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Risk Assessment of Urban Sectors to Climate Change in Istanbul

Aysun
AYGÜN
Istanbul Technical University
Istanbul, Turkey, 34437, Sisli, Taksim, Taskisla
Pamukkale University
Pamukkale, Turkey, 20160, Denizli, Kınıklı Campus
E-mail: aaygun@pau.edu.tr
ORCID: 0000-0002-9403-7124; Researcher ID: AAP-3539-2020

Tüzin
BAYCAN
Istanbul Technical University
Istanbul, Turkey, 34437, Sisli, Taksim, Taskisla
E-mail: tbaycan@itu.edu.tr
ORCID: 0000-0001-6073-1188; Researcher ID: O-5347-2015

Abstract. The aim of the present study is to investigate the risk of climate change on Istanbul. Istanbul is the largest city, in terms of both population and economic activity capacity, in Turkey meaning that any climate-related risk would be destructive not only for the city but also for the country. The urban system has been identified based on urban sectors that are the issues of activities, management areas, ecological systems, resources and species and critical for economic viability and public health of the city, also likely to be affected by climate-related disasters. 11 urban sectors and 25 sub-sectors, which are also presented as planning areas, have been determined considering the development strategies of Istanbul as water resources, health, energy, agriculture, transportation, development and land use, public safety, infrastructure, biodiversity and ecology, culture and materials. ICLEI's handbook titled "Preparing for Climate Change: A Guidebook for Local, Regional and State Governments" guided the risk assessment of these planning areas and sectors. The data has been obtained via in-depth interviews with city stakeholders and the sectors have been ranked considering the risk factors of each. The results of this study

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reveal the urban sectors that are under the greatest and lowest risk due to the impacts of climate change. Highlighting the climate change risk on vital sectors of Istanbul is essential for decision makers to develop further strategies to mitigate the impacts of climate change and adapt the upcoming impacts.

Key words: climate change, risk assessment, urban resilience, Istanbul.

1. Introduction

Non-natural climate change due to human activities has become the major global problem over the last few decades[1]. Climate change has directly impacted on ecosystems, physical systems and related human actions [1], and projections reveal that these impacts will be more severe in the future. Inevitably city systems, including settlements, infrastructure, and resources will be impacted by climate change [2; 3]. The level of preparedness of urban regions to climate change's adverse effects is critical in retaining viability and protecting inhabitants, and the first step in being prepared is to understand the risks of climate change for cities. Decisions made without an understanding of the risks and vulnerabilities would be meaningless so for, risk assessment is an essential part of resilience.

Turkey, has only recently started to discuss the negative impacts of climate change on the country and required adaptation and mitigation strategies [4]. Global concern about changing climate and the efforts of NGOs has led to increased awareness, however, Turkey still has a long way to go to achieve climate change resilience. Turkey needs both national and local strategies[2] in order to build more resilient structures.

In Turkey, resilience development is a fairly new topic whose pathway has not been discussed or determined yet. Therefore, the motivation of this study is to guide this pathway towards a more resilient model. Istanbul, as the largest metropolitan city in Turkey, should be the frontrunner in developing a resilient system guided by clear knowledge of the risks of the city.

The aim of the present study is to assess the risk of climate change on Istanbul's urban system. For this reason, 11 urban sectors (water resources, health, energy, agriculture, transportation, development and land use, public safety, infrastructure, biodiversity and ecology, culture and materials) and 25 subsectors (planning areas) have been determined to analyze regarding the ISTKA Regional Plan[3], which addresses Istanbul's strategic sectoral development axes. In this study, a multi-dimensional methodology which combines data collection from literature and institutions, in-depth interviews and risk assessment index is conducted and as a result, the sectors are ranked regarding their index values. This study is a part of a more comprehensive resiliency development study that consists of 3 main parts: vulnerability assessment [5]; risk assessment; and prioritization assessment of Istanbul's sectors. This article encompasses the risk assessment component in its results and conclusions.

The next section draws the conceptual framework of climate change risk, risk factors, resilience and risk assessment. After reviewing the literature on risk, the third section presents

[1] *IPCC. Climate change 2001: synthesis report; a contribution of Working Groups I, II, and III to the third assessment report of the Intergovernmental Panel on Climate Change,* 2001. Cambridge: Cambridge University Press.

[2] Metropolitan cities with high populations are a critical part of those strategies.

