

The expected environmental impact of the King Abdulaziz Public Transport Project on the level of air quality

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Abstract

This paper study King Abdulaziz Public Transport Project in Riyadh. Its expected impact on reducing air pollution and raising its quality level in 2030. Without a doubt, transportation is one of the basic pillars of sustainable development; nevertheless, it is one of the most important sources of air pollution. The main objectives of the study: identifying the current situation of air pollution in Riyadh, reviewing the efforts of the authority to improve the air quality, estimating the size of the population and expected daily trips in 2020 and 2030, and determining the project's expected effects on air quality.

The result estimated the population of Riyadh is expected to reach about (7.8) million in 2020 and rise to about (10.4) million in 2030. As for the number of daily trips is expected to reach more than (9) million trips in 2020 and rise to more than (12) million trips in 2030. It is expected that the implementation of the KAPTP will start in 2022. Furthermore, it is expected that about 20% of daily trips will change after operating the project, and the alteration will increase to about 25% in 2030. Therefore, the project is expected to reduce air pollution by about 30% after operating the project, and then to about 40% in 2030. The study recommends preparing an extensive media plan to prepare the community, encourage it to use public transport, and study public transport tariffs and motivate public transport by imposing fees for using roads and parking lots.

Introduction

Transport is the mainstay of development and the backbone of contemporary life, its importance increases steadily with the increase in the area, and the expansion of its ends, also, the pressure on transportation means increases with the increase in population density. The increase in the demand for transportation means many problems: economic, social, and environmental; this calls on the authorities responsible for cities to find innovative solutions to these problems. Also, public transport in cities is one of the best solutions for providing mobility services; to facilitate the movement of the population, and to reduce many environmental problems caused by the expansion of cars.

Air pollution is one of the most prominent problems facing urban centers, especially the major ones, whether in developed or developing countries. Means of transportation are among the most important sources of this pollution; Because of the products of fuel combustion that are emitted from vehicle exhaust (Ferronato, & Torretta, 2019). Therefore, the engines' quality, efficiency, and the fuel's specifications have a great relationship with the combustion products (Kampa, & Castanas, 2008, Ibrahim & Alamro, 2021). According to the French Agency for Food, Environmental, and Occupational Health & Safety, about one-third of air pollution comes from vehicle exhaust emissions. Air pollution from transportation is one of the most important and most dangerous types of pollution. Because of the quality of gaseous pollutants emitted from transportation exhausts, the proximity of the pollution resulting from them to the population, the ease of transmission and spread from one place to another in a limited period, and its effects on human health and the environment (ANSES, 2021).

Air pollution means that the air contains substances that may be harmful to human health and the environment if they reach certain levels (Kampa, & Castanas, 2008; Al-Duwerj, 2019). Exposure to it increases the risk of some diseases such as lung cancer, stroke, heart disease, and chronic infections. Air pollution is intensified in some of the fastest-growing urban areas, where increased economic activities contribute to higher pollution rates and increased exposure (ANSES, 2021). Among the most critical pollutants emanating from the transportation of all kinds are carbon oxides, nitrogen oxides, and microplankton, and the most dangerous of them is carbon monoxide, a colorless and odorless gas it is poisonous, resulting from incomplete combustion. Also, nitrogen dioxide, a brown poisonous gas, has a pungent odor, so it is the most obvious type of pollution resulting from high-temperature combustion. Also fine suspended particles, including PM 10 and PM 2.5 (Bernstein, et al., 2008; Al-Duwerj, 2019).

Public transport is of great importance in urban centers for its vital role in providing transport service to its residents, whether for work, education, or various life requirements. It serves economic and social development and plays a significant role in reducing many environmental problems caused by excessive use of cars, including Air pollution from exhaust gases from cars.

The city of Riyadh, the capital of the Kingdom of Saudi Arabia, and its largest city has witnessed great and rapid development steps during the past five decades, accompanied by a significant expansion in the dependence of its residents on cars in their daily commute; to meet their economic, social, educational and other needs. Cars are one of the most visible manifestations of development, and their numbers have increased rapidly, but they are not without negative effects that are synonymous with development: traffic congestion, traffic accidents, noise, pollution, and others (Lal, Saroj, and Ashley, 2001; Al-Duwerj, 2019).

The Royal Commission for the City of Riyadh has paid great attention to the city's environment and has been keen to protect it. The authority focused on improving its air quality. In cooperation with the relevant government agencies, it carried out many major development projects; for the sustainable development of the city.

Among the most important of these projects is the KAPTP, which aims to develop public transport in the city, improve its efficiency, and coordinate its services; It is associated with achieving many important goals. The project will increase reliance on public transportation for transportation, thus reducing traffic congestion, air pollution from transportation exhaust, protecting the environment, and raising the quality of life (HCDR, 2014). The project's approval was issued in 2013, implementation began in 2014, and it is expected to start operating in 2022 (Al-Muqri, 2015).

Riyadh is one of the fastest-growing cities, and a steady increase has followed this in the number of cars and daily trips. Excessive use of the vehicle has reduced the rate of speed and increased the length of the journey; As a result, traffic congestion worsened, which was one of the main reasons for the increase in emissions from vehicle exhaust, the high level of air pollution, and its effects on the health of the population and the environment. (Chamber of Commerce and Industry, 2011).

