Urban Heat and Athens, Greece

How can a critical historic framework generate more effective implementation strategies for UHI mitigation?

Undergraduate Honors Thesis – University of Colorado

Thesis Author: Constantine Chrisafis

Chair: Dr. Danielle Rivera

Outside Chair: Dr. Mehdi P. Heris

Honors Council Representative: Dr. Paul Chinowsky

Abstract

This thesis challenges the current approach to urban heat island effect (UHI) mitigation in Athens, Greece by using a historic framework to identify the internal and external forces that have shaped the city over time. Athens' contemporary urban expansion has been characterized by an inability to implement stated urban policy goals, and approaches to UHI mitigation in the city must acknowledge this historic reality. In a field riddled with comparative case study analyses and broad mitigation approaches, using a hyper-specific single case yielded potentially more effective implementation strategies. Urban heat island mitigation cannot simply be a set of spatial directives or practices generalized across cultures and cities. A more intersectional and critical framework is needed to understand how "best practices" can be adapted in a complicated implementation reality. The case of Athens, Greece proposes that a historic framework is an effective way to engender this kind of discourse when considering mitigating UHI. Future work needs to further delve into the benefit of a qualitative historical analysis in improving UHI mitigation outcomes in other urban settings.

Figure 1. Left: The Acropolis and Parthenon in Athens, Greece.

Table of Contents

Introduction

Athens, Greece is Europe's sixth largest capital (Salvati, 2017). Sprawling across the arid Attica Basin, the metropolitan area comprises 3.7 million people (Gounaridis, 2018). The city is the economic, political, and civic epicenter of a highly centralized Greek state (Karatzas, 2012). As the southernmost capital on the European mainland, the city records the highest average temperatures of any major city in the European Union, and climate predictions paint a dire picture for the already hot metropolis (Georgakis, 2017; Santamouris, 2017).

There is a direct correlation between urban form and an increase of temperature in the surrounding environment (Aflaki, 2017; Ward, 2016). This phenomenon, known as the urban heat island effect (UHI), is linked to a number of negative externalities relating to human health, economic growth, and political stability (Arnfield, 2008).

Athens exhibits especially high temperatures throughout the summer months. These temperatures are amplified by the urban heat island effect, which can cause the city's urban core to rise 10° F warmer than the surrounding rural countryside (Fotini, 2014; Kotroni, 2011; Theoharatos, 2010). In Athens, the southern latitude of the city predisposes it to a warmer climate. However, its sprawling and dense urban morphology amplifies temperatures throughout the area (Salvati, 2017). Contending with an aging population, a high density of people, a long history of urban mismanagement, unregulated growth, a lack of public investment in urban infrastructure, and the lowest green space per capita out of any European capital, Athens is extremely vulnerable to scorching urban temperatures during the summer (Debbage, 2015; Karatzas, 2012; Stone, 2019; Ward, 2016). These factors amplify UHI and create dangerous urban climate conditions, especially during large heatwaves.

Urban heat island mitigation strategies have the potential to ameliorate the effects of the city's pervasive heat, cool the metropolis, and create a more resilient Athenian fabric. By retrofitting the city's dense impervious core with a variety of green infrastructure initiatives, and utilizing federal power to hasten their application, Athens could begin addressing this issue. The city has, in fact, developed an urban heat island

Figure 2. Left: Looking at the classical Agora in the foreground and central Athens in the background.

mitigation framework through the Athens Master Plan, whose most recent update in 2009 propagates a policy framework for addressing the issue. Despite offering a number of progressive strategies to fight endemic urban heat across the city, the plan has failed to result in any significant action (Asprogerakas, 2019; Feliciantonio, 2018; Gospodini, 2009; Gounaridis, 2018; Sarigiannis, 2020; Theoharatos, 2010).

Urban heat island mitigation strategies are often presented, and contextualized, as regulatory guidelines embedded in an urban policy context (Stone, 2019). There is a scientific consensus on methods to mitigate urban heat. However, the lack of a diverse set of implementation strategies, coupled with an accountability mechanism, make it difficult for cities with weak municipal governance systems, like Athens, to truly combat this problem.

Athen's contemporary urban expansion has not been guided by regulation but, in fact, by a disregard of urban policy. While many cities develop according to the visions laid out in their master plans, Athens does not. The regulatory framework for UHI mitigation in the city, which is embedded in its Master Plan, ignores this important historic precedent. This points to a deeper problem with UHI mitigation literature, which often fails to elaborate on implementation strategies and context-specific approaches, instead providing broad design and policy guidelines. This thesis seeks to understand and challenge the current approach to UHI mitigation in Athens, Greece, but more broadly question through this case study: **How can a critical historic framework generate more effective implementation strategies for UHI mitigation?**

Historic analyses and frameworks are an established way to approach spatial planning problems. This tool can help identify specific organizations, policies, governance systems and communities which are responsible for urban change over time (Adler, 1989). The urban heat island effect is seldom approached through a historic lens; however, effectively addressing the phenomenon is intrinsically linked to a city's historic urbanization and governance systems. This framework is used to identify the problems with the Athens Master Plan as a vehicle for UHI mitigation, and seeks to identify more effective implementation strategies for the city. The historic

conditions that have shaped Athens' urban expansion are at odds with the current regulatory framework in place. This study aims to understand how the city has experienced urban growth and development, in order to improve future UHI mitigation in Athens.

A municipal regulatory framework is inadequate for a city which lies outside of the traditional levels of stronger governance enjoyed by its wealthier European counterparts. Athens struggles with managing urban heat and lacks critical urban policy implementation strategies to combat it (Vaiou, 2002; Georgakis 2017; Santamouris, 2017). As heat waves increase in frequency and severity, the city will suffer more extreme effects from high ambient temperatures and the need to intervene will grow in urgency (Musco, 2016; Tokarska, 2019). The city presents a compelling case study to examine how a historic approach to UHI mitigation could embed implementation strategies more effectively.

The urban heat island effect is a positive feedback loop, with climate change and urbanization continually amplifying temperatures. Cities that are most vulnerable, like Athens, demand a more critical eye to implementation. The ubiquitous paradigm of UHI mitigation as a municipal regulatory framework (Arnfield, 2008; Aflaki, 2017) must be challenged, before climate change puts an even greater strain on cities sitting at the forefront of a global climate crisis.

Literature Review

The literature review begins by defining the urban heat island effect and establishes its negative externalities. It then lays out scientifically proven interventions to mitigate UHI. Finally, the review concludes by introducing literature discussing the implementation of UHI mitigation strategies. The content of the literature review reveals that no one prescribed set of solutions to mitigating UHI exists. A qualitative analysis is necessary to acknowledge the political, cultural and economic realities of different countries and cities. By understanding that implementation does not happen in homogeneous and controlled environments, approaching UHI mitigation through first understanding a city's history could be advantageous; in some cases, to select and ultimately implement the most efficacious and meaningful strategies to reduce the profound effects of UHI.

Figure 3. Left: Image of Tokyo, Japan which is the most populous urban area in the world. Cities accross the globe are struggling to manage the urban heat island effect.

What is UHI?

The urban heat island effect is a complex phenomenon involving the interaction of various human and natural systems which cause a warmer urban microclimate. An urban “heat island” describes an urbanized area which exhibits higher temperatures compared to its neighboring, non-urbanized counterparts (Aflaki, 2017). A severe UHI is recognized when the temperature of an urbanized area reaches 5 to 10° F (12 - 15° C) warmer than surrounding rural areas (Environmental Encyclopedia, 2011).

This phenomenon is linked directly to urbanization. When large numbers of impervious surfaces are introduced into a landscape, temperatures rise as vegetation is removed and replaced with materials like asphalt and concrete (Aflaki, 2017). These two materials are the most commonly recognized surfaces in urban areas, and their thermal bulk and surface radiative properties are the most significant factors in creating higher ambient temperatures (Hathway, 2012). As global demographics have shifted to become decisively more urban in the past century, understanding the urban heat island phenomenon has become increasingly salient in discussions revolving around urbanization, climate change, and public health.

High ambient temperatures are a natural part of environments around the world during summer months and heatwaves (Kleerekoper, 2012). However, the urban heat island effect creates unnaturally warm conditions where temperatures in urban areas are amplified greatly and fail to cool down during the evening (Aflak, 2017). The urban heat island effect is generally more pronounced during the evening, however most of its serious negative externalities manifest during the day, particularly during large summer heat events (Theoharatos, 2010). An anthropogenic microclimate induced by urbanization, UHI negatively impacts both urban and natural systems in a built area through a constant “thermal stress” (Theophilou, 2015).

The English scientist, Luke Howard, provided the first modern observation of the phenomenon in 1833 with a report describing the microclimate of London (Bouyer, 2017). He found that air temperatures in the city were higher than in the surrounding countryside.

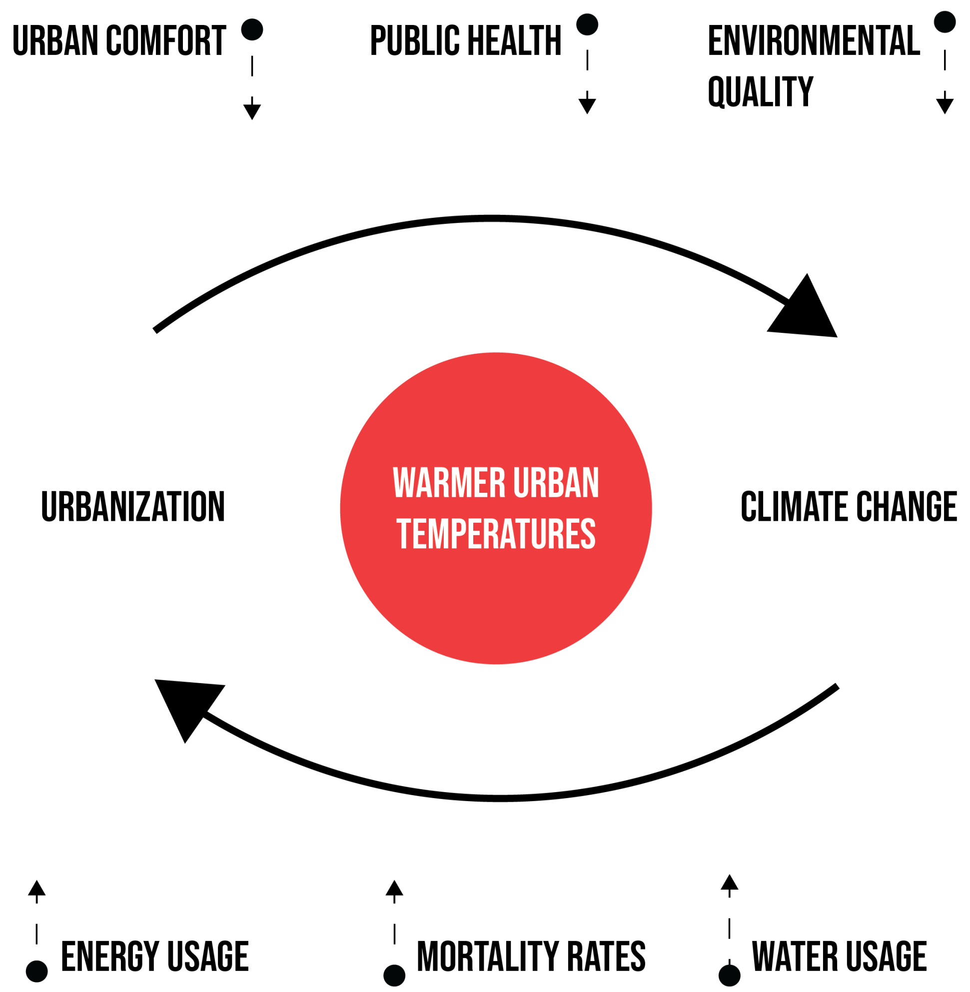
The study of urban heat expanded considerably in the latter half of the 20th century and 21st century, as scientists, urban planners, and policy makers pursued a deeper understanding of the negative ramifications that this phenomenon has on urban centers and human populations.

Urban systems are negatively impacted by urban heat islands, where elevated ambient temperatures strain existing infrastructure. The phenomenon is correlated with increased energy demand for cooling, greater water usage, and deteriorating comfort conditions in urban environments (Bouyer, 2017). Increased energy demand for cooling often translates into higher air conditioning bills, putting particular strain on vulnerable populations who are unable to afford increased utility costs (Aflaki, 2017). The effect is compounded when electrically fed air-conditioners release hot air into the surrounding environment, further raising temperatures (Arnfield, 2008). What is an individual solution for addressing uncomfortably high temperatures exacerbates the problem on a broader level, and complicates efforts to mitigate urban heat. This cycle inflates demand for power, further warming cities and putting populations who cannot afford artificial cooling systems at an even greater risk of suffering the negative effects of high urban temperatures.

UHI also degrades natural environments. It is associated with raising the temperature of hydrological systems, as runoff is heated while traversing warmer paved surfaces (Aflaki, 2017). This “urban runoff” can negatively affect the health of riparian and aquatic habitats, and decrease water quality (Glaeser, 2010). The effect also impacts air quality. Urban heat islands are correlated with increased air pollution, as warmer temperatures accelerate chemical interactions between impervious surfaces and the atmosphere (Allmendinger, 2017). Air and water quality are closely associated with human health, and large heat islands have significant public health consequences that can impact municipalities and even entire regions (Debbage, 2015). A report studying the mortality rate of large heat waves across the Chicago area, over two decades, concluded that the urban heat island effect greatly exacerbated air quality problems and contributed to a significant increase in mortality rates during large summer heat events. (Arnfield, 2008).

