DOKUZ EYLUL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DETERMINATION OF AIR QUALITY FROM MOBILE SOURCES IN THE CITY OF IZMIR

by
Pınar ERGÜN

March, 2010
İZMİR

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **Determination of Air Quality from Mobile Sources in the City of Izmir** completed by **PINAR ERGÜN** under supervision of **Assoc.Prof.Dr. Tolga ELBİR** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Assoc.Prof.Dr. TOLGA ELBİR

Supervisor

Prof.Dr. Mustafa ODABAŞI	Assoc.Prof.Dr. Sait C. Sofuoğlu
(Jury Member)	(Jury Member)

Prof. Dr. Mustafa SABUNCU

Director

Graduate School of Natural and Applied Sciences

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DETERMINATION OF AIR QUALITY FROM MOBILE SOURCES IN THE CITY OF IZMIR

ABSTRACT

The scope of this study is to determine the air pollution levels from on-road mobile sources in the city center of Izmir which is the third greatest metropolis of Turkey. Within the scope of the study, 19 main streets were selected to count and classify the vehicles due to their locations and high traffic densities. The vehicles were estimated in other main streets (n=46) by using some additional methods such as high resolution satellite images and video camera records at crossroads. Vehicle counting was done at the selected points in 19 streets with portable vehicle classifier systems. The traffic activity was determined separately on each street but simultaneously for both directions (departure and arrival) during a week.

Furthermore, the ambient air quality levels were also measured in the selected streets by a mobile air quality monitoring station. Major pollutants and several meteorological parameters were observed for approximately 10 days in each street during the measurement campaigns in both summer and winter in order to obtain hourly, daily, weekly and seasonal variations of air quality. These results were also used to validate the dispersion model used in the study.

The emissions for 5 pollutants (nitrogen oxides, carbon monoxide, sulfur dioxide, non-methane total volatile organic compounds and particulate matter were calculated by using the traffic activity data on the streets and the selected emission factors from literature. It was also found that these emissions cause serious air quality levels for human health in the atmosphere of the city.

The CALMET/CALPUFF modeling system was used to calculate the dispersion of pollutants from mobile sources in the city. Model runs were done only for the peak hours of several episodes in the year 2006 in order to find the contribution of traffic sector to urban air quality in these periods. The maximum hourly concentrations predicted by the model in summer mornings.

Keywords: Air pollution, traffic, emission inventory, mobile source, air quality modeling, air quality monitoring

İZMİR KENTİNDE TRAFİK KAYNAKLI HAVA KALİTESİNİN BELİRLENMESİ

ÖZ

Bu çalışmanın amacı, ülkemizin üçüncü büyük metropolü konumundaki İzmir'in kent merkezi içinde sahip olduğu karayolu ulaşım ağında hareket halindeki motorlu taşıtlardan kaynaklanan hava kirliliği seviyelerinin belirlenmesidir. Bu amaçla İzmir kent merkezi içinde seçilen 19 önemli caddede motorlu karayolu taşıtları türlerine göre kategorize edilerek sayılmıştır. Taşıt sayımları, diğer ana caddelerde (n=46) video kamera kayıtları ve yüksek çözünürlüklü uydu görüntüleri kullanılarak tahmin edilmiştir. Taşıt sayımları, sözkonusu caddeler üzerinde seçilen sayım noktalarında taşınabilir otomatik trafik sayım ve sınıflandırma cihazları ile yapılmıştır. Sayımlar her bir caddede çift yön (gidiş-geliş) için ayrı ayrı ve aynı anda kesintisiz 1 hafta boyunca yapılmıştır.

Taşıt sayım bilgileri ve literatürden seçilen emisyon faktörleri kullanılarak temel 5 kirleticiye [azot oksitler (NO_X), karbonmonoksit (CO), kükürtdioksit (SO_2), metan dışı toplam uçucu organik bileşikleri (NMVOC) ve havada asılı partikül madde (PM_{10})] ait emisyonlar hesaplanmıştır. Bu emisyonların insan sağlığı açısından önemli hava kalitesi seviyelerine neden olduğu belirlenmiştir.

Dış hava kalitesi seviyeleri seçilen caddelerde mobil ölçüm istasyonu ile ölçülmüştür. Önemli kirleticiler (NO_X, CO, SO_2, NMVOC, PM_{10}) ve bazı meteorolojik parametreler (rüzgar yönü, rüzgar hızı, sıcaklık, basınç) herbir cadde için 10 gün yaz ve kış mevsimleri için ayrı ayrı ölçülmüştür. Bu sonuçlar aynı zamanda dispersiyon modellemesi çalışması sonuçlarının doğrulanması için de kullanılmıştır.

Şehirdeki trafikten kaynaklanan hava kirleticilerin dağılımlarını hesaplamak için CALMET/CALPUFF modelleme sistemeleri kullanılmıştır. Model 2006 yılında bazı episodların pik saatleri için çalıştırılmıştır. Model ile bulunan en yüksek konsantrasyonlar yaz sabahlarına aittir.

Anahtar Sözcükler: Hava kirliliği, trafik, emisyon envanteri, çizgisel kaynak, hava kalitesi modellemesi.

CONTENTS

CHAPTER ONE
INTRODUCTION

The rapid growth of the world's motor-vehicle fleet due to population growth and economic improvement, the expansion of metropolitan areas, and the increasing dependence on motor vehicles because of changes in land use has resulted in an increase in the fraction of the population living and working in close proximity to busy highways and roads.

Traffic related sources are widely recognized as major contributors to airborne pollution, especially in urban and industrialized areas (Archetti et al., 2006; Bradley et al., 1999; Flachsbart, 1999; Ghose et al., 2004; Gram, 1996; Rad and Jamzad, 2005; Saija and Romano, 2002; Vuk, 2005; Yli-Tuomi, 2005). A comprehensive understanding of traffic emissions, particularly exhaust emissions, is therefore typically considered as a fundamental component of effective local air quality strategies, traffic management and environmental impact assessments.

With a few exceptions, all modes of transport emit air pollution from the combustion of liquid fossil fuel. Most transport sources today therefore emit similar pollutants, although the relative abundance of these varies depending on the exact composition of the fuel and details of the combustion conditions. The most significant transport emissions to the atmosphere by mass are carbon dioxide (CO_2) and water vapor (H_2O) from the complete combustion of the fuel. Some transport power sources achieve almost complete combustion by ensuring there is plenty of excess air, as in a diesel engine. A feature that distinguishes other mobile combustion sources from almost all stationary sources, however, is that combustion is incomplete, and a small fraction of the fuel is oxidized only to carbon monoxide (CO) with some volatile hydrocarbons also emitted as vapor in the exhaust and carbonaceous particles from incompletely burnt fuel droplets. In addition to the mixture of hydrocarbons, all fuels contain some impurities. Sulfur is oxidized mostly to sulfur dioxide (SO_2) on combustion, and sometimes to sulfate that can assist in the nucleation of particles in the exhaust. Several other impurities such as vanadium in oil do not burn or have combustion products that have a low vapor pressure and so contribute further to particle formation. The organic lead compounds are still added to high-octane petrol only in parts of Africa and Asia to prevent premature combustion also form particles in the exhaust (Colvile et al., 2001). Finally, at the high combustion temperatures of most transport sources of air pollution, atmospheric nitrogen (N_2) is oxidized to nitric oxide (NO) and small quantities of nitrogen dioxide (NO_2), in addition to smaller quantities from nitrogen containing impurities in the fuel. Nitrous oxide (N_2O) is emitted only in small quantities from the combustion process, but is somewhat more abundant in the exhaust of cars fitted with catalytic converters. Each of these, along with secondary by-products, such as ozone and secondary aerosols (e.g., nitrates and inorganic and organic acids), can cause adverse effects on health and the environment.

Pollutants from vehicle emissions are related to vehicle type (e.g., light or heavy duty vehicles) and age, operating and maintenance conditions, exhaust treatment, type and quality of fuel, wear of parts (e.g., tires and brakes), and engine lubricants used. Concerns about the health effects of motor-vehicle combustion emissions have led to the introduction of regulations and innovative pollution-control approaches throughout the world that have resulted in a considerable reduction of exhaust emissions, particularly in developed countries. These reductions have been achieved through a comprehensive strategy that typically involves emissions standards, cleaner fuels, and vehicle inspection programs.

Exhaust gases include mainly the pollutants of NO_2, CO and dust. Generally in urban centers, 43.9% of CO emissions, 41% of NO_X emissions, 26.2% of HC (hydrocarbon) emissions and particulate matter (PM_{10}) emissions belong to motor vehicles in Europe (EEA, 2007). Those figures maybe compared with those of the Environmental Protection Agency of the United States (EPA), where nationwide mobile sources are estimated to contribute more than half of NO_X emissions; 42% of VOC emissions; one-quarter of PM_{10} emissions; and 80% of CO emissions (Schifter et al., 2005).

The quantification of motor-vehicle emissions is critical in estimating their impact on local air quality and traffic-related exposures and requires the collection of travel-activity data over space and time, and the development of emissions inventories. Emissions inventories are developed based on emissions models that provide exhaust and evaporative emissions rates for total HC, CO, NO_X, PM, sulfur dioxide (SO_2), ammonia (NH_3), selected air toxics, and greenhouse gases (GHGs) for specific vehicle types and fuels. The quality of the travel-activity data (such as vehicle-kilometers traveled, number of trips, and types of vehicles) and the emission factors selected from literature are the most important factors for the quality of an emission inventory (HEI, 2010).

The actual measurement of motor-vehicle emissions is critically important for validating the emissions models. Studies that have sampled the exhaust of moving vehicles in real-world situations (specifically, in tunnels or on roadways) have contributed very useful information about the emissions rates of the current motor-vehicle fleet and also have allowed the evaluation of the impact of new emission control technologies and fuels on emissions.

Ultimately, an important goal of emissions-characterization studies is to improve our ability to quantify human exposure to emissions from motor vehicles, especially in locations with high concentrations of vehicles and people. Such characterization requires improving emissions inventories and a more complete understanding of the chemical and physical transformations on and near roadways that can produce toxic gaseous, semi-volatile, and particle phase chemical constituents.

The aim of this study is to prepare a comprehensive activity-based emission inventory from mobile sources in the city of Izmir, Turkey. In the study, a local emission inventory with 1 hr temporal and 1 km spatial resolution was prepared as a first step. At the second part of the study, calculated emissions were transformed into air quality predictions near highways by using a dispersion model. Model results were tested with monitoring data from a mobile air quality monitoring station for the year 2007. Results of the present air quality estimates in the region were discussed.

CHAPTER TWO
LITERATURE REVIEW

Characterization of the nature and extent of travel activity is essential for estimating emissions from motor vehicles. The key determinants of emissions in a region are the vehicle volume and speeds, total number of vehicle-km traveled per day, number of trips per day, and types of vehicles operating. Detailed characterization of travel activity is needed to develop the spatially and temporally resolved emission inventories that are required by regional and local scale air quality models.

The most widely used method of measuring the magnitude of vehicle travel and roadway use in an area is to count traffic volume at selected locations along the roadways. Traffic volume is defined as the number of vehicles passing a given location on a given roadway during a specified period of time. Traffic volumes are routinely measured on major roadways in many parts of the world (Archetti et al., 2006; Gram, 1996; Rad and Jamzad, 2005; Saija and Romano, 2002; Vuk, 2005).

Transport planning at all levels requires understanding of actual conditions. This involves determination of vehicle numbers, vehicle types, vehicle speeds, vehicle weights, as well as more substantial information such as trip length and trip purpose and trip frequency. The first group of data dealing with the characteristics of vehicle movement is obtained by undertaking traffic counts.

There is a wide range of counting methods available. It is useful to distinguish between intrusive and non-intrusive methods. The former include counting systems that involve placing sensors in or on the roadbed; the latter involve a remote observational techniques. In general the intrusive methods are used most widely because of their relative ease of use and because they have been employed for decades. The only widely used non-intrusive method is manual counting, because of its ease of use.

The major intrusive methods include:

- **Bending plate:** a weight pad attached to a metal plate embedded in the road to measure axel weight and speed. It is an expensive device and requires alteration to the road bed.
- **Pneumatic road tube:** a rubber tube that is placed across the lanes that uses pressure changes to record the number of axle movements in a counter placed on the side of the road. The drawback is that it has limited lane coverage, may become displaced, and can be dislodged by snow ploughs.
- **Piezo-electric sensor:** a device that is placed in a groove cut into the roadbed of the lane(s) being counted. This electronic counter can be used to measure weight and speed. Cutting into the roadbed can affect the integrity of the roadbed and decrease the life of the pavement.
- **Inductive loop:** a wire embedded in the road in a square formation that creates a magnetic field that relays the information to a counting device at the side of the road. This has a generally short life expectancy because it can be damaged by heavy vehicles, and is also prone to installation errors.

The major non-intrusive methods include:

- **Manual observation:** a very traditional method involving placing observers at specific locations to record vehicle movements. At its simplest, observers use tally sheets to record, but numbers, on the other hand there are mechanical and electronic counting boards available that the observer can punch in each time an event is observed. It can record traffic numbers, type and directions of travel. Manual counts give rise to safety concerns, either from the traffic itself or the neighborhoods where the counts are being undertaken.
- **Passive and active infra-red:** a sensor detecting the presence, speed and type of vehicles by measuring infra-red energy radiating from the detection area. Typically the devices are mounted overhead on a bridge or pylon. The

major limitation is the performance during inclement weather, and limited lane coverage.

- **Passive magnetic:** magnetic sensors that count vehicle numbers, speed, and type are placed under or on top of the roadbed. In operating conditions the sensors have difficulty differentiating between closely spaced vehicles.
- **Microwave- Doppler/ Radar:** mounted overhead the devices record moving vehicles and speed. With the exception of radar, devices they have difficulty in detecting closely spaced vehicles and do not detect stationary vehicles. They are not affected by weather.
- **Ultrasonic and passive acoustic:** devices that sound waves or sound energy to detect vehicles. Those using ultrasound are placed overhead to record vehicle presence but can be affected by temperature and turbulence; the acoustic devices are placed alongside the road and can detect numbers and vehicle type.
- **Video image detection:** use of overhead video cameras to record vehicle numbers, type and speed. Various software is available to analyze the video images. Weather may limit accuracy.

In the United States, the Federal Highway Administration requires state departments of transportation to collect and annually report traffic volumes on all national highways. It also requires counts of traffic volumes on selected highways for 13 vehicle classes reflecting the number of tires and axles as well as whether the vehicles are single or multiple-unit trucks (HEI, 2010). General Directorate of Highways in Turkey also uses same system for counting and classifying of the vehicles in 1056 different locations on highways. In both countries, traffic volumes on highways and arterials are often measured continuously with high time resolution. In contrast, data on traffic volumes on rural and urban collector and local roads are usually sparse and are often collected only for special study periods. Traffic volumes are often reported as annual averages. Day-specific, seasonal, weekday, and weekend traffic volumes are reported less frequently or not at all.

Vehicle speed is also important in estimating vehicle emissions. “Spot speed” at specific locations is commonly measured on many roadways. However, these instantaneous measurements can differ from the type of data needed for estimating emissions, which are the average speed over a given length of a roadway that reflects delays encountered by vehicles. These latter data are often collected in travel time surveys. In special studies, vehicles have been equipped with global-positioning systems and data loggers to collect vehicle speeds, travel times, trip lengths, and day of week usage for periods of more than a week (Asensio et al., 2009; Huai et al., 2006; Wolf et al., 2001). The collected data can be linked with transportation-network data from a geographic information system (GIS) to calculate speeds on specific road segments.

Computer models used to estimate emissions from on-road vehicles have evolved over three decades and now provide estimates of emissions rates in grams per kilometers for total HC, CO, NO_X, PM_{10}, SO_2 and selected air toxics. The large number of parameters and complex algorithms used in these models suggest the presence of significant uncertainties and limitations in the resulting emission estimates. In addition, emissions models do not account for the effects of roadway grade, operating mode (other than average speed), and high emitting vehicles.

MOBILE6 is version 6.0 of MOBILE, a computer model developed by the U.S. EPA to predict emissions from on-road motor vehicles that was first released in 1978 as MOBILE1. Modified versions of MOBILE are used throughout the world to estimate emissions factors. MOBILE6, the current basic version of the model, estimates emissions of HC, CO, and NO_X in grams per mile. More recent versions (MOBILE6.1 to MOBILE6.3) (*www.epa.gov/otaq/m6.htm*) also estimate emissions of PM, sulfur oxides, ammonia, air toxics, and selected GHGs. MOBILE6 is designed to include all types of on-road (also known as on-highway) vehicles, including light-duty cars and trucks, heavy-duty trucks, motorcycles, and buses. It also includes data suitable for predicting average fleet-emissions rates in the United States (excluding California) from 1987 to 2051. This model has been used to estimate on-road emissions in many researches (Boriboonsomsin and Uddin, 2006;

Cooper and Arbrandt, 2004; Pokharel et al., 2002; Weilenmann et al., 2005; Yao et al., 2005).

Other models of motor-vehicle emissions have been developed. The EMFAC model was developed by the California Air Resources Board to estimate fleet-average emissions rates for California vehicles (California Air Resources Board 2007). Because vehicles sold in California have to meet stricter emissions standards than vehicles sold in other states, the California Air Resources Board developed EMFAC, which uses data on California vehicle certification and activity. EMFAC was developed in parallel with MOBILE and takes the same overall approach using data specific to vehicles traveling on California roads (Shah et al. 2006). Marr et al. (2002), Motallebi et al. (2008), Niemeier et al. (2004) and Shah et al. (2006) have used EMFAC model as an estimation tool for their emission inventories.

Singer and Harley (1996) developed a fuel-based method for calculating inventories of motor-vehicle emissions. In this method, emissions factors are normalized to fuel consumption and expressed as grams of pollutant emitted per gallon of fuel burned (rather than per mile of vehicle travel). Fleet-average emissions factors are calculated from measured on-road emissions of a large, random sample of vehicles. The potential benefits of this method are that fuel-consumption data might be more accurate than VMT, and the resulting estimates of vehicle-emissions rates are based on in-use measurements rather than certification-test data and deterioration factors. Potential difficulties in applying the method are that it requires many remote-sensing measurements and that not all pollutants of interest can be measured remotely with adequate sensitivity.

Contrary to the US case, only a few attempts have been made to evaluate common road vehicle emission models and emission factors applied for mobile source emission inventories within Europe (John et al., 1999; Sturm et al., 2000). The most commonly used emission model within EU today is the COPERT III model, which was developed on behalf of the European Environmental Agency to support European countries for their international reporting obligations, such as the

UNFCCC and UNECE CLRTAP (Ntziachristos and Samaras, 2000). In 2003, about 15 European countries were using the COPERT III model for official emission estimates, among them Belgium, Denmark, France, Greece, Ireland, Italy and Spain (Ekstrom et al., 2004).

Up to this point, most of the discussion has focused on trends in motor-vehicle fleets, regulations, and control technologies as well as on models that estimate motor vehicle emissions and their contribution to ambient air pollution. However, the actual measurement of motor vehicle emissions is critically important for validating the models and for estimating human exposure to traffic-related pollutants. Demonstrating the validity of emissions models and the efficacy of regulatory controls introduced over the past three decades remain the greatest challenges to air quality researchers. Field-measurement approaches that they have been used in recent years to address specific elements of the characterization, quantification, and tracking of motor-vehicle emissions (Daham et al., 2005b; El-Shawarby et al., 2005; Frey et al., 2001; Guenther et al., 1996; Hart et al., 2002; Kelly and Groblicki, 1993; Rouphail et al., 2001; Schurmann and Staab, 1990; Takada et al., 2002).

Many roadside measurement studies have been designed principally to evaluate dispersion models applied to describe the dispersion of pollutants near roadways and to address specific issues associated with motor-vehicle pollution. These field studies typically involve the deployment of measurement platforms downwind of a road (based on the prevailing wind direction) to measure the concentration gradient of emitted species (Carr et al., 2002; Carslaw, 2005; Carslaw et al., 2006; Ghose et al., 2004; Imhof et al., 2005; Sturm et al., 2003; Yli-Tuomi, 2005). The development of fast-response real-time instrumentation for the measurement of trace gases and the determinations of the composition of aerosols as well as size distributions (Kolb et al., 2004) has provided new opportunities for characterizing in-use on-road motor-vehicle emissions, as described above in detail. New portable emissions-monitoring systems provide another option for the measurement of these emissions (Cadle et al., 2008; Unal et al., 2004).

Recently, Gaussian dispersion models have been used in conjunction with GIS. This combination has allowed information from empirical monitoring systems and data on population distribution in the study area to be analyzed together. A more realistic representation of the problem is formed with the addition of data on the topography of the study area, a model of the road network, and traffic observations. These models have been used for various kinds of pollutants, such as total suspended particles, NOx and CO (Bartonova et al., 1999; Benson, 1989; Bellander et al., 2001; Hao et al., 2000; Jensen et al., 2000;; Kumar et al., 2004; McConnell et al., 2006; Peace et al., 2004).

In consideration of literature summarized up to now, it could be stated that generation of regional or aggregated data for use in emissions inventories for urban implementation plans, determinations of transportation plan conformity, analyses of emissions trends, environmental-impact statements, and hotspot analyses, the extent of the evaluation and verification of these models by means of actual field measurements has been quite limited. This represents a major shortcoming that should be considered when evaluating the results from an emissions-based model and the local impact of motor-vehicle emissions on air quality and human exposure.

In this study, an activity based emission inventory was prepared for mobile sources in the city of Izmir. The vehicles were counted and categorized in 19 major streets in the year 2007. Emission factors from CORINAIR emission factor database were used for the estimation of emissions instead use of an emission model (MOBILE, COPERT, EMFAC, etc.). These emission models do not preferred to be used in the study, because, they do not account for the effects of roadway grade and operating conditions other than use of average speeds. Roadside air quality measurement studies have been designed principally to evaluate dispersion model (CALPUFF) applied to describe the dispersion of pollutants near roadways and to address specific issues associated with vehicle pollution.

CHAPTER THREE
THE STUDY AREA

3.1 Characteristics of The Study Area

The city of Izmir with about 3.3 million inhabitants is located at the west side of the Aegean Region in Turkey with longitude between 26°52'E and 27°19'E, and latitude between 38°19'N and 38°32'N (TSI, 2010). Surface area of the city is 12,012 km² and population density is approximately 311 capita per km² (TSI, 2010). Metropolitan center of Izmir is the third biggest urban agglomeration of Turkey and the acknowledged industrial and commercial capital of the Aegean Region of Turkey. Several provinces, Balikesir in north, Manisa in east and Aydin in south surround the city. Figure 3.1 shows the location of the city.

Figure 3.1 Location of the city.

The city is located in a basin surrounded by a mountain range of approximately 1000–1500 m height with only the west end open to the Aegean Sea. This natural barrier has a strong influence in the meteorological conditions determining the air pollution situation. The region is mostly classified within the local climate of the Mediterranean Sea, but actually, the region tends to the semi–arid climate. The annual rainfall reaches 508 mm while highest monthly rainfall is 130 mm during October 2007. February is the coolest month with a daily average temperature of 10.3 ^{o}C, while in July the daily average reaches 30.0 ^{o}C for the year 2007. The maximum hourly average temperature in the city is 40.5 ^{o}C, while the minimum hourly temperature is 0.3 ^{o}C. The minimum and maximum daily average temperatures for the months are given in Table 3.1. The annual mean wind speed is 3.5 m/s while the predominant wind directions are: W, 34.0%; SSE, 13.4% and SE, 10.1% for the year 2007. The monthly wind roses are given in Figure 3.2 and the annual wind rose is given in Figure 3.3. There are several surface meteorological stations and one upper air station in the city. The main meteorological station that is Guzelyali located at the center of city is both upper air station and surface station.

Table 3.1 The maximum and minimum daily average temperatures in the city for the year 2007 (^{o}C)

	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ava.
Min.	6.2	3.3	8.2	12.1	17.6	22.5	26.6	25.3	20.9	13.9	8.7	5.9	14.3
Max.	16.2	14.6	18.9	19.8	27.2	33.4	35.4	34.9	31.2	24.5	23.1	14.6	24.5

3.2. Transportation In The City

Izmir has been known as a center of art, culture, tourism and trade throughout its history. The city has four ports (Alsancak Port, Aliaga-Nemrut Port, Cesme Port and Dikili Port) and one airport (Adnan Menderes Airport) that connect many other cities worldwide. The city of Izmir area's economy is divided in value between various types of activity as follows: 30.5% for industry, 22.9% for trade and related services, 13.5% for transportation and communication and 7.8% for agriculture (ICC, 2008). In 2008, Izmir provided 10.5% of all tax revenues collected by Turkey and its exports corresponded to 6% and its imports 4% of Turkey's foreign trade (ICC, 2008).

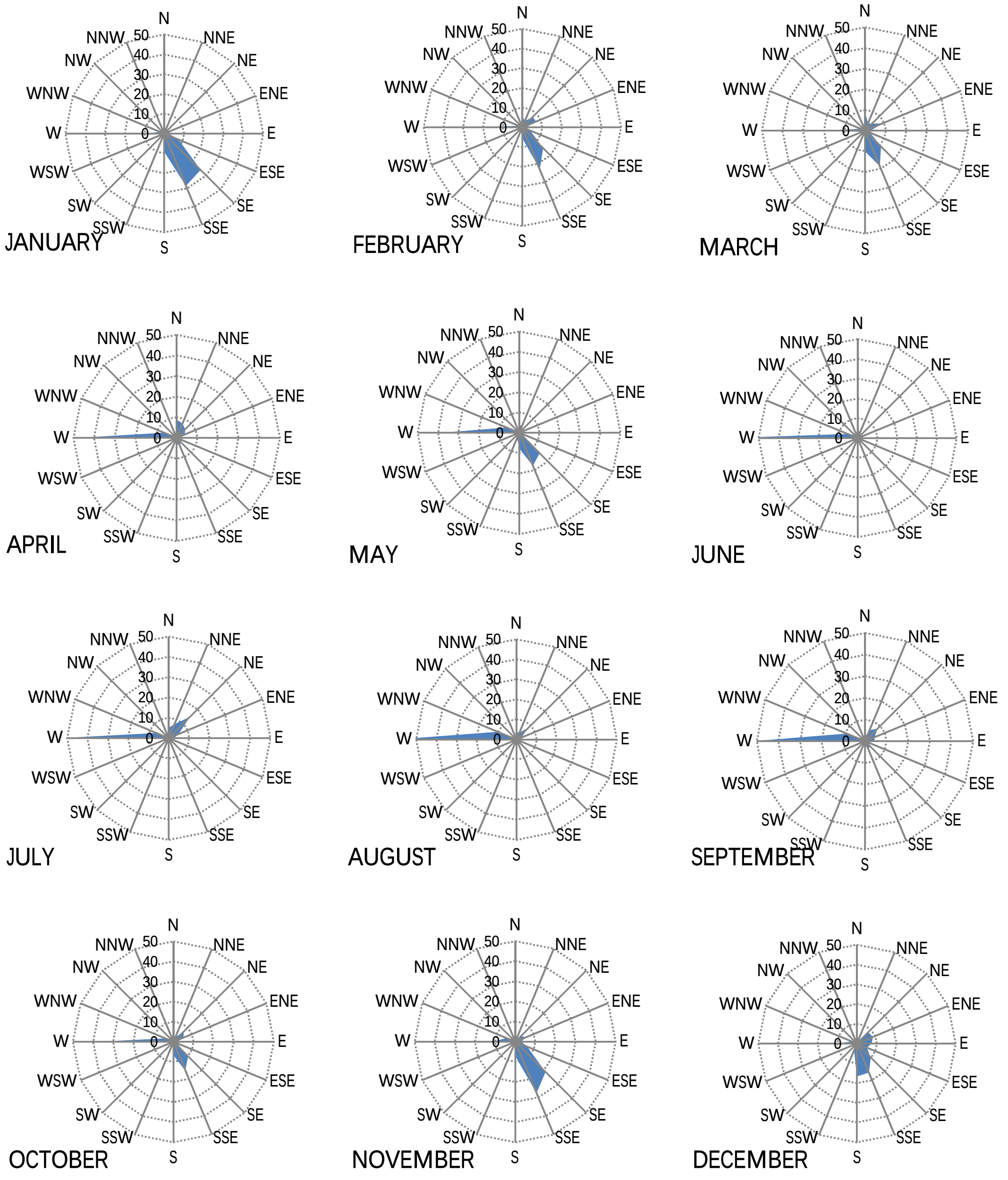

Figure 3.2 Monthly wind roses in the city of Izmir.

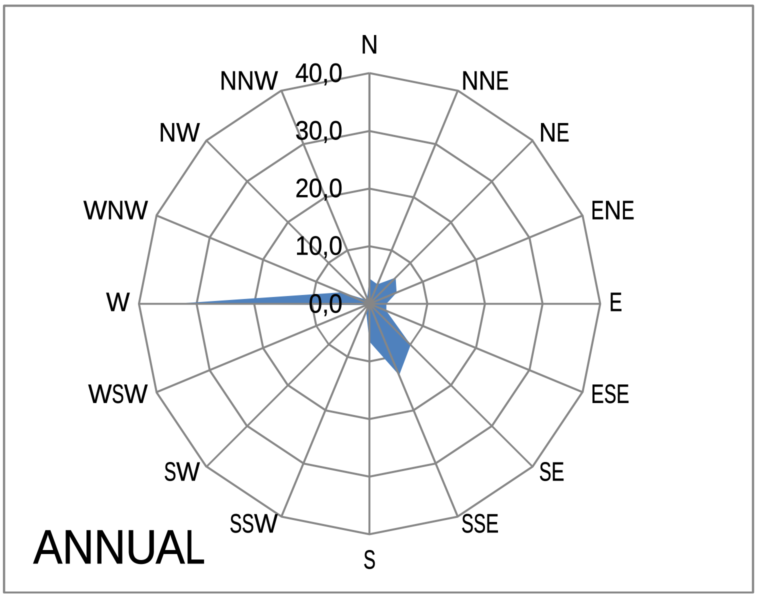

Figure 3.3 The annual wind rose for the year 2007 in Izmir.

Public transport of Izmir is conducted by municipality related companies. The major part of bus service operated by a company (ESHOT). ESHOT operates about 1,500 buses. Another company, IZULAS, operates 400 buses in the city. In total, there are 1900 buses in the public transport sector in Izmir.

Passenger ferries are widely used in the city. Twenty four ferries shuttle between 8 routes in the city (Bostanli, Karsiyaka, Bayrakli, Alsancak, Pasaport, Konak, Göztepe and Uckuyular).

Izmir has a subway network that is constantly being extended with new stations being put in service. The network consisting of one line, starts from Ucyol station in Hatay in the southern part of the metropolitan area and runs towards northeast to end in Bornova. The line is 11.6 km long.

The city has the Adnan Menderes Airport well served with connections to Turkish and international destinations. Its new international terminal was in service in September 2006 and it was aimed for the airport to become one of busiest in Turkey. A recently-built large bus terminal in Altındag suburb on the outskirts of the city has intercity buses to points all over Turkey. The city has rail service from several terminals in downtown to Ankara in the east and Aydin in the south.

3.3 Air Quality In The City

Air is polluted all the year round due to problems of non-compliance with existing laws around the polluting industrial facilities, power stations and major roads with heavy traffic. When cases of Turkish air pollution incidences are individually studied for their causes, it can be seen that they also originate from unplanned urbanization and industrialization, use of low-grade fuels in combustion systems that are not particularly suitable to these fuels as well as industrial process losses and leaks (Elbir et al., 2000; Muezzinoglu et al., 1998).

Air pollution is one of the most important environmental problems in Izmir, Turkey. The metropolitan city of Izmir is the center of a highly industrialized area on the Aegean Sea shoreline of Turkey. Industry is a major air-polluting sector in the city (Elbir, 2002). Several (3335 small industrial facilities and 4334 medium–sized or larger) industries are polluting the city of Izmir and its surroundings (Muezzinoglu et al., 2003) in the year 2000. The main industrial sectors are leather, food, textile, paper, machinery and metals, chemical, petrochemical, ceramic, cement, iron–steel and petroleum refinery. Larger industrial facilities are usually agglomerated in the organized industrial zones.

Ninety one percent and 9% of the total emissions were estimated to come from industries and domestic heating, respectively (Elbir, 2002). The reason for such high SO_2 emissions is the use of fossil fuels with high sulfur content. At the city center combustion of lignite coals of less than 1% sulfur content are allowed for domestic heating. Therefore, 93% of total industrial SO_2 emissions were found to come from outside of the metropolitan area (Elbir, 2002).