The authority and other responsible authorities have paid great attention to this dilemma, so it conducted a study of air pollution in Riyadh, revealing the city's low level of air quality (RCRC, 2018). Also, a study by Al-Sanhoury, and Al-Nashmi (1996) showed the types of pollutants emanating from transportation, and that they vary according to the fuel used, and that there are major violations in many environmental measures of air quality for gases emitted from transportation exhausts, and their danger to the health of the population and the environment, and that transportation was Contributed to about 70% of the city's air pollution;

Although some studies dealt with air pollution in the city of Riyadh, such as the Al-Qahtani study (1999) of air pollution in some Saudi cities; the Al-Khudairi study (2008) of air pollution in the city of Riyadh based on the measurements of the five monitoring stations of the King Abdulaziz City for Science and Technology; Alharbi, et al., (2014) to assess air quality in Riyadh by measuring six types of gases; Al-Duwais (2015) to measure ozone concentration (ozone) in Riyadh; and Al-Duwerj (2019) designed a web map using modern GIS to represent the big data of air pollution in Riyadh. However, these studies did not discuss the expected impact of the KAPTP in Riyadh in reducing the city's air pollution.

Therefore, the study seeks to know the expected environmental impact of the KAPTP on reducing air pollution in Riyadh and raising its quality level.

Objectives

The study seeks to achieve the following Questions:

- What is the estimation of the population size and the expected daily trips in Riyadh in the years 2020–2030?
- What is the current situation of air pollution in Riyadh?
- What is the expected impact of the KAPTP on the air quality the Riyadh?
- What are the most important recommendations that can reduce howl pollution in light of KAPTP outputs?

Framework:

Population and urban growth:

The population of the city of Riyadh has witnessed rapid growth, as a result of the economic booms experienced by the KSA, and the city is still witnessing high growth rates; this made it one of the fastest-growing cities in the world. Among the most critical factors that led to this rapid growth: natural increase, large internal migrations from different regions of the Kingdom, and external migrations represented by incoming labor; To participate in urban, industrial, and commercial projects, as Table (1) shows the population growth in the Riyadh city during the past seven decades

Table (1) Population growth in Riyadh during 1954–2019

Year	Population in thousands	Year	Population in thousands
1954	106	1992	272.2
1964	185	2004	4261.1
1974	662	2010	5328.2
1986	1389	2019	7778.0 *

Source: HCDR (2019), Riyadh in Sixty Years, p. 54.

This population growth has been accompanied by accelerating demand for housing and other land uses; to meet their needs, such as service, commercial and industrial buildings, road networks, etc., which led to a rapid urban expansion, accompanied by qualitative shifts in the development of building patterns, as shown in table (2).

According to the technical report on land uses in Riyadh (2012), the urban area in 2012 reached about 2435km². Al-Maqri (2015) also indicated that the city's geographical extension from east to west amounted to 74km, while from north to south it amounted to 50km, and that the city includes (150) neighborhoods, distributed over (15) municipalities. The RCRC (2018) showed that developed lands amounted to 1487km², which constitutes about 61% of the urban area. Table (2) explain Urban expansion of the city of Riyadh during the period 1940–2019.

Table (2): Urban expansion of the city of Riyadh during the period 1940–2019

Year	Area km ²	Year	Area km ²
1940	2.2	1996	765.0
1950	9.0	2010	1000.0
1970	64.0	2015	1297.0
1980	180.0	2019	1487.0

The researchers prepared the table based on data collected from several sources from the Royal Commission for the Development of Riyadh.

Roads and Transportation

Al-Muqri (2017) and Al-Rafi's (2019) indicated that the parts of Riyadh and its neighborhoods are linked to each other through a huge gradual network of about 19840 km of roads and streets, which represents about 33% of the developed land area. The responsible authorities have allocated huge financial resources to implement road projects on a large scale with high-level designs and specifications, develop

existing roads; to meet the growing demand for transportation. The components of this network include the following types of roads and streets: (Highways- Arterial roads- Collective streets- - Local streets).

In the field of transportation, a study prepared by the RCRC (2010) indicated the increased need for movement between parts of the city, and that the number of daily trips was (6.2) million, distributed as follows: (85% of them were made by private vehicles, 8% was done by private buses, and 5% by taxi). Public transport shares only about 2% of these trips.

The RCRC (2015) also mentioned in Urban Indicators (2015) the percentage of dependence on private cars on business trips in Riyadh and four major cities, where fast and safe public transport consists of trains and buses. The RCRC (2015) indicated that the percentages of dependence on the car on business trips in those cities were as shown in Table (3).

Table (3) Car dependence rates in the city of Riyadh and four major cities.

City	Reliance on the car
Riyadh	93%
Chicago	61%
London	38%
Seoul	25%
Source: HCDR (2014).	

The comparison shows the percentage of dependence on public transport in these cities, that the percentage of dependence on public transport in Riyadh is very low. The Riyadh Chamber of Commerce and Industry (2011) also indicated that the percentage of public transport use in Riyadh is very low compared to international rates. This because (Al-Raqeeba and Ahmad, 1998; Al-Hussein, 2013; Al-Damari, 2013; and Al-Muqari, 2015):

- Limited service coverage, irregularity, reckless and dangerous driving of buses, and lack of safety standards.
- The buses are old, not air-conditioned, and uncomfortable, their seats are worn out, and their general appearance is dilapidated, which is not commensurate with the economic level of society and its requirements.
- The private car outperforms the result in terms of comfort, privacy, and ease of access.
- Relatively low fuel prices.
- Low population density in many neighborhoods of Riyadh.
- The lack of a safe and comfortable environment for pedestrians, especially when facing dangerous traffic.
- Social factors that limit the use of public transport.

