INTEGRATED URBAN AND ENVIRONMENTAL STRATEGIES FOR CLIMATE RESILIENCE IN THE ATHENS METROPOLITAN AREA

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Abstract
The Athens Metropolitan Area constitutes the largest urban region in Greece and ranks among the most extensive metropolitan regions in Europe. Despite its significance, the region is currently burdened by severe urban and environmental challenges, including chronic traffic congestion, inadequate transportation infrastructure, elevated levels of air and noise pollution, and heightened vulnerability to climate-related hazards such as heatwaves, wildfires and flooding. Moreover, pressures from overtourism and an increasingly unaffordable housing market further exacerbate the degradation of urban living conditions. Although ongoing initiatives—such as the expansion of public transit networks, implementation of smart city technologies, development of green and cooling infrastructure, and climate resilience planning—are in place, these efforts remain insufficient in addressing the growing complexity of urban stressors.

This study proposes an integrated urban and environmental design strategy for the Athens Metropolitan Area, aimed at enhancing mobility systems, mitigating climate impacts, and improving bioclimatic conditions, with a strong emphasis on ecological sustainability and human well-being. The proposed interventions concentrate on strategic zones, particularly the Eleonas district and the Egaleo mountain range, while promoting new intermodal connections and upgrades to existing arterial routes, including their transformation into higher-capacity motorways or highways. The design framework seeks to achieve multiple outcomes: improved air quality, urban heat island mitigation through temperature reduction, decreased greenhouse gas emissions, enhanced stormwater drainage capacity, minimized flood risk, and overall urban sustainability enhancement.

Key words: *urban planning, environmental design, Athens Metropolitan Area, climate resilience*

1. INTRODUCTION

The Athens Metropolitan Area is the biggest and most crowded urban region in Greece and one of the most extensive metropolitan areas in Europe. As the main political, economic, and cultural center of Greece, Athens is indispensable to both regional and national development. On the other hand, the city's urban systems, which are less and less able to withstand the increasing structural, environmental, and socioeconomic pressures, are still heavily burdened by this centrality.

Traffic congestion, which is a direct consequence of the steadily growing use of private cars, is the first most serious problem of the Athens metropolitan area. Public transport systems are less attractive, less reliable, and less efficient due to the existence of several gaps and inefficiencies in the transport infrastructure. Consequently, Athens records very high levels of noise and air pollution almost throughout the year, thus causing a decline in environmental quality, public health, and general urban livability.

Meanwhile, prolonged droughts are making the occurrence of wildfires in the nearby forest areas more likely, and higher temperatures and frequent heatwaves are intensifying the urban heat island effect in Athens. Furthermore, heavy rainfalls combined with insufficient stormwater management facilities, especially in the most densely populated areas, cause flooding. The climate situation affects the most vulnerable groups of people, and the resources of the local government are also in danger.

Social issues have become more severe because of overtourism and the rapid changes in the housing market. On the other hand, the rising number of visitors puts more pressure on public areas, infrastructure, and local services. All these factors deepen social inequality, cause displacement, and decrease the overall standard of living in cities.

A wide range of planning measures and policy initiatives have been put in place to counter these problems. Among them are the creation of green spaces and cool, down infrastructure, modernizing and expanding public transport systems, implementing smart city technologies for better urban management, and developing comprehensive climate adaptation and resilience plans. Nevertheless, these measures are not enough to tackle the scale and complexity of the changing urban stressors in Athens, although they are well, intentioned and yield some incremental benefits. Hence, a more integrated, long, term, and socially inclusive approach is necessary to ensure the sustainable and resilient future of the metropolis.

2. INTEGRATED URBAN AND ENVIRONMENTAL DESIGN STRATEGY FOR THE ATHENS METROPOLITAN AREAS

The redesign of the Athens Metropolitan Area throughout this study incorporates a multi, scalar and integrated framework of the city. This is mainly aimed at the production and maintenance of an urban environment that is ecologically sustainable, socially resilient, and inclusive. Based on the principle that urban systems form a network of interconnections, the strategy attempts to cohere the city`s spatial planning, infrastructures development and environmental management to solve the intricate problems that the city has.

The proposed approach presents an integrated urban and environmental design strategy for the Athens Metropolitan Area, focusing on:

- Enhancing mobility systems and intermodal connections
- Mitigating climate impacts and improving bioclimatic conditions
- Prioritizing ecological sustainability and human well-being

Interventions are localized around mainly strategic zones that have a high potential of being radically changed, among which the Eleonas district and the Egaleo mountain range stand out the most. These places are considered the most important nodes of a wider urban network, being able to hold new ways of movement, natural recovery and urban regeneration. The proposal facilitates the innovation of new intermodal connections that are in line with public transport, active mobility and regional networks, while at the same time the major arterial routes are being enhanced. These routes, by means of redesign and reprogramming, are changed into high capacity, multi, functional corridors which, apart from the fact that they meet mobility requirements, also have green infrastructure and climate, adaptive design features integrated into them.

The study, through the application of this integrated framework, aspires to bring about quantifiable and lasting advantages for the Athens Metropolitan Area. Some of the goal outcomes consist of cleaner air, decreased urban heat stress, diminished greenhouse gas emissions, increased stormwater management capacity, and a substantial lowering of flood risk. In aggregate, the positive changes make Athens a metropolitan region that is cleaner,

more resilient, and environmentally friendly, which is in line with the city's move to a more balanced and future, oriented urban model.

Enhancing Mobility systems and intermodal connections

One of the significant changes envisaged by the strategy to achieve these goals is the introduction of four new major transport connections that span the Athens metropolitan area. With the help of these measures, the business district, city centers, and local communities in the region are to be better connected to each other and to the surrounding areas. Furthermore, the new transit services will increase the capacity of the present networks and foster the harmonious interlinking of the urban, suburban, and regional mobility systems.

Western Corridor

This scheme envisions a new corridor, connecting Athinon Avenue with Egaleo Ring Road. After extending the east-west connection to the western industrial sector, the corridor becomes a very efficient way of rerouting the traffic between the western suburbs and Thriasio Plane reducing travel times and pressure on overloaded roads.

Central Axis

The Central Axis creates a change of course that directly connects the east side of Athinon Avenue with Chamosternas Avenue. This link consolidates the flow of the network inside the city, making traffic circulations less heavy and solving the problem of traffic queues at the most congested intersections. Apart from the car flows, the axis is designed as a multimodal transport route, which can be combined with public transport and non, motorized forms of transport.

Southern Corridor

This corridor establishes a fresh strategically west-south connection that links Kifissos Avenue to Vouliagmenis Avenue. The main purpose of the intervention is to ease the heavy traffic that has been going on for a long time along the routes that run parallel to each other, to make it easier for people to move across the city through the urban core and to improve the connection between the western and southern districts.

