Air Quality and Urban Planning Policies

The Case of Cairo City CBD

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Abstract

Over the past fifty years, the population of Cairo city, the capital of Egypt has exploded from about two million people in 1952 to nearly twenty million nowadays. Immigration to the attracting city created this dramatically augmented population, which resulted in a number of daunting challenges pressuring the city. One of these difficulties is the release of hundreds of pollutants, either by natural factors such as the dust, in particular with the lack of rainfall or by man’s activity, exacerbating the urban environment, moreover, placing Cairo in the second place in levels of particulates in the world after New Delhi. Particulate materials are considered the most threatening component in the city polluted air, as they represent 96 percent of the total economic cost of air pollution that reaches to $1.8 billion annually. In addition to their contribution in spreading diseases leading to thousands of premature deaths, impaired child development, and lost worker productivity. Therefore, the research aims at exploring and highlighting the possible urban planning policies and strategies to counter the pollution problem as to protect and enhance the air quality. Cairo’s downtown is selected as a case study, as it suffers from traffic congestion, high auto- dependency, and an elevated air pollution level. Currently, the Egyptian local authorities had banned parking on the sideways in downtown, in order to control traffic jams, but is this enough to alleviate the poor air quality? This paper discusses and analyzes current initiatives to reduce air pollution in Downtown, and hurdles facing implementing the Egyptian environmental law. It concludes with proposed policies to mitigate the dilemma and prevent it from threatening future generations. The policies comprise expanding green spaces; adopting green roofs; providing well connected improved public transportation system; diverting through traffic, transforming selected areas to low emission zones, encouraging cycling and walking; and restructuring the land use plan of the area. Other measurements are suggested such as vehicle testing and tune-up; utilizing cleaner vehicle fuels, and increasing the use of compressed natural gas (CNG) buses. Finally, it is found that executing air quality policies requires the collaboration of national institutions, local governments, technical professionals, business and the public, as well as awareness campaigns. Short and long term solutions are proposed to safeguard better air quality, thus better health and enhanced quality of life for all city residents.

1. Introduction

Egypt, as a developing country, is categorized as a highly rated urbanized Third World country, its capital city, Cairo suffers from prompt increase in the population, reaching 22 million in 2016 (Capmas, 2016). Such rapid population growth and related economic development have a large effect on the life in Cairo and has created a number of challenges that city must meet in order to face the future. A major challenge is the low air quality generated due to vehicle emissions, industry, and the open burning of agricultural waste (USAID/Egypt, 2004a). Natural factors, including the dusty environment and the lack of rainfall, aggravate the air pollution dilemma, resulting, for example, in a severe air pollution episode labeled by the “black cloud” during the fall (USAID/Egypt, 2004). Additionally, Cairo has a poor dispersion factor ¹as a result of the lack of rain and its layout of high buildings and narrow streets; both create a bowl effect (Hassanein, 2016).

When analyzing Cairo’s air pollutant substance, it is found that particulate matter has been tagged as the most dangerous pollutant.

¹ The dispersion factor is how fast the pollutants in the air are dispersed because of the weather conditions like the wind, rain, air, temperature, as it makes a difference in the severity of exposure to air pollution.
Particulate matter (PM) is a complex mixture of various things which are suspended in the air. It is made up of nitrates, sulfates, dust and soot and is easily inhaled by humans. PM are categorized into three types, first is PM10 is for particles 10Um or less and PM2.5 for particles of 2.5Um or less and ultra-fine particles (less than 0.1Um) (EEB et al., 2015). High levels of PM can result in allergies, respiratory disease, cardiovascular disease, coughing, the risk of mortality among young children, and lung cancer. Furthermore, it has also been associated with economic costs for cities and health systems (Slovic et al., 2015; EEB et al., 2015). In 2014 the estimated damage is at least 6,000 premature deaths annually, 5,000 cancer cases over the lifetimes of current Cairo residents, approximately 35,000 additional hospital admissions annually due to respiratory and heart diseases, and 6 million working days lost annually by Cairo’s workforce due to illness (USAID/Egypt, 2004a). Another estimation stated that the air pollution costs the Egyptian economy at least $1.3 billion annually from particulate matter, $26 million or more annually from sulfur dioxide, and $25 million or more annually from lead (USAID/Egypt, 2004a). The sources of air pollution in Cairo differ as shown in [Figure 1]. Emissions from motor vehicles (fossil fuel emissions) contribute to 32 percent to the problem, dominating the sources of air pollution (USAID/Egypt, 2004). Vehicle emissions are the sources of pollutants such as particulate matter, nitrogen, and ozone. As for particulate matters (PM2 & PM10), their annual average levels in Cairo both exceed the WHO and Egyptian standards by double to 9 times [Figure 2] (Kamal, 2012). This health and economic burden are particularly concentrated in areas with high traffic congestion, such as the city’s CBD, due to hosting different uses and activities. Traffic congestion compromises the district air quality, therefore the health of all exposed population.

