Research Paper

A Study on Urban Planning to Protect Cultural Heritage from Air Pollution

Focusing on the protection of Gyeongju's cultural heritage from air pollution

Dong-Seok Kim, Dong-A university, Republic of korea

Seok-Ho Hong, Gwangju university, Republic of korea

Abstract

Air pollution not only harms human health and the environment, but also damages historical cultural heritage. It is mainly metal cultural heritage or stone cultural heritage that are outdoors that are affected by air pollution. Due to important air pollution factors such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) chloride ions, cultural heritage suffer from phenomena such as dissolution, deterioration, corrosion, discoloration, and deprivation. In other words, corrosion and pollution of cultural heritage caused by air pollution can cause serious economic losses due to high maintenance and restoration costs. This paper selects sites in South Korea and analyzes sustainable future urban planning policy to cope with air pollution. The area selected as the research site is Gyeongju-si, Korea. Gyeongju-si is one of the oldest cities in Korea, and it is a place where cultural heritages are damaged by air pollution because there are many metal cultural heritages or stone cultural heritages outdoors. This study analyzes the air pollution level of Gyeongju-si through an environmental satellite (GEMS) and proposes an urban plan to cope with air pollution with the results of the analysis. The biggest sources of air pollution in urban planning are industrial facilities and transportation. The results were derived that industrial facilities that cause pollution should be distributed or facilities that can reduce pollution emissions should be added. This paper proposes urban planning policy, including technology for responding to air pollution, to provide theoretical grounds and references for protecting cultural heritages from air pollution.