Southeastern Extension

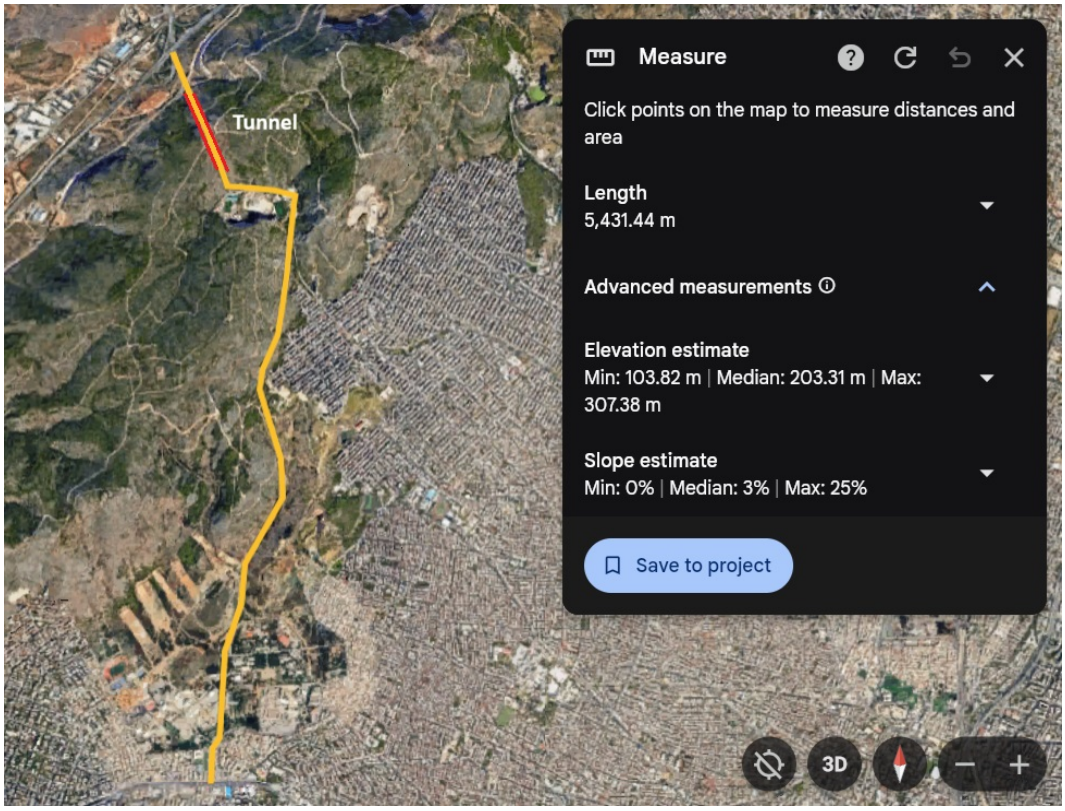
The Southeastern Extension envisions a new corridor connecting Vouliagmenis Avenue with Varis-Koropiou and Lavriou Avenues. The link facilitates the flow of traffic to the Athens Riviera, the eastern metropolitan zone, and the airport area, thus, it is a great tool for economic growth, tourism expansion, and area integration.

Western Corridor – Athinon Avenue to Egaleo Ring Road

Project Characteristics

The length of the proposed infrastructure intervention is about 5.5 kilometers, and it has been planned with two lanes of traffic in each direction. One of the most important elements of the project is a tunnel section of 700 meters that goes from the area of Poikilo Polychoros to Egaleo Ring Road (Image 1). The line leads directly to the Egaleo Ring Road at the Nato Avenue junction, thus a node of strategic importance is being created within the western industrial road network. The estimated cost of construction is between €70 and €100 million, which corresponds to the size of the project as well as the presence of tunneling and the related infrastructure works.

Image 1: Western Corridor (https://earth.google.com/web)



Advantages and Expected Benefits

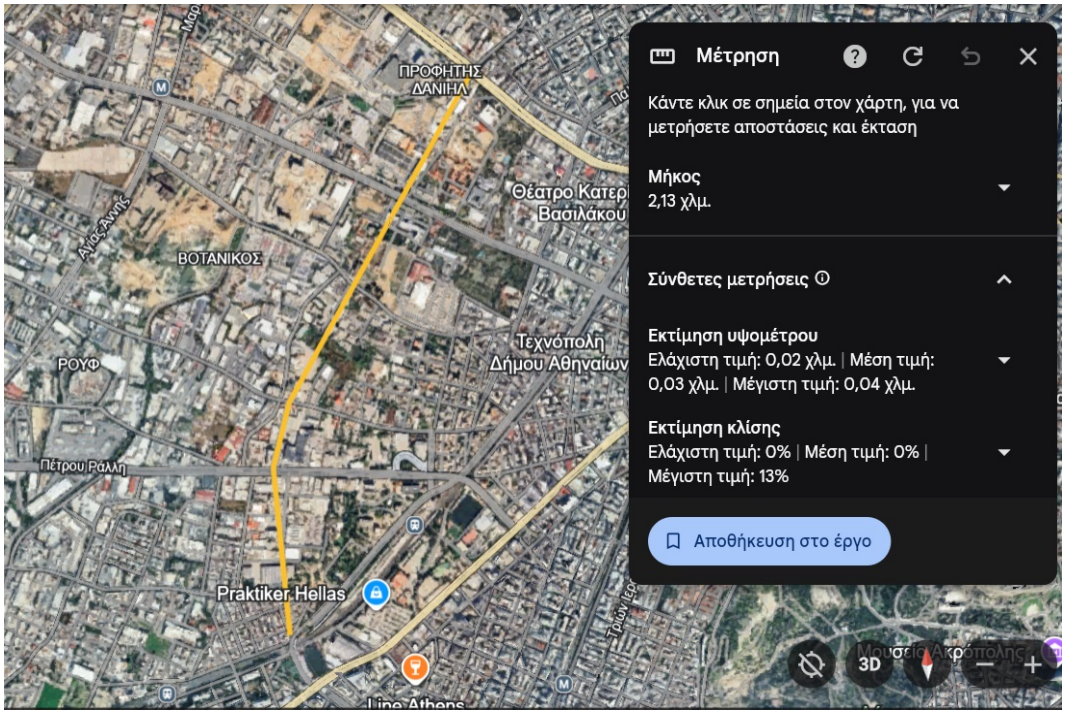
The project is set to contribute significantly to mobility and urban performance across the whole western Athens metropolitan area. As a result of the diversion of through, traffic from local streets, surface road networks in Petroupoli, Peristeri, and Egaleo would be less congested, thus traffic flow and road safety would be improved in these densely populated districts. Moreover, the new link offers the shortest and most efficient way from the western suburbs to the Egaleo Ring Road as well as the Thriasio industrial area, thus both commuter accessibility and freight logistics get easier. Consequently, the time spent on the road between the residential neighborhoods and major employment and industrial areas will be shortened greatly, thus economic efficiency will be increased, vehicle emissions will be lowered, and urban livability will be improved in general.

Central Axis – Athinon Avenue to Chamosternas Avenue / Peiraios Junction

Project Characteristics

The planned infrastructure project will span around 2.2 kilometers in total length, with the idea of having two traffic lanes in each direction (Image 2). The sizable and technically intricate nature of the intervention is mirrored in the approximate cost of construction between €80 and €120 million. This estimate includes charges for extensive structural works, possible grade separations, and the blending of the project with the existing arterial road networks.

Image 2: Central Axis – (https://earth.google.com/web)



