more vulnerable to stress resulted from $PM_{2.5}$ than the progressive group.

Of extraordinary note is that there is a large increase in stress by $PM_{2.5}$ in a group that is not active in social participation.

The reasons that they are passive in social participation and report greater stress may be diverse, including voluntary or compulsory reasons. It may be because there is a lack of physical assets (such as time and cost) or political-economic opportunity, or because there is less social capital (such as social network or membership in a community), or because there is less trust in society (i.e., societal discontent).

Distrust and cynicism towards the public sector are led by alienation in the decision-making process, as a way of social participation (Walker, Simmons et al., 1998, Bickerstaff, 2004). In contrast, trust in society or engagement to society serves to enhance not just individual happiness but also sustainability (Layard, 2005, Berger-Schmitt, 2000, Leyden, Glodberg et al., 2011, Helliwell, Layard et al., 2019). There is also research with a conclusion that social capital helps reduce the level of depression caused by fine dust (Wang, Xue et al., 2018).

Through the primary survey conducted in this study, the experts mentioned that “children”, “the elderly people”, or “people with underlying disease” may be more vulnerable to stress caused by fine dust.

At the same time, “a class psychologically sensitive to fine dust” was frequently pointed out. Although they did not specify who the “psychologically sensitive” group is, it is worth taking special note of the fact that words such as “weak”, “deprivation”, or “distrust” were mentioned together.

What is crucial is that when we figure out who is passive in social participation and why they are, we are able to understand much more the causes and patterns of stress inequality caused by fine dust. Especially, it seems that the characteristics of those who are ***compelled*** to be passive can explain why and how stress inequality occurs. But this is also left for the next study.

6) What is the relation between stress inequality and social cohesion?

This study does not provide a direct explanation of the correlation between stress inequality and social cohesion but confirmed that the higher the fine dust level was, the lower the index of social trust was. As seen before, without trust in the public sector, social participation or cohesion is hard to be encouraged. In this condition, most of the public policies on fine dust may have a limit to be effective.

5.2_Recommendation and discussion

The policy for the reduction of PM is essential. However, the findings of this study imply that it is time for the government to take consideration of the need to manage the individual stress problem worsened by fine dust simultaneously.

This is because the stress caused by fine dust can lead to health inequality, social inequality, social discontent, and further undermine social cohesion as reviewed.

For the government, it implies that no matter how perfect policies towards fine dust are proposed in the future under this condition, it will not buy much of the public approval and may end in another failure.

Six out of ten experts on fine dust in South Korea also agreed that policies to respond to negative affectivity caused by fine dust are required along with the direct measures for fine dust reduction.

Although a few of them suggested even a very specific recommendation on the medical care system, a majority of them put an emphasis on the necessity to strengthen communication.

It has a similar meaning with the result that 'reinforcing public-private governance (citizen participation) in policymaking' was chosen by the third most experts in the survey, asking to pick up only one top priority policy that the government should take on PM.

Participation in the policy-making can help citizens to reduce helplessness on the matter of fine dust, to strengthen social capital with the other people sharing similar concerns on fine dust, and to contribute to the success of public measures on fine dust. It is not easy to expect that citizens with less trust in the government willingly join a public policy implemented by a government.

On balance, one expert's opinion in the survey is noteworthy.

▷Researcher (female)

> In order to resolve the problem of fine dust, civic participation is important. If social distrust is widened, it will be more retarded to solve the matter due to lowered receptivity of the citizens about public policies or measures.

To conclude, in order that the problem of fine dust should be resolved, not just a scientific approach but also a social approach which aims at social integration is needed of perforce.

Even though it needs a plethora of changes in our daily life, and renovations of society, as well as a vast input of public resources, there is no reason that this crisis should not become a new momentum of sustainable development in Seoul and South Korea (Maria, Marina et al., 2015, Campbell, 1996, Stiglitz, 2002, Gowdy, 2005, Glaeser, 2011, OECD, 2012).