Extreme heat events are, on average, responsible for more climate-related fatalities in the United States than any other form of severe weather, and air quality is only one component (Debbage, 2015). The urban heat island effect has a variety of direct consequences on human health. It is most significantly linked to "heat stress," an increase in heat-related illnesses and higher mortality rates (Arnfield, 2008). Heat stress is a condition that develops when the human body is exposed to high temperatures for extended periods of time, primarily due to amplified evening temperatures which prevent the body from releasing excess heat accumulated during the day (Ward, 2012; Theoharatos, 2010). In an attempt to cool itself, the human body mounts a physiological response, rushing blood to the surface of the skin (Theophilou, 2015). Due to this natural response, less blood is available to the brain, muscles, and other parts of the body causing strength and mental capacity to diminish (Allmendinger, 2017). Continued exposure to elevated temperatures, and lack of medical intervention, can cause loss of concentration, irritability, and dehydration (Theophilou, 2015). In severe cases, it can result in fainting and death (Fotini, 2011).

Heat stress is the most prominent ailment correlated with the urban heat island effect, but a myriad of other conditions from diabetes, high blood pressure, and asthma have been found to be exacerbated by UHI (Fotini, 2011). Elderly populations, the sick, and people with compromised immune systems are all at greater risk for hospitalization during heatwaves, and the phenomenon of the urban heat island effect puts them at particular risk (Edmondson, 2016; Taslim, 2015). The health consequences of UHI can levy considerable stress on public health systems over time. The direct impact of urban heat islands on public health is well-documented, with a study in Athens correlating a two-day heat event in 2007 with over 700 hospital visits and 150 deaths (Georgakis, 2017). Increased hospital usage put enormous pressure on the city's fragile public health system, already one of the weakest in Europe. A number of other deaths occurred weeks and months after the heatwave, with an incalculable toll that is hypothesized to be the country's largest during any major heat event (Kotroni, 2011). The negative human health impacts of the phenomenon are well-documented, and buttress support for mitigating UHI.



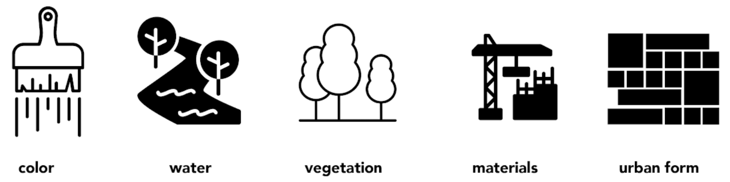
Above: A diagram illustrating the phenomenon of the urban heat island effect, where climate change and urbanization are constantly working to create hotter urban temperatures.

The negative health externalities of UHI are not experienced evenly across economic classes. There is an insidious environmental justice component to the problems posed by UHI. Lower income populations and communities are found to be disproportionately affected by heatwaves (Aflaki, 2017; Kotrini, 2011; Arnfield, 2008). Strenuous physical activity and extended time outside in urban environments, especially during heat waves, predisposes certain populations to the negative health effects associated with it. Lower income populations often lack access to air-conditioned environments, both at home and in the workplace, and therefore suffer more from the health consequences of "heat stress." On a spatial level, lower income communities often lack access to amenities which ameliorate the effect, such as greenspace, shaded public areas, and efficient public health systems.

While the urban heat island effect disproportionately affects lower income communities, it also threatens lower income countries. A 2016 report from die Technische Universität in Berlin found that the European Union's poorest member states would bear the brunt of climate related mortality on the continent, and that they were the least prepared to combat rising temperatures (Ward, 2016). An earlier report from Deutsche Bank in 2008 predicted a vast economic impact in the coming century for Europe's southernmost countries, as rising temperatures put enormous strain on populations and already overburdened public infrastructure systems (Ehmer, 2008). Climate change is causing global temperatures to rise, triggering more frequent and severe heat waves across the world. The urban heat island effect will expand its intensity and breadth in the coming decades, negatively impacting the health and welfare of urban residents, metropolitan areas and entire economies. This reality has galvanized climate and urban researchers to understand how best to mitigate this effect.

UHI Mitigation Strategies

The urban heat island effect is a complex microclimate phenomenon, requiring a broad range of interventions from the building scale to the greater urban landscape. A comprehensive understanding of the different elements which mitigate the urban heat island effect is therefore essential in addressing this problem (Aflaki, 2017).



Above: Common ways to combat UHI.

The breaking apart of large conglomerations of impervious surfaces is the most essential strategy in mitigating the effect (Debbage, 2015), and increasing vegetation has been identified as one of the most effective techniques. The introduction and expansion of urban vegetation has the capacity to greatly cool the surrounding urban environment, and can integrate into streets, buildings, and public spaces (Edmondson, 2016). Trees are the most effective vegetation to introduce into urban spaces, and have been shown to decrease soil temperature and cool the surrounding environment by providing shade and transpiration. In order to maximize cooling benefits, trees must be mature, leafy, and watered regularly (Edmondson, 2016). Failure to maintain urban trees can nullify their positive cooling effects, and multiple studies have confirmed the importance of having a system for proper care of public trees (Skoulika, 2014; Chow, 2003; Arnfield, 2008). Non-leafy vegetation, such as palm trees, provide little benefit in mitigating UHI. In arid climates where the growth of large leafy trees is prohibitive without extensive irrigation, shade structures on streets and in public spaces provide a comparable cooling benefit (Chow, 2011). Herbaceous vegetation, while not as effective at cooling temperatures, can still be integrated into urban areas and contribute positively to environmental quality (Stone, 2019). Breaking up impervious surfaces by introducing more vegetation near roads and sidewalks, and in public plazas, cools urban environs.

Parks and contiguous public greenspaces, which conglomerate vegetation, are an even more effective means to cool surrounding environments. Regardless of size, parks have been shown to ameliorate local heat conditions to a distance of approximately half the parks width away (Hathway, 2012). A case study looking at the effects of a 60,000 square meter “medium-size” urban park in Athens on the surrounding area illustrated the benefits that urban greenspaces can provide (Skoulika, 2014). The greenspace is surrounded by a dense urban area with residential and commercial buildings and heavy traffic. The well-watered grass, bushes, olive and eucalyptus trees in the park were found to filter pollutants, mask noise, stabilize soil and prevent erosion as well as provide a highly-used recreational space for the surrounding neighborhood (Skoulika, 2014). This study illustrates that even modest-sized parks are capable of ameliorating the urban heat island effect, with the park being on average 2° C cooler than the surrounding urban landscape. Larger systems of interconnected greenspaces have been shown to even more dramatically cool surrounding urban environments.

The presence of running water is shown to decrease temperatures 3-7° C, when combined with a 10-foot vegetated buffer (Hathway, 2012). The integration of these “green” and “blue” systems could be of particular interest to urban planners and landscape architects seeking to cool environments. Cities, particularly in the past century, have buried their rivers and hydrological systems in the name of urban expansion. This trend has contributed to the increased warming of urban areas (Iojă, 2018). Restoring and daylighting hydrological systems has the potential, when combined with greenspace, to more significantly decrease urban temperatures (Hathway, 2012). Cities around the world have begun uncovering their natural waterways or creating new ones, most famously in Seoul, South Korea. In 2003, the city removed the Cheonggyecheon expressway and implemented a nine-kilometer artificial river and park in its place (Galagoda, 2018). The project has been estimated to cool summer temperatures about 3.6-5° C. As urbanized areas seek to understand how new greenspace can be implemented, their buried hydrological systems covered by car-

oriented infrastructure networks provide compelling opportunities to expand greenspace and address the urban heat island effect.

Figure 4: Images of the former Cheonggyecheon expressway in Seoul, South Korea. The river and park system that replaced the highway has resulted in a notable decrease in ambient temperatures throughout the surrounding urban enviornment.

Green walls, facades and rooftop gardens have become popular amongst architects and city planners as a way to introduce more vegetation to building facades and roofs. However, their ability to reduce the urban heat island effect is mixed (Sharma, 2016). While they do cool interior spaces and streets, they often require a high degree of engineering and carry prohibitive costs (Allmendinger, 2017). A 2016 study from Chicago found that rooftop gardens and green facades might even compound the urban heat island effect by obstructing wind patterns (Sharma, 2016). In contrast to planting on buildings and roofs, changing their color is a more economically feasible way to mitigate the urban heat island effect (Bouyer, 2017; Hu, 2016). Light-colored facades have the capacity to create cooler interiors and exteriors around buildings (Theophilou, 2015). Their high albedo reflects sunlight and heat, instead of absorbing and holding it (Santamouris, 2013). White facades are the most effective in mitigating urban heat islands (Allmendinger, 2017). White and brown colored roofs reflect sunlight and heat and, when combined with light-colored facades, can considerably improve energy efficiency as well as indoor and outdoor thermal comfort (Jusuf, 2019; Kleerekoper, 2012). The color of a building's roofs, walls and facades are part of what intensifies UHI. However, when the aforementioned techniques are combined and executed on a large enough scale, they have the potential to improve the comfort of outdoor and indoor conditions (Aflaki, 2017).

Materials used in building facades in urban areas have also been shown to influence indoor and outdoor temperatures. Certain materials have the capability of reducing outdoor temperatures and improving energy efficiency (Aflaki, 2017). Stones are the best suited natural construction material, due to their high heat capacity and relatively low heat conductivity (Santamouris, 2013). Hollowed out bricks filled with concrete, a common and low-cost building material in many developing countries, are shown to be extremely ineffective at maintaining comfortable thermal conditions. A 2016 study found that extensive use of hollow bricks contributed to higher heating and cooling costs (Musco, 2016). Additionally, this construction method creates warmer indoor environments correlated with higher mortality rates during summer heat events (Rantzoudi, 2017). Large glass facades, a hallmark of modern architectural projects, trap solar radiation, increase energy costs and raise ambient temperatures. Utilization of large glass facades rely on complex heating and cooling systems to create comfortable thermal conditions.

The spatial configuration of cities can affect how urban environments alter local energy balances. Previous studies have reached the paradoxical conclusions that both sprawling and high-density urban development amplify urban heat island intensities (Debbage, 2015). The geometric organization and form of buildings on a broader neighborhood and city level greatly affect the UHI and urban microclimate (Hu, 2016). "Urban canyons," formed by dense blocks of wall-to-wall development decrease airflow and can significantly increase urban temperatures (Aflaki, 2017). A dense urban morphology, lack of open, public spaces, and dearth of vegetation amplify the UHI effect (Bouyer, 2017). Building regulations and urban plans have the capacity to guide the development of new urban forms to create more amiable conditions, but the vexing problem of existing dense urban morphology poses structural challenges to mitigating urban heat.

Figure 5: Images of Cycladic architecture, a vernacular style which utilizes color, material and urban form to reduce urban temperatures on the hot and arid Greek isles.

Implementing UHI Mitigation Strategies

Mitigation strategies to combat urban heat, and its associated negative externalities, have been identified. When implemented on a large enough scale, they can significantly lower temperatures and alleviate the condition. A 2019 study from the Journal of Planning Education and Research modeled the impacts of heat management strategies, including tree planting and other green infrastructure, cool roofing and paving, and a reduction in waste heat emissions from buildings and vehicles, on estimated heat-related mortality across Louisville, Kentucky (Stone, 2019). Their assessment found that the combination of these urban heat management strategies decreased temperatures by as much as 10° F on hot days and have the potential to reduce estimated heat-related mortality by more than 20 percent (Stone, 2019). However, this model assumed that these mitigation strategies could be implemented city-wide, and significant portions of the city were required to be completely overhauled and reconfigured to create more amiable urban conditions.

The study, while promising, illuminated the difficulties in implementing a comprehensive UHI mitigation strategy, an emerging topic amongst researchers looking to combat the effect (Stone, 2019). How are UHI mitigation strategies applied in the context of already established and built-out communities? What is the "ideal" urban fabric for combating urban heat in dense historic cities? A 2017 study which looked at the negative consequences of the urban heat island effect in Kuala Lumpur, Singapore, and Hong Kong found that the lack of sufficient attention to the practical application of effective heat mitigation strategies in existing urban development was dramatically intensifying the impacts of UHI (Aflaki, 2017). While urban codes may address the urban heat island effect in new development, the most vexing problems stem from trying to modify and retrofit existing fabric.

Enforcement of regulations regarding new development, and plans to retrofit existing morphology may only exist in regulatory and planning documents. Codified mitigation strategies may lack physical application strategies and specific urban plans. While interest in the urban heat island effect and its

mitigation is growing, implementation of codified strategies is largely "operative," assumed to be embedded in municipal regulatory documents. This limits the ability of UHI mitigation to transcend "urban policy documents," such as master plans and guiding land use documents. A number of studies challenged the scale and methods embedded in existing urban planning paradigms for UHI mitigation, and recognized the urgent need for new, unconventional implementation strategies (Aflaki, 2017; Galagoda, 2018; Stone, 2019; Taslim, 2015).

In cities that struggle with enforcing regulatory frameworks and actualizing plans, the urgency of new "unconventional implementation strategies" is paramount. Uncontrolled urban growth has adverse effects on the environment and its citizens, and this becomes glaringly apparent with UHI. Cities grappling with urban mismanagement and informality often manifest the most significant urban heat islands and struggle the most with mitigation (Aflaki 2017, Akande, 2019). Contributing to this problem is that much of the research concerning UHI mitigation has originated from higher-income countries, which are often the least burdened by the effect, and most capable of transforming their cities (Aflaki, 2017; Taslim, 2015; Theoharatos, 2010).

Historic Framework

A historic framework is an established way to approach spatial planning problems, and has the potential to elucidate "effective and implementable mitigation strategies." The issue of implementing UHI mitigation strategies is uniquely qualified for a historic analysis because the tool identifies the specific organizations, policies, governance systems and communities that are responsible for urban change over time (Adler, 1989).

