ASSESSMENT OF **THE AIR QUALITY EFFECTS** OF PEDESTRIANIZATION ON İSTANBUL'S HISTORIC PENINSULA

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Motor İskeleleri

INTRODUCTION

İstanbul's Historic Peninsula, bounded by the old walls of İstanbul, is one of the most well known UNESCO World Heritage areas of the world. The area and its surroundings have seen habitation by different civilizations, which have produced different land use patterns over the centuries. In the present day, however, this diversity in land use characteristics is dominated by the Peninsula's use as a central commercial area, primarily housing the service industry built around tourism, the area attracts about 2.5 million visitors including 433,796 people resided within the Historic Peninsula, 276,809 people employed in the area and 1.5 million passengers every day according to the İstanbul Transportation Master Plan, in 2009.[1] As the epicenter of tourism, commerce, urban activities and daily logistic activities, İstanbul has become more car-oriented in the recent decades; the Historic Peninsula however is pedestrianized in the inner sections which caused high density of traffic within the limited area of roads mostly at water sides.

Starting in 2005, İstanbul Metropolitan Municipality (İBB) launched a series of pedestrianization projects to reduce the negative effects of vehicle traffic on tourist and commercial activities and improve the quality of life in the area. In 2010, in cooperation with Danish architecture and planning firm Gehl Architects and the İstanbul Metropolitan Municipality, EMBARQ Turkey identified problems in the pedestrianization process and developed proposals and strategies for the area with the publication of "İstanbul Public Spaces and Public Life" report. Since 2010, 295 streets in Eminönü, Tahtakale, Beyazıt, Laleli, Gedikpaşa and Hocapaşa have been pedestrianized. The municipality has also implemented supporting infrastructure for pedestrianized areas such as re-pavement, signalization, and reorganization of waste management services. Based on surveys with business owners, residents and students, EMBARQ Turkey also published the "Current State Assessment of the Historic Peninsula Pedestrianization Project" in June 2014 to evaluate user groups' perception of social and environmental conditions during this process.

In theory and practice, transforming car-oriented streets into functional public spaces and pedestrianized environments would result in better urban environmental quality and reduce harmful impacts on public health. Given that the high volume of visitors in the Historic Peninsula, pedestrianization's role of improving air quality and resulting impacts on public health cannot be understated.

The purpose of our study on local air quality assessment in İstanbul's Historic Peninsula is to evaluate how the pedestrianization of

[1] Gehl Architects (2010) İstanbul Public Spaces and Public Life.

the area has altered local air quality by comparing former air quality profile study of the Peninsula before pedestrianization was assessed by Professor Ferhat Karaca of Fatih University as a TÜBİTAK project in 2009-2010. Post-pedestrianization air quality assessments were carried out in the same locations in the last quarter of 2014 with the collaboration of İstanbul Metropolitan Municipality Department of Environmental Protection, Fatih University and EMBARQ Turkey. Air quality assessments were done with passive samplers in 23 locations through 5 field campaigns, where NO_2, SO_2, O_3, HCl and HF were the critical pollutants assessed.

This issue paper serves as the first baseline study to assess the change on air quality by measuring certain local emissions such as NO_2, SO_2, O_3, CH_4, HF and HCl in order to measure the impact of fossil fuel-powered motor vehicles on the environmental and public health impact of pedestrianization to support IBB's four planned pedestrianization projects in central locations such as Historic Peninsula. Even though Ministry of Environment and Urbanization installed an air quality measurement station in the area, unfortunately it is located outside of the pedestrianized area. Moreover, municipality does not have a fully functioned mobile source emissions measurement station in the area. Therefore, current data collection on local emissions do not provide input for a before and after study to show the impact of pedestrianization. To overcome this issue, EMBARQ Turkey collaborated with Fatih University Department of Environment which is the only institution that has the local emission measurements from 2010 and 2011 which correspondence the main pedestrianization period of the Historic Peninsula. This collaboration helps to provide major understanding and awareness for the before and after data collection regarding to the impact assessment studies on sustainable urban transport and green mobility.

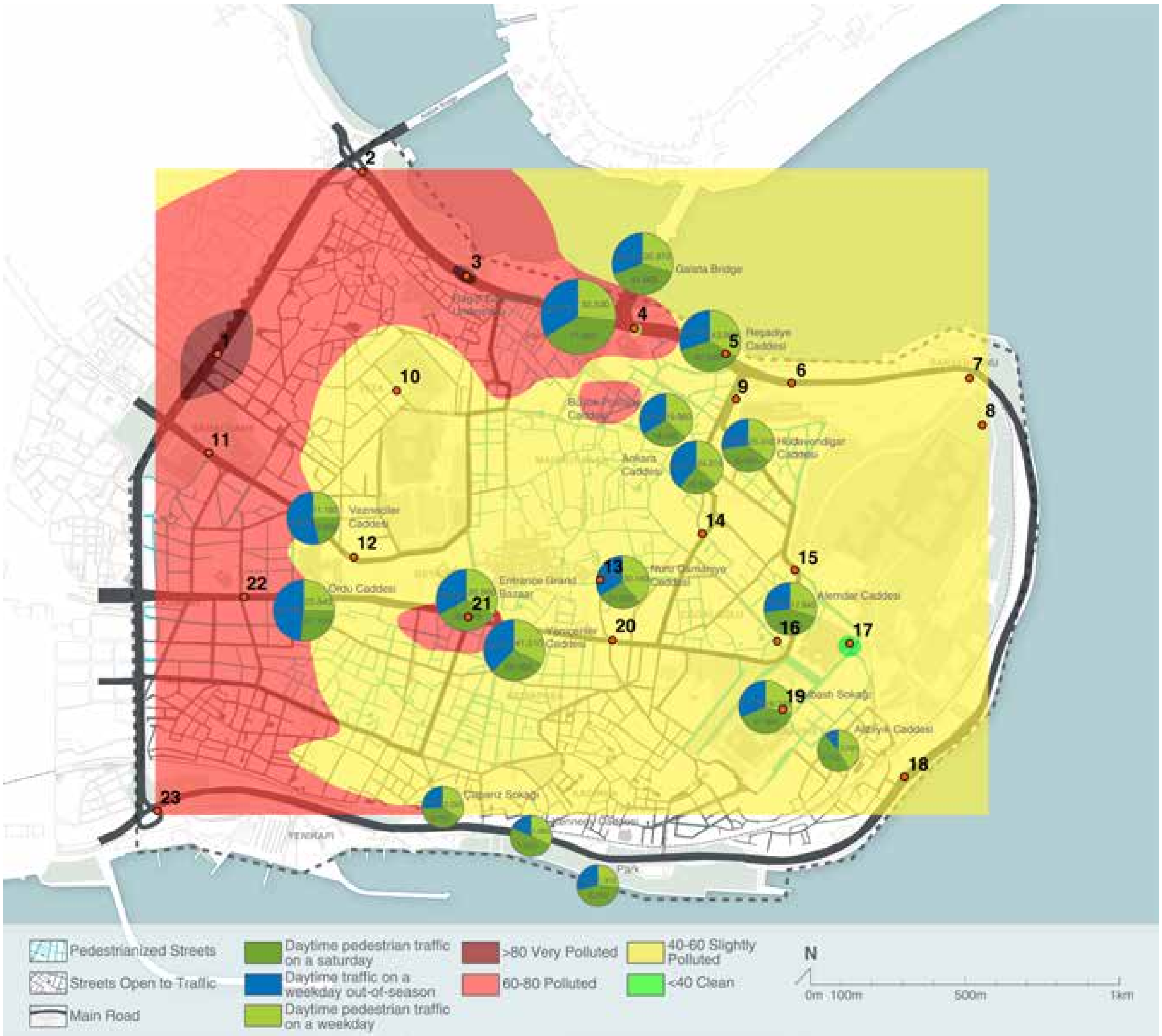
This issue paper addresses the following topics:

- Seasonal air quality measurements of critical pollutants such as NO_2, SO_2, O_3, CH_4, HCl and HF;
- Assessment of the air quality effect of pedestrianization regarding to the before and after measurements;
- Tailored based recommendations on sustainable and green mobility solutions for Historic Peninsula according to the air quality comparison study and former pedestrianization studies of EMBARQ Turkey.

Findings:

- In the aftermath of the pedestrianization of the Historic Peninsula, there have been considerable positive changes in the area's vehicle emissions-related air pollution profile on location base measurements and ground-level distribution of pollutants.
- After the pedestrianization of the area, NO_2 levels in the area have decreased by 42% and SO_2 levels have reached negligible levels and have fallen below urban baseline levels. The average SO_2 levels are reduced 80% in Historic Peninsula comply with the urban ambient air quality background measurements in İstanbul and also show parallels with European cities.
- While NO_2 levels in the area show similarities with the pollution profiles of European cities like Barcelona, NH_3 levels in the area are fourfold of European urban air pollution levels. This finding suggests that similar to examples from the United Kingdom, there may be a high concentration of vehicles and public busses with older diesel engines using selective catalytic reactor (SCR) systems.
- As shown in the figure below, the public health risk evaluation is positive only one sampling location (number 17, the entrance of Topkapı Palace) is classified as safe in terms of air pollution profile.
- However, sampling locations in Unkapanı and Eminönü (numbers 1 and 3) are the most polluted and highest health risk locations the study. Overall, residential areas in the North are highly affected by pollution from congestion and constitute the most polluted areas of the Historic Peninsula.
- NO_2 levels in the Historic Peninsula, which used to be much higher than European averages before

Figure 1 NO_2 Pollution Risk Areas in the Historic Peninsula with Daytime and Seasonal Changes of Pedestrian Traffic



the area's pedestrianization (86 µg/m^3), have decreased by about 42%. However, it should be noted that NO_2 levels in some locations are still above European levels.

- Showing similarities with similar European cities, in the past 5 years, SO_2 levels have reached negligible levels, falling below urban baseline levels.
- High ratio of NH_3 to NO_2 suggests that here may be a high concentration of vehicles and public buses with older diesel engines using selective catalystic reactor (SCR) systems in the Historic Peninsula's traffic.
- Finally, when sampling results from before and after pedestrianization are compared, pollution levels show a considerable decrease from the outer to the inner areas of the Peninsula. From 2010 to 2014, there have been significant reductions in vehicle emissions and resulting pollution in areas that have been pedestrianized.

This report is composed in four main sections.

The first section of the study explains the purpose of the study and summarizes pedestrianization efforts in the Historic Peninsula. The first section provides information on effects of vehicle emissions on public health, preservation of historic buildings and climate change. It also gives an overview of the area's recently implemented pedestrianization projects and case study examples illustrating pedestrianization's impact on air quality.

The second section provides background information on İstanbul's air quality problem and presents the methodology of the study and related field campaigns for air quality assessment.

The third section discusses the main findings of the study, provides maps to illustrate the problem of traffic density and distribution of critical air pollutants in the Historic Peninsula. The third section also includes a public health risk analysis based on findings from field measurements.

Lastly, the fourth section identifies recommendations regarding better enforcement of existing pedestrianization measures, traffic calming measures, strengthening of pedestrian networks, promotion of an integrated public transportation system and the use of cleaner vehicles, and ultimately, the establishment of a congestion charge area in the future. Some key recommendations for the improvement of air quality (options that could be taken that would help improve air quality) in the Historic Peninsula include the following:

- Existing measures that make pedestrianized streets exclusive to pedestrian traffic should be enforced.

- Illegal idling, especially tour buses that are idling in Sultanahmet Square, should be reduced.

- Policies on overall traffic calming in the Historic Peninsula should be accompanied by an integrated mass transportation system with increased efficiency and higher carrying capacity.

- Bus routes and bus transit hubs should be relocated away from the central part of the Historic Peninsula.

- Private vehicle traffic should also be redirected away from the Historic Peninsula, through the development of park and ride solutions.

- Clean and innovative freight transport solutions, such as the use of cargo-cycles within the Peninsula, should be explored to facilitate daytime delivery. Also for a long term strategy, wholesalers in the peninsula should be moved to another places in order to reduce logistics traffic.

- Cycling should be integrated with other travel modes, such as mass transportation or walking.

- Tourists should be presented with multiple travel modes to reach and tour the Historic Peninsula, such as light rail systems, walking and cycling routes.

- A comprehensive, long-term transport plan should be prepared to create a low-emissions zone (LEZ) through the establishment a congestion charge area in the Historic Peninsula that will enable the regulation of traffic entering the peninsula.

SECTION 1. PURPOSE OF THE STUDY

Surrounded by the Golden Horn, the Bosphorus, and the Sea of Marmara, and bordered by Byzantine city walls, İstanbul's Historic Peninsula is home to four UNESCO World Heritage Sites. The area and its surroundings saw the first settlements in İstanbul and habitation by different civilizations, serving as the capital of Roman, Byzantine and Ottoman Empires which have produced different land use patterns over the centuries. In the present day, however, this diversity in land use characteristics is dominated by the Peninsula's use as a central commercial area, primarily housing the service industry built around tourism, as well as locally dense residential areas. UNESCO periodically evaluates the state of conservation in World Heritage Sites. In its latest Periodic Report for the Historic Areas of İstanbul, UNESCO identified effects arising from use of transportation infrastructure as a "catastrophic" factor and air pollution as a "significant" factor affecting area's preservation (UNESCO, 2013). The density of heritage monuments in the Historic Peninsula requires special attention for governance of urban activities in the area.

İstanbul's Historic Peninsula is both a dense residential area and the central commercial area of İstanbul, including service industries, education, housing and tourism. While touristic activities are concentrated in Sultanahmet and its immediate surroundings, educational and commercial activities are spread throughout the Peninsula. The Historic Peninsula is also a transportation hub, serviced by many different types of public transportation systems. Tram and ferry lines intersect in Eminönü, while Yenikapı houses the intersection of Marmaray and metro lines. Despite the presence of effective and various modes of mass transportation, however, the Historic Peninsula still suffers from the pressures of an ever-growing and highly motorized city. Surrounding coastal streets such as Kennedy, Reşadiye and Ragıp Gümüşpala carry high volumes of vehicle traffic and serve as the main arteries of road transport.

According to pedestrian countings conducted by GEHL Architects for the "İstanbul Public Spaces and Public Life" report, approximately 2.5 million visit the Historic Peninsula on a daily basis (GEHL, 2010). According to the İstanbul Transportation Master Plan, in 2009, 433,796 people resided within the Historic Peninsula, with 276,809 people employed in the area and 1.5 million passengers visiting daily (IUAP, 2011). The Master Plan predicts that by 2023, 5.5% of all trips in İstanbul will be made within the area, while 2.7% will be residing in the area.