In the urban area of Izmir, the Greatest Izmir Municipality monitors continuous SO_2 and particulate matter (PM) levels. The monitoring network contains four permanent stations (Karsiyaka, Konak, Bornova and Alsancak).

CHAPTER FOUR
MATERIAL AND METHODS

4.1 Vehicle Counting

For vehicles to be automatically counted there needs to be a means of detecting them. The most common form of vehicle detection uses an inductive loop buried in the road surface. As a vehicle passes over the loop, the loop inductance changes causing the loop monitoring circuit (loop detector) to output a signal. If two such loops are placed close together along the path of the vehicle, the direction in which the vehicle is travelling can also be detected.

In this study, automatic counts were carried out using a portable vehicle classifier system, MetroCount Roadside Units, Model 5600 (METROCOUNT, 2010). This automatic counter is made of two main components. These are a roadside unit, which has the electronic circuitry for storage of digital data; and two pneumatic tubes that act as detectors for traffic. The pneumatic tubes are installed across the road with a known separation. When the vehicle's first axle hits the tubes, the classifier measures the traversal time to calculate its speed, and then uses subsequent hits to obtain the axle separation. The classifier uses the number of axles and axle separations to derive vehicle classes from a classification scheme. This scheme used in the study is given in Table 4.1. The order of tube hits gives the direction of travel. To distinguish vehicles, the classifier assumes a minimum inter-vehicle time. Figure 4.1 shows a view of the vehicle classifier system used in the present study.

The roadside unit does not process traffic data during the counts, rather it all axle events in a compressed format. The actual task of classifying the vehicles is performed later when the information is downloaded to a personal computer. The system records time of the first axle of the vehicle, direction of the vehicle, speed of the vehicle, wheelbase of the vehicle, number of axles in the vehicle, number of axle groupings in the vehicle and error code indicating a mismatch in sensor hits.

Tablo 4.1. Vehicle classification list

Level 1	Level 2		Level 3	ARX			
Length	Axles and Groups		Vehicle Type	Classification			
Type	**Axles**	**Groups**	**Description**	**Class**		**Parameters**	**Dominant Vehicle**
	Light Vehicles						
Short up to 5.5 m	**2**	**1 or 2**	**Very Short** Bicycle or Motorcycle	**MC**	**1**	d(1)<1.7m and axles=2	
	2	**1 or 2**	**Short** Passenger Cars	**SV**	**2**	d(1)<1.7m,d(1)<=3.2 m and axles=2	
Medium 5.5 m to 14.5m	**3, 4 or 5**	**3**	**Short-Towing** Trailer, Cravan, Boat, etc.	**SVT**	**3**	groups=3, d(1)>=2.1m,d(1)<=3.2 m, d(2)>=2.1m and axles=3,4,5	
	Heavy Vehicles						
	2	**2**	**Two Axle Truck or Bus**	**TB2**	**4**	d(1)>3.2m and axles=2	
	3	**2**	**Three Axle Truck or Bus**	**TB3**	**5**	axles= 3 and groups=2	
	>3	**2**	**Four Axle Truck**	**T4**	**6**	axles>3 and groups=2	
Long 11.5m to 19.0m	**3**	**3**	**Three Axle Articulated** Three axle articulated vehicle or Rigid vehicle and trailer	**ART3**	**7**	d(1)>3.2m , axles=3 and groups = 3	
	4	**>2**	**Four Axle Articulated** Four axle articulated vehicle or Rigid vehicle and trailer	**ART4**	**8**	d(2)<2.1m or d(1)<2.1m or d(1)>3.2m axles=4 and groups>2	
	5	**>2**	**Five Axle Articulated** Five axle articulated vehicle or Rigid vehicle and trailer	**ART5**	**9**	d(2)<2.1m or d(1)<2.1m or d(1)>3.2m axles=5 and groups>2	
	>=6	**>2**	**Six Axle Articulated** Six (or more) axle articulated vehicle or Rigid vehicle and trailer	**ART6**	**10**	axles=6 and groups> 2 and groups > 6 and groups = 3	
Medium and Long Combination Over 17.5	**>6**	**4**	**B Double** B Double or Heavy truck and trailer	**BD**	**11**	groups = 4 and axles > 6	
	>6	**>=5**	**Double or Triple Road Train** Double road train or Heavy truck and two trailers	**DRT**	**12**	groups = 5 or 6 and axles >6	
	Ungrouped Classes						
			Unclassifiable Vehicle		**13**		
			Unclassifiable Axle Event		**0**		

Figure 4.1 The portable vehicle classifier system placed on a road surface.

The vehicle classifier system categorizes the vehicles by grouping them into 12 standard categories composed of motorcycle, passengers cars, passengers cars with trailer, pick up, truck, minibus, bus, lorry, transporter with multi axles considering their numbers of axles and the distances between the axles. New categories that are different from standard categories can be added modifying the software of the system. The vehicles in this study were counted into four main categories by MetroCount roadside units. These categories are:

1. Motorcycles
2. Passenger cars
3. Light–duty vehicles (minibus + pickup)
4. Heavy–duty vehicles (bus + truck)

Devices can detect the vehicles without any problem if the speeds of vehicles are between 10 km/hour and 160 km/hour. With one device at least 10,000 axles can be counted and a total of 250,000 axles data can be stored in the standard memory (512 kb) of one device. This means that the data obtained for 3-4 days in a major street can be stored in one device. Therefore, in the study, the data stored in the devices were regularly transferred into a portable computer in every 2-3 days. The data collected into the computer were converted into hourly, daily, and weekly vehicle count reports using the licensed software (Traffic Executive) of the devices. All these reports were exported into Microsoft Excel files and all statistical analyses were done in this medium.

The traffic counting studies were carried out between the dates of January 10, 2007 to September 24, 2007 in the study. Counts were carried out at the locations specified at 19 main streets in the city of Izmir. Figure 4.2 shows the location of these streets in the city. Table 4.2 also gives the names, lengths, widths and lane numbers of these streets. In the study, 19 main streets were selected only to count the vehicles due to their locations and high traffic densities although there are approximately 65 main streets in the transportation network of the city. These selected streets are the key highways in the transportation network, because they connect all other major streets (n=46) each other. In the other words, it is possible to estimate traffic densities in these 46 streets by using additional methods such as high resolution satellite images and video camera records at crossroads if the vehicles are continuously counted in the key streets (n=19). There are also a large number of small streets in the city. However, their contribution to urban air quality was neglected in the study due to low traffic densities. Consequently, in the present study, the vehicles were counted in 19 major streets by portable vehicle classifier system and traffic densities and the vehicles were estimated in other main streets (n=46).

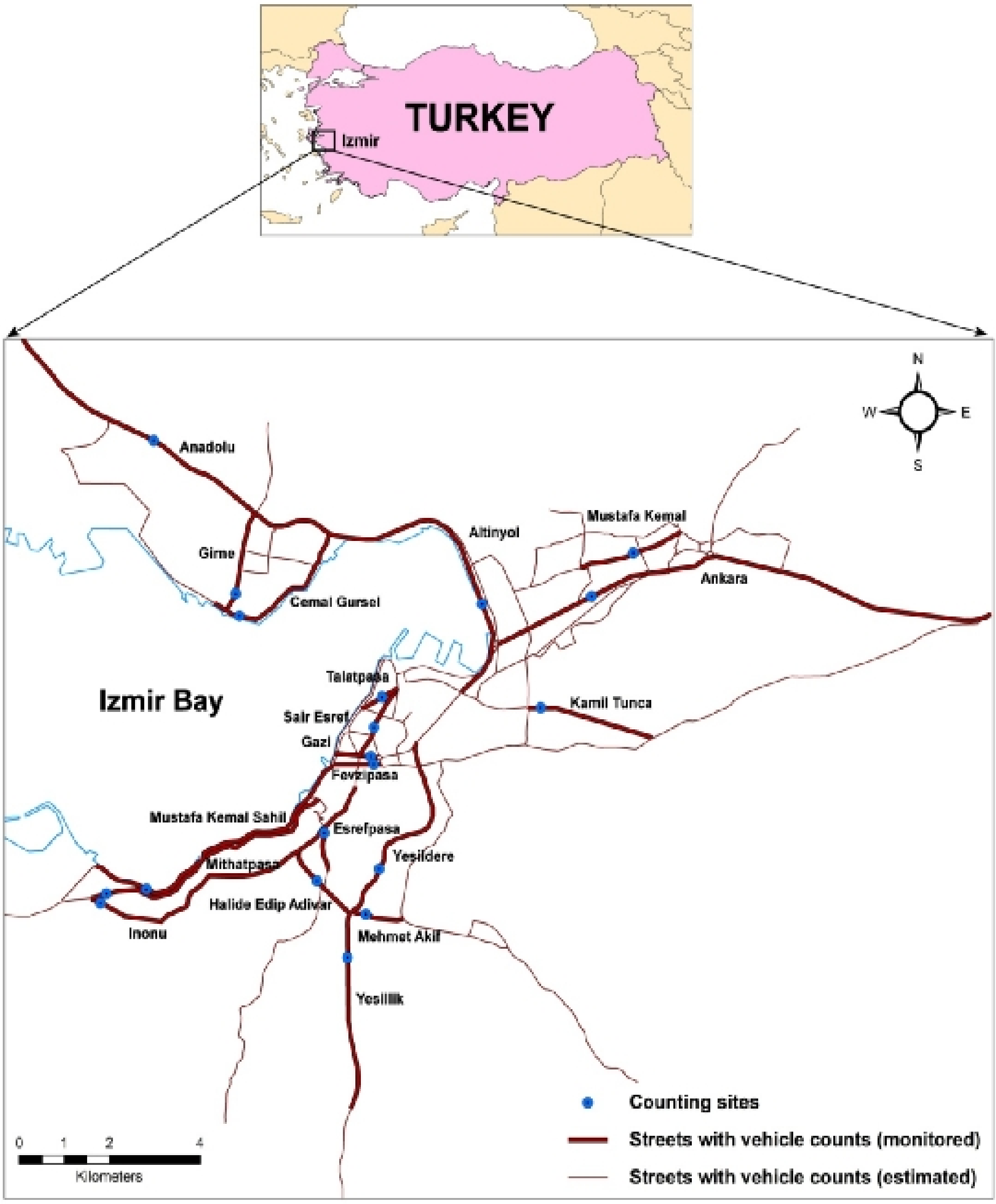

Figure 4.2 Location of major streets studied in the study.

Table 4.2 The properties of the selected streets in the study

No	Street name	Length (m)	Average width (m)	Lane number
1	Inonu Street	6,000	25	4
2	Esrefpasa Street	2,075	20	4
3	Mehmet Akif Street	1,170	20	4
4	Halide Edip Adivar Street	1,780	25	6
5	Mithatpasa Street	5,950	25	4
6	M. Kemal Sahil Avenue	6,525	25	6
7	Talatpasa Avenue	920	15	4
8	Sair Esref Avenue	1,675	25	4
9	Kamil Tunca Avenue	2,850	15	4
10	Fevzipasa Avenue	1,060	20	4
11	Gazi Avenue	950	25	4
12	Yesillik Street	4,225	25	6
13	Yesildere Street	4,520	25	6
14	Mustafa Kemal Street	2,370	15	4
15	Cemal Gursel Street	3,600	25	6
16	Girne Avenue	2,175	20	4
17	Anadolu Street	21,300	25	6
18	Altinyol Street	5,050	25	6
19	Ankara Street	11,530	40	6

The vehicles were counted continuously for 24 hours during a week in each selected street in order to determine the daily and hourly fluctuations of vehicle numbers. The seasonal changes in the vehicle numbers were also studied at all sampling points by repeating the counting campaigns in two different weeks representing summer and winter seasons. The time schedule for counting campaigns in the streets is seen in Table 4.2.

Table 4.3 The time schedule of vehicle counting campaigns in the selected streets

No	Street Name	Working period for winter	Working period for summer
1	Inonu Street	10 – 17 January 2007	3 – 11 July 2007
2	Esrefpasa Street	18 – 25 January 2007	3 – 11 July 2007
3	Mehmet Akif Street	29 January – 6 February 2007	11 – 23 July 2007
4	H. Edip Adivar Street	29 January – 6 February 2007	11 – 23 July 2007
5	Mithatpasa Street	8 – 18 February 2007	24 July – 1 August 2007
6	M. Kemal Sahil Avenue	8 – 18 February 2007	24 July – 1 August 2007
7	Talatpasa Avenue	19 – 27 February 2007	1 – 8 August 2007
8	Sair Esref Avenue	19 – 27 February 2007	1 – 8 August 2007
9	Kamil Tunca Avenue	28 February – 9 March 2007	8 – 16 August 2007
10	Fevzipasa Avenue	10 – 18 March 2007	21 – 29 August 2007
11	Gazi Avenue	10 – 18 March 2007	21 – 29 August 2007
12	Yesillik Street	19 – 29 March 2007	4 -10 September 2007
13	Yesildere Street	19 – 29 March 2007	4 -10 September 2007
14	Mustafa Kemal Street	30 March – 10 April 2007	8 – 16 August 2007
15	Cemal Gursel Street	30 March – 10 April 2007	17 September – 11 October 2007
16	Girne Avenue	10 – 18 April 2007	17 – 24 September 2007
17	Anadolu Street	10 – 18 April 2007	2 – 10 September 2007
18	Altinyol Street	17 – 29 May 2007	26 June – 3 July 2007
19	Ankara Street	17 – 29 May 2007	6 – 13 August 2007

In the study, four vehicle counting and classifying devices were used simultaneously on the streets. Two devices were used in a single street at the same time for counting vehicles on two directions of the street. Some technical criteria were considered for the selection of the sampling points to be counted on the streets. The first criterion was that the sampling point should be away from the curves, junctions and signalization systems where traffic flows slowly. The second criterion was the necessity to install the tubes on a smooth street ground. The last criterion was the availability of a tall object on the street like a utility pole or a tree so that the devices can be left securely on the streets.

4.2 Emission Inventory

Emissions were estimated in each street by using hourly traffic activity data on the streets and CORINAIR emission factors (EEA, 2007). Hourly, daily, weekly and annual emissions were calculated for each street and the whole transportation network.

The selection of the emission factors used for mobile sources depend on the following parameters:

- Ø vehicle type (motorcycle, passenger car, light-duty vehicles and heavy-duty vehicles)
- Ø engine technology (production date, engine capacity, etc.)
- Ø fuel type (gasoline, diesel, LPG)
- Ø road type (highway, urban, rural)
- Ø vehicle speed

The emission factors in the database are given as equations that include the vehicle speed as the main variable. CORINAIR emission factors for mobile sources are called by the names of the related regulations set by the European Union in the database. The classification names used in the database with their abbreviations and the periods included are listed below:

- preECE 1971 and before
- ECE 15 00& 01 1972-1977
- ECE 15 02 1978 -1980
- ECE 15 03 1981 – 1985
- ECE 15 04 1986 – 1992
- EURO 1 1993 -1997
- EURO 2 1997 -1999
- EURO 3 2000 -2004
- EURO 4 2005 and after

Emissions for five main pollutants were calculated in the study. These are nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), particulate matter (PM_{10}) and sulfur dioxide (SO_2). The emission factors given in CORINAIR for these pollutants are mostly in the form of equations based on mainly vehicle speed. For example, CO emission factor for a gasoline passenger car in EURO 4 category is as follows:

$$EF = (0.136 - 0.000891 * V) / (1 - 0.0141 + 0.0000499 * V^2)$$

where, EF : CO emission factor (g/km), V: speed of the vehicle (km/hour)

CO emission factors for the other passenger car categories are given in similar equations with different coefficients. Figure 4.3 shows the graph of CO emission factors versus the vehicle speed for gasoline passenger cars. It is possible to draw similar graphs for different vehicle types and pollutants by using related equations and coefficients.

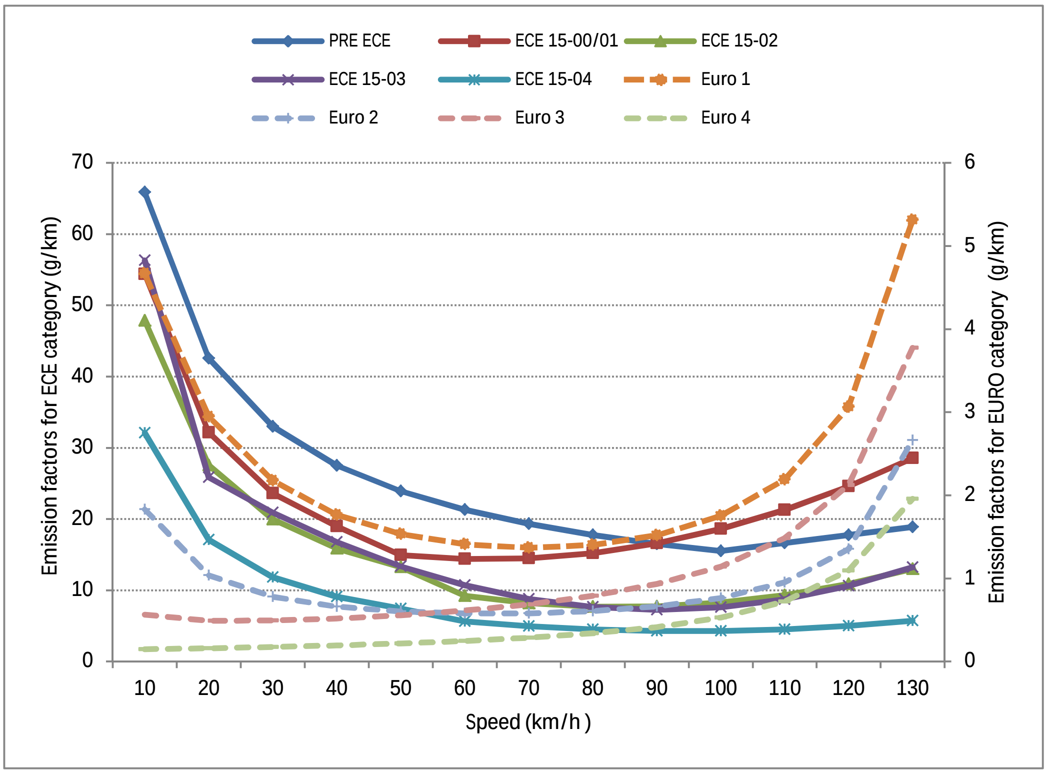

Figure 4.3 CO emissions factors for gasoline passenger cars (g/km).

The emissions were calculated in MS-Excel. For each street, a separate Excel file was created and the emissions in these files were calculated on hourly basis for:

- each pollutant
- both sides of the street
- all days in a week
- vehicle types and engine technologies
- fuel type

4.3 The Measurements of Ambient Air Quality

Ambient air quality measurements were made simultaneously during vehicle counting campaigns in the same streets. A mobile ambient air quality monitoring station was used in the study. In the measurement station, the following parameters were measured:

- sulfur dioxide (SO_2)
- carbon monoxide (CO)
- nitrogen oxides (NO- NO_2- NO_x)
- particulate matter (PM_{10})
- ozone (O_3)
- hydrocarbon (total methane and outside methane hydrocarbon)
- meteorological parameters (wind direction and speed, moisture, temperature, and pressure)

The devices used in the stations are mainly Thermo Inc. brand and EPA approved devices. In the measurement of PM_{10}, Beta Ray Adsorption method was used; in the measurement of CO, infrared method was used and in the measurement of NO_x, Chemiluminescence method was used. These devices are shown in Figure 4.4.

The mobile station was placed at the sampling points near the selected streets in the study. Therefore, the contributions of the vehicles to urban air quality on the street could be directly estimated. The locations of these sampling points were selected according to several criteria such as security, availability of electricity and no obstacle between the sampling point and the street. For that reason, the sampling points were generally in the garden of a public institution or a commercial company. In Figure 4.5, the location of mobile measurement station in different streets are shown. Mobile station was continuously operated during approximately 10 days so as to observe the fluctuations of daily and hourly air quality in a week at sampling points. When a measurement campaign in a street was completed, the new one in another street was started and all devices were calibrated before operation.

Figure 4.4 The equipments used in the station.

The measurement schedules in the streets are given in Table 4.4. The monitoring station was not operated in only Fevzipasa Avenue, because there was not any safe place to locate the station in the street.

Figure 4.5 Locations of the station in different streets.

Table 4.4 The measurement schedules in the streets

No	Street Name	Starting Date	Ending Date
1	Cemal Gursel Street	04.10.2007	17.10.2007
2	Halide E.Adivar Street	17.10.2007	01.11.2007
3	Mustafa Kemal Street	01.11.2007	13.11.2007
4	K. Tunca Avenue	13.11.2007	22.11.2007
5	Yesillik Street	22.11.2007	13.12.2007
6	Altinyol Street	13.12.2007	25.12.2007
7	Cumhuriyet Avenue	25.12.2007	04.01.2008
8	Sair Esref Avenue	04.01.2008	17.01.2008
9	Girne Avenue	17.01.2008	29.01.2008
10	M. Kemal S. Avenue	30.01.2008	12.02.2008
11	Mithatpasa Street	12.02.2008	25.02.2008
12	Inonu Street	27.02.2008	12.03.2008
13	Mehmet Akif Street	12.03.2008	20.03.2008
14	Esrefpasa Street	20.03.2008	26.03.2008
15	Ankara Street	26.03.2008	09.04.2008
16	Yesildere Street	09.04.2008	21.04.2008
17	Anadolu Street	30.04.2008	16.05.2008
18	Talatpasa Avenue	21.05.2008	30.05.2008
19	Gazi Avenue	05.06.2008	17.06.2008

4.4 Air Quality Modeling

The CALMET/CALPUFF modeling system (Scire et al., 2000) was used to calculate the dispersion of pollutants from mobile sources. The CALMET/CALPUFF has been adopted by the United States Environmental Protection Agency (EPA) in its Guideline on Air Quality Models (USEPA, 2005) as a preferred model for assessing transport of pollutants and their impacts. The CALMET/CALPUFF modeling system includes three main components: CALMET, CALPUFF and post processing and graphical display programs. CALMET is a diagnostic meteorological model that generates mass consistent wind fields over complex terrain. The CALMET meteorological model in its basic form produces hourly fields of three-dimensional winds and various micrometeorological variables based on the input of routinely available surface and upper air meteorological observations. CALPUFF is a Lagrangian puff model and a multi–layer, gridded non–steady–state puff dispersion model that can simulate the effects of temporally and spatially varying meteorological conditions on pollutant transport, removal by dry and wet deposition processes, and transformation through chemical reactions. The model is developed to simulate continuous puffs of pollutants being emitted from a source into the ambient wind flow. As the wind flow changes from hour to hour, the path of each puff takes changes to the new wind flow direction. Puff diffusion is Gaussian and concentrations are based on the contributions of each puff as it passes over or near a receptor point (Scire et al., 2000).

CALPUFF model requires each line source to be described according to the emission inventory: street length, street width and emissions. CALMET model requires local meteorological data such as hourly surface observations of wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure and relative humidity. The output of the model is then calculated for each grid of the study area.

The study area was selected as 25 km x 30 km to cover the city center (Figure 4.6). CALMET uses an interpolation scheme that allows observed wind data to be heavily weighted in the vicinity of the meteorological stations. Due to the existing meteorological stations (n=7) outside the metropolitan area, the modeling domain for CALMET was expanded to an area of 120 km x 130 km to provide more representative wind field data for CALPUFF. The grid size used for estimating the grid-based emissions and concentrations is 250 m x 250 m. This extended modeling domain required a regional scale model like CALPUFF taking into account the three-dimensional wind fields and other boundary layer parameters. CALMET land use categories and associated geophysical parameters based on the U.S. Geological Survey Land Use Classification System were used for the study area. The default land use categories and the default values of several geophysical parameters such as surface roughness length (i.e., 0.001 m for water body and 1.0 m for urban land), albedo, bowen ratio, soil heat flux parameter and heat flux can be found elsewhere (Scire et al., 2000). In modeling calculations, it was assumed that the background concentrations are negligible. Therefore, the results represent the air quality levels originated only from the sources located in the modeling domain. Table 4.5 summarizes model inputs.

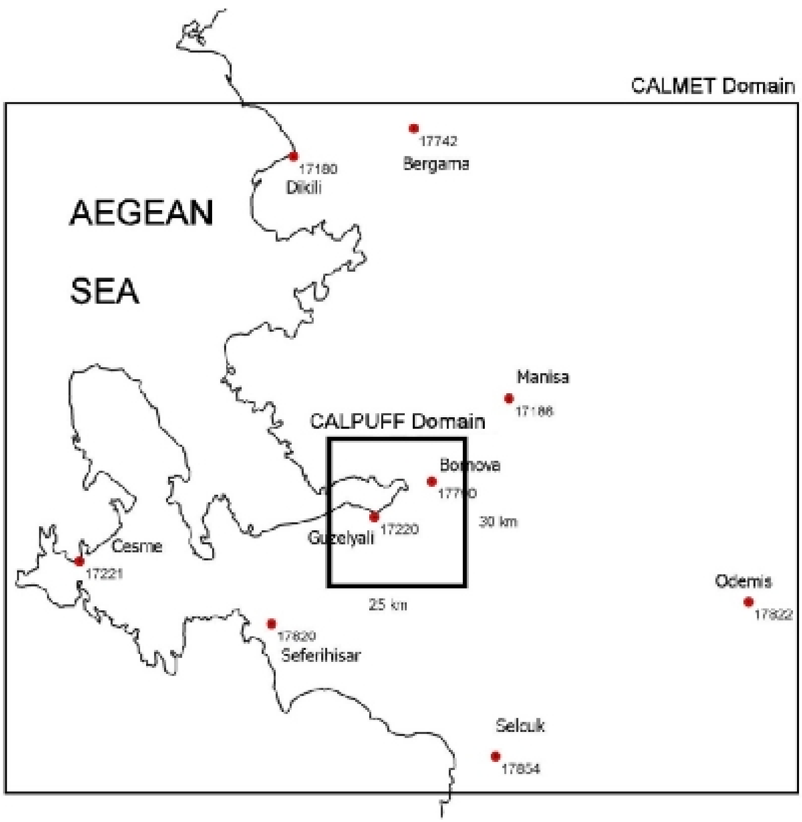

Figure 4.6 Meteorology and dispersion modeling domains.

Table 4.5 Summary of input data for models

Data Category	Data Type	Notes
Meteorological Data	Hourly observations of : • wind speed • wind direction • temperature • cloud cover • ceiling height • surface pressure • relative humidity • precipitation rate • precipitation type code Twice daily observed vertical profiles of : • wind speed • wind direction • temperature • pressure	Meteorological data used for meteorological models was obtained from 9 meteorological stations operated by DMI which are located around the center of the city of Izmir. The data for the parameters of wind speed, wind direction, temperature, pressure, humidity, precipitation and cloudiness were taken from all stations as hourly basis for the year 2006. Radiosonde measurements were also taken from Guzelyali station.
Pollutant Sources and Emission Data	• Line sources (65 streets in 455 segments)	the details are given in Chapter 4.2
Geophysical Data	Gridded fields of : • terrain elevations • land use categories • surface roughness length (optional) • albedo (optional) • Bowen ratio (optional) • Soil heat flux constant (optional) • Anthropogenic heat flux (optional) • Vegetative leaf area index (optional)	Topographical data having a few meters resolution in electronic format was obtained from General Command of mapping - Turkey. Landuse data used as input was obtained from the web site of United States Geological Survey (USGS) - Global Landuse Data (http://eros.usgs.gov/products/landcover/glcc.php).

CHAPTER FIVE
RESULTS AND DISSCUSSION

5.1 Vehicle Counts

There were 11,695,611 registered vehicles in December 2007 in Turkey. Izmir is the third biggest city with the portions of 7.4% (866,072 vehicles), after Ankara (1,143,379 vehicles) and Istanbul (2,570,599 vehicles) (TSI, 2007). The distribution of vehicle numbers registered in Turkey on the basis of cities is given in Figure 5.1.

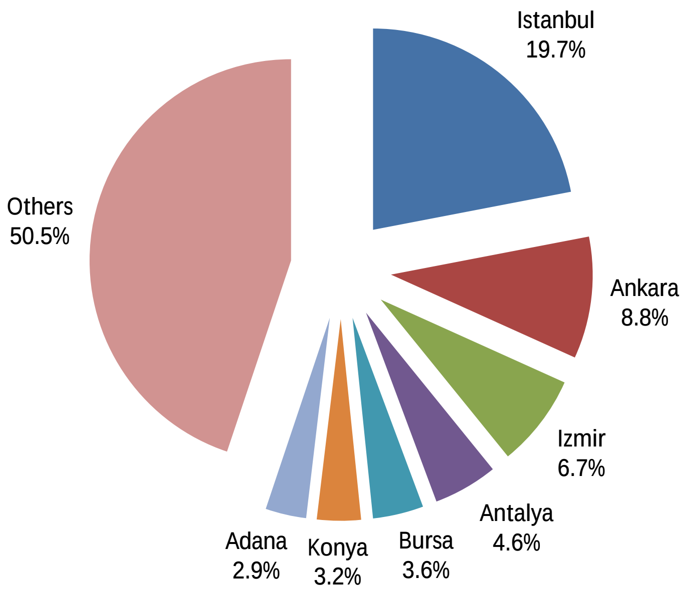

Figure 5.1 The distribution of vehicles registered in Turkey on the basis of cities, %.

Passenger car with the rate of 56% is the most commonly used vehicle type in Izmir for the year 2007. The monthly growth rate for the sales of passenger cars is 0.6% for the city. Monthly vehicle numbers in Izmir are given in Table 5.1. Distribution of fuel types, vehicle types and engine technology are given Table 5.2 and Figure 5.2.

Table 5.1 Monthly vehicle numbers in the city for the year 2007

Months	Motorcycle	Passenger cars	Minibus	Pickup	Bus	Lorry	Total
January	129,013	436,595	14,122	138,820	14,686	34,901	**816,355**
February	129,696	437,730	14,159	139,566	14,763	35,051	**819,294**
March	130,849	440,235	14,206	140,748	14,852	35,234	**824,590**
April	131,999	442,327	14,263	141,732	14,907	35,411	**829,235**
May	133,357	444,271	14,268	142,657	14,969	35,537	**833,750**
June	134,866	446,213	14,311	143,718	15,046	35,664	**838,652**
July	136,890	448,262	14,336	144,764	15,029	35,805	**844,045**
August	138,124	449,549	14,339	145,778	15,118	35,951	**847,897**
September	139,690	451,510	14,379	146,831	15,212	36,128	**852,865**
October	141,012	453,890	14,417	147,879	15,263	36,273	**857,984**
November	141,894	455,743	14,446	148,927	15,296	36,408	**862,079**
December	142,296	457,791	14,487	150,132	15,357	36,511	**866,072**

Table 5.2 Distribution of fuel use according to vehicle types, %

Vehicle Type	Gasoline	Diesel	LPG	TOTAL
Motorcycle	99.4	0.6	-	100.0
Passenger Cars	70.6	11.4	18.0	100.0
Light-duty vehicles	10.7	89.3	-	100.0
Heavy-duty vehicles	6.6	93.4	-	100.0

There are totally 160,000-180,000 vehicles in the peak hours on all important streets (n=65) in the city. These numbers indicate that 21% of the vehicle fleet in winter and 20% of vehicle fleet in summer are active on the roads. In these calculations one vehicle might be counted more than once within the same hour. This case was ignored in the study.

The peak hours in the city are generally between 08:00 and 09:00 a.m., and between 18:00 and 19:00 p.m. The total number of vehicles on all streets (n=65) is 68,108 between 08:00 and 09:00 a.m., and 71,860 between 18:00 and 19:00 p.m. in winter. In summer, these numbers are 64,097 and 68,180 for the same hours, respectively. The total vehicle numbers in peak hours on all streets are given in Figure 5.3.