Advantages and Expected Benefits

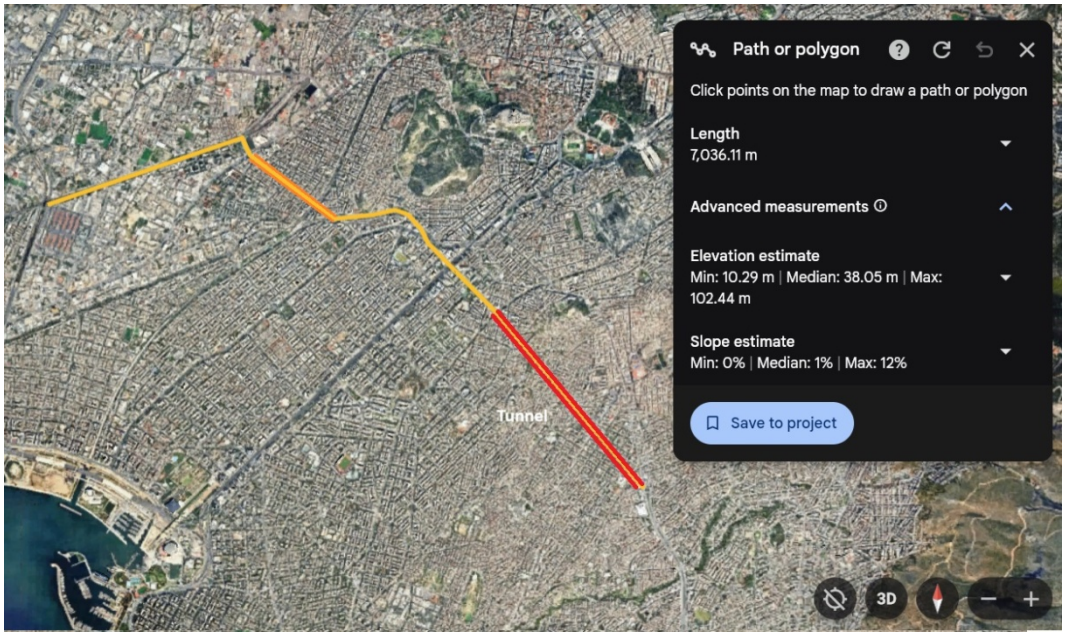
This project broadly improves the connectivity of the Athens Metropolitan Area to the southwest and west with an emphasis on freight movement that is to be enhanced between Athinon Avenue and the southeastern suburbs through direct integration with the planned Southern Corridor. Besides that, the intervention is heavily anticipated to remove traffic bottlenecks along Kifissos Avenue, especially at the very congested stretch between the Athinon Avenue junction and the Neo Faliro / Poseidonos junction. By redistributing traffic flows and removing the traffic load from this crucial corridor, the project leads to a smoother circulation and higher network resilience. Moreover, the enhanced connection facilitates the accessibility of western Athens to the southern suburbs, thus the travel times are getting shorter, and the reliability of daily commuters is improving.

Southern Corridor – Kifissos Avenue to Vouliagmenis Avenue

Project Characteristics

The total length of the proposed corridor is about 7 kilometers, and the plan includes two traffic lanes in each direction. The main feature of the project is a tunnel of 1,900 meters in length, going from Chamosternas Avenue to Vouliagmenis Avenue under the densely built area of Ano Nea Smyrni (Image 3). In this underground part, the corridor goes beyond the limitations at the surface and at the same time, it minimizes the impacts on the existing neighborhoods and the urban fabric. The estimated construction cost is between €250 and €350 million, which corresponds to the extent of the intervention, the tunneling works, and the necessary integration with major arterial routes.

Image 3: Southern Corridor (https://earth.google.com/web)



Advantages and Expected Benefits

The project creates a west-south urban corridor that extends the connectivity to the core of the city and beyond the metropolitan area. It links the western districts with the center of Athens, the southern neighborhoods, and the coastal zone. By giving a direct and uninterrupted route, the corridor elevates the cross, city access and is compatible with the most efficient transport solutions of different urban sectors.

The main advantage of the measure is the elimination of the excessive through, traffic that Syngrou Avenue and Vouliagmenis Avenue are currently suffering from. By distributing a large proportion of long, distance and cross, city traffic away from these two very congested areas, the project leads to better traffic flow, shorter travel times, and lower noise and air pollution levels on the existing routes.

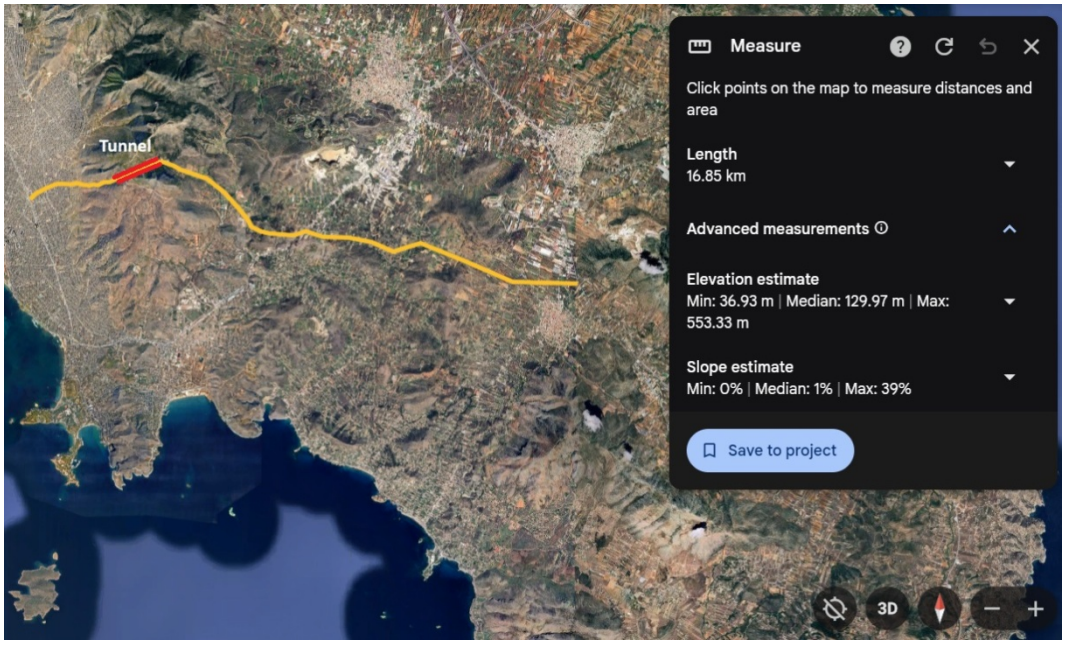
Besides the private vehicles, the corridor aims at public transit integration thus allowing the introduction of a high, capacity transit service like Bus Rapid Transit (BRT) or a dedicated electric bus route.

Southeastern Extension – Vouliagmenis Avenue to Varis–Koropiou Avenue / Lavriou Avenue

Project Characteristics

The planned southeastern passageway extends for about 17 kilometers and has been laid out with two traffic lanes in each direction. One of the most significant technical features of the project is a tunnel of 1,300 meters traveling from Ano Glyfada to Lamptres Kropias, which enables the route to go under the difficult terrain with a minimum surface disturbance and less impact on nature (Image 4). The total building cost is believed to be between €150 and €200 million, which is a direct consequence of the corridor's length, the amount of tunneling, and the necessary junctions with the existing main roads.

Image 4: Southeastern Extension (https://earth.google.com/web)



Advantages and Expected Benefits

The corridor mainly facilitates the southeast metropolitan movement of people by establishing a direct and fast connection between the seashore and the inner parts of the Athens Metropolitan Area. By making it easier to get around this fast, growing part of the region, the initiative is instrumental in achieving a more balanced territorial development pattern and it also increases the daily mobility of residents, workers, and visitors. Moreover, the new road is an efficient way of getting away towards Attiki Odos, decreasing the traffic load that is caused by the southmost part of Varis-Koropiou Avenue, which is the source of heavy traffic. Through the redistribution of traffic flows and the extension of network redundancy, the operation is a step towards sub, system integration, and hence, it increases the systems overall resilience and reliability. In addition, the corridor is instrumental in the operation of a clear and efficient connection between Athens International Airport and the rest of the area, thus, helping to improve the logistics effectiveness of the entire southeastern metropolitan zone.

Enhancing Mobility systems and intermodal connections - Overall Assessment

Main Benefit

The main advantage of the suggested plan is the major upgrade of urban connectivity throughout the Athens Metropolitan Area. With the creation of new high, capacity corridors and better network integration, the plan alleviates traffic on the current arterial roads and makes the travel time between the main residential, industrial, commercial, and coastal areas shorter.