Figure 2 Map of Pedestrianization in the Historic Peninsula and Locations of 23 Sampling Stations in the Historic Peninsula

1. 1. PURPOSE OF POST-PEDESTRIANIZATION AIR QUALITY ASSESSMENT

In recent years, with fuel switching policies and increased share of natural gas in İstanbul's energy supply, traffic-related emissions have begun to dominate the emission profile in the city center. With 295 streets pedestrianized in the Historic Peninsula since 2010, an intervention with such an extensive scope is expected to alter social, economic and environmental conditions in the area. While businesses, visitors and residents will be largely affected by this transformation with resulting changes to mobility and logistics, the most important change in environmental conditions will be seen in the local air quality profile. Thus, the limitation brought to private vehicle use with the Historic Peninsula's pedestrianization is expected to alter the area's air quality. To date, changes in the air quality profile of the Historic Peninsula before and after pedestrianization has not been evaluated through quantitative measuring and monitoring.

While vehicle emissions have implications for a variety of issues from the preservation of historic buildings to the contribution of local emissions to climate change, this study has only considered the public health impact of changing trends in vehicle emissions in the Historic Peninsula following the pedestrianization process. The scientific community recognizes that integrated risk management of the urban atmosphere requires an assessment of the acute and chronic effects of air pollution as well as exposure risks. The US Environmental Protection Agency (EPA) considers exposure analysis central to strategic planning for air pollution risk management. Accordingly, management plans need to be formulated by identifying critical air pollutants bearing public health risks and periodically investigating their exposure impacts through dose-response studies (Karaca, 2012). Therefore, strategic planning for the pedestrianization of the Historic Peninsula requires the evaluation of environmental impacts and public health impacts. The purpose of this study is:

- Simultaneous monitoring of traffic-related emissions in the Historic Peninsula through the set up of multiple air quality monitoring stations
- Comparison of analysis results with 2010 baseline study findings
- Evaluation of pedestrianization project's environmental and public health impacts

1. 2. PEDESTRIANIZATION PROCESS IN THE HISTORIC PENINSULA

EMBARQ defines pedestrianization as "the conversion of streets into walkways exclusive to pedestrians or the extension of areas suitable for walking through the implementation of development plans" (EMBARQ, 2014). In 2005, the İstanbul Metropolitan Municipality (İBB) decided to re-evaluate the Historic Peninsula's multi-layered structure and launched a series of pedestrianization projects with the aim of increasing quality of life, while taking into account the Peninsula's role as a historical, cultural, and transportation center.

İstanbul Metropolitan Municipality began pedestrianizing the Historic Peninsula after 2010 to protect historic and cultural monuments in the area, as planned in the İstanbul Municipal Environmental Plan and İstanbul Transportation Master Plan. Goals of the pedestrianization are the "reduction of road traffic in historic areas and creation of pedestrian transport axes" and "development of alternatives to minimize emissions of exhaust gases" (IUAP, 2011).

Transportation Coordination Center (UKOME) introduced a set of regulations throughout 2005-2009, limiting access to private vehicles and only allowing pedestrians and official vehicles in Eminönü, Beyazıt, Ayasofya Square, and Gülhane Park. Sultanahmet Square and its surrounding streets were pedestrianized in 2010. In the same year, in cooperation with GEHL Architects, İstanbul Metropolitan Municipality and EMBARQ Turkey identified problems and developed pedestrianization proposals and strategies for the area with the completion of the "İstanbul Public Spaces and Public Life" project. Since 2010, 295 streets in Eminönü, Tahtakale, Beyazıt, Laleli, Gedikpaşa and Hocapaşa have been pedestrianized. The municipality has also implemented supporting infrastructure for pedestrianized areas such as re-pavement, signalization, and reorganization of waste management services.

Reported Benefits from EMBARQ Turkey's 2013 Survey

Based on surveys with business owners, residents and students, EMBARQ Turkey published the "Current State Assessment of the Historic Peninsula Pedestrianization Project" in June 2014. Overall, 740 business units were surveyed on their satisfaction with the pedestrianization project, which amounts to about 20% of businesses in the Historic Peninsula. Additionally, 495 people living across diverse neighborhoods of İstanbul participated in the residents' survey and 91 students responded to the online student survey (EMBARQ Türkiye, 2014). Although the surveys cover a limited sample size of residents and students, they are valuable in terms of evaluating related user groups' thoughts on the pedestrianization project.

When respondents to the resident survey were asked about the benefits of the Historic Peninsula's pedestrianization, the most common benefit reported was increased street safety (68%). Other benefits include increased visual quality (58%), strengthened attraction of historical buildings (56%), and improved walkability (52%). Illustrating similarities with the residential survey, 55% of students indicated that pedestrian safety was significantly improved. Improved walkability (51%) and increased visual quality (50%) were also common responses. In the commercial survey, 83% of employees or business owners identified improvements in walkability as the project's most significant benefit, and 77% of commercial survey respondents thought that streets had become safer for pedestrians. (EMBARQ Türkiye, 2014).

The respondents were also asked to evaluate the environmental quality in the area after pedestrianization. Across the three surveys, respondents predominantly stated that disturbances caused by motorized vehicles and vehicle noise decreased significantly after pedestrianization. There was a mix of responses, however, towards the state of air pollution and street pollution. While 61% of employees or business owners felt that there has been a decrease in air pollution, only 41% of students and 52% of residents surveyed thought that air quality in the area improved. As a whole, the surveys show an overall satisfaction rate of 80% among residents, students and employees or business owners.

1. 3. FINDINGS FROM 2012 BASELINE STUDY

Professor Ferhat Karaca of Fatih Univeristy evaluated the air quality profile of the Historic Peninsula before pedestrianization by measuring NO_2, SO_2, O_3, NH_3, HCl and HF gases using passive samplers in more than 50 monitoring stations throughout the Historic Peninsula between December 2010 and January 2011 (Karaca, 2012). Dr. Karaca's 2012 study on "Mapping the corrosion impact of air pollution on the Historical Peninsula of İstanbul" is based in this fieldwork that has been used as a baseline study in this report. Overall, the study found that NO_2 and SO_2 gases have similar exposure distribution maps, suggesting that high NO_2 and SO_2 levels are attributed to high levels of congestion. Not surprisingly, corrosion effects on calcareous building stones and metals were observed in the identified areas for high NO_2 and SO_2 levels. As a result of these findings, pedestrianization of the Peninsula, which limits vehicle emissions, is expected to reduce these corrosion effects by reducing traffic-related emissions in the area.

To show the choronological studies related to the Historic Peninsula regarding to the pedestrianization and air quality impact assessment, a timeline for projects and studies of EMBARQ Turkey and other organizations are given in Figure 3.

1. 4. CLEAN AIR AS A PUBLIC GOOD

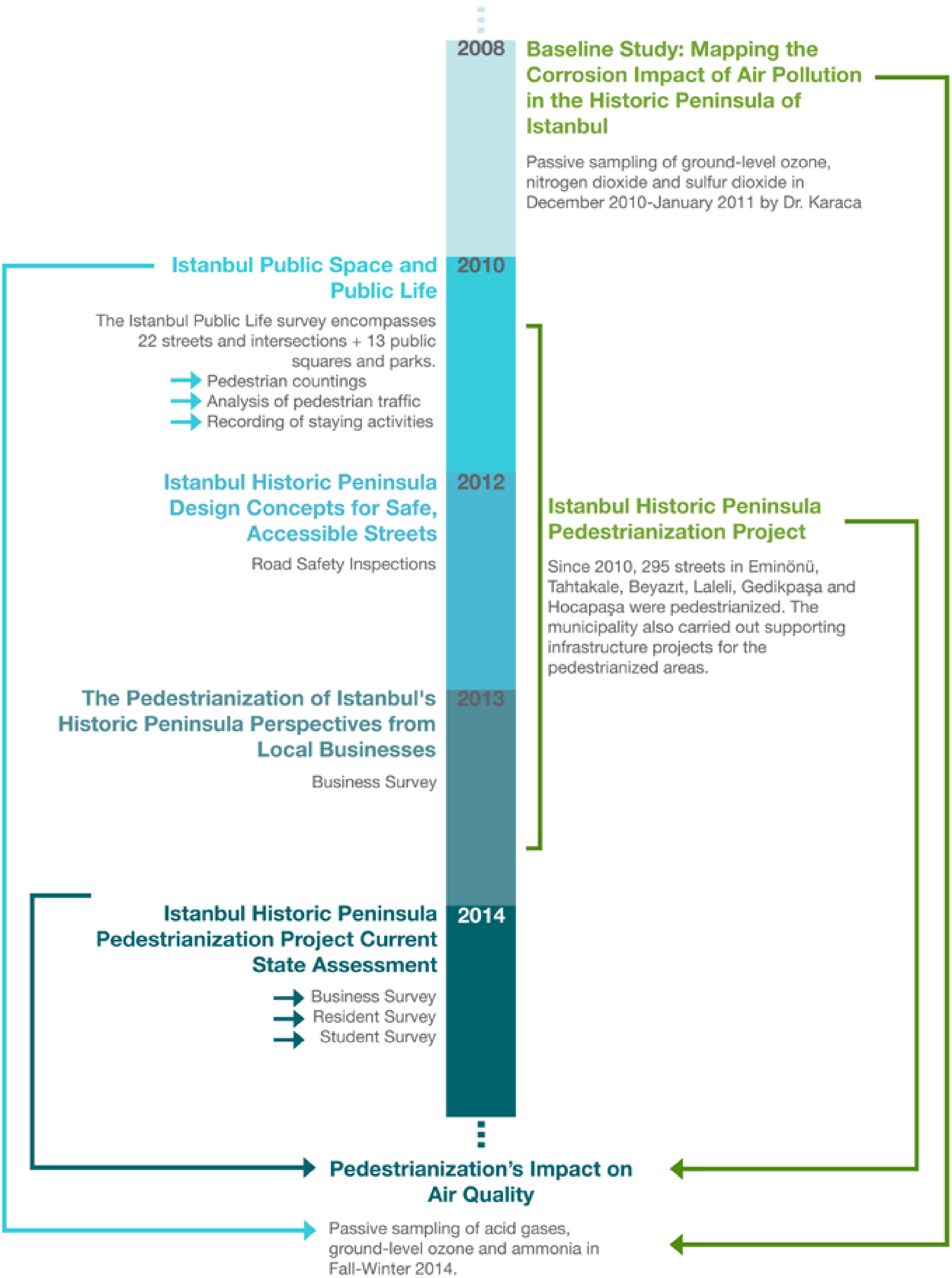
Traffic-related emissions are inherent by-products of the combustion of petrochemicals. Internal combustion engines of vehicles—especially from the combustion of gasoline and diesel in the Historic Peninsula—produce a large number of pollutants, including sulfur oxides, nitrogen oxides, carbon monoxide, volatile organic compounds, lead, particulate matter and ground level ozone, which have critical effects on public health the and preservation of historic buildings and monuments. As a result, clean air is a public good that requires comprehensive planning and concerns the public at large, with important implications for public health and preservation of historic buildings at the local scale and climate change at a more global scale.

Vehicle Emissions and Public Health

Urban policies and investments that favor motor vehicles over other modes impose a "triple health penalty"—as termed by the World Health Organization (WHO)—(WHO, 2011) on pedestrians by increasing exposure to pollutants and risk of injury as well as by posing barriers to mobility and access. Although air pollution is caused by sources ranging from industrial to biogenic activities, emissions from motor vehicles have some of the most adverse effects as they are released at locations and levels where human activity is the highest. Exposure to heavy traffic, even living near a major road, is associated with poorer child and adult health and increased death rates (Brugge, 2007).

According to the WHO, outdoor air pollution caused 3.7 million premature deaths worldwide in 2012, some 88% of which occurred in low- and middle-income countries (WHO, 2014). WHO estimates that about 80% of outdoor air pollution-related premature deaths were due to ischaemic heart disease and strokes, while 14% of deaths were due to chronic obstructive pulmonary disease or acute lower respiratory infections; and 6% of deaths were due to lung cancer.

Figure 3 Timeline of Pedestrianization related Projects on Historic Peninsula



Children's health and development is particularly at risk from ambient air pollution (Brugge, 2007). A recent study conducted by the Columbia Center for Children's Environmental Health demonstrates for the first time that prenatal exposure to airborne hydrocarbons may cause chromosomal aberrations and increase cancer risk in newborns (Bocskay, 2005).

Air pollution-related premature deaths has seen a growing trend, given that from 2005 to 2010, the death rate resulting from outdoor air pollution rose by 4% worldwide between 2005 and 2010. In contrast, air pollution in developed countries has decreased in recent years, partly due to tighter emission controls, including on motor vehicles (UNEP, 2014). Nevertheless, evidence suggests that in 2010, road transport accounted for 50% of the cost of the health impacts of air pollution in OECD countries, an amount close to US$1 trillion (OECD, 2014). In Europe, for example, exposure to air pollution from road transport costs about US$137 billion per year (UNEP, 2014).

In a study conducted by İstanbul University Faculty of Medicine researchers who analyzed the relationship between air pollution data and incoming patients—60,602 admissions were recorded from 1997 to 2001—a positive correlation was found between chronic obstructive pulmonary disease (COPD) admissions and SO_2, CO, NO and PM_{10} concentrations. They concluded that "air pollution and meteorological parameters should be seen as a widespread public health problem, which can trigger admission and even death due to COPD" (Hapcioglu, 2006). Below is a table of health outcomes associated with transport-related air pollutants, followed by more detailed descriptions of the health effects of critical air pollutants such as nitrogen oxides, sulfur dioxide, ground level ozone which were examined in this study and also particulate matter (PM) even though it were not measured on the field because of the budget and time limitations, it examined within the measurements of Aksaray air quality station.

Nitrogen Oxides (NO_X)

Nitrogen oxides (NO_X) emissions can have serious adverse health effects, causing major respiratory problems and leading to premature death. Mono-nitrogen oxides NO and NO_2 react with ammonia (NH_3), moisture, and other compounds to form nitric

Table 1 Health Effects of Pollutants from Vehicle Emissions (WHO, 2011)

Pollutants	Health Effects
Nitrogen Dioxide	Eye and respiratory disease, adverse reproductive outcomes, cancer
Sulfur Dioxide	Respiratory diseases, adverse reproductive outcomes
Ground-level ozone	Respiratory diseases, eye and nose irritation, asthma, decreased immunity
Particulate Matter	Heart diseases and failure, respiratory diseases, increases in rate of stillbirths and adverse reproductive outcomes, cancer
Ammonia	Skin and eye irritation, respiratory diseases, ingestion damage (mouth, throat and stomach)
Hydrogen Fluoride	Respiratory damage, irritation of the eyes and nose, malformation of fetal bones and teeth
Hydrogen Chloride	Corrosive to the eyes, skin, and mucous membranes. Diarrhea, coughing, hoarseness, inflammation and ulceration

acid vapor and related particles. These small particles can penetrate deeply into the sensitive lung tissue and damage it, causing premature death in extreme cases or respiratory diseases such as emphysema or bronchitis (US EPA). In addition to health problems, NO_X is also implicated in a number of environmental problems, leading to the formation of tropospheric ozone and aerosols, acidification, and eutrophication (Streets, 2013).