A historic framework requires at the very least an understanding of the external forces that have shaped a city, the internal dynamics that have driven urban change, and how these forces have evolved over time (Adler, 1989). A more comprehensive historic framework also considers the evolution and manifestation of public agencies over time (Abbott 1983). A planning analysis which delves into local planning history, the evolution of relevant national policies, and patterns of urban settlement, can help elucidate how planning problems develop and can be used to propose meaningful solutions. Historical analyses lack the predictive precision that is usually claimed by quantitative or social science models, but offers a systematic way to understand the changing context of cities, communities, and policies (Adler, 1989).

A significant body of theoretical work buttresses applying a more intersectional and critical framework to planning problems. Sandercock, Watson, and Robinson are urban theorists who critique modernist planning practices and advocate for more diverse and heterogeneous responses to urban planning problems (Robinson, 2016; Sandercock, 1998; Watson, 2009). More specifically, Watson identifies the urgency of utilizing more intersectional methods especially in communities struggling with informality, whose processes of addressing urban problems differ significantly from more traditionally planned communities (Watson, 2009). A historic framework can challenge existing urban planning paradigms for UHI mitigation and provide a framework which can adapt to the diverse needs of different cultures, cities, and urban histories.

In summary, the large number of scientifically proven UHI mitigation strategies require a more qualitative planning tool to select relevant techniques and place them in the context of different cities. A historical framework elucidates the realities that need to be considered when approaching UHI mitigation: political, regulatory, socio-economic, financial, cultural, and existing urban form. This framework can be used by governments interested in identifying realistic ways to protect cities, people, institutions and economies from the damaging effects of urban heat islands.

Methods

This thesis looks at Athens, Greece as a single case study to understand the research question: How can a critical historic framework generate more effective implementation strategies for UHI mitigation?

The primary method of data collection is a qualitative content analysis comprising five historic Athens master planning documents, in conjunction with numerous historical narratives from 1830-2020. The focus in reviewing both the planning documents and the narratives was to ascertain the efficacy and implementation of the various plans to determine the forces which have driven Athenian growth over time. The ultimate goal of this qualitative content analysis was to question the 2009 Athens Master Plan as an efficacious vehicle to combat the urban heat island effect.

An important rationale for using a single case is when it represents a critical example in testing a well-formulated theory (Yin, 2009). Athens provides this compelling "critical" case to understand the capabilities of a historic framework in helping select and implement efficacious approaches to UHI mitigation. In a field riddled with comparative case study analysis (Aflkai, 2017; Chow, 2011; Eliasson, 2000; Robinson, 2016; Taslim, 2015) and broad mitigation strategies, taking a hyper-specific single case approach has the potential to yield more effective city-specific implementation strategies.

Athens has been identified as one of the most vulnerable cities in Europe regarding rising temperatures, exhibiting one of the most dramatic urban heat islands on the continent (Mullis, 2016). Compounding this problem are climate projections which show Athens growing warmer and wetter as the century progresses (Alexandropoulou, 2013; Georgakis, 2017). The city is an example of an extreme case among the European member states in regards to climate vulnerability (Mullis, 2016; Akande, 2019), further buttressing a planning analysis which delves into Athenian local planning history and patterns of urban settlement.

A 2019 report commissioned by the EU, "Ranking Smart Sustainable Cities in Europe", found Athens to be the third least sustainable European city, behind Bucharest and Sofia (Akande, 2019). The report identified the city's sprawling, unregulated, and dense urban morphology as a major concern and identifies the city as one of the most precarious in the EU for confronting the challenges of climate change. Athens also has been identified in a number of other reports

as having a "lower than European average" healthcare system, high unemployment rate (16% in October 2019) and a very low amount of disposable income (Akande, 2019).

These factors put the city in a uniquely precarious position to suffer greatly from the negative externalities of UHI, and compels further exploration of mitigation. The lack of follow-through on the ground regarding the city's most recent 2009 Master Plan warrants a deeper look into why the current planning approach is failing. The results from the case have broader implications outside of Athens, as a historic framework could be useful for other cities that struggle with both informality and urban mismanagement, and whose unique cultures and histories clash with "operative" ways to approach UHI.

A Historic Framework for Athens

The proposed framework ecompasses Athens' contemporary history, urban morphology, previous master plans, and development of major infrastructure systems. The historic framework comprises Athens history, which is analyzed in conjunction with the city's previous master plans, to understand the growth of the city from 1830 onwards. By understanding Athens' previous master plans in relationship to the its gestation over time, the internal dynamics that have driven urban change can be identified and followed to understand the manifestation of the Athenian planning system and existing morphology.

The contemporary data analyzed is the current Athens Master Plan, most recently updated in 2009. The plan offers a series of resiliency strategies which attempt to combat the urban heat island effect. The aforementioned historic framework is used to help understand why each of Athens' urban plans have not been actualized, beginning in 1832. The reasons for past and more recent failures will be contextualized by using the historic framework. Lessons learned from this approach are used to suggest ways to improve the selection and implementation of UHI mitigation strategies.

Data

The Emergence of Modern Greece
The Birth of Contemporary Athens (1830-1896)
Interwar Athens (1896-1940)
War and Postwar Period (1940-1980)
The Consequences of Informality (1980-1990)
Modern Athens and the Olympic Games

Figure 6. Left: Looking out into central Athens.

The Emergence of Modern Greece

Recognized as one of the oldest inhabited cities in the world, Athen's recorded history extends over 3,400 years, but the city's contemporary history arguably started in 1834 when the city became the capital of a newly proclaimed Greek state. From 1453 until 1821, the area which now constitutes the country of Greece was under the rule of the Ottoman Turks (Vaiou, 2002). Prior to the Greek War of Independence (1821-1832), during the final period of Ottoman rule in the early 19th century, Athens was a small but dense town with a population of about 12,000 (Karatzas, 2012).

The modern notion of a Greek state was born in 1830, following the signing of The Treaty of London, where the Great Powers of Britain, France and Russia recognized the country as an autonomous territory after nine years of warfare (Karatzas, 2012). The uprising against the Ottoman Empire is one of the most important moments in modern Greek history, and had dramatic ramifications for the city of Athens (Georgiadis, 2001). The War for Greek Independence was violent, messy, and disallied. Multiple insurrections occurred in different areas around the country beginning in 1821, and what began as a revolt against the Ottoman's lack of flexibility regarding the political autonomy of the region, soon turned into a full-blown war for independence. Different factions with competing ideologies for a modern Greece became pitted against each other as they vied for control over the new nation state, and the uprising against the Ottomans soon descended into civil war (Vaiou, 2002).

The concept of "Greek" identity had survived four centuries of Ottoman occupation, but there was no true concept of a national Greek state. Instead, a fragmented set of dissidents had their own agendas in overthrowing the Ottoman presence in the region. The Eastern Orthodox Church was a major unifying factor for many, with communities fighting to restore the former "Byzatine Empire" and re-establish a Christian state in Constantinople (Georgiadis, 2001). There was also a sizable Greek aristocracy that had developed during the Ottoman occupation. Merchants, ship builders, and landowners controlled much of the region's assets, but were forced to pay exceptionally

high taxes under the thumb of Istanbul. They saw pushing the Ottomans out as a matter of financial gain, which would allow them greater flexibility and power (Karatzas, 2012). There were also local clans and independent warlords claiming Greek legitimacy as ancestors of the long-fallen classical state (Vaiou, 2002). Amongst the chaos of a budding country locked in a civil war, the three Great Powers of Great Britain, France and Russia, saw an opportunity to gain a strategic foothold next to the waning Ottoman Empire (Georgiadis, 2001). In 1828, following seven years of insurrection, each of the Great Powers sent their navies to secure the new country and declared the legitimacy of an independent Greek State to the international community (Vaiou, 2002).

The Birth of Contemporary Athens (1830-1896)

In 1832, after much infighting between the Great Powers about who they would institute as ruler of the new country, Prince Otto of Bavaria was proclaimed King of Greece (Karatzas, 2012). He adopted the Greek spelling of his name, Othon, and moved the capital to Athens (Vaiou, 2002). Athens was chosen as the capital of a proclaimed "re-unified" country largely for historical reasons. The city had suffered greatly from the decade-long struggle for independence, lay in ruins due to bombardments during the war, and was hardly an amiable location for the new political order (Georgiadis, 2001). However, Othon saw the ancient bones of the city, and its historic status as the capital of Classical Greece, as the foundation to forge a new national identity for the country (Karatzas, 2012).

The tabula rasa of a destroyed Athens was an opportunity for Othon to impose a unifying neoclassical architectural style that conjured a vision of the city at the height of its classical power. Othon needed to convince the disparate factions in Greece that they had achieved independence and fulfilled their national aspirations (Georgiadis, 2001). A catalyst was required to assimilate the citizens of the newly independent country and make them subservient to a new ruling class. By defining Athens as the center of a modern Hellenic Empire, a sense of Greek national unity could be fostered, overcoming existing ethnic and local divides (Karatzas, 2012). In order to create this new Athens as a catalyst to engender Greek national identity, Othon brought in the architects Kleanthis and Schaubert to commission the city's first master plan (Georgiadis, 2001). The architects had both received their education from the Academy of Munich, and were chosen by the King largely due to their austere interpretation of classical architecture (Karatzas, 2012). Unlike the more fanciful Baroque and Beaux-Arts architectural movements popular in France and Russia at the time, Bavarians preferred a strict Greek classical tradition. Othon sought to capitalize on Kleanthis' and Schaubert's Bavarian education to forge his reimagined Athens. The initial Plan of Kleanthis, sent to the King in 1833, introduced the concept of urban design to the Greek territory for the very first time (Vaiou, 2002).

The 1833 plan used the city's classical history to set the foundation for the development of the capital. Schaubert and Kleanthis utilized a symmetrical layout with several major axes, connecting the city's core to the surrounding undeveloped countryside and a proposed port. A series of wide boulevards established connections between new public buildings and classical ruins. Most importantly, a new palace was proposed at the end of a major axis, oriented towards the Parthenon (Vaiou, 2002). New ministries and bureaucratic structures were planned along these major boulevards (Georgiadis, 2001).

The Ottoman Empire had no legacy of town planning, and issues arose when the King proposed implementing his ambitious agenda. The allocation of public space in the plan and layout

of wide boulevards was foreign to residents of the new capital, and an uproar ensued amongst the population following the publishing of Othon's intents (Karatzas, 2012). The Greek aristocracy, who were the primary land owners, were appalled at the proposition to seize large amounts of private land for public use (Georgiadis, 2001). Due to this backlash, the plan was altered significantly. The number of public spaces and plazas proposed was drastically curtailed, streets were narrowed to not infringe on private land, a number of public buildings were removed, and the palace-Parthenon axis was eliminated (Vaiou, 2002).

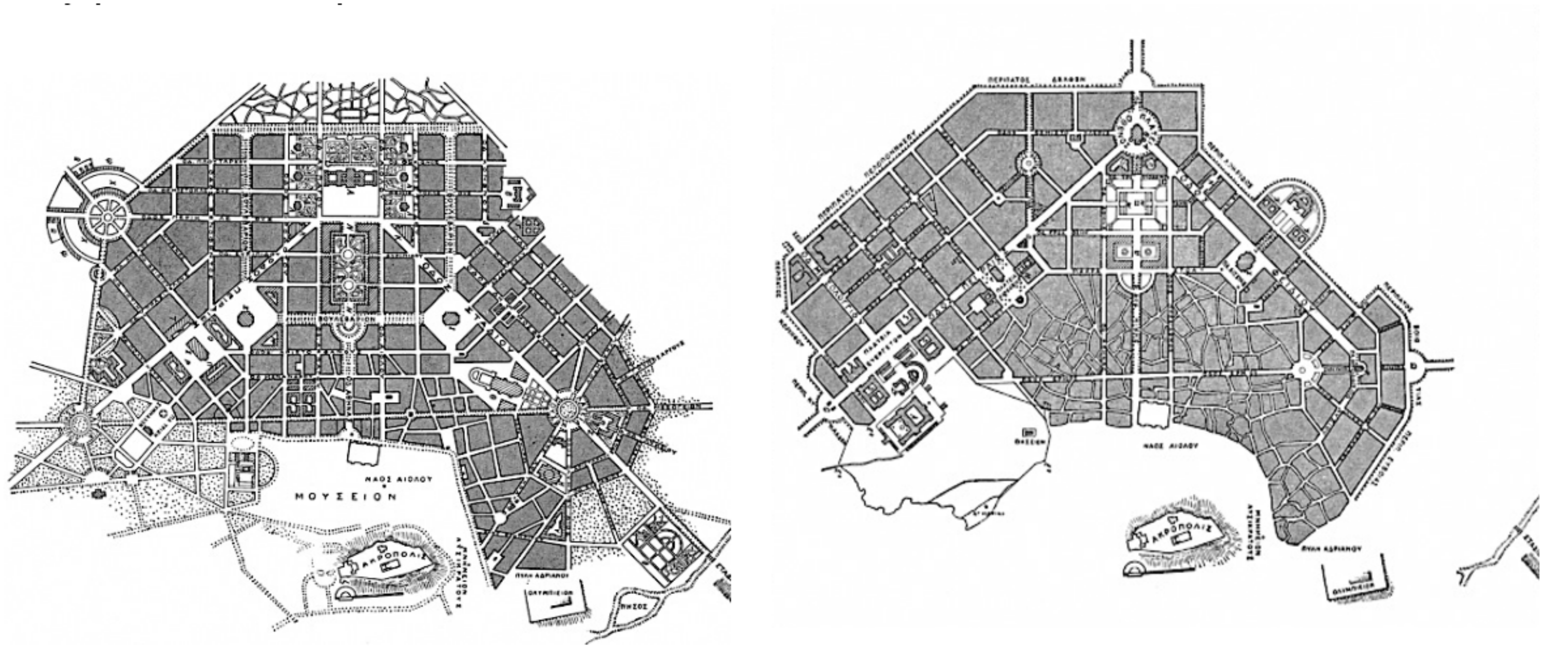


Figure 7. Left: Original Plan of Kleanthis (1833). **Right:** Amended Plan of Kleanthis (By Leo von Klenze 1834).