Environmental Value

Environmentally, the approach has a very positive impact. It can make a big difference in the air quality situation by moving traffic that is causing heavy emissions out of heavily polluted urban areas and thus reduce the total amount of greenhouse gases released into the atmosphere. When the strategy is implemented together with the use of the green and blue

infrastructure, the effect will be very positive for the environment which will be beneficial for public health and will increase climate resilience at the metropolitan scale.

Total Estimated Cost
The overall estimated investment needed to put into action all the proposed measures is a minimum of between €550 and €770 million depending on the final design choices, construction methods, environmental mitigation measures, and results of detailed feasibility studies.

Mitigating Climate Impacts and Improving Bioclimatic Conditions

By using the integrated framework as a base for sustainable urban transformation, this part of the plan concentrates on extending climate resilience and raising bioclimatic performance all over the Athens Metropolitan Area. Since the city is exposed to the risk of increased temperatures, urban heat islands, and climate, related hazards, the approach mainly focuses on the regeneration of the landscape, restoration of the hydrological balance, and provision of thermal comfort. To accomplish these goals, the city is implementing three interlinked interventions that are each aimed at strengthening ecological functions, enhancing urban livability, and providing the creation of multifunctional green infrastructure.

Reforestation of Mt. Egaleo
This intervention aims to cover Mt. Egaleo extensively with forest and vegetation, especially its east and southeastern slopes that face the western suburbs of Athens. The initiative purports to alter the microclimates of the area, lessen the urban heat island effect, and purify the air by elevating tree density and introducing various plant species. As a matter of fact, the reforestation exercise is also a weapon against the foehn effect, the hot-dry winds that blow down the slopes and thereby increase summer temperatures in the western metropolitan areas. Besides temperature regulation, the project also enriches the local fauna, offers leisure facilities, and deepens the visual and ecological bond between the city and the adjacent nature.

Transformation of the Eleonas Area into a Metropolitan Park (with Artificial Lake)
The Eleonas area, which has been a heavily industrial and neglected region in the past, will become a large metropolitan park combining vast green areas with a central artificial lake. It is planned that the lake will feature treated water coming from Kifissos and Psitalia water recycling plants, thus promoting sustainable water management. The aim of this change is to supply an urban oasis of various functions that will help to cool down the city, provide recreational facilities, and be a significant ecological reserve among the highly built, up city center. By integrating green infrastructure with water, sensitive design, the initiative is also useful for dealing with stormwater, lessening the risk of floods, and improving the air quality in the local area, thus turning Eleonas into a pioneer of climate, resilient urban regeneration.

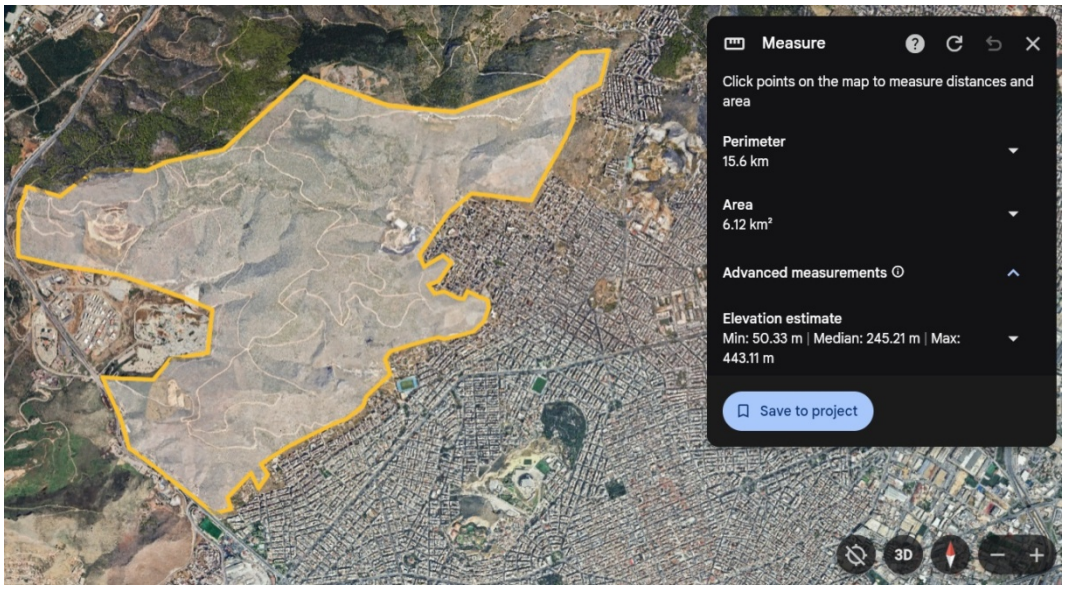
Construction of Small Dams in Mt. Egaleo and Mt. Imittos
This intervention envisages a series of small, scale retention dams that will be strategically placed along the seasonal gorges, streambeds, and natural depressions of Mt. Egaleo and Mt. Imittos. The dams are intended to hold rainwater and runoff during seasonal precipitation, thus facilitating the greening of the adjoining areas and lessening the flood risk downstream. By regulating the water flows, these dams also raise soil moisture levels, improve local vegetation, and create microhabitats that increase urban biodiversity. Furthermore, the stored water may be used for irrigation of nearby urban

parks and landscaped areas, thus linking water management with public space enhancement and making a significant contribution to the metropolitan ecosystem's resilience.

Reforestation of Mt. Egaleo

The first objective of this treatment is to develop a vast forest and green vegetation cover all over Mt. Egaleo, especially the eastern and southeastern slopes that have a view of the western suburbs of Athens (image 5). Through the expansion of green cover, the initiative intends to adjust local microclimates, decrease heat stress in summer, and restrict the foehn effect that raises temperatures in the western metropolitan districts to a great extent at the time of the hottest period of summer. In addition to temperature control, the planting of trees in deforested areas enhances the diversity of species, purifies the air, and creates a healthy ecological bond between the city and the natural landscapes around it.

Image 5: Reforestation of Mt. Egaleo (https://earth.google.com/web)



Temperature Regulation

One of the main factors to cool the earth in the areas where the temperature is high is the application of planting trees. It is very effective in lowering both the temperature of the surface and the air of the surrounding area. By giving shade, raising evapotranspiration, and lessening heat absorption in urban areas, reforestation helps the heat that comes from the city to be less in areas around the residential and industrial ones. In this way, people benefit from better living conditions, the need for energy to be used for cooling decreases, and the health of the people is stabilized especially during long summer heatwaves.

Wind Flow Moderation

Recently planted tree-covered areas serve as natural windbreaks that regulate and calm local wind patterns. These vegetated areas, by diminishing the strength and velocity of hot, dry air masses (such as the foehn effect), are the main factors that prevent the flow of excessive heat from the surrounding rural areas to central urban districts. This cooling effect also leads to more stable microclimatic conditions, which are favorable for the local population and urban vegetation.

Air Quality Improvement
Plants in the forest replaced areas, naturally, are the ones who breathe new life into the air of these reforested areas. Besides absorbing carbon dioxide, which they store in their trunks and roots, they also help mitigate climate change by reducing the occurrence of global warming gases. These plants also absorb very tiny particle matters ($PM_{2.5}$ and PM_{10}) that are suspended in the air in addition to nitrogen oxides (NOx) and thus make the air clean and fresh.