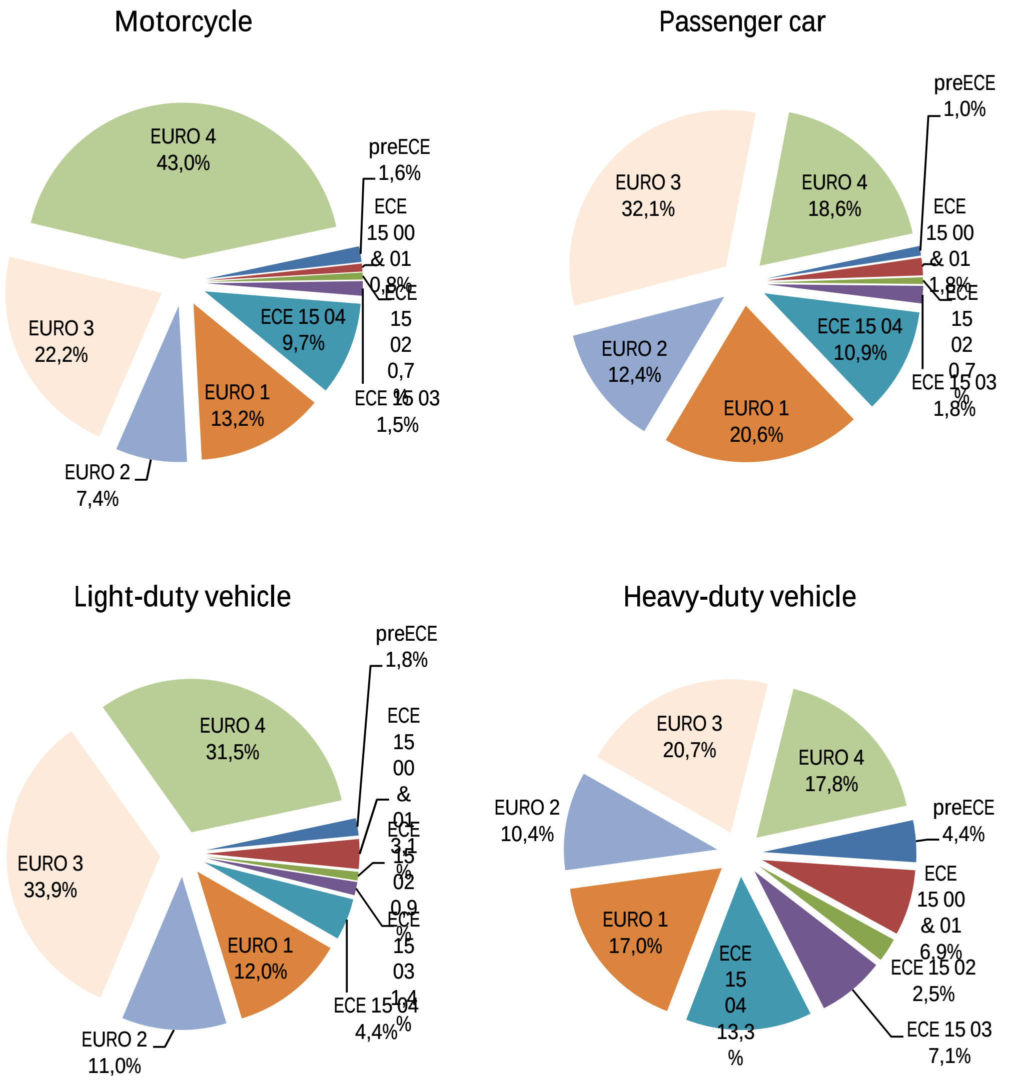

Figure 5.2 The distribution of vehicle type and the technology use, %.

On the other hand, the highest traffic density is occurred in Friday in the city while Sunday has the lowest traffic density. Over 1,000,000 vehicles are in traffic on Friday in the streets (n=19) while 800,000 vehicles are available in traffic on Sunday. The total numbers of vehicles for each day of the week are given in Figure 5.4.

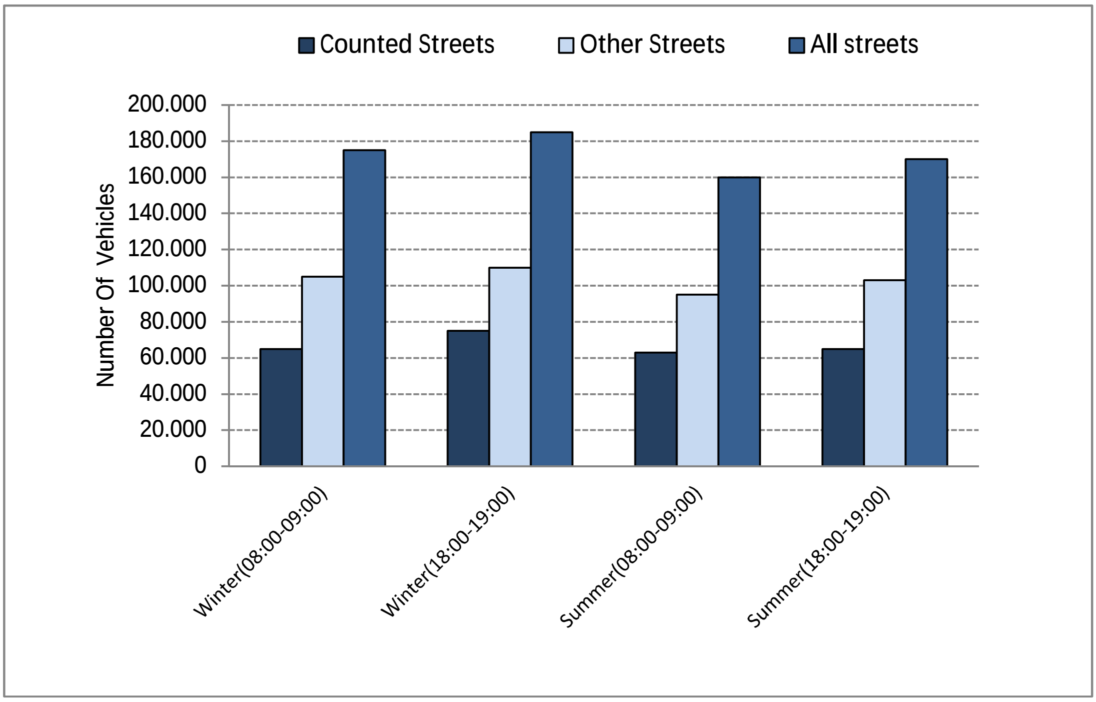

Figure 5.3 The total vehicle numbers counted at the peak hours in the city centre.

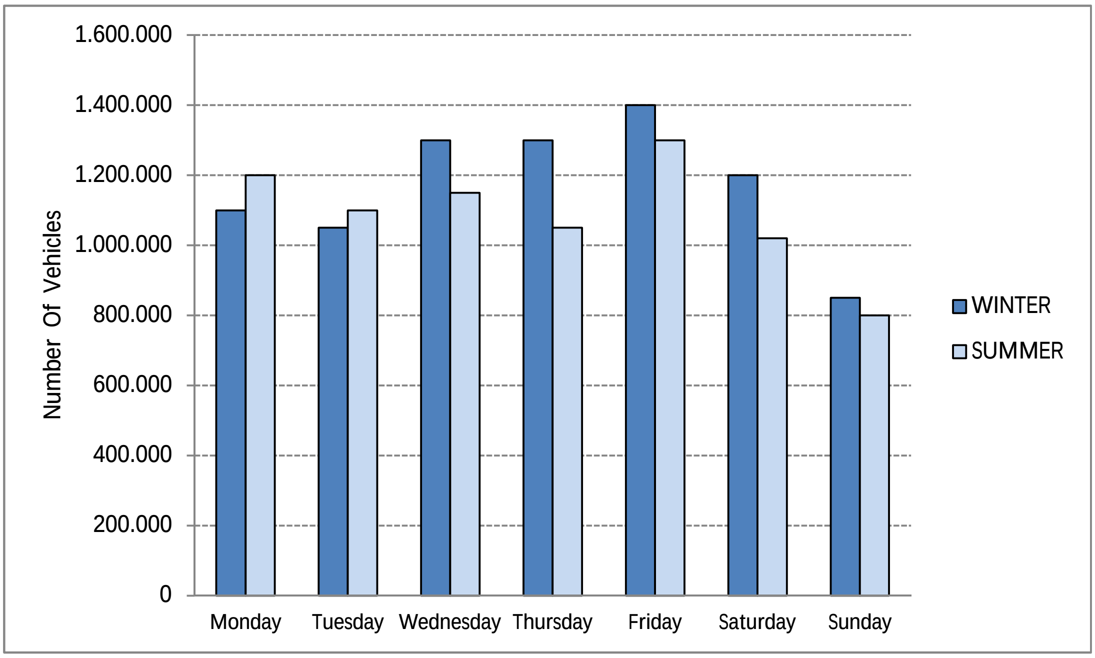

Figure 5.4 Total daily vehicle numbers on the streets (n=19).

In the weekdays, the portions of the vehicle types in the traffic is 82% for passenger cars, 12.5% for light-duty vehicles, 4.2% for heavy-duty vehicles and

1.3% for motorcycle. The contributions at weekends are 83.3% for passenger cars, 11.5% for light-duty vehicles, 4.0% for heavy-duty vehicles and 1.2% for motorcycle. In a study carried out in Italy (Bellasio et al., 2006), similar ratios were found in the Sardinia region of Italy. In this area there are 1,070,000 registered vehicles and 85% of the vehicles in the traffic is passenger cars.

Ankara Street is the most crowded street in the city lying from the eastern part of the Gulf of Izmir and to the east of the city. This street has three lanes on each side and is accompanied by secondary roads with two lines at both sides and having 40 meters average width. A view in the Ankara Street is given in Figure 5.5. The length of street is approximately 6.5 kilometers. This road connects Kemalpasa and Manisa organized industrial zones to the Izmir Port (Figure 5.5). In this study, Altinyol Street is the second crowded street following Ankara Street. Altinyol Street is the main artery which transfers the whole traffic from the north of Izmir to the city centre and to the south. The length of the street is around 3.5 kilometers. Altinyol Street is divided in to 3 lanes on both sides. A view from the Altinyol Street is given in Figure 5.6. Altinyol Street is also the part of Canakkale-Izmir highway that remains in the city centre. Yesildere Street is the third crowded street that provides the transportation between northern counties and southern counties of Izmir. Its length and average width are 4.5 km and 25 m, respectively.

Total numbers of vehicles counted for one week show that the portions of these three major streets in totals (n=65) are 12% for winter and 11% for summer. The average vehicle numbers in the peak hours (08:00-09:00 and 18:00-19:00) for both seasons are given in Table 5.3.

Figure 5.5 A view from Ankara Street.

Figure 5.6 A view from Altinyol Street.

Table 5.3 Average vehicle numbers at the peak hours in the city, vehicle/hour

Street Name	**WINTER**		**SUMMER**	
	Morning	**Evening**	**Morning**	**Evening**
	8:00-9:00	**18:00-19:00**	**8:00-9:00**	**18:00-19:00**
Ankara Street	8,978	8,416	7,680	7,561
Altinyol Street	7,997	7,924	6,951	7,479
Yesildere Street	6,955	7,221	7,214	7,252
Yesillik Street	4,937	5,260	4,295	4,463
Anadolu Street	4,930	4,904	3,729	3,885
M. Akif Street	4,234	3,999	4,160	3,890
M.K.Sahil Avenue	3,771	4,561	3,784	4,625
H. E. Adivar Street	3,285	4,149	3,317	3,916
Fevzipasa Avenue	3,118	2,892	2,302	2,479
Gazi Avenue	2,699	2,479	2,836	2,689
Sair Esref Avenue	2,578	2,503	2,232	2,475
C. Gursel Street	2,427	3,026	3,187	3,533
Inonu Street	2,327	2,372	2,322	2,699
M. Kemal Street	1,922	2,131	1,411	1,851
Talatpasa Avenue	1,778	1,923	1,705	1,463
Esrefpasa Street	1,633	2,185	2,195	2,212
K. Tunca Avenue	1,585	2,367	2,121	2,202
Girne Avenue	1,537	1,835	1,456	1,875
Mithatpasa Street	1,498	1,713	1,200	1,631
Total (n=19)	*68,189*	*71,860*	*64,097*	*68,180*
Other Streets (n=46)	*107,760*	*110,690*	*96,153*	*105,103*
TOTAL (n=65)	*175,868*	*182,550*	*160,250*	*173,283*

The portions of the streets (n=19) in the total streets (n=65) for winter and summer are given in Figures 5.7–5.8. Figures indicate that similar distributions of traffic density are available in both seasons. Ankara Street is the most crowded road in both seasons.

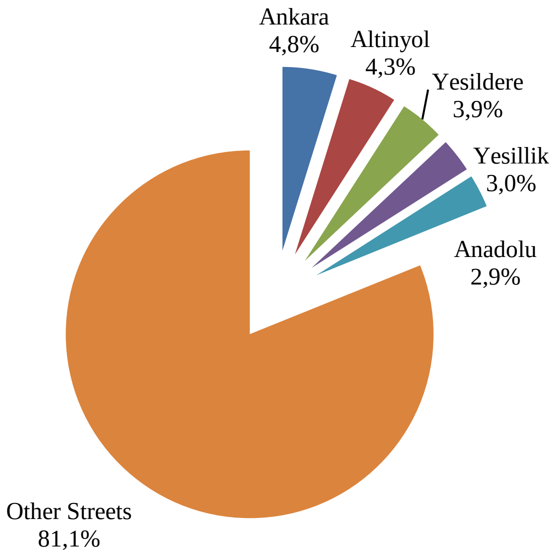

Figure 5.7 The portions of the streets in total weekly vehicle figures for winter, %.

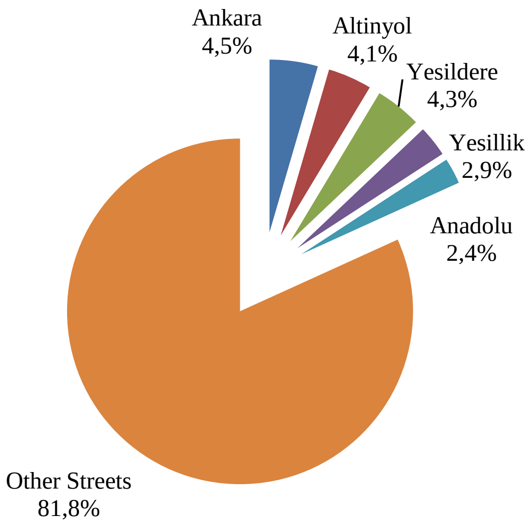

Figure 5.8 The portions of the streets in total weekly vehicle figures for summer, %.

Mithatpasa Street has the least traffic in both seasons in the city. The street is located in the south of the city center and parallel to both coastline and Mustafa Kemal Sahil Avenue. The length and width of the street are 6 km and 25 m, respectively.

As mentioned before, the highest traffic density was observed between 08:00-09:00 in the morning and 18:00-19:00 in the evening in almost all streets (n=19). On the other hand, the lowest traffic density occurred between the hours of 03:00 and 05:00. The hourly variations of total vehicle numbers for the days of an average week were given in Figure 5.9 for winter and in Figure 5.10 for summer. These figures show that the traffic volume of 20,000–40,000 vehicle/hour was observed at midnight. Even at the earliest hours of the morning, 4,000-5,000 vehicles were still active on 19 streets. Considering all the roads (n=65), 45,000–80,000 vehicles were on the traffic between 00:00-01:00 at midnight although the lowest vehicle figures (10,000–15,000) were observed between 03:00–04:00. Although Saturday resembles a weekend, the hourly distribution of the vehicle numbers on Saturday is different. There are almost not peak hours as there is on a weekday. The distribution of Sunday is totally different as a weekend day and indicates an off day.

The portions of vehicle types in all streets are given in Table 5.4. The highest traffic density for passenger car category was observed on Mustafa Kemal Sahil Avenue extending throughout the southern coastline of the Gulf of Izmir. The length and width are 6.2 km and 25 m for the street. Due to the fact that there is not public transportation on the street by bus or minibus, the most dominant vehicle type is passenger car. A view from the Mustafa Kemal Sahil Avenue is given in Figure 5.11.

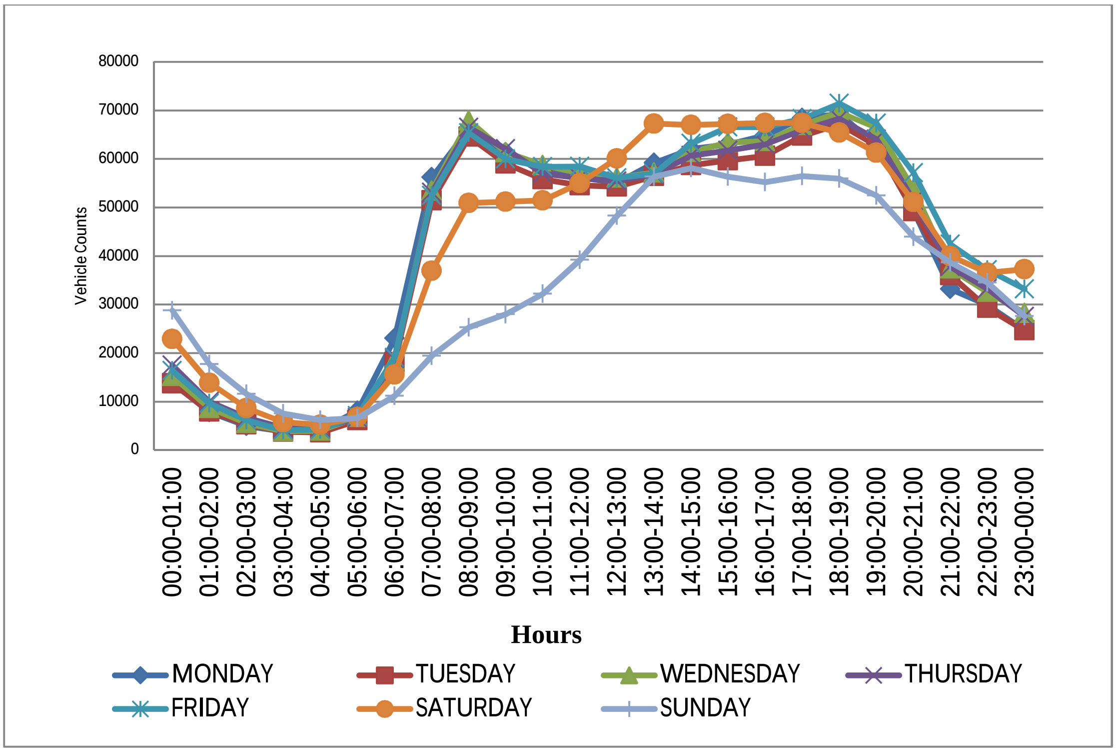

Figure 5.9 Hourly variation of total vehicle numbers for the days of an average week in winter, vehicle/hour.

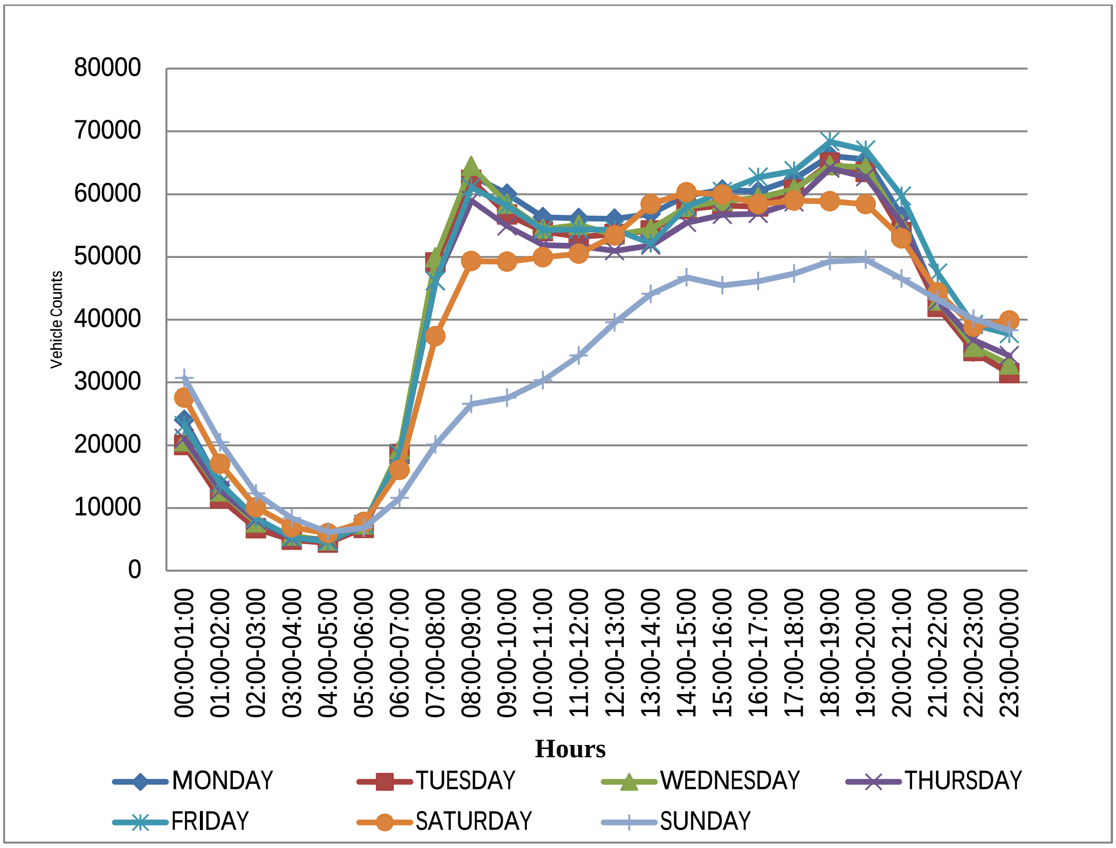

Figure 5.10 Hourly variation of total vehicle numbers for the days of an average week in summer, vehicle/hour.

Figure 5.11 A view from the Mustafa Kemal Sahil Avenue.

The highest contribution for the category of light-duty vehicle belongs to Kamil Tunca Avenue (Table 3.4). Kamil Tunca Avenue is located in Bornova district that is located east of the city center. Its length is about 2.5 km and its average width is 15 m. Due to its position in the city (linking the central bus terminal to the city center), minibus density was high on it. The urban minibuses widely use this street for carrying passengers almost from all districts of Izmir to bus terminal. Urban links of intercity bus companies also use this street quite often. A view from the street is given in Figure 5.12.

When the distribution of the heavy-duty vehicle category in the streets is considered, it is noticed that Sair Esref Avenue had the densest traffic of heavy-duty vehicles, particularly in winters. This street is located in Alsancak district where lots of city buses pass. The contribution of heavy-duty vehicles was 10.2 % in this street.

Table 5.4 The portions of the vehicles types in all streets in summer and winter, (%)

Street Name	WINTER					SUMMER				
	Motorcycle	**Passenger Cars**	**Light-duty Vehicles**	**Heavy-duty Vehicles**	**TOTAL**	**Motorcycle**	**Passenger cars**	**Light-duty Vehicles**	**Heavy-duty Vehicles**	**TOTAL**
Inonu Street	1.4	82.6	11.3	4.6	100.0	2.0	79.0	14.9	4.1	100.0
Esrefpasa Street	2.7	85.0	5.6	6.6	100.0	3.0	84.0	6.5	6.5	100.0
M.Akif Street	1.2	84.5	11.7	2.6	100.0	1.9	83.9	11.3	2.9	100.0
H.E. Adivar Street	0.9	86.5	10.7	2.0	100.0	1.4	84.2	12.3	2.1	100.0
Mithatpasa Street	1.8	88.1	6.7	3.4	100.0	2.9	84.1	8.8	4.2	100.0
M.K.Sahil Avenue	0.8	92.1	6.0	1.2	100.0	1.4	91.5	6.0	1.1	100.0
Talatpasa Avenue	1.9	89.9	5.4	2.8	100.0	2.4	90.3	4.9	2.5	100.0
Sair Esref Avenue	2.2	82.7	4.9	10.2	100.0	3.0	80.0	5.8	11.2	100.0
K.Tunca Avenue	1.9	70.9	24.4	2.8	100.0	2.5	70.8	24.2	2.4	100.0
Fevzipasa Avenue	1.8	89.3	5.0	3.9	100.0	2.7	88.1	5.6	3.6	100.0
Gazi Avenue	1.4	89.9	6.4	2.3	100.0	1.5	89.5	6.7	2.4	100.0
Yesillik Street	0.6	83.8	13.2	2.4	100.0	0.9	86.3	10.2	2.6	100.0
Yesildere Street	0.8	88.4	9.4	1.5	100.0	0.9	87.0	10.6	1.4	100.0
M. Kemal Street	2.4	82.0	12.2	3.4	100.0	3.2	77.7	15.3	3.8	100.0
C. Gursel Street	0.9	86.4	9.1	3.6	100.0	1.3	86.6	8.1	3.9	100.0
Girne Avenue	1.8	83.8	8.6	5.8	100.0	2.4	82.2	9.2	6.2	100.0
Anadolu Street	1.0	79.7	14.6	4.7	100.0	2.0	55.5	27.0	15.4	100.0
Altinyol Street	1.1	72.9	20.8	5.2	100.0	1.3	75.2	16.1	7.4	100.0
Ankara Street	1.2	72.3	18.3	8.2	100.0	1.6	68.9	19.7	9.7	100.0
TOTAL	**1.2**	**82.2**	**12.3**	**4.2**	**100.0**	**1.3**	**82.0**	**12.4**	**4.3**	**100.0**

The daily vehicle numbers in weekdays and weekends for summer and winter seasons are given separately in Figures 5.13 – 5.14. There are important differences between the weekday and weekend traffic in some streets (Ankara Street, Altinyol Street, Yesildere Street, etc.) but on some streets (Esrefpasa Street, Mithatpasa Street, Cemal Gursel Street, Girne Avenue, etc.) did not have any difference.

Figure 5.12 A view from Kamil Tunca Avenue.

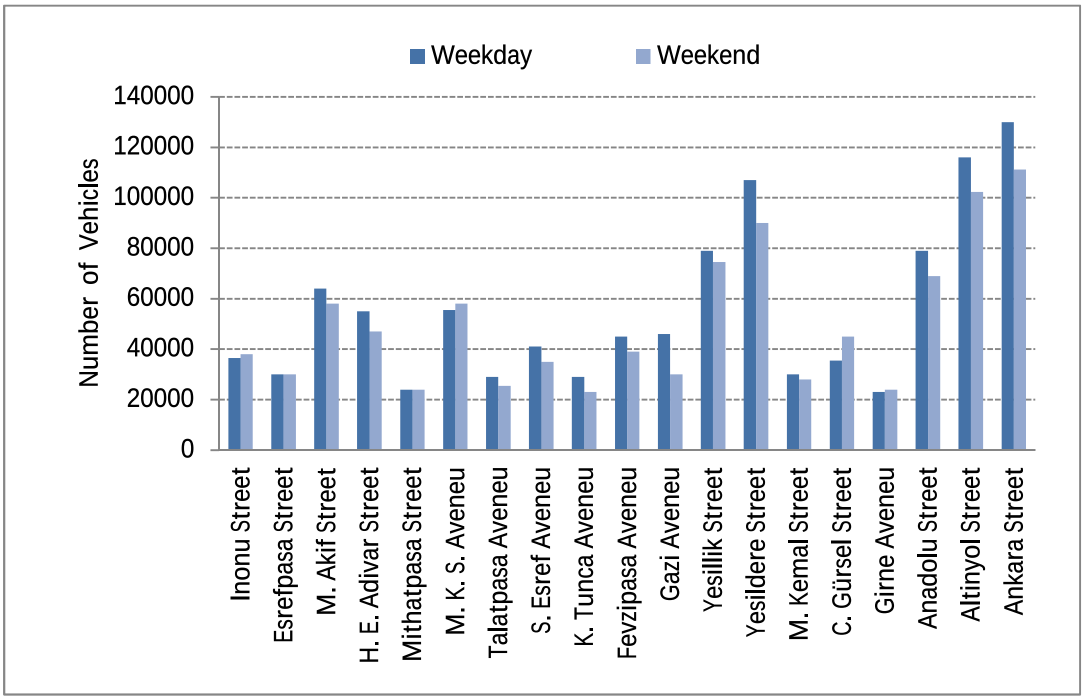

Figure 5.13 Daily vehicle numbers for weekdays and weekends in winter, vehicle/day.

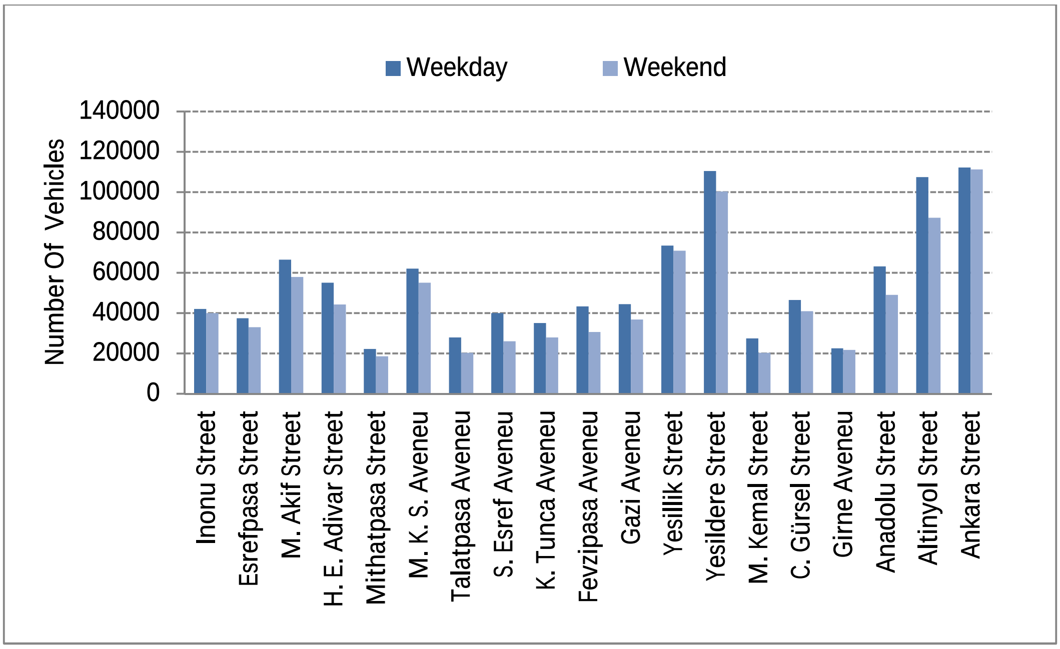

Figure 5.14 Daily vehicle numbers for weekdays and weekends in summer, vehicle/day.

The vehicle classifier system used for vehicle counting also records the speeds of the vehicles. In the study, the streets were categorized as the streets with 6 or 4 lanes. The streets that were classified as 6 lanes are Ankara Street, Altinyol Street, Anadolu Street, Cemal Gursel Street, Yesildere Street, Yesillik Street, Mustafa Kemal Sahil Avenue and Halide Edip Adivar Street. The remaining streets were classified as 4 lanes. The reason for this categorization was that the streets with 6 lanes in the city are assumed as a highway and the speeds on these streets are much higher in comparison with the streets with 4 lanes. The average speeds were 60-70 km/hour during daytimes on the main streets with 6 lanes in the city while these average values were 70-80 km/hour during nights. The average speeds for the streets with 4 lanes are 35-40 km/hour during daytimes and 45-50 km/hour at nights.

The hourly variations of average vehicle speeds according to vehicle types are given in Figures 5.15-5.18. While the average speeds were 35-40 km/hour during the daytimes on the streets with 4 lanes, these values were 65-70 km/hour for the streets with 6 lanes. There is almost no difference between the speeds in winter and summer.

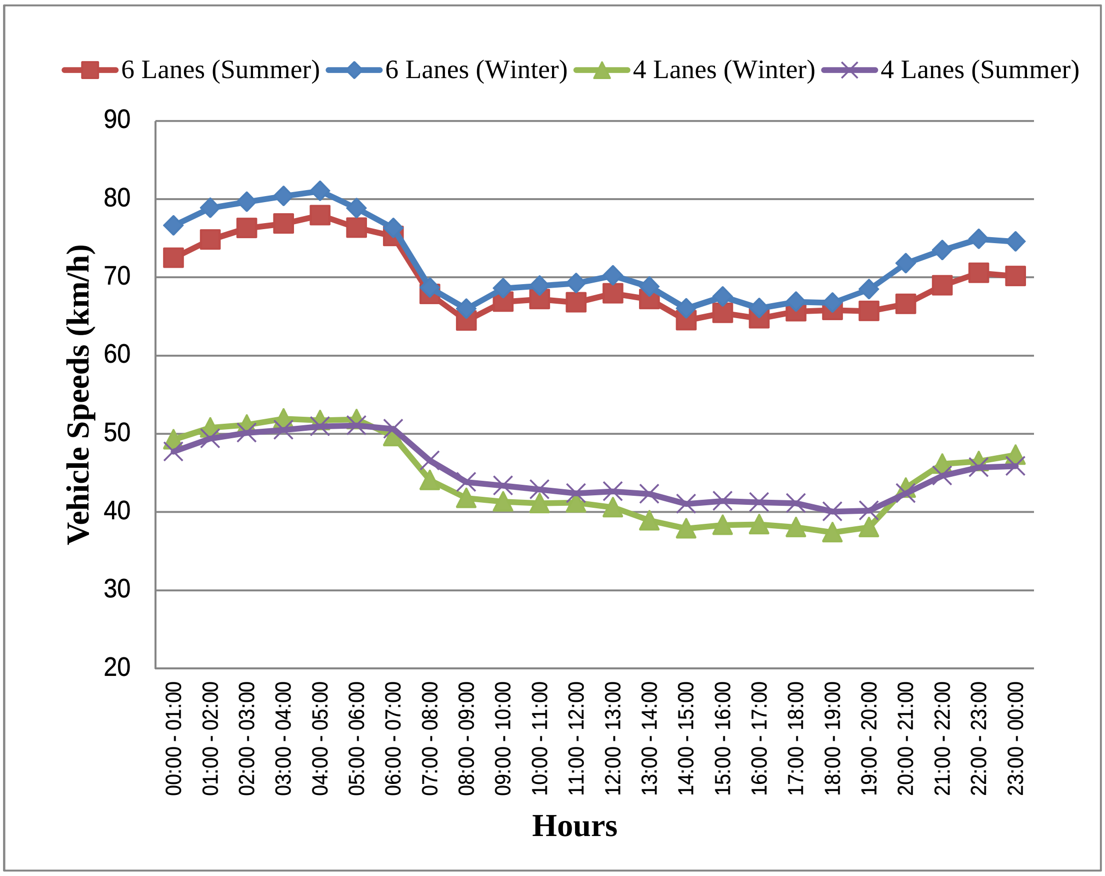

Figure 5.15 The hourly variations of vehicle speeds for passenger cars in the city.