2. Research methods

This study was conducted using primary and secondary data. A characteristic survey of Cairo's CBD physical environment was conducted, in addition to interviews with distinguished urban planners. The physical characteristics comprised the existing land uses, parking facility availability, walkway provision and usage, horizontal and vertical compactness of buildings in the study area, and finally the existing streetscape. The interviews were conducted with leading urban planner2, in order to apprehend their professional feedback on the proposed paradigm, and to capture their options regarding the impact of the solutions, the feasibility of applying, obstacles facing implementation and recommended urban policies and actions to improve the air quality in the case study.

3. Cairo CBD traffic cognition

3.1 Case study overview

Downtown Cairo was developed by Khedive Ismail in 1869 to showcase a modern Cairo as “the symbol and showpiece of Egypt’s progress” [Figure 3]. The downtown was designed with a radial network of straight, wide streets connected by squares, and public green spaces, all which contrast with the complicated network of narrow streets in the urban design of Islamic Cairo (Awatta, 2015). The CBD connects north Cairo (Nasser City) with west and south districts as Giza and Maadi. The case study boundaries are shown in [Figure 4] enclosed between Ramsis street, Mohamed Mahmud Street, El Gomhoria and Nagib El Rehani street. That area includes main and local streets.

A transformation in the identity of downtown started in 1950, from an elite and exclusive space into a commercial center inhabited by middle-income families. Currently, it hosts state-owned business enterprises, department stores, cultural activities, entertainment uses and administrative buildings generating thousands of

2 Professors of urban planning in Cairo University, who participated in studies and development projects in Cairo’s CBD.
traveling journeys. By time, Downtown has been overtaken by traffic, with little public space left, the cancerous expansion of street vendors overtook several lanes and sidewalks causing traffic and parking obstruction.

3.2 Traffic emissions in Cairo’s CBD

Traffic congestion is a serious problem, especially in the downtown during the peak hours of the mornings and evenings. It causes noise pollution and contributes to creating heat islands, by adding 5 degrees to the average temperature (Chew et al., 1998). The CBD is responsible for 5.8% of the congestion cost in traffic zones in the Great Cairo Metropolitan, as it is estimated around 400 million Egyptian pounds (ECORYS Nederland BV and SETS Lebanon, 2010). Congestion is said to occur when transport demand exceeds transport supply at a specific point in time and in a particular section of the transport system (Aderamo, 2012). It is reflected by slower speed, longer trip times and increased motor vehicular queuing (Kiunsi, 2013). The number of passenger cars entered the downtown in 2012 was 286,500 car, 56,755 taxis, 1,972 buses, 36,808 trucks. The public transport daily trip generation is estimated for 2017 by 522,053. Average speed is 11 kilometers per hour in morning peak period (8:00-10:00 am) and evening peak period (5:00-7:00 pm) (ECORYS Nederland BV and SETS Lebanon, 2010; World Bank Group, 2014). Idling vehicles and vehicles in stop -and go traffic emit more pollutants than vehicles traveling at even speeds (Spirn, 1986). [Figure 5] shows that private cars and taxis dominate the traffic mode, which indicates a high auto dependency rate. Nearly 70% of all registered vehicles in the country are greater than 15 years old, and more than 64,000 micro-buses are greater than 20 years old. 63% of the bus fleet and 43% of the minibus fleet exceed 12 years age (Krambeck, 2010) [Figure 6]. The aging fleet is prone to frequent breakdowns and low-quality emissions.

Auto dependency in the CBD can be explained by the falling car prices, insufficient mass transit. As well as users’ strong preferences for comfort, time saving, convenience, flexibility, reliability, privacy, obtainable by private vehicles. The increased demand for cars and hence road space have aggravated the traffic congestion. Not to exclude other reasons intensifying the traffic predicament, as poor traffic management, weak enforcement of traffic rules and regulations. Similarly, limited parking capacity, few traffic signals, random stops by cars and minivans, the absence of proper pedestrian crossings and U-turns, and the violation of the right of way (World Bank Group, 2014). Unfortunately, municipal regulations in Egypt have contributed to misallocating land use, by permitting the conversion of residential buildings to commercial purposes. In addition to deep, narrow street canyons oriented perpendicular to prevailing winds, with long blocks and buildings of similar height, which created places with poor air circulation trapping the pollutants in the street Canon (Spirn, 1986), causing elevated PM10 levels, exceeding double the annual Egyptian maxim limit [Figure 7].