5.3_Limitation and Recommendation

The level of negative affectivity such as stress or depression will be determined by individual assets and a variety of urban surroundings. There may be other important variables as much as the ones used in this study but most of them were not within accessibility. For the reason, this study could not consider factors related particularly to individual drinking or smoking rates, the change of real estate price, size of expenditures, and any data about the education of children which have great meaning in a Korean's life.

Fine dust was identified by the unit of 25 districts in Seoul and then applied to regression analysis. It is inevitable to assume that over 40,000 citizens (every year) are affected by 25 different levels of PM in the given survey period. All of the regional variables, such as crime rate, traffic accident rate and greenness rate, lay in the same assumption. It might be different from the reality simply when considering residents dwelling in a border between districts. Seoul consists of 25 districts with around 424 smaller administrative units, called Dong in the Korean. More segmentalized regional data as a variable will allow greater accuracy of research. Such data by the level of Dong is not available at present but the variable of PM should be sought at a more sophisticated geographical level in future research.

The Seoul Survey was conducted in October in 2015-2016, and in September in 2017-2018. This study utilized the average concentration of the previous two months (including the month when the survey was conducted) as a variable. It is because the Seoul survey takes place a month, as asking if a respondent experienced stress or depression for the last 2 weeks or the last month. It means a fair number of respondents had to answer by making reference to the conditions in the previous month. If this research could have utilized PM data coinciding with a day or period when each respondent was surveyed, the validity of this research would be more reinforced. It was tried to collect that kind of data but confirmed that the Seoul Metropolitan government did not stock the information of each respondent's survey time.

And a few regional data which were not updated, especially the greenness rate, were forced to be utilized.

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Annex 1: Data of secondary quantitative analysis

1.1_Description of Variables by SPSS and data Sources: Chapter 4.1

Table 18. The traits of the variables

Variables		N	Minimum	Maximum	Mean	Source	Web site
Dependent	Stress	178124	1	5	3.515	Seoul Survey	data.si.re.kr/node/523
	Depression et al.	135133	1	5	2.546	Seoul Survey	
Reference	Happiness (overall)	178124	0	10	6.96	Seoul Survey	
	Life Satisfaction (overall)	135133	0	10	7.152	Seoul Survey	
Independent	$PM_{2.5}$	178124	9	26.5	17.482	NIER / Seoul Metropolitan government	airkorea.or.kr
	PM_{10}	178124	16	46	30.987		
Individual	Gender	178124	0	1	0.481	Seoul Survey	
	Age	178124	15	102	45.437	Seoul Survey	
	Marital Status	178124	0	1	0.663	Seoul Survey	
	House Owning	178124	0	1	0.584	Seoul Survey	
	Religion	178124	0	1	0.453	Seoul Survey	
	Happiness on Health	178124	0	10	7.184	Seoul Survey	
	Income (household)	178124	25	1122.9	499.11	Seoul Survey	
	Happiness on Financial status	178124	0	10	6.293	Seoul Survey	
	College (over 2-years)	178124	0	1	0.541	Seoul Survey	
	White-collar Job	178124	0	1	0.298	Seoul Survey	
Regional	Population Density	178124	6771	28098	17920.62	Seoul Metropolitan Government	data.seoul.go.kr

	Traffic Accidents (per 10K cars)	178124	67.4	222.9	112.435	Seoul Metropolitan Government / Seoul Metropolitan Police Agency	data.seoul.go.kr
	Crime Rate (per 10K persons)	178124	57.74	383.99	122.743	Seoul Metropolitan Police Agency	data.go.kr/dataset
	Medical Cost (1000 won)	178124	863.64	1636.63	1125.052	National Health Insurance service	nhis.or.kr/menu
	Local Tax revenue (1000 won)	178124	0.52	10.75	1.76	Seoul Metropolitan Government	data.seoul.go.kr
Environment	Greenness Rate	178124	9.31	55.71	22.292	Seoul Metropolitan Government	data.seoul.go.kr
	Noise Conflicts (per 10K persons)	178124	11.61	114.9	50.013	Seoul Metropolitan Government	data.seoul.go.kr
	Valid N (listwise)	135133					