NO_X is primarily formed by combustion processes, and emission factors can vary depending on fuel type and combustion conditions. In the European Union, for example, diesel vehicles are the largest contributor to total nitrogen oxide emission. Especially in urban areas of Europe—such as in Barcelona where mean annual average concentration of NO_2 is 54.7—measured nitrogen oxide emission levels are often higher than the 40 $\mu g/m^3$ legal limit set by the European Union (Cyrys, 2012). NO_2 levels in İstanbul and more specifically in the Historic Peninsula are also above acceptable limits, which will be discussed more in detail in the Methodology Section.

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is emitted from the combustion of fuels containing sulfur, predominantly coal and oil, as well as metal smelting and other industrial processes. SO_2 has adverse respiratory effects and can irritate the nose, throat, and airways to cause coughing and shortness of breath. Studies indicate that SO_2 causes nerve stimulation in the lining of the nose and throat that leads to irritation, and a feeling of chest tightness, which may cause the airways to narrow. People suffering from asthma are particularly sensitive to SO_2 concentrations.

Additionally, acid deposition is an important environmental effect of SO_2 that contributes to acidification of soils and inland waters, accelerated corrosion of buildings and monuments, and reduced visibility. Along with particulate matter, SO_2 also plays a role in the formation of winter-time smog. Over the past few decades, however, SO_2 emissions have declined with the switch to alternative fuels from solid fuels, improved abatement technology and more stringent legislation on the sulphur content of some fuels (Cyrys, 2012).

Ground-level Ozone (O_3)

When oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) react in the presence of sunlight, ground level ozone (O_3) is formed, a primary ingredient that causes smog. As a result, high ozone levels often occur in locations downwind from emission sources. While ozone is beneficial in the upper atmosphere, at ground level, it irritates the respiratory system and can cause coughing, choking, and reduced lung capacity. Concentrations of ozone exceeding 80 parts per billion sustained over an 8 hour period has been found to reduce lung capacity, increase instances of severe asthma, and in certain cases, impact life expectancy (Hoek, 2012). A study by Silva et al. from 2013 found that at present, 470,000 premature respiratory deaths are linked to anthropogenic ozone pollution worldwide. Children are at the greatest risk from exposure to ozone as their lungs are still developing and they are more likely to be active outdoors in urban areas with high ozone levels.

One study used the 1996 Summer Olympic Games in Atlanta, Georgia as an opportunity to evaluate the connection between vehicle travel, air quality and respiratory health (Friedman, 1998). Anticipating over a million visitors, Atlanta provided an integrated 24-hour public transportation system, added 1,000 buses for park and ride services, encouraged alternative work hours, closed the downtown area to private vehicles and altered downtown delivery schedules. During this time, morning peak hour traffic decreased by 22 percent; and peak hour ozone levels decreased by 28 percent. Even when controlling for weather variables, the study found that reductions in peak hour traffic could explain a 13 percent decrease in ozone levels. During the same time, various measures of acute asthma decreased between 11 and 44 percent. As a result, the study concluded that decreasing vehicle traffic reduces both emissions and asthma attacks.

In addition to its impact on human health, ozone also has many negative effects throughout the ecosystem and can harm sensitive vegetation during the growing season. It is estimated that global losses to soybean, maize and wheat crops due to ground-level ozone pollution could be US$ 17-35 billion per year by 2030 (UNEP, 2014).

Particulate Matter

Particulate matter is produced by the incomplete combustion of fossil fuels and biomass. All particle emissions from a combustion source are broadly referred to as particulate matter (PM) and usually delineated by sizes less than 10 micrometers (PM_{10}) or less than 2.5 micrometers ($PM_{2.5}$), which can penetrate deep into the lungs and blood stream. A study by the International Agency for Research on Cancer (IARC) concluded in 2013 that particulate matter is carcinogenic to humans. A study involving 29 European cities found that a 10 $\mu g/m^3$ increase in the concentration of PM_{10} would result in a 0.6 increase in mortality rates (Katsouyanni, 2001). Another study that compared death rates in six U.S. cities with differing PM levels over 10 years found that residents of city with the highest PM levels had death rates that were 26 percent higher than those in the city with the lowest PM levels (Bell, 2014).

Particulate matter pollution is an environmental health problem that affects people around the globe, but low- and middle-income countries disproportionately experience this burden. In many developing countries, poorly performing diesel vehicles often are responsible for the greatest proportion of small particle emissions from vehicles (Krzyzanowski, 2005). According to the World Health Organization, studies reveal that worldwide, air pollution from fine particulate matter is estimated to cause about 16% of lung cancer deaths, 11% of chronic obstructive pulmonary disease deaths, and more than 20% of ischaemic heart disease and strokes (WHO, 2014). A study by Silva et al., published in 2013 by an international group of scientists, found that at present, approximately 2.1 (or 1.3 to 3.0 million) premature respiratory deaths are associated with anthropogenic $PM_{2.5}$-related cardiopulmonary diseases (93%) and lung cancer (7%).

Vehicle Emissions and the Preservation of Historic Buildings

Critical air pollutants can lead to the corrosion of materials used in the construction of historic and cultural monuments. While this process occurs naturally, due to biogenic sources and the presence of reactive gases in the atmosphere, increased levels of pollutant concentrations quicken this process, possibly exponentially (Tidblad, 2012). Pollutants like nitrogen dioxide and sulphur dioxide result in acid deposition, which affects most materials to some degree—limestone, marble, carbonate stones and sandstone, which are used in most ancient monuments are particularly vulnerable. Due to critical air pollution exposure, cultural heritage stocks in the Historic Peninsula are under the risk of corrosion, caused by chemical reactions with SO_2, NO_2, and O_3. Dr. Ferhat Karaca's "Mapping the corrosion impact of air pollution on the Historical Peninsula of İstanbul" article (Karaca, F. 2013), which presents findings from the most comprehensive study conducted in the area for the evaluation of corrosion levels due to air quality, concludes that the level of pollutants, such as NO_2, SO_2, and O_3, in the area in 2009-2010 was critically high, leading to the corrosion of heritage sites in the Peninsula.

Vehicle Emissions and Climate Change Impact

The combustion of petroleum-based products in internal combustion engines result in the emissions of greenhouse gases. The largest sources of transportation-related greenhouse gas emissions are private vehicles and commercial trucks. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) are some of the greenhouse gases emitted during fuel combustion. A small amount of hydrofluorocarbon (HFC) emissions also result from the use of mobile air conditioners and refrigerated transport.

In addition to greenhouse gases, black carbon, which is a solid particle or aerosol, also contributes to warming of the atmosphere. Black carbon is the solid fraction of $PM_{2.5}$ that strongly absorbs light and converts that energy to heat. Black carbon is emitted due to incomplete combustion and is one of three short-lived climate pollutants targeted for reduction along with methane (CH_4) and hydrofluorocarbons (HFCs). Given the lack of data and measuring equipment, this study was not able to assess $PM_{2.5}$, and therefore cannot provide detailed information on black carbon pollution in the Historic Peninsula. Nonetheless, black carbon emission is a critical issue, as it has been estimated that fast action on black carbon, together with methane, would reduce the rate of climate change in half for the next several decades and reduce air pollution-related deaths by as much as 2.4 million per year and avoid annual crop losses of 50 to more than 100 million tonnes (UNEP, 2014).

Pedestrianization's Impact on Air Quality: Case Study Examples

Road transport is a major source of environmental degradation in urban centres. With increased mobility throughout the globe, related trends in vehicle emissions create an important public health concern. Transportation policy is a critical area of intervention that can alter this trend, by offering major potential to improve outdoor air quality and reduce greenhouse gas emissions at the heart of cities. Pedestrianization can have a significant impact on local environmental conditions in urban centers by provoking changes in the characteristics of traffic flow and patterns of vehicle emissions.

Early pedestrianization case studies from the European Union are indicative of the political will to transform the way in which cities can facilitate the mobility of inhabitants while also ensuring that the physical environment can safeguard their health. Copanhagen is one of the first examples of pedestrianization, where until 1962, all streets in the medieval city center were filled with cars and public squares were used as car parks. On 17 November 1962, Copenhagen's main street, Strøget was pedestrianized. This marked the beginning of a gradual transformation that has continued ever since. Today the city of Copenhagen has over 96,000 m^2 of car-free spaces. In the city centre, 80 % of all journeys are made on foot, and 14 % by bicycle. Car traffic in the city core has been reduced and congestion is no longer a problem (EC Environment Directorate, 2004).

Similarly, in the 1970s the pedestrianization case of Nuremberg resulted in one of the first studies directly linking pedestrianization with air quality change. The study found that the actual traffic reduction in the historic city centre was twice as large as predictions. By 1993 a total of 36,044 vehicles had exited the fleet entering the city centre and local emissions of NO_2 decreased by about 30 % and carbon monoxide and particulate matter by about 15 %. More recently in Burgos, Spain, the city's historic centre was pedestrianized between 2006 and 2008 to reduce air pollution and protect city monuments. 75% of streets in the historical centre were converted to pedestrian-only zones over a 4km^2 area. As a result, the city saw a 30% increase in the number of pedestrians and a remarkable 200% increase in the number of cyclists in the center (Civitas, 2013).

In Latin America, Bogota saw the creation of hundreds of kilometres of pedestrian-only streets and plazas during mayor Enrique Penalosa's 1998-2001 term. Bogota now has the world's longest pedestrian street with the 17km-long the Alameda el Porvenir, which connects the city's low-income southwest district with public schools, libraries, and TransMilenio bus rapid transit stations. Additionally, there have been several pedestrianization projects in the city centre, such as the transformation of "Carrera 15," where two lanes of traffic and on-street parking have been removed to a make space for a wide pedestrian space, and the "Zona Rosa T" project that involved closing two streets to traffic, formig a pedestrianised "T" shape. Bogota has seen a comprehensive change to improve urban quality through the reclamation of public space, improvement of public transport, promotion of non-motorised transport and auto restriction measures. Results comparing ambient emission levels before and after TransMilenio, for example, show a significant decrease in SO_2 and PM_{10} levels, and slight reductions in NO_2 and CO levels from 2000 to 2001 (Wright and Montezuma, 2004). The simultaneous application of these policies has produced quantifiable benefits to air quality and quality of life of city residents.

The pedestrianization of Broadway in New York City is a recent case that has drawn attention from urban planners and environmental engineers alike. In 2009 the city closed off a portion of Broadway in Times Square to cars for use as a pedestrian plaza for 6 months. Data from winter and spring 2009 air monitoring, prior to the closure, showed that concentrations in Times Square of NO and NO_2, two pollutants that are closely associated with traffic, were among the highest in the city. After the pedestrian plazas were created, concentrations of these same pollutants during the same seasons in the next year were substantially lower and less than in other locations—NO pollution levels decreased 63%, and NO_2 levels decreased 41% in Times Square (NYC DOHMH, 2012). The city plans to expand pedestrianization by creating permanent pedestrian plazas throughout Broadway, which will be complete in 2016 and will cover over 120,000 sq ft (NYC DOHMH, 2012).

As the case studies show, however, the impact on different pollutant gases can be quite different depending on the project and the context. While the pedestrianization of Broadway in Times Square, New York City, saw significant reductions in NO_2 levels, for example, the TransMilenio project in Bogota has not affected NO_2 levels to the same extent. This context-specific nature of air quality impact indicates that local air monitoring studies will be an important tool for air quality management.

1.5. İSTANBUL'S AIR QUALITY PROBLEM

Air pollution is one of the most challenging environmental problems that İstanbul is facing today. According to the World Bank's "World Development Indicators 2012" report, air pollution levels in İstanbul frequently exceed the maximum acceptable limits set by the WHO. For example, analysis of in-situ measurements suggests that exceedance for the 24-hour limit value of 50 µg/m^3 for PM_{10} can be as high as 157 days in a year (World Bank, 2012). In the late 1980s and beginning of 1990s, İstanbul has experienced significant particulate matter and sulfur dioxide episodes due to the fossil fuel burning for domestic heating and industrial acivities. However, effective policies and strategies to reduce air pollution have been largely effective. Following the fuel switching policy in the 1990s from high-sulfur lignite to natural gas, particulate matter concentrations and sulfur dioxide levels have gradually decreased in İstanbul. From 1990 to 2009, for example, urban-population-weighted PM_{10} concentrations have decreased from 88 µg/m^3 to 42 µg/m^3 (World Bank, 2012). However, today the city is still faced with high concentrations of acid gases, especially nitrogen oxides, sulfur dioxide, ground-level ozone, as well as secondary particulate matter ($PM_{2.5}$) as a result of vehicle emissions.

1.6. AIR QUALITY STANDARDS

There are several air quality standards across different countries and organizations for the regulation of critical air pollutants such as NO_2, SO_2 ve O_3 gases that have been evaluated in this study. Air quality standards have been developed to establish health based standards so that adverse health effects from exposure to air pollutants in ambient air are minimized. The European Union (EU) has legislated the Ambient Air Quality and Cleaner Air for Europe (CAFE) Directive, which sets upper limits on the concentration of several critical pollutants. These standards, which are summarized in Table 2, apply over differing periods of time because the observed health impacts associated with the various pollutants occur over different exposure times.[2]

Increasing Private Vehicle Ownership as a Barrier to Air Quality Improvement

Many efforts to reduce air pollution go hand in hand with technological enhancements that also improve energy efficiency, thereby producing additional economic and environmental benefits. Although technology is available to make vehicles less polluting, innovations and their adoption may take time. It should be noticed that there is a dramatically decrease in SO_2 emissions due to increase in natural gas usage for heating in building environments, likewise NO_x emissions decreased due to adaptation of young vehicle fleets. However, progress in emission reductions per unit can often be outweighed by rapid increases in the number of units, or in the case of air pollution, the number vehicles (UNEP, 2014). In İstanbul, there has been a steady increase in the total number of vehicles since 1979, which has ranged from 4 to 6 percent in the last 5 years. Among types of vehicles, the increase in the number of automobiles (private cars) was 7.3 percent from 2012 to 2013, which is an alarming rate that can offset efforts to regulate outdoor air quality (Turkish Statistical Institute, 2013). However, improving land use policies, facilitating healthy transport modes, improving vehicle and fuel standards as well as incentivizing the use of public transportation through investments in infrastructure and pedestrianization are some of the policy interventions that can address the public health consequences of vehicle emissions.