Keywords

Urbanplannig policy, Cultural heritage, Air pollution

1. Theoretical Background

1.1 The Severity of Air Pollution in Republic of korea

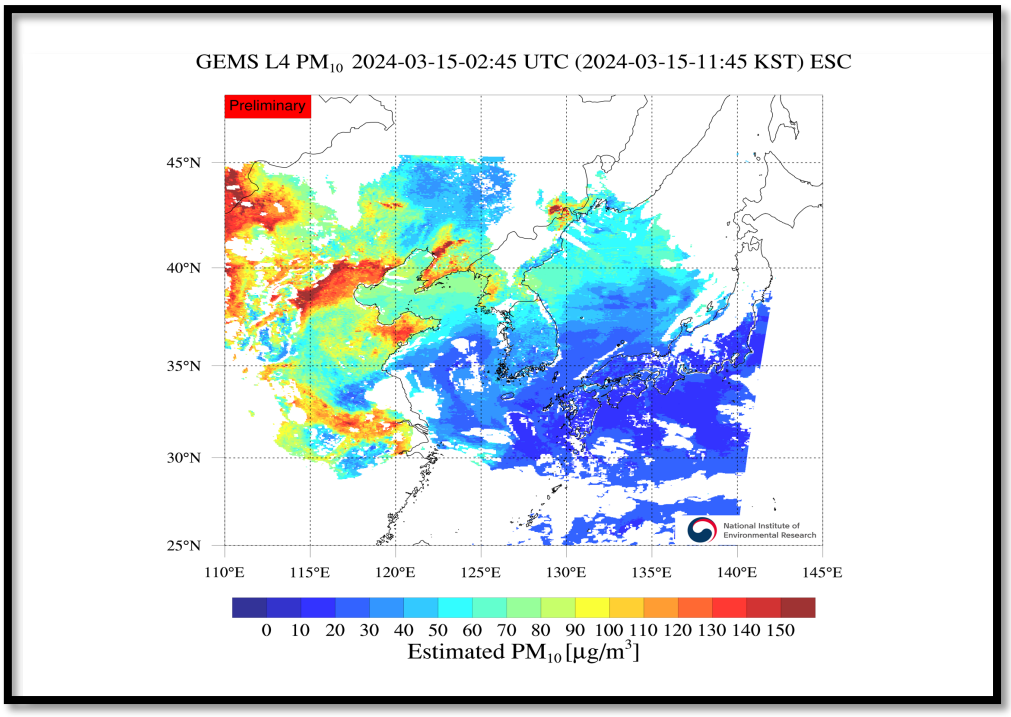


Figure 1. PM 2.5 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

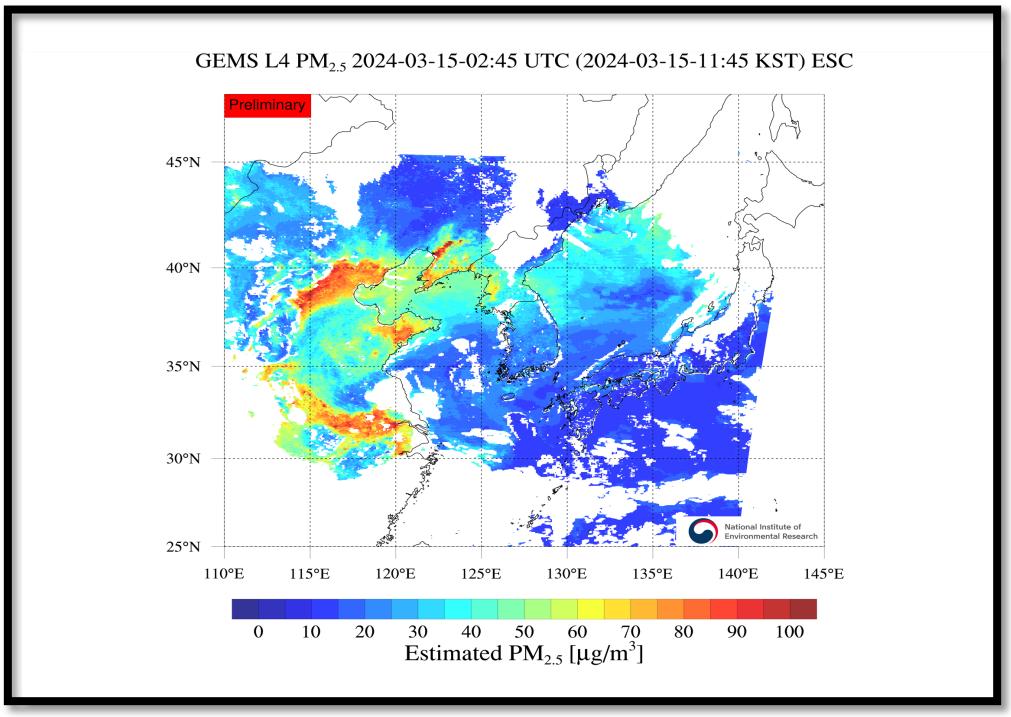


Figure 2. PM 10 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

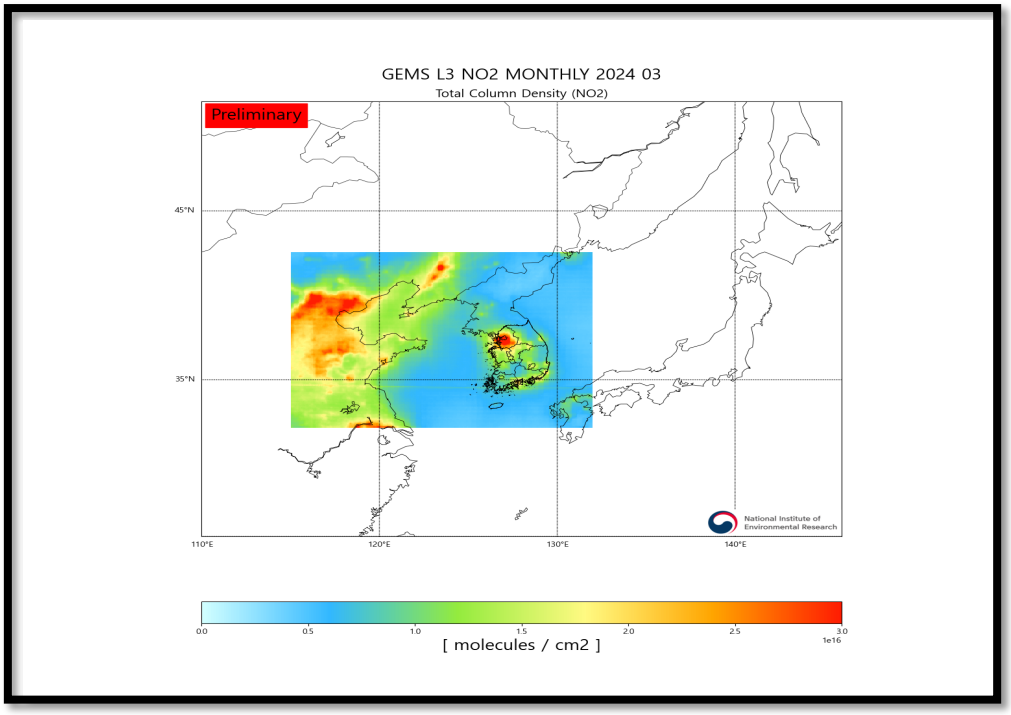


Figure 3. NO_2 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

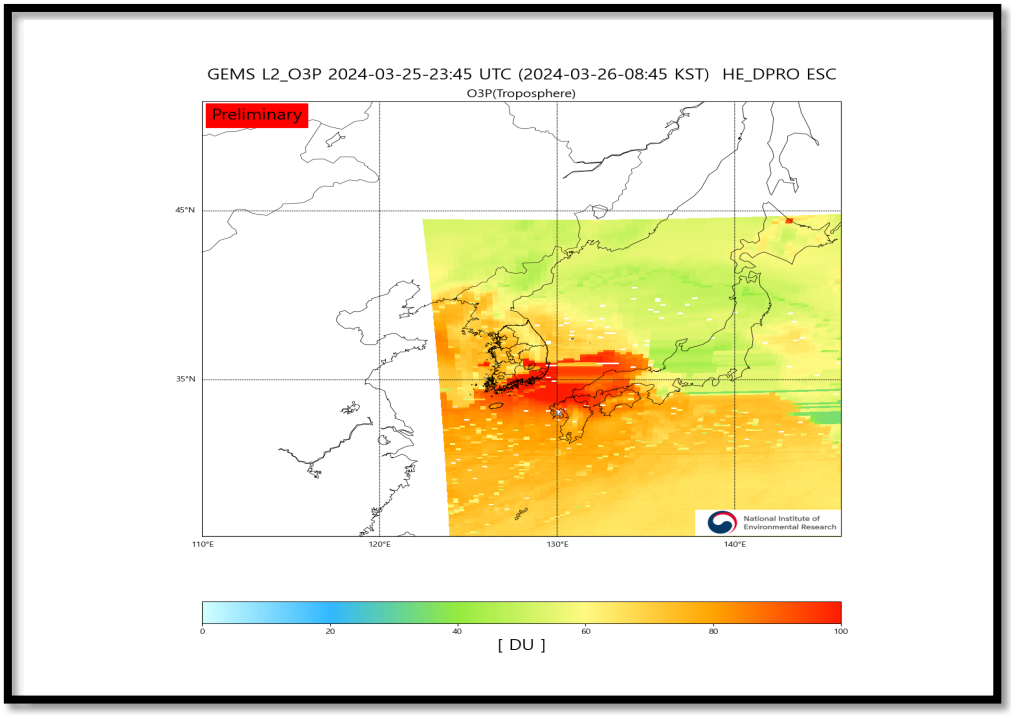


Figure 4. O_3 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

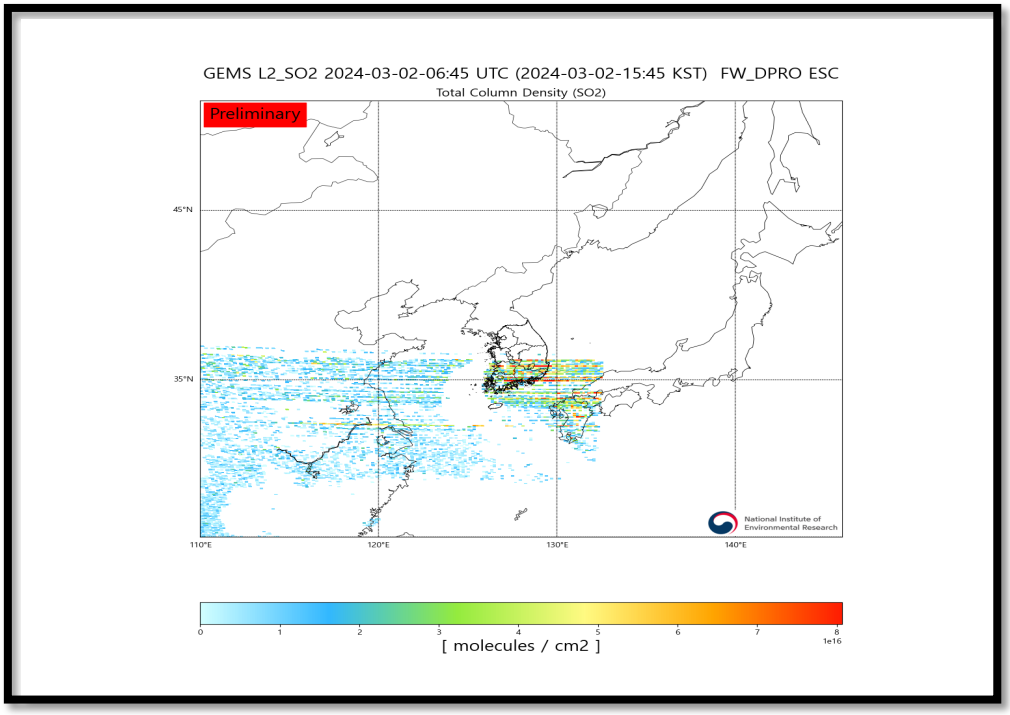


Figure 1. SO_2(Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