Source: Author, 2019

1.2_Description of Variables/sub-groups by SPSS and data Sources: Chapter 4.3

Table 15. Traits of the variables

Variables		N	Minimum	Maximum	Mean	Source
Dependent	Trust in Public sector	178124	1.0	5.0	3.067	Seoul Survey

Sub-Groups			Frequency	Percent	Valid Percent	Cumulative Percent	Source
Income	Valid	Low	62692	35.2	35.2	35.2	Seoul survey
		Mid	64832	36.4	36.4	71.6	
		High	50600	28.4	28.4	100	
		Total	178124	100	100		
Education	Valid	Under high school	81835	45.9	45.9	45.9	
		0ver 2-year college	96289	54.1	54.1	100	
		Total	178124	100	100		
White Collar	Valid	White Collar	125099	70.2	70.2	70.2	
		Non-White collar	53025	29.8	29.8	100	

		Total	178124	100	100		
Political Inclination	Valid	Progressive	64425	36.2	36.2	36.2	
		Conservative	58921	33.1	33.1	69.2	
		Neutral	54778	30.8	30.8	100	
		Total	178124	100	100		
Social Participation	Valid	Non-passive	23668	13.3	13.3	13.3	
		Passive	154456	86.7	86.7	100	
		Total	178124	100	100		
Voting	Valid	Voting	92561	52	70.5	70.5	
		Non-voting	38726	21.7	29.5	100	
		Total	131287	73.7	100		
	Missing	System	46837	26.3			
	Total		178124	100			

Source: Author, 2019

Annex 2: Data of primary qualitative analysis

2.1_ Questionnaire of Survey in English using Google Survey

1. How serious would you say Particulate Matter in Seoul is?

① Not serious at all ② Not very serious ③ Neutral ④ Somewhat serious ⑤ Very serious

2. How much would you say Particulate Matter affects the usual happiness of Seoulites or not?

① Not influential at all ② Not very influential ③ Neutral ④ Somewhat influential ⑤ Very influential

2-1. What do you think is the reason? (You may write sentences or list simple keywords.)

3. How much would you say Particulate Matter affects stress or depression of Seoulites, such as stress, depression, or not?

① Not influential at all ② Not very influential ③ Neutral ④ Somewhat influential ⑤ Very influential

3-1. What do you think is the reason? (You may write sentences or list simple keywords.)

4. Have you experienced any stress or depression due to Particulate Matter in the last six months?

① Not at all ② Not very much ③ Neutral ④ Somewhat ⑤ Very much

4-1. What do you think was the reason? (You may write sentences or list simple keywords.)

5. Would you say that Koreans' reactions to Particulate Matter this year are sensitive or insensitive in comparison to the actual PM level?

① Much more insensitive than reality ② A little more insensitive than reality ③ Moderate

④ A little more sensitive than reality ⑤ Much more sensitive than reality

5-1. What do you think is the reason? (You may write sentences or list simple keywords.)

6. Would you say that Koreans' reactions to Particulate Matter this year in comparison to the actual PM level has become more/less sensitive than 1~2 year ago?

① It has become much more insensitive than it was

② It has become a little more insensitive than it was

③ It is similar.

④ It has become a little more sensitive than it was

⑤ It has become much more sensitive than it was.

6-1. What do you think is the reason? (You may write sentences or list simple keywords.)

7. Do you think there are relatively more vulnerable groups in terms of stress or depression (psychological health effects) caused by Particulate Matter? If so, what kind of groups do you think they are? (You may write sentences or list simple keywords.)

8. Would you say that individual stress or depression caused by Particulate Matter has negative effects on Korean society?