[3] *ISTKA* (İstanbul Kalkınma Ajansı). 2010–2013 İstanbul Bölge Planı, Istanbul. 2010

the case study, first explaining the sectors, data and methodology of the study, then evaluating the risk for each sector and planning area, finally, concluding by ranking the risk levels of all sectors. The last section is the conclusion and offers a roadmap for further research and plans. In this study, all sectors are considered with a comprehensive and multidimensional perspective in order to make a conclusion that compares and includes all systems; however, each sector can be analyzed in more detail in future studies.

2. Risk and climate change: conceptual framework

Risk is *"the chance of injury or loss as defined as a measure of the probability (likelihood) and severity of an adverse effect to health, property, environment or other things of value"*[4]. According to ISO 31010, the general definition of risk is the accumulation of the "consequences of a hazard and the probability of its occurrence"[5]. United Nations International Strategy for Disaster Reduction (UNISDR)[6] defines disaster risk as *"the potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period"*. All these definitions refer to disaster risks from both climatic and non-climatic hazards [6]. The definitions focus on *'the probability'* of a disaster's occurrence and *'the consequences'* of the hazard. Climate risk has the same basic definition; however, it includes climatic hazards such as landslides, droughts, floods, sea level rise, fires, windstorms, heat waves amongst others, only[7]. The severity of consequences are highly related to the vulnerability of the system and exposure [7].

The changing climate and the spatial distribution of the climate risks have been an important research area [8] especially for urban development discourse. Scientists stress that climate change particularly threatens metropolitan areas and cities[8] [9; 10] and metropolitan cities are the focal locus of climate- related risks due to their demographic structures, high population densities, and the concentration of cultural and economic services. Natural risks that pose a threat particularly to urban infrastructure will be more intense [10]. Climate change risk can thus be explained as the interrelation of governance and natural hazards. Decisions concerning land use and urban development affect the level of risk when a natural disaster occurs. The socio-economic impacts depend on governance strategies in risk areas [7].

2.1. Risk factors of climate change in cities

Cities are complex systems with various interconnected services, which leads to difficulties with disaster risk issues. The factors that determine the level of risk in cities are urban development, governance, infrastructure, human activities, and coordination among institutions. Rapid urban population growth and increasing density create pressure on land and services. Urban sprawl and high demand for urban development may cause extension of settlements to the urban risk areas. In terms

[4] Disaster Resilient Communities Initiative. Hazard, Risk and Vulnerability Analysis Tool Kit. Ministry of Public Safety and Solicitor General Provincial Emergency Program, 2004. British Columbia, p. 22.

[5] *European Commission. Commission Staff Working Paper: Risk assessment and mapping guidelines for disaster management,* 2010, p. 10.

[6] *UNISDR (International Strategy for Disaster Reduction).* Terminology: Disaster Risk Reduction. 2009. United Nations, Geneva, p. 25.

[7] *IPCC. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* 2007. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

[8] EEA (European Environment Agency). The European environment – State and outlook 2010 (SOER 2010). Understanding climate change. 2010. Copenhagen: European Environment Agency

of governance, the central concentration of resources and capacities and the uncertainties of disaster response measures at the local level weaken local government and prevent more effective action. The weakness of local government and lack of local stakeholders' participation in planning and decision-making may mislead decision-makers about local risks. Inadequate urban infrastructure systems such as sewage systems, drainage systems, solid-waste management and water-resource management, may cause disasters and health problems. Loss of natural resources and ecosystems because of human activities such as pollution and urban sprawl decreases the potential of beneficial services from nature. The lack of coordinated emergency services to prepare for, or respond to, natural disasters may cause more damage to the system and citizens[9].

Climate change can have various direct impacts on cities such as heat waves, seal level rise, extreme weather events[10], but indirect impacts such as health problems and damage to resources, buildings and infrastructure can often be much wider. The systems in cities are closely connected within themselves and with other cities and regions and can be affected by any failure in that complex structure. Floods can damage residential areas and business sites and cause loss of jobs and services such as maintenance of energy, transportation, or clean water. Heat waves can be detrimental to public health, reduce citizens' ability to work, and cause trouble for services and social life. In addition, damage to roads results in problems with the supply of goods. All of these consequences can put economic pressure on a city[11]. Thus, a climate change adaptation requires a broader perspective of risk reduction, resilient response and sustainable development [1].

2.2. Linking Risk and Resilience

In recent years, resilience has gained the attention of many academic studies and policies from various disciplines and sectors. Observed climate change impacts, uncertainty, and increasing risk have made resilience a major discussion topic for cities [11].