The images above represent the overall distribution of air pollutants across the Korean Peninsula. The WHO standards for air pollutants are as follows: PM2.5: 5 μg/m^3, PM10: 15 μg/m^3, NO_2: 10 μg/m^3, O_3: 60 μg/m^3, and SO_2: 40 μg/m^3 (World Health Organization, 2021). However, in most of the figures, it can be observed that air pollution levels exceed these standards, resulting in noticeable visual changes. This indicates the severity of air pollution in Republic of Korea.

1.2 Gyeongju as a Cultural Heritage Hub

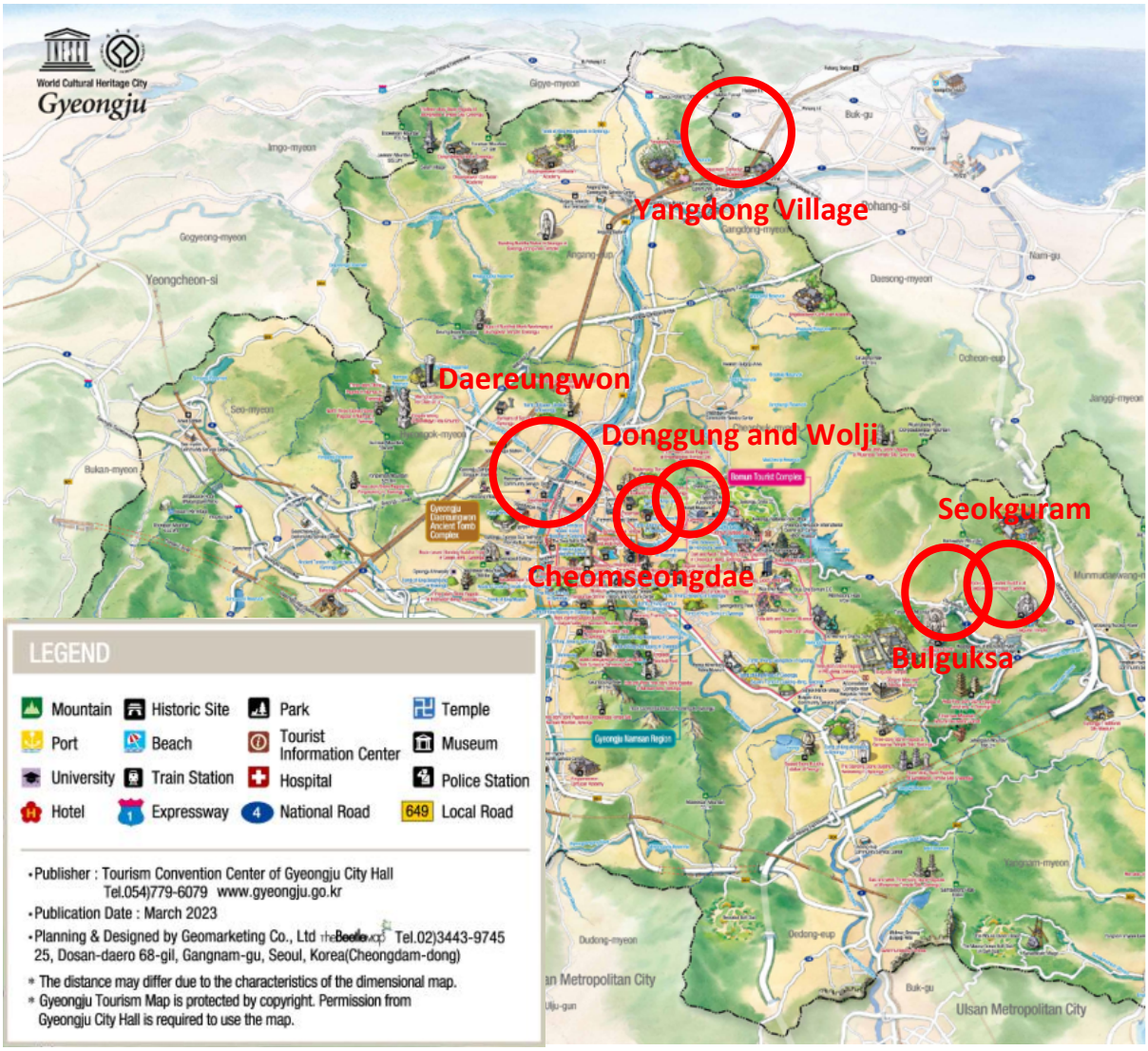


Figure 2. Cultural Heritage Site in Gyeongju, Republic of korea. Source: Gyeongsangbuk-do Province Gyeongju City Hall.