① Not influential at all ② Not very influential ③ Neutral ④ Somewhat influential ⑤ Very influential

8-1. What do you think is the reason? (You may write sentences or list simple keywords.)

9. How well would you say think the central government is responding to the problem of Particulate Matter?

(0: the worst 10: the best)

9-1. What do you think is the reason? (You may write sentences or list simple keywords.)

10. How well do would you say the Seoul metropolitan government is responding to the problem of Particulate Matter? (0: the worst 10: the best)

10-1. What do you think is the reason? (You may write sentences or list simple keywords.)

11. How well do would you say the Korean individuals are participating in and cooperating with the public policy to solve the problem of Particulate Matter? (0: the worst 10: the best)

11-1. What do you think is the reason? (You may write sentences or list simple keywords.)

12. What is the most necessary measure to address the problem of Particulate Matter? Please pick the first one out of your top priorities.

①Establishing a wide-area public transportation network and strengthening public transportation services

② Strengthening regulations on diesel cars and construction machinery

③ Strengthening regulations on air pollutant emission facilities

④ Strengthening standards and alarm systems for air pollutants

⑤ Reinforcing public-private governance (citizen participation) in policymaking

⑥ Stopping private cars from running in parts of downtown in Seoul.

⑦ Reducing the operation of coal-fired power plants

⑧ Raising awareness of citizens and strengthening education on countermeasures

⑨ Resolution through new technologies such as artificial rain

⑩ Implementing a full-scale vehicle two-part system when PM exceeds a certain level.

⑪ Resolution through diplomatic cooperation with China

⑫ Others:

12-1. What is the most necessary measure to address the problem of Particulate Matter? Please pick two following the first one.

①Establishing a wide-area public transportation network and strengthening public transportation services

② Strengthening regulations on diesel cars and construction machinery

③ Strengthening regulations on air pollutant emission facilities

④ Strengthening standards and alarm systems for air pollutants

⑤ Reinforcing public-private governance (citizen participation) in policymaking

⑥ Stopping private cars from running in parts of downtown in Seoul.

⑦ Reducing the operation of coal-fired power plants

⑧ Raising awareness of citizens and strengthening education on countermeasures

⑨ Resolution through new technologies such as artificial rain

⑩ Implementing a full-scale vehicle two-part system when PM exceeds a certain level.

⑪ Resolution through diplomatic cooperation with China

⑫ Others:

13. Do you agree there is a need for measures to address individual stress or depression caused by Particulate Matter at the same time when the government tries to reduce the level of PM concentration?

① Strongly disagree ② Disagree ③ Neutral ④ Agree ⑤ Strongly agree

13-1. What do you think is the reason? (You can write it as a sentence or list the keywords and more.)

11-2. If so, what should the government do? (You can write it as a sentence or list the keywords and more.)

11-3. If so, what should an individual do? (You can write it as a sentence or list the keywords and more.)

11-4. If so, what should the media do? (You can write it as a sentence or list the keywords and more.)

2.2_ Introduction of the Questionnaire of Survey in English using Google Survey

My name is Im, Intack
I am a journalist, working at Hankyoreh media company since 2003.
Before taking a one-year leave last year, I had worked for an investigative reporting team and am supposed to return to the company this year.
During my one-year leave from the company, I am studying in the Master's program, urban management and development (specializing in Urban environment, sustainability and climate change), as a graduate student at Erasmus University Rotterdam, Netherlands.
I am writing to ask for your response to a survey on the problem of fine dust in South Korea. I intend to complete the thesis on the issue by conducting a survey and interview with experts, based mainly on fine dust, along with statistical analysis of big data.
This survey is designed to be conducted only for the expert who contribute to solving the problem of fine dust, by being asked by the government or media.
Relying on your answers, I hope to improve the understanding and insight on this subject and share it with the public or authorities in the future.
This questionnaire consists of 13 questions and has an option that you can express your own opinions besides. You may list simple keywords as an answer to each question.