![Figure 4. Case study boundaries](image4.png)

Source: Researcher

![Figure 5. Traffic mode composition](image5.png)


![Figure 6. Distribution of age of all registered vehicles in Great Cairo](image6.png)

Source: Central Department of Air Quality and Noise Protection, 2007

![Figure 7. Annual Average concentration (PM10 in the case study from 1999—2015](image7.png)

3.3 What is done to control air pollution the CBD?

Several attempts are accomplished to combat air pollution in Cairo city on the national and the local level [Figure 9]. The Cairo Air Improvement Project (CAIP), is a significant investment by both USAID and the Egyptian government, responsible for air pollution control activity on the national level, it established a network of 36 monitoring sites in Greater Cairo to sample the air. Another attempt is the Egyptian Environmental Policy Program (EEPP), which is dedicated to laying down policy elements essential to Egypt’s environmental management agenda. Their contribution in eliminating traffic emissions can be summarized into the following (USAID/Egypt, 2004; USAID/Egypt, 2004a):

- Introducing compressed natural gas transit buses, which release 91 percent fewer particulates than diesel buses and are expected to remove 64 metric tons of particulates from the air over its lifetime.
- Starting to convert government vehicles to CNG, already about 250 vehicles have been converted.
- Launching a national vehicle emissions testing program, as testing is now mandatory for 500,000 vehicles in Cairo.
- Transferring Nearly $20 million in US environmental technology and related commodities to cover buses and their maintenance, air and industrial monitoring, vehicle laboratories, and vehicle emissions testing.
- Providing a comprehensive air monitoring system for greater Cairo.
- Introducing unleaded gasoline.

In order to alleviate the traffic in the city, a new ring road is being designed to carry traffic not destined for Cairo around the city, easing congestion on the roads. The third metro line is being constructed, seeking to reduce the amount of automobile traffic. On the Local scale, initiatives in the CBD primarily aimed at reducing the traffic jams, which directly affect the air quality. In 2014, the governorate of Cairo commenced a campaign to remove all street vendors by force from the streets of the downtown, particularly Tal`at Harb, Qar al-Nil, 26th of July, and Ramsis streets. Moreover, the government installed new traffic lights (Awatta, 2015). The second stream of interventions is the opening of the Tahrir underground garage, that accommodates 1,700 vehicles. This compliments `Umar Makram parking garage (600 vehicles), El Opera garage (1370 vehicles), Tala Harb garage (700-vehicles), Bab El louk garage (150 vehicles), El Bostan garage (10000 vehicles). Moreover, few streets were transformed to pedestrian paths as El Alfy Street.

Despite the exerted efforts, it appears that such approaches have not fully delivered the desired results regarding minimizing the number of vehicles penetrating the CBD and reducing the air pollution. For instance, the emission tests are not applied, and CNG buses are not enough. In the CBD, it is found, though the traffic flow has improved, the number of cars has increased. Commuters are discouraged to use the new garages due to the high prices, particularly for those who work and need to leave their vehicles for over 8 hours or those who live in downtown (Awatta, 2015). Moreover, there is no public transportation to connect the garages with the CBD, in addition to the extended time that vehicles consume looking for a parking spot on secondary streets, which mean more emissions. Consequently, it could be concluded that the local government solutions did not aid the air pollution predicament.
4. Urban planning policies and air pollution

The role of urban planning is to manage the spatial organization of cities for efficient allocation of urban infrastructure and land use. Depending on how it is applied, urban planning can improve air quality in the long run by strategic locations of polluting sources and exposed population, and by encouraging a city structure that would minimize pollution emissions and build-up (Bertaud, 2002). For a given urban population, the length and number of daily trips are closely correlated with the average population density in built-up areas, and the spatial distribution of trip destinations and origins (Bertaud, 2002). Therefore, the aim of current and future urban development plans should include decreasing the number of trips and preventing the accumulation of pollutants. The former objectives don't only have an impact on air pollution, but also result in substantial secondary benefits, such as less hazardous roads, reduction in CO2 emissions, less noise, and improved health (Slovic et al., 2015). There are a variety of urban planning strategies to improve air pollution that can be implemented at a local level, as the following [Figure 10]:

Strategy 1. Prevent Emissions
- Remove source of emission
- Prevent release of pollutants

Strategy 2. Reduce Emissions
- Minimise the number of vehicles
- Improve traffic flow
- Reduce peak emissions

Strategy 3. Enhance the Air Circulation
- Promote penetration of winds
- Avoid spatial confinement

Strategy 4. Remove Pollutants from the Air
- Plant landscape filters
- Use special coating and construction material to absorb the pollutants

Figure 9. National and local actions to control air pollution in the CBD
Source: Researcher and USAID/Egypt, 2004
4.1 Balance Land use plan

Land use planning measures are considered to counter air pollution since their benefits are long term. The urban shape determines locations of emission sources and where people spend their time, as well as emission levels by influencing the amount of polluting activities (Bertaud, 2002; Spiri, 1986). Land use strategies that maintain a high density, limit sprawl, and promote local destinations, could moderate growth in travel distances, therefore, control the emissions released into the air (Rayle et al., 2010; Litman 2016; Thambiran and Diab, 2011). A successful plan would balance between minimizing the commuting distance/ number of vehicles, and between preventing over populating and traffic congestion. This plan could be established through a solid integration between land use planning and traffic planning (Arizona Department of Transportation Research Center, 2012).