The reason for selecting Gyeongju as the study site is that the city has established itself as a hub of World Heritage. In addition to the five cultural heritage sites listed below, Gyeongju is home to various cultural assets within its historic areas, making it a historically significant city that requires preservation.

1. Seokguram Grotto and Bulguksa Temple

Seokguram and Bulguksa Temple are UNESCO World Heritage Sites and are ancient Buddhist ruins created during the Silla period. Seokguram is the only artificially made granite stone cave carrying Buddha statues, and Bulguksa Temple is a temple structure. It is an architecture and sculpture representing Buddhist culture in the Unified Silla Period around the 8th century, and Seokguram shows technical and artistic value in artificial stone caves and Buddha sculptures, and Bulguksa Temple is a valuable cultural property that is

evaluated as a building with a harmony of stone and wooden architecture(Korean National Commission for UNESCO, 2024).

2. Cheomseongdae Observatory

Cheomseongdae is the oldest observatory in East Asia and is a cultural heritage symbolizing governance and science, including agriculture and ritual schedule management (Korea Heritage Service, 2024). The 27 stone layers represent the twevle months of the year and the twenty-four solar terms and have cultural heritage value in that they contain scientific and astronomical knowledge.

3. Daereungwon Tomb Complex

Daerungwon is a UNESCO World Heritage Site. The ancient tombs of Silla royalty and aristocrats, representing the authority and wealth of the Silla royal family (Korean Heritage Service, 2024). In particular, the golden artifacts found in the Cheonmachong and Hwangnamdaechong show ancient culture and technology of Silla. It is also a place to represent the afterlife, the dignity of the ruling class, the social structure and funeral culture of the Silla period.

4. Donggung Palace and Wolji Pond (Anapji Pond)

Donggung Palace and Wolji Pond is also part of UNESCO World Heritage Site. The royal culture and architectural beauty of Silla can be seen through Silla's Byeolgung Palace and artificial ponds, and various Silla relics were found here, emphasizing historical and cultural importance (Korean Heritage Service, 2019).

5. Yangdong village

Andong Hahoe Village and Gyeongju Yangdong Village, which were established in the 14th and 15th centuries, are clan villages representing the Republic of Korea(Korean National Commission for UNESCO, 2024). In addition, Yangdong Village is a traditional Hanok village in the Joseon Dynasty and has been designated as a UNESCO World Heritage Site. Traditional architectural styles and living cultures have been preserved as Yangban families have lived for generations, and traditions that show the lifestyle and social structure of Confucian families in the Joseon Dynasty have been preserved.

2. Analysis of the Impact of Air Pollutants

2.1 Pollutants Affecting Cultural Heritage & Mechanisms of Damage

Cultural heritage structures affected by air pollution are exposed to various pollutants, including particulate matter (PM), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and carbon dioxide (CO_2). The following section will explain each pollutant and the mechanisms through which these pollutants cause damage to buildings.

- Particulate Matter(PM) contains corrosive chemical substances, which, upon deposition on structures, promote corrosion. Additionally, it acts as a catalyst for the formation of nitric ac(Oscar Julian Esteban-Cantillo et al.,2024).

-Nitrogen dioxide (NO_2) combines with water to form nitric acid, which primarily causes corrosion on limestone and marble, materials commonly used in cultural heritage structures (Silvestro Antonio Ruffolo et al., 2023).

-Ozone (O_3) oxidizes organic materials such as wood, weakening fibers, and accelerates the corrosion of metals and stone structures(Bo Xiao et al.,2022)

-When sulfur dioxide (SO_2) comes into contact with rain or moisture, it forms sulfuric acid (H_2SO_4), which is a component of acid rain. This sulfuric acid reacts with the calcium carbonate in stone, leading to the formation of gypsum (calcium sulfate), which weakens the surface of the stone over time(Oscar Julian Esteban-Cantillo et al.,2024).

- Carbon dioxide (CO_2) dissolved in atmospheric moisture, forms carbonic acid, which reacts with building materials, particularly those made of calcium carbonate ($CaCO_3$), such as limestone and marble (Spezzano, 2021).

2.2 Sources of Air Pollution

PM (Particulate Matter): Natural sources include sea salt, crustal dust, pollen, and volcanic ash. Anthropogenic sources predominantly stem from the combustion of fossil fuels in power plants and vehicles, heating of households, as well as non-combustion emissions from vehicular traffic and the resuspension of road dust(Dušan Jandačka, 2015).

NO_2 (Nitrogen Dioxide): Nitrogen dioxide is primarily emitted during land-based transportation, agricultural activities, fuel production, power generation, and the combustion of solid biofuels in households (Chowdhury et al., 2021).

O_3 (Ozone): Photochemical reaction of NOx from industrial sources and vehicles with VOCs emitted by automobiles, industrial sources, and solvents. (Raffee et al., 2022).

SO_2 (Sulfur Dioxide): Natural sources such as biological decay and sea spray emit sulfur, while anthropogenic sources like coal combustion, oil, and smelting operations release sulfur dioxide (SO_2) into the atmosphere. Approximately 70% of anthropogenic emissions are attributed to coal combustion (Kumar, 2020).