The altered Plan of Kleanthis was implemented in 1834, after being redrafted by the Bavarian engineer Leo von Klenze, and drove Athenian growth throughout the rest of the century (Karatzas, 2012). The plan included a number of regulations regarding the construction of private structures, and contained building codes which imposed a neoclassical style onto private dwellings (Skayannis (2013). However, the Athenian public was wary of building laws infringing on their private property rights and largely ignored the design guidelines required by the plan. A lack of enforcement and widespread bribery of public officials slowed the adoption of neo-classicism in the city's vernacular architecture (Vaiou, 2002). However, the construction of large-scale neo-classical public buildings commenced. Starting in the 1840s, residences for the city's new bourgeoisie began to utilize neoclassical elements and adopt Othon's preferred architectural form (Georgiadis, 2001). Gradually this style was reflected in the homes of lower-class Athenians, who greatly simplified neo-classical elements and created a new urban vernacular (Georgiadis, 2001). The resulting form of austere neo-classicism defined the urban morphology of private dwellings in the city for the next century, and reflected the gradual cohesion of the Greek nation state (Karatzas, 2012). Despite concessions from Othon and the abandonment of a state-mandated architectural style, Athens nonetheless transformed from a typical Ottoman town into a neoclassical capital in less than a generation (Vaiou, 2002).

The decades following the implementation of the Plan of Kleanthis saw Athens grow from a backwater town into a regional settlement. However, this period also laid the cultural, social, and economic groundwork which would influence how future planning systems evolved in the city. Constructing buildings and public infrastructure was an attempt at nation-building by the Bavarian royal family, making citizens wary of new municipal projects (Georgiadis, 2001). The importance of private land ownership as a means to accumulate money and power ultimately shaped the development of the city

.

The bypassing of regulation, through bribes and neglect, reflected a burgeoning cultural apathy towards government rule. From the occupation of the Ottomans to the Bavarian royal family, Greeks were wary of political organization with its rules, regulations and taxes. This endemic distrust caused the emergence of an individual- and family-centered society, which profoundly impacted the city's development (Stavrides, 2008). Athens grew slowly for the remainder of the 19th century and into the 20th, with its population increasing from 44,500 to 123,000 between 1870 and 1896 (Vaiou, 2000). During this period, the "Great Idea" ('Μεγάλη Ιδέα') was formed, which sought to incorporate all Greek-populated territories into the new independent state, until the size of the late Byzantine Empire was reached (Karatzas, 2012). The Μεγάλη Ιδέα resulted in a number of military campaigns and annexations expanding the boundaries of Greece to the North and East. This ideology would have profound ramifications for the future of Athens and would come to greatly influence the city's growth.

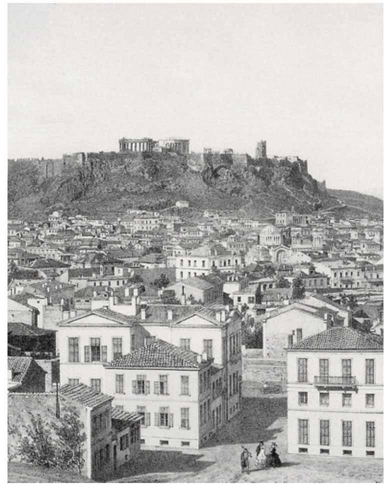


Figure 8. Top: The Academy of Athens, with the Othonian-mandated neoclassical design (1859). **Bottom left:** Typical residence from the period, with a modified austere neoclassical style. Photo taken in May 2019. **Bottom right:** Athens in 1861.

Interwar Athens (1896-1940)

The "Great Idea" continued to drive military incursions, mainly into the Balkan Peninsula, throughout the first decades of the 20th century. This resulted in modest gains to Greece's land area. The country's military was constantly engaged in conflict, either with its Balkan neighbors or with Turkey. As new territory was gained, refugees from recently annexed lands poured into Athens, expanding the city's population to 473,000 by 1921 (Karatzas, 2012). Although this represented an almost quadrupling of the city's population since 1896, it paled in comparison to the demographic growth of the coming years.

The defeat of Greece in a disastrous war with Turkey in 1921 caused one of the largest upheavals in the city's and country's history. Starting in 1922, the governments of Greece and Turkey underwent a transformative population exchange. All ethnic Greeks, or Orthodox Christians, living in Turkey were forcibly expelled and sent to Greece (Vaiou, 2002). This precipitated the arrival of over 1.5 million refugees into the country (of only 4.5 million at the time), with most migrating to Athens (Stavrides, 2008). The population of the capital doubled in under a year, overwhelming the resources of state and city governments (Georgiadis, 2001). Since Athens was unable to control the growth or provide enough housing for the new arrivals, informal settlements proliferated around the established urban core (Karatzas, 2012). The informal growth patterns established dense, impervious settlements that remain integral parts of the city to this day. Districts that now constitute part of the contemporary urban center of Athens, most notably Nea Ionia and Nea Smyrni, began as such refugee settlements (Vaiou, 2002). These communities formalized over the interwar period into dense urban areas, with built typologies completely different from the planned growth of the previous century.

The unexpected wave of new citizens changed Athenian culture and transformed its urban form. Landowners around Athens took advantage of the housing shortage, dividing their farmland into plots and selling them to refugees for development. This period of growth enabled a large number of peasants to ascend into a burgeoning Greek middle class (Chorianopoulos, 2010). The migrants built homes haphazardly on the arbitrarily plotted fields, employing local building techniques, and introducing new architectural vernaculars into Athens (Stavrides, 2008). This corrupted the city's cohesive neoclassical style and impacted the city's formal architectural community. Athenian architects began to question the Bavarian neo-classical traditions of the past century, and searched to find an authentic Greek typology in these new communities (Journal, 2016). The push to discover the definition of modern Greek architecture coincided with an expansion of the concept of Greek identity (Moatsoi, 2012). The newly arrived refugees, largely from Asia Minor, were culturally different from the existing Greek population (Georgiadis, 2001). However, the informal refugee settlements were largely situated directly next to established neighborhoods, where social cohesion and assimilation began to occur.

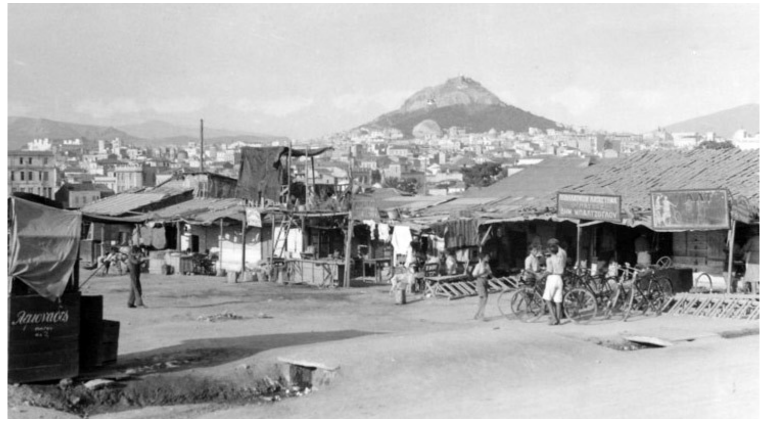


Figure 9. Informal settlements in Athens (1923).

Above. Informally developed neighborhood of Nea Ionia in 2019

Above. Informally developed neighborhood of Nea Smyrni in 2019

The period laid the groundwork for much of Athen's contemporary road network, urban morphology, and cultural values. The city attempted to plat streets and curtail the rampant informal conditions that permeated throughout the region with a series of Town Plans. From 1925-1935, the city embarked on an initiative to guide the growth of new development, curtailing new housing to allocate space for broader roads, parks, public space, and harmonized street grids (Karatzas, 2012). However, much like the Plan of Kleanthis, these initiatives failed due to private land owners plotting their own parcels to maximize profit. The city was able to construct considerable amounts of public housing as a result of the plans, but Athenians continued to defy urban regulation (Georgiadis, 2001). Overburdened with harmonizing almost one million new refugees into the city, the

government was not able to enforce the Town Plans and the city came to be defined by narrow streets, overlapping grids, and densely packed homes which proliferated endlessly across the Attica Basin.

The period between 1921 and 1940 enshrined the importance of land ownership as a means to economic mobility in the Greek social ethos. Leading up to Greece's entrance into WWII (1940), the informal communities established by the population exchange continued to formalize organically (Skayannis, 2013). The city worked during this time to establish urban infrastructure in these migrant communities: paving roads, building sidewalks, installing sewers and delivering other forms of city infrastructure (Georgiadis, 2001). Over time, these communities were brought into the larger urban fabric, assimilating into the city much like their inhabitants slowly assimilated into a broader Greek culture. The informal development of large swaths of the city is a lasting legacy that would continue to impact growth in Athens into the remainder of the century.

War and Postwar Period (1940-1980)

Figure 10. The Nazi flag rising in Athens in 1941 at the onset of German occupation.

The Nazi occupation of Athens during World War II and the subsequent civil war severely damaged the city's infrastructure systems and precipitated the widespread decay of the pre-war building stock (Karatzas, 2012). Following a decade of conflict in the city, Athens emerged from the wars with a host of urban issues, and the complex task of rebuilding the capital. In the years following 1949, the city received substantial aid from the United States as part of a Cold War bid for influence over the country (Maloutas, 2007). The Greek government used this opportunity to set up programs financing the rehabilitation and reconstruction of Athens' heavily damaged building stock.

In accordance with the reconstruction program, the government also began developing a new master plan. The plan proposed the construction of multiple new cities around Athens, alleviating the housing crisis in the urban core, and guiding the region's growth (Skayannis, 2013). An urban rail network was proposed to connect these cities to the center of Athens, along with a greenbelt surrounding the region to cull informal suburbanization (Vaiou, 2002). The post-war redevelopment plan also called for the renovation of major streets in Athens and the establishment of an extensive system of public squares and plazas (Woditsch, 2008).

Figure 11. A British soilder in Athens during the recapturing of the city from the Axis powers in 1944.

Despite ambitious intentions, the plan ultimately failed to be implemented. There was a heated backlash from the Athenian public who saw the proposed amenities as infringing on their property rights (Georgiadis, 2001). The interest in accommodating the automobile ultimately resulted in the opening and widening of roads throughout the city, but that is the only element shown to be enacted (Skayannis, 2013). By rejecting the city's postwar master plan, Athenians forfeited the creation of new public spaces, an extensive greenbelt, and the planned expansion of the region.

The rejection of a comprehensive master plan meant that Athens experienced its largest period of demographic growth without a guiding vision. This would have enormous consequences for the city moving forward. Between 1950 and 1980, the city's population exploded from 1,347,400 to just under 3,000,000 and cemented its status

Figure 12. Decaying pre-war building stock in Athens (1949).

as the cultural, social, political, and economic heart of postwar Greece (Vaiou, 2002). The associated building boom completely decimated the city's neoclassical vernacular, and transposed a new form of modernist multi-family construction that defines the city to this day.

Athens not only lacked a master plan, but also a guiding land-use document. This caused new development in the city to be dictated by a series of federal building codes (Asprogerakas, 2019). The morphology of the postwar building boom was characterized by the demolition of older single family homes, and the proliferation of mass-produced apartment buildings, referred to as polikatoikies (πολυκατοικίεσ). Two important federal planning laws enabled the acceptance of multi-family housing into Greek society. The first law of "horizontal property ownership" (referred to in Greek as οριζόντια ιδιοκτησία) meant that newly developed condominiums were technically viewed as vertically stacked pieces of land in the eyes of the government (Woditsch, 2008). This convinced more citizens in Greece to invest in multi-family housing, a practice unpopular previously due to the importance placed on land ownership in Greek society (Maloutas, 2007).

The second law legalized the practice of αντιπαροχή (antiparochi) (Giakoumatos, 1999). Antiparochi was a practice developed by the middle class to finance the construction of an apartment building, by working directly with a civil engineer (Woditsch, 2008). Families lived in close multi-generational proximity, and the passing down of property to children was a culturally important practice (Karatzas, 2012). The civil engineer would develop a plan and coordinate the building of a polikatoikia. The new apartments in the building would be divided up between the civil engineer and the owner of the land (Giacumacatos, 1999). The practice of antiparochi became the most common method for financing the construction of these new polikatoikies from the 1950s onwards. It allowed families with grown children to live in separate apartments, but in the same building (Aesopos, 2001). These new buildings often utilized low-cost construction

methods and materials, maximizing the civil engineers' profits (Maloutas, 2007). The result was the elimination of the city's historic neoclassical vernacular, and replacement with standardized, unadorned concrete structures.

The city's post-war legacy was initially characterized by the rejection of a master plan and the embrace of private property rights as the guiding force for urbanization. The lack of spatial planning during this period dramatically transformed Athens into a chaotic sprawling city which grew to occupy the entire Attica Basin.

Figure 13. Athens in 1960. Polikatoikies already dominate the city's inner core, redefining the skyline and urban morphology of the city.