The poor contribution of public transport, and the excessive use of the car, have exacerbated the problem of traffic congestion, and even traffic jams in some parts of the city, not only in rush hours but in many hours of the day.

Attention to air quality in Riyadh:

Air pollution is one of the most important and dangerous types of environmental pollution, Figure (1) shows the main sources of air pollution. For ease of transmission and spread from one place to another in a limited period of time. Its danger is attributed to its impact on human, animal, and plant health and the environmental and economic damage it causes (Salman et al., 2016; Ibrahem & Alamro, 2020). Transportation is one of the most important and dangerous sources of pollution; because of the pollutants emitted from its exhaust and the proximity of pollution sources to the population. Numerous studies conducted around the world showed that most major cities suffer from a high rate of air pollution, including the largest Arab cities, and that about 60% of pollution comes from transportation (Shaaban, 2004; Al-Dosari, 2006; Al-Rafi'i, 2019; ANSES, 2021).

Figure (1) Sources of air pollution (Minnesota Pollution Control Agency (2021))

Improving air quality has received great attention from the government of the KSA, which included the system for improving air quality within Article 2 of the General Environment Law, and placed it as one of the objectives of the Tenth Development Plan. The HCDR has also paid great attention to the health and protection of Riyadh's environment from pollution. At the forefront of her concerns is air pollution. It sought to improve its quality. The first study on air pollution in Riyadh in 1992 revealed a low level of air quality; Due to several factors, the most important of which is automobile exhaust emissions, in addition to the activities of crushers, industrial activities, and power plants (HCDR, 1995; Al-Dosari, 2006).

The negative effects of air pollution were also evaluated, proposals were made to control the level of air pollution, and several studies were conducted to identify the quality of air in Riyadh and ways to improve it, including a study to monitor the level of pollution by dirt plankton, a study to measure the level of lead pollution, and a study to measure air quality.

Whereas a study by Al-Sanhoury and Al-Nashmi (1996) indicated that the types of pollutants emanating from transportation means vary according to the fuel used, and they can be summed up in carbon monoxide, hydrogen carbonates, sulfur oxides, nitrogen oxides, and suspended particles that contain aerosols in diesel engines and lead in gasoline engines. Pollutants are usually produced by transportation; Either as a result of combustion or incomplete combustion or as a result of adding fuel materials such as lead. The results showed significant violations in many environmental measures of air quality concerning emissions from transportation. Studies also showed that transportation was responsible for about 70% of the total air pollutant emissions in Riyadh, and that the problem of air pollution with car exhaust emissions increases with the use of old or poorly maintained cars, or both (RCRC, 2018).

Based on these results, the RCRC and HCDR, in coordination with other concerned authorities, made efforts to contribute to reducing air pollution resulting from transportation, including:

- Establishing an air quality management and control program to follow up and monitor changes that occur to it, and take appropriate measures in this regard.
- Characterization and implementation of a periodic inspection program that includes a number of technical procedures, including testing the level of exhaust emissions; to reduce transportation exhaust emissions.
- Production of unleaded fuel.

RCRC (2006) approved the formation of the Higher Committee for Environmental Protection in Riyadh to monitor and protect the environment. Al-Duwerj (2019) also indicated that the HCDR had taken measures to preserve air quality, including adopting an air quality strategy in Riyadh, operating air monitoring stations, building new stations to cover the city, cooperating with authorities of common interest, and establishing an environmental database related to air quality.

HCDR (2018) also adopted the comprehensive plan for the city, which included the environmental strategy and the executive program for its protection, which included (50) programs covering six axes, topped by the air quality axis. Air quality is monitored through (32) air pollution monitoring stations, including (17) stations operated by the authority, (14) stations operated by the General Authority for Meteorology and Environmental Protection, one station located in the second industrial city affiliated to the industrial cities. The purpose of these stations is to measure the concentration of the pollution level of ten polluting elements. These stations were distributed in the city; it measures air quality every 15 minutes for continuous monitoring of air pollution. These stations have contributed to an accurate assessment of pollution levels, which helped improve the air quality level in the city. The reports of the air quality monitoring stations of the authority concluded that the air quality rate is at a positive level.

Al-Khudairi (2008) study of air pollution in Riyadh relied on the measurements of the five monitoring stations of the King Abdulaziz City for Science and Technology, and compared the pollution rates in Riyadh with the Saudi standards, and concluded that the average concentrations of sulfur dioxide, carbon monoxide, ozone, hydrogen sulfide, and nitrogen oxides are all located Within the acceptable limits according to air quality standards in the Kingdom.

The air quality in Riyadh was evaluated by measuring six types of gases from 1999–2004. It was found that 71% of the air is good, and the northeastern part of Riyadh is the least polluted (Alharbi, et al., 2014). Al-Duwais (2015) also measured the ozone concentration in Riyadh, and found that the air quality in the city is good, with a rise in ozone levels in the south, south, east, and west of the city.

Health risks of air pollution:

Air pollution is one of the leading risk factors for death. In low-income countries, it tops the list. In 2017, it was responsible for an estimated 5 million deaths globally. That means it contributed to 9% – nearly 1-in-

10 – deaths (Ritchie and Roser, 2017).