CO_2 (Carbon Dioxide): Natural sources of carbon dioxide emissions include volcanic eruption, fire, ocean vapors, dust storms, and the fermentation of organic materials. Anthropogenic sources, on the other hand, include industry, transport, agriculture, energy production, domestic heating (Abderrezak Khelfi, 2018).

2.3 The relationship between air pollutants and diseases

Air pollutants also harm cultural heritage, but PM, SO_2, NO_2, and O_3 are also causing diseases related to various fields such as cognitive disorder, respiratory tract, high blood pressure, cardiovascular system, and cerebrovascular system in cities. Many studies are still trying to determine the correlation, but some of the related diseases have been identified by the results of the studies.

-Exposure to Particulate Matter (PM) air pollution causes respiratory deposition by being transported to the alveoli through inhalation (Chen et al., 2023). PM10 and PM2.5 are predominantly present in the upper respiratory tract, PM2.5 and ultrafine dust are more deeply present, causing lung function decline, respiratory symptoms, bronchitis, lung emphysema, and circulatory diseases (Gandhimathi A et al., 2023). In addition, Chronic obstructive pulmonary disease (COPD) also shows that increasing PM10 by 10μg/m^3 increases COPD hospitalization by 2.7%, COPD mortality by 1.1%, and PM2.5 also has significant correlation (Zhu et al., 2020).

- "Short-term exposures to NO_2 may increase the risk of cerebrovascular mortality, specifically for ischemic stroke and sequelae of cerebrovascular disease" (Qian et al., 2023).

2.4 Gyeongju Air Quality Data

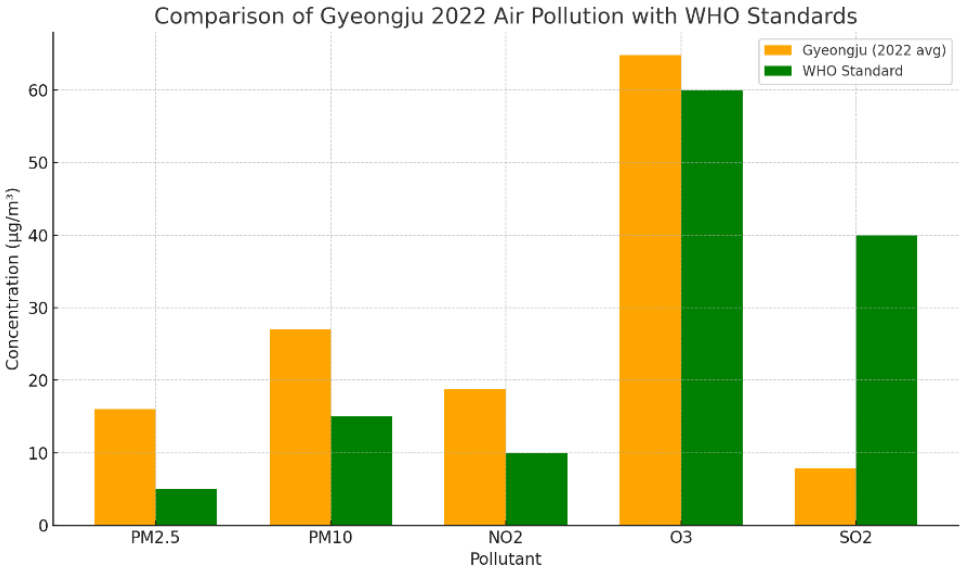


Figure 3. Comparison of Gyeongju 2022 Air pollution with WHO Standards. Source: National Institute of Envireonmental Research in korea.

	Gyeongju (2022 avg)	WHO(2021 standard)
PM2.5	16 μg/m³	5 μg/m³
PM10	27 μg/m³	15 μg/m³
NO_2	18.82 μg/m³(=0.010 ppm)	10μg/m³
O_3	64.79 μg/m³(=0.033ppm)	60μg/m³(peak season) [a]
SO_2	7.86 μg/m³(=0.003 ppm)	40μg/m³(24hours) [b]

Table 1. Comparison of Gyeongju 2022 Air pollution with WHO Standards. Source: National Institute of Envireonmental Research in korea.

[a] 99th percentile (i.e. 3–4 exceedance days per year) (World Health Organization, 2021).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running- average O_3 concentration(World Health Organization, 2021).

The above graph and table are data comparing Gyeongju City and WHO Air Quality Guideline based on the Korea 2022 Air Quality Yearbook of the National Institute of Environmental Research in Korea. It can be seen that Gyeongju, the target site, is two to three times different from WHO guidelines in most indicators (PM2.5, PM10, NO_2). In the case of O_3 and SO_2, the WHO's guideline provided the values of peak season and 24 hours rather than annual standards, so it could be compared indirectly. Among the air pollutants

that exceeded the standard, the biggest difference can be seen as PM10 (+12 μg/m ^{3}), and the relatively small differences were observed as NO_2 and O_3.

Of course, the environmental satellite data of the Korea National Institute of Environmental Research showed the seriousness of air pollutants exceeding WHO guidelines through graphs and tables, and it was determined that there would be a need to protect the cultural heritage of Gyeongju, Korea from air pollution.

3. Urban planning policy proposal

Establish effective air pollution measures in Gyeongju by identifying the characteristics and causes of air pollutants that damage cultural heritage. The causes of air pollution covered in Part 2 include transportation and industrial facilities. Analyze and propose urban planning policies that can be implemented in Gyeongju in air pollution.



Figure 4. Gyeongju Map. Source: Naver Map

Target Site: Gyeongju-si, Gyeongsangbuk-do, Republic of korea

Area: 1,324.95 ㎢

Population: 245,475

3.1 Transportation

The decrease in major air pollutants during COVID-19 was mainly due to reduced emissions due to reduced urban traffic due to the pandemic(Woo-cheol et al.,2021). This document shows the impact of the transportation sector on air pollution. Therefore, it is analyzed that it is necessary to reduce air pollution in the transportation sector. Deteriorated diesel vehicles contribute to the increase of air pollutants, which affect cultural heritage. This problem can be solved by inducing the transition to electric vehicles through a subsidy program for the disposal of aged diesel vehicles in Gyeongju.