The Consequences of Informality (1980-1990)

Entering into 1980, Athens was the densest city in all of Europe, characterized by a hyper-dense, multi-use, and impervious urban core (Stavrides, 2008). This period marked the beginning of the city's need to confront the serious negative externalities associated with the informal growth of the postwar period. The city's previous approach to urban governance became untenable during this time, as the societal realities of increased car ownership and suburbanization strained the city's poorly developed infrastructure systems. The postwar building boom had been characterized by a relentless optimism for a new Greek urban life and the pursuit of economic expansion (Vaiou, 2002). However, this doctrine had created a tragedy of the commons, which led to a number of issues during the 1980s.

Of paramount concern were the issues of traffic and pollution. Beginning in the 1960s, cars began to proliferate throughout the city, and public transportation usage dramatically declined (Karatzas, 2012). Parking regulations were non-existent, and the vast majority of buildings in the city lacked parking. The dearth of off-street parking led to a chaotic interaction between the city's narrow informal street network (the majority of it one lane) and on-street parking (Moatsoi, 2012). Parked cars became an ingrained part of the streetscape, littering sidewalks, and blocking alleyways and park entrances, adding chaos to the transportation quagmire (Moatsoi, 2012). By the 1980s, the Athenian public transportation system was in complete disarray. The system was derelict and frequently on strike, leading to inconsistent service and a continued drop in usage. Trolley buses imported from the Soviet Union in the 1930s were still widely used on a number of lines (Feliciantonio, 2018). Decay of the public transportation system in the city, chaotic urban organization, and lack of a cohesive modern road network made Athens known for some of the worst traffic congestion in the world (Vaiou, 2002).

Figure 14. Athens in the 1980s. Informal development practices left the city with some of the worst recorded air pollution in the world.

Figure 15: 1930s-era Soviet trolley bus in use in 1988.

The rampant congestion also exacerbated the problem of air pollution, which was the most severe on the European continent (Woditsch, 2008). Surrounded by mountains, the city already sat at a disadvantage regarding air quality. However, the unfettered growth of the city over the past century resulted in the widespread loss of natural features. Athens once had an extensive network of hydrological systems, forests, meadows, and olive groves which occupied the majority of the city's basin (Mallinis, 2014). However, most natural features had been paved over in the name of economic expansion and property rights by the 1980s, with the city's built fabric now spreading out over the entire Attica Basin. The lack of planning led Athens to have the lowest greenspace per capita out of any major city in Europe, a distinction the capital still holds today (Mallinis, 2014). The public spaces and parks that did exist in the city suffered from neglect and lack of maintenance (Vaiou, 2002). The multiplicity of factors, from rampant congestion, persistent air pollution, lack of greenspace, and informality, drove the city to reform its planning system and enact its first modern master plan, the Athens Comprehensive Master Plan of 1985.

This regulatory master plan was the city's first real attempt to plan growth in the capital during the second half of the 20th century. Greece entered the European Union in 1981, and the plan reflected this historic moment, laying out extensive initiatives to forge the city into a modern European capital (Asprogerakas, 2019). Of paramount concern, was reducing density in the city center and curtailing the expansion of informal settlements. The plan proposed a polycentric urban vision for Athens and created a number of subsidies to attract investment outside of the city center (Asprogerakas, 2019). The subsidies were effective in restructuring the city's economy and decreasing its population. However, the plan provided no vehicle for the organized growth of the city. Athens continued to grow informally and unauthorized expansion into the outskirts never stopped (Skayannis, 2013).

The 1980s were marked by an ineffective attempt by Athens to address ramifications of urban mismanagement and sprawling informal growth. Instead of galvanizing around solving the urban issues present in the city, the Athens Comprehensive Master Plan of 1985 largely focused on dispersing the urban economy and population of Athens (Aesopos, 2001). Despite a new more formalized planning system which distributed power more clearly, urban growth in the city continued to defy regulation and Athens still lacked the capacity to guide new development (Gounaridis, 2017).

Modern Athens and the Olympic Games (1990-2009)

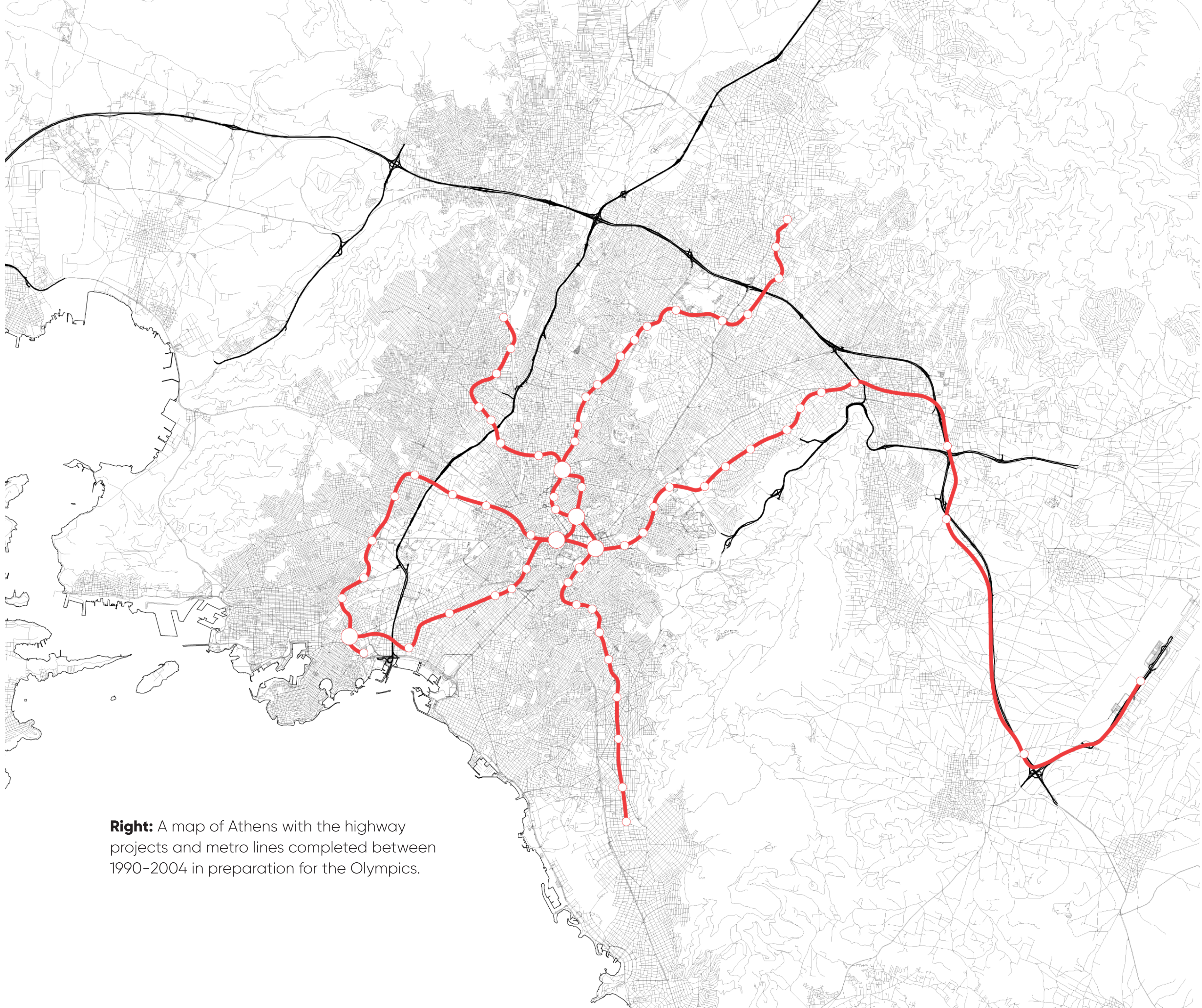
Despite the failings of the 1985 Master Plan, the decade of the 1990s marked another transformative period of growth for Athens and saw the city again fail to address the follies of the previous decades. In the early 1990s, Athens still had some of the worst traffic congestion and air pollution in the world (Diakakis, 2014). This posed a new threat to the ancient monuments of Athens, as traffic vibration weakened foundations and air pollution corroded marble (Asprogerakas, 2019). Despite the modest improvements from the last decade, the legacy of unplanned growth in the city continued to cripple the area and began threatening the country's economic growth.

The city's inability to enforce regulations and solve environmental and infrastructure problems finally came to a head when the city failed to secure the 1996 Olympic Games in 1990 (Maloutas, 2007). This represented a turning point in the city's urban history, as it galvanized a massive federal response. The Greek federal government had been one of the driving forces of infrastructure investment in the city and, after decades of a laissez-faire attitude regarding Athens, became increasingly interested in improving the city (and more specifically its infrastructure) to benefit the entire country's economy (Journal, 2016). Despite the failure of the Athens Comprehensive Master Plan of 1985, the federal government intended to secure the 2004 Olympics, and began making a series of federal declarations to usurp control of Athens and implement a series of far-ranging infrastructure projects. "Special laws, such as Law 2730/1999, were passed in order to accelerate and legitimize projects which did not exist in the master plan of the city" (Skayannis, 2013).

Property rights, enshrined in the municipal framework for Athens, made the seizing of private land nearly impossible (Vaiou, 2002). However, the Greek federal government, emboldened by new power, was able to bypass the majority of the city's planning laws (Feliciantonio, 2018). Aided by European Union funds, the country achieved an impressive list of investments in about 14 years which drastically transformed the capital. In this time, the federal government undertook building a new Athens Airport, a three-line metro system, tram network, and an expansive ring road (Asprogerakas, 2019). The government imposed emergency laws on Athens to tackle air pollution and congestion by strengthening restrictions on automobile usage in the city center, barring cars with even numbered-license or odd-numbered plates on seperate days (Karatzas, 2012). Many Athenians circumvented this restriction by bribing a public official to get a second license plate for their car or using their second car ending in the number that was allowed to enter on a particular day (Karatzas, 2012). However, despite this, the restrictions finally began to positively impact air quality in the city.

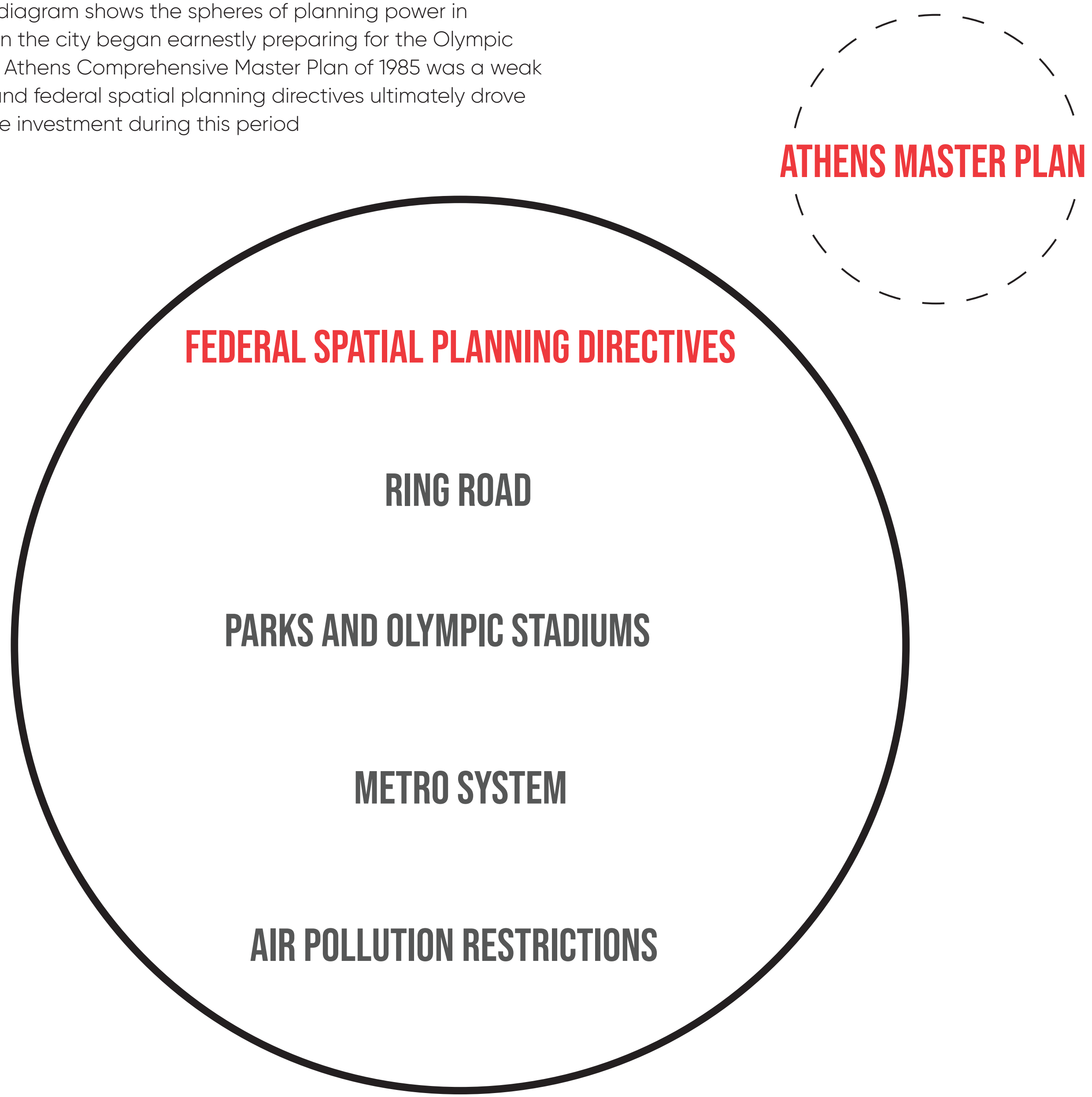
As a result of the unprecedented overhaul of the entire urban region, Athens was awarded the 2004 Olympic Games in 1997 (Gospodini, 2009). The major achievement of the Olympic Games in Athens was that the event served as a catalyst for the construction of desperately needed transportation projects. Most of the projects constructed were not included in the Athens Comprehensive Master Plan of 1985 and were imposed top-down (Skayannis, 2013).