4.2 Design for carfree zones

Low Emission Zones (LEZs) are urban areas or roads where vehicles are restricted from entering. The resurrection means that cars are banned, or in some cases charged, if they enter the LEZ when they do not comply with certain emission requirements. Restrictions can be set on a permanent basis for certain streets, or temporarily such as during certain times of the day. LEZ is useful for substantial and immediate effects in areas with poor air. In Berlin, LEZs have been effective since 2008, one year after applying, Berlin’s emissions of diesel exhaust particulates had decreased by one-quarter and nitrogen oxide (NOx) emissions had fallen by 14% (EEB et al., 2015).

4.3 Minimize car parking

Regulating and limiting the number of available parking spaces are effective ways to encourage the use of other modes of transport in various cities. Paris, Copenhagen, and Zurich have recently modernized their parking policy by decreasing the number of public parking spaces and by turning free parking places into paid ones, or increasing existing fees. These measures facilitated reducing commuter car traffic. In Copenhagen, new parking spaces were created underground for residents while the city closed on-road parking spaces, hence improving urban space and urban environment. In addition to its deterrent effects, parking management can also include economic incentives, such as in Amsterdam, where owners of cleaner cars benefit from reduced parking fees (EEB et al., 2015). In Vienna, parking facilities on the outskirts of the city have been established and makes it easy to change from individual car to public transportation (such as underground, or bus) (EEB et al., 2015)

4.4 Discourage private car use

Congestion pricing can also contribute to partly inhibit the use of private cars and solve parking problems in cities Iglesias and Apsimon, 2004). In Stockholm, where a congestion charge has been implemented since 2006, a significant decrease of traffic has been observed (traffic entering the inner city dropped by 18%) (EEB et al., 2015). Benefits include reduction of air pollutants and CO2 emissions, fewer accidents and road casualties. Moreover, the congestion tax generates revenues, which can be reinvested into the same locality (EEB et al., 2015). In many European cities, lowering urban speed limits has been put in place, leading to a significant reduction in emissions. In Stockholm, the majority of the roads are now limited to 30km/h and are accompanied by enforcement measures. Establishing lower speed limits helps to develop other transport modes such as cycling and walking due to a safer environment. One problem is that low-speed procedures depend on law enforcement and the compliance of drivers.

4.5 Eliminate Through traffic

Through traffic solutions involve making the neighborhood streets less attractive to traffic not intending to visit the neighborhood itself. Lower speed limits, more intersections, slower flow, speed humps, congestion fees, all will help to upsurge the travel time and discomfort, hence eliminating through traffic. Proving accessible highways around the neighborhoods is fundamental to divert the traffic far away, protecting residents from fuel emissions.

4.6 Deign streets to accommodate alternative transport modes

Providing spaces to accommodate active transportation and multi-modal means of transport can discourage the use of private motor vehicles and contribute to decreasing emissions in the city. Such spaces could include, lanes for bus rapid transit, bike paths, separated tram lanes (Becerra et al., 2013; Woodcock et al., 2009). Measures to increase the attractiveness of public transport should be implemented to support the urban policies, including aspects as availability, accessibility, reliability, pricing, safety, comfort and accommodate users with disabilities (Litman, 2013). In the case of cycling and walking, it is important to ensure they are safe and convenient means of transport, either by separating the paths and lanes or limiting traffic speed to 30km/hr. To boost using bikes, extensive bike-parking facilities are needed, especially at train/ underground stations and bus stops, in addition to providing a bike-sharing
system (Pucher and Buehler, 2008). The promotion of low-emission vehicles such as electric vehicles as a replacement of conventional cars is also an important measure to reduce air pollution in city centers. Cities should ensure that charging points are easily accessible (EEB et al., 2015).

4.7 Urban form for better dispersion of pollutants

High concentration of PM can occur due to poor urban air ventilation in high-density urban areas. The bulky building blocks, compacted urban volumes and very limited open spaces seriously prevent the pollutant dispersion in these deep street canyons (Yuan et al., 2014). Therefore, apart from having control measures to decrease vehicle emissions, understanding pollutant dispersion as related to the urban planning and design mechanism is necessary in order to guide planners and architects in crafting better environments. Pedestrian-level pollutant concentration depends on the permeability of the entire street canyon. Consequently, to encounter more efficient air pollutant dispersion, the urban form should strive to separate the buildings, create stepped podium void, increase porosity, and avoid narrow spaces between buildings. Although a high building porosity off ground level cannot increase the wind speed at the pedestrian level, it can decline pedestrian-level air pollutant concentrations (Yuan et al., 2014). In street canyons with a rectangular cross-section oriented perpendicular to wind direction, pollutants will tend to concentrate on the windward side of the street. The more sudden the changes in building heights and the more open areas around them, the rougher the surface posed to the wind and the greater the turbulence created. Street canyons lined with buildings the same height tend to have poorer air circulation than street canyons lined with buildings of different heights or that are interspersed with open areas (Spirn, 1986).