The answer you presented to us will be utilized only for academic purposes under anonymity. If it is necessary for a detailed quote under a real name, a further interview will be conducted in person at the individual level.

You can contact me at demianism@gmail.com or 010-6899-6896.

2.3_ Introduction and the Questionnaire of Survey in Korean

안녕하십니까, 선생님. 전 한겨레신문 임인택 기자라고 합니다.
2003년 입사해 지난해 1년 휴직을 하기 전엔 탐사보도팀에서 활동했고, 올해말 복귀를 앞두고 있습니다.
휴직 기간 동안, 네덜란드 로테르담에 위치한 에라스무스대학 대학원 석사생으로, HIS

도시관리개발학(세부전공: 도시 환경 및 지속가능)을 공부하고 있습니다.
한국사회 문제 가운데 하나인 미세먼지를 소재로, 관련 데이터 분석에 주로 기반하되, 전문가 대상의 설문조사 및 인터뷰를 병행하여 논문을 완성하고자 합니다.
정부 주관 토론회나 언론 등을 통해 미세먼지 문제에 대한 역할을 요구받거나 기여해 주셨던 국내 전문가님들께 제한적으로 다음과 같은 질문을 여쭙고 주제에 대한 이해와 통찰을 높이며, 이후 시민들과도 공유할 수 있었으면 좋겠습니다.
주신 답변은 익명과 함께 학문적 목적 외 사용되지 않으며, 향후 실명의 자세한 인용이 필요할 경우 직접동의를 구하거나 추가 인터뷰를 진행하도록 하겠습니다.
질문은 모두 13개이며, 보기 선택이 가능하지만 부가 질문 등을 통해 자유롭게 의견을 더해주실 수 있도록 마련했습니다. 이때는 키워드만 쭉, 제한없이 나열해 주셔도 좋겠습니다.
감사합니다.

제 연락처는 demiansim@gmail.com, 010-6899-6896입니다.

<질문>

1. 귀하께선 서울의 미세먼지 문제가 얼마나 심각하다고 생각하십니까?

① 전혀 심각하지 않다 ② 심각하지 않은 편이다 ③ 보통이다 ④ 심각한 편이다 ⑤ 매우 심각하다

2. 미세먼지가 서울시민들의 평소 행복감에 영향을 미친다고 생각하십니까, 미치지 않는다고 생각하십니까?

① 전혀 영향을 미치지 않는다 ② 영향을 미치지 않는 편이다 ③ 보통이다
④ 영향을 미치는 편이다 ⑤ 매우 영향을 미친다

2-1. 그 이유는 무엇이라고 보십니까?

(문장으로 써 주셔도 좋고 핵심 낱말 등을 쭉 나열해 주셔도 좋습니다.)

3. 미세먼지가 평소 서울 시민들의 부정적 감정상태, 즉 스트레스나 우울감, 짜증, 분노 등의 형성에 영향을 미친다고 생각하십니까, 미치지 않는다고 생각하십니까?

① 전혀 영향을 미치지 않는다 ② 영향을 미치지 않는 편이다 ③ 보통이다
④ 영향을 미치는 편이다 ⑤ 매우 영향을 미친다

3-1. 그 이유는 무엇이라고 보십니까? (이하 똑같이 안내함)

4. 귀하께선 최근 6개월 동안 미세먼지로 인해 스트레스나 우울감을 경험한 적이 있습니까?

① 전혀 경험하지 않았다 ② 경험하지 않은 편이다 ③ 보통이다
④ 경험한 편이다 ⑤ 매우 많이 경험했다

4-1. 그 이유는 무엇이라고 보십니까?

5. 올해 한국인들의 미세먼지에 대한 반응이 미세먼지 실제 농도나 실태에 견줘 상대적으로 더 과도하거나, 과소하다고 생각하십니까?
① 실태보다 매우 둔감하게 반응한다 ② 실태보다 둔감하게 반응하는 편이다 ③ 적당하다
④ 실태보다 민감하게 반응하는 편이다 ⑤ 실태보다 매우 민감하게 반응한다.