Following the Olympics, the city thrived with new investment and private construction. Despite another update to the city's master plan in 2000, Athens was still unable to guide new growth. The new freeway and metro system created a surge in projects along the periphery of the city, and were the major drivers of urbanization. New development clustered densely around metro stations, and the ring road introduced a sprawling new single family typology to the region (Colantoni, 2016). The Greek central government observed the sprawl begin encroaching on the mountains around Athens, and imposed a growth limit (for the first time) on developing the hills that form the Attica Basin (Karatzas, 2012).



Right: A map of Athens with the highway projects and metro lines completed between 1990-2004 in preparation for the Olympics.

Below: This diagram shows the spheres of planning power in Athens, when the city began earnestly preparing for the Olympic Games. The Athens Comprehensive Master Plan of 1985 was a weak document and federal spatial planning directives ultimately drove infrastructure investment during this period



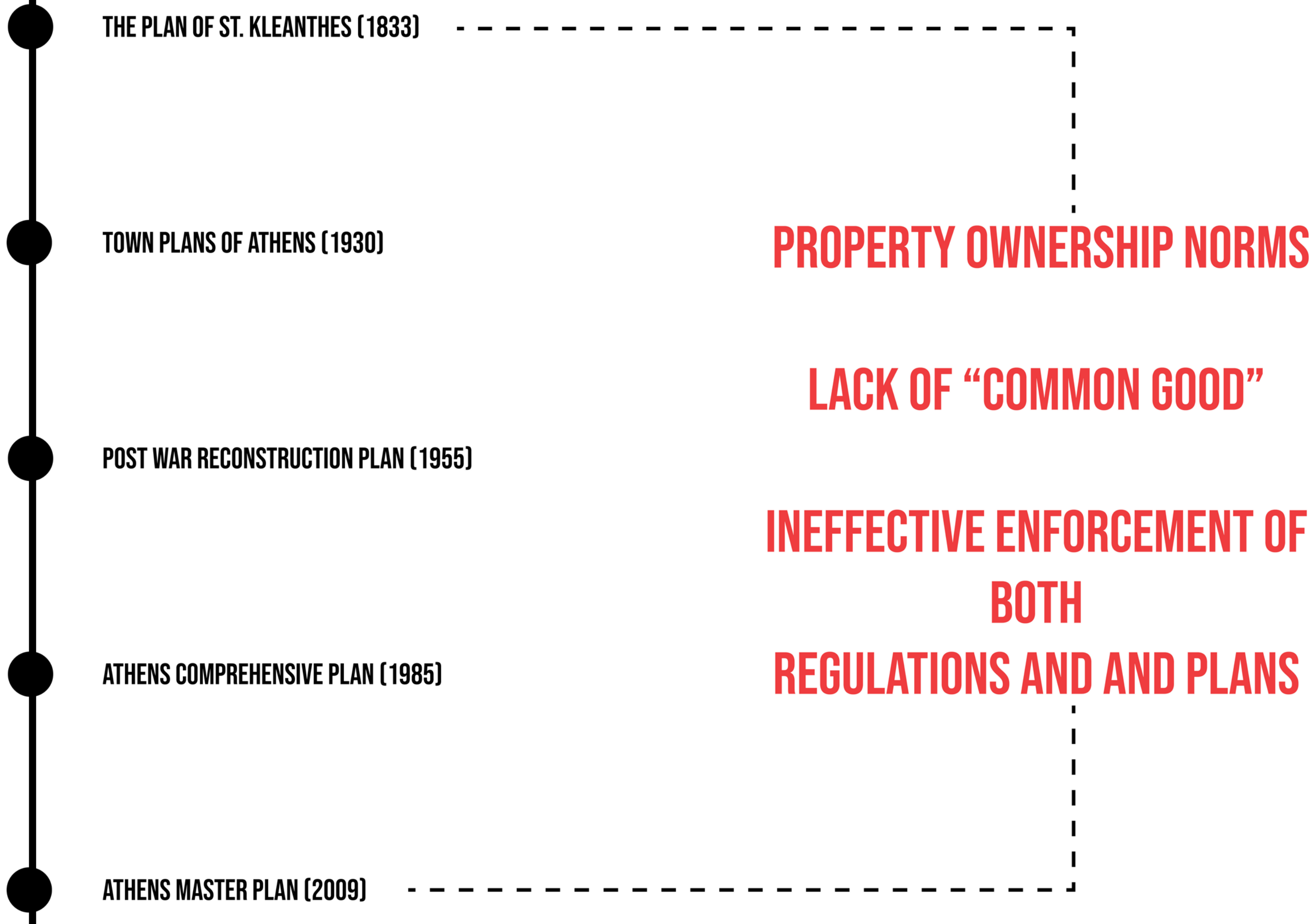
Despite the continued inability of Athens to direct and manage new growth, the post-Olympic period saw the emergence of the EU as a driving force to improve Greece's spatial planning framework (Chorianopoulos, 2010). In the mid-2000s, the European Union embarked on an initiative to harmonize the urban policies of its member states, with a particular focus on capital cities (Akande, 2019). Athens' chaotic planning system was still an overlapping mess of different community authorities at the time, with no clear system for cooperation among the different neighborhood councils (Skayannis, 2013). Attempting to harmonize the bureaucratic nightmare that constituted the city's planning structure was an enormous task. However, the EU sent delegates to Athens and worked with the federal government to reform the system. In just under two years, from 2006-2008, the city reorganized its planning system and set up a number of new frameworks to foster cooperation throughout the region (Gospodini, 2009). This ultimately resulted in a new master plan for Athens in 2009, which laid out another comprehensive vision for the city.

Data Analysis: The 2009 Athens Master Plan and Urban Heat

This analysis uses historical data compiled from a qualitative content analysis of five historic Athens master planning documents in conjunction with numerous narratives from 1830-2020. The ultimate goal of this data analysis is to answer the question: Is the 2009 Athens Master Plan the most efficacious vehicle to combat the urban heat island effect?

The current Athens Master Plan was most recently updated in 2009. Formally known as the Regulatory (or Strategic) Plan of Athens, the plan has been periodically updated since first being enacted in 1985 (Skayannis, 2013). The plan sets the spatial priorities for the entire Attica region, and gives strategic directions for the organization of urban space, infrastructure networks, and also directs land use policy (Sarigiannis, 2020).

URBAN PLANS OF ATHENS



Above: The plans included in the data section and the main reasons for their failings.

For the first time in the city's history, the plan outlines various strategies to create a more resilient Athenian fabric, and proposes a number of resiliency strategies to mitigate UHI.

The problem of the urban heat island effect has been observed in Athens since as early at 1977, when the city recorded the highest temperature reading in European history 48.0° C (118.4 ° F) (Agathangelidis, 2016). However, the urban heat island effect was the least of the city's problems during the time and, generally, has played little to no role in Athenian planning discourses. This changed with the 2009 Athens Master Plan, as the effects of the phenomenon manifested greater externalities and precipitated interest among Athenian planning officials. Two heatwaves in 2007, among the most severe in Greece's history, were the catalyst for the inclusion of these strategies in the city's plan (Mullis, 2016). Widely reported across Greece, these heat waves triggered country-wide wildfires and cost the country millions of dollars in damaged infrastructure (Georgakis, 2017). Two separate heat waves in the summer of 2007 (June and July) caused extremely high levels of human thermal discomfort across the Attica Basin (Agathangelidis, 2016). An Athens' meteorological report categorized most urban areas in the city as under "extreme heat stress'' throughout both events (Agathangelidis, 2016). The heat wave in June generated especially high levels of thermal discomfort during daytime and nighttime hours, and sent more heat-related patients into Athenian hospitals than in any previous heat event in the city's history (Theoharatos, 2010). The event was uncharacteristically hot and damp for Athens, a phenomenon that is predicted to become more frequent as warmer air masses moving into the region from Africa pick up more Mediterranean moisture (Kotroni, 2011). These 2007 events are partially responsible for the inclusion of new UHI mitigation policies in the Athens Master Plan. Other significant heat events have occured since, and the associated studies have confirmed a regional heat problem (Agathangelidis, 2016; Georgakis, 2017; Theoharatos, 2010; Ward, 2016).

A sizable paragraph in the plan outlines various initiatives and goals that the city proposes to cool the urban area. The spatial strategies include increasing green areas in low-green Athenian Districts, and the inclusion of shading elements throughout public areas. The plan states that "the above actions will have a significant effect in the reduction of air conditioning use as cooling devices during the hottest of months" (Sarigiannis, 2020). The document also proposes a number of policy recommendations: the establishment of a municipal fund for energy upgrading of residential buildings, the ameliorating of local bioclimatic conditions through the use of cool materials, and the establishment of a municipal fund that assists residents to implement energy upgrading of their buildings and cut costs (Sarigiannis, 2020).

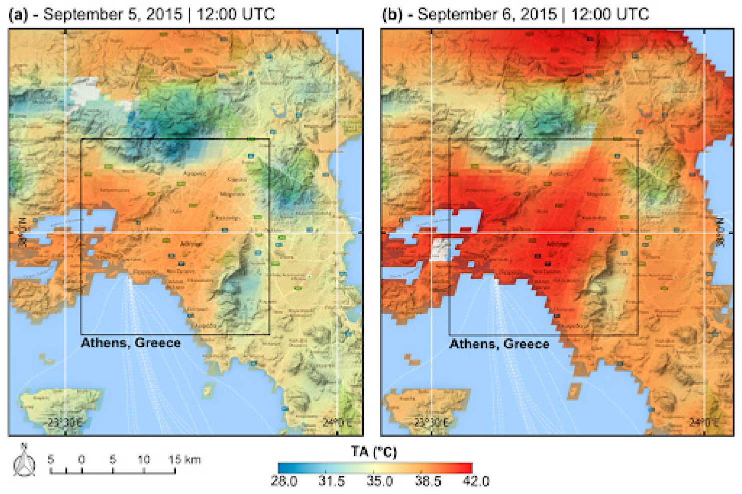


Figure 16: A seminal study in 2017 visualized temperature data from a heat wave and found that thermal discomfort was extremely high during the day and the night across the entire Athens area. It showed that urban heat was a vast regional problem that inflated temperatures in the built area about 10° F across the Attica Basin.

This plan, while a positive first step forward for UHI mitigation in the city, fails to provide a detailed framework for the implementation of these strategies, and a number of scholars tracking the implementation of the document have found no follow-through regarding these initiatives (Feliciantonio, 2018; Gospodini, 2009; Gounaridis, 2018; Sarigiannis, 2020; Theoharatos, 2010; Asprogerakas, 2019). The update to the most recent Athens Master Plan was largely catalyzed by the European Union's spatial cohesion policy, which attempts to align the urban plans of every capital amongst the European member states (Asprogerakas, 2019). The plan was updated to create a new set of policy goals to address the

recession impacting the economy of Greece (Feliciantonio, 2018). As a result, the document focused on initiatives to improve the city's economic competitiveness through investment in transportation infrastructure and the creation of lending programs for businesses. Sustainability (while mentioned in the plan) is not the primary focus of the document, and there is a disconnect between the infrastructure and economic goals of the plan and the "resiliency strategies" (Sarigiannis, 2020). While the document states a number of resiliency strategies, they are not explained at length. Instead, they are broad policy declarations that provide little guidance on how the city should specifically begin to address the problem of urban heat.

In Athens, a historic lack of municipal leadership and oversight has contributed to creating urban conditions ripe for urban heat. Despite the face value of Greece's spatial planning overhaul since 1985, the Greek spatial planning system still reflects its historic context. The hyper-centralization of the Greek administration system means that implementation of spatial planning goals requires the cooperation of several public bodies from the central government. This means that, despite the effective UHI mitigation strategies mentioned in the master plan, they fail to connect with broader federal planning goals and the history of the city.Compounding this problem is the weakness of the Athens master plan as a vehicle for UHI mitigation.

The lack of master plan implementation in Athens is arguably the hallmark of its urban development. The byproduct of this history is that urban life in Athens today is more difficult than in many other cities. Every period of the city's contemporary history is marred by the partial or total disregard of regulation, and the rejection of comprehensive master plans. As early as the Plan of Kleanthis, private landowners refused to give up any portion of their property to create public space, amenities, and infrastructure. The municipal government proved incapable of taking away property in the name of eminent domain, for the utilization of public purpose. This inability to challenge property owners is apparent in every period of the city's history. The interwar period provided the first tangible ramifications of this by establishing the informal urbanization patterns that would come to define the city's development. The Athenian government did not envision development occurring this way, but was again unable to exercise eminent domain to enforce the Town Plans of the time. Instead, the government focused on delivering basic urban infrastructure and allowing private citizens to develop their own properties as they saw fit.

In the postwar period, there continued to be grand visions. Just like the lan of Kleanthis and Town Plans, the post-WWII Reconstruction Plan proposed public spaces, infrastructure investments and urban amenities to benefit the broader community. Once again, the Athenian public predictably saw the guidance of the region's growth through public projects and the provision of planned private development as infringing on their property rights, preferring the money be applied directly to landowners.

The rapid proliferation of the polikatoikies during this time exposed the deleterious impacts of informal growth on a massive scale. The urban landscape transformed from single-family homes to concrete multi-family structures, which enveloped the city in an impervious mass, with little provision for greenspace or natural features. These elements impacted the failed municipal planning efforts of the 1980s and exposed the previous abandonment of public investments in common infrastructure systems. The cultural and social ramifications of the past century inhibited the city's response, as no short term interventions could solve the endemic problems of a chaotic road system, lack of public space, an untended public transit system, and dearth of greenspace.