4.8 Vegetation works as filters

Urban air pollution can be mitigated through planning and design strategies, including plant preservation and vegetating buildings (Baldauf and Nowak, 2014). Nowadays, more and more researches and studies are focusing on the vegetation benefits as they can aid in reducing air pollution by decreasing energy consumption, and carbon emissions, and also providing barriers between sources and exposed populations. Trees remove gaseous air pollution, primarily by leaf or plant surface. Trees also remove pollution by intercepting airborne particles. The intercepted particle often is re-suspended into the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall (Smith 1990). In one case, the pollution removal by urban trees in the United States has been estimated at 711,000 tons per year or about 11 g per square meter of canopy cover (Nowak et al. 2006). The complex and porous structure of trees and bushes can increase air turbulence and promote mixing and particle impaction as air flows through and around the vegetation. However, tree canopies can also reduce wind speed and boundary layer heights, which can reduce dispersion and potentially increase concentrations in certain areas (Nowak et al., 2000). Trees may also cause trapping of pollutants behind the barrier due to decreased wind flow. Therefore, the proper design for urban vegetation is vital to improve air quality (Baldauf and Nowak, 2014).

Tree selection within urban areas can influence the air quality. It is recommended to select trees that can adapt to the local environment, tolerate compacted soil, and drought, in order to increase longevity. Furthermore, trees with large, rough, dense, hairy/ sticky leaves, and have a low VOCs \(^3\) emission can collect particles better (Spink, 1986). Adopting a mixture of evergreen trees, coniferous and deciduous trees is a good option for particulate matter reduction. In addition to species selection, the design of the vegetation structure impact the air quality, as increasing the leaf surface area (both horizontally and vertically) can deflect pollutants away from receptors (Nowak, 2000; Spink, 1986). Green roofs can also participate in enhancing air pollution; green roofs are green spaces in the intermediate floors of high-rise buildings (podium garden or elevated garden) or on the rooftops (Ong, 2003). Cities all over the world are exploiting the use of green roofs, for example, in Germany, a law was passed in the year 1989, that requires the design of green roof in new buildings (Peck et al., 1999). Green roof plants reduce carbon dioxide in the atmosphere, produce oxygen, and reduce the heat island effect, which is the leading cause of ozone production. Besides, they remove heavy metals, airborne particles and volatile organic compounds (European Federation of Green Roof Associations, 2016). The level of air pollution removal by green roofs in Chicago was quantified using a dry deposition model. The result showed that a total of 1675 kg of air pollutants was removed by 19.8 ha of green roofs in one year with O3 accounting for 52% of the total, NO2 (27%), PM10 (14%), and SO2 (7%) (Yang et al., 2008).

4.9 Building materials and pollutant absorption

Using new technology in construction materials can play a part in mitigation poor air quality. Integrating a new type of concrete that cleans pollutants from the air by using sunlight to power a catalytic reaction to convert them into harmless salts has been used to build a unique building in Milan. The Palazzo Italia is one of the first buildings in the world to use cement that can clean the air. Another example is a decorative façade on a Mexico City hospital,

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\(^3\) VOCs: volatile organic compounds; they interact with nitrogen oxides and sunlight to produce ozone and other chemicals.
made of a material that absorbs pollutants from the air. The hospital chose the tiles, called Prosolve370e, for their ability to clean the air and for their visually appealing forms. A superfine titanium dioxide (TiO2) coats the tiles, and when activated by ambient daylight, they break down nitrous oxides and volatile organic chemicals (byproducts of automobile emissions) effectively neutralizing them. The shapes of the tiles are also necessary. Their random, omnidirectional shapes attract pollutants from all directions, enhancing their ability to receive and scatter UV light (Sustainable business, 2013). Researchers have shown that it is technically feasible to coat glass, tiles, and other building materials with a transparent thin film of TiO2 photocatalyst (PIER Energy, 2007). The most significant benefit is that the photocatalytic treatment with TiO2 coating has positive effects on methane concentration and particulate matter concentration and emission (Costa et al., 2012).

**URBAN POLICIES TO ENHANCE AIR QUALITY**

<table>
<thead>
<tr>
<th>Control Emissions</th>
<th>Mitigate Air Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize the number of vehicles</td>
<td>Absorb/ filter air pollution</td>
</tr>
<tr>
<td>Zero emission</td>
<td>Disperse pollutants</td>
</tr>
<tr>
<td>Land use planning</td>
<td>Vegetation</td>
</tr>
<tr>
<td>Manage parking lots</td>
<td>Green roofs</td>
</tr>
<tr>
<td>Eliminate through traffic</td>
<td>Façade materials</td>
</tr>
<tr>
<td>Pedestrian zones</td>
<td>Urban form</td>
</tr>
<tr>
<td>Cycle lanes</td>
<td>Trees’ distribution</td>
</tr>
<tr>
<td>Electric transportation</td>
<td></td>
</tr>
<tr>
<td>Buses</td>
<td></td>
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<tr>
<td>minibuses</td>
<td></td>
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<tr>
<td>Under ground</td>
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</tbody>
</table>