[2] http://ec.europa.eu/environment/air/quality/standards.htm

Table 2 EU Air Quality Standards under the CAFE Directive and World Health Organization's Air Quality Guidelines

Pollutant	Averaging Period	EU Guideline (µg/m³)	WHO Guideline (µg/m³)
Sulphur dioxide (SO_2)	24 hours	125	20
Nitrogen dioxide (NO_2)	1 hour 1 year	200 40	200 40
PM_{10}	24 hours 1 year	50 40	50 20
Fine particles ($PM_{2.5}$)	1 year	25	10
Ozone	Maximum daily 8 hour mean	120	100

US Environmental Protection Agency's National Ambient Air Quality Standards (NAAQS)[3] set a annual mean concentration limit of 53 ppb (~100 µg/m³) for NO_2, hourly limit of 75 ppb (~200 µg/m³) for SO_2 and a 0,075ppm (~160 µg/m³) limit for O_3 for an 8-hour period. World Health Organization's Air Qulity Guidelines[4] set a concentration limit of 100 µg/m³ 8-hour mean for O_3, 40 µg/m³ annual mean for NO_2 and, 20 µg/m³ 24-hour mean for SO_2. In Turkey, harmonization with EU Air Quality Standards has begun in 2013 with the Air Quality Evaluation and Management Regulation (HKDYY) memorandum. During the harmonization period from 2013 to 2019, identified air pollutants will be gradually reduced. Given that the fieldwork for this study was conducted in the Fall and Winter of 2014, the 2015 limits set in HKDYY can be used as guidelines for air quality standards. These guidelines set a limit if 20 µg/m³ 24-hour mean for SO_2, and 56 µg/m³ annual mean for NO_2.

Table 3 Maximum and average concentrations of SO_2, NO_2 and PM_{10} at Aksaray Station for 2014 compared to EU Air Quality Standards

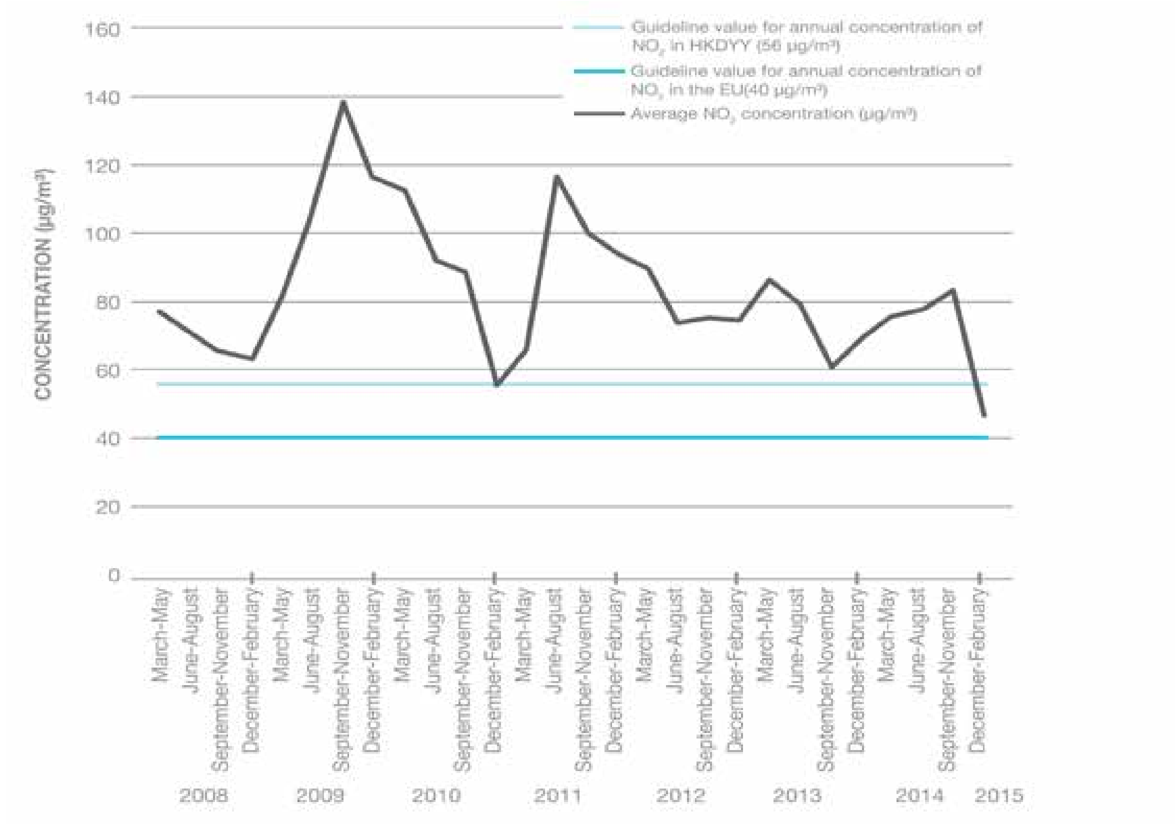
Parameter	EU Guideline for Limit Value	Value	March-May 2014	June-August 2014	September-November 2014	December 2014 - February 2015
SO_2	350 µg/m³/hour 125 µg/m³/24 hours	Maximum Average	24 10.71	32 5.36	108 8.44	156 15.50
NO_2	200 µg/m³/hour 40 µg/m³/year	Maximum Average	481 75.82	164 77.95	271 82.70	154 46.80
PM_{10}	50 µg/m³/24 hours 40 µg/m³/year	Maximum Average	178 31.40	252 39.50	300 27.90	153 17.90

Air quality data collected by IBB's Department of Environmental Protection at the Aksaray air quality station, which is within the bounds of this study's fieldwork area, provides insights into the air quality profile of the region. Table 3 indicates that for the most recent calendar year, NO_2 and PM_{10} levels at Aksaray station have frequently exceeded EU guidelines. Similarly, averages from 2008 to 2014, 3-month seasonal averages in the area frequently exceed acceptable limits set by both the EU as well as Turkish national air quality standards (see Graph 1). Similarly, seasonal maximums indicate that PM_{10} values can be

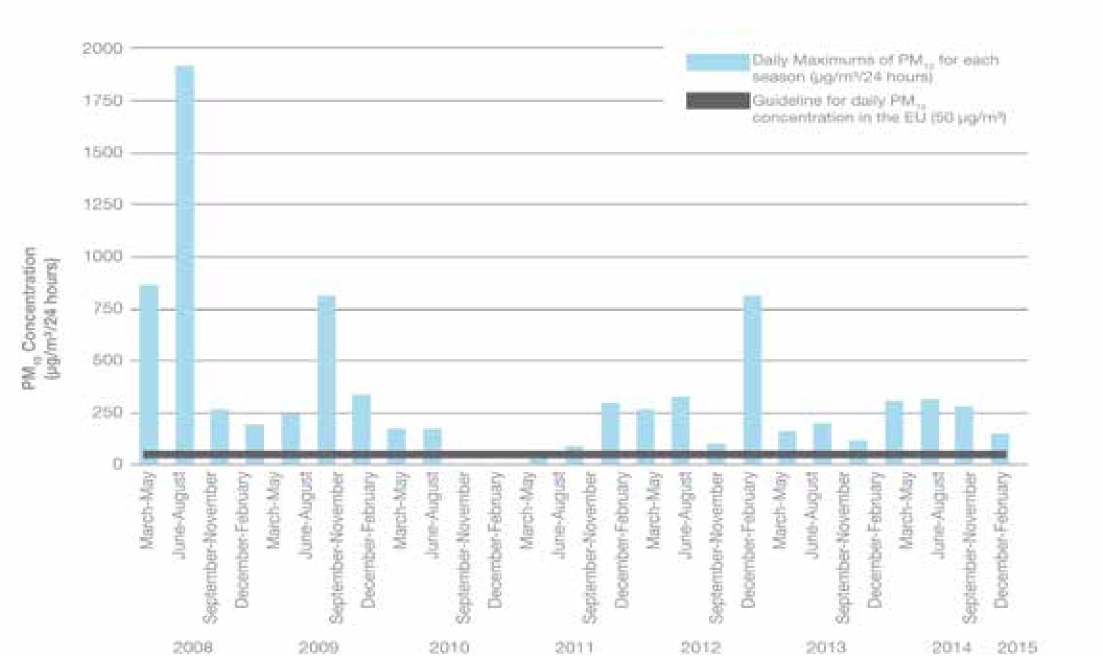
[3] http://www.epa.gov/air/criteria.html
[4] Guidelines, A.Q., World Health Organization (WHO) Regional Office for Europe. 2005.

frequently above the 50 μg/m³ limit set by the WHO as a guideline (see Graph 2). These concentrations from the Aksaray air quality station suggest that there are opportunities for vast improvements in the air quality profile of the Historic Peninsula, the wider district of Fatih, and more generally in İstanbul.

Graph 1 Seasonal Mean Concentration of NO_2 (μg/m³/hr) compared to guideline values of EU Air Quality Standards and Turkey's Air Quality Evaluation and Management Regulation (HKDYY)



Graph 2 Daily maximums of PM_{10} Concetrations for each season compared to EU guideline



SECTION 2. SCOPE AND METHODOLOGY

2. 1. FIELDWORK METHODOLOGY

Passive Sampling

The setup and operation of active sampling systems for air quality monitoring at the ground level is costly. For the assessment of pollutant distribution at the ground level and the detection of emission sources, however, the set up of multiple monitoring stations is necessary, since the accuracy of distribution profiles is positively correlated with the number of sampling stations. Given the cost of setting up multiple active sampling systems, passive sampling techniques offer a more cost-effective way of conducting analysis of pollutants throughout an area. One disadvantage of passive sampling systems is the long time span of sampling, as installed difussion tubes can only be collected and analyzed after 7-15 days, which gives an average value of pollutant concentrations accumulated over the course of 15 days. This method does not pose a challenge for this study; however, since the objective of the study is to determine long-term regional exposure. In addition to financial, technical and scientific factors influencing the study's methodology, guidelines outlined by the EPA and national directives recommend the use of passive samplers for "research on regional air quality" (Yeşilyurt, 2001).

Critical Air Pollutants Measured

The Gehl Architects (2010) established that the Historic Peninsula is primarily exposed to traffic-related air pollution and that other sources of pollution, such as heating or industrial activities, are not prevalent in the area. Since the pedestrianization project is directly affecting traffic-related air pollution, or vehicles as emission sources, traffic-related pollutants NO_2 and SO_2 are the two main criteria pollutants of this study. As the Baseline study has evaluated these two pollutants before the area's pedestrianization, it has been possible to compare before and after results.

Although Carbon Monoxide and Particular Matter are listed as critical pollutants there are no passive sampling methods for the evaluation of the concentration of these gases. Therefore, despite being important traffic-related pollutants with public health implications, these two gases were not included in this study. Further study into these two pollutants is needed to provide a broader picture of air quality, and this is something to consider in the future.

NH_3 emissions from road transport are released as a result of an unwanted reaction involving hydrogen, which reduces NO to NH_3. Studies on NH_3 vehicle emissions indicate that older generation gasoline fueled vehicles and buses, especially those using selective catalystic reactor systems, comprise the source of these emissions. However emissions have fallen since 2000, and are projected to fall in the future as second generation of catalysts, which emit lower levels of NH_3 than first generation catalysts, penetrate the vehicle fleet (EEA, 2012). Since it is possible to measure NH_3 concentrations with passive sampling methods, NH_3 gas has also been included in the study to evaluate the make up of vehicle types in the area.

Given that SO_2, NO_2 and NH_3 gas emissions can have industrial sources, determining whether these gases in the Historic Peninsula are emitted by traffic-related sources requires additional measurements—through the measurement of HCl and HF gases, which are directly emitted from industrial sources and have a very limited association with traffic-related emission sources. Since HCl and HF acid gases can be measured with passive sampling methods, these gases have been included in the study to determine the influence of industrial activities and residential heating in the area's air quality. Accordingly, it will be possible to evaluate the extent to which NO_2 ve SO_2 concentration levels are dependent on traffic-related emission sources.

Finally, ground level ozone (O_3) is a secondary reaction that occurs when oxidized gases emitted from vehicles in the presence of sunlight. Pollutants from traffic-related emissions are oxidized through a series of reactions. Intensity of sunlight, humidity, temperature, presence of aerosols and geographic locations influence this process. As a result, this study has also measured ozone concentrations in the Historic Peninsula to assess the role of traffic-related pollutant gas emissions and their photochemical oxidation in the formation of ozone.

Time Period and Locations for Sampling

Measurement campaigns have been undertaken in the September-December period for the post-pedestrianization phase and compared with previous study from 2010-2011. Due to lack of rainfall, low levels of residential heating and mild temperature and humidity values, Fall is the most appropriate transition season for air quality measurements. In order to accurately understand the affect of traffic-related emissions after the area's pedestrianization, the post-pedestrianization campaign was conducted in the Fall, with follow-up campaigns in December for comparison with pre-pedestrianization findings. While the first measurement campaign in 2014 saw an average temperature of 17.4 °C, throughout other campaigns, there have only been 2-3 °C changes in average temperatures (See Table 4).

Table 4 Start and finish dates, measurement lengths and average temperatures

	2014-2015 1st Campaign (September-October)	2014-2015 2nd Campaign (October)	2014-2015 3rd Campaign (October-November)	2014-2015 4th Campaign (November-December)	2014-2015 5th Campaign (December)
Start Date	29.09.2014	14.10.2014	30.10.2014	13.11.2014	02.12.2014
End Date	14.10.2014	30.10.2014	13.11.2014	02.12.2014	17.12.2015
Average Sampling Duration (minutes)	21 480	23 040	20 100	27 360	21 600
Average Temperature (°C)	17.4	15.4	13.1	10.6	9.6

The distribution characteristics during the winter season do not indicate distinguished hotspots and the pollutants are more dispersed over the wider areas. Therefore, it is not surprising to have such dispersions during winter seasons, as lower levels of mixing depths that derive a better exposure dispersion are typical over the atmosphere of Istanbul during winter time.

Besides, there are typical differences in seasonal wind characteristics in the region. The dominant wind directions were north and north-easterly during the fall and summer seasons, whereas the winter season was dominated by south and south-westerly winds.