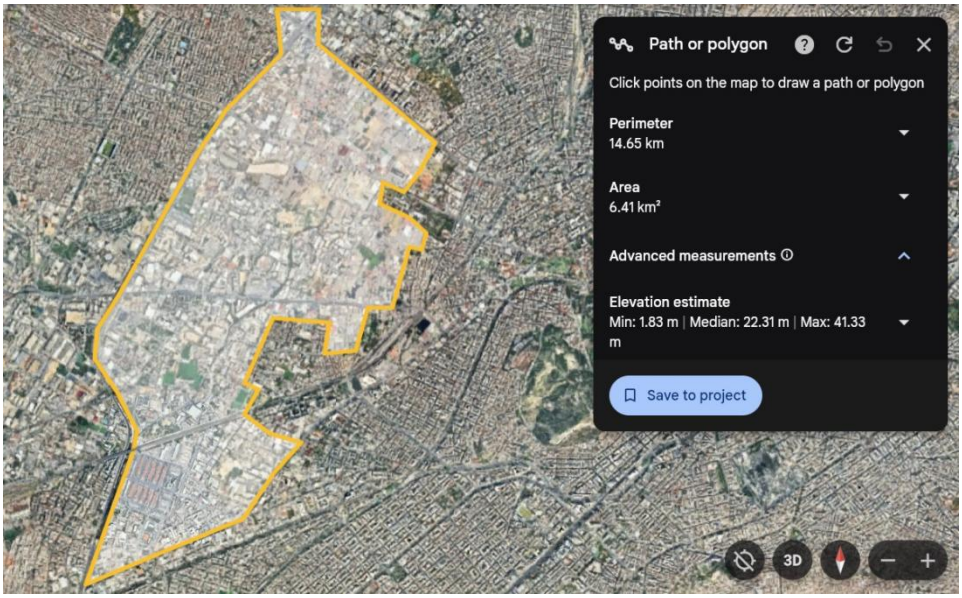
Erosion and Runoff Control
Roots of freshly planted trees hold the soil tight on inclines and lessen the chance of soil washing away, especially in areas that are either hilly or have been heavily degraded. Through the improvement of rainwater infiltration and the decrease of surface runoff, reforestation is able to not only lower the risks of floods but also it makes the local hydrological cycles healthier, and it even recharges the groundwater.

Estimated Cost
Initial calculations put the expense of a massive reforestation project covering about 1,500 hectares planting, site preparation, and the first five years of maintenance at around €40 and €60 million.

Transformation of the Eleonas Area into a Metropolitan Park (with Artificial Lake)

The main aim of the first intervention is to change a big part of the Eleonas district, which has been a shipping area of heavy industrial uses, uncooperative landowners, and neglected or abandoned plots, into a large, scale metropolitan park (Image 6). The redevelopment of the area around the lake is the core idea of the district transformation that is there to serve as the environmental and social anchor of the area both. The lake will be enriched with clean water from Kifissos River and Psitalia wastewater treatment and recycling plants, thus ensuring a sustainable and closed water cycle. This project intends to bring nature back to one of the most polluted urban areas of Athens, which will attract new residents and businesses.

Image 6: Transformation of the Eleonas Area into a Metropolitan Park (https://earth.google.com/web)



Urban Cooling
The creation of large, scale green spaces alongside open water bodies can, in fact, lead to a substantial decrease of local air temperatures in the areas that surround such quarters, where the respective cooling effects may reach up to around 2-3°C. The decrease is essentially the outcome of shading, evapotranspiration from plant cover, as well as the thermal buffering ability of water surfaces. Hence, the measure lessens the urban heat island effect, elevates the level of thermal comfort in periods of extreme heat, and lessens the energy consumption for cooling in the closest residential and commercial buildings.

Microclimate Regulation
By the addition of evaporation, cooling, and stabilizing humidity levels from the dense urban core, the artificial lake is the main source of local microclimate regulation. As a result, the heat situation is relieved, the outdoor comfort is improved, and it becomes easier to carry on with the usual activities, especially in the hottest summer days. Together the water and greenery are making the urban climate less extreme and more resistant to future changes.

Ecosystem Restoration
The project transforms a degraded brownfield landscape, into a multifunctional ecological system that accommodates native plant species, aquatic habitats, and urban wildlife. Through the recovery of natural processes and the planting of uninterrupted green spaces, the place turns into a biodiversity hub, at the same time, it also becomes a great public recreation space. Such a nature comeback not only makes the area more resistant to different kinds of environmental hazards but also re-establishes the connection between city dwellers and nature.

Air Quality and Carbon Benefits
An enlarged tree canopy along with open water surfaces lead to better air quality as they capture airborne pollutants like particulate matter and nitrogen oxides. In the same period, vegetation absorbs and stores carbon dioxide supporting climate change mitigation.

Social and Urban Value
Besides the ecological benefits, the big park in the city area brings a lot of social and urban value. Improved access to high-quality green space promotes physical activity, mental well-being, and social interaction, enhancing public health outcomes. At the same time, the transformation of Eleonas increases land value of the surrounding area resulting in sustainable urban regeneration, capital inflow, and long-term economic revitalization.

Estimated Cost
The combined estimated expenditure for the change of Eleonas into a metropolitan park, covering land rehabilitation, soil remediation where necessary, park and landscape construction, as well as the installation of water recycling and management infrastructure, is between €80 and €120 million.

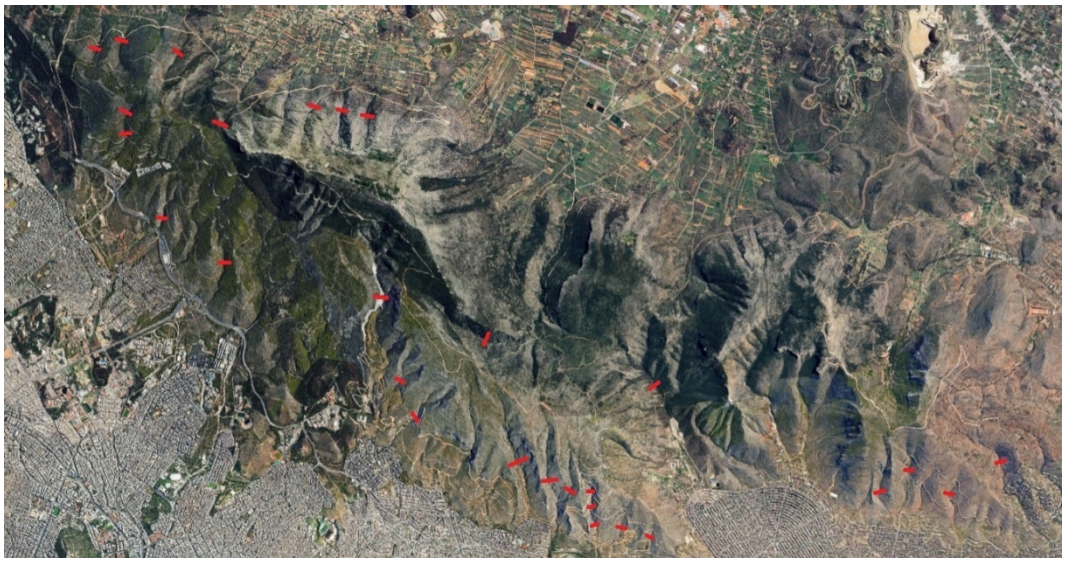
Construction of Small Dams in Mt. Egaleo and Mt. Imittos

The main goal of this operation is the creation of a concerted system of small, scale retention dams that are placed in a very targeted way in the many seasonal gorges, ravines, and dry streambeds of Mt. Egaleo (Image 7) and Mt. Imittos (Image 8). These are intended to capture and even hold stormwater during short but heavy rain episodes, thus facilitating water retention, helping the growth of surrounding green areas, and lessening the risk of flooding of

the downstream areas which are already built, up. The plan is centered on nature, based and minimally invasive engineering solutions which are compatible with the current topography and ecosystems.