5-1. 그 이유는 무엇이라고 보십니까?
6. 한국인들의 미세먼지에 대한 반응이 미세먼지 실제 농도나 실태에 견줘 1~2년 전보다 더 과도 또는 과소해졌다고 생각하십니까?
① 과거보다 매우 둔감하게 반응하고 있다 ② 과거보다 둔감하게 반응하는 편이다 ③ 비슷하다
④ 과거보다 민감하게 반응하는 편이다 ⑤ 과거보다 매우 민감하게 반응하고 있다

6-1. 그 이유는 무엇이라고 보십니까?

7. 미세먼지에 의한 스트레스나 우울감 형성(정신건강 영향)에 있어 상대적으로 더 취약한 부류가 있다고 보십니까, 어떤 부류라고 보십니까?

7-1. 그 이유는 무엇이라고 보십니까?

8. 미세먼지에 의한 개인적 스트레스나 우울감 형성이 한국 사회에 끼치는 부정적 영향이 있거나 있을 것이라고 보십니까?
① 나쁜 영향이 전혀 없다 ② 나쁜 영향이 없는 편이다 ③ 보통이다
④ 나쁜 영향이 있는 편이다 ⑤ 나쁜 영향이 매우 크다

8-1. 어떤 영향을 미칠 수 있다고 보십니까?

9. 미세먼지 문제 해결을 위한 현 정부의 대응 수준이 10점 만점에서 몇 점이라고 생각하십니까? (0: 매우 못하고 있다. 10: 매우 잘하고 있다)

9-1. 그 이유는 무엇이라고 보십니까?

10. 미세먼지 문제 해결을 위한 서울시정부의 대응 수준이 10점 만점에서 몇 점이라고 생각하십니까? (0: 매우 못하고 있다. 10: 매우 잘하고 있다)

10-1. 그 이유는 무엇이라고 보십니까?

11. 미세먼지 문제 해결을 위한 공공정책에 우리 국민들이 동참하고 협조하는 수준이 10점 만점에서 몇 점이라고 생각하십니까? (0: 매우 협조적이지 않다 10: 매우 협조적이다)

11-1. 그 이유는 무엇이라고 보십니까?

12. 미세먼지 문제 해결을 위해 가장 필요한 대책은 무엇입니까? 최우선 대책 한가지만 꼽아주십시오.

① 광역 대중교통망 구축 및 대중교통 서비스 강화
② 경유차 및 건설기계 규제 강화
③ 대기오염물질 배출시설 규제 강화
④ 대기오염물질 기준 및 경보체계 강화
⑤ 정책결정 때 민관 거버넌스(시민참여) 강화
⑥ 서울 도심 일부 구간 자가용 통행 중단
⑦ 석탄화력 발전소 운행 축소
⑧ 시민들의 경각심 제고 및 대책교육 강화
⑨ 인공강우 등 신기술 통한 해결
⑩ 일정기준 초과 때 전면적 차량2부제 실시
⑪ 중국과의 외교적 협력을 통한 해결
⑫ 기타

12-1. 미세먼지 문제 해결을 위해 다음으로 필요한 대책은 무엇입니까? 2가지를 꼽아주십시오.

① 광역 대중교통망 구축 및 대중교통 서비스 강화
② 경유차 및 건설기계 규제 강화
③ 대기오염물질 배출시설 규제 강화
④ 대기오염물질 기준 및 경보체계 강화
⑤ 정책결정 때 민관 거버넌스(시민참여) 강화
⑥ 서울 도심 일부 구간 자가용 통행 중단
⑦ 석탄화력 발전소 운행 축소

⑧ 시민들의 경각심 제고 및 대책교육 강화

⑨ 인공강우 등 신기술 통한 해결

⑩ 일정기준 초과 때 전면적 차량2부제 실시

⑪ 중국과의 외교적 협력을 통한 해결

⑫ 기타

13. 미세먼지 저감대책과 동시에, 미세먼지로 인한 시민의 스트레스나 우울감 관리 정책이 별도로 필요하다고 보십니까?