Despite planning reforms on paper, the Olympics elucidated an effective way to intervene in an environment marred by ineffective urban leadership. The federal government's top-down approach finally delivered critical infrastructure to Athens. The precedent set by the early history of the city laid the groundwork for the failure

of the 2009 Master Plan, with a lack of results affecting the viability of the city's approach to UHI mitigation.

In an urban context that has constantly acquiesced to citizens focused on their own welfare, the barriers to implementing an effective community planning system are enormous. It requires fundamental and far-reaching change by Athenians and the government, both long-term propositions. UHI mitigation cannot wait. These realities will continue to dominate the city for the foreseeable future and need to be strongly considered when attempting to solve the intensifying problem of the urban heat island effect.

Above: The photos show Athens' dense urban form and narrow streets. Many of these streets were proposed for a redesign by the 2009 Master Plan; however, no follow-through on these proposals has been observed. Photos taken in May 2019.

Figure 17. Right: Satellite imagery of Athens in 2019. The city's urban sprawl dominates the entire Attica Basin.

Figure 18. Pages 60-61: Athens looking south toward the Port of Pireaus.

Conclusions

Policy Implications for UHI Mitigation in Athens

This thesis looks at Athens, Greece as a single case study to understand the research question: **How can a critical historic framework generate more effective implementation strategies for UHI mitigation?** This thesis challenges the internal and external forces that have shaped the city over time. Athens' contemporary urban expansion has not been guided by regulation, but by an inability to implement stated urban policy goals. While many cities develop according to the visions laid out in their master plans, Athens has never been able to successfully implement a guiding vision. The city's framework for UHI mitigation, embedded in the 2009 Master Plan, ignores the failures of the past two centuries.

The history of Athens reveals a number of implications for the effective implementation of urban heat island mitigation strategies. Despite a contemporary overhaul of the city's spatial planning system, there continues to be a complete lack of implementation regarding urban projects and regulations without federal involvement (Feliciantonio, 2018; Gospodini, 2009; Gounaridis, 2018; Theoharatos, 2010; Asprogerakas, 2019). Greek urban scholars have recognized, as recently as 2019, that the role of municipalities in urban and regional planning remains mostly advisory (Asprogerakas, 2019). This necessitates the inclusion of federal directives in local matters, even though this approach is contrary to broader European planning principles.

In the past three decades, the national government has been capable of organizing and completing enormous spatial change. Private land ownership and top-down infrastructure investments have been defining features of Athens' urban growth and contemporary gestation. The city's failure to secure the 1996 centenary Olympic Games, and the subsequent federal intervention, exposed weaknesses in the recently overhauled Athenian municipal planning system (Gospodini, 2009). Recommendations in the city's urban

plan need to leverage the argument that UHI mitigation is an essential infrastructure investment, and implementation must involve the federal government.

In order to contextualize UHI mitigation in Athens as an infrastructure investment, a specific project or set of projects need to be proposed outside of the city's master plan. Based on the historic framework, the uncovering of Athen's buried hydrological features could provide an effective means to address a number of the city's urban ills. During Athens' rapid demographic expansion in the latter-half of the 20th century, most natural features were removed in the name of economic expansion and social equity (Stergiouli, 2012). An entire system of urban rivers was buried and paved over. However, these hidden features have the potential to form the structure of a new system of expanded greenspace for the city. By creating a federally-sponsored project for the rehabilitation of Athens' hydrological features, the country could lobby the EU for funding and the organizational tools to support construction. Combining blue and green systems is proven to be one of the most effective means to cool urban climates, and a system of parks centered along these forgotten features has the potential to improve the environmental quality of the city, and translate a broad, ineffective policy goal into an implementable spatial strategy. This is an example of adapting a policy strategy to more effectively utilize existing governance systems.

The incorporation of UHI mitigation strategies in the construction of new publicly-funded buildings and infrastructure projects should be required. The implementation of mitigation techniques in new public buildings is feasible, and would contribute to a more resilient typology within the public sector. In the private sector, Athens lacks the capacity to enforce a UHI mitigation framework on new construction projects. While it is a highly desirable goal that could have real impact, the historical apathy towards urban regulation has created a weak municipal regulatory culture incapable of implementing these kinds of requirements.

However, the public sector has control over numerous buildings across the city. Public housing projects, municipal structures, schools, hospitals, and other government-owned assets provide an opportunity to adopt significant UHI mitigation practices.

An important historical finding is that the urban planning model adopted by Greece in the 1980s, under the duress of the EU, did not consider the failures of previous urban governance. Athens, Greece presents a seminal example of the discord between a generalized model for heat mitigation and the reality of applying UHI mitigation strategies within the context of a unique planning history.

The critical historic framework identified the external forces that have shaped Athens over time, and the internal dynamics that have driven urban change. Understanding this history and its underlying cultural elements can help urban planners propose more meaningful solutions. The philosophy of European spatial planning cohesion guided the development of a "modern" planning system in Greece. By bringing Athens' regulatory framework in line with other EU capitals, the cohesion policy ignored a host of societal realities that inhibit the application of this planning model in Athens. Advocating for a top-down, federally-driven approach to urban planning is a controversial proposition. However, the city's local planning history elucidates the need for a different model, informed by the past two centuries of data.

The policy goals, laid out in the 2009 Athens Master Plan, of increasing green areas in low-green Athenian Districts, ameliorating local bioclimatic conditions through the use of cool materials, and including shading elements throughout public areas are accepted UHI mitigation strategies. However, lacking an accompanying implementation plan portends their eventual failure to be actualized. Further research should capitalize on the findings of this study and translate the broad UHI mitigation goals of the 2009 Athens Master Plan into more implementable strategies and specific projects. Additional research looking to improve broader

spatial planning in Athens should consider how equitable strategies can factor into a federally-driven, top-down approach to urban planning. Forty percent of the nation's population resides in Athens, and the city is responsible for over 60 percent of the country's GDP (Sarigiannis, 2020). As a hyper-centralized node in Greece's economy, addressing urban issues in the city has profound ramifications for the entire country. This unique position, along with the historic problems identified, makes the efficacy of the current planning system worth examining. This is especially relevant with the ever present issue of UHI; however, such an endeavor could produce other positive benefits for the city as it copes with the challenges of the 21st century.

Conclusions: Broader Theoretical Implications

Approaching UHI mitigation using a historic framework has a direct application for other European cities, which have also amended their urban plans in adherence to EU territorial cohesion policies. Urban areas across the European Union, especially in Eastern and Southern Europe, should consider how to harmonize "Western" spatial planning systems with their own unique histories and practices. Further research expanding this single case into a comparative analysis looking at the effects of European spatial cohesion policies on a number of cities across the continent could generate interesting results.

UHI studies often delve directly into scientific findings and reports to buttress the use of certain mitigation strategies. Instead of starting from this quantitative standpoint, research could begin by reviewing the past conditions of a city's development to inform the selection and implementation of UHI mitigation strategies. A number of UHI studies recognized the need for a new approach, which can incorporate the qualitative aspects of a city's governance and history (Aflaki, 2017; Galagoda, 2018; Stone, 2019; Taslim, 2015).

The urban heat island effect creates negative externalities and microclimates which influence human health, urban comfort, air quality and energy consumption. However, despite this knowledge, it has been recognized that climate issues generally have low impact on the urban planning process in practice (Eliasson, 2000). This begets addressing the problem of UHI in more robust ways. Proposed solutions need to fit into an existing urban area, and have to consider its political, cultural, and socio-economic realities. A historic framework elucidates these factors and can help reveal more specific and salient implementation strategies.

More broadly, this thesis contributes to a larger theoretical discourse which advocates applying critical frameworks to solve spatial planning problems (Robinson, 2016; Sandercock, 1998; Watson, 2009). By applying a qualitative

(historic) framework to the single case of Athens, Greece this thesis buttresses the argument to use more unconventional planning methods to address urban heat island mitigation, especially in communities struggling with informality.

Climate change is poised to put an enormous strain on cities around the world, as rising temperatures continue to threaten urban environments and extreme weather events become more frequent. The strategies we use to create more resilient urban fabrics derive from quantitative analysis and research. However, implementation of these approaches will ultimately determine their success. Urban heat island mitigation cannot simply be a set of spatial directives and practices generalized across cultures and cities. A more intersectional and critical framework is needed to understand how "best practices'' can be adapted in a complicated implementation reality. A historic framework has proven to be an effective way to engender this kind of discourse when considering mitigating UHI.

Figure 19. Pages 68-69: Vantage point from the Acropolis looking southeast towards Kaisariani.

Works Cited

Figure 19

Abbott, Carl. 1983. Portland: Planning, Politics, and Growth in a Twentieth Century City. Lincoln: University of Nebraska Press.

Adler, Sy. 1989. "Historical Analysis as a Planning Tool." Journal of the American Planning Association 55 (4): 467–73. https://doi.org/10.1080/01944368908975435.

Aesopos, Yannis. "The Contemporary Greek City". The Contemporary (Greek) City. (Athens: Metapolis Press, 2001). pp 32-60.

Aflaki, Ardalan, Mahsan Mirnezhad, Amirhosein Ghaffarianhoseini, Ali Ghaffarianhoseini, Hossein Omrany, Zhi Hua Wang, and Hashem

Akbari. 2017. "Urban Heat Island Mitigation Strategies: A State-of-the-Art Review on Kuala Lumpur, Singapore and Hong Kong." Cities 62: 131–45. https://doi.org/10.1016/j.cities.2016.09.003.

Agathangelidis I, Cartalis C, and Santamouris M. 2016. "Estimation of Air Temperatures for the Urban Agglomeration of Athens with the Use of Satellite Data." Geoinformatics & Geostatistics: An Overview 04 (02). https://doi.org/10.4172/2327-4581.1000139.

Akande, Adeoluwa, Pedro Cabral, Paulo Gomes, and Sven Casteleyn. 2019. "The Lisbon Ranking for Smart Sustainable Cities in Europe." Sustainable Cities and Society 44 (August 2018): 475–87. https://doi.org/10.1016/j.scs.2018.10.009.

Alexandropoulou, Victoria, Kjetil Torseth, and Mihalis Lazaridis. 2013. "The Effect of Forest Fires in Emissions of Biogenic Volatile Organic Compounds and Windblown Dust over Urban Areas." Air Quality, Atmosphere and Health 6 (1): 277–94. https://doi.org/10.1007/s11869-012-0170-y.

Allmendinger, Thomas. 2017. "Measures at Buildings for Mitigating the Microclimate." Environment Pollution and Climate Change 01 (03): 1–9. https://doi.org/10.4172/2573-458x.1000128.

Arnfield, A. John, Roger D. Peng, Jennifer F. Bobb, Claudia Tebaldi, Larry McDaniel, Michelle L. Bell, Francesca Dominici, John P. Sayas, and Louis Wassenhoven. 2008. "Two Decades of Urban Climate Research: A Review of Turbulence, Exchanges of Energy and Water, and the Urban Heat Island." Boletin de La Asociacion de Geografos Espanoles 119 (46): 53–76. https://doi.org/10.1289/ehp.1002430.

Asprogerakas, Evangelos, and Vasiliki Zachari. 2019. "The EU Territorial Cohesion Discourse and the Spatial Planning System in Greece." European Planning Studies 0 (0): 1–21. https://doi.org/10.1080/09654313.2019.1628925.

Bouyer, Julien, Marjorie Musy, Yuan Huang, and Khaled Athamena. 2017. "Effect by Urban Design" 164–81.

Chorianopoulos, I., T. Pagonis, S. Koukoulas, and S. Drymoniti. 2010. "Planning, Competitiveness and Sprawl in the Mediterranean City: The Case of Athens." Cities 27 (4): 249–59. https://doi.org/10.1016/j.cities.2009.12.011.

Chow, Winston T.L., Ronald L. Pope, Chris A. Martin, and Anthony J. Brazel. 2011. "Observing and Modeling the Nocturnal Park Cool Island of an Arid City: Horizontal and Vertical Impacts." Theoretical and Applied Climatology 103 (1): 197–211. https://doi.org/10.1007/s00704-010-0293-8.

Colantoni, Andrea, Efstathios Grigoriadis, Adele Sateriano, Giuseppe Venanzoni, and Luca Salvati. 2016. "Cities as Selective Land Predators? A Lesson on Urban Growth, Deregulated Planning and Sprawl Containment." Science of the Total Environment 545–546: 329–39. https://doi.org/10.1016/j.scitotenv.2015.11.170.

Debbage, Neil, and J. Marshall Shepherd. 2015. "The Urban Heat Island Effect and City Contiguity." Computers, Environment and Urban Systems 54: 181–94. https://doi.org/10.1016/j.compenvurbsys.2015.08.002.

Diakakis, Michalis, Aggelos Pallikarakis, and Katerina Katsetsiadou. 2014. "Using a Spatio-Temporal GIS Database to Monitor the Spatial Evolution of Urban Flooding Phenomena. The Case of Athens Metropolitan Area in Greece." ISPRS International Journal of Geo-Information 3 (1): 96–109. https://doi.org/10.3390/ijgi3010096.

Edmondson, J. L., I. Stott, Z. G. Davies, K. J. Gaston, and J. R. Leake. 2016. "Soil Surface Temperatures Reveal Moderation of the Urban Heat Island Effect by Trees and Shrubs." Scientific Reports 6: 1–8. https://doi.org/10.1038/srep33708.