There is a direct relationship between the percentage of lead used in car fuel and its concentration in the air and human blood, and that this substance is one of the most dangerous pollutants; Because of its toxicity and its negative impact on the nervous system, especially cognitive development in children (Shaaban, 2004). Air pollution with gases emitted from automobile exhaust causes many diseases, primarily respiratory diseases, in addition to its contribution to global warming, increased mortality, and childhood cancer. (Pope et al., 2002; Reynold et al., 2002). Table (4) show the effect of some air pollutants.

Table (4) the effect of some air pollutants

Type of pollutant	Produced from	Effect on health
CO	incomplete combustion	It leads to difficulties in transporting oxygen in the tissues, and in case of its high concentration, it may lead to suffocation and death
CO2	complete combustion	It causes difficulty breathing and a feeling of suffocation and affects the mucous membranes, causing inflammation in the bronchi.
NO2	By-products of high-temperature fuel combustion	It causes a high sensitivity of the lung to many diseases and is also involved in the formation of some compounds that irritate the mucous membrane of the eyes.
Hydrocarbons	Unburned or partially burned fuel	It contains toxic and carcinogenic substances.
Lead particles	Fuel combustion	Joint and muscle pain, anemia, inflammation of the peripheral nerves, and kidney disease also negatively impacts cognitive development.
* SOURCE: Al-Muqri, (2015); World Health Organization (2018); Chen, G., et al. (2015); Kampa, & Castanas, (2008)		

Table (4) shows KSA death rates from air pollution over time – shown as the total air pollution, in addition to the individual contributions from outdoor and indoor pollution.

Table (4) KSA pollution deaths rates

Saudi Arabia	1990	2017	Absolute Change	Relative Change
Air pollution (total)deaths per 100,000	75.39	64.08	-11.32	-15%
Indoor air pollution deaths per 100,000	15.28	0.16	-15.12	-99%
Outdoor particulate matter deaths per 100,000	3.92	2.7	-1.23	-31%
* SOURCE: Ritchie and Roser (2017).				

The impact of emissions from transportation exhausts on air pollution in Riyadh and its health risks to its residents are clear. And according to the continued growth of the city's population and its geographical expansion, these risks will be exacerbated.

However, the authority, in cooperation with other responsible authorities, was aware of this and sought to improve air quality through pollution control and implementation of major transport development projects, the most important of which is the King Abdulaziz Project for Public Transport; to promote social and economic development, protect the environment, and improve the quality of life in the city.

Study Procedures:

The study relied on the statistical analytical approach using the statistical and qualitative data of the Royal Commission for the City of Riyadh and the Higher Commission for the City of Riyadh and analyzes previous studies on the King Abdulaziz Project for Public Transport in the city and on the data on pollution and air quality in the city available to the Environmental Department. Some mathematical equations were also used to predict the population of Riyadh for the years 2020–2030, and the number of daily trips in the city.

The Results

To answer the first question, the expected growth of Riyadh until 2030:

According to the Authority's expectations, the population of Riyadh will grow by 4% annually until 2020 and then decrease to 3% until 2030. Based on these percentages, the study made population projections for the years 2020 and 2030, using the following equation:

$$\text{Population} = \text{Population} (1 + g)$$

Where: *Population* = the number of people in the year to be expected; *Population* = the number of people in the base year; *g* = the percentage of population increase in Riyadh, which is (4% in the thirties)

and (3% in the forties); and m = the number of years between the base year and the year to be expected.

To find the expected number of daily trips, the ratio of trips to the population in 2010 was used, which is (11799) daily trips for every ten thousand population. Table (4) shows that the expected population of Riyadh in 2020 will reach about (7.8) million and rise to about (10.4) million in 2030. While the number of daily trips will reach more than (9) million trips in 2020, then it rises to more than (12) million trips by 2030.

Table (5): The expected numbers of residents and daily trips in Riyadh in 2020 and 2030

The year	expected numbers of residents	expected daily trips
2010 (actual)	5254560	6200000
2020	7778032	9180000
2030	14530255	12330000

* Table prepared by researchers

This rapid growth in the city's population and the number of their daily trips will exacerbate the problem of traffic congestion, and consequently, transportation exhaust emissions will increase. Air pollution will increase, with severe repercussions for the health of the population and the environment.

To answer the second question, the current situation of air pollution in Riyadh:

The rapid growth in the city's population, its urban expansion. Its sprawling outskirts, the lack of a public transportation system in the city, and the excessive dependence on the car; Making the city suffer from traffic congestion and its effects from increased emissions from vehicle exhaust. Air pollution is a concern for the population and the responsible authorities. Table (6) shows the most important air pollutants during 6 years.

Table (6) most important pollutants in Riyadh during 6 years

Concentration of	2013	2014	2015	2016	2017	2018
O ₃	89	96	92	78	44	50
co	40	42	56	44	19	12
So ₂	2	2	2	2	1	3
No ₂	93	100	73	100	64	45
* <i>The General Authority for Meteorology and Environmental Protection (2018); HCDR (2019); RCRC (2018)</i>						

To reduce air pollution from vehicle exhaust emissions, the responsible authorities have taken measures and measures that have proven their feasibility in reducing air pollution. The most important of which are: the production of unleaded fuel and the development of the periodic inspection program for cars by applying mechanical inspection systems to include the level of gas emissions from the exhaust; Which reduced the contribution of transportation to the air pollution in Riyadh. The authority also monitors air quality through (17) air pollution monitoring stations, distributed throughout the city, to measure the concentration of the pollution level of ten polluting elements; For continuous monitoring of air pollution from its various sources, and its evaluation as in table (7).