Figure 10. Urban policies to reduce air pollution  
Source: Researcher

5 .Results

Local urban planners participated with their expertise to evaluate the compatibility of the preceding international interventions, to the local context, the results of the dialogue are presented in [Table 1]. It could be concluded from the discussion that "Restructuring Land Use" policy can benefit in alleviating the colossal pressure that Cairo's CBD experience, due to thousands of daily trips generated to serve or seek civil services. Fortunately, this alternative is supported by a political will that desires to relocate the seat of government to the new capital city, planned in North East Cairo. However, it is vital to maintain the CBD character and to sustain it as a vibrant district. Hence, syndicates, corporations, firms, banks, small businesses, retail shops, commercial and recreational facilities are to be preserved. Since those activities have different peak hours distributed all along the day, it is expected that they would not magnify the traffic congestion. Local regulations and time required to construct the new capital are the hurdles facing this policy.

Although "Restricting Vehicle Penetration" policy, it is found to be very effective, the lack of adequate parking areas, the poor connection between the existing garages and the CBD, the forceless laws, and the elevated auto-dependency cripple the policy implementing. Additionally, it should be noticed that some issues need to be addressed on a larger scale, such as managing through traffic, which demand huge investments. "Alternative Transport Modes" policy is considered fundamental to decrease air pollution levels. To adopt this policy, infrastructure and design amendments are required in the street canyons, as providing cycle lanes, improving sidewalks and installing overhead catenary. Finally, the "Mitigation" policies are primarily based on expanding vegetation. However, the lack of administration and public awareness diminish the opportunity to utilize planting to combat pollution. Other complications are providing space, water, maintenance and the absence of national standards related to the proper application of green roofs. Regarding the using TiO2 in coating the building, it is expected to have a limited impact, due to the large volumes of air that must be processed.
<table>
<thead>
<tr>
<th>Land use plan</th>
<th>Intervention</th>
<th>Impact on air pollution</th>
<th>Implementation Feasibility</th>
<th>Main Obstacles and current problems preventing the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relocate headquarters of governmental institutions</td>
<td>High</td>
<td>Medium</td>
<td>The new capital city is still under construction. High cost to connect the new capital city with Cairo by mass transit.</td>
<td></td>
</tr>
<tr>
<td>Remove storages for relocated companies</td>
<td>Medium</td>
<td>Easy</td>
<td>No regulations to transfer the storages.</td>
<td></td>
</tr>
<tr>
<td>Relocate car repair workshop</td>
<td>Medium</td>
<td>Medium</td>
<td>No regulations to prohibit workshops. Owners resistance. No incentives to move out.</td>
<td></td>
</tr>
<tr>
<td>Minimize on-street parking</td>
<td>High</td>
<td>Easy</td>
<td>No affordable and well-distributed garages. Crowded public transportation.</td>
<td></td>
</tr>
<tr>
<td>Car-free zones</td>
<td>High</td>
<td>Medium</td>
<td>No parking lots, thus poor access to residential buildings and business.</td>
<td></td>
</tr>
<tr>
<td>Partial vehicle restriction access</td>
<td>High</td>
<td>Easy</td>
<td>Feeble enforcing of regulations. No parking lots, thus poor access to residents and business.</td>
<td></td>
</tr>
<tr>
<td>Eliminate through traffic</td>
<td>High</td>
<td>Hard</td>
<td>Adjacent streets are already loaded. Tunnels, bridges are expensive. The need for regional solutions.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle restriction</th>
<th>Intervention</th>
<th>Impact on air pollution</th>
<th>Implementation Feasibility</th>
<th>Main Obstacles and current problems preventing the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encourage walking</td>
<td>High</td>
<td>Easy</td>
<td>Small sidewalks, many levels and poor condition. No shade available (thermal comfort). Many intersections with traffic reduces safety. No connection to drop off points.</td>
<td></td>
</tr>
<tr>
<td>Support cycling</td>
<td>Medium</td>
<td>Easy</td>
<td>No designated lanes. Cultural aspects (especially for female and elder bicycle riders). Low ownership of bikes.</td>
<td></td>
</tr>
<tr>
<td>Electric tram/bus</td>
<td>High</td>
<td>Medium</td>
<td>Infrastructure unavailable. High Cost.</td>
<td></td>
</tr>
<tr>
<td>Bus lanes</td>
<td>High</td>
<td>Easy</td>
<td>Feeble law enforcement.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Mitigations</th>
<th>Intervention</th>
<th>Impact on air pollution</th>
<th>Implementation Feasibility</th>
<th>Main Obstacles and current problems preventing the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rarefaction the urban form</td>
<td>Low</td>
<td>Hard</td>
<td>Compacted urban form.</td>
<td></td>
</tr>
<tr>
<td>Increasing trees and shrubs</td>
<td>High</td>
<td>Easy</td>
<td>Narrow sidewalks, water scarcity.</td>
<td></td>
</tr>
<tr>
<td>Establish new green area/pocket parks</td>
<td>High</td>
<td>Medium</td>
<td>High land value. Maintenance cost, water scarcity. No legislations to obligate investors to create pocket parks as a part of their new projects.</td>
<td></td>
</tr>
<tr>
<td>Utilize the surface of underground garages as green areas</td>
<td>High</td>
<td>Easy</td>
<td>Consider water drainage. Maintenance difficulties.</td>
<td></td>
</tr>
<tr>
<td>Roof gardens on government property/private building</td>
<td>High</td>
<td>Medium</td>
<td>No regulations or codes. No fund. No incentives. No awareness.</td>
<td></td>
</tr>
<tr>
<td>Building coating (TiO2)/Materials (Biodynamic cement)</td>
<td>Medium</td>
<td>Hard</td>
<td>Fund difficulties. No awareness.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The assessment of urban measurements to enhance air pollution in Cairo's CBD