Ehmer, Philipp, Eric Heymann, Tobias Just, Gerda Fuchs-sobolew, Sabine Kaiser, and Norbert Walter. 2008. "Klimawandel Und Tourismus: Wohin Geht Die Reise." Deutsche Bank. Translated from German

Eliasson, Ingegärd. 2000. "The Use of Climate Knowledge in Urban Planning." Landscape and Urban Planning 48 (1–2): 31–44. https://doi.org/10.1016/S0169-2046(00)00034-7.

Feliciantonio, Cesare Di, Luca Salvati, Efthymia Sarantakou, and Kostas Rontos. 2018. "Class Diversification, Economic Growth and Urban Sprawl: Evidences from a Pre-Crisis European City." Quality and Quantity 52 (4): 1501–22. https://doi.org/10.1007/s11135-017-0532-5.

Galagoda, R. U., G. Y. Jayasinghe, R. U. Halwatura, and H. T. Rupasinghe. 2018. "The Impact of Urban Green Infrastructure as a Sustainable Approach towards Tropical Micro-Climatic Changes and Human Thermal Comfort." Urban Forestry and Urban Greening 34 (May): 1–9. https://doi.org/10.1016/j.ufug.2018.05.008.

Georgakis, Chrissa, and Mattheos Santamouris. 2017. "Determination of the Surface and Canopy Urban Heat Island in Athens Central Zone Using Advanced Monitoring." Climate 5 (4). https://doi.org/10.3390/cli5040097.

Georgiadis, Sokratis. 2001. "The Creation of Modern Athens: Planning the Myth Eleni Bastéa." Journal of the Society of Architectural Historians. https://doi.org/10.2307/991768.

Giacumacatos, Andreas. "From Conservatism to Populism, Pausing at Modernism" in Greece: 20th Century Architecture, Savas Condaratos and Wilfried Wang (Munich: Prestel, 1999), 36-46.

Gospodini, Aspa. 2009. Post-Industrial Trajectories of Mediterranean European Cities: The Case of Post-Olympics Athens. Urban Studies. Vol. 46. https://doi.org/10.1177/0042098009103859.

Gounaridis, Dimitrios, Ioannis Chorianopoulos, and Sotirios Koukoulas. 2018. "Exploring Prospective Urban Growth Trends under Different Economic Outlooks and Land-Use Planning Scenarios: The Case of Athens." Applied Geography 90 (December 2017): 134–44. https://doi.org/10.1016/j.apgeog.2017.12.001.

Hathway, E. A., and S. Sharples. 2012. "The Interaction of Rivers and Urban Form in Mitigating the Urban Heat Island Effect: A UK Case Study." Building and Environment 58: 14–22. https://doi.org/10.1016/j.buildenv.2012.06.013.

Hu, Youpei, Marcus White, and Wowo Ding. 2016. "An Urban Form Experiment on Urban Heat Island Effect in High Density Area." Procedia Engineering 169: 166–74. https://doi.org/10.1016/j.proeng.2016.10.020.

Iojă, Ioan Cristian, Gabriela Osaci-Costache, Jürgen Breuste, Constantina Alina Hossu, Simona R. Grădinaru, Diana Andreea Onose, Mihai Răzvan Niță, and Hana Skokanová. 2018. "Integrating Urban Blue and Green Areas Based on Historical Evidence." Urban Forestry and Urban Greening 34 (June): 217–25. https://doi.org/10.1016/j.ufug.2018.07.001.

Jim, C. Y. 2013. "Sustainable Urban Greening Strategies for Compact Cities in Developing and Developed Economies." Urban Ecosystems 16 (4): 741–61. https://doi.org/10.1007/s11252-012-0268-x.

Journal, International. 2016. "The (Master) Plans of Athens and the Challenges of Its Re-Planning in the International Journal of Architectural Research Architecture Planning Built Environment Studies," no. August 2015. https://doi.org/10.26687/archnet-ijar.v7i2.165.

Jusuf, Steve Kardinal, Marcel Ignatius, Wong Nyuk Hien, and Hasheem Akbari. 2019. "Editorial: Urban Heat Island (UHI) and Its Mitigation through Urban Planning, Design, and Landscaping." Architectural Science Review 62 (1): 1–5. https://doi.org/10.1080/00038628.2019.1548095.

Kalyvas, Stathis. 2008. "Armed Collaboration in Greece, 1941–1944." European Review of History—Revue Européenne d'histoire 15 (April): 129–42. https://doi.org/10.1080/13507480801931051.

Karatzas, Georgios, Peter G Stone, Peter Davis, and Chris Whitehead. 2012. "Athens : The Image of Modern Hellenism." Heritage, Ideology, and Identity in Central and Eastern Europe 6: 155–74. http://www.jstor.org/stable/10.7722/j.ctt3fgm0r.12.

Kleerekoper, Laura, Marjolein Van Esch, and Tadeo Baldiri Salcedo. 2012. "How to Make a City Climate-Proof, Addressing the Urban Heat Island Effect." Resources, Conservation and Recycling 64: 30–38. https://doi.org/10.1016/j.resconrec.2011.06.004.

Kotroni, V., K. Lagouvardos, and A. Retalis. 2011. "The Heat Wave of June 2007 in Athens, Greece - Part 2: Modeling Study and Sensitivity Experiments." Atmospheric Research 100 (1): 1–11. https://doi.org/10.1016/j.atmosres.2010.12.007.

Mallinis, Giorgos, Nikos Koutsias, and Margarita Arianoutsou. 2014. "Monitoring Land Use/Land Cover Transformations from 1945 to 2007 in Two Peri-Urban Mountainous Areas of Athens Metropolitan Area, Greece." Science of the Total Environment 490: 262–78. https://doi.org/10.1016/j.scitotenv.2014.04.129.

Maloutas, Thomas. "Segregation, Social Polarization and Immigration in Athens during the 1990's. Theoretical expectations and contextual difference". International Journal of Urban and Regional Research 31.4 (December 2007): pp 736-750.

Moatsoi, Olga. 2012. "Polykatoikia: The Popularization of a Status Symbol." In , 494–97. Ecole Polytechnique de Lausanne, Switzerland.

Mullis, Daniel, and Raumproduktionen Der Politik. 2016. "Krisenproteste in Athen und Frankfurt." (In German)

Musco, Francesco. 2016. Counteracting Urban Heat Island Effects in a Global Climate Change Scenario. https://doi.org/10.1007/978-3-319-10425-6.

Rantzoudi, Eleni C., and Julia N. Georgi. 2017. "Correlation between the Geometrical Characteristics of Streets and Morphological Features of Trees for the Formation of Tree Lines in the Urban Design of the City of Orestiada, Greece." Urban Ecosystems 20 (5): 1081–93. https://doi.org/10.1007/s11252-017-0655-4.

Robinson, Jennifer. 2016. "Comparative Urbanism: New Geographies and Cultures of Theorizing the Urban." International Journal of Urban and Regional Research 40 (1): 187–99. https://doi.org/10.1111/1468-2427.12273.

Salvati, Luca, and Marco Zitti. 2017. "Sprawl and Mega-Events: Economic Growth and Recent Urban Expansion in a City Losing Its Competitive Edge (Athens, Greece)." Urbani Izziv 28 (2): 110–21. https://doi.org/10.5379/urbani-izziv-en-2017-28-02-003.

Sandercock, Leonie. 1998. Making the Invisible Visible : A Multicultural Planning History. California Studies in Critical Human Geography. Berkeley: University of California Press.

Sarigiannis, G. (2020). The Regulatory Plans of Athens and the change of their contexts. www.greekarchitects.gr (Accessed in 2020) (in Greek).

Santamouris, M. 2013. "Using Cool Pavements as a Mitigation Strategy to Fight Urban Heat Island - A Review of the Actual Developments." Renewable and Sustainable Energy Reviews 26: 224–40. https://doi.org/10.1016/j.rser.2013.05.047.

Sharma, A., P. Conry, H. J.S. Fernando, Alan F. Hamlet, J. J. Hellmann, and F. Chen. 2016. "Green and Cool Roofs to Mitigate Urban Heat Island Effects in the Chicago Metropolitan Area: Evaluation with a Regional Climate Model." Environmental Research Letters 11 (6). https://doi.org/10.1088/1748-9326/11/6/064004.

Skayannis, Pantoleon. 2013. "The (Master) Plans of Athens and the Challenges of Its Re-Planning in the Context of Crisis." Archnet-IJAR 7 (2): 192–205. https://doi.org/10.26687/archnet-ijar.v7i2.165.

Skoulika, Fotini, Mattheos Santamouris, Dionysia Kolokotsa, and Natalia Boemi. 2014. "On the Thermal Characteristics and the Mitigation Potential of a Medium Size Urban Park in Athens, Greece." Landscape and Urban Planning 123: 73–86. https://doi.org/10.1016/j.landurbplan.2013.11.002.

Stavrides, Stavros. 2008. "Urban Identities : Beyond the Regional and the Global . The Case of Athens." Regional Architecture and Identity in the Age of Globalization, Proceedings of 2nd International Conference of CSAAR, Tunis, 577–88. https://doi.org/10.1016/j.ydbio.2011.12.028.

Stergiouli, Martha Leto, and Kimon Hadjibiros. 2012. "The Growing Water Imprint of Athens (Greece) throughout History." Regional Environmental Change 12 (2): 337–45. https://doi.org/10.1007/s10113-011-0260-7.

Stone, Brian, Kevin Lanza, Evan Mallen, Jason Vargo, and Armistead Russell. 2019. "Urban Heat Management in Louisville, Kentucky: A Framework for Climate Adaptation Planning." Journal of Planning Education and Research. https://doi.org/10.1177/0739456X19879214.

Taslim, Shima, Danial Monsefi Parapari, and Arezou Shafaghat. 2015. "Urban Design Guidelines to Mitigate Urban Heat Island (UHI) Effects in Hot-Dry Cities." Jurnal Teknologi 74 (4): 119–24. https://doi.org/10.11113/jt.v74.4619.

Theoharatos, George, Katerina Pantavou, Anastasios Mavrakis, Anastasia Spanou, George Katavoutas, Panos Efstathiou, Periklis Mpekas, and Dimosthenis Asimakopoulos. 2010. "Heat Waves Observed in 2007 in Athens, Greece: Synoptic Conditions, Bioclimatological Assessment, Air Quality Levels and Health Effects." Environmental Research 110 (2): 152–61. https://doi.org/10.1016/j.envres.2009.12.002.

Theophilou, M. K., and D. Serghides. 2015. "Estimating the Characteristics of the Urban Heat Island Effect in Nicosia, Cyprus, Using Multiyear Urban and Rural Climatic Data and Analysis." Energy and Buildings 108: 137–44. https://doi.org/10.1016/j.enbuild.2015.08.034.

Vaiou, Dina. 2002. "Milestones in the Urban History of Athens." Treballs de La Societat Catalana de Geografia. https://doi.org/10.2436/tscg.v0i53-54.37291.

Ward, Kathrin, Steffen Lauf, Birgit Kleinschmit, and Wilfried Endlicher. 2016. "Heat Waves and Urban Heat Islands in Europe: A Review of Relevant Drivers." Science of the Total Environment 569–570: 527–39. https://doi.org/10.1016/j.scitotenv.2016.06.119.

Watson, Vanessa. 2009. "Seeing from the South: Refocusing Urban Planning on the Globe's Central Urban Issues." Urban Studies 46 (11): 2259–75. https://doi.org/10.1177/0042098009342598.

Weber, Christiane, Chryssanthi Petropoulou, and Jacky Hirsch. 2005. "Urban Development in the Athens Metropolitan Area Using Remote Sensing Data with Supervised Analysis and GIS." International Journal of Remote Sensing 26 (4): 785–96. https://doi.org/10.1080/0143116051 2331316856.

Woditsch, Richard. "From Thinking with to Thinking of the Polykatoikia: The Need for a Theoretical Knowledge about the Public and Private Spaces of the Polykatoikia". Domes (March 2008): pp 46-55.

Yin, Robert. 2009. "Case Study Research: Design and Methods. " Applied Social Research Methods Series (5): 46-50.

Figures and Images

Downloaded and accessed April 2020

Figure 1 From https://unsplash.com/photos/OQr38nR9DDs. Accessed April 2020
Figure 2 From https://unsplash.com/photos/emWsmLNossA. Accessed April 2020
Figure 3 From https://unsplash.com/photos/Nx77-APoI3E
Figure 4 From https://www.thestar.com.my/lifestyle/living/2017/11/11/restoration-cheonggye-stream-seoul/ in April 2020
Figure 5 From https://www.greeka.com/cyclades/serifos/architecture/photos-1/
Figure 6 From https://unsplash.com/photos/emWsmLNossA
Figure 7 From Skayannis (2013).
Figure 8 Top: From http://www.academyofathens.gr/. **Bottom right:** From Karatzas, 2012.
Figure 9 From https://www.mixanitouxronou.com.cy
Figure 10 From https://rarehistoricalphotos.com
Figure 11 From Kalyvas, 2008.
Figure 12 From hhttps://www.athensvoice.gr/culture/arts/426639_i-athina-mesa-apo-ta-fotografika-arheia-toy-moyseioy
Figure 13 From hhttps://www.athensvoice.gr/culture/arts/426639_i-athina-mesa-apo-ta-fotografika-arheia-toy-moyseioy.
Figure 14 From http://alessandrocaputo.site/collective-oikodomiko
Figure 15 From https://mesametaforas.gr/busgallery displayimage.php?pid=16385
Figure 16 From Georgakis, 2017.
Figure 17 From Google Earth 2019
Figure 18 From https://horizon-magazine.eu/article/athens-named-2018-european-capital-innovation.html
Figure 19 From: https://unsplash.com/photos/5wAqXwhHwrg