Table (7) Air Quality Monitoring Network Locations in Riyadh

No.	Site/station category	Station location	Pollutants to be monitored
1	Back round	North - the government humanitarian city of Sultan bin Abdul Aziz City for Humanitarian Services	PM10, PM2.5, NOX, SO2, O3, benzene, Pb (PM10 gravimetric), PM2.5 (gravimetric)
2	Back round	East - National Guard Hospital	PM10, PM2.5, NOX, O3
3	Back round	South - Ha'ir Road	PM10, PM2.5, NOX, SO2, O3
4	Back round	Western - Wadi Hanifa / Dam Al-Rida	PM10, PM2.5, NOx, O3
5	Suburban	Azizia	PM10, PM2.5, NOX, SO2, CO, H2S, NMHC, benzene
6	Suburban	Alshifaa	PM10, PM2.5, NOX, SO2, CO
7	Suburban	Alabama	PM10, PM2.5, NOX
8	Suburban	Downtown - Al Fota Park	PM10, PM2.5, NOX, SO2, CO, O3, benzene, Pb (PM10 gravimetric), PM2.5
9	Suburban		PM10, PM2.5, NOX
10	Suburban	South city- Almoraj Park	PM10, PM2.5, NOX, SO2, O3, benzene
11	Suburban	Western city- Arij Park	PM 10, PM2.5, NOX
12	Traffic	King Abdullah Street	PM10, PM2.5, NOx, co, benzene
13	Traffic	King Fahed street	PM10, PM2.5, NOX, CO, benzene, Pb (PM10 gravimetric), PM2.5 (gravimetric)
14	Traffic	Makkah street	PM10, PM2.5, NOx, co, benzene
15	Traffic	Northern Ring Road	PM10, PM2.5, NOx, CO
16	Traffic	Southern Ring Road	PM10, PM2.5, NOx, CO
17	Mobile	Mobile	PM10, PM2.5, NOX, SO2, CO, O3, benzene, NMHC, H2S
* General Authority of Meteorology and Environmental Protection (2016); HCDR (2019); RCRC (2018)			

The Riyadh Air Quality Index has been specifically designed to suit the situation in the city. The Riyadh Air Quality Index includes 6 pollutants: (NO2, O3, PM, PM25, PM10, CO, and SO2). The Riyadh Air Quality Index uses the approved beam/band system Riyadh Development Authority (ADA), Presidency of Meteorology and Environment (PMIE), King Abdul-Aziz City for Science and Technology (KACST), and Saudi Industrial Property Authority Using the index system 1–10 + divided into five packages (Al-Dosari, 2006; RCRC, 2018).

The AQI Air Quality Index is a numerical system used to show relevant stakeholders what the current and (where possible) expected situation is. The level of pollution and the greater the health concern. When the indicator's value rises, a larger proportion of the population is more likely to experience adverse health effects.

Which helped to improve the level of air quality in the city, and the reports of monitoring stations concluded that the level of air quality is positive and reassuring.

To answer the third question, the expected impact of the KAPTP in on the air quality the Riyadh:

The authority was keen to implement many sustainable development projects in the city; to improve the quality of life and protect the city's environment. Among these development projects, major transportation projects. At the forefront of this is the KAPTP. It is a giant project that is considered a quantum leap in sustainable development. Because it provides modern transportation, runs on a network that covers the city's neighborhoods, and provides safe and efficient transportation services regularly during most hours of the day.

Al-Rafi'i (2019) The project network paths used in them have been defined according to several criteria, the most important of which are: Compatibility with the general structural plan of the city, and its future expansion, the results of traffic simulation models, which are based on the investigation of the origin and purposes of trips and the volume of traffic on city roads and streets, the concentration and distribution of population densities in the city, and serving high traffic attractions such as universities, schools, hospitals, and commercial complexes. In light of these criteria, the project consisted of two main sectors:

(1) *Riyadh's rail network* consists of six lines, 176.5 km long, distributed over the city's neighborhoods, as shown in figure (1) and table (7). The network's trains run on electric power and rely on automation. This network will form the backbone of public transportation in Riyadh. It covers most densely populated areas, major government agencies, universities, downtown, King Abdullah Financial District, King Khalid Airport, public transport center, and others.

Table (7): The rail network lines and their lengths in the KAPTP.

The line	Color	Length by Km
first line	blue	38.0
second line	the Red	25.3
third line	orange	40.7
quarter line	yellow	29.6
Fifth line	the green	12.9
Sixth line	Violet	30.0
Total		176.5

These lines are characterized by a short run-down time, ranging between (180–220) seconds at the start of the operation; then it decreases to a range between (90–220) in 2030. These lines pass through (85) stations, distributed as follows: (Four main stations at the intersections of the train network lines, Five transfer stations for transfer between train tracks or integration with the bus network, and 76 regular stations).

(2) *A bus network*: The network aims to be a major tributary to the train network and a major transporter for passengers. The network is about 1,200 km long, passing through 6,700 stations. As Figure (2) Shows, the bus network consists of three levels of service: (Three bus lines with dedicated lanes on the main roads, 18 regular bus lines on main roads and streets, and Bus lines feeding into neighborhoods).