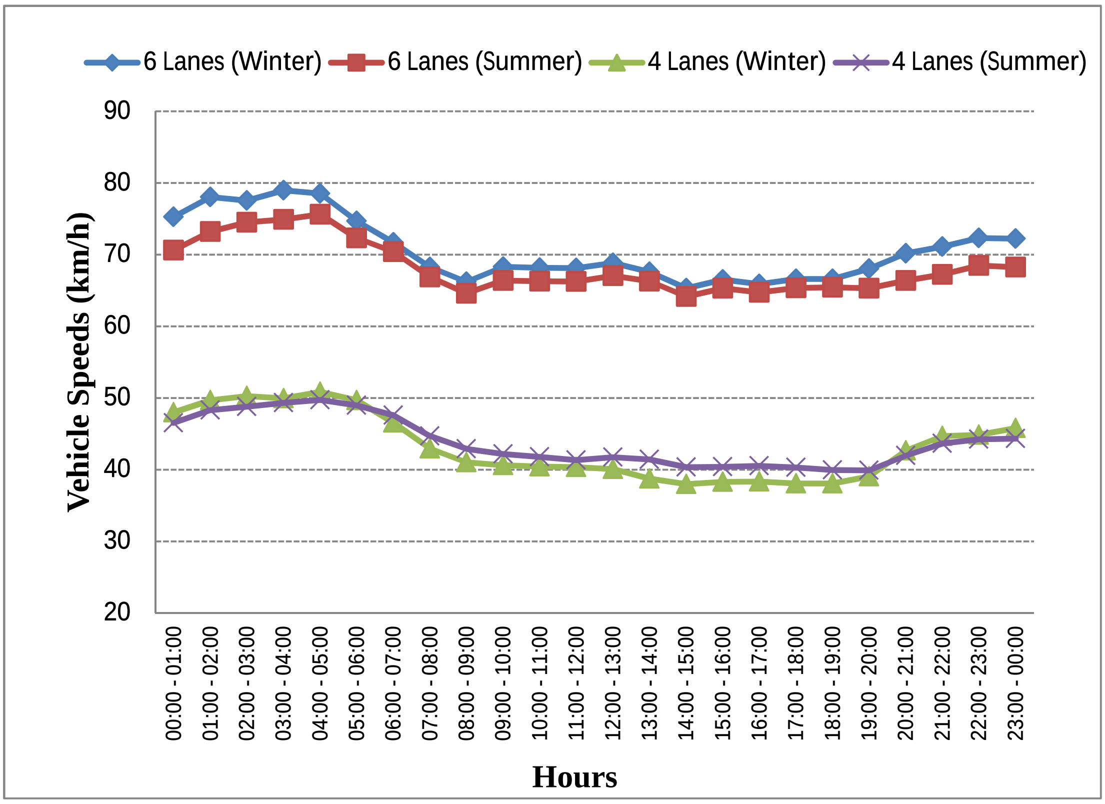

Figure 5.16 The hourly variations of vehicle speeds for light-duty vehicles in the city.

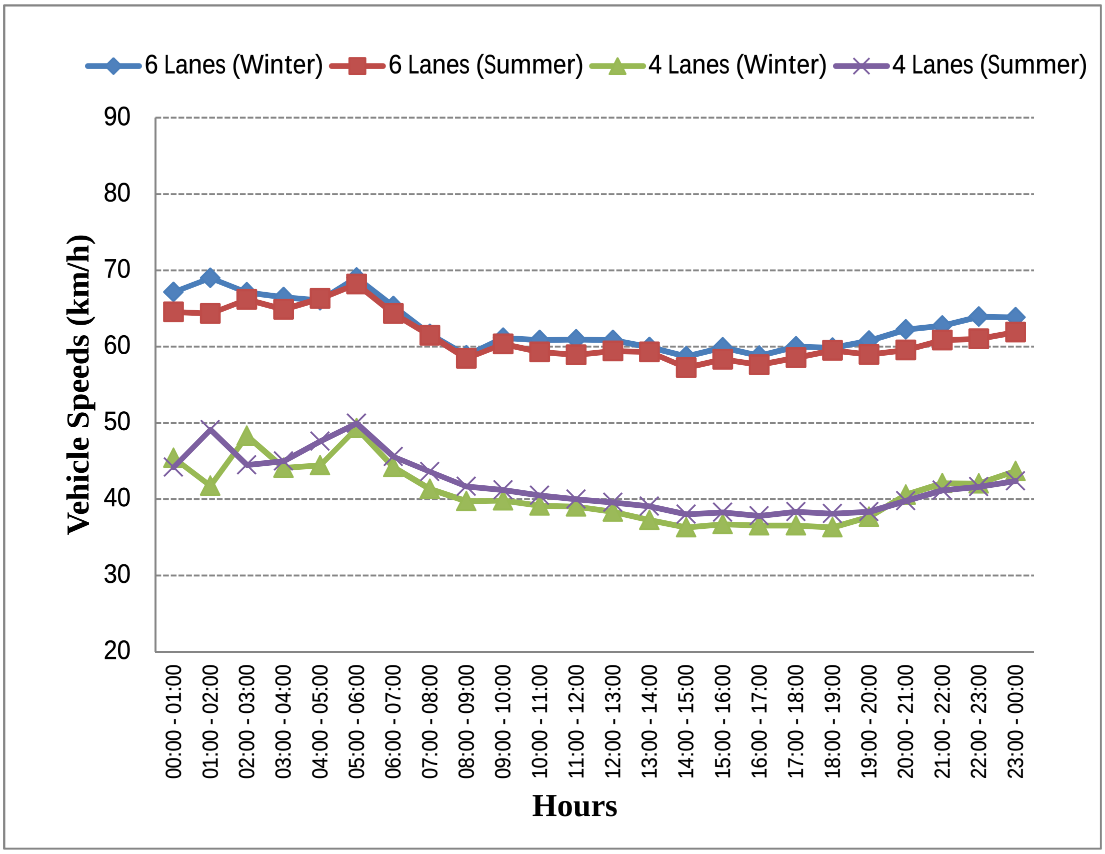

Figure 5.17 The hourly variations of vehicle speeds for heavy-duty vehicles in the city.

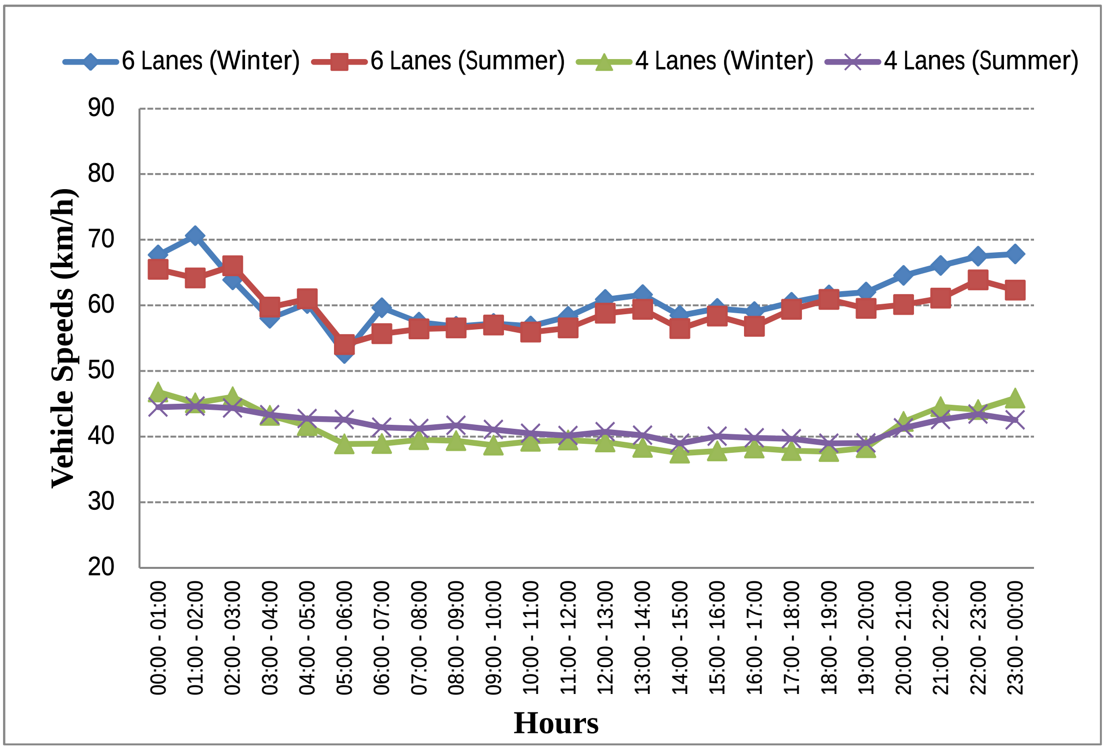

Figure 5.18 The hourly variations of vehicle speeds for motorcycles in the city.

5.2 Emissions Inventory

The emissions were calculated by using emission factors from the literature, average vehicle speeds observed and the vehicle numbers on the streets. The emissions were calculated for 5 pollutants (CO, NO_x, NMVOC, PM_{10} and SO_2). Accordingly, the total amounts of emissions emitted from mobile sources in all streets (n=65) during 1 week were 108 tons for CO, 14 tons for NMVOC, 48 tons for NO_x, 2 tons for PM_{10} and 6 tons for SO_2 in winter. In summer, the values were 107 tons for CO, 15 tons for NMVOC, 48 tons for NO_x, 2 tons for PM_{10} and 7 tons for SO_2. It was estimated that total annual emissions are 5,590 tons for CO, 754 tons for NMVOC, 2,496 tons for NO_x, 104 tons for PM_{10} and 338 tons for SO_2. If these emissions are compared with the emissions emitted from industrial plants and domestic sources in the city, it is seen that NO_x emissions from traffic are higher than the emissions from both sectors (industry: 2,631 tons/year, domestic heating: 1,124 tons/year) (Elbir, 2004).

On the streets (n=19) where vehicle counting was made and on the other streets (n=46) where the numbers of vehicles were estimated, total weekly emissions per unit distance in the winter and summer are given in Table 5.5 and Table 5.6. Geographical distribution of total weekly emissions are almost similar for all pollutants in the city. The maps for geographical distribution of weekly NO_X emissions are given for winter and summer (Figures 5.19-20).

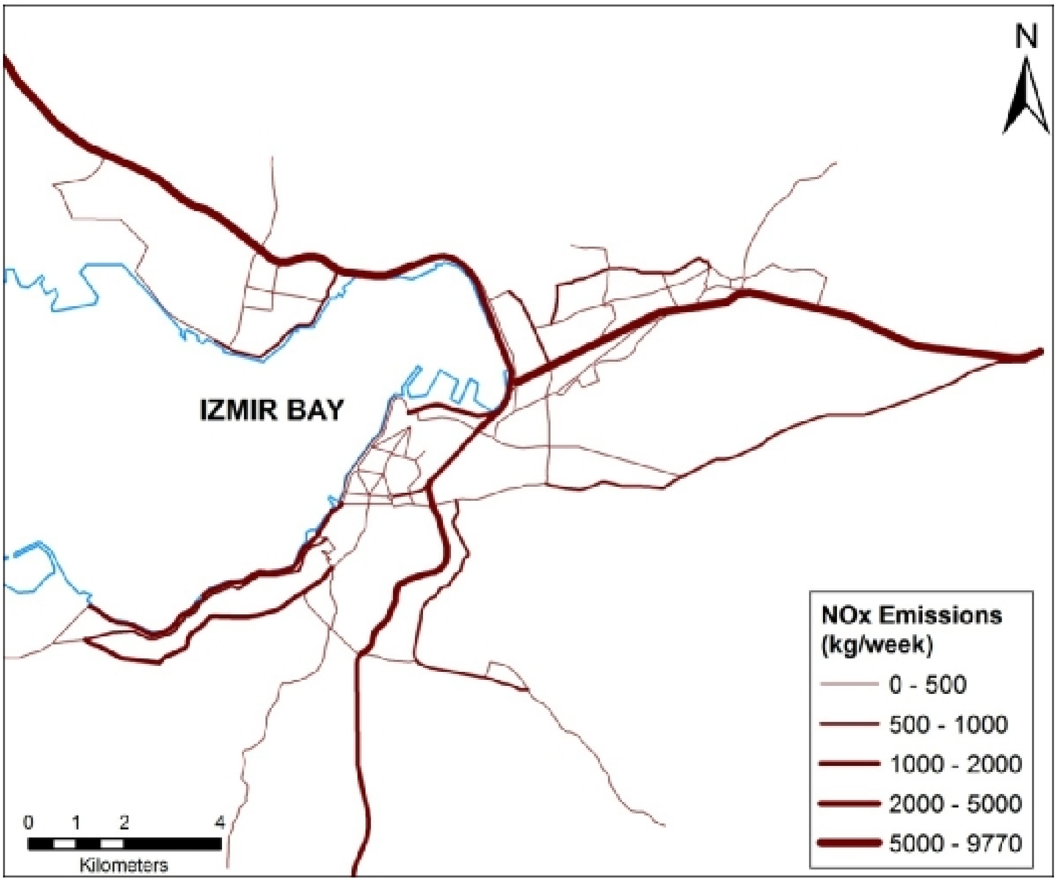

Figure 5.19 Geographical distribution of weekly NO_x emissions for winter.

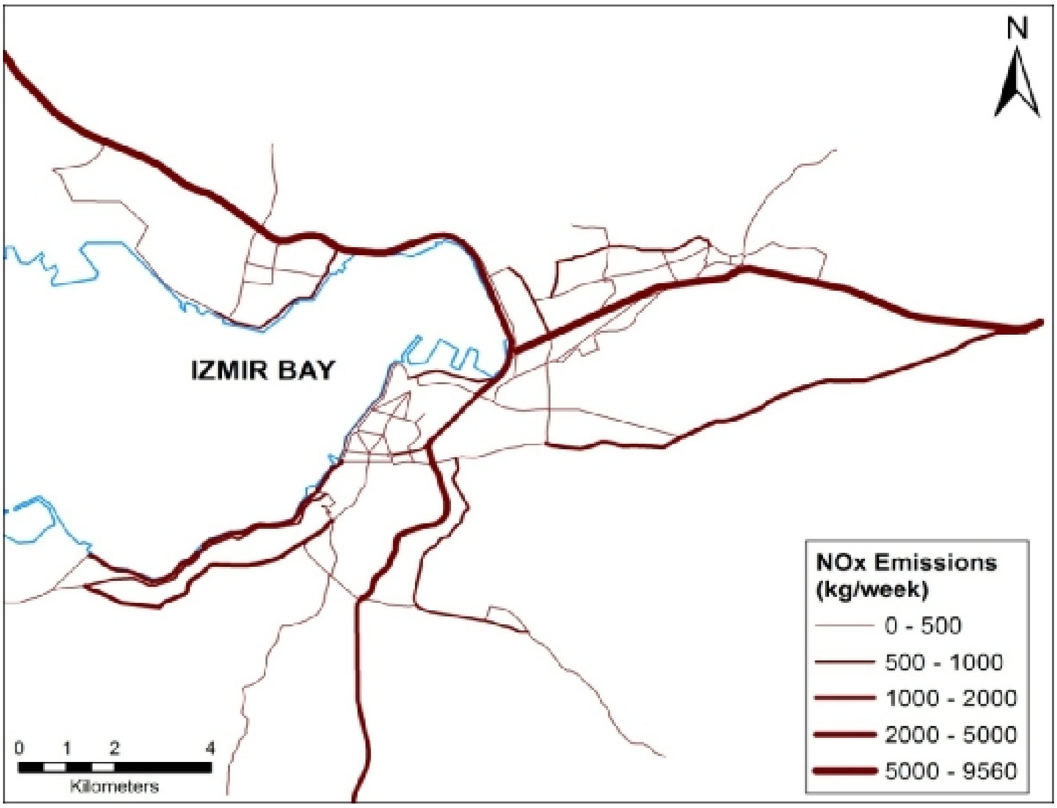

Figure 5.20 Geographical distribution of weekly NO_x emissions for summer.

Ankara Street has the highest emissions per unit distance for all the pollutants for both seasons. However, when these emissions are multiplied with the length of the streets, the highest emissions for some pollutants were emitted by the vehicles in Anadolu Street. While the length of Ankara Street is 11.5 kilometers, the length of Anadolu Street is 21.3 kilometers. Altinyol and Yesildere Streets follow these two streets in terms of both per unit distance and the total emissions emitted from the whole street. The contribution of each street in terms of the total weekly emissions is given in the Table 5.6. Figures 5.21–5.25 also show the portions of each street for different pollutants.

A critical increase was determined in the figures of heavy-duty vehicles in summer in Anadolu Street. While the portion of heavy-duty vehicles was around 5% in winter, this value was 15% in summer. The reason might be that Anadolu Street is a part of Izmir–Canakkale Highway and there are lots of holiday resorts (Foca, Aliaga, Dikili and Ayvalik, etc.) on the drive.

Table 5.5 Total weekly emissions per unit distance in the winter and summer, kg/km.week

Street Name	**SUMMER**					**WINTER**				
	CO	**NMVOC**	**NO_X**	**PM_{10}**	**SO_2**	**CO**	**NMVOC**	**NO_X**	**PM_{10}**	**SO_2**
Inonu Street	553.8	83.8	199.6	9.7	29.0	506.8	74.5	177.3	7.5	24.0
Esrefpasa Street	617.1	98.5	180.2	10.2	23.7	589.0	92.6	162.8	9.1	21.9
Mehmet Akif Street	759.5	111.1	300.3	12.5	34.5	728.4	101.7	289.0	10.3	33.6
Halide Edip Adıvar Street	603.3	86.8	231.4	9.1	27.5	634.8	87.9	233.8	7.8	27.7
Mithatpasa Street	272.1	42.1	105.3	5.2	11.4	304.8	44.7	109.9	4.7	11.5
M. Kemal Sahil Avenue	646.7	84.3	275.1	8.5	21.3	588.9	73.9	255.7	6.5	19.9
Talatpasa Street	475.5	70.9	106.0	5.6	12.6	537.9	78.3	116.7	5.7	14.7
Sair Esref Street	645.2	105.7	208.0	11.8	29.4	732.4	114.8	221.8	11.4	30.8
Kamil Tunca Avenue	377.4	59.8	157.2	8.9	27.0	339.6	52.2	142.9	7.4	24.8
Fevzipasa Avenue	719.2	110.8	171.0	9.7	21.7	734.2	108.3	172.6	8.4	22.0
Gazi Avenue	742.8	106.2	175.4	7.7	22.1	702.0	99.4	162.1	6.9	20.4
Yesillik Street	1,120.4	156.8	319.3	12.1	42.6	867.5	116.2	361.0	11.3	43.8
Yesildere Street	1,127.6	138.9	514.4	15.6	50.1	1,083.2	134.1	479.6	13.6	44.8
Mustafa Kemal Street	370.6	59.7	120.8	7.4	18.6	447.6	68.7	136.3	7.2	19.5
Cemal Gursel Street	525.4	73.4	221.3	7.6	22.8	437.9	60.2	186.1	5.9	19.6
Girne Avenue	323.2	51.4	113.2	5.7	14.9	333.5	50.8	115.9	5.2	14.7
Anadolu Street	772.7	111.6	448.5	21.7	78.9	825.4	102.9	418.8	14.4	50.9
Altinyol Street	1,233.2	145.5	647.0	24.8	86.1	1,255.5	144.6	670.8	27.3	97.0
Ankara Street	1,461.0	168.3	792.1	33.7	117.2	1,573.7	171.2	846.8	32.8	118.8
Subtotal	*13,346.6*	*1,865.8*	*5,286.0*	*227.5*	*691.2*	*13,223.1*	*1,777.0*	*5259.9*	*203.3*	*660.4*
Other Streets (n=46)	*19,185.2*	*3,006.2*	*7,622.6*	*355.1*	*1,037.8*	*19,664.1*	*2,920.3*	*8032.2*	*339.2*	*1,112.8*
TOTAL	*32,531.8*	*4,872.0*	*12908.6*	*582.6*	*1,729.0*	*32,887.2*	*4,697.3*	*13,292.1*	*542.5*	*1773.2*

Table 5.6 Total weekly emissions per unit distance in the winter and summer, tons/week

Street Name	**SUMMER**					**WINTER**				
	CO	**NMVOC**	**NO_X**	**PM_{10}**	**SO_2**	**CO**	**NMVOC**	**NO_X**	**PM_{10}**	**SO_2**
Inonu Street	3.32	0.50	1.20	0.06	0.17	3.04	0.45	1.06	0.05	0.14
Esrefpasa Street	1.28	0.20	0.37	0.02	0.05	1.22	0.19	0.34	0.02	0.05
Mehmet Akif Street	0.89	0.13	0.35	0.01	0.04	0.85	0.12	0.34	0.01	0.04
Halide Edip Adivar Street	1.07	0.15	0.41	0.02	0.05	1.13	0.16	0.42	0.01	0.05
Mithatpasa Street	1.62	0.25	0.63	0.03	0.07	1.81	0.27	0.65	0.03	0.07
M. Kemal Sahil Avenue	4.22	0.55	1.79	0.06	0.14	3.84	0.48	1.67	0.04	0.13
Talatpaşa Street	0.44	0.07	0.10	0.01	0.01	0.49	0.07	0.11	0.01	0.01
Sair Esref Street	1.08	0.18	0.35	0.02	0.05	1.23	0.19	0.37	0.02	0.05
Kamil Tunca Avenue	1.08	0.17	0.45	0.03	0.08	0.97	0.15	0.41	0.02	0.07
Fevzipasa Avenue	0.76	0.12	0.18	0.01	0.02	0.78	0.11	0.18	0.01	0.02
Gazi Avenue	0.71	0.10	0.17	0.01	0.02	0.67	0.09	0.15	0.01	0.02
Yesillik Street	4.73	0.66	1.35	0.05	0.18	3.67	0.49	1.53	0.05	0.18
Yesildere Street	5.10	0.63	2.33	0.07	0.23	4.90	0.61	2.17	0.06	0.20
Mustafa Kemal Street	0.88	0.14	0.29	0.02	0.04	1.06	0.16	0.32	0.02	0.05
Cemal Gursel Street	1.89	0.26	0.80	0.03	0.08	1.58	0.22	0.67	0.02	0.07
Girne Avenue	0.70	0.11	0.25	0.01	0.03	0.73	0.11	0.25	0.01	0.03
Anadolu Street	16.46	2.38	9.55	0.46	1.68	17.58	2.19	8.92	0.31	1.08
Altinyol Street	6.23	0.73	3.27	0.13	0.43	6.34	0.73	3.39	0.14	0.49
Ankara Street	16.85	1.94	9.13	0.39	1.35	18.14	1.97	9.76	0.38	1.37
Subtotal	*69.30*	*9.28*	*32.95*	*1.42*	*4.73*	*70.03*	*8.77*	*32.71*	*1.20*	*4.13*
Other Streets (n=46)	*38.01*	*5.98*	*14.97*	*0.70*	*2.05*	*38.32*	*5.64*	*15.61*	*0.66*	*2.17*
TOTAL	*107.31*	*15.26*	*47.92*	*2.12*	*6.78*	*108.35*	*14.41*	*48.32*	*1.86*	*6.30*

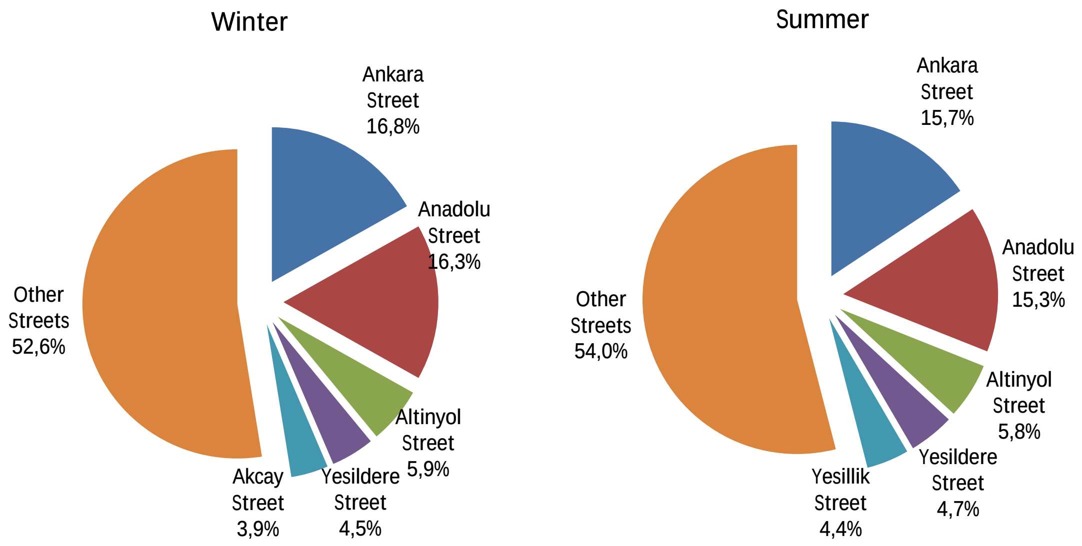

Figure 5.21 The portions of the streets on total weekly CO emissions, %.

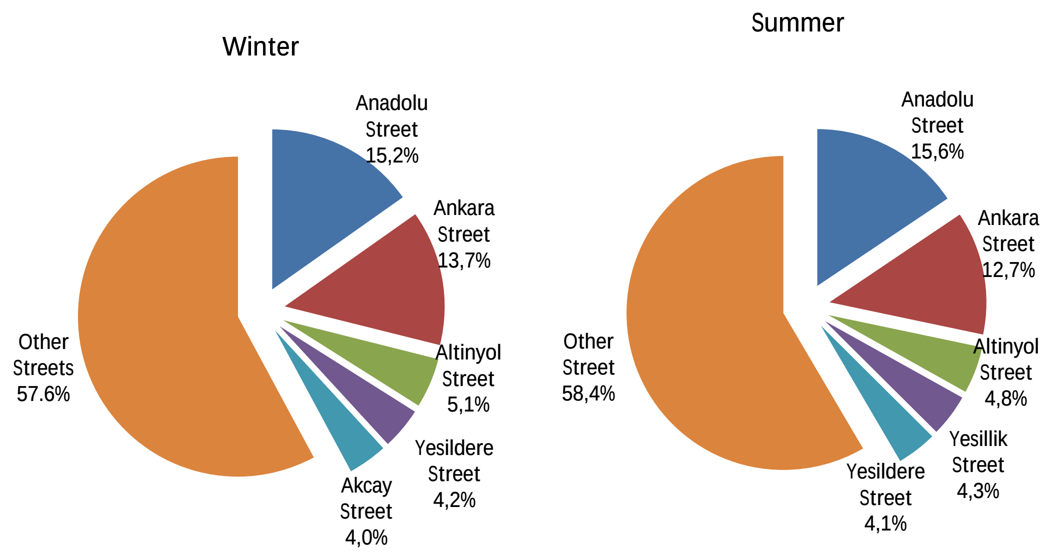

Figure 5.22 The portions of the streets on total weekly NMVOC emissions, %.

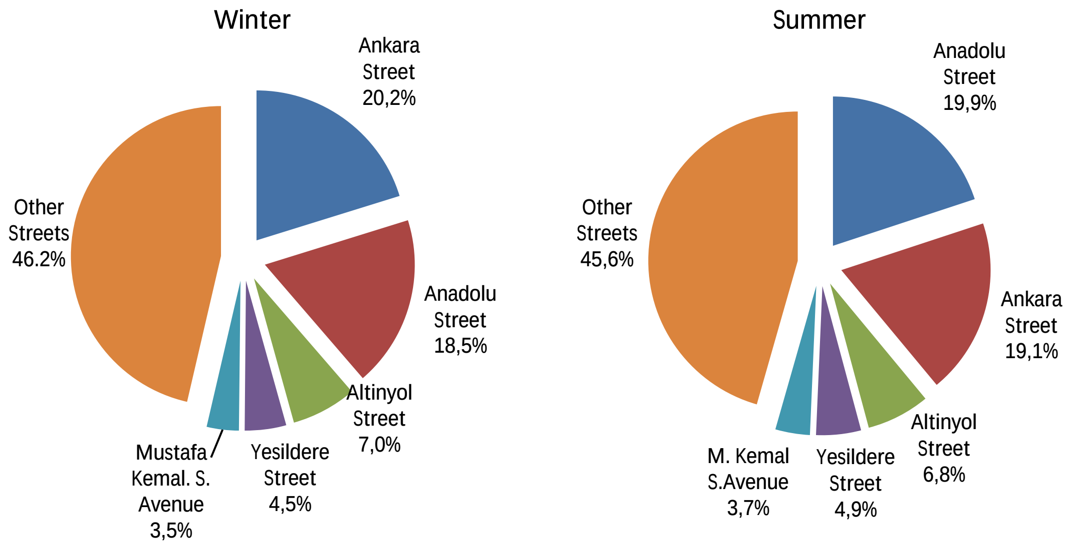

Figure 5.23 The portions of the streets on total weekly NO_X emissions, %.

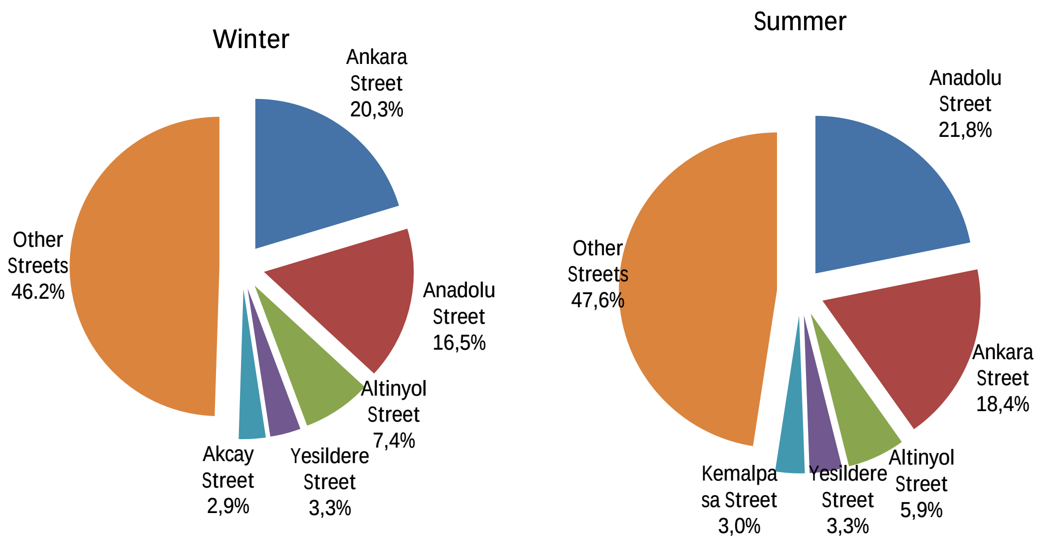

Figure 5.24 The portions of the streets on total weekly PM_{10} emissions, %.