In order to make the most accurate analysis of the effect of pedestriaization on vehicle emissions, the post-pedestrianization study conducted passive sampling measurements in the exact same locations of the baseline study's sampling locations. Within this scope, EMBARQ Turkey, together with researchers from Fatih University and officials from İstanbul Metropolitan Municipality's Department of Environmental Protection, installed passive samplers in 23 different locations in the Historic Peninsula. Table 5 provides information on location descriptions and coordinates that have been determined using Global Positioning Systems and used as input in Geographical Information Systems for further analysis. Table 5 and Figure 2 shows the positions of measurement locations, as well as pedestrianized streets and public transportation networks in the Historic Peninsula.

Table 5 Sampling locations and coordinates

Station Code	Description of Location	Coordinates	Coordinates (In Google Maps Format)
1	Unkapanı Bozburun Aqueduct, across the Health Ministry Directorate building	41°00'60.0"N 28°57'22.5"E	41.016655, 28.956255
2	Unkapanı intersection, near overpass	41°01'19.4"N 28°57'42.4"E	41.022067, 28.961783
3	Third lamppost behind Eminönü İstanbul Commerce University	41°01'08.5"N 28°57'57.1"E	41.019033, 28.965867
4	Post at the Eminönü tramway stop, in front of the New Mosque	41°01'03.2"N 28°58'20.6"E	41.017550, 28.972400
5	Post in front of Eminönü Bosphorus ferry station	41°01'00.6"N 28°58'33.4"E	41.016832, 28.975950
6	Post in front of Harem ferry station on Kennedy Street	41°00'57.7"N 28°58'42.7"E	41.016017, 28.978533
7	Traffic island at the entrance of Gülhane Park	41°00'58.3"N 28°59'07.5"E	41.016199, 28.985429
8	Gülhane Park tea garden	41°00'53.4"N 28°59'09.4"E	41.014830, 28.985958
9	Post in front of the Sirkeci train station	41°00'55.8"N 28°58'35.0"E	41.015500, 28.976400
10	Entrance of Süleymaniye Mosque	41°00'56.4"N 28°57'47.6"E	41.015657, 28.963237
11	Green area between Şehzade Mosque and İstanbul Metropolitan Municipality building	41°00'49.5"N 28°57'21.5"E	41.013743, 28.955965
12	Post in front of Vezneciler Police Staion on Fevzi Paşa Street	41°00'38.6"N 28°57'41.9"E	41.010733, 28.961633
13	Entrance of Nuri Osmaniye Mosque	41°00'36.5"N 28°58'16.4"E	41.010149, 28.971207
14	İstanbul Governorship Building at the intersection of Ankara Street and Cağaloğlu Yokuşu	41°00'41.5"N 28°58'30.5"E	41.011538, 28.975134
15	Entrance of Gülhane Park on Alemdar Street	41°00'37.7"N 28°58'43.4"E	41.010476, 28.978712
16	Post by Yücel Culture House across from Yerebatan Cistern	41°00'30.3"N 28°58'41.1"E	41.008425, 28.978097
17	Main Entrance of Topkapı Palace	41°00'30.1"N 28°58'51.3"E	41.008367, 28.980917
18	Aybıyık Bus stop in front of Cankurtaran Social Facility	41°00'16.1"N 28°58'59.2"E	41.004475, 28.983101
19	Post inside Sultanahmet Mosque's garden overlooking central fountain	41°00'23.1"N 28°58'42.0"E	41.006417, 28.978333
20	Post in front of Çemberlitaş Hamam	41°00'30.2"N 28°58'18.1"E	41.008400, 28.971700
21	Across the street from bus transit hub in Beyazıt Square	41°00'32.5"N 28°57'58.0"E	41.009017, 28.966100
22	Across the street from Laleli Mosque on Ordu Street	41°00'34.3"N 28°57'26.6"E	41.009533, 28.957400
23	Yenikapı roundabout	41°00'11.6"N 28°57'14.9"E	41.003217, 28.954133

2. 2. PUBLIC HEALTH RISK ANALYSIS

Studies indicate that nitrogen oxides, especially nitrogen dioxide (NO_2), predominantly come from traffic-related emission sources and pose significant public health risks (Costa, 2014). NO_2 is regarded as one of the most concerning critical pollutants due to increasing trends in NO_2 concentrations in urban areas, where average concentrations of other pollutants, such as SO_2, have significantly decreased. A study by Costa et al., for example, mentions that the risk for circulatory diseases rose by 0.8, 0.5, and 2.2% per 10-µg/m^3 increase in daily levels of NO_2 (Costa, 2014).

US Environmental Protection Agency's Air Quality Index (AQI) is a tool that provides timely information on local air quality profiles and related health risks (US EPA). The tool considers the health risks of critical air pollutants holistically by taking into account the synergistic effects between pollutants. Since the sampling measurements in this study only some pollutant gases, like NO_2 in the Historic Peninsula, the public health risk analysis will not determine an overall AQI score, but will evaluate the contribution of NO_2 levels to the index. Table 6 shows how NO_2 levels contribute to an AQI score. An AQI value of 100 corresponds to the national air quality standard for the pollutant, while an AQI value of 50 represents good air quality, with little potential to affect public health and a value over 300 represents hazardous air quality. Given that an AQI value of 50 represents good air quality, NO_2 alone has a significant contribution to overall health risks. In addition, while this study has used average concentrations from15-day sampling periods, the AQI uses hourly averages, which have higher values than longer period averages. Thus, the AQI score should be considered as a rough guideline for public health risk assessment from this study's findings.

Mapping of Surface Pollutant Distribution

Surface pollutant distribution maps modelled with Geographic Information Systems are increasingly used as health risk assessment tools. Three factors affect how environmental conditions pose public health risks: exposure levels, probability of risk and the magnitude (severity) of an adverse event. By mapping pollution distribution patterns, it is possible to determine exposure levels and corresponding risks in residential areas or locations with high population density.

Surface Pollutant Distribution modelling requires the input of an area's traffic density data, which was acquired through İstanbul Traffic Coordination Center's traffic flow count data between years 2010 and 2014. Accounting for the Historic Peninsula's topography and traffic density, surface pollutant distribution maps were created with Geographic Information Systems using the Co-Kriging method (See Section 3 for distribution maps). The geostatistical analysttool of ArcGIS® 9.1 was used for generating GIS-based surface pollution and corrosion distribution maps. Several methods including inverse distance weighting (IDW), and kriging and cokriging methods with their geostatistical algorithms followed by semivariogram models were tested and chosen based on the lowest prediction parameters error criteria, which specifies that the best output obtained was the spherical and K-Bessel model of cokriging, with elevation as a supplementary data set (Karaca, 2013).

Table 6 Contribution of measured NO_2 concentration levels to AQI score

Percentage of Sampling Stations	NO_2 concentration (µg/m^3)	Contribution to AQI score
25%	45	21
50%	53	26
75%	62	31
97%	98	49

SECTION 3. FINDINGS

3.1 NO_2 AND SO_2

Sampling results after the pedestrianization of İstanbul's Historic Peninsula show that NO_2 concentrations in the area vary from a minimum of 37.1 µg/m³ and a maximum of 101 µg/m³. The average for NO_2 concentrations in Northern Europe is about 38.2 µg/m³, while this number is 50.1 µg/m³ in Western Europe and 67.2 µg/m³ in Southern Europe (Cyrys et al., 2012). Given that concentration values vary from 13.8 to 109.0 µg/m³ in Barcelona, 7.3 to 102.7 µg/m³ in London and 6.8 to 96.8 µg/m³ in Paris, it is possible to conclude that İstanbul's Historic Peninsula has similar air quality characteristics with traffic-dense European metropolitan areas, where traffic-related pollutants like NO_2 may have high concentrations.

The average NO_2 concentration in the Historic Peninsula after pedestrianization is about 56 µg/m³, which is similar to that of Barcelona (54.7 µg/m³) yet higher than that of London (35.8 µg/m³) and Paris (33.8 µg/m³) (See Table 7) (Cyrys, 2012). Following the pedestrianization of the Historic Peninsula, there has been a considerable decrease in NO_2 concentrations from the baseline study findings, which measured

Table 7 Statistical information on air quality measurements before and after pedestrianization

	(2010- 2011)			(2014-2015)					
	NO_2	SO_2	O_3	NO_2	SO_2	O_3*	NH_3	HF	HCl
Average (µg/m³)	82	23	9.20	56	3	29	24	2.01	2
Geometric Average (µg/m³)	79	23	5	54	3	26	24	1.98	2
Std Dev. (µg/m³)	22	6	5.28	15	1	19	4	0.42	1
CoV (%)	27	25	57	30	20	50	20	21	21
Skewness	1.22	0.79	-0.07	1.38	-0.26	1.37	0.26	1.05	0.34
Data Range (µg/m³)	[53.6-144.1]	[15.9-38.6]	[0-20.4]	[37.1-101]	[1.5-4.2]	[12.7-71.7]	[18.4-30.8]	[1.4-3.1]	[1.2-3.4]

*** These values have been divided by a factor of 1.36 due to errors incurred during passive sampling as some diffusion tubes were installed without caps. Therefore, it should be noted that ozone values have been subjected to error, with a high level of uncertainty.**

average concentration (82 μg/m^3) in the area for 2010-2011. Nonetheless, the findings of this study still indicate that the level of pollution in the area is still above European averages.

Studies indicate that as vehicle speeds decrease, emission of exhaust gases like NO_X increases, contributing more to NO_X concentrations in the local air quality profile. Given the Historic Peninsula's cultural and historical identity, the area attracts about 2.5 million visitors a day and is also a center for commercial activities, which results in high traffic densities and movement of vehicles at low speeds. This characteristic of slow traffic flow in the area affects NO_2 emission factors, exacerbating pollution levels. Table 8 shows how median NO_2 concentrations and car ownership rates compare in different urban areas in Europe and in İstanbul. While car ownership rates are much higher in European cities, in İstanbul, particularly in the Historic Peninsula, there is high density of private mainly followed by public traffic, which affects the level of NO_2 pollution. Therefore, it can be argued that concentrations of critical pollutants are higher in the Historic Peninsula because traffic densities are also higher, despite a much lower level of car ownership at about 152 cars per 1000 inhabitants.

Measurements indicate also that there has been a significant decrease in SO_2 concentrations, which have fallen from 23 μg/m^3 in 2010-2011 to 3 μg/m^3 after pedestrianization in 2014. Showing similarities with global trends, this decrease can be associated with the switch to fuels with low or no sulphur content. In a study conducted in Europe, SO_2 trends in multiples cities were tracked from 1993 to 2009. Findings reveal that there has been a sharp fall in numerous cities: SO_2 levels fell from 24.6 μg/m^3 to 3 μg/m^3 in Barcelona, 37 μg/m^3 to 2.7 μg/m^3 in London, 18.8 μg/m^3 to 3.4 μg/m^3 in Paris (Henschel, 2013). Similarly, in İstanbul's Historic Peninsula, there has been 80% decrease in SO_2 concentrations levels.

Table 8 Median NO_2 Concentrations and Car Ownership Rates for Urban Areas in Europe

Urban Area	Median NO_2 Concentration (μg/m^3)*	Car Ownership (per 1000 inhabitants)**
Paris	33.8	330
London	35.8	305
Rome	41.7	641
Barcelona	54.7	361
Historic Peninsula	56	152***

* In all study areas NO_2 and NO_X were measured using standardized methods between October 2008 and April 2011 (Source).
** Car ownership values represent numbers for main urban areas (Di, 2013).
*** This number is the ownership rate in the İstanbul Metropolitan area (Turkish Statistical Institute, 2013).

3.2 COMPARISON WITH AIR QUALITY STANDARDS

World Health Organization’s Air Quality Guidelines (WHO, 2005) set the concentration limit for O_3 at 100 µg/m^3 for an 8-hour period, 40 µg/m^3 annual mean and 200 µg/m^3 hourly mean for NO_2 and 20 µg/m^3 24-hour mean for SO_2. In the aftermath of pedestrianization, measured pollutants are all below these limits. Nonetheless, if the 40 µg/m^3 annual mean instead of the 200 µg/m^3 hourly mean for NO_2 is taken as a guideline, several locations in the Historic Peninsula show concentration levels that have exceeded this limit.

Given that the fieldwork for this study was conducted in the Fall and Winter of 2014, the 2015 limits set in Turkish legislations within the HKDYY memorandum can also be used as a guideline for air quality standards. These guidelines set a limit of 20 µg/m^3 24-hour mean for SO_2, and a 56 µg/m^3 annual mean for NO_2. After pedestrianization, average SO_2 concentration in the Historic Peninsula is 3 µg/m^3, with a minium-maximum range of 1.5 to 4.2 µg/m^3, indicating the area’s SO_2 pollution profile is considerably below legal limits. However, NO_2 levels after pedestrianization, which range from 37.1 to 101 µg/m^3, exceed the limit in nearly all locations in the Historic Peninsula, except for one station at the entrance of Topkapı Palace.