Image 7: Construction of Small Dams in Mt. Egaleo (https://earth.google.com/web)

Image 8: Construction of Small Dams in Mt. Imittos (https://earth.google.com/web)



Flood Risk Reduction

Small, scale retention dams built can make stormwater captured and temporarily stored during a peak of rainfall. These facilities, by slowing down runoff and reducing its volume, significantly lower runoff velocity and thus the risk of flash flooding in urban areas downstream. The controlled water management thus ensures the safety of residential

neighborhoods, transport infrastructure, and public assets located at the foothills and low-lying zones of the metropolitan area.

Groundwater Recharge
Through the retention of water in natural gorges and streambeds, the dams can facilitate the infiltration of water into the soils around as well as into the geological formations beneath. This, in turn, helps to refill local aquifers, thus making groundwater more accessible and increasing the resilience of the water supply system over the coming years.

Vegetation Growth
The retention of water in these areas creates ideal moisture conditions along water courses where the growth of riparian vegetation can be expected, and the regeneration of the degraded landscapes can take place. The greening resulting from this, serves to broaden the variety of microhabitats available to the native flora and fauna, raises the biodiversity level and reinforces the ecological corridors that link mountainous areas with urban green spaces.

Local Climate Moderation
As a result of the better water availability, more vegetation cover has a positive influence on the local climate. One of the main functions of green corridors is shading and evapotranspiration through which they help to lower air temperatures and keep the humidity at a certain level.

Estimated Cost
The overall estimated cost of the project to build several small-scale retention dams is roughly between €25 and €40 million.

Mitigating Climate Impacts and Improving Bioclimatic Conditions - Overall Impact and Integration

Urban Heat Mitigation
The planned combined use of green and blue infrastructure strategies should result in a cooling effect of the local urban and peri-urban areas by 2-4°C on average. With a higher shading, evapotranspiration, and better surface permeability enabled by the changes, the urban heat island effect is materially reduced, the thermal stress at extreme hot events is lessened, and the general outdoor comfort of inhabitants is improved.

Flood Management
By implementing water-sensitive urban design elements, there small-scale retention systems, restored natural watercourses, and enhanced infiltration zones, lowers the risk of stormwater overflow that results from heavy rainfall. The implemented measures slow and temporarily retain peak flows, thus, releasing the existing drainage infrastructure that is under pressure, and increasing flood resilience in susceptible neighborhoods.

Air Quality Improvement
The growth of tree canopies, reforested lands, and tree, lined corridors are all factors that improve air quality, as a result of increased carbon dioxide absorption and the removal of pollutants from the air that include dust and fine particulate matter. This nature-based solutions are aligned with public health goals and thus, they make a significant contribution to climate change mitigation by decreasing the exposure to toxic emissions.

Ecosystem and Biodiversity Recovery
The establishment of novel urban green and blue habitats, such as reforested hillsides and riparian corridors, as well as metropolitan parks and water bodies, not only supports the recovery of ecosystems but also the return of native flora and fauna.
Through the reinforcement of ecological connectivity throughout the metropolitan area, the strategy broadens the range of species, increases the resilience of habitats, and brings back the natural processes of the city.

Social Benefits
The strategy brings considerable social advantages by enhancing urban livability and the quality of life. Easier access to attractive green and blue spaces motivates physical activity, improves mental health and well, being, and strengthens social interaction and community cohesion. These advantages, which are essentially concentrated in densely populated urban areas where open space is scarce, have the greatest influence.

Estimated Total Cost
The total investment needed to carry out the integrated package of interventions is calculated to be around €120 and €180 million.

Prioritizing Ecological Sustainability and Human Well-Being

This component of the strategy focuses on creating a healthier, more resilient, and energy-efficient urban environment by addressing the physical characteristics of the built fabric, reorganizing mobility and parking patterns, and ensuring equitable access to efficient and sustainable transport options. By combining urban design, city planning, and environmental performance, this innovative approach is designed to: mitigate heat stress; reduce energy consumption; minimize exposure to air and noise pollutants; and, on top of that, it can significantly enhance urban comfort, safety, and the general quality of life for residents and users of the city.

Increasing the Albedo of Human-Made Surfaces
The goal of this intervention is deliberate spreading of reflective surface features over the roofs, pavements, and outer walls of the buildings, mainly in the compact urban areas where the problem of heat build-up is the strongest. The strategy, which involves the use of cool materials, reflective coatings, and light-colored finishes, reduces the solar heat absorbed and thus lowers the surface temperatures. These steps lead to lower temperatures in the open air, less need for cooling of the interior spaces, and consequently lower energy consumption, at the same time the urban heat island effect is being alleviated, and the thermal comfort level at the neighborhood scale is improving.
Parking Reformation: Diagonal Parking and One-Way Street Systems
The changes in parking and traffic patterns include the introduction of diagonal parking layouts and one-way street systems to make the space utilization more efficient and the circulation better. With this method, the widths of the roads needed for the movement of vehicles are decreased, thus the space that is reclaimed can be used for wider sidewalks, bicycle lanes, street trees, and green infrastructure. Besides making pedestrian safety and accessibility better, the reconfiguration also raises the possibilities of urban greening, helps traffic calming, and results in a more balanced and human, scaled street environment.

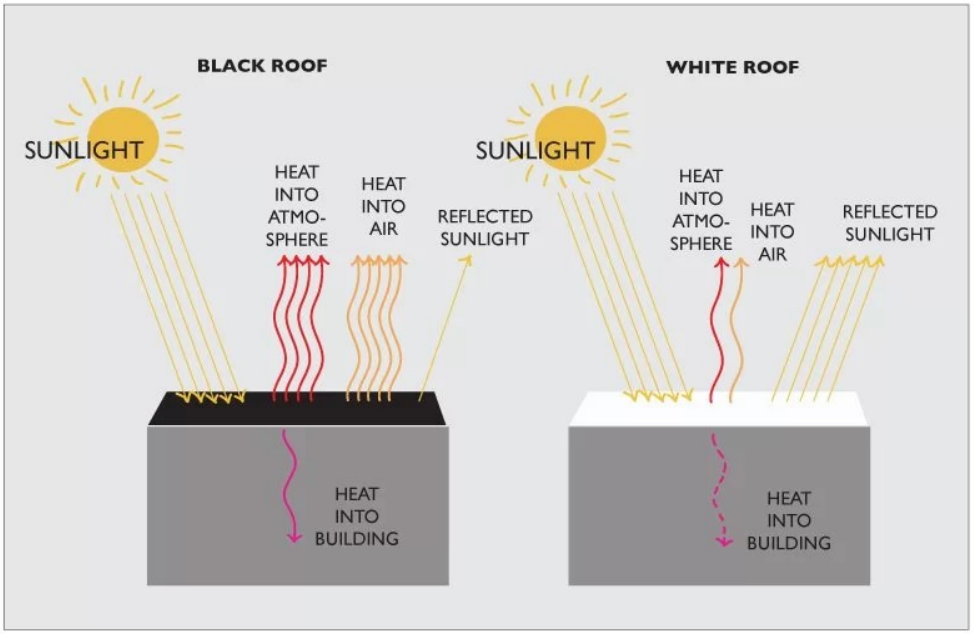
New Transportation Lines in Industrial and Commercial Zones

This intervention focuses on the establishment of new or extended public transport lines—such as bus rapid transit (BRT), light rail, or metro extensions—serving industrial, logistics, and commercial zones with high concentrations of employment and freight activity. Consequently, the strategy through such means as a clean, high, capacity, and reliable transport option eliminates the need for private vehicles, thus decongesting the area and enabling the emergence of more eco-friendly commuting patterns. In addition, increased public transport connectivity acts as a fuel for economic growth by making a city more accessible to the labor force and more compatible with the gradual transition to a metropolitan mobility system that is both more efficient and environmentally friendly in the long run.