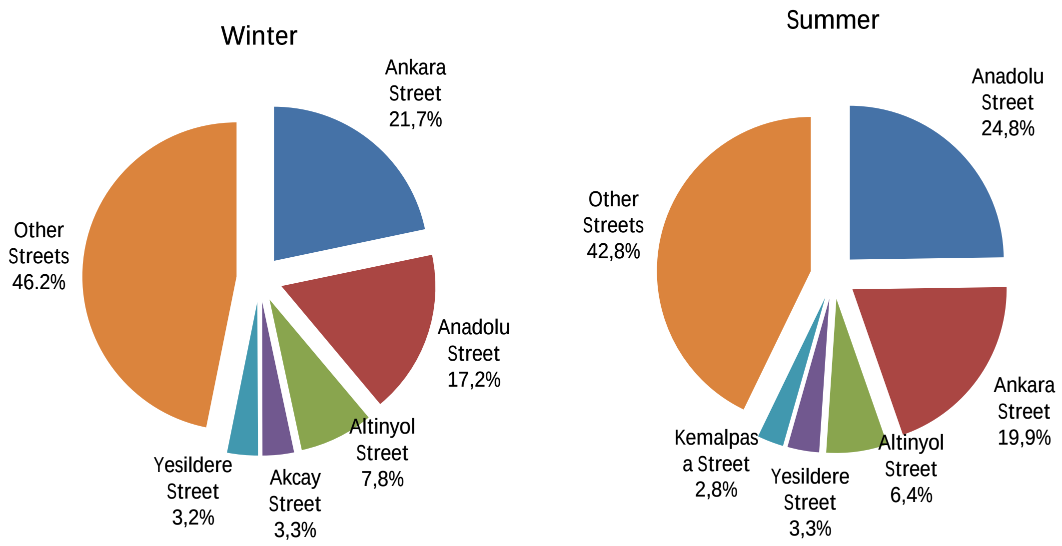

Figure 5.25 The portions of the streets on total weekly SO_2 emissions, %.

The contributions of vehicle types to total weekly emissions are given in Figures 5.26–5.30. It was observed that the greatest portion for all pollutants, except SO_2 and PM_{10}, in both seasons belong to passenger cars with a ratio of 56%–77%. In terms of SO_2, the category of light-duty vehicles had the greatest portion due to diesel use on these vehicles.

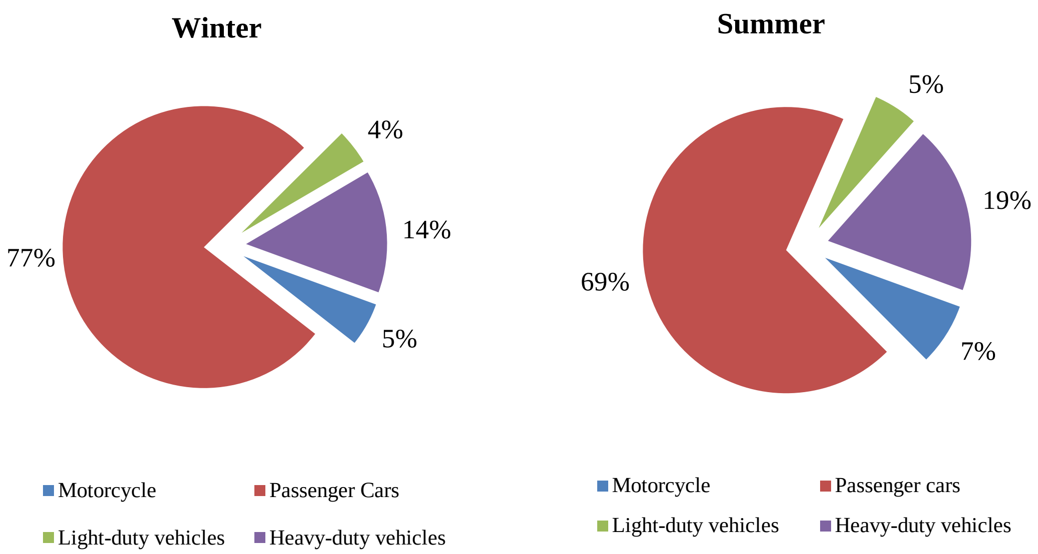

Figure 5.26 The contributions of vehicle types to total CO emissions, %.

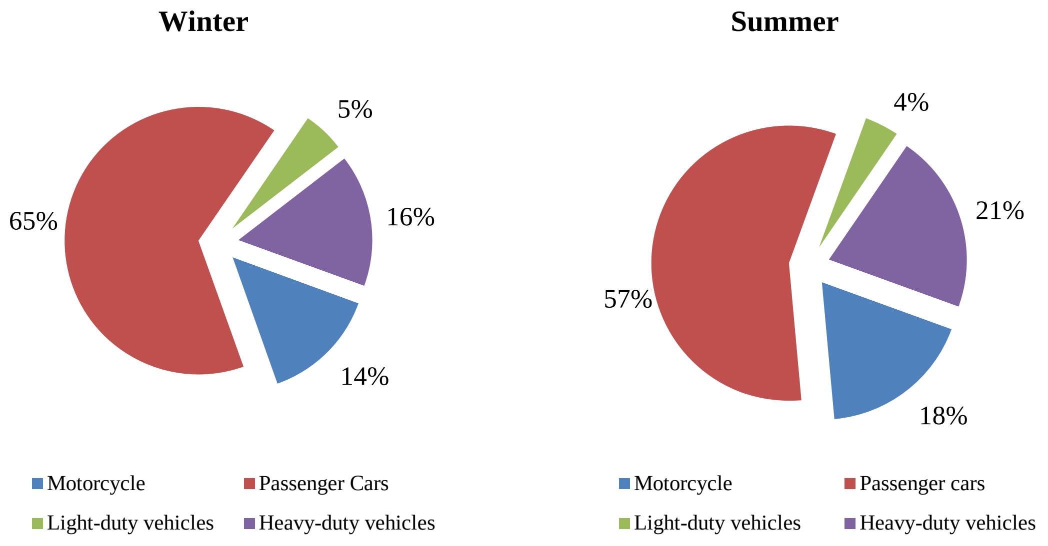

Figure 5.27 The contributions of vehicle types to total NMVOC emissions, %.

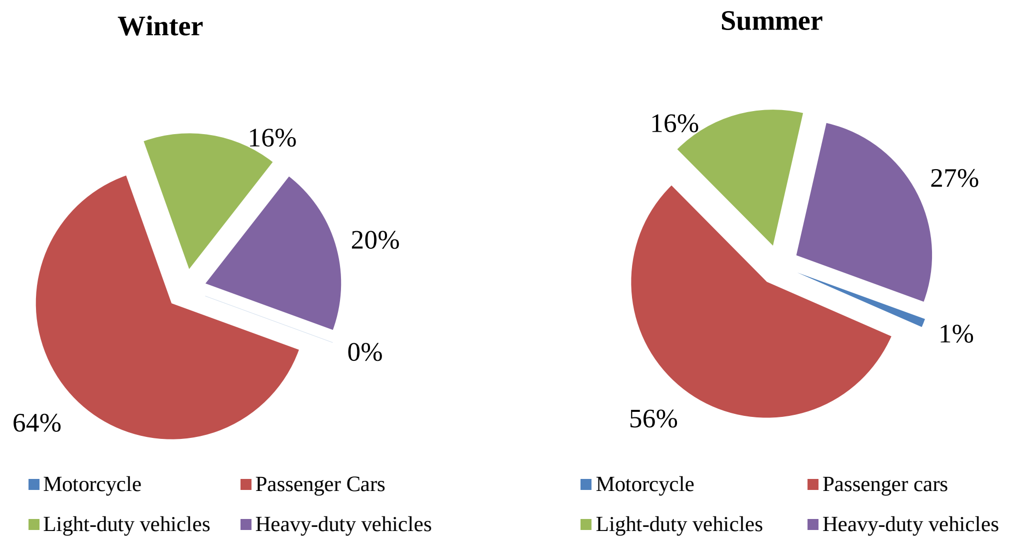

Figure 5.28 The contributions of vehicle types to total NO_X emissions, %.

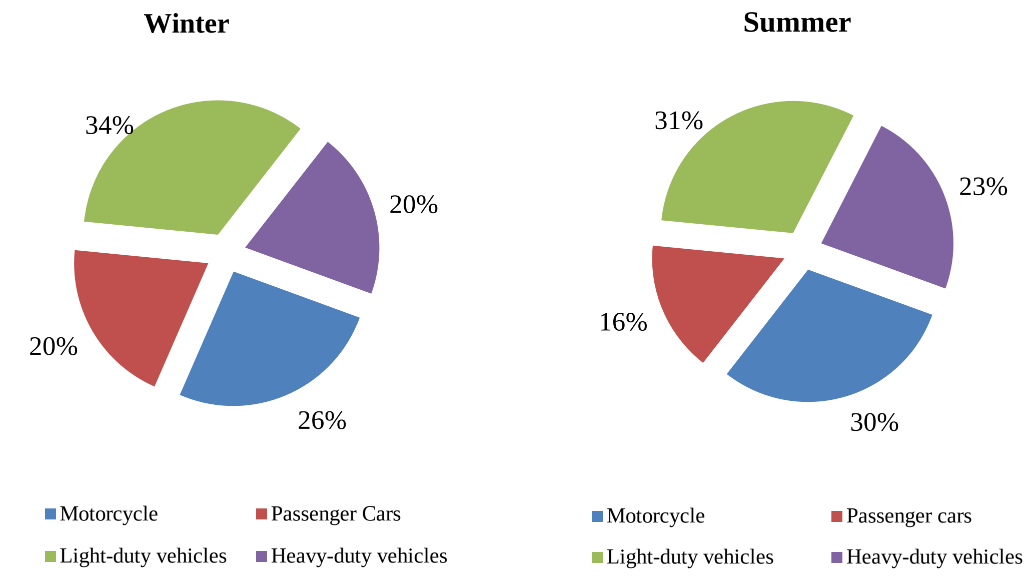

Figure 5.29 The contributions of vehicle types to total PM_{10} emissions, %.

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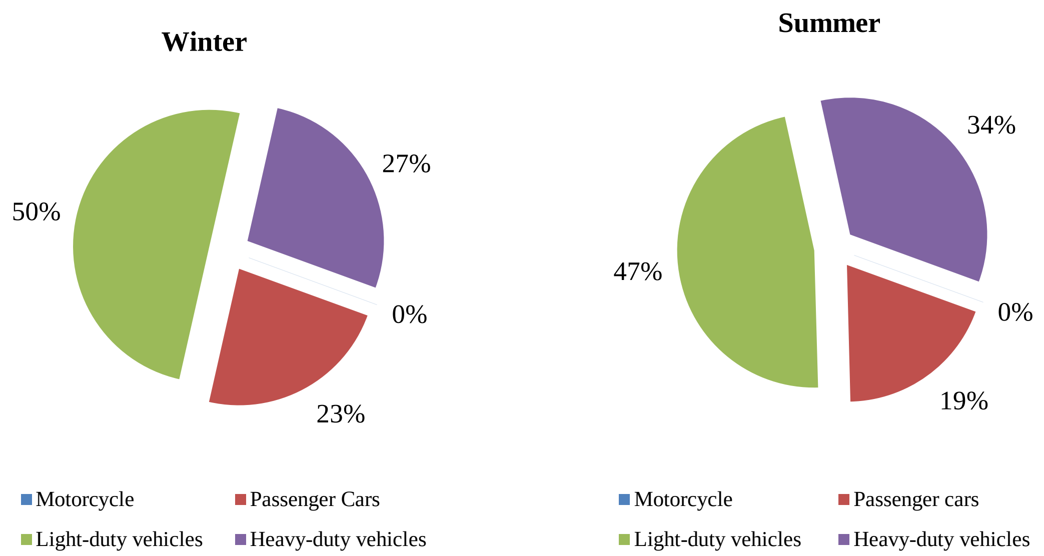

Figure 5.30 The contributions of vehicle types to total SO_2 emissions, %.

The daily variation of total emissions in the city for the summer and winter were given in Figures 5.31-5.35. The highest emissions of all pollutants in the city were occurred on Monday and Friday. In spite of the decreases in the numbers of vehicles, another reason for higher emissions in the summer months is the fact that the average speeds on the streets decrease.

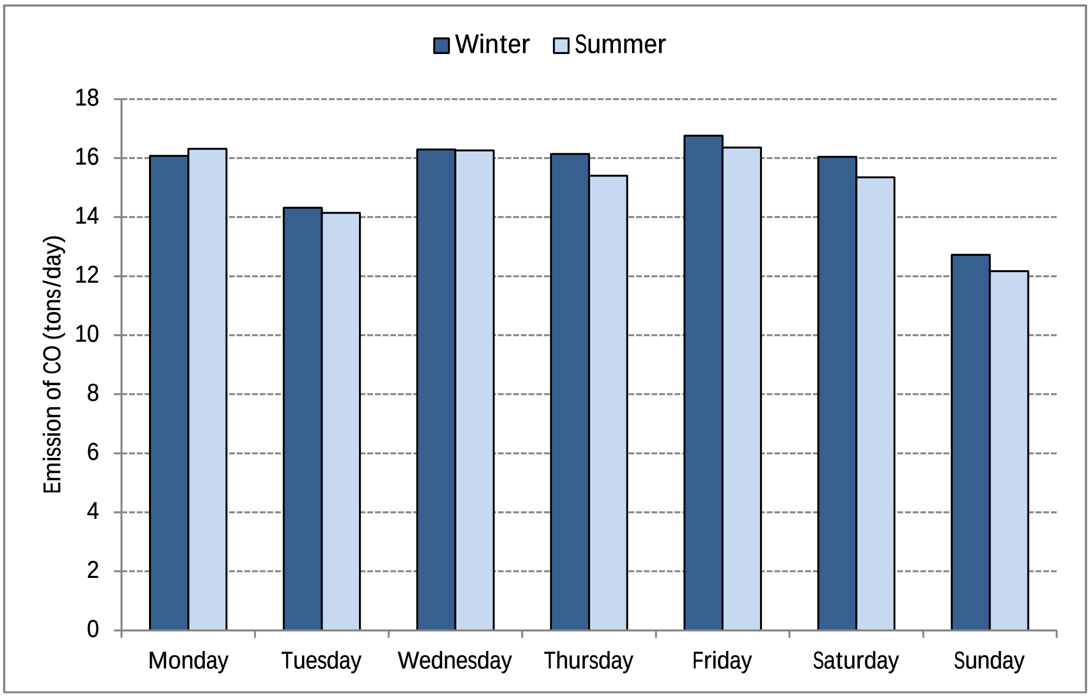

Figure 5.31 The daily variation of total CO emissions in the city, tons/day.

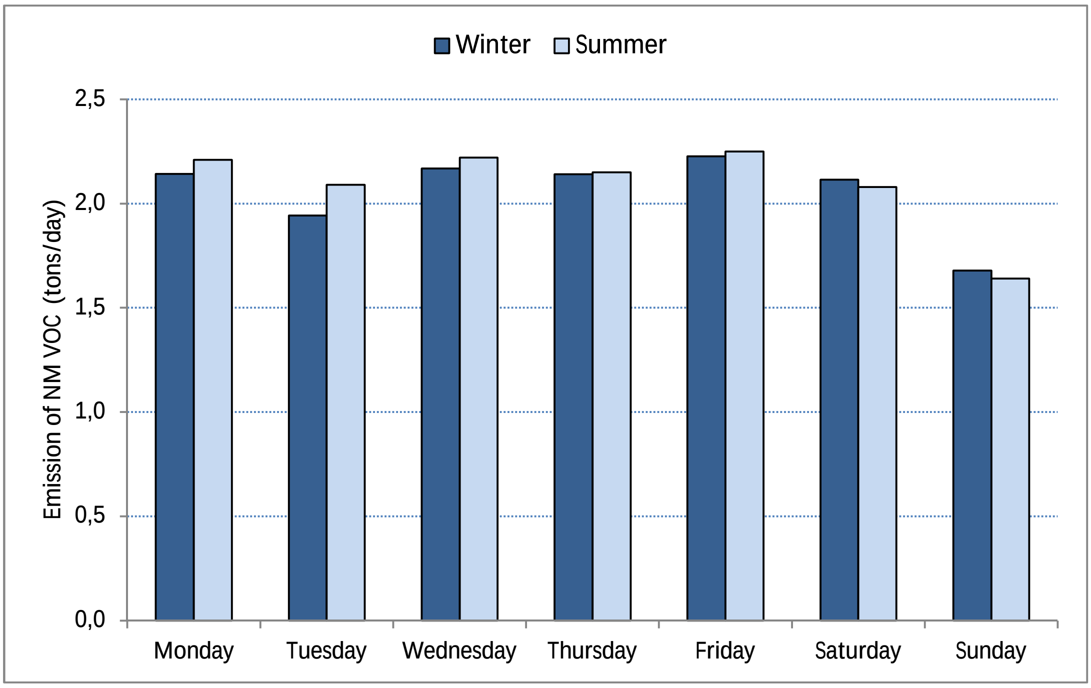

Figure 5.32 The daily variation of total NMVOC emissions in the city, tons/day.

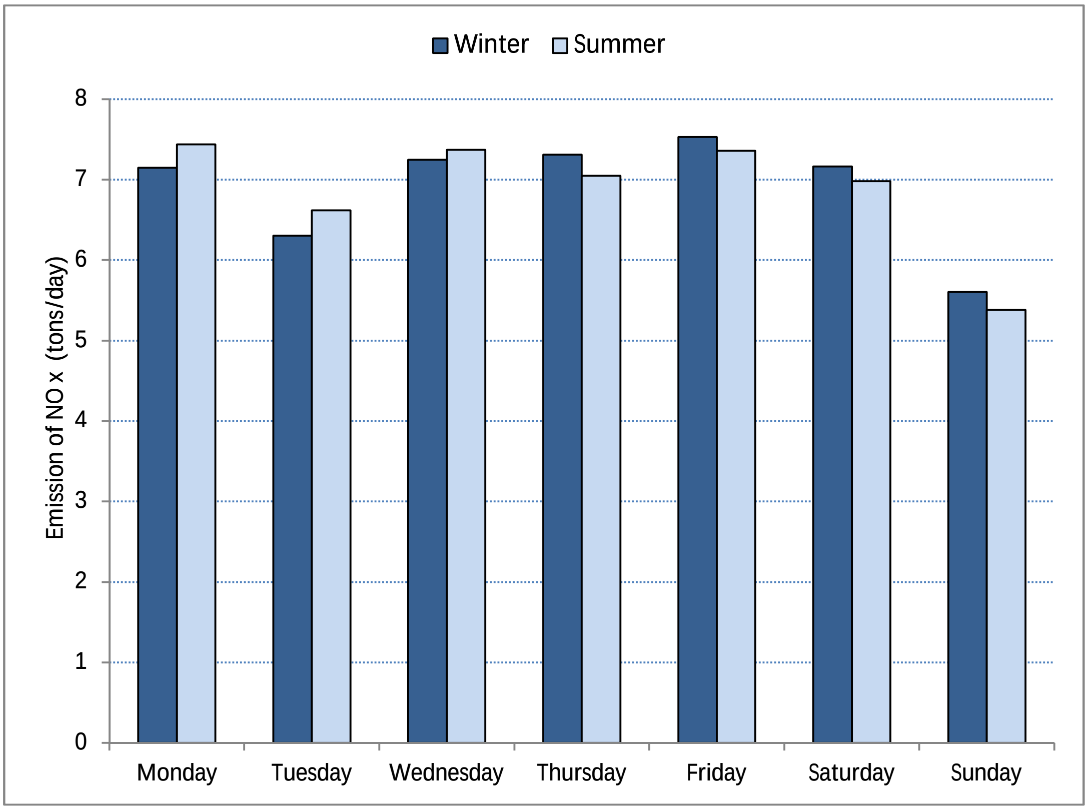

Figure 5.33 The daily variation of total NO_X emissions in the city, tons/day.

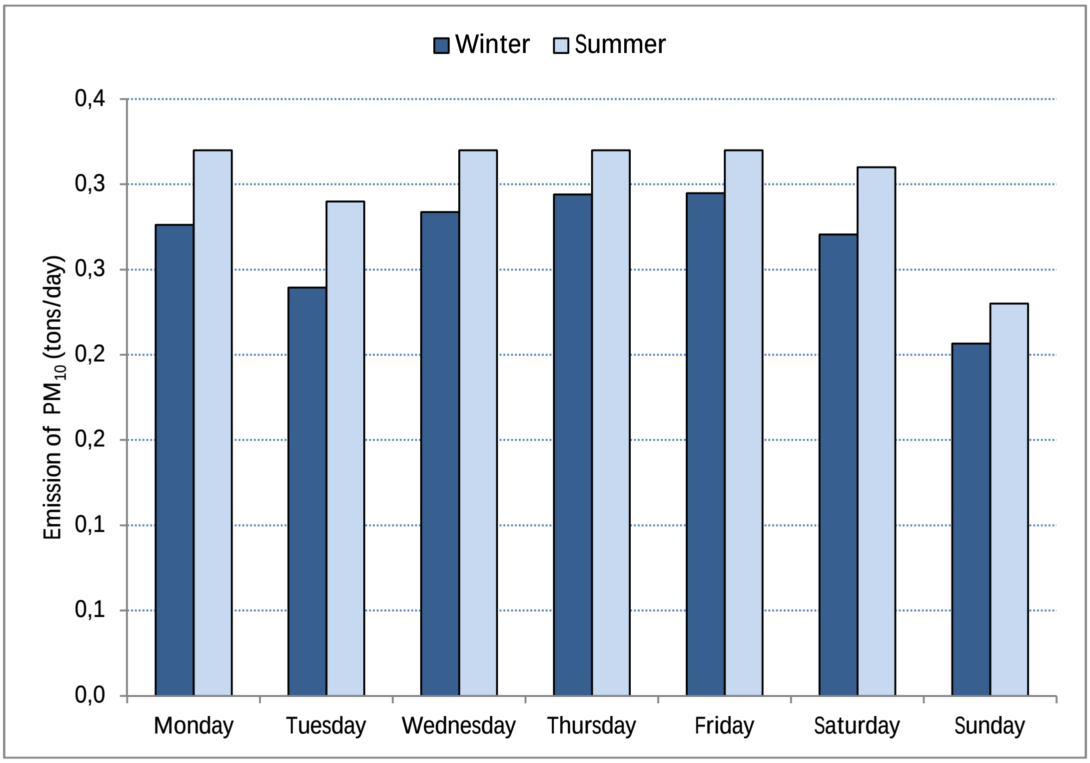

Figure 5.34 The daily variation of total PM_{10} emissions in the city, tons/day.

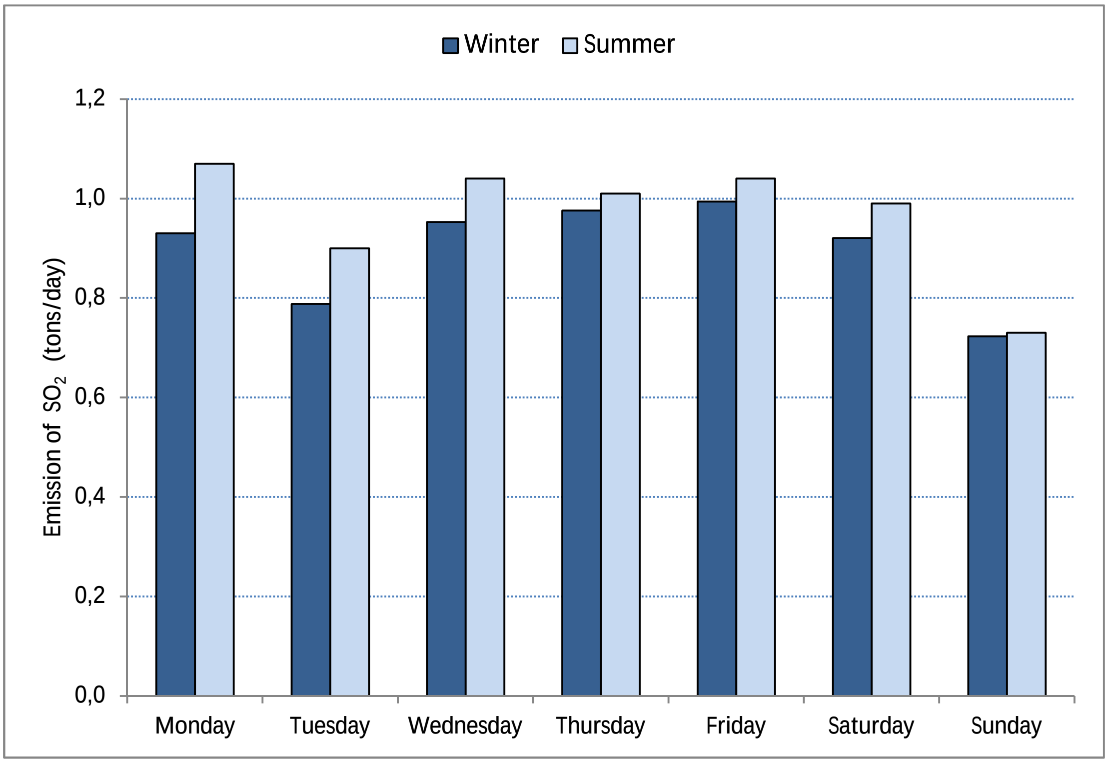

Figure 5.35 The daily variation of total SO_2 emissions in the city, tons/day.

The hourly variations of total emissions for both seasons are given in Figure 3.36-3.40. The lowest emissions were obtained at the period of three hours between 02:00 – 05:00 a.m. After 05:00 a.m. a significant increase was started and continued till 09:00 a.m. A decrease was seen in the emissions for a short period after 09:00 a.m. and 18:00 p.m.

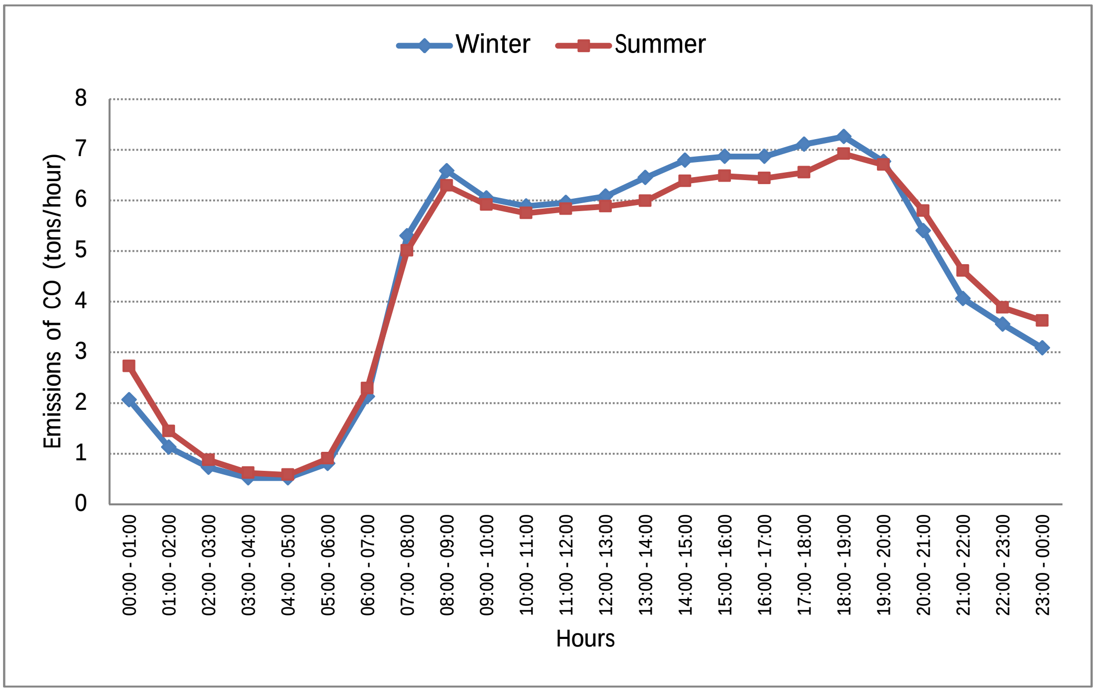

Figure 5.36 The hourly variation of total CO emissions in the city, tons/hour.

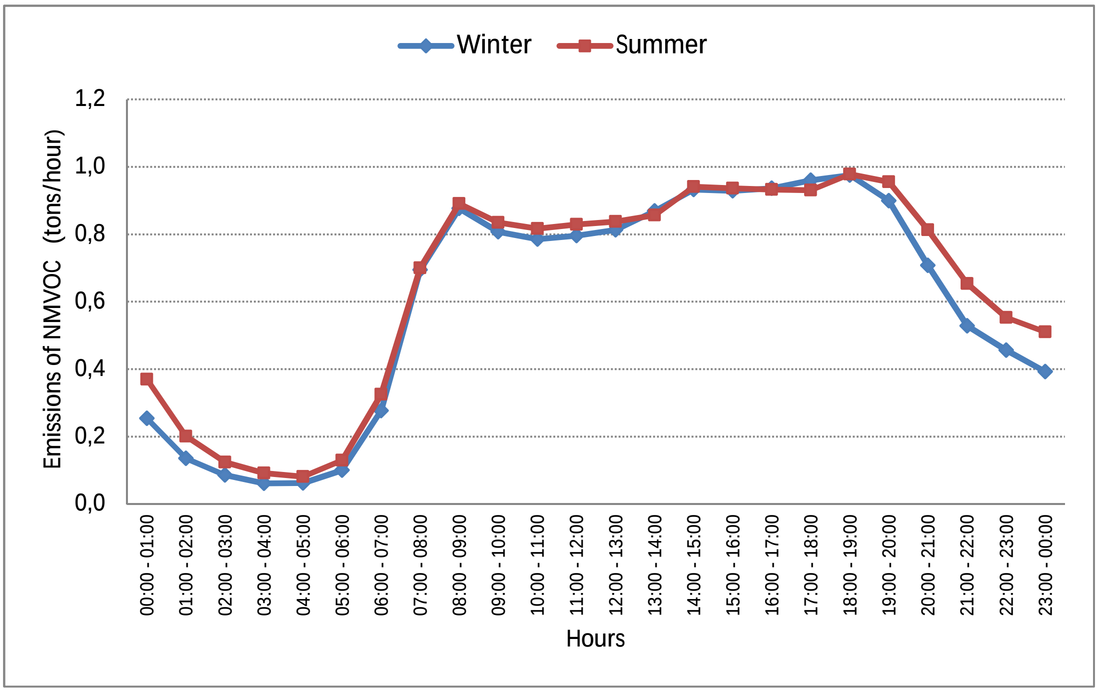

Figure 5.37 The hourly variation of total NMVOC emissions in the city, tons/hour.

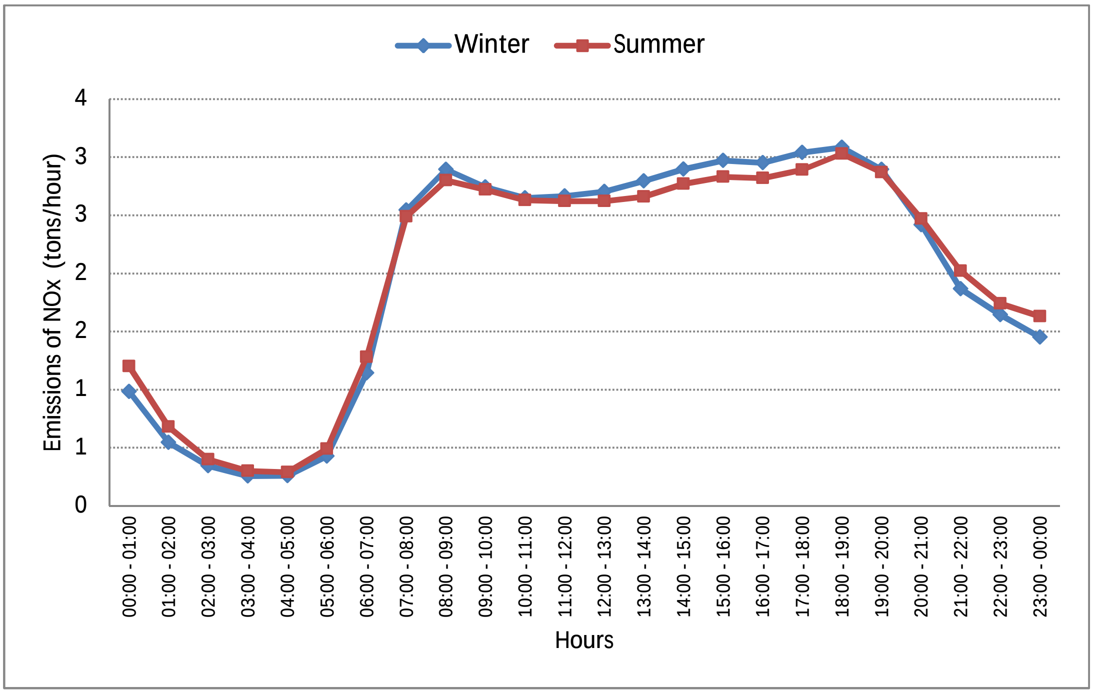

Figure 5.38 The hourly variation of total NO_X emissions in the city, tons/hour.