The bus fleet consists of three sizes of buses of a unified design, commensurate with the volume of transportation demand, and is equipped with modern technologies; To facilitate tracking and provide passengers with updated information on flight times. These buses are equipped with diesel engines that use clean fuels complying with the high standards set by the European Union "Euro 5"; To ensure the reduction of harmful emissions from car exhaust, it is a semi-sulfur-free diesel, as the percentage of sulfur is very low, less than (10) parts per million, compared to (500) parts per million in regular diesel, and its advantages: Extending the operating life for vehicle engines, reducing harmful emissions from the combustion process, that is, it helps reduce pollution and preserve the environment.

Figure (1) Routes of the public transport network in Riyadh: trains and buses

The Authority has announced that the completion rate of the project has reached more than 85%. The study expects that operation will start in 2022. The authority expects that the project, after its operation, will contribute to the transfer of about 20% of daily trips, and it was estimated at (1.16) million trips on the Riyadh train, and (900,000) trips on the Riyadh buses, and of course, part of the Bus trips will continue on the train, and it is expected that the number of passengers will increase in 2030 to (3.6) million passengers per day.

The study considers that many factors can help a large percentage of Riyadh residents and visitors switch from a private car or taxi to public transportation, and they can be classified into three categories, as follows:

1. The attractive features of the King Abdul Aziz Public Transport Project, the most prominent of which are: (Comprehensive service coverage for the city's neighborhoods, short rushing time, integration between the train and bus networks, proximity between the passenger and the nearest station, the use of modern technology in operation, transfer, and exchange of information, attention to security and safety, taking into account the privacy of society, securing private parking for passenger cars).
2. The repulsive features of the traffic movement, the most important of which are: (the traffic congestion witnessed in Riyadh, and even the traffic jam in many places at different times, the seriousness of the traffic movement and the consequent many traffic problems such as traffic accidents, nervous exhaustion, and psychological tension while driving).
3. It is enacting the necessary legislation and policies. The shift from a private car to public transportation will depend on enacting legislation and policies and taking measures. To reduce the use of private cars, and to facilitate the use of public transport, the most important of which are: (that the tariff for its use is within reach of most segments of society, imposing fees on the use of highways and some main roads, imposing fees on public parking or provided by employers, intensifying and tightening traffic control for parking violations).

All of these factors will help convert a large proportion of trips carried out by private cars or taxis to public transportation. On the other hand, this advanced public transportation will stimulate the generation of many trips, which the owners were unable to take; for reasons of transportation.

The study expects that the implementation of the project will be completed, and its operation will start in 2022. According to the project bulletin, after the city residents and visitors adapt to it, and its impact stabilizes, the authority expects to transfer 20% of daily trips from other means of transportation, especially from the car, whether private or taxi, to transportation in terms of trains and buses. As for the study results, it is expected that the number of daily trips that public transport will carry around (1.8) million trips per day, which is slightly less than the expectations of the authority.

According to the project bulletin after ten years of operation (in 2030), the number of trains will increase from 190 to 300, and consequently, the time of trains will be reduced by almost half. In addition, the study, based on its previous predictions that the city's population would rise to more than ten million people in 2030, and the improvement in public transport services referred to above; It expected the number of daily trips carried by public transport to rise to about three million trips per day, which is also slightly less than the authority's expectations.

The expected impact of the project on air quality:

To reach an adequate estimate of the impact of the KAPTP in reducing pollution in the city, the following aspects must be taken into consideration:

- Energy sources for public transport: As the project, trains will be powered by electric power, and the buses are powered by Euro 5 diesel, which is a clean type of diesel; because it is free of sulfur. Therefore, the percentage of pollution issued by the two means of transport in the project is minimal.
- Shifting trips to public transport: The shift of 20% of trips from the car to public transport after it becomes operational in 2022 will reduce energy consumption and thus reduce air pollution from vehicle exhaust emissions. The study estimates that air pollution due to cars will decrease by about 20% after the project is operational, and then decrease further to about 30% in 2030.
- Traffic flow: One of the most prominent positive effects of switching from private cars or taxis to public transport is the significant improvement in the flow of traffic, and the fading of traffic congestion on the city's road network, except for peak hours, but it will be lighter. This means an improvement in the efficiency of transportation in the city, and its most prominent manifestations are an increase in the average speed and a decrease in the average time for daily trips. This means a further reduction in air pollution caused by car exhaust emissions, and the study estimates that it will decrease by about 10%.

From the above, we conclude that the project's expected impact will lead to a reduction in air pollution from car exhausts by about 30% after the project is operational in 2022, and the percentage will rise to 40% in 2030.

Therefore, this project is one of the most important sustainable development projects implemented by the authority, for its expected role in providing a safe and efficient public transportation service in Riyadh; Reducing the city's community's dependence on the private car or taxi, alleviating traffic congestion and the problems arising from it, and enhancing the flow and smoothness of traffic. All of this will help reduce air pollution from vehicle exhaust, which will significantly improve air quality, improve quality of life, and protect the environment and society.

To answer the fourth question, the most important recommendations that can reduce pollution in light of KAPTP outputs.

A questionnaire was designed for the most important recommendations that could reduce pollution in the light of the KAPTP, and the questionnaire was directed to fifty experts in the field of pollution treatment.