In addition, if the vehicle stops for a long time, this means that there is more air pollutants emitted from the car (Kim, Hui-jae, 2014). Therefore, the idling of cars at signal intersections where cars stop without turning off their engines must be restricted. In Fig 6, the area where cultural heritage concentrated areas are selected is designated as an idle restricted area, and a 'heritage protection traffic tax' is imposed to protect heritage on cars that are not equipped with an automatic Idle Stop and Go system that passes through this area. In addition, by providing traffic signal information through vehicle-to-infrastructure to

vehicles, a system is introduced that calculates the signal waiting time based on the information, and the driver adjusts the speed and goes to the signal intersection to minimize signal waiting.

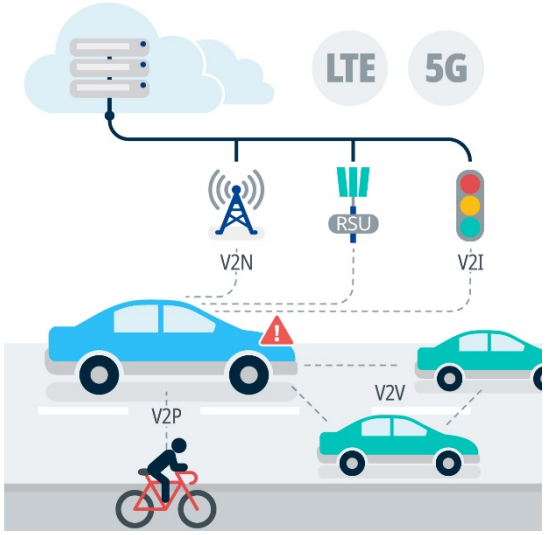


Figure 5. vehicle-to-infrastructure.

Source: Telecommunications Technology Association, TTA

3.2 Industrial complex planning Proposal

An issue to be considered in urban planning is the arrangement when planning an industrial complex. Gyeongju is a historical city, but it is adjacent to the sea where it can secure abundant industrial water and has a large land. Since the surrounding cities are Ulsan and Pohang, which are port cities with large-scale industrial complexes, there are many industrial complexes in Gyeongju.



Figure 6. Distribution Map of Gyeongju Industrial Complex.

Source: Korea Industrial Complex Corporation.

In Gyeongju, general industrial complexes occupy 15,520,121 ㎡, and nuclear power plants, which are national industrial complexes, occupy 3,692,816 ㎡. Fig 10, Indicating at the distribution of industrial

complexes, the main industries are other machinery and equipment, automobiles and trailers, other transport equipment, primary metal manufacturing, and textile product manufacturing. Ozone, emitted from industrial facilities such as chemical plants and oil refineries and from various sources such as natural generation, nitrogen dioxide generated in high-temperature combustion processes such as automobiles and power plants and chemical manufacturing processes such as burning fuels (mainly coal and petroleum), metal smelting processes, and other industrial processes are major air pollutants that damage cultural properties. In other words, when planning an industrial complex first, it must be distributed and arranged to prevent air pollutants emitted from factories.



Figure 7. Master Planning of Gyeongju Industrial Complex. Source: Gyeongsangbuk-do.

Fig.11 is a master plan for an industrial complex in Gyeongju, but it lacks a lot of green space. Most industrial complexes in Gyeongju, as well as this area, show similar characteristics. This paper propose to secure green areas to reduce pollutants generated from factories that cause air pollution. In order to increase green space by 30% and strengthen green network, green will be created throughout the building structure of the target area.

The theory of industrial complex planning in Gyeongju proposed by this paper increases the green area by 30% from the originally planned green area. To strengthen the green network, a natural space is created in some of the building structures in the target area. It is designed so that the shade of trees in the complex covers more than 30% of the area. Public green spaces or buffered green spaces are located within 300m of each other. In each green space is planned tbe planted with less than 10% of the same species, less than 20% of the same genus, and less than 30% of the same family. The building is arranged so that the wind road can be applied by analyzing the wind blowing pattern.

Monitor air quality by scanning satellite industrial complexes in real time through environmental satellites (National Institute of Environmental Research). Devices that communicate with this satellites using the Internet of Things (IoT) and automatically spray mist to dilute air pollutants when certain air pollution indices increase are placed in industrial complexes vulnerable to air pollution.

3.3 Energy Transition

At the 28th United Nations Climate Change Conference (COP28) held in Dubai, the United Arab Emirates, KHNP announced the Small Modular Reactor (SMR), a next-generation nuclear power plant. At COP28, nuclear power received attention as one of the energy sources to replace fossil fuels. Gyeongju was designated as SMR National Industrial Complex. As explained above, air pollutants are generated a lot in industrial complexes. If Gyeongju achieves the energy conversion from conventional fossil fuel energy to nuclear energy, it can reduce air pollutants generated from industrial complexes.