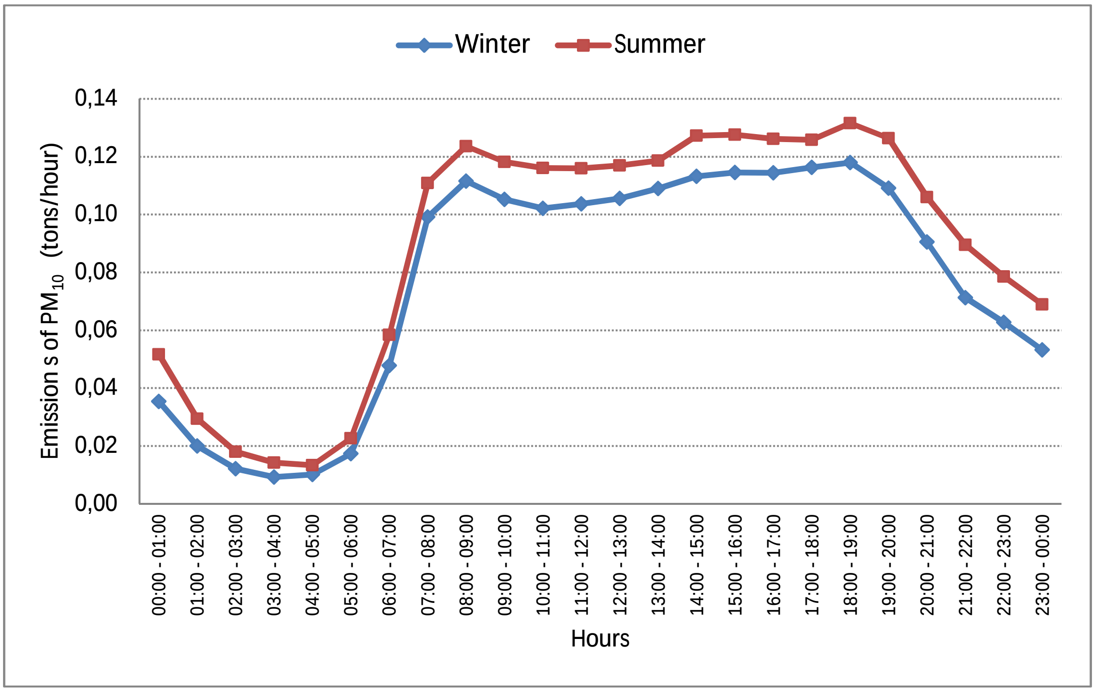

Figure 5.39 The hourly variation of total PM_{10} emissions in the city, tons/hour.

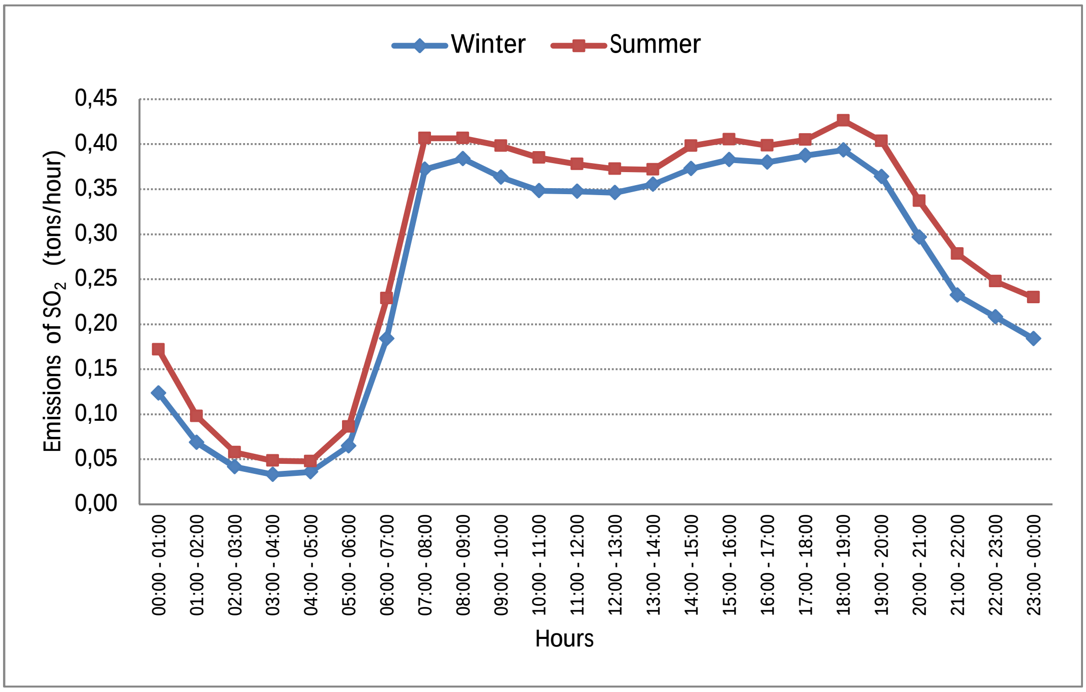

Figure 5.40 The hourly variation of total SO_2 emissions in the city, tons/hour.

5.3 Air Quality Measurements

Air quality was monitored in 19 major streets of the city using a mobile air quality monitoring station. The measurements in each street were made for a period between 7–15 days, parallel to vehicle counting campaigns. The pollutants of PM_{10}, CO, SO_2, NO_X, O_3, and several meteorological parameters such as wind speed and direction, temperature, pressure and humidity were continuously measured with the equipments located inside of the mobile station. Data was recorded through the cables into a computer in the station.

Several statistical indicators for hourly PM_{10} concentrations (µg/m^3) observed in 19 streets were provided in Tables 5.7 – 5.13.

The hourly pollutants concentrations measured and the vehicle numbers for one week Ankara Street at the same hours are given between Figures 5.41-5.45.

Table 5.7 Several statistical indicators for hourly PM_{10} concentrations (μg/m^3) measured in the selected streets of the city

No	Streets Name	Measurement period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gursel Street	4-17 October 2007	66.7	0.3	262.2	45.4	55.9	164.9	191.6
2	Halide Edip Adivar Street	17 October -1 November 2007	The data couldn't be obtained due to the technical failure of the computer system in the station.						
3	Mustafa Kemal Street	1-13 November 2007	85.8	6.8	344.5	61.1	72.2	206.3	249.4
4	Kamil Tunca Avenue	13-22 November 2007	62.4	1.2	284.8	50.5	47.3	174.7	212.5
5	Yesillik Street	22 November -13 December 2007	92.0	1.7	461.5	76.2	78.4	247.4	307.7
6	Altinyol Street	13-25 December 2007	142.1	1.9	635.2	123.9	90.0	376.3	532.1
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	124.2	18.8	665.6	85.2	100.0	280.4	345.6
8	Sair Esref Avenue	4-17 January 2008	137.4	22.7	803.7	120.6	100.0	364.3	503.4
9	Girne Avenue	17-29 January 2008	117.3	2.1	614.2	106.8	83.1	330.1	473.0
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	113.7	2.3	612.8	93.2	79.6	317.8	394.6
11	Mithatpasa Street	12-25 February 2008	67.5	5.9	397.5	60.2	49.2	199.6	240.5
12	Inonu Street	27 February -12 March 2008	66.8	0.8	246.9	37.3	58.1	135.5	181.0
13	Mehmet Akif Street	12-20 March 2008	70.6	4.6	338.3	48.5	62.2	161.4	212.4
14	Esrefpasa Street	20-26 March 2008	94.0	10.9	330.7	54.8	80.8	191.2	232.4
15	Ankara Street	26 March - 9 April 2008	87.5	6.3	312.4	46.1	78.0	173.3	197.6
16	Yesildere Street	9-21 April 2008	82.8	0.1	441.8	62.3	60.5	209.1	249.3
17	Anadolu Street	30 April -16 May 2008	76.2	10.5	186.0	27.7	73.3	129.7	153.4
18	Talatpasa Avenue	21-30 May 2008	50.6	2.4	129.7	25.5	45.4	105.2	119.8
19	Fevzipasa Avenue	5-17 June 2008	43.1	7.8	116.6	13.7	40.7	68.8	84.6

Table 5.8 Several statistical indicators for hourly SO_2 concentrations ($\mu g/m^3$) measured in the selected streets of the city

No	Streets Name	Measurement period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gursel Street	4-17 October 2007	12.2	0.1	97.5	15.8	7.3	45.2	64.6
2	Halide Edip Adivar Street	17 October -1 November 2007	16.5	3.0	59.7	8.1	15.7	30.2	36.8
3	Mustafa Kemal Street	1-13 November 2007	15.0	2.6	73.0	12.5	11.7	44.1	53.6
4	Kamil Tunca Avenue	13-22 November 2007	12.8	2.2	43.2	8.0	11.0	30.1	34.9
5	Yesillik Street	22 November -13 December 2007	12.4	0.1	60.7	11.0	8.3	34.7	39.0
6	Altinyol Street	13-25 December 2007	24.6	5.3	104.9	16.7	19.3	59.6	70.5
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	46.6	18.6	203.0	25.8	39.3	88.6	118.5
8	Sair Esref Avenue	4-17 January 2008	38.4	15.7	148.2	19.3	32.8	69.8	103.0
9	Girne Avenue	17-29 January 2008	21.3	3.9	147.8	13.8	17.0	45.4	56.8
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	27.4	3.7	198.7	27.3	20.6	79.6	116.1
11	Mithatpasa Street	12-25 February 2008	26.0	5.0	141.4	23.0	15.5	70.1	100.3
12	Inonu Street	27 February -12 March 2008	12.4	2.2	43.0	4.8	11.2	20.4	26.3
13	Mehmet Akif Street	12-20 March 2008	9.7	2.0	25.3	4.7	9.4	17.8	22.2
14	Esrefpasa Street	20-26 March 2008	8.1	1.5	17.3	2.7	7.5	13.2	16.2
15	Ankara Street	26 March - 9 April 2008	9.4	3.1	24.2	3.6	8.4	17.0	18.7
16	Yesildere Street	9-21 April 2008	10.6	3.1	22.8	4.4	9.1	19.0	20.2
17	Anadolu Street	30 April -16 May 2008	8.6	3.8	15.0	2.0	8.7	11.7	12.7
18	Talatpasa Avenue	21-30 May 2008	8.6	3.4	22.9	4.5	6.9	17.4	19.6
19	Fevzipasa Avenue	5-17 June 2008	4.0	0.9	13.7	2.5	3.3	9.2	10.5

Table 5.9 Several statistical indicators for hourly CO concentrations (μg/m^3) measured in the selected streets of the city

No	Streets Name	Measurement period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gursel Street	4-17 October 2007	628.7	172.9	2,589.0	325.5	561.1	1,286.7	1,505.7
2	Halide Edip Adivar Street	17 October -1 November 2007	The data couldn't be obtained due to the technical failure of the computer system in the station						
3	Mustafa Kemal Street	1-13 November 2007	1,332.5	469.2	4,566.9	709.4	1,164.6	2,862.6	3,825.2
4	Kamil Tunca Avenue	13-22 November 2007	955.9	344.3	3,608.8	508.6	798.9	2,104.6	2,559.6
5	Yesillik Street	22 November -13 December 2007	1,257.9	502.5	5020.1	687.9	1,065.7	2,758.9	3,248.2
6	Altinyol Street	13-25 December 2007	2,644.2	255.9	1,0154.4	2,254.0	1,636.5	7,168.5	8,404.9
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	2,055.9	627.1	8,547.7	1,020.0	1,782.1	3,808.4	4,963.4
8	Sair Esref Avenue	4-17 January 2008	2,264.2	622.4	1,2517.4	1,862.3	1,644.7	6,051.8	8,312.1
9	Girne Avenue	17-29 January 2008	1,952.4	685.9	7,047.2	1,238.0	1,493.6	4,649.8	6,010.7
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	1,798.5	268.9	7,964.3	1,392.7	1,228.8	4,974.2	6,124.0
11	Mithatpasa Street	12-25 February 2008	1,335.7	343.4	5,016.9	912.8	1,106.3	3,572.6	3,821.9
12	Inonu Street	27 February -12 March 2008	1,122.3	302.2	3,666.3	629.3	962.6	2,331.3	3,117.2
13	Mehmet Akif Street	12-20 March 2008	1,041.3	452.8	3,295.2	493.0	882.8	1,999.0	2,567.8
14	Esrefpasa Street	20-26 March 2008	1,046.4	319.4	2,781.3	470.7	973.1	1,790.1	2,241.1
15	Ankara Street	26 March - 9 April 2008	1028.9	454.2	3,276.7	373.6	960.5	1,680.5	1,857.5
16	Yesildere Street	9-21 April 2008	728.6	403.9	1,725.2	277.5	628.9	1,385.8	1,577.3
17	Anadolu Street	30 April -16 May 2008	1,721.8	606.8	2,711.0	328.1	1,697.5	2,252.2	2,343.2
18	Talatpasa Avenue	21-30 May 2008	1,354.0	300.9	3,052.9	807.9	954.9	2,528.9	2,700.3
19	Fevzipasa Avenue	5-17 June 2008	768.0	215.8	1,811.2	373.7	718.9	1,461.9	1,675.1

Table 5.10 Several statistical indicators for hourly NO_2 concentrations ($\mu g/m^3$) measured in the selected streets of the city

No	Streets Name	Measurement period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gursel Street	4-17 October 2007	46.0	4.1	120.8	27.7	39.8	97.8	108.6
2	Halide Edip Adivar Street	17 October -1 November 2007	56.9	14.3	103.2	17.0	56.8	86.2	90.3
3	Mustafa Kemal Street	1-13 November 2007	56.2	10.3	109.4	21.5	56.0	91.9	96.1
4	Kamil Tunca Avenue	13-22 November 2007	39.7	5.7	80.9	18.4	38.1	70.2	73.8
5	Yesillik Street	22 November -13 December 2007	44.2	7.4	92.7	18.8	42.4	77.1	83.6
6	Altinyol Street	13-25 December 2007	50.4	9.8	104.9	19.9	45.2	93.5	102.4
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	56.6	22.4	101.7	13.1	56.9	76.1	81.0
8	Sair Esref Avenue	4-17 January 2008	52.1	16.0	100.1	17.2	50.6	83.6	91.8
9	Girne Avenue	17-29 January 2008	51.2	7.5	86.5	15.9	51.8	75.4	80.1
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	49.8	0.3	110.1	21.9	49.4	87.5	95.0
11	Mithatpasa Street	12-25 February 2008	47.8	5.8	100.5	20.1	50.7	77.3	87.1
12	Inonu Street	27 February -12 March 2008	49.3	17.1	85.1	14.8	50.9	71.5	74.4
13	Mehmet Akif Street	12-20 March 2008	54.0	24.4	104.8	13.9	54.8	74.7	84.2
14	Esrefpasa Street	20-26 March 2008	54.6	15.3	84.1	15.9	59.0	76.0	80.7
15	Ankara Street	26 March - 9 April 2008	60.9	20.2	114.4	20.1	58.9	100.6	104.2
16	Yesildere Street	9-21 April 2008	36.4	13.4	84.9	15.1	32.6	68.3	73.9
17	Anadolu Street	30 April -16 May 2008	73.7	21.0	129.6	17.3	73.8	98.3	104.1
18	Talatpasa Avenue	21-30 May 2008	44.6	17.0	95.4	16.5	41.8	75.4	84.2
19	Fevzipasa Avenue	5-17 June 2008	69.8	16.3	164.0	29.4	66.3	117.6	136.3

Table 5.11 Several statistical indicators for hourly NO concentrations (μg/m^3) measured in the selected streets of the city

No	Streets Name	Measurement period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gürsel Street	4-17 October 2007	36.3	0.1	413.7	53.8	15.1	134.7	209.9
2	Halide Edip Adivar Street	17 October -1 November 2007	69.1	0.7	652.0	82.5	43.7	238.3	281.2
3	Mustafa Kemal Street	1-13 November 2007	76.6	1.2	339.5	71.6	58.3	246.4	285.0
4	Kamil Tunca Avenue	13-22 November 2007	38.6	0.1	241.6	46.4	21.9	143.0	178.2
5	Yesillik Street	22 November -13 December 2007	65.4	0.1	473.1	82.7	33.5	253.6	339.6
6	Altinyol Street	13-25 December 2007	174.5	0.4	569.5	155.7	124.6	446.5	503.0
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	100.5	1.5	377.7	74.4	81.7	242.7	286.1
8	Sair Esref Avenue	4-17 January 2008	61.6	0.4	518.3	77.6	35.3	192.8	300.6
9	Girne Avenue	17-29 January 2008	63.6	0.1	444.7	85.1	27.6	262.8	326.6
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	53.6	0.1	332.5	79.6	12.9	252.9	268.1
11	Mithatpasa Street	12-25 February 2008	40.6	0.1	341.6	61.0	16.2	174.4	217.6
12	Inönü Street	27 February -12 March 2008	38.4	0.3	308.7	51.4	22.1	138.6	217.1
13	Mehmet Akif Street	12-20 March 2008	44.1	0.8	277.3	45.6	29.0	124.9	205.5
14	Esrefpasa Street	20-26 March 2008	64.7	0.2	273.8	58.6	46.6	177.9	229.5
15	Ankara Street	26 March - 9 April 2008	81.1	0.1	478.1	80.7	54.7	246.4	270.7
16	Yesildere Street	9-21 April 2008	24.2	0.1	199.8	38.1	4.5	110.7	131.0
17	Anadolu Street	30 April -16 May 2008	100.6	4.1	299.4	45.8	99.8	177.7	191.8
18	Talatpasa Avenue	21-30 May 2008	12.8	0.1	94.5	18.1	4.4	51.2	67.6
19	Fevzipasa Avenue	5-17 June 2008	23.7	0.1	111.6	25.8	13.5	75.8	96.1

Table 5.12 Several statistical indicators for hourly NO_X ($NO + NO_2$) concentrations (μg/m^3) measured in the selected streets of the city

No	Streets Name	Measurement period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gürsel Street	4-17 October 2007	81.3	0.2	531.7	75.6	59.0	225.9	292.8
2	Halide Edip Adivar Street	17 October -1 November 2007	125.9	15.0	742.8	90.7	104.5	301.3	344.2
3	Mustafa Kemal Street	1-13 November 2007	132.5	11.5	450.3	88.9	116.6	334.7	378.2
4	Kamil Tunca Avenue	13-22 November 2007	78.2	6.0	322.3	61.0	58.6	204.6	240.4
5	Yesillik Street	22 November -13 December 2007	106.2	6.8	553.1	92.5	79.8	303.5	390.2
6	Altinyol Street	13-25 December 2007	224.8	12.0	659.7	173.3	171.7	539.4	600.1
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	157.1	24.9	453.6	84.5	138.8	313.1	357.8
8	Sair Esref Avenue	4-17 January 2008	113.7	16.7	593.7	87.8	89.7	266.8	379.6
9	Girne Avenue	17-29 January 2008	113.7	7.3	531.2	94.4	81.0	327.2	394.3
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	99.9	7.8	427.4	93.6	63.7	315.8	347.6
11	Mithatpasa Street	12-25 February 2008	82.8	4.9	438.6	72.1	62.1	229.7	292.7
12	Inönü Street	27 February -12 March 2008	87.6	17.4	348.6	56.1	80.8	191.2	258.7
13	Mehmet Akif Street	12-20 March 2008	98.0	25.1	353.9	56.4	86.2	188.0	292.8
14	Esrefpasa Street	20-26 March 2008	117.5	15.0	338.7	68.3	103.6	241.5	285.9
15	Ankara Street	26 March - 9 April 2008	142.0	20.6	591.4	97.1	115.3	339.7	362.7
16	Yesildere Street	9-21 April 2008	60.6	13.7	234.3	48.2	39.0	170.2	194.6
17	Anadolu Street	30 April -16 May 2008	174.3	41.9	429.0	53.3	179.7	255.5	274.3
18	Talatpasa Avenue	21-30 May 2008	57.3	18.0	163.8	29.2	49.5	118.7	136.1
19	Fevzipasa Avenue	5-17 June 2008	93.2	16.4	205.3	49.3	82.9	182.6	193.0

Table 5.13 Several statistical indicators for hourly O_3 concentrations (µg/m^3) measured in the selected streets of the city

No	Streets Name	Measuring Period	Average	Minimum	Maximum	Standard Deviation	Percentiles		
							50%	95%	98%
1	Cemal Gürsel Street	4-17 October 2007	48.2	3.3	211.7	39.3	40.8	126.4	150.9
2	Halide Edip Adivar Street	17 October -1 November 2007	26.5	2.3	145.0	21.9	22.3	59.6	68.3
3	Mustafa Kemal Street	1-13 November 2007	16.1	0.1	97.6	12.8	14.1	37.2	42.5
4	Kamil Tunca Avenue	13-22 November 2007	24.7	2.5	65.9	16.3	21.9	55.9	59.1
5	Yesillik Street	22 November -13 December 2007	13.5	2.0	68.0	10.4	9.6	34.2	37.9
6	Altinyol Street	13-25 December 2007	4.9	0.3	14.4	2.7	3.9	11.3	12.9
7	Cumhuriyet Avenue	25 December 2007-4 January 2008	6.6	2.3	34.2	2.6	6.5	7.9	8.7
8	Sair Esref Avenue	4-17 January 2008	7.4	5.0	13.2	1.3	7.2	9.6	11.3
9	Girne Avenue	17-29 January 2008	8.9	3.7	51.9	4.7	7.6	14.1	18.2
10	Mustafa Kemal Sahil Avenue	30 January – 12 February 2008	12.6	4.0	52.0	8.8	8.9	30.0	39.2
11	Mithatpasa Street	12-25 February 2008	9.4	1.8	41.3	6.1	8.1	19.9	22.2
12	Inönü Street	27 February -12 March 2008	11.1	3.2	48.9	7.8	8.0	29.3	37.1
13	Mehmet Akif Street	12-20 March 2008	4.7	1.8	15.6	2.7	4.0	11.2	12.2
14	Esrefpasa Street	20-26 March 2008	4.1	1.2	18.0	2.9	3.1	7.3	15.0
15	Ankara Street	26 March - 9 April 2008	3.9	0.3	55.1	3.9	46.6	8.4	10.9
16	Yesildere Street	9-21 April 2008	7,4	3,0	21,5	3,9	6,1	15,9	18,0
17	Anadolu Street	30 April -16 May 2008	3,6	1,7	22,1	1,3	3,6	4,8	6,3
18	Talatpasa Avenue	21-30 May 2008	10,7	1,6	39,6	6,9	9,0	24,0	30,0
19	Fevzipasa Avenue	5-17 June 2008	15,5	0,9	81,0	14,2	10,9	43,2	54,4

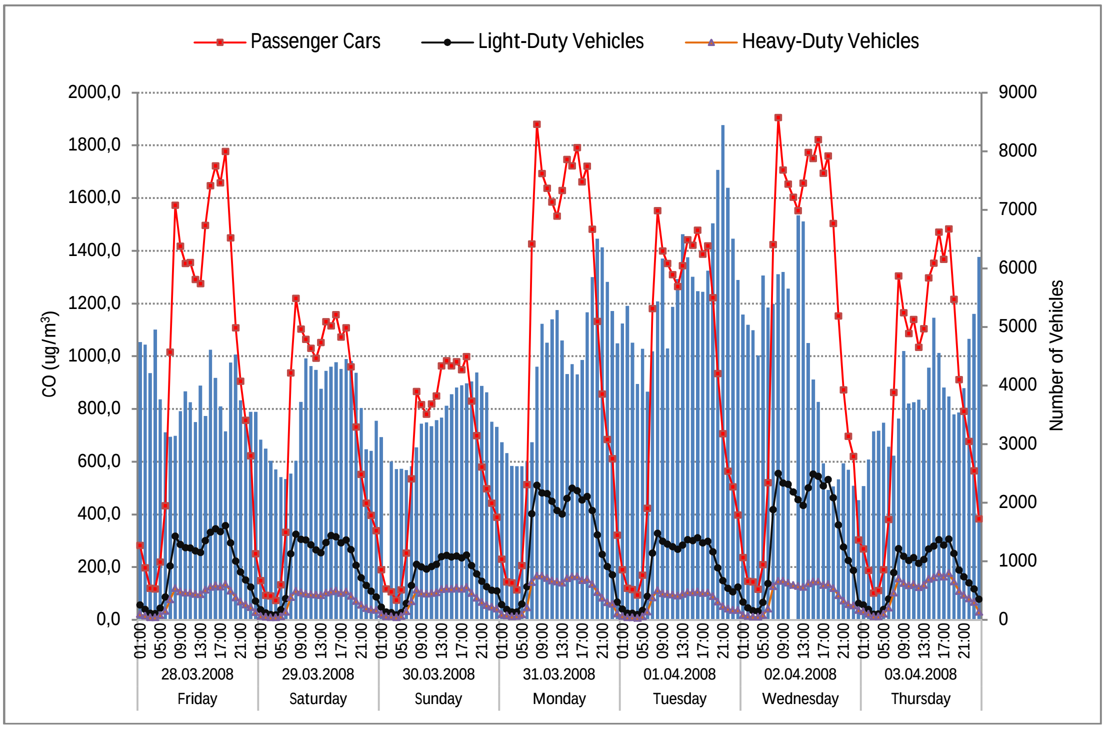

Figure 5.41 Hourly CO concentrations measured and the vehicle numbers counted in Ankara Street.

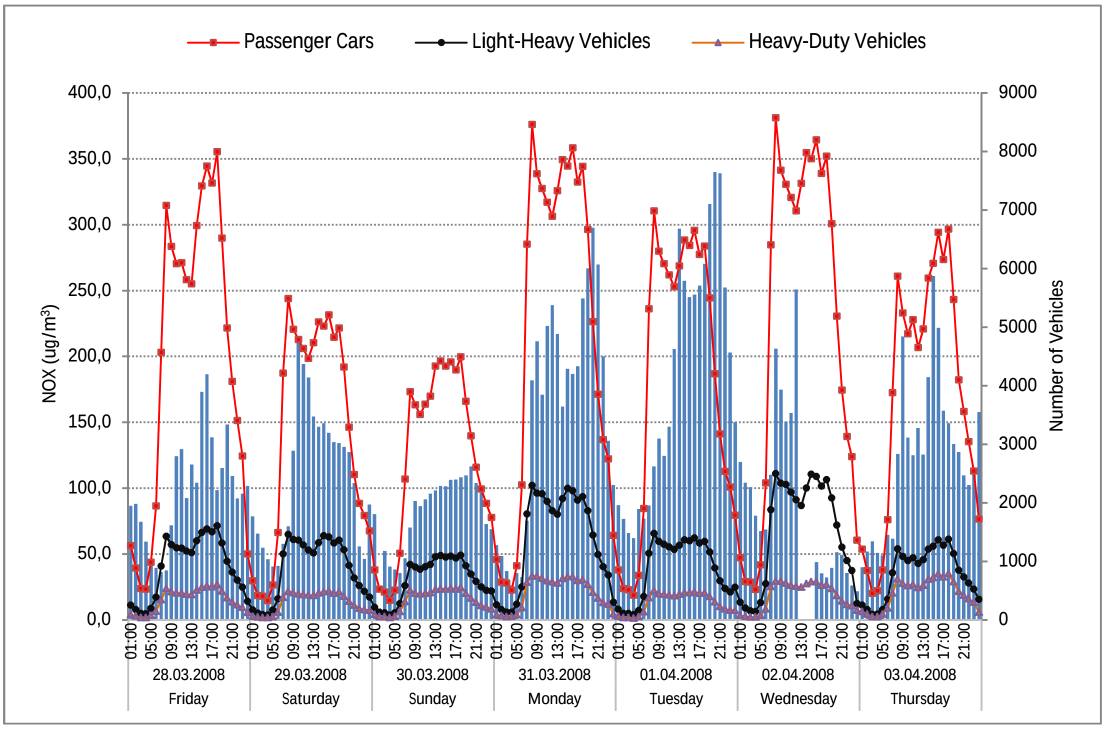

Figure 5.42 Hourly NO_X concentrations measured and the vehicle numbers counted in Ankara Street.

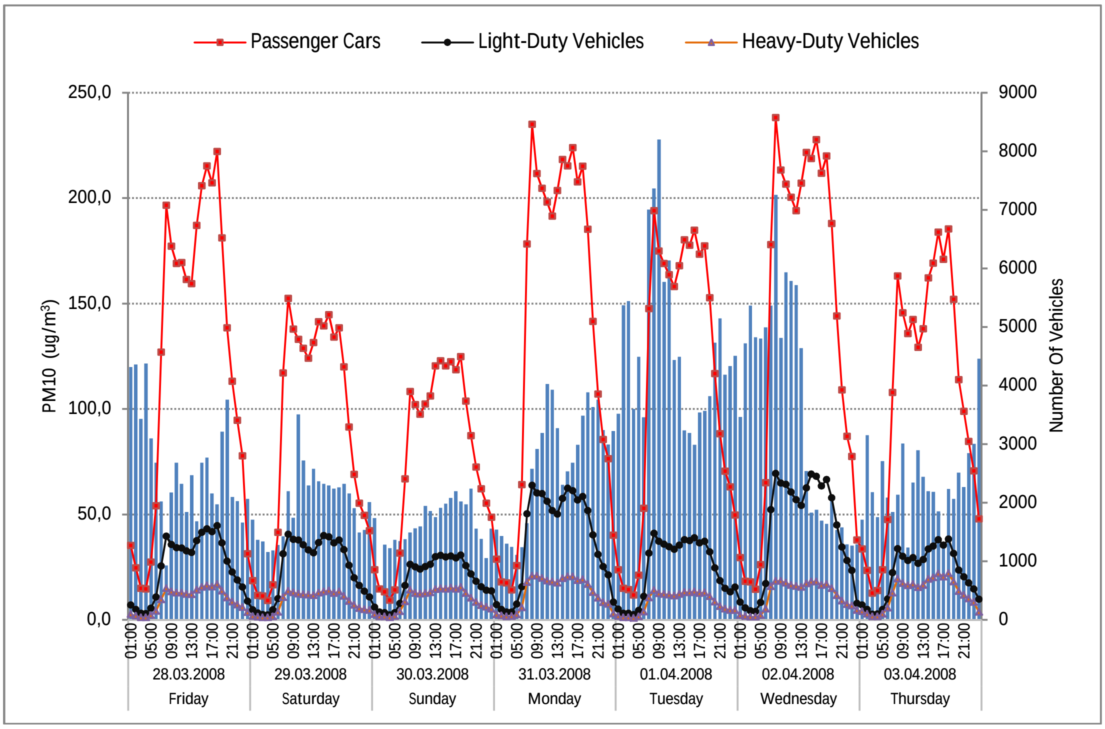

Figure 5.43 Hourly PM_{10} concentrations measured and the vehicle numbers counted in Ankara Street.