Increasing the Albedo of Human-Made Surfaces

The main goal of this action intervention is to systematically increase the surface reflectivity (albedo) of human-made surfaces—including building roofs, streets, sidewalks, public squares, and facades—to reduce solar heat absorption and lower both outdoor and indoor temperatures (Image 9). The strategy is mainly aimed at dense urban districts where dark, impermeable materials are the most used and, therefore, heat from the urban environment accumulates and raises the temperature in these areas. By changing the properties of the surface instead of the urban form, this intervention is a cheaper and faster way to be able to adapt to the climate.

Image 9: Albedo mechanism (rscentre.com.au/thermal-efficiency)



Temperature Reduction

Changing the surface albedo of urban materials from standard values of about 0.15 (which is typical for asphalt, dark concrete, and traditional roofing) to around 0.45 using reflective coatings and light, colored materials can have a very big effect on the reduction of heat that is

absorbed. This alteration can bring down the outdoor air temperature at the neighborhood level by about 1-1.5°C. The temperature inside the buildings, for instance, in the top, floor apartments and the houses or buildings with a small amount of insulation, can be reduced by 2-4°C. Such decreases make a very small use of air-conditioners thus a cooling energy demand of about 15-25% is saved at the hottest hours of summer.

Urban Heat Island Mitigation
Highly reflective surfaces on roads and rooftops absorb less heat during the day and consequently, they also release less of this heat during the night, which is the main cause of the urban heat island effect. Besides they have a positive effect on cooling nighttime temperatures which leads to improvement of thermal comfort in compact residential areas, better conditions for sleep, and reduction of accumulation of heat fatigue during long, lasting heatwaves.

Air Quality Improvement
Lower surface and ambient temperatures have the effect of slowing the photochemical reactions that lead to the formation of ground, level ozone as well as the production of heat, related air pollutants, thus their concentration decrease. As a result, improved albedo conditions contribute indirectly to better air quality, reduced respiratory irritation, and lower public health risks, particularly for vulnerable populations.

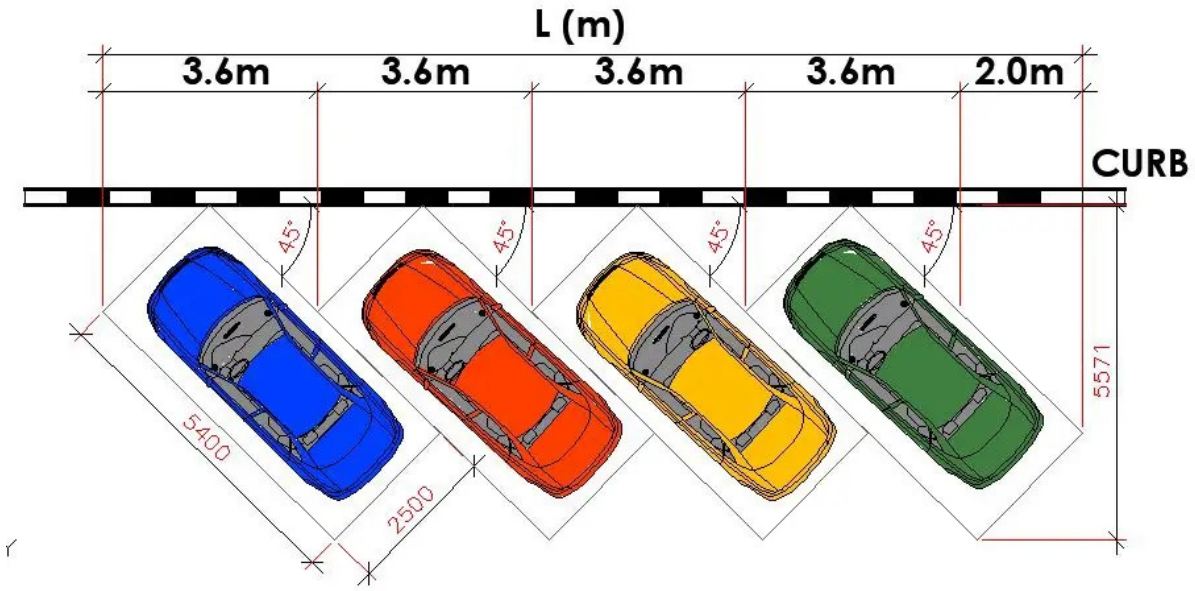
Economic and Health Benefits
Lowering the need for cooling leads to less electricity consumption and therefore energy costs go down for households, businesses, and public buildings. At the same time, cooler indoor and outdoor environments reduce the incidence of heat-related illnesses, hospital admissions, and heat-induced mortality, especially during extreme weather events. The total of these benefits has a positive effect on the economy over time and contribute to making public health more resilient.

Estimated Cost
It is estimated that the combined investments necessary for different high, albedo surface interventions implemented throughout a city amount to somewhere between €40 and €60 million the exact figure depends on factors such as the degree of coverage, the choice of materials, the requirements for surface preparation, and the planning of maintenance.

Parking Reformation: Diagonal Parking and One-Way Street Systems

This intervention aims to reorganize parking and circulation of the traffic in the selected urban areas to increase the spatial efficiency, enhance the safety of pedestrians and create the opportunity of urban greening (Image10). The strategy, through optimizing the way street space is allocated and used, aims at balancing the needs of vehicles, pedestrians, cyclists, and public space, to a level that is compatible with the benefits of improved environmental performance and urban quality of life.

Image 10: Parking Reformation: Diagonal Parking (structville.com/geometric-design-of-parking-facilities)



Spatial Efficiency

Diagonal parking makes it possible for vehicles to be placed in a clearer and more organized way, thus the limited street width can be used more efficiently, especially in dense neighborhoods with narrow or irregular road layouts. This method of parking by clearly marking parking bays helps to eliminate illegal stopping and double, parking that are frequently the main reasons of congestion and blocked sightlines. The increase in parking organization results in less traffic congestion and more predictable street behavior for all users.

Traffic Flow Optimization

The changes of certain streets to one-way systems help to streamline the flow of traffic and lower the number of points where vehicles can come into conflict at crossroad junctions. Fewer opposing traffic streams result in less stop-and-go driving, shorter idling times, and improved travel time reliability.

Space Reallocation

By making parking layouts and traffic circulation more efficient, it is possible to return valuable sidewalk and roadside space to the community. The space that has been released can be given back to nature or the city in the form of green strips, bioswales, permeable surfaces, or street trees. These measures not only help with the control of stormwater but also improve the local microclimate due to shading and evapotranspiration and make the urban streetscape more attractive and of a size suitable for humans.

Human Well-Being

Where vehicle conflicts are less, lower traffic speeds and noise levels make for a safer pedestrian environment which in turn is likely to be walked, cycled, and used for street, level interaction. Enhanced walkability is good for physical health, mental well, being, and social interaction, and it also contributes to the growth of neighborhood identity and local economic vitality.