With the approaching operation of the KAPTP, and to reduce pollution caused using transportation, based on the results of the study, the following recommendations emerged in table 8 (as Experts showed in the questionnaire):

Table (8): the most important recommendations that can reduce pollution in light of KAPTP

No.	<i>Recommendations to reduce pollution in light of KAPTP</i>	%	Mean	Standard Deviation
1	Be careful to study the public transportation tariff in light of the community's social specificity and economic conditions.	90%	3.44	.76
2	Imposing fees for the use of highways and some arterial roads in the city of Riyadh.	94%	3.16	.53
3	Regulating the movement of transport within the city, especially some traffic signals on the main streets; to increase its carrying capacity; Which will help in more smooth traffic.	92%	3.15	.88
4	Imposing fees on private parking spaces provided by government institutions and bodies.	90%	3.98	.88
5	Intensifying traffic control and tightening it on parking violations.	92%	3.98	1.00
6	Availability of public transportation to transport students at nominal prices, or at least secondary school students, while providing them with safety precautions.		3.65	.44
7	We encourage walking, whether to go to public transport stations or to nearby walks, and prepare more sidewalks for pedestrians, keep them away from dangerous traffic, and remove dangerous objects or obstacles to movement.	88%	3.78	.19
8	They are studying reducing the number of public taxis, evaluating licensing procedures, and preventing companies from using dilapidated buses to transport their workers.	86%	3.78	.45
9	Awareness and education of the importance of public transport and its relationship to air quality, and consequently the quality of life, health of the population and the environment.	90%	3.95	.82
10	They are enhancing the role of community members in protecting the air from pollution through their cooperation with the concerned authorities and encouraging them to reduce air pollution.	92%	3.99	.96

Conclusion

The study examined the expected impact of one of the major sustainable development projects in Riyadh on air pollution caused by vehicle exhaust emissions, the KAPTP, whose final stages are being implemented, and the project is expected to be completed and operational in 2022. Among the most important findings of the study:

- The population of Riyadh in 2020 is expected to reach about (7.8) million and rise to about (10.4) million in 2030.
- It is expected that the number of daily trips will reach more than (9) million trips in 2020 and increase to more than (12) million trips in 2030.

- The project's expected impact will lead to a reduction in air pollution from car exhausts by about 30% after the project is operational in 2022, and the percentage will rise to 40% in 2030.
- It is expected that the implementation of the KAPTP, with its two parts: trains and buses, will be completed and will start operating to serve the city's residents and visitors in 2022.
- In 2022, it is expected that 20% of daily trips will shift from other means of transportation, especially the car, to public transportation, including trains and buses. That is about (1.8) million trips per day, which will have a significant positive impact on traffic flow.
- In 2030, given the nearly doubled number of trains, and the increase in the city's population, the project's contribution to transportation is expected to increase to about 25% of the number of daily trips, or about three million daily trips.
- Due to the dependence of trains and buses on clean energy, and the conversion of a large proportion of daily trips from private cars or taxis to public transport, and the significant improvement in transportation efficiency, the project is expected to reduce air pollution from gases emitted from automobile emissions by about 30% after operating The project, and then to about 40% in 2030. It should be noted that this expected improvement in the flow of traffic will encourage some to use private cars, so it is necessary to take the necessary measures; to reduce their use, and stimulate the use of public transport.

Declarations

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Conflict of Interest:

There is no conflict of interest in this manuscript.