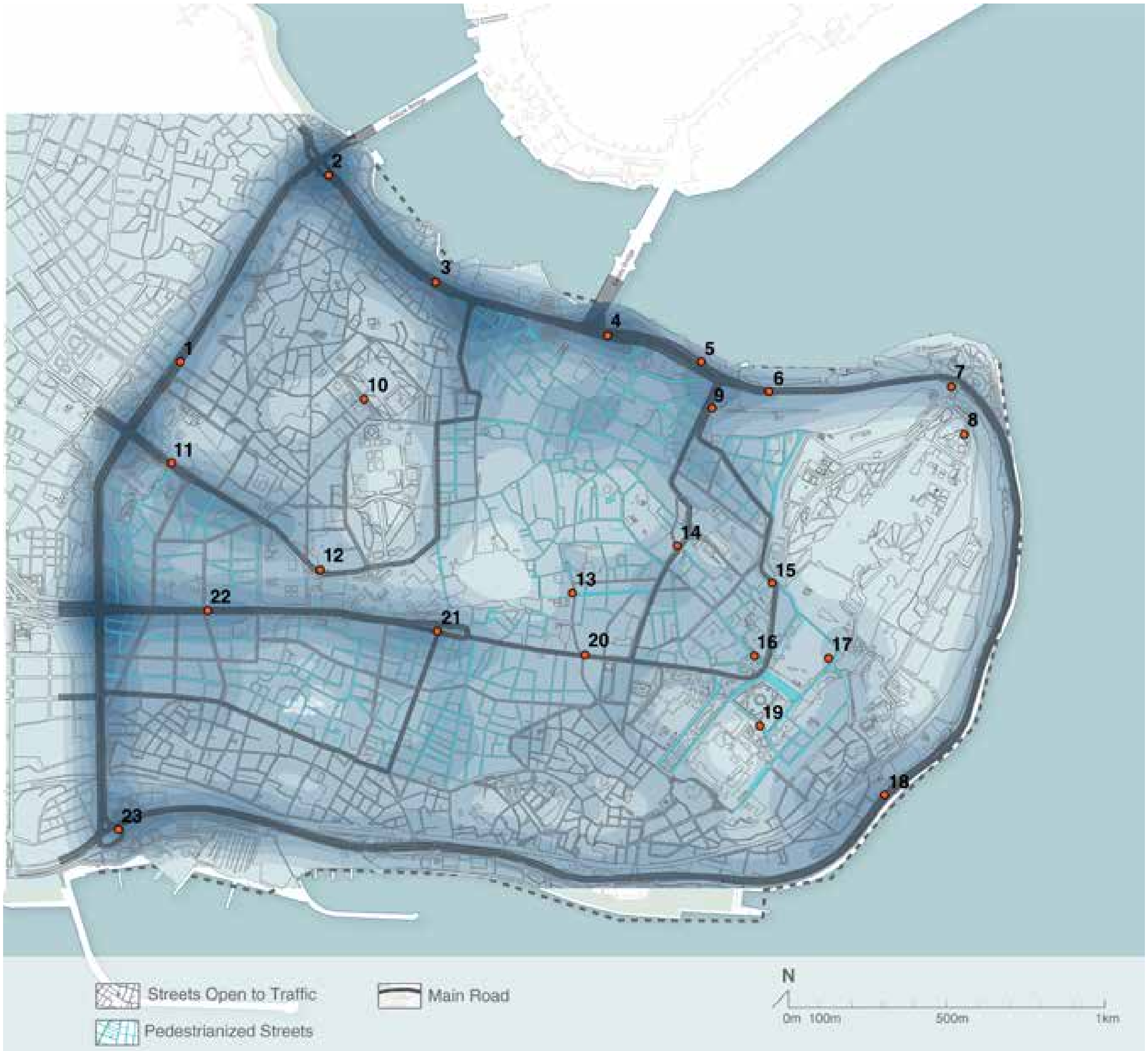
Air quality standards do not include limit values for NH_3, HCl ve HF gases. As in Europe, the main source of atmospheric NH_3 emissions is agricultural activity (European Environment Agency, 2013). Nonetheless, in urban centers motorized vehicles, industrial activities, sewage systems, waste collection facilities and coal burning can also be sources of NH_3 emissions (Sutton, 2000). The sources of traffic-related NH_3 emissions include older generation gasoline fueled vehicles and diesel fueled vehicles with selective catalystic reactor (SCR) systems, as concluded in a study conducted in the United Kingdom (Carslaw, 2013). Measurements in the Historic Peninsula after pedestrianization show that NH_3 levels range from a minimum of 18.4 µg/m^3 to a maximum of 30.8 µg/m^3, with 24 µg/m^3 on average. While the Historic Peninsula has a similar air pollution profile with Barcelona in terms of NO_2 concentrations, Barcelona’s NH_3 levels (at 4.5 µg/m^3) are much lower than that of the Historic Peninsula. The high level of NH_3 levels in the Historic Peninsula suggests that there might be a high proportion of older generation vehicles and public buses.

Emission Sources

To determine the emissions sources of the 6 pollutant gases, correlation and factor analyses were conducted (Karaca, 2015). The main sources of these two pollutants NO_2 and SO_2 are motorized vehicles in the Historic Peninsula. HCl and HF acid gases, which are known to affect ozone formation and absorption reactions, however, are typically emitted by industrial activities and are not emitted from traffic-related sources. Analysis shows that HCl and HF gases have a negative correlation with NO_2 and NH_3. Therefore, we conclude that these gases are not emitted from the same sources. Additionally, SO_2 and HCl gases, which have a positive correlation, have a common emission source of fossil fuel combustion from residential heating. To summarize, correlation and factor analyses of gas emissions result in the following findings:

- NO_2 and NH_3 have a common source, which in the Historic Peninsula is mainly from traffic-related emissions. Nonetheless, depending on vehicle type, fuel type and traffic density, emission levels for each gas may vary. For example, buses may be emitting comparatively more NH_3 than NO_2.
- Given that there are no industrial emission sources in the Historic Peninsula, the presence of SO_2 and HCl gases in the area can be attributed to pollutant transport (at urban baseline levels) or residential heating, particulatly the use of coal in some households.
- Ozone, which does not share similar characteristics with other gases in terms of emission sources, is formed in the atmosphere in secondary and photochemical reactions, and in this process, contributes to the removal of NO_2.

Figure 4 Historic Peninsula's Traffic Density and Locations of 23 Sampling Stations



Traffic Density

Traffic density is defined as the number of vehicles per unit length of the roadway. The traffic density map in Figure 4 was modeled based on vehicle numbers from camera recordings obtained from the İstanbul Traffic Coordination Center (Karaca, 2015). A traffic density map is used as a basemap to determine emission sources and pollutant distribution in the following sections. It is possible to create more accurate analysis of emissions and pollutant distribution maps with more data input such as vehicle types, engine types and average velocity per kilometer. Nonetheless, since obtaining such detailed data sets has not been possible, this study has used vehicle counts to determine density values.

Figure 5 NO_2 ($\mu g/m^3$) surface distribution values for 2014

Pollutant Distribution

Distribution of NO_2 levels in 2014 indicate that the highest concentration levels in the Historic Peninsula are in Unkapanı, at stations 1 and 2, where traffic density is high, at stations 2, 3 and 4, where converging roads direct traffic to the Galata Bridge, and at stations 22 and 23 in the Laleli - Yedikule direction (See Figure 5). The Northern region of the Historic Peninsula suffers the most from NO_2 pollution in the Historic Peninsula. The tip of the Peninsula, where stations 7 and 8 are located and the historic protected area, including stations 15, 16 and 17- exhibit the lowest levels of NO_2 pollution. Therefore, the areas where the pedestrianization project has been implemented show significant reductions in the concentrations of traffic-related emissions.

Figure 6 NH_3 (µg/m³) surface distribution values for 2014

Figure 6 shows NH_3 (µg/m³) surface distribution for 2014, which has similarities with the distribution of NO_2. NH_3 emissions, like NO_2, are highest in the three traffic dense areas of the Historic Peninsula. It should be noted, however, that average NH_3 levels only vary between 20 and 29 µg/m³. NH_3 levels are particularly low in areas where there is limited access to motorized vehicles.

Vehicle Types and Traffic Flow

NH_3 to NO_2 ratios reveal information about possible vehicle types and also the speed of traffic flow. As mentioned in the Methodology Section, older generation gasoline fueled vehicles and diesel fueled vehicles with selective catalytic reactor (SCR) systems have high NH_3 emissions. Figure 7 shows that this ratio is high around stations 13 and 21. These relatively high level of NH_3 emission can be accounted for by two factors: firstly, the high number of older generation vehicles and buses with SCR systems, which is plausible given the fact that there is a bus transit hub by Beyazıt Square near station 21, and secondly, the slow flow of traffic in the area due to pedestrianization, where vehicles emit more NH_3 when running at low engine speeds or idling. The fact that NH_3 levels are higher in pedestrianized areas suggests that, as observed in field observations as well, there have been problems with enforcement pedestrianization regulations and vehicles are illegally entering areas where access is prohibited to motorized vehicles. The relatively high level of NH_3 in the Sultanahmet area can also be due to the fact that tour buses are illegally idling near the pedestrianized square.

Idling also causes high concentrations of PM in such areas and also in vehicles. In a study conducted by Assoc. Prof. Dr. Burcu Onat of İstanbul University on 'Personal exposure of commuters in public transport to $PM_{2.5}$ and fine particle counts' in İstanbul shows

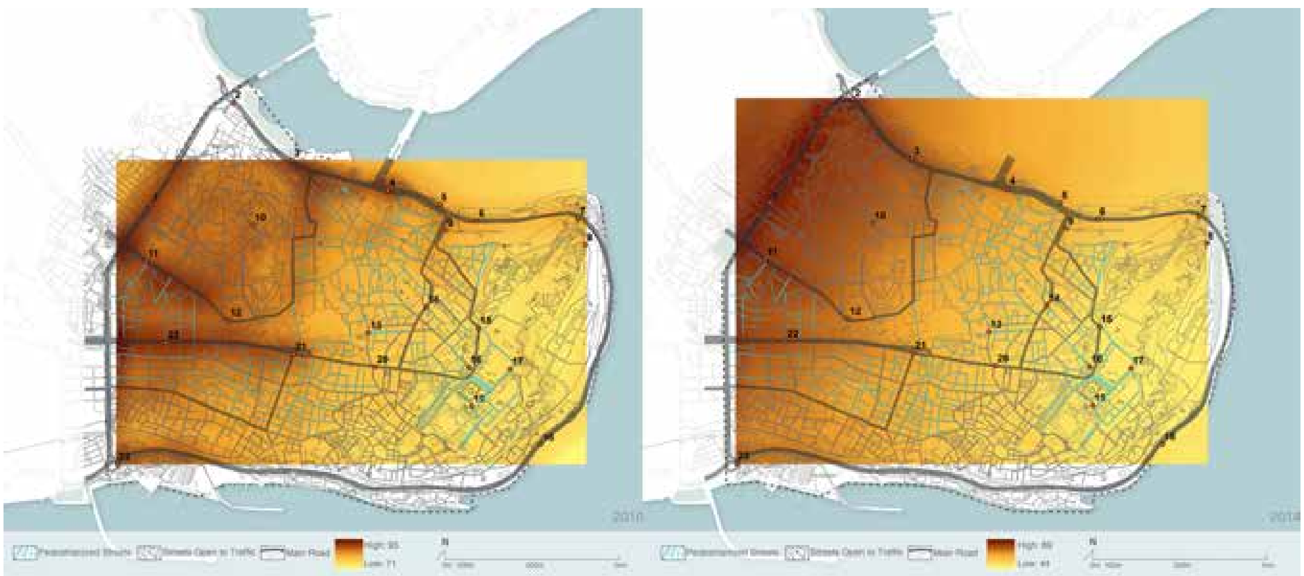
Figure 7 NH_3 to NO_2 ratio surface distribution in the Historic Peninsula for 2014

that the $PM_{2.5}$ level in a car with the air conditioning fan off was approximately 2.5 times lower than the level with the air conditioning fan on. The average $PM_{2.5}$ concentration inside the car during rush hours was 59.5±26.3 µg/m³ for AC fan on and 27.8±11.5 µg/m³ with the AC fan off. During non–rush hours, the average $PM_{2.5}$ concentration inside the car was 52.5±14.5 µg/m³ with the AC fan on and 30.4±17.0 µg/m³ with the AC fan off. The reason for this could be that with the fan on, a large amount of air in the cabin came from outside. The high in–vehicle exposures were related to outside emissions are affected by heavy traffic, busy intersections and meteorology.

Air Quality Before and After Pedestrianization

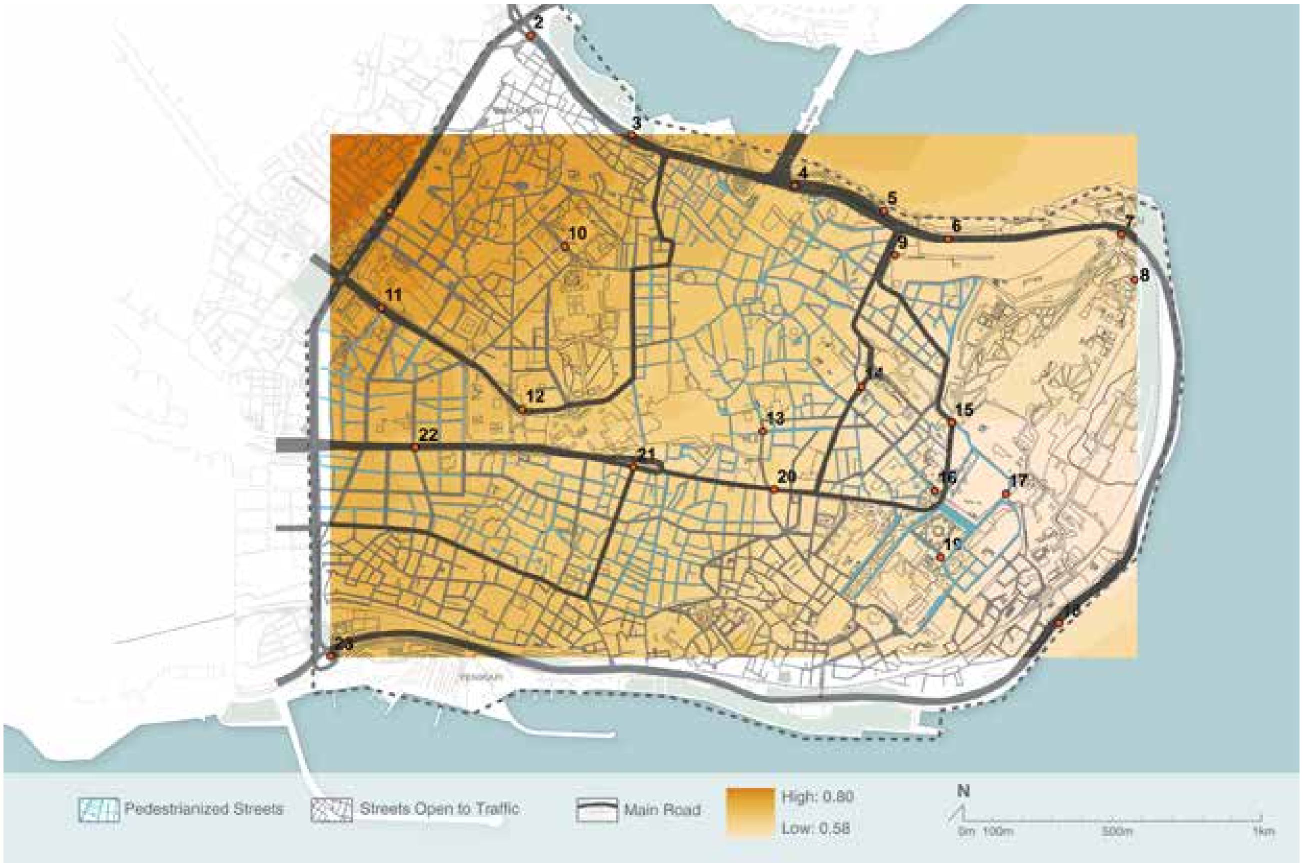
One of the primary aims of this study is the assessment of how traffic-related emissions in the Historic Peninsula have changed after the area's pedestrianization. Emission distributions in 2010, before pedestrianization, and in 2014, after pedestrianization show many similarities. In both periods, the main arteries constitute the primary source of traffic-related emissions, yet the 2010 period's pollutant distribution map shows that concentrations are high in secondary roads as well. In 2014, the distribution of pollutants suggests a retreat towards the Unkapanı area, through which the main artery E-5 highway passes (See Figure 8).