Source: Researcher after a questionnaire with professional urban planners

Mass transit: A system of large-scale public transportation in a given metropolitan area, typically comprising buses, subways, and elevated trains.
6. Recommendations

The study recommendations illustrate short and long term urban interventions, which are qualified to be adopted in Cairo's CBD, as an attempt to enrich the air quality in the vital district [Figure 11]. Additionally, solutions are offered to overcome obstacles inhibiting the implementation of such policies. Priority of interventions is shown in [Figure 12]. However, all of these solutions require governments to recognize the impact of urban planning on air quality and realize the hazards of polluted air on public health and the city economy. The study also acknowledges the importance of the integration between urban policies and other policies in the city to achieve a national vision dedicated to a better air quality [Table 2].

6.1 Short-term interventions and recommendations

- Evacuate storages owned by companies that left the CBD to their new destinations, and reuse vacant buildings for retail shops, museums or recreational facilities. Investors should be welcomed to transform demolishes buildings into multi-storage garages or other recreational uses.
- Relocate car repair workshops, placed in Maaroof street to El Harfeen (a complex for car services), with offering incentives for shop owners to leave the area. Deteriorated shops may be transformed into open spaces or parking lots.
- Minimize side parking on main streets through law enforcement, while providing more illustrative signs showing parking lot locations, vacant spaces in current and new garages to help guide the CBD car users.
- Connect current car garages with affordable natural gas bus fleet to transfer commuters to/from the CBD.
- Paid parking is recommended for secondary streets to create income (to improve the CBD), while it is essential that the majority of the parking would be designated for the CBD users, and not reserved for shop owners only.
- Select park free zones based on the availability to provide adequate, and affordable parking lots to serve residents and retail shops.
- Partial restriction of traffic can be accomplished by automatic rising bollards or by law enforcement personnel. Another restriction could be applied through prohibiting the entrance of aged buses using fuel, especially in peak hours.
- Applying cognition tax to private cars and taxis, decreasing allowed speeds, converting fuel stations in the CBD to natural gas stations would benefit eliminating through traffic.
- Provide wider, shaded sidewalks, with seats and handicap ramps to encourage walking, and ensure connection the pedestrian network with mass transit and parking lots. The intersections between pedestrian paths and traffic should be addressed to increase safety by traffic lights or stop bumps. Finally, shop extensions on sidewalks and street vendors should not be tolerated.
- Cycling could be used to move within the CBD district. Therefore it is recommended to provide separated bike lanes, and start with offering rental bicycles, with affordable fees to encourage users to use them. Bicycle racks should be placed at garages exit points and distributed all over the area. Private companies are suggested to manage the project.
- Providing a separate bus lane would increase its speed and encourage more people to use it, the challenge is to prevent the private cars from using the lane, which could be accomplished through law enforcement and penalties.
- Increase the vegetation in the CBD, via planting sidewalks, and open spaces such as the space in front of El Mogamea and the space above El Tahrir garage. It is crucial to select the type of trees that compact pollution and place trees in a way that guarantees visual clarity and wind penetration. It is recommended to use treated water for irrigation to preserve potable water. NGO's such as "tree lovers society" should be invited and encouraged to participate financially or technically in expanding greenery in the CBD.
- Green roof represents an opportunity to increase vegetation in such compacted site. The local government is advised to issue regulations, offer incentives (tax exemption) and technical support for privately owned buildings to embolden local community to host green roofs. It is suggested that local leading companies in green roofs such "Schaduf" would be offered the opportunity to advertise their services through establishing green roofs for administrative buildings as a pilot project.

6.2 Long-term interventions and recommendations

- Relocate the seat of government to new Cairo city, and assure connecting the new capital with Cairo city via sufficient, comfortable and affordable mass transit (buses / metro).