① 전혀 필요하지 않다 ② 필요하지 않은 편이다 ③ 보통이다 ④ 필요한 편이다 ⑤ 매우 필요하다

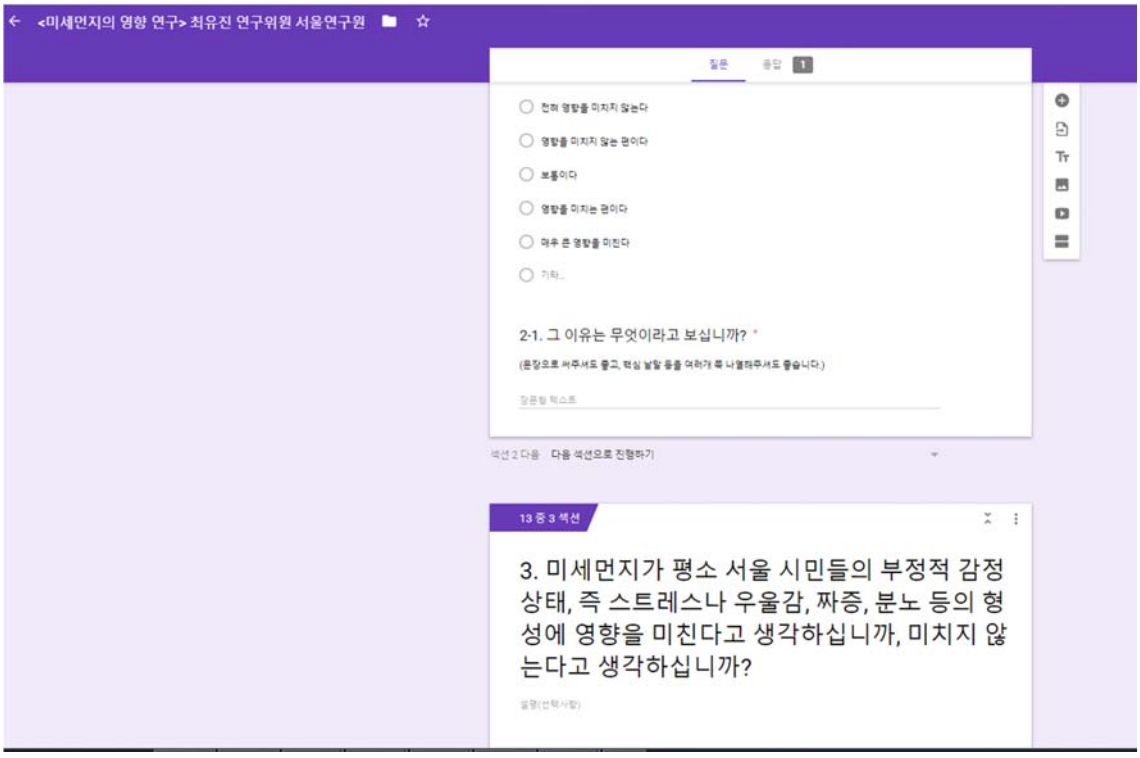
13-1. 그 이유는 무엇이라고 보십니까?

13-2. 그렇다면 정부가 서울시가 이를 위해 해야 하는 것은 무엇입니까?

13-3. 개인이 이를 위해 해야 하는 것은 무엇입니까?

13-4. 언론이 이를 위해 해야 하는 것은 무엇입니까?