Figure 8 NO_2 (µg/m³) surface distribution values for 2010 and 2014



A comparison map, prepared using the ratio of average concentration levels in 2014, after pedestrianization, to 2010, before pedestrianization, visualizes the differences between the 2010 and 2014 distribution maps. In Figure 8, the dark areas delineate higher ratios, while lighter areas represent low ratios. This means that there has been less reduction of traffic-related emissions in dark areas and a significant amount of reduction in light areas. Therefore, we are able to conclude that there has been a considerable reduction of traffic-related emissions at the tip of the Historic Peninsula, in Sultanahmet and gradually along stations 17 and 22, which are all areas that have been pedestrianized. The residential area in the Northeast of the Historic Peninsula, which has not been pedestrianized, shows little or no reduction in traffic-related emissions.

Figure 9 Traffic-related NO_2 (µg/m³) emissions before and after pedestrianization [NO_2 (2014)/ NO_2 (2010)]



Public Health Risk Analysis

Nitrogen dioxide is considered one of the most critical air pollutants due to increasing trends in NO_2 concentrations in urban areas, where average concentrations of other pollutants, such as SO_2, have significantly decreased. Since the sampling measurements in this study only a few pollutant gases, the public health risk analysis will not determine an overall Air Quality Index (AQI) score, but will evaluate the contribution of NO_2 levels to the index (See Methodology Section for more information). Table 6 in the Methodology Section shows how NO_2 concentration levels contribute to AQI score. The limit value of average annual concentration of NO_2 that is deemed safe for public health in the European Union is also at 40 µg/m³. Given that passive sampling was used for measurements in this study, the results are closer to annual averages. Therefore annual averages have been used to for the public health risk analysis, and air quality levels have been classified as clean or polluted accordingly in Table 9.

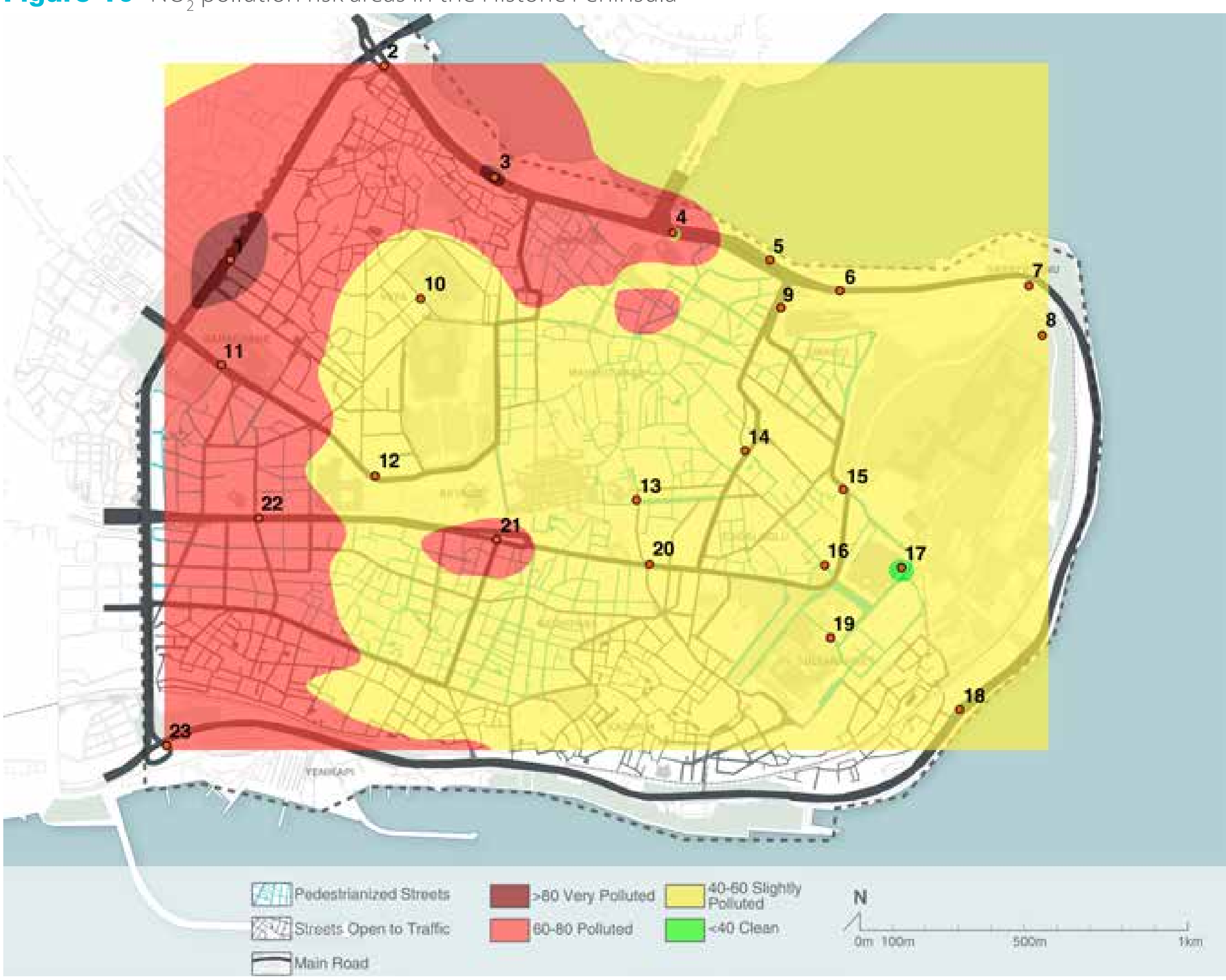
Table 9 Types of Air Quality Used as Reference for the Historic Peninsula Study

NO_2 levels [µg/m³]	Type of Air Quality
<40	Clean
40-60	Slightly Polluted
60-80	Polluted
>80	Very Polluted

NO_2 levels in the Historic Peninsula, which average at about 56 µg/m³, exceed the 45 µg/m³ limit assigned to acceptable urban baseline levels (25% of sampling stations). Figure 10 illustrates how different areas of the Historic Peninsula are classified in terms of public health risks due to distribution of function of the area and measured NO_2 pollution. The map shows (Figure 10) that station 17, at the entrance of Topkapı Palace, is the only location where air quality is considered clean. Conversely, stations 1 and 3, in Unkapanı and Eminönü are the most polluted locations and pose the highest public health risks. The map also reveals that the residential areas of the Historic Peninsula, which have not been pedestrianized, are one of the most polluted areas. This level of high NO_2 pollution in these areas can also be attributed to their proximity to main arteries with high densities of traffic such as the E-5 highway and the arteries along Yenikapı and Eminönü ferry hubs.

Based on surveys with business owners, residents and students, EMBARQ Turkey published a “Current State Assessment” of the area’s pedestrianization in 2014 (EMBARQ Turkey, 2014). The surveys revealed that respondents predominantly reported a decrease in the disturbances caused by motorized vehicles after pedestrianization. There was a mix of responses, however, towards the state of air pollution and street pollution. While 61% of employees or business owners felt that there had been a decrease in air pollution, only 41% of students and 52% of residents surveyed thought that air quality in the area improved. This finding was not surprising, given that residential areas (Northwest and Southwest of the Historic Peninsula) and the area around İstanbul University (stations 12, 21, 22) has not been pedestrianized and are classified as polluted areas. Therefore, perceptions by inhabitants and air quality measurements show parallel results. Indeed, the areas that have been pedestrianized have clean to slightly polluted air profiles. Overall, it is possible to conclude that pedestrianization has mostly derived benefit in the areas of touristic interest and commercial activity.

Figure 10 NO_2 pollution risk areas in the Historic Peninsula



SECTION 4. POTENTIAL INTERVENTIONS FOR FURTHER IMPROVEMENTS

The aim of this chapter is to present a set of strategies that can further improve air quality and resulting public health impacts by building on the successes of the pedestrianization process. In this respect, this section contains different recommendations, ranging from better enforcement of existing traffic calming measures to a longer-term establishment of a "clean zone" or congestion charge area. It is important to recognize the co-benefits of such measures, which will not only improve the Peninsula's air quality, but will also increase levels of protection for pedestrians, improve living conditions through the reduction of noise and pollution, and promote an active policy of access.

EMBARQ's mission is to catalyze and help implement environmentally and financially sustainable transport solutions to improve quality of life in cities - working to improve road safety and health, including:

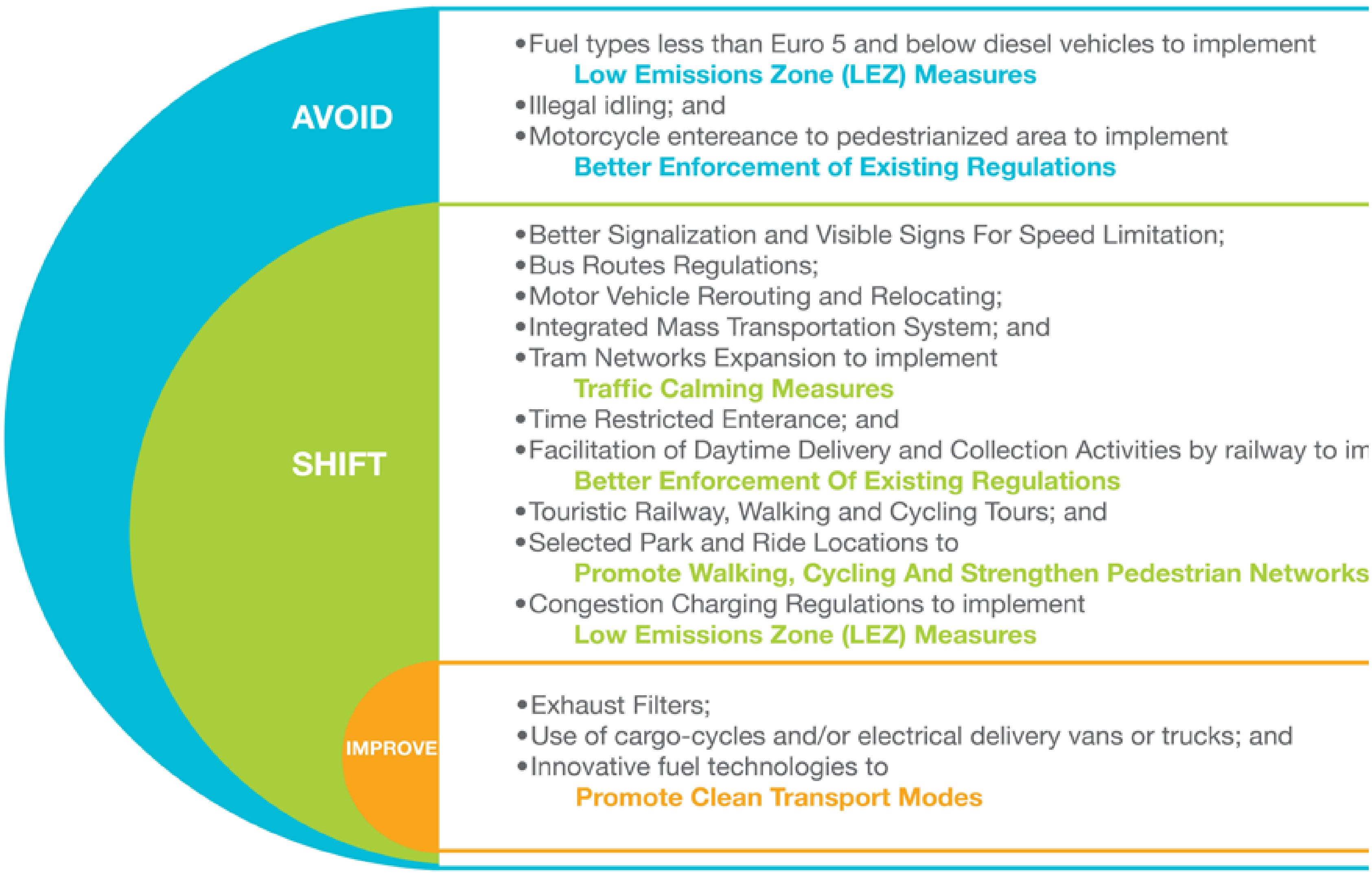
Avoid motorized travel through the integration of sustainable land use and transport planning increasing accessibility, saving lives and protecting the environment.

Shift to safer, healthier and more environmentally friendly modes, such as public and non-motorized transport, or preserve the current share of these modes, particularly in developing countries.

Improve vehicle and fuel technology of all modes of transport, and ensure safe system design and operations, to maximize the health and environmental efficiency of each kilometer traveled (EMBARQ, 2012).

Main recommendations regarding to Avoid-Shift-Improve (ASI) approach to improve current pedestrianization and implement integrated mobility solutions in Historic Peninsula are presented in Table 10 and also showed briefly in Figure 11.