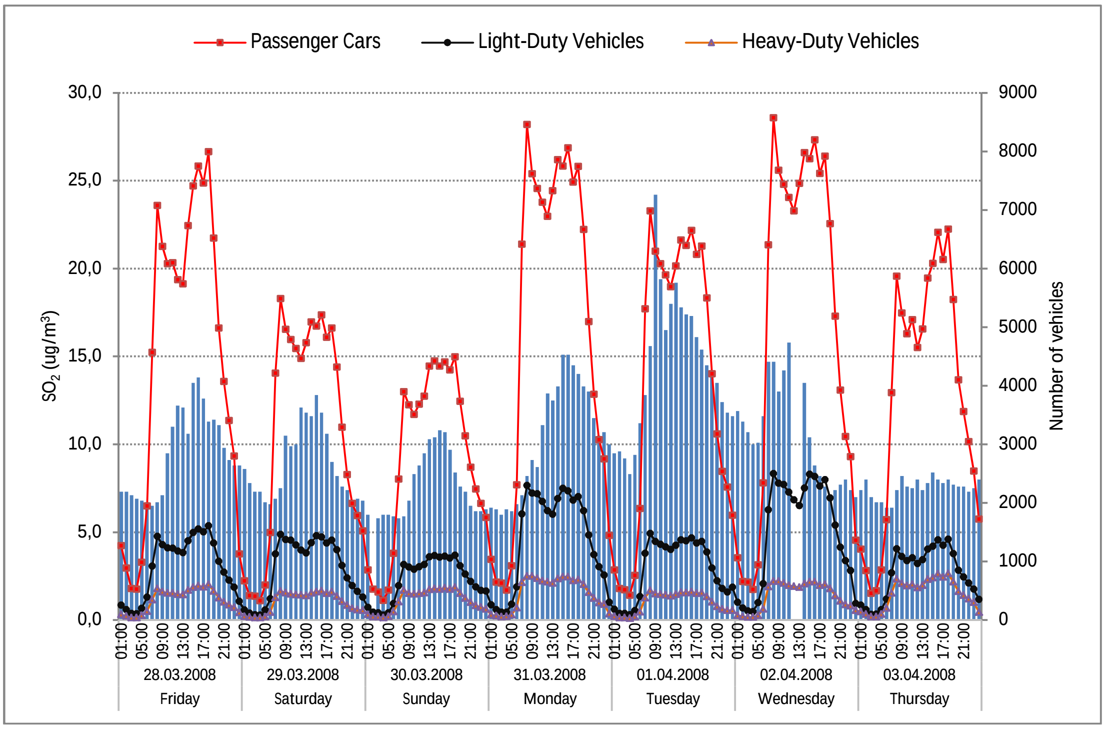

Figure 5.44 Hourly SO_2 concentrations measured and the vehicle numbers counted in Ankara Street.

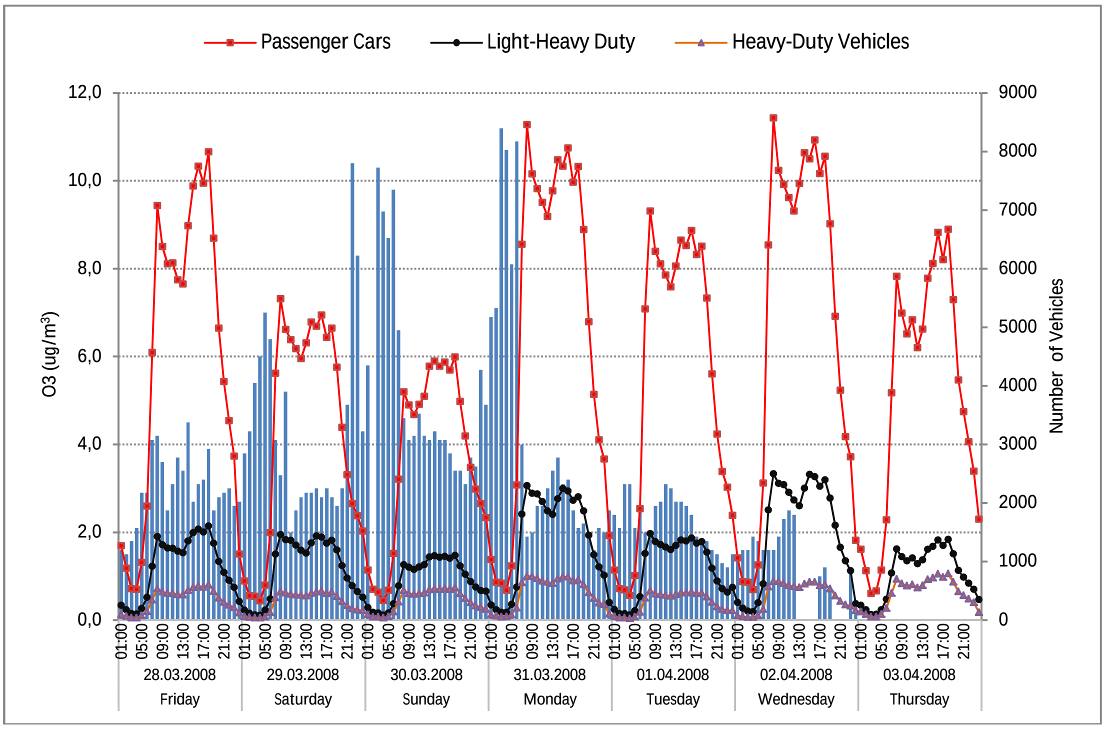

Figure 5.45 Hourly O_3 concentrations measured and the vehicle numbers counted in Ankara Street.

The levels of NO_X were rather high than the other pollutants. This shows directly the effect of traffic at the measurement points. The second high parameter was PM_{10} concentrations. Among the pollutants arising from traffic, SO_2 was the pollutant that has the lowest levels.

The evaluations regarding the pollutants measured within the scope of the study are given below in detail:

The particle matter (PM_{10}): PM_{10} levels were the highest pollutant levels measured on the roads except NO_X. During the measurement campaigns, the mean values were measured between 43.1 – 142.1 µg/m^3 and the highest values changed between 166.0– 804 µg/m^3. Considering the fact that the current annual threshold value is 150 µg/m^3, the values were almost reached in Altinyol Street and Sair Esref Avenue. Short term values were also exceeded in four streets.

Sulfur dioxide (SO_2): SO_2 had the lowest levels among the other pollutants. The mean values were between 4.0 – 46.6 µg/m^3 and the highest levels were changed between 13.7 and 203 µg/m^3. The reason of low levels was that SO_2 is the pollutant directly depending on fuel impurities.

Carbon monoxide (CO): The highest levels of carbon monoxide were between 1,725.2 – 12,517.4 µg/m^3 although the mean values were between 629 – 2,264 µg/m^3. The levels measured were rather below the current threshold levels.

Nitrogen oxides (NO_X): Nitrogen oxides are expressed as the sum of NO and NO_2 measured in the atmosphere. NO levels were higher than NO_2 levels at the morning and evening hours when the traffic is dense in the streets. The mean NO_2 concentrations were between 36.4 – 73.7 µg/m^3 while the highest levels were between 80.9 – 121 µg/m^3.

5.4. Air Quality Modeling

The predicted concentrations due to traffic emissions were plotted in the form of maps for the pollutants. Model runs by CALPUFF were done only for the episodes in the year 2006. The aim of these runs was to find the contribution of traffic sector to air quality in the episodes. For the episode selection, air quality levels of SO_2 and PM_{10} observed in the stationary monitoring stations of Izmir Municipality was used. There were several episodes indicating highest concentrations simultaneously recorded in all stations. Two days (August 16 and December 4, 2006) representing winter and summer were selected for model runs.

The daily average values of four stations were 86 µg/m^3 for SO_2 and 187 µg/m^3 for PM_{10} on December 4, 2006. The highest values for both pollutants (159 µg/m^3 for SO_2 and 180 µg/m^3 for PM_{10}) were simultaneously measured in Alsancak station. The daily concentrations of SO_2 and PM_{10} were recorded as 22 µg/m^3 and 54 µg/m^3 respectively on August 16, 2006 in the city of Izmir. The highest value was measured in Karsiyaka station, and these values were 72 μg/m^3 for SO_2 and 58 μg/m^3 for PM_{10}. The time series of daily average SO_2 and PM_{10} values are given Figures 5.46-5.47.

The air quality levels at 08:00 a.m. in the episode days were studied, because this hour was the most crowded time in almost all streets in the city. The domain for modeling studies was selected as 25 km x 30 km to cover the Izmir metropolitan area. The spatial resolution of the grid system used was 250 m. Figure 4.68 and 4.67 give the results of CALMET meteorological modeling indicating 3-dimensional wind speed and direction fields on the topography of the city. The distribution maps calculated by CALPUFF were plotted for different pollutants. These maps plotted by a Geographical Information System (GIS) are given between Figures 5.50 and 5.51.

The dominant wind directions are seen clearly in Figures 5.48 and 5.49. South-east (SE) was dominant wind direction of winter season and north-west (NW) was the dominant in summer. The distributions of the pollutants are given in Figures 5.50 and 5.59. According to modeling results, maximum concentrations occurred on the streets or on a few hundred meters away from the streets. These results show the concentrations of summer were higher than the concentrations in winter. The maximum hourly concentrations predicted by the model in summer morning were found as 400 μg/m^3 for CO, 222 μg/m^3 for NOx, 12 μg/m^3 for PM_{10}, 60 μg/m^3 for NMVOC and 40 μg/m^3 for SO_2. CO, NO_x, $PM_{10,}$ NMVOC and SO_2 concentrations were similar for the winter period (311 μg/m^3, 163 μg/m^3, 7 μg/m^3, 36 μg/m^3 and 24 μg/m^3 respectively).

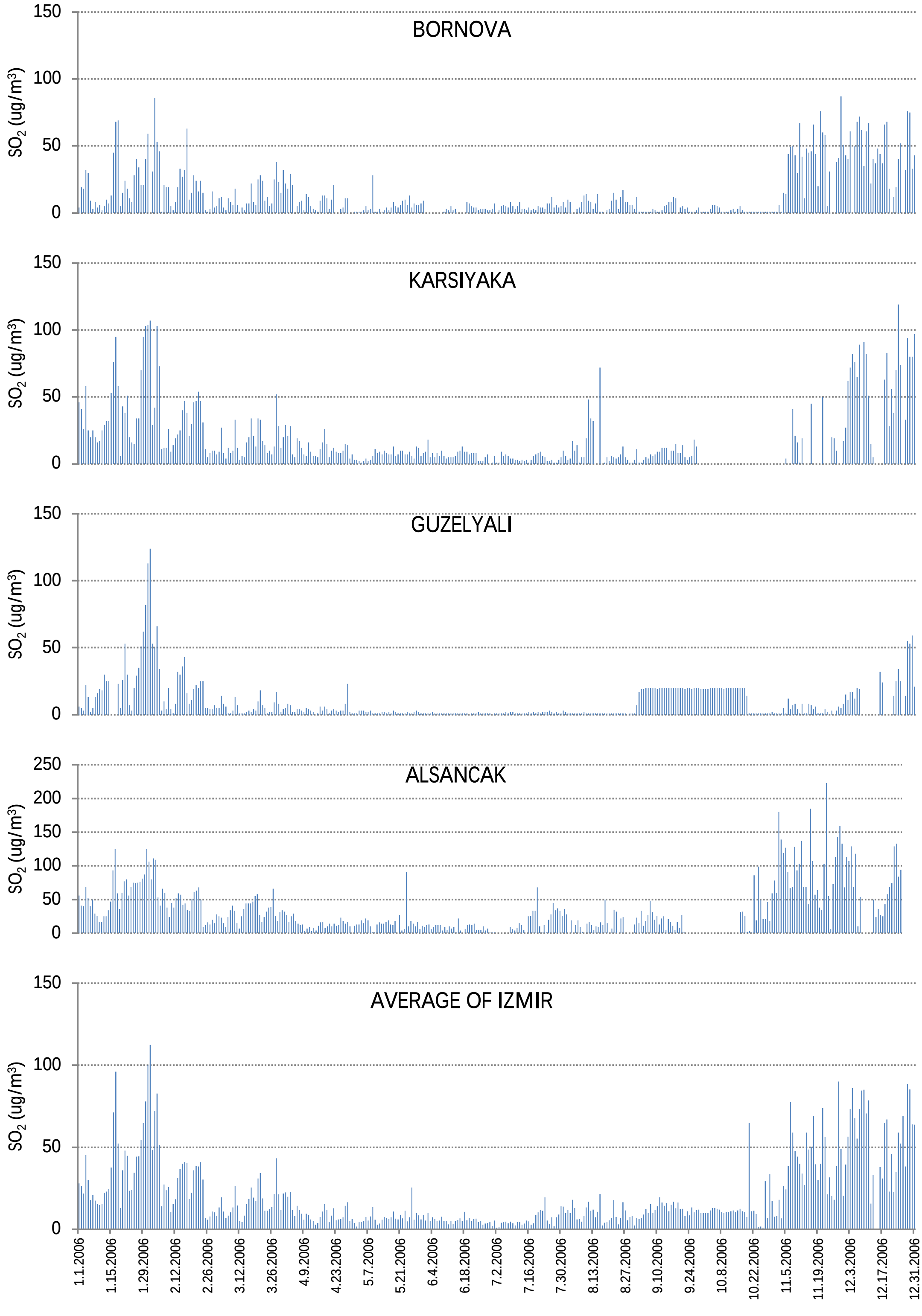

Figure 5.46 Daily SO_2 concentrations observed in the ambient air quality monitoring stations of the city, µg/m^3.

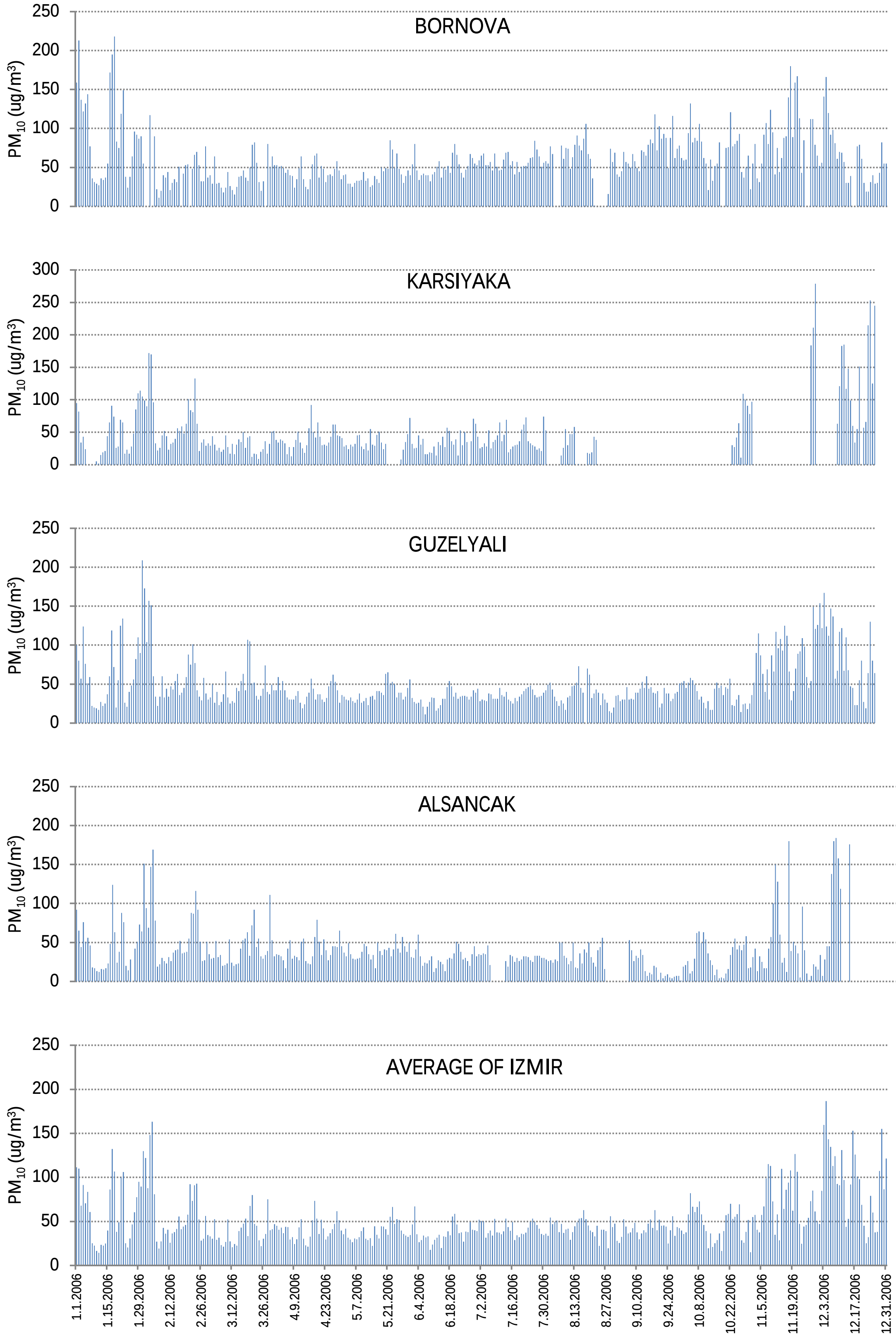

Figure 5.47 Daily PM_{10} concentrations observed in the ambient air quality monitoring stations of the city, $\mu g/m^3$.

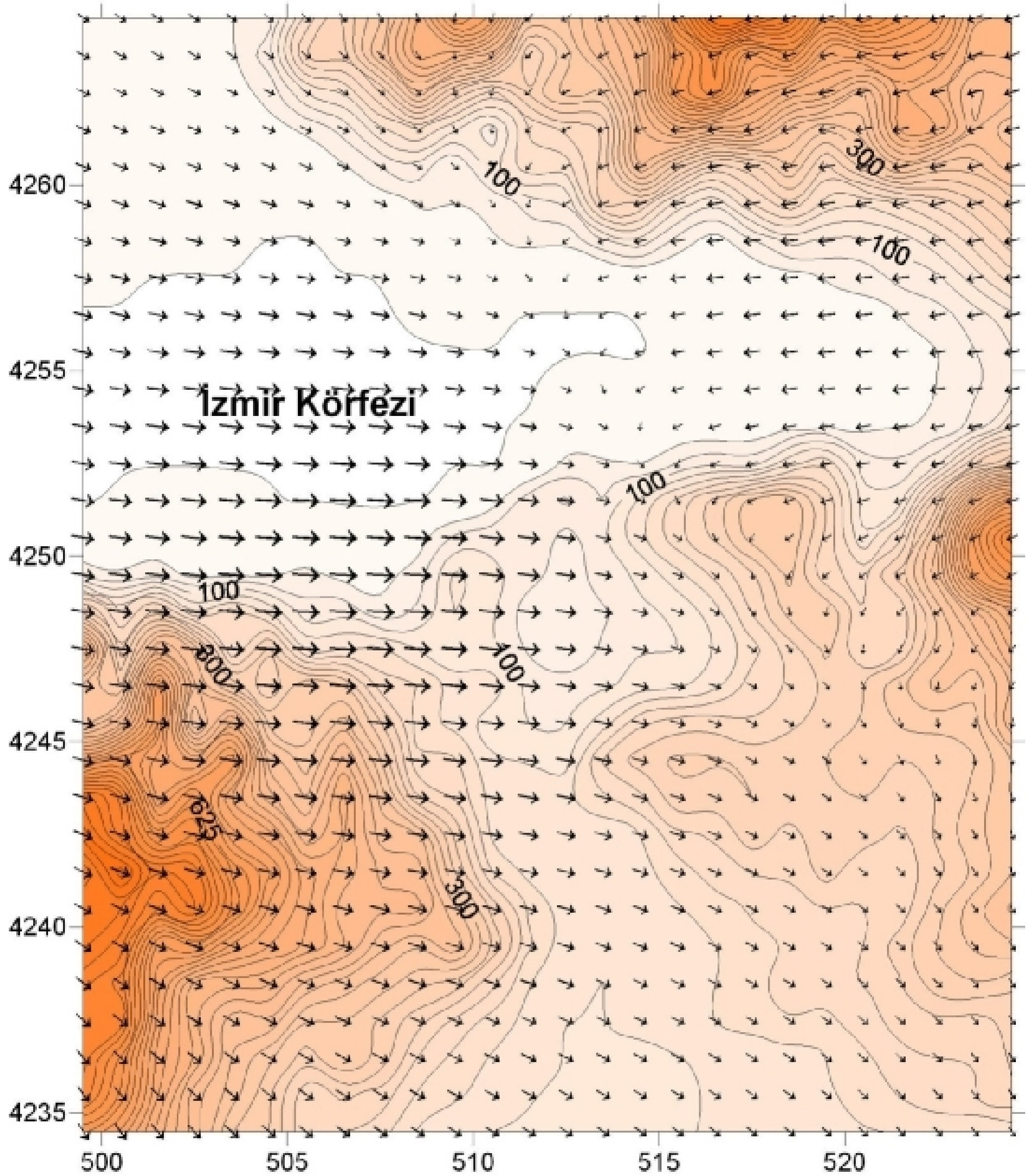

Figure 5.48 Distribution of wind speed and direction at 8 am. on August 16, 2006.

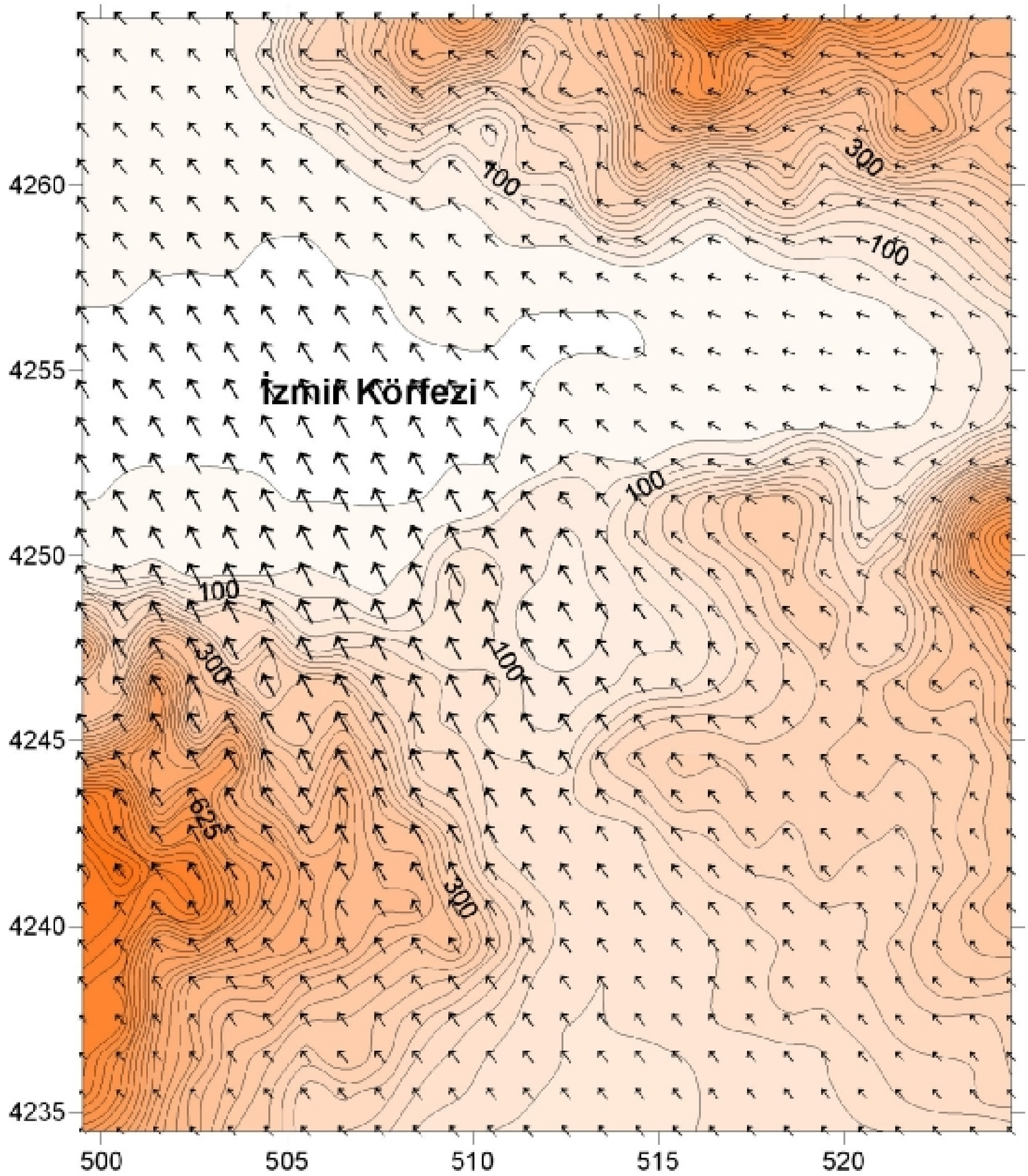

Figure 5.49 Distribution of wind speed and direction at 8 am. on December 4, 2006.

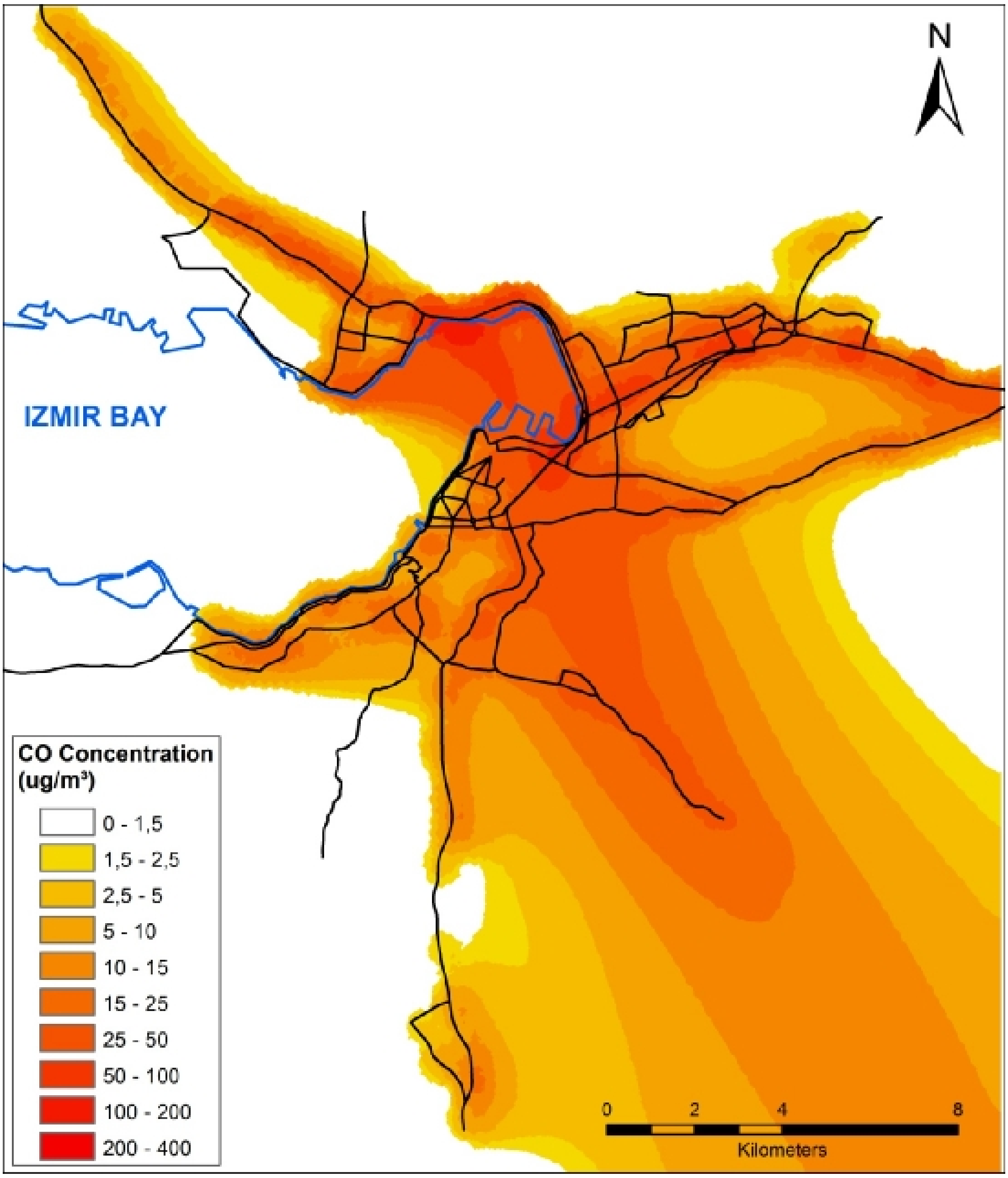

Figure 5.50 Distribution of CO concentrations from mobile sources at 8 am. on August 16, 2006.

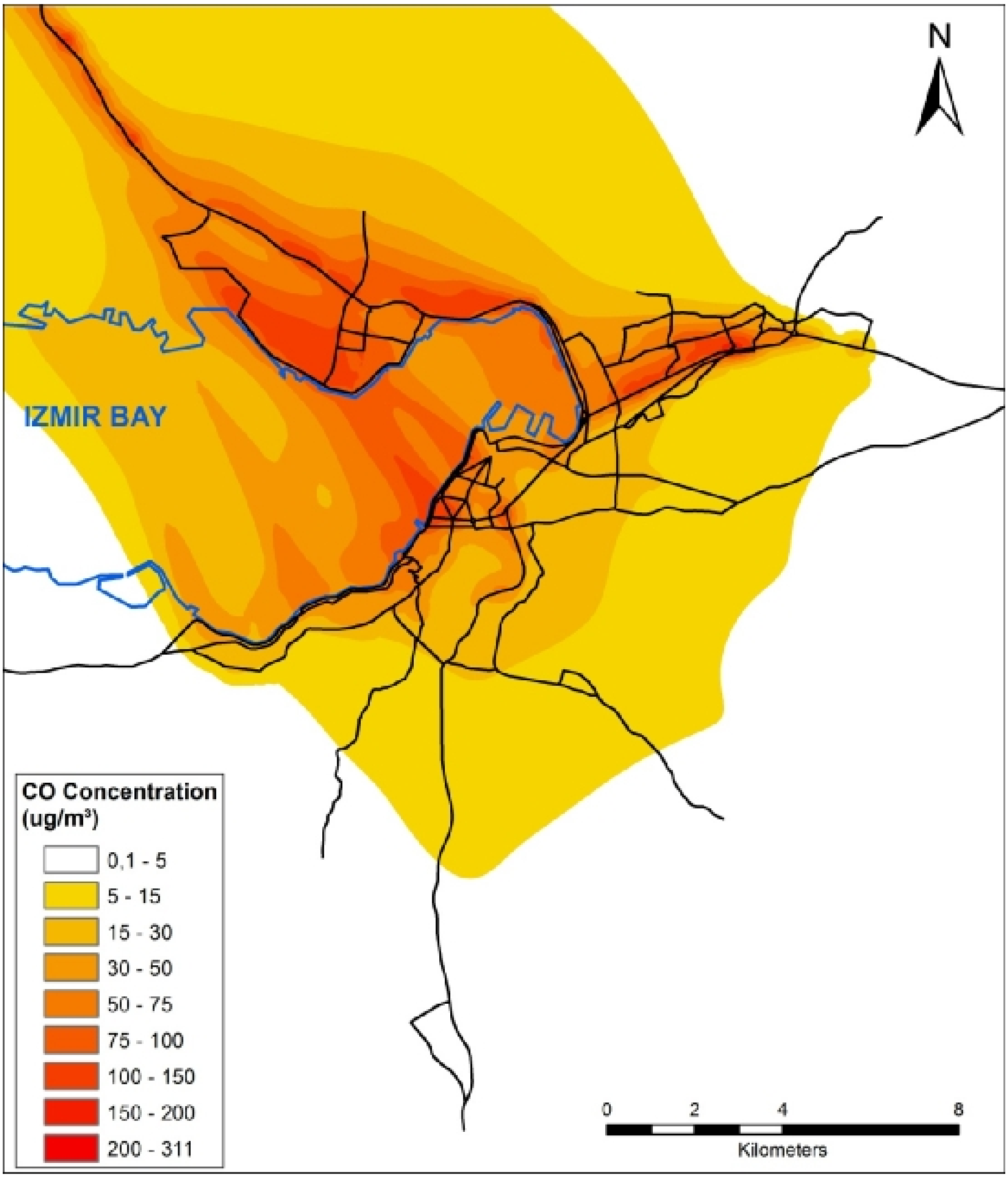

Figure 5.51 Distribution of CO concentrations from mobile sources at 8 am. on December 4, 2006.