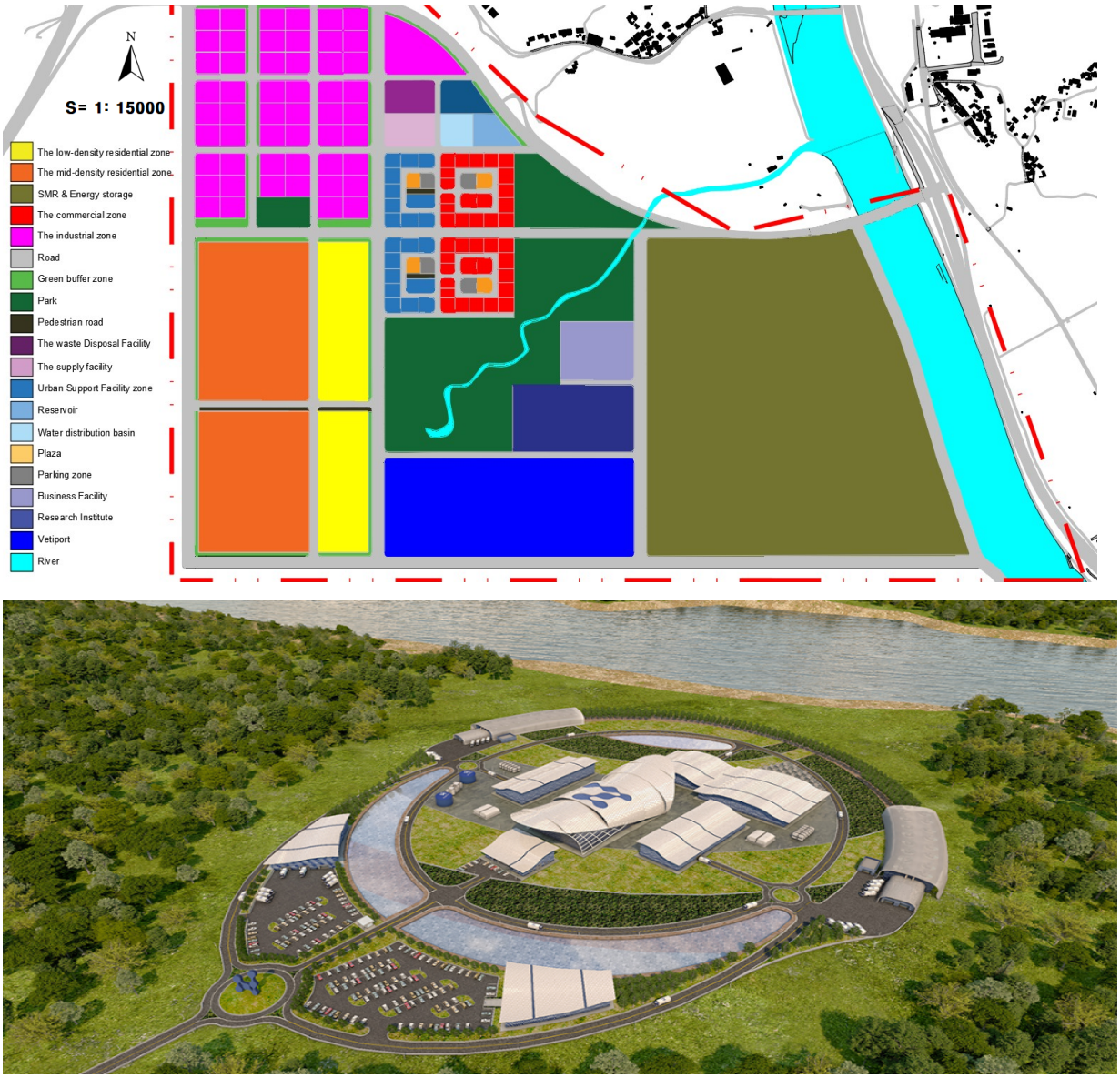


Figure 8. Urban Planning SMR Industial Complex. (Kim.D.S., 2024).

Fig 12 is an expected drawing of urban planning for a Gyeongju industrial complex that introduced SMR. Small modular reactors (SMR) are next-generation nuclear power generation technologies that compensate for the risk of accidents, construction costs, and time, which are the disadvantages of existing nuclear power plants. The SMR uses reactors with an output of less than 300 MWh and are called small nuclear power plants. Unlike conventional nuclear power plants, SMR has no major restrictions on location conditions and can be built in cities because it is safe (Kim.D.S., 2024).

It replaces fossil energy through nuclear energy by deploying SMR in industrial complexes that require a lot of energy. The replacement of fossil energy in industrial complexes will reduce air pollution, which means that cultural properties in Gyeongju can be protected from air pollution. Urban planning, including SMR, change the way energy is supplied in future cities.

4. Conclusion

This study compared air pollutant levels in Gyeongju, Gyeongsangbuk-do, Republic of korea, with the WHO Air Quality Guidelines, analyzing that most levels exceed WHO standards by two to three times. These pollutants, produced by fuel production, power generation, transportation, and heating of households, adhere to cultural heritage sites, leading to structural corrosion and surface weakness. Air pollution remains a persistent threat to cultural heritage, and even Gyeongju, a hub of Cultural heritage, is not immune to these risks. Because of its large number of industrial complexes and the resulting heavy traffic, Gyeongju's cultural heritages are exposed to high levels of air pollution. The damage caused by air pollution causes huge losses to cultural heritage.

This paper proposes urban planning and policies related to transportation, industrial complexes, and energy transition to tackle the air pollution issues. It is expected to give various implications in the process of making and implementing urban planning policies in response to air pollution in the future.

However, since the analysis was selected and analyzed at a specific time point and a specific area, there is a limit to interpretation through generalization. In future studies will be expanded the scope of the survey to all seasons and present an urban design drawing that visualizes the results in 3D.

5. References

Reference list

Abderrezak Khelfi (2018). Sources of Air Pollution. *Advances in environmental engineering and green technologies book series*, pp.220–258. doi:https://doi.org/10.4018/978-1-5225-3540-9.ch011.

Chen, T.-Y., Chen, S.-C., Wang, C.-W., Tu, H.-P., Chen, P.-S., Hu, S.C.-S., Li, C.-H., Wu, D.-W., Hung, C.-H. and Kuo, C.-H. (2023). The impact of the synergistic effect of SO2 and PM2.5/PM10 on obstructive lung disease in subtropical Taiwan. *Frontiers in Public Health*, 11. doi:https://doi.org/10.3389/fpubh.2023.1229820.

Choi, W.-C. and Cheong, K.-S. (2021). Analysis of the Factors Affecting Fine Dust Concentration Before and After COVID-19. Journal of the Korean Society of Hazard Mitigation, 21(6), pp.395–402. doi:https://doi.org/10.9798/kosham.2021.21.6.395.