Figure 31. The Captured Image of Questionnaire of Survey using Google Survey



Annex 3: Answers to the survey (multiple-choice questions)

Table 19. The Answers to the survey on the experts

no	Field	Specialization	Time Stamp	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q12-1	Q13
1	Professor	Chemical Eng.	7-21-2019 18:36:28	3	5	5	2	5	5	existing	5	1	7	8	5	1, 3	3
2	Doctor	Psychiatry	7-21-2019 19:20:30	5	5	5	5	1	2	children, the elderly, respiratory patients	5	1	1	5	11	3, 4	5
3	Professor	Environment	7-21-2019 19:58:03	5	5	4	4	5	5	housewife	4	6	6	3	5	5, 11	5
4	Researcher	Environment	7-21-2019 20:29:43	4	4	3	4	5	5	children, the elderly, respiratory patients and their family	4	7	8	6	3	1, 2	4
5	Professor	Public health	7-21-2019 23:29:06	5	5	5	2	5	5	people with strong social resentment	4	8	8	7	3	1, 11	4
6	Professor	Public health	7-22-2019 12:57:19	4	5	5	2	5	5	the elderly	4	3	5	2	12	10, 11	2
7	Professor	Environment	7-22-2019 14:22:07	4	5	5	2	5	3	--	4	2	1	6	8	1, 8	4
8	NGO	Public health	7-22-2019 8:31:44	5	5	5	5	2	4	the elderly, environmentalist	5	2	3	4	10	3, 11	5
9	Doctor	Medicine	7-24-2019 11:29:01	4	5	4	3	4	4	little study existing for this question, but the sensitive people to PM	2	4	6	9	2	2, 7	2
10	CEO	Lawyer	7-25-2019 22:36:59	4	5	4	3	3	4	I don't know	5	1	3	8	2	7	3
11	Professor	Environment	7-26-2019 11:12:10	5	5	4	4	3	4	children	5	10	10	7	3	11	4
12	Researcher	Chemical Eng.	7-26-2019 15:13:27	3	4	4	2	5	4	--	4	4	5	2	2	5	4
13	Researcher	Resource Eng.	7-26-2019 9:04:14	4	5	5	4	4	4	the respiratory patient, people with mental problem, children, the elderly	4	0	2	4	12	12	5
14	NGO	Environment	7-29-2019 16:07:41	4	5	4	3	4	5	the vulnerable, the sensitive,	4	6	7	2	3	4, 7	3
15	Researcher	Environment	7-30-2019 18:01:13	4	4	4	3	4	5	children, the elderly	4	2	3	6	12	12	4
16	Researcher	Environment	7-31-2019 12:05:57	4	5	5	4	4	4	the sensitive, the vulnerable	5	4	6	7	11	2, 5	5
17	Researcher	Environment	8-01-2019 08:52:47	4	5	5	4	5	3	the infirm, female	4	5	6	4	3	2, 12	3

18	Doctor	Medicine	8-01-2019 23:46:16	4	5	5	4	6	4	the socioeconomically vulnerable	4	7	7	6	1	1, 2	4
19	Researcher	Environment	8-02-2019 10:33:54	4	4	5	4	5	5	family with the vulnerable member, group without asset to respond to find dust	5	7	7	3	3	1, 3	1
20	NGO	Transportation	8-02-2019 16:44:11	4	4	4	3	3	4	people with underlying disease	3	3	8	5	5	12	3
21	Doctor	Medicine	8-02-2019 17:56:46	5	5	5	4	5	5	the elderly, low-income people	5	5	5	0	8	3	1
22	NGO	Lawyer	8-04-2019 8:26:16	4	4	5	4	3	4	Mother taking care of children	5	6	7	5	3	2, 7	4
23	Internat'l Org.	Regional Study	8-05-2019 16:30:22	5	5	5	5	2	1	respiratory patients, cardiovascular patients, parents having children, outside workers, policy makers	5	4	6	4	7	2, 10	3
24	Professor	Environment	8-08-2019 16:32:47	4	4	4	2	4	3	the infirm, the elderly, children	4	7	7	5	3	2	4

Source: Author, 2019

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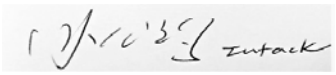
Your Signature(s) : _____  _____

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