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5 Due to weak control, the attempts to transform all onstreet parking to be paid by rechargeable cards, ended up by reserving the space for dwellers and shop owners, not benefiting the CBD visitors.
- Reuse the relinquished governmental buildings as multi-storage garages, retail shops, museums, libraries, bookshops or recreational facilities.
- Connect new car garages with affordable, clean public transportation to move commuters to and from the CBD.
- New activities located in the CBD should not overload its capacity and should have various peak hours, distributed all over the day.
- Invest in enhancing the cohesion of regional arteries as to minimize through traffic causing congestion, especially that the main traffic flow in Great Cairo is generated from East to West and vice versa. For example, connect 6 October bridge with El Azhar tunnel.
- Adding a trolley bus or an electric tram would help users to access the CBD with releasing fewer pollutants in the air, additionally, it would result in reducing vehicle lane width and lower their speed.
- New legislations regarding building setbacks are needed, in order to extenuate the urban compactness and allow wind penetration. Furthermore, adopting the pocket park concept in deserted spaces in the CBD would help to disperse the pollutants, besides offering venues for people to socialize, and recreate.
- Encourage the use of titanium dioxide (TiO2) to cover building exposed to high levels of air pollution (main streets).

Figure 1. The impact and the feasibility of the urban policies combating air pollution in the CBD
Source: Researcher

Figure 11. The impact and the feasibility of the urban policies combating air pollution in the CBD
Source: Researcher

Figure 11 is a visual illustration of findings, the closer the urban policy to the upper right side of the graph, the better it is for quick and effective implementation. For example, minimizing on-street parking and increasing vegetation can have a substantial impact on the pollution and at the same time can be relatively implemented quickly. By contrast, all policies close to the lower left side of the graph, are found to have a fragile impact on air pollution and are rather harder to implement. Therefore they are considered as a low priority.

Figure 12. Intervention priorities in Cairo's CBD
Source: Researcher
<table>
<thead>
<tr>
<th>Urban Policies</th>
<th>Other Policies</th>
</tr>
</thead>
</table>
| Land use      | o Monitor the CBD’s developmental programs  
|               | o Implement traffic management solutions  
|               | o Increase car prices  
|               | o Enforce vehicle emissions testing and tune-up  
|               | o Gradual removal of fuel subsidies  
|               | o Attract investors to participate in garages operation  
|               | o Replace fossil fuels, with clean, renewable energy  
|               | o The use of diesel particulate filters  
|               | o Enforce strict emission standards and vehicle technology improvements  
| Restrict vehicle access | o Investment in improved mass transit (increased capacity / less time / better service/ affordable)  
|               | o Encourage the private sector to access the public transport services with coordination and integration with the government  
|               | o Introduce a new multimodal ticketing system  
|               | o Separate between investment in infrastructure and financing of operations  
|               | o Offer incentives to replace old taxis with new ones using natural gas  
|               | o Apply green public procurement  
|               | o Encourage car sharing programs  
| Alternative transportation | o Increase environmental awareness of the population, industry & governments through communication, and launching media and educational programs  
|               | o Establish effective environmental monitoring & surveillance mechanisms  
| Mitigation    | o Create legislative & governmental agencies to develop rational & achievable standards and laws.  

Table 2. Associations between urban police and other policies to enhance air quality  
Source: Researcher

7. Conclusion

This paper investigates the dynamics of traffic congestion and urban planning policies in Cairo’s CBD. It aims at exploring the most efficient and feasible urban policies to enhance air quality through lessening the traffic congestion and air filtering. The research begins with examining the nature of traffic congestion problems, and the national/ local government interventions to contain air pollution complications. The results indicate that regulatory policies are the most frequently used strategy to control traffic congestion, and urban policies are not considered when planning to encounter the exacerbated pollution levels. Therefore, the research presents short and long term interventions, to integrate urban policies in the air mitigation process. It is suggested to start with relieving some of the pressure on the CBD through transforming unnecessary/appropriate uses into parking lots and open spaces. Afterward, comes improving the physical environment of sidewalks/pedestrian paths to boost walkability. In addition to expanding the greenery through planting streets and creating roof gardens. Followed by long-term solutions represented in introducing clean transport systems to access and move inside the area, and providing regional strategies to address the through traffic dilemma.

The research accentuates the importance of incorporating the preceding policies in a comprehensive strategy aiming to revive the CBD. Thus, it calls to elude applying an isolated intervention, as it will probably result in aggravating the traffic congestion, consequently, harm the air quality. The air pollution is a multi-dimensional problem, that cannot be addressed from one perspective. Therefore, it is essential that other strategies such as public health, economic policies and legislations to support and coordinate with urban planning policies. Lastly, environmental protection and restoration should be a national priority seeking the cooperation of all segments of the Egyptian society, business, local governments, professionals, NGOs, and researchers, not only traffic engineers or urban planners. Policy makers have the responsibility to create entities to monitor air pollution, enforce the law and take corrective measures to protect the local air quality and the public health.

References