Table 10 Avoid-Shift-Improve Recommendation Chart of İstanbul's Historic Peninsula Pedestrianization



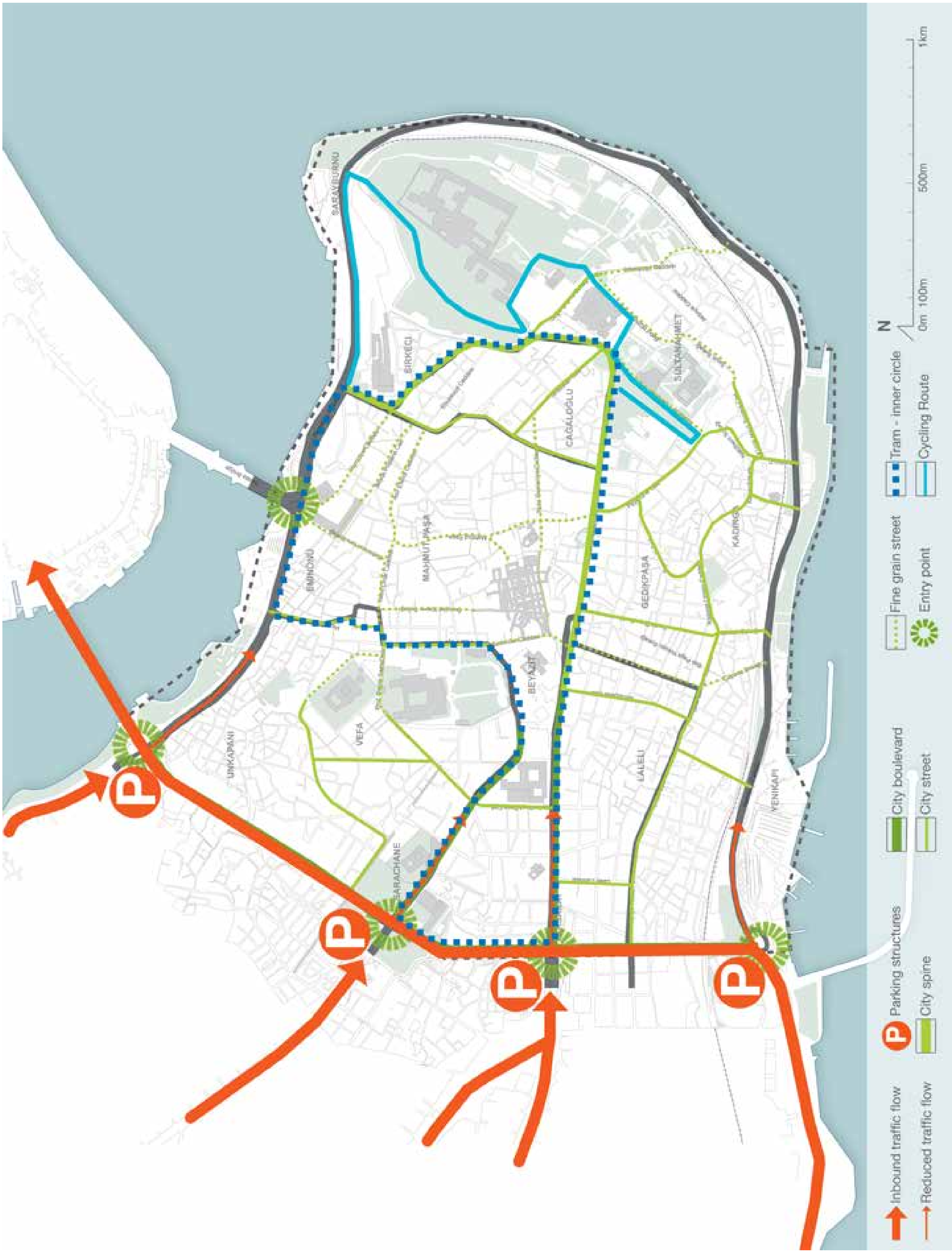


Figure 11 Recommendations for integrated mobility solutions in Historic Peninsula

Source: http://helptrafficticket.com/points-traffic-tickets-may-vary.html

Better Enforcement of Existing Regulations

- **Existing measures that make pedestrianized streets exclusive to pedestrian traffic should be enforced.** With some exceptions, pedestrianized streets are exclusive to pedestrian traffic between 10:00- 18:00. Nevertheless, pedestrian counts conducted at the Historic Peninsula indicated that pedestrian flow continues outside these designated hours. In addition to better enforcement of existing measures, specified hour-based traffic restriction should be reconsidered to meet pedestrian demand.

- **Illegal idling should be reduced, especially through measures for tour buses that are idling in Sultanahmet Square.** Tourist buses have a severe impact on the streets and squares in the Peninsula today, and are partly why ammonia levels around Sultanahmet Square are some of the highest in the Peninsula. Narrow streets around the Grand Bazar and in Sultanahmet are frequently used as bus routes. Squares like Çemberlitaş are used primarily as a parking space for tourist buses causing detriment to the area as a whole. Therefore, routes and stations of tour busses, which operate in Sultanahmet most frequently, should be subjected to through planning. A regulation restricting their access to the Historic Peninsula within specific hours might also regulate traffic flow.

Traffic Calming Measures

- **Methods of traffic calming should be implemented to reduce vehicle speed in cases where speed limit signs are proven to be insufficient.** Infrastructural design improvements should be developed for wide streets such as Ragıp Gümüşpala Street, Reşadiye Street, Kennedy Street, Atatürk Boulevard, Ordu Street and Şehzadebaşı Street. Smooth speed bumps, downscaling of wide streets and other physical obstacles are among the diverse tools designed for regulating speed.

- **Policies on overall traffic calming in the Peninsula should be accompanied by an integrated mass transportation system with increased efficiency and higher carrying capacity.** The Current State Assessment of the Pedestrianization Project showcased that residents, college students and employees/ business owners consider mass transportation opportunities in the area insufficient. While the Marmaray and Taksim-Yenikapı Metro Line will contribute to the mass transportation network in the area, the Eurasia Transit Motorway Tunnel Project raises concern, as it will make the Historic Peninsula a through fare accessible to private vehicles from throughout İstanbul.

Source: http://bristowbeat.com/news/lawson-seeks-feed-back-on-estate-manor-drive-speed-tables/

- **Bus routes should be removed from the central part of the Historic Peninsula and number of routes on Kennedy Street and Ragıp Gümüşpala Street should be reduced.** The bus terminals on Ragıp Gümüşpala Street and Ordu Street could be relocated outside of the Historic Peninsula, possibly in connection to key entry points such as the Yenikapı transit hub.

- **Different approaches for the relocation of private vehicle traffic within the Historic Peninsula, such as park and ride solutions, must be developed.** The “Current State Assessment of the Historic Peninsula

Pedestrianization Project" found that the demand for parking in the Historic Peninsula, even in its pedestrianized centre, remains high. Parking spaces are of utmost importance in relocating transit traffic away from the Historic Peninsula. High-capacity parking spaces outside of the Historic Peninsula, with direct and easily accessible connections to walking routes and mass transportation stations should be developed.

Promote Walking, Cycling and Strengthen

Source: taken by VeloTurkey

Pedestrian Networks

- **The pedestrianized area must be integrated with existing and planned mass transportation lines.** Vehicle traffic is prioritized in most of the zones of mass transportation within the Historic Peninsula, which results in unsafe and difficult walking conditions both for pedestrians and travelers who use mass transportation. Mass transportation hubs and transit stations should be redesigned for providing comfort, accessibility and clear visual signage.

- **The pedestrianization of Beyazıt Square should also encompass the relocation of the bus station hub at the entrance of the Grand Bazaar and prioritize pedestrian access.** The relocation of the Beyazıt bus hub to the Yenikapı transit hub would not only improve pedestrian access, but would also improve the local air quality profile, particularly reducing ammonia emissions from buses and other vehicles in congested traffic.

- **Tourists should be presented with multiple travel modes to reach and tour the Historic Peninsula, such as light rail systems, walking and cycling routes.** Creating streets appropriate for walking would not only enable tourists to access historic places by foot, but also would also improve the air quality profile of the area by reducing traffic-related emissions.

Promote Clean Transport Modes

- **The tram networks in the Historic Peninsula should be expanded.** As proposed in "İstanbul Public Spaces and Public Life", the tram network can be developed into two loops to service the central part of the Historic Peninsula as well as the periphery. This expanded tram network can be supported with electric service buses across the Historic Peninsula. The outer ring could be supplemented with single bus routes along Kennedy Street, Ragıp Gümüşpala Street and Atatürk Boulevard.

- **Innovative solutions, such as the use of cargo-cycles within the Peninsula or electric delivery vans or trucks, should be explored to facilitate daytime delivery and collection activities of wholesalers.** New freight transport solutions should be promoted to assist wholesalers in arranging their time-restricted freight operations. Since urban freight can be more polluting than long distance freight transport, due to constant acceleration and deceleration and vehicle idling, transitioning to cleaner vehicles for delivery would vastly improve the area's air quality.

Source: taken by Pınar Köse

- **Cycling should be integrated with other travel modes, such as travelling on foot and by means of mass transportation. Recreational cycling routes in connection to the waterfront promenade and along the sea walls can be implemented along the current seaside walking track at the Historic Peninsula.** The "Current State Assessment of the Historic Peninsula Pedestrianization Project" survey found that only 1% of employees or business owners in the area ride bicycles. Nevertheless, 20% have indicated that they would prefer to ride bicycles if necessary conditions were provided. Therefore, it is plausible that there is a population ready to use cycling opportunities in the Historic Peninsula, if the relevant infrastructure is improved. Supporting transportation via cycling would also correspond with traffic calming plans and would contribute to the reduction of traffic-related emissions in the area. As proposed in the Gehl Report, bicycle lanes may be implemented on streets such as Kennedy, Ragıp Gümüşpala, Şehzadebaşı and Ordu streets depending on the natural and historical features of the Historic Peninsula.

Low Emission Zone Measures

- **A comprehensive long-term transport plan should be prepared to create a low-emission, "clean zone." Investigating the implementation of a congestion charge area in the Historic Peninsula will allow the regulation of traffic volumes entering the area.** The Peninsula is still car-dominated, and NO_2, PM_{10} and $PM_{2,5}$ emissions are high thus pressure needs to be increased to improve first by retrofit with exhaust after treatment technology, like particle traps and secondly switch to the old cars to environmentally friendly, green technology vehicles. Such abatement measures in Berlin focus on the transport sector especially in the inner city area in "S-Bahn Ring". Pushed by Berlin the German government eventually adopted a national labelling scheme, which provides the basis to control emission related traffic restrictions in LEZ for four pollution classes since 2007. Vehicles not meeting any of these criteria belong to pollution class 1. They cannot be exempted from any traffic ban. Two-wheelers,

Source: https://tfl.gov.uk/modes/driving/congestion-charge

vintage cars, off-road vehicles, police, fire brigade and emergency vehicles are exempted from the scheme (Lutx, 2009). In long-term process, limitation to vehicular access and only allowing green vehicles such as euro 5 diesel standards for official and logistical vehicles, and hybrid or electric cars, air quality can be improved. The congestion charge should also include the incoming vehicles from car ferries at Yenikapı, and traffic should be directed out of the Historic Peninsula to the east or north.

- **A congestion charge area should be accompanied by larger parking structures located outside the congestion charge area in connection to key entry points to the Historic Peninsula.** Easy and pleasant transfer to public transport should be ensured along with strong pedestrian connections if such an area is to be established. Environmental improvements may be supplemented by additional public health benefits due to decreased traffic accidents and increased walking and cycling. With the Clean Air Action Plan of 2013 Beijing started the discussion on introducing congestion charging to reduce traffic volume by reduceing the total demand travelling by car, relieve congestion and subsequently transport related air pollution both in trips and vehicle kilometres. While Beijing is still discussing the feasibility of congestion charging, few prominent cities around the world have implemented it. Stockholm, London, Singapore, Milan are some of the cities that are currently operating a congestion charging scheme as an economic instrument to reduce congestion and its detrimental effects. An alternative way of dealing with issue would be to impose a fee on every driver that wants to use the road during the rush hour. Those travellers paying the charge can enjoy not being stuck in queues and the ones not willing to pay and choosing to do something else can enjoy not having to pay. The income from these fees can be used for example to improve public transit, invest in bicycle infrastructure or to resolve other infrastructure bottlenecks (GIZ, 2015). Such measure is taken in London and current studies show that traffic accidents have fallen in the capital by an astonishing 40% since 2003. A spokesperson for Transport for London (TfL) told New Scientist that congestion charging cut emissions of nitrogen oxides by 8% and particulate matter created by diesel engines by 15% (Callaway, 2008).

4.1 RECOMMENDATIONS FOR FURTHER STUDY

- **To better understand the impact of traffic-related emissions on public health, air quality assessment in the Historic Peninsula should be expanded to include particulate matter, particulary PM_{10} and $PM_{2.5}$, which are currently at critical levels and have long-lasting impacts on human health. Additionally, measurement of $PM_{2.5}$ would allow an assessment of black carbon pollution, which has a significant climate change impact.** Given the lack of data and measuring equipment, this study was not able to assess $PM_{2.5}$. Nonetheless, black carbon emission is a critical issue, as it has been estimated that fast action on black carbon, together with methane, would reduce the rate of climate change in half for the next several decades and reduce air pollution-related deaths by as much as 2.4 million per year and avoid annual crop losses of 50 to more than 100 million tonnes (UNEP, 2014).

- **Status of Tour Buses should be re-evaluated through the analysis of the current tourist bus movements in the Historic Peninsula and the future forecasts.** Tourist buses pose a significant challenge to the Peninsula's environmental quality today, and are partly why ammonia levels around Sultanahmet Square are some of the highest in the Peninsula. Therefore, routes and stations of tour busses, which operate in Sultanahmet most frequently, should be subjected to thorough planning to address the specific needs and challenges of the tourist industry in terms of moving tourists between destinations.

- **The impact of planned Eurasian Tunnel should be taken into consideration.** As mentioned in the Gehl Report, the planned vehicle tunnel from Asia is expected to have a severe negative impact on the waterfront environment by further separating of the city from the water, attracting more traffic into the Historic Peninsula.

SECTION 5. CONCLUSION

The ongoing Historic Peninsula Pedestrianization Project, which is a first in terms of its extensive scale with the pedestrianization of 295 streets throughout the entire district, has brought important economic, social and environmental transformations. Building on the “Current State Assessment” report, this report considered how the project has affected the area’s environmental quality, specifically the local air quality profile in the aftermath of pedestrianization. Several months of fieldwork campaings, with air quality data gathered through passive sampling, and comparisons with baseline studies (Karaca, 2015) indicates that pedestrianization has significantly improved the area’s air quality. Nonetheless, pollutant levels, especially traffic-related NO_2 emissions remain high, given the high volume of traffic in the main arteries, as well as issues with enforcement regarding existing pedestrianization regulations.

Overall, pedestrianization has mostly derived benefit in the areas of touristic interest and commercial activity. Future plans to continue the pedestrianization process should take into account that there are still vast opportunites for improvement in the residential areas in the Northwest and Southwest of the Historic Peninsula. This study also shows that the pedestrianization process can be improved through the enforcement of existing regulations, traffic calming measures, promotion of cleaner transport modes and an integrated mass transportation system with increased efficiency and higher carrying capacity. While the Marmaray and Taksim-Yenikapı Metro Line have strengthened the mass transportation network in the area, the Eurasia Transit Motorway Tunnel Project raises concern, as it will make the Historic Peninsula a thoroughfare accessible to private vehicles from throughout İstanbul.

Ultimately, this study shows that the monitoring of local, surface-level air quality is an important tool to assess the effectiveness of implemented plans, and in the future, effectively targeting policy efforts at the sources for local emissions and in those communities that are the most impacted.

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EMBARQ, an initiative of the WRI Ross Center for Sustainable Cities, is a global network that helps cities make sustainable transport a reality.

EMBARQ catalyzes and helps implement environmentally, socially and financially sustainable urban mobility and urban planning solutions to improve people's quality of life in cities. Founded in 2002 as a program of the World Resources Institute (WRI), EMBARQ operates through a global network based in Brazil, China, India, Mexico, and Turkey.

The EMBARQ network collaborates with local and national authorities, businesses, academics and civil society to reduce pollution, improve public health, and create safe, accessible and attractive urban public spaces and integrated transport systems. EMBARQ has built its global recognition on its local experience, and addressing national and international policies and finance.

More information at www.embarq.org

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