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Figures

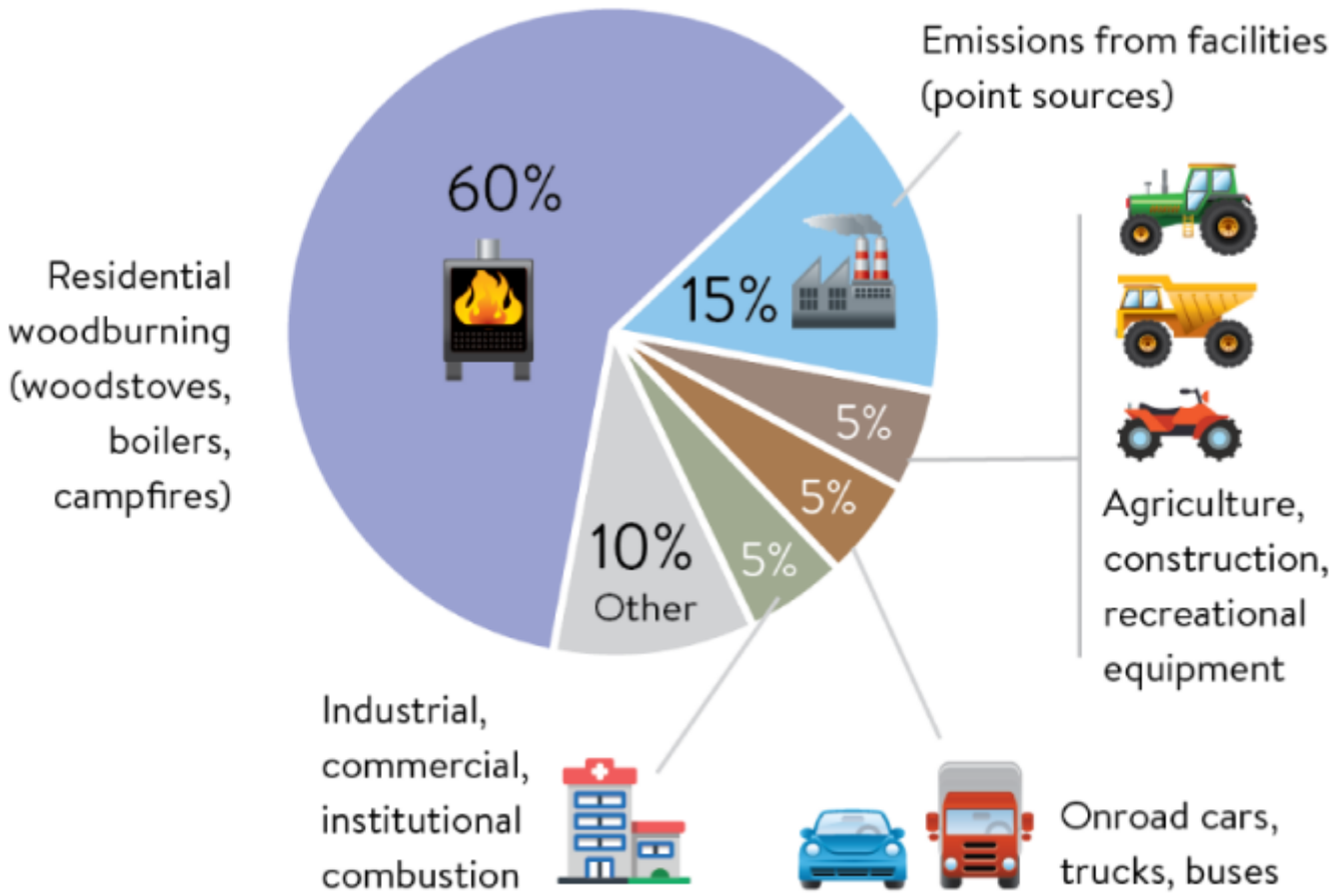


Figure 1

Sources of air pollution (Minnesota Pollution Control Agency (2021))

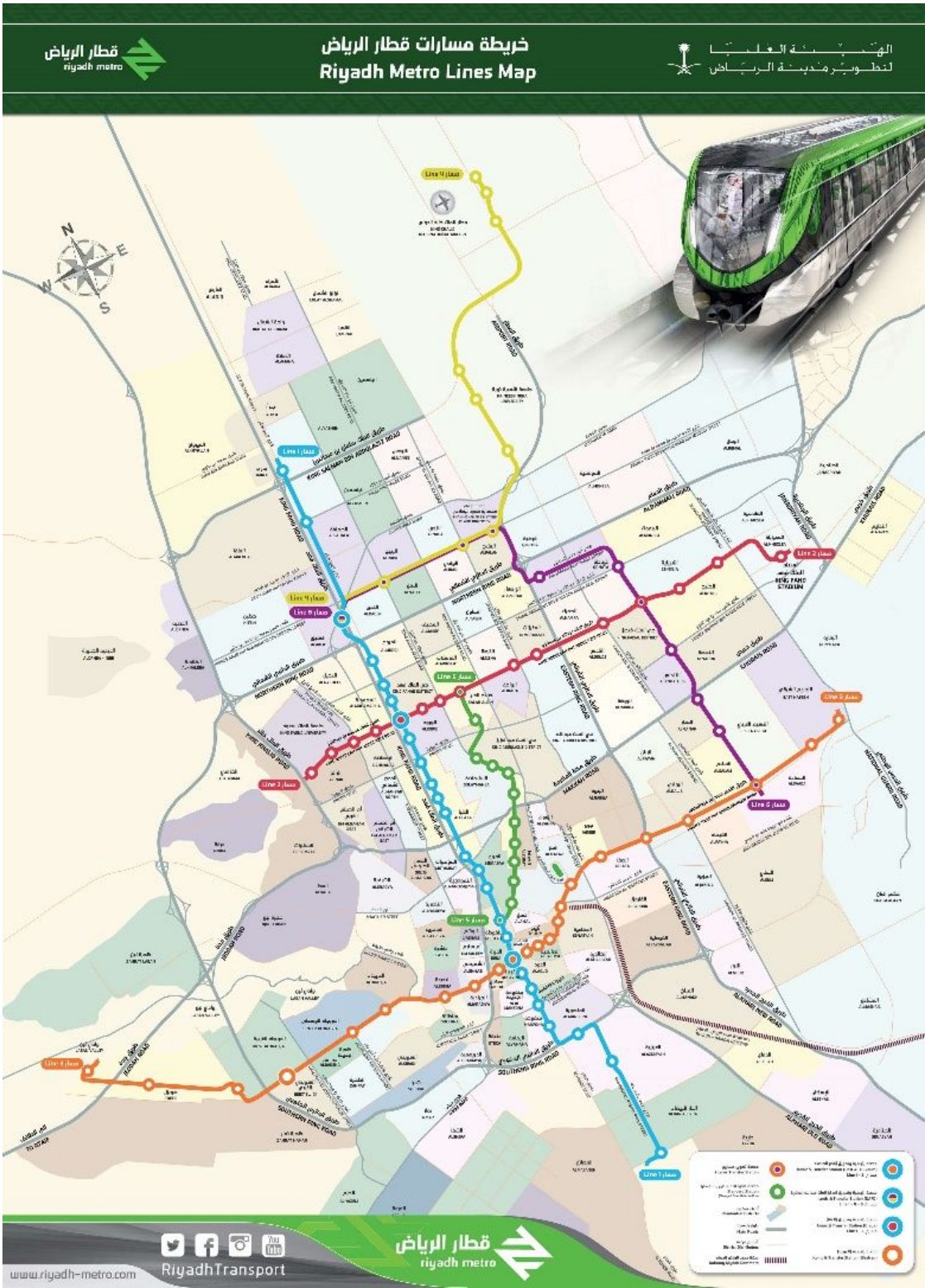


Figure 2

Routes of the public transport network in Riyadh: trains and buses