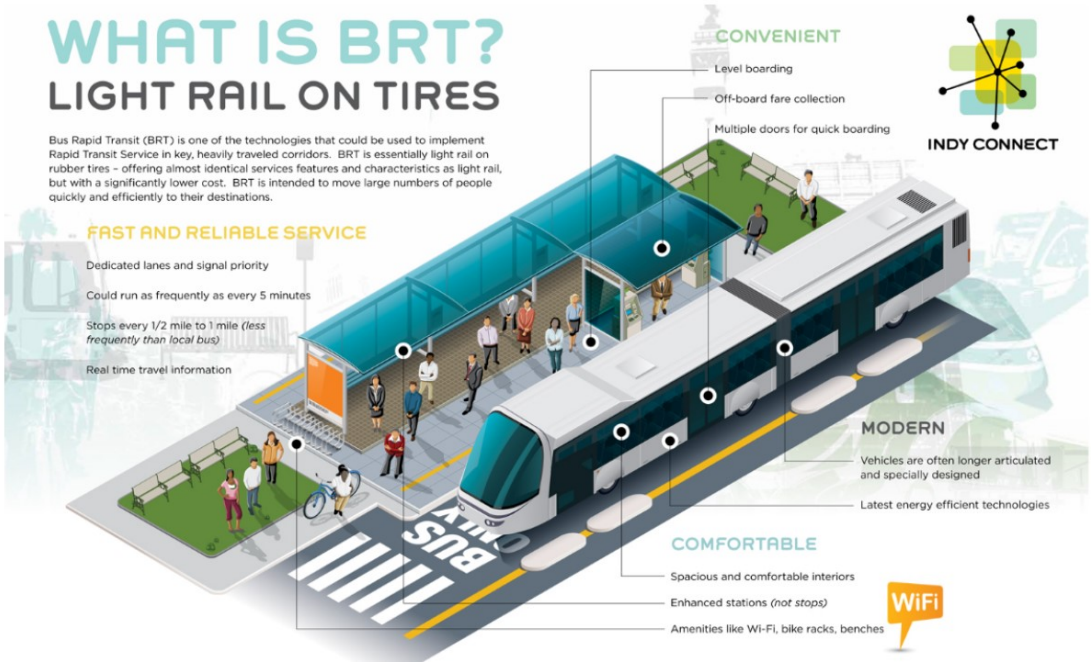
Estimated Cost

It is estimated that the price of carrying out these actions in a city, wide manner would run somewhere between €5 and €10 million. The variation in the cost depends on how far the measures are applied and how many streets are counted.

New Transportation Lines in Industrial and Commercial Zones

This intervention aims at the creation of new or the extension of existing public transport lines e.g. bus rapid transit (BRT), light rail systems, or targeted metro extensions directly serving industrial and commercial areas with a high concentration of employment, logistics, and freight activities (Image 11). With the supply of high, capacity, reliable, and low, emission transport to these zones, the strategy intends to lower the use of private cars to a significant level, enhance the efficiency of the daily journey, and back the emergence of sustainable mobility patterns in the whole metropolitan area.

Image 11: New Transportation Lines in Industrial and Commercial Zones (https://betterbuscoalition.org/bus-rapid-transit)



Emission Reduction

New high, capacity public transport lines mainly attract many people who previously used a private car thereby a shift from the one to the other is strongly observed. Such a shift is singled out to happen particularly in the areas of the city where there is a heavy flow of commuter and freight traffic. Consequently, this mode shift causes the decrease of the areas of congested traffic and the reduction of their carbon dioxide (CO) emissions, nitrogen oxides (NOx), and particulate matter ($PM_{2.5}$ and PM_{10}) becomes visible. In addition, the substitution of diesel buses, trams, or trains with cleaner technologies, including battery electric buses, modern metros or light rail, hardly fails to reverse air pollution and makes a positive contribution to climate change mitigation goals.

Accessibility
Enhanced public transport connectivity improves access for workers employed in major industrial and commercial districts such as Eleonas, Rentis, Thriasio, Metamorfosi, and Markopoulo. Good and regular services bring down the times when traveling is a matter of chance, thus, the actual labor catchment area of these zones becomes larger, and their interconnection with the adjoining residential neighborhoods is intensified, supporting both economic productivity and workforce mobility.

Efficiencys
During peak hours, high-capacity transit services are instrumental in congestion reduction as they are able to take in a larger proportion of commuter demand and at the same time offer quicker and more predictable travel times than what can be achieved by private vehicles. The use of dedicated lanes or segregated rail corridors essentially removes the delays caused by traffic conflicts which in turn results in shorter traveling times, better service reliability, and general increases in network efficiency.

Urban Regeneration
The presence of modern public transport infrastructure acts as a catalyst for sustainable urban regeneration in industrial and commercial areas. Improved accessibility attracts investment, supports mixed-use development, and enables the implementation of green logistics solutions, such as electric bus fleets, rail-based freight transport, and low-emission last-mile delivery systems. These changes contribute to cleaner, more resilient, and future-oriented economic activity.

Social Equity
By expanding affordable and reliable transport options, the intervention enhances access to employment opportunities, services, and amenities for lower-income residents and workers who rely on public transport. Improved connectivity reduces transport-related social exclusion, supports equal access to jobs, and contributes to a more inclusive and balanced metropolitan mobility system.

Estimated Cost
The estimated capital needed to put in place new public transport lines is said to be between €50 and €150 million per line.

Prioritizing Ecological Sustainability and Human Well-Being - Overall Impact and Integration

These planned measures should result in concrete environmental, energy, and social advantages that spread over the Athens Metropolitan Area. To illustrate the level of satisfaction with the temperature, the triple strategy of high-albedo surfaces, urban greening, and better street design can lead to a decrease in indoor temperatures of up to 4°C and outdoor temperature reductions of 1-2°C in the areas that have been treated with the mentioned interventions thus, heat stress in these areas will be mitigated significantly in the warm season.

Lowering these temperatures, they are talking about a 15-25% decrease in the cooling energy that is needed and thus help lowering the emissions of gases that contribute to global warming and the costs related to these operations for households and businesses decrease. Changes in mobility to become more efficiently parking reorganization, better street layouts, and expanded public transport access in areas with a high concentration of

industry and commerce should lead to less congestion, fewer emissions from vehicles that are not moving, and general better functioning of the urban transport network.

Moreover, the quality of public space has been significantly improved with safer traffic conditions, the return of the street space, and several green areas resulting in more walkable, greener, and human, centered streets. These spatial changes enhance social interaction, active mobility, and a stronger sense of local community in neighborhoods. Less exposure to extreme heat, air pollution, and noise, from a public health and well, being perspective, is resulting in better physical and mental health, especially for a sensitive group of children, the elderly, and outdoor workers. All these factors, when taken together, make the urban environment more livable and resilient.

The overall approximate capital needed to carry out these initiatives varies between €100 million and €220 million, depending on the extent of the citywide application and the chosen transport modes.

3. CONCLUSIONS

The proposed framework is a single, coherent strategy that aligns the issues of urban mobility, climate resilience, and human well, being, and Athens' immediate challenges as well as its long, term future. Instead of treating transportation, environment, and public space as separate systems, it acknowledges their profound interrelation and arranges their interaction.

At the core of the strategy is a move to smarter and cleaner transport solutions, getting rid of the congestions that have been happening for a long time, reducing emissions, and making it possible to easily move around again the whole metropolitan area. Efficient, accessible, and environmentally friendly mobility is what will make it possible to move away from car dependency toward more balanced mobility choices in the city.

Nature reintroduction in the urban fabric is, however, as important as the other points. The large, scale reforestation of Mt.Egaleo coupled with the transformation of Eleonas into a metropolitan park creates not only a cooling but also an ecological network that will moderate temperatures, purify the air, and return green space to the most heavily populated parts of the city.

This green network is supported by the development of small-scale water retention bodies whose purpose is to delay runoff, mitigate the risk of flooding, and facilitate the revival of the local ecosystems. These measures not only ramp up the city's climate resilience capacity but also re-establish the city's connection with its natural hydrological cycles.

At the neighborhood level, this means the implementation of reflective materials, redesigned parking layouts, and new public transport lines that transform the streets we use daily into cooler, safer, and people, oriented places. Streets become areas where people can move, interact and relax, not just spaces for vehicles.

When combined, these measures present a way to express a shared vision of Athens: a city that is environmentally sustainable, socially inclusive and economically viable, creative while being respectful to nature, and where urban development results in an improved quality of life for all citizens.

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