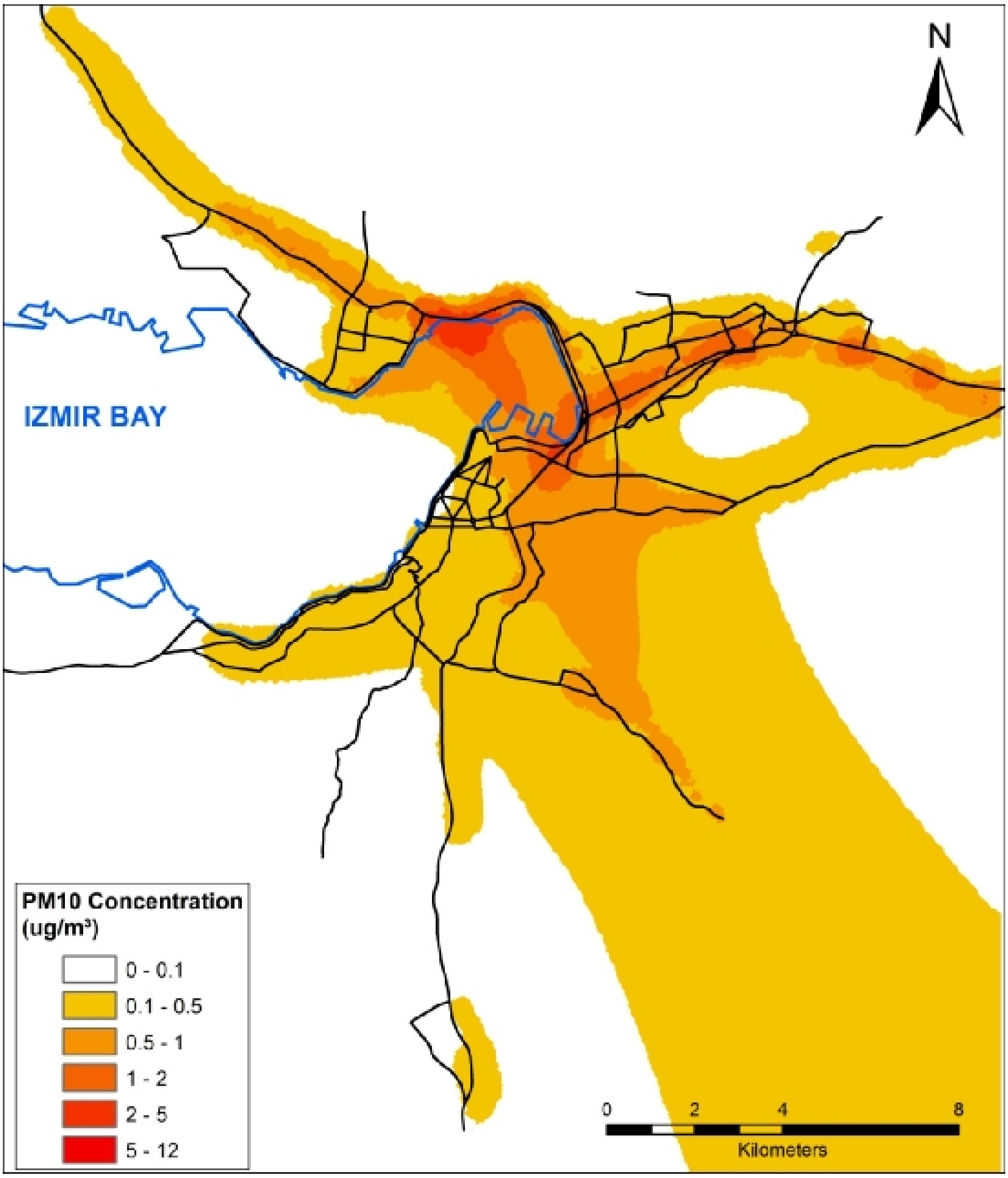

Figure 5.52 Distribution of PM_{10} concentrations from mobile sources at 8 am. on August 16, 2006.

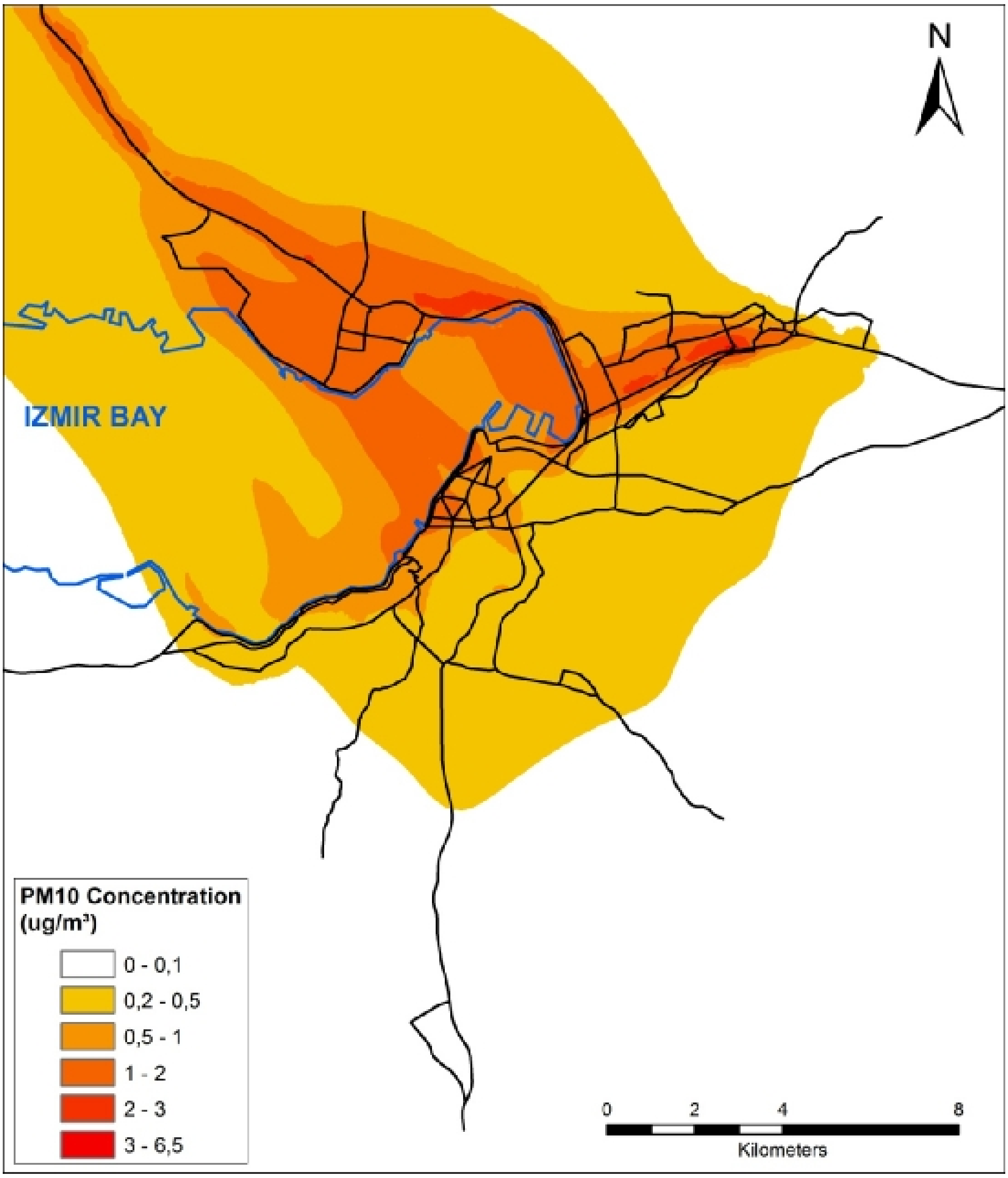

Figure 5.53 Distribution of PM_{10} concentrations from mobile sources at 8 am. on December 4, 2006.

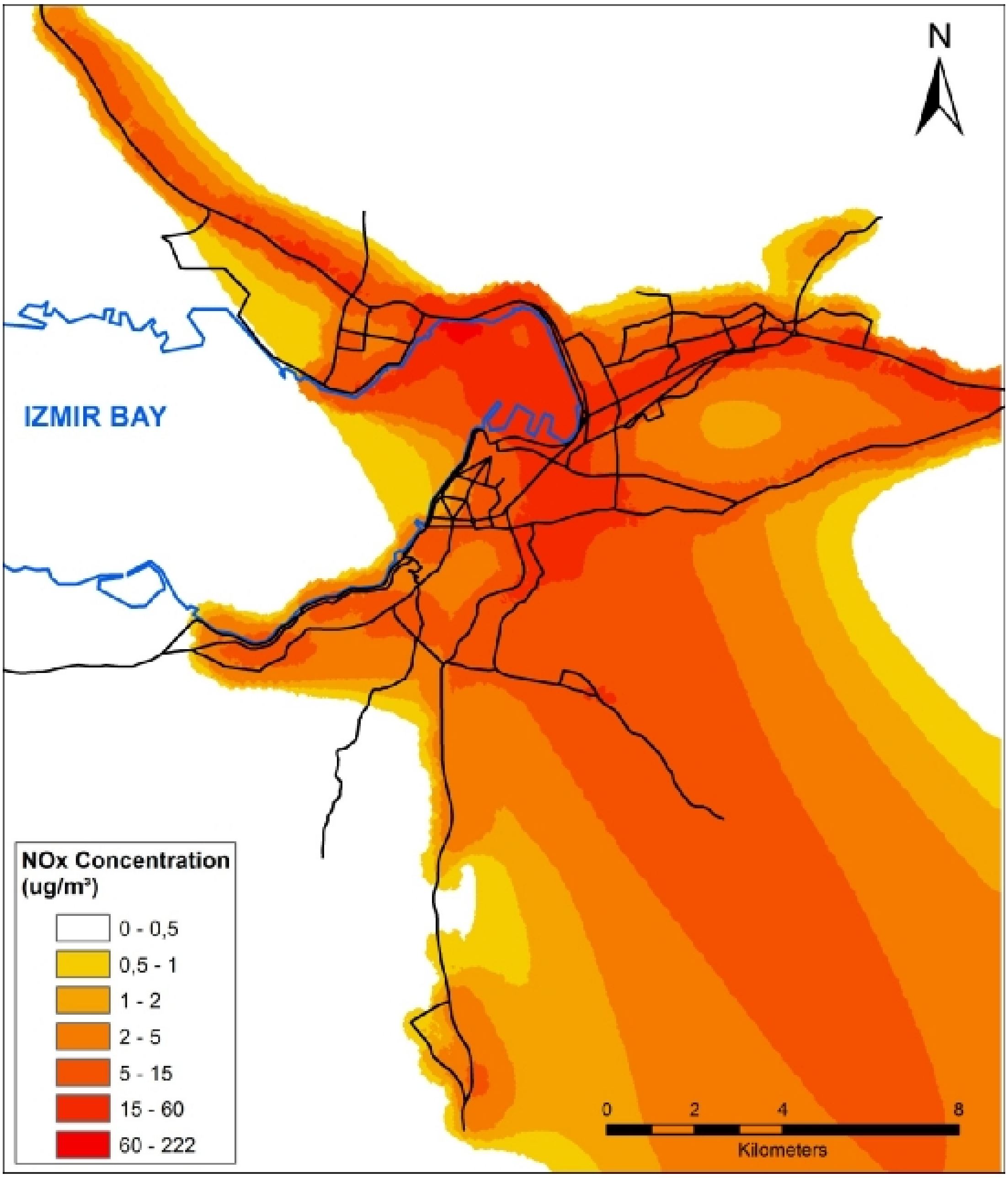

Figure 5.54 Distribution of NO_X concentrations from mobile sources at 8 am. on August 16, 2006.

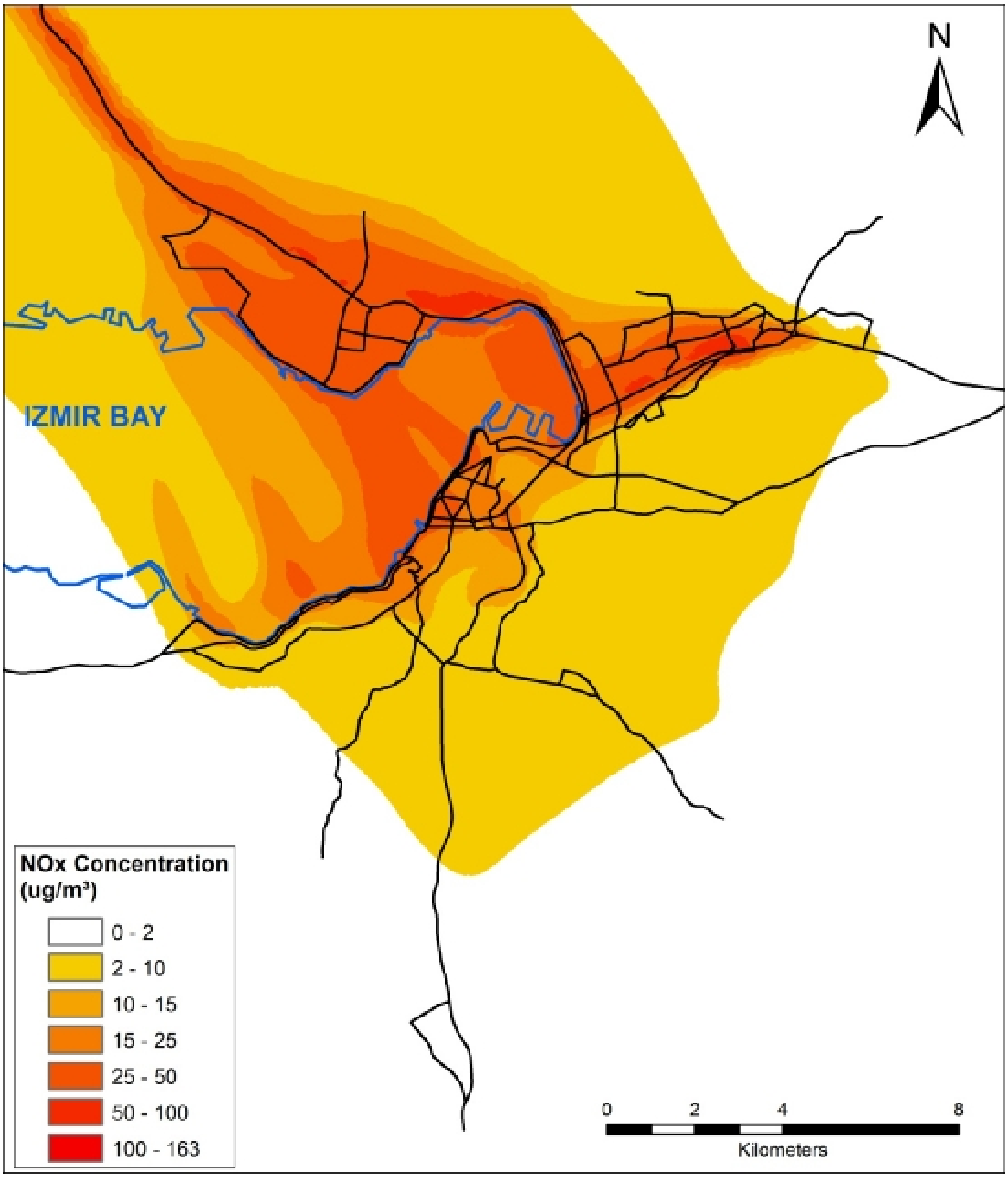

Figure 5.55 Distribution of NO_X concentrations from mobile sources at 8 am. on December 4, 2006.

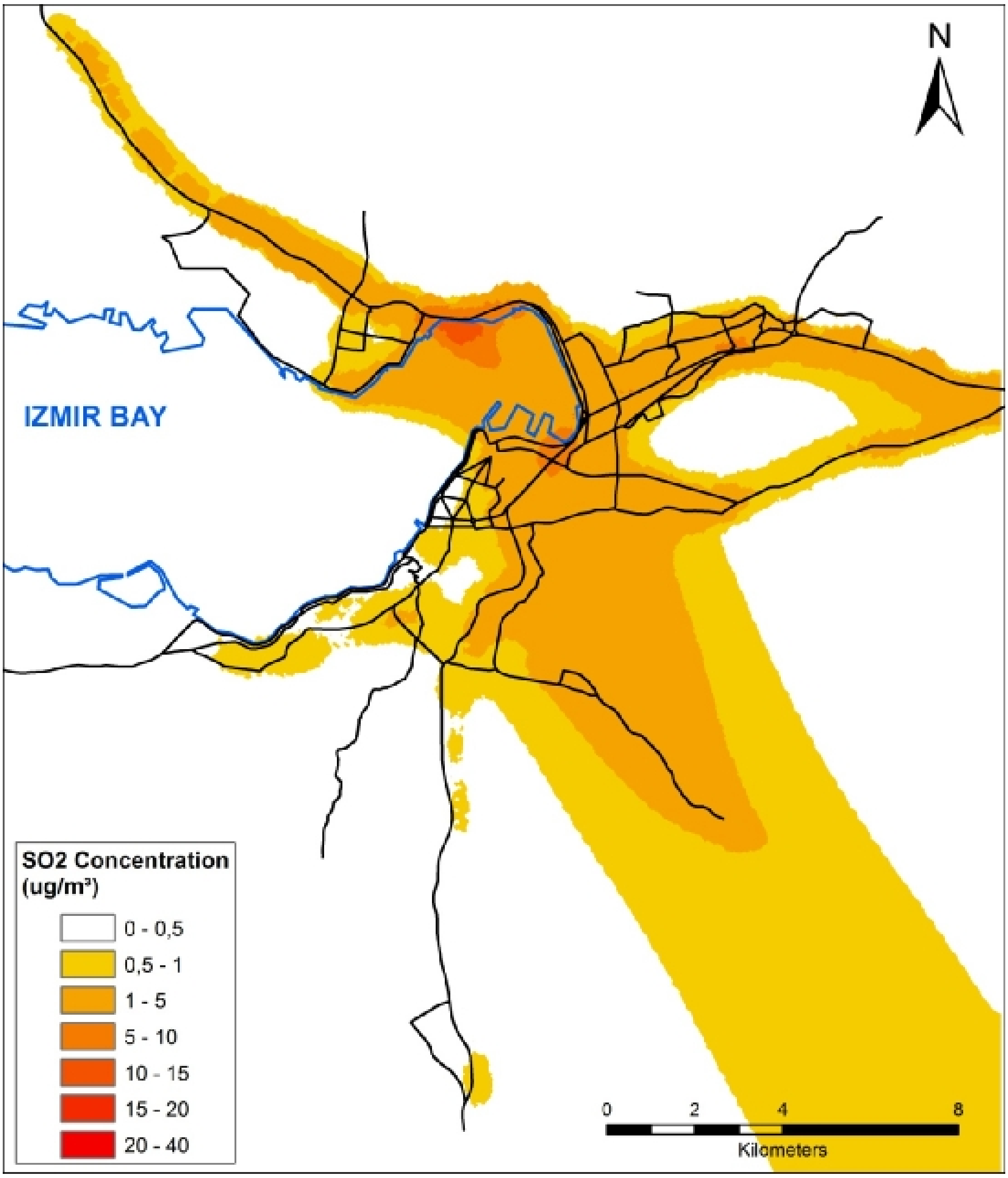

Figure 5.56 Distribution of SO_2 concentrations from mobile sources at 8 am. on August 16, 2006.

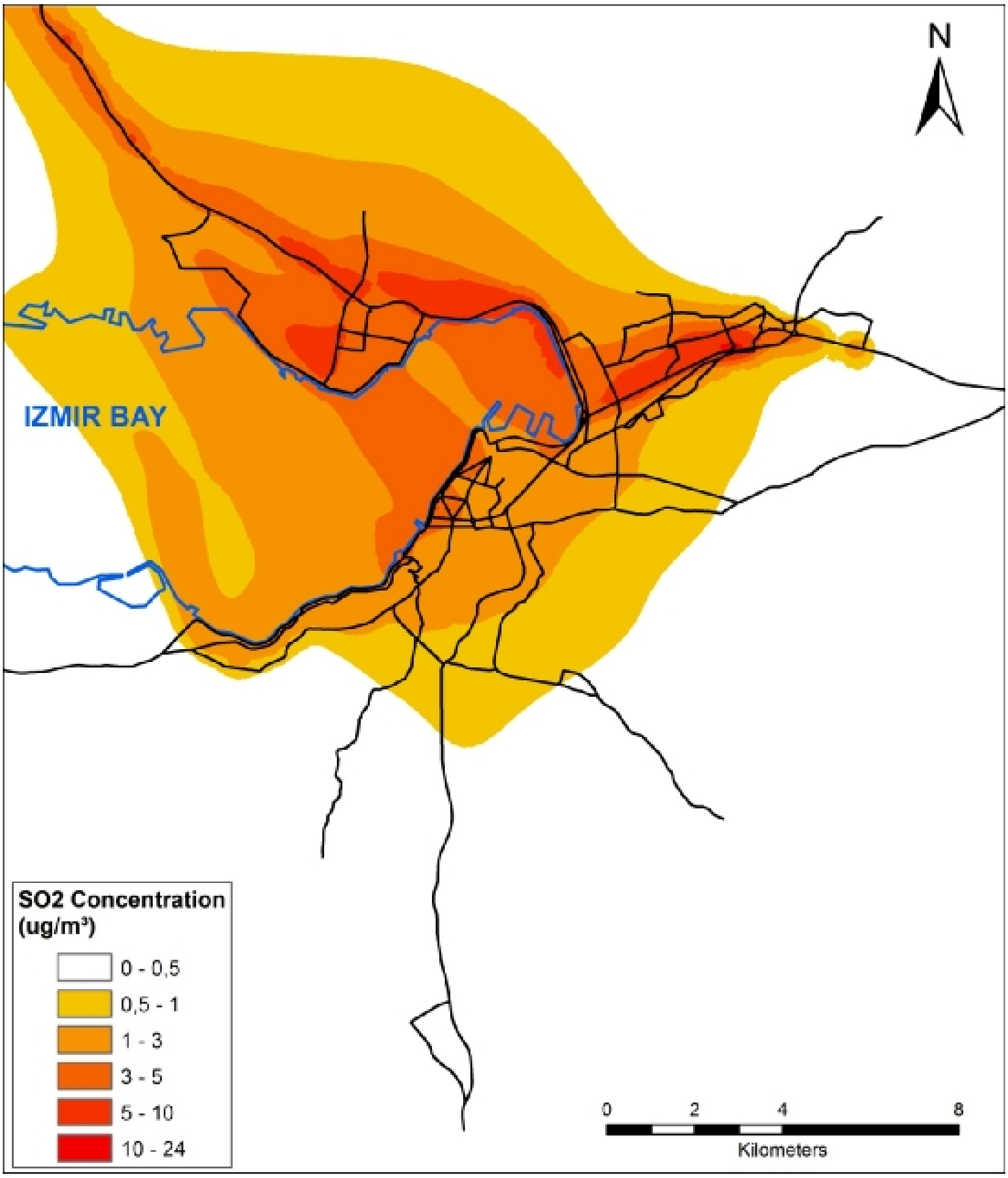

Figure 5.57 Distribution of SO_2 concentrations from mobile sources at 8 am. on December 4, 2006.

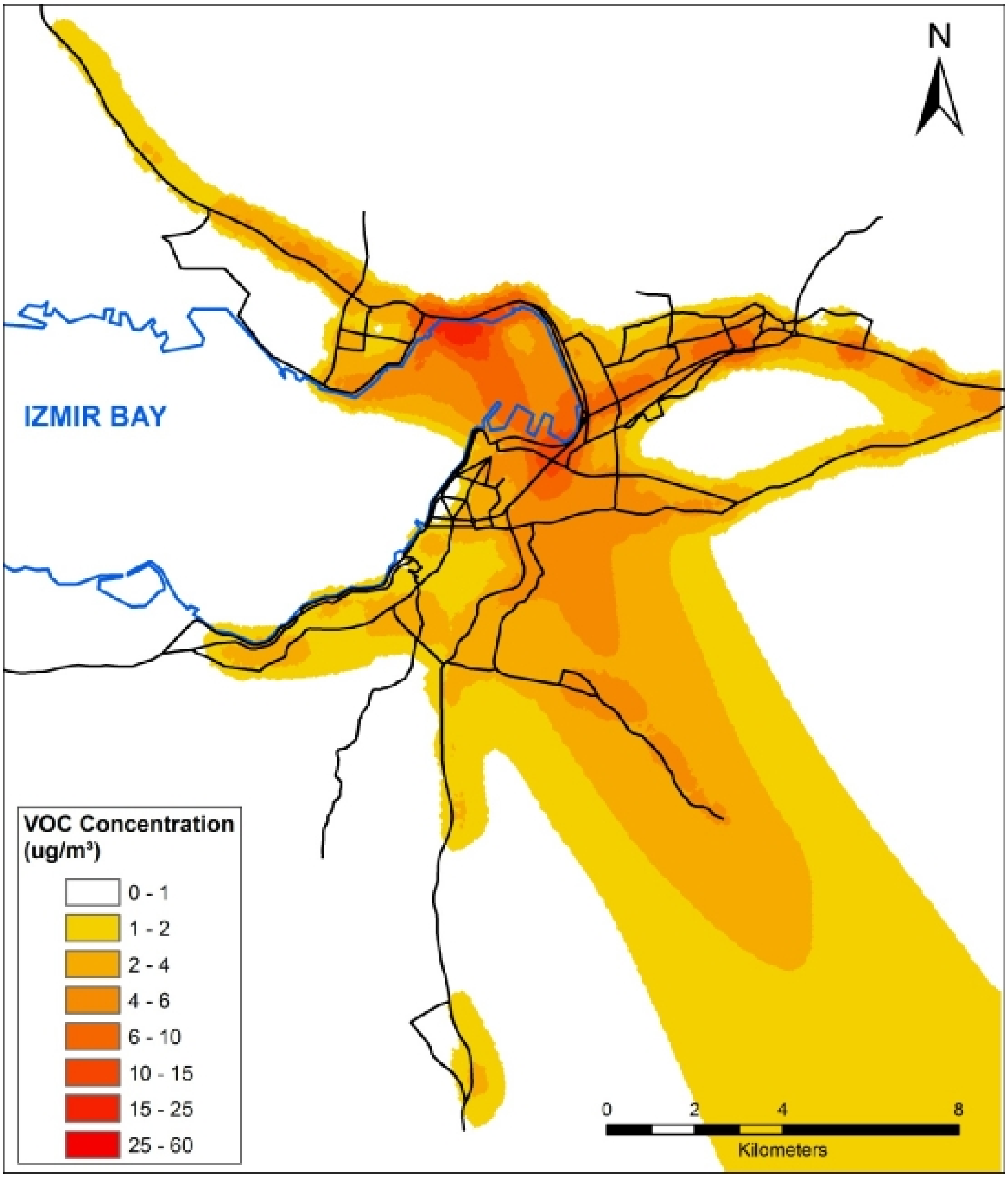

Figure 5.58 Distribution of NMVOC concentrations from mobile sources at 8 am. on August 16, 2006.

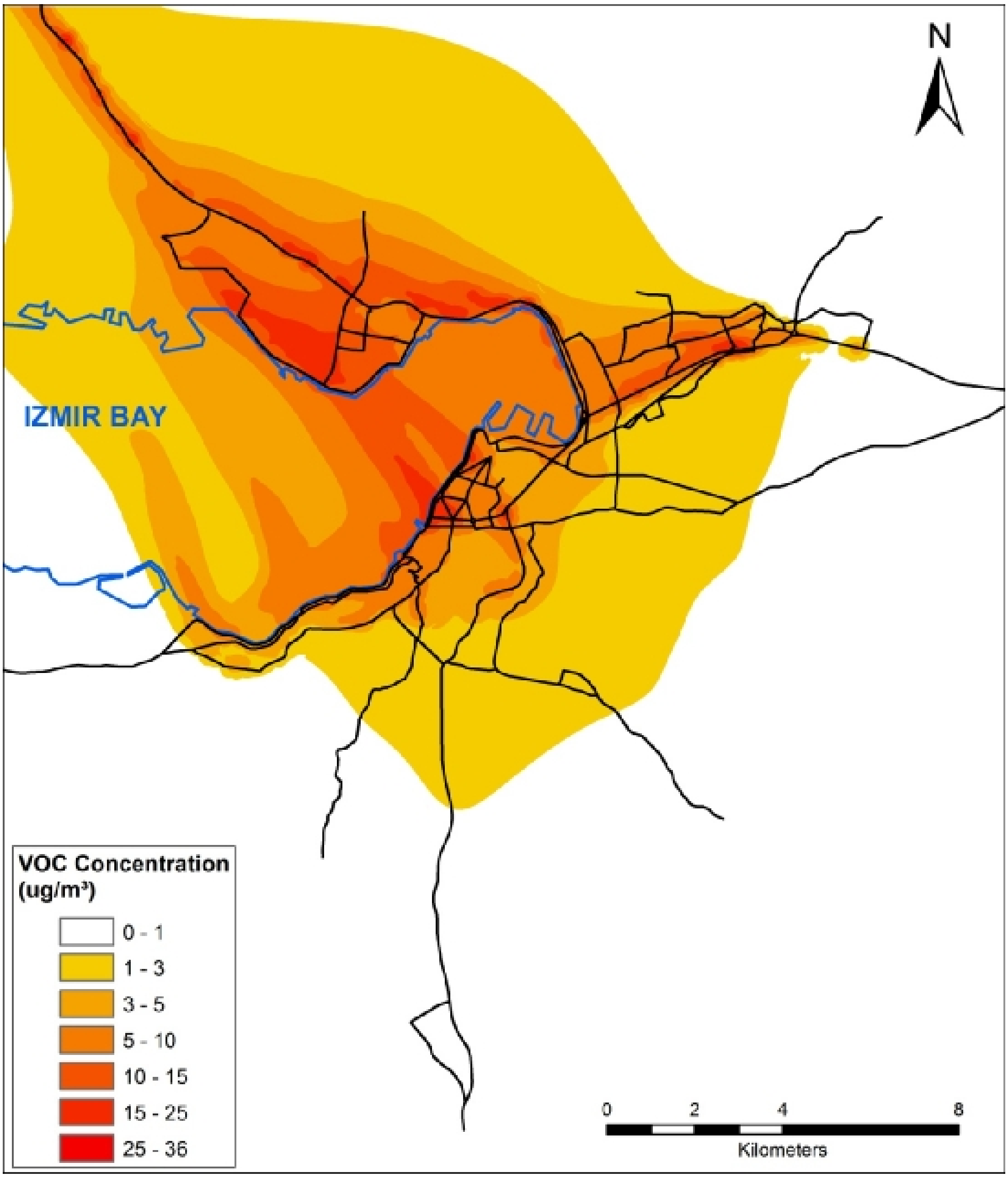

Figure 5.59 Distribution of NMVOC concentrations from mobile sources at 8 am. on December 4, 2006.

CHAPTER SIX
CONCLUSIONS

In this study, the air pollution levels caused by road traffic were investigated in the city of Izmir. The motor vehicles categorized were counted in selected major streets. Vehicles were continuously counted with the portable vehicle classifier systems during one week in the seasons of summer and winter. Thus, hourly, daily and seasonal variations in the traffic density were examined in the study.

The exhaust emissions were calculated using emission factors from Corinair database. For different pollutants hourly, daily, weekly and annual total emissions were calculated and a detailed emission inventory was prepared within the scope of the study.

The air quality levels from exhaust emissions of motor vehicles were predicted by a mathematical air quality dispersion modeling system (CALMET-CALPUFF). Modeling studies were done to estimate the air quality on the streets and to be used in air quality management plans of the city.

The pollutants were also monitored by a mobile ambient air quality monitoring station in selected streets. The main results are as follows:

Vehicle counting: The city has a special traffic density profile. The daily and hourly variations of vehicle numbers follow similar trends in almost every street. The traffic density in the city during the summer months did not decrease because the city is tourism center in the region. Traffic density in the city has not any major difference between summer and winter.

Many streets have no alternative paths in the city. Therefore the total numbers of vehicles are very high on these streets during the day times. The vehicle speeds decrease due to high traffic density at the morning and evening hours. Low speeds on the streets cause the formation of high pollutant emissions.

Emission inventory: The emissions from motor vehicles are more important from industrial facilities and heating system in the city. For example, NO_X emissions from major 65 streets are estimated 2,500 tons/year. In a previous study, NO_X emissions were found 1,100 tons from domestic heating and 2,600 tons from industrial sector (Elbir, 2004).

The emission factors for mobile sources depend on the vehicle types (motorcycle, passenger car, light-duty vehicles and heavy-duty vehicles), engine technology (production date, engine capacity, etc.) and fuel types (gasoline, diesel, LPG). The information related to the records of licensed vehicles in the city could not be obtained due to lack of data in the related institutions. Obtaining this data could improve the emission inventory in future studies.

Ambient air quality monitoring: High pollutant concentrations were measured in several major streets. These concentrations are higher than current limit values in the Turkish regulations. The more critical limit values that are much lower than current observations will be valid on January 1, 2014 in Turkey.

Air quality modeling: The results of distribution models are very successful in the study. The differences are between modeled pollution levels and measured values will decrease if the high quality meteorological data and improvement of emission inventories would used. Consequently, the pollutants levels can estimate without measuring (Elbir et al., 2010).

Concentrations of SO_2 and PM_{10} have decreased in the city due to use of natural gas in residential heating and industrial sources. On the contrary these sources, the contribution of traffic to urban air quality has increased.

To develop the traffic management plans emission control technologies should be studied in future studies. The use of alternative fuels such as LPG and the expanding public transport in the city could be other solution for emission reduction.

As a result, the pollutants from mobile sources are incomplete in the emission inventories that were done in our country. There are vehicle count, emission calculations and air quality measurement in this study that is the most extensive study in our country.

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