Chowdhury, S., Haines, A., Klingmüller, K., Kumar, V., Pozzer, A., Venkataraman, C., Witt, C. and Lelieveld, J. (2021). Global and national assessment of the incidence of asthma in children and adolescents from major sources of ambient NO2. Environmental Research Letters, 16(3), p.035020. doi:https://doi.org/10.1088/1748-9326/abe909.

Dušan Jandačka (2015). Sources of PM10 Air Pollution in Rural Area in the Vicinity of a Highway In Žilina Selfgoverning Region, Slovakia. Civil and Environmental Engineering, 11(1), pp.58–68. doi:https://doi.org/10.1515/cee-2015-0008.

Gandhimathi A, Manju R, Ramadevi K, Rajalakshmi S and Mayilvahanan I (2023). A STUDY OF ENVIRONMENTAL IMPACT OF AIR POLLUTION ON HUMAN HEALTH: PM DEPOSITION MODELLING. Global NEST: the international Journal, 25(6). doi:https://doi.org/10.30955/gnj.004613.

Gyeongsangbuk-do, About Gyeongsangbuk-do Industrial Complex. (2019). Available at: https://www.gb.go.kr/Sub/open_contents/section/invest/page.do?mnu_uid=4167&LARGE_CODE=430&MEDIUM_CODE=30 [Accessed 31 Oct. 2024].

Kim, D.S. (2024). Future Scenario for Sustainable Carbon Neutral Urban Planning with SMR. Lecture notes in networks and systems, 851, pp.153–166. doi:https://doi.org/10.1007/978-3-031-71076-6_9.

Kim, Hui-jae (2014). “Analysis on Relationship between Urban Development Characteristics and Air Pollution Level - a Case of Seoul Metropolitan Region -.” Journal of Korea Planners Association, vol. 49, no. 7, 30 Nov. 2014, p. 151, https://doi.org/10.17208.

Korea Industrial Complex Corporation, Distribution Map of Gyeongju Industrial Complex. (2024). Available at: https://www.kicox.or.kr/home/mwrc/policyRsrch/fdrmPblictn/fdrmPblictn04.jsp [Accessed 20 Oct. 2024].

Korean Heritage Service. (2019). National Heritage Information. [online] Available at: https://www.heritage.go.kr/heri/cul/culSelectDetail.do?pageNo=1_1_1_1&ccbaCpno=1333700180000 [Accessed 30 Oct. 2024].

Korean Heritage Service. (2024a). *National Heritage Information*. [online] Available at: https://search.khs.go.kr/srch_org/search/search_top.jsp?searchCnd=&searchWrd=&home=total&mn=&gubun=search&query=%EC%B2%A8%EC%84%B1%EB%8C%80 [Accessed 30 Oct. 2024].

Korean Heritage Service. (2024b). *National Heritage Information*. [online] Available at: https://www.heritage.go.kr/heri/cul/culSelectDetail.do?pageNo=1_1_1_1&ccbaCpno=1333705120000 [Accessed 30 Oct. 2024].

Korean National Commission for UNESCO. (2024). *World Heritage Sites in Korea*. [online] Available at: https://unesco.or.kr/heritage [Accessed 31 Oct. 2024].

Kumar, A. (2020). A Review on Ionic Liquids as Novel Absorbents for SO2 Removal. *Water science and technology library*, pp.285–307. doi:https://doi.org/10.1007/978-3-030-38152-3_15.

National Institute of Environmental Research. (2024). Available at: https://nesc.nier.go.kr [Accessed 17 Oct. 2024].

Oscar Julian Esteban-Cantillo, Menendez, B. and Quesada, B. (2024). Climate change and air pollution impacts on cultural heritage building materials in Europe and Mexico. *Science of the total environment*, 921, pp.170945–170945. doi:https://doi.org/10.1016/j.scitotenv.2024.170945.

Qian, Y., Cai, R., Su, X., Li, Q., Jin, S., Shi, W., Chen, R., Wang, C. and He, J. (2023). Residential Nitrogen Dioxide Exposure and Cause-Specific Cerebrovascular Mortality: An Individual-Level, Case-Crossover Study. *Toxics*, 12(1), pp.10–10. doi:https://doi.org/10.3390/toxics12010010.

Raffee, A.F., Hamid, H.A., Rahmat, S.N. and Jaffar, M.I. (2022). The cause-and-effect analysis of ground level ozone (O3), air pollutants and meteorological parameters using the causal relationship approach. *Journal of Engineering Research*, 11. doi:https://doi.org/10.36909/jer.17233.

Silvestro Antonio Ruffolo, Francesco, M., Rovella, N. and Ricca, M. (2023). The Impact of Air Pollution on Stone Materials. *Environments*, 10(7), pp.119–119. doi:https://doi.org/10.3390/environments10070119.

Spezzano, P. (2021). Mapping the susceptibility of UNESCO World Cultural Heritage sites in Europe to ambient (outdoor) air pollution. *Science of The Total Environment*, 754(142345), p.142345. doi:https://doi.org/10.1016/j.scitotenv.2020.142345.

World Health Organization (2021). *What are the WHO Air quality guidelines?* [online] World Health Organization. Available at: https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines [Accessed 30 Oct. 2024].

Xiao, B., Ning, L., Lin, Z., Wang, S. and Zang, H. (2022). The Impact of Air Pollution on the Protection of World Cultural Heritage in China. *International Journal of Environmental Research and Public Health*, 19(16), p.10226. doi:https://doi.org/10.3390/ijerph191610226.

Zhu, R.-X., Nie, X.-H., Chen, Y.-H., Chen, J., Wu, S.-W. and Zhao, L.-H. (2020). Relationship Between Particulate Matter (PM2.5) and Hospitalizations and Mortality of Chronic Obstructive Pulmonary Disease Patients: A Meta-Analysis. *The American Journal of the Medical Sciences*, [online] 359(6), pp.354–364. doi:https://doi.org/10.1016/j.amjms.2020.03.016.