According to UNISDR[12], resilience is *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions"*. It implies a capacity to resist and overcome a disaster, as well as preparedness and reparation. Resilient thinking transcends prevention, control, or resistance to extreme weather events and instead adopts a framework of learning, evolution, and adaptation [12]. A resilient city learns from experience and adapts itself to a more risky environment [13] instead of struggling with it and as such, it rids itself of its rigid structure and becomes more flexible and adaptable to new conditions.

Resilience to climate change includes adaptation and risk reduction, especially for critically vulnerable areas [14]. Indeed, there is a strong relationship between risk and resilience in terms of the challenge of climate change. In order to be prepared for climate change threats, reduce risk, increase the safety in cities, and sustain economic viability and social wellbeing, cities must be more resilient. Unless cities adopt

[9] *UNISDR. How to Make Cities More Resilient: A handbook for local government leaders. A contribution to the global campaign 2010–2015*, 2012. Geneva.

[10] UNFCCC (United Nations Framework Convention on Climate Change). Climate Change: Impacts, vulnerabilities, and adaptation in developing countries. 2007

[11] EEA. Urban adaptation to climate change in Europe: Challenges and opportunities for cities together with supportive national and European policies, 2012, Copenhagen.

[12] UNISDR, 2009, p. 24.

resilient development, the risk will remain and increase in vulnerable areas[13].

Reducing risk can be an opportunity to improve economic, natural and social conditions, deal with unpredictable or uncertain shocks, and make communities more secure than before[14]. Decreased resilience means increased vulnerability to uncertainties and surprises for a community that generates risk and can cause system crises or chaos in smaller disruptions or stresses[15].

2.3. Climate Change Risk Assessment

Risk assessment is an inherent part of risk reduction and resilient development [15]. In order to understand risks and make accurate decisions about risk reduction, risk factors, including all kinds of city services and sectors, should be analyzed [6]. Risk analysis and risk assessment are needed to inform decision makers, prioritize projects, determine risk reduction measures, and identify high, medium, and low risk areas by considering vulnerabilities, cost, effectiveness, and interventions. Based on its exposure and vulnerabilities, each local and urban structure is affected by climate-related disasters and natural hazards differently and has a different level of risk[16]. Therefore, risk assessment should consider exposure and vulnerability in a multidimensional and integrated approach [16].

The literature doesn't suggest a universally accepted approach to risk assessment[17] [9]. However, recent studies emphasize a risk-based multi-dimensional assessment approach for the effective urban development [14]. The risk literature emphasizes the terms *'probability'* and *'consequences'* as shown above. Snover et al. [17] have created a risk assessment framework from this perspective and defined probability as the likelihood of a climate hazard to occur and consequences as the social, economic, cultural, or natural impacts of any climate hazard[18]. According to Snover et al. [17], each sector of a complex city system should be analyzed individually, in terms of the impacts and probability of any climate-based risk in order to assess the risk. The impact of potential risk on each sector would be different in a city structure. Therefore, urban systems require an assessment of each vital sector in the city to reveal the differences in risk levels.

3. Climate change risk assessment of Istanbul's urban sectors

3.1. Initial remarks

The population of Istanbul has already reached 15 million according to official numbers[19]. The economically powerful location of Istanbul has made it a center of migration in Turkey since the 1950s. The city is unique in Turkey, being not only the most populated city but also a center of culture, tourism and national and international trade. It has a particular value among the world's metropolitan cities as well, with its history, resources and geographical location. Its service hinterland extends to the other 80 provinces of Turkey in terms of social facilities and the central offices of national or international institutions. The GDP of the service sector in Istanbul makes up 1/5 of the national GDP[20]. In 2018, the GDP

[13] UNISDR.. Making cities resilient: My city is getting ready, 2010–2011. World Disaster Reduction Campaign. 2010.

[14] UNISDR, 2012.

[15] Resilience Alliance.A Research Prospectus for Urban Resilience: A resilience alliance initiative for transitioning urban systems towards sustainable futures. 2007.

[16] *Ibidem*.

[17] Climate change impacts and the urban development process are complex and sometimes unclear, therefore the assessment is difficult.

[18] A multidimensional approach to climate change risks in terms of their likelihood and consequences is required in order to understand the interrelation of various climate-related risks.

[19] http://www.turkstat.gov.tr, date retrieved 01.03.2018.

[20] IMP (İstanbul Büyükşehir Belediyesi İmar ve Şehircilik Daire Başkanlığı Şehir Planlama Müdürlüğü). 1/100.000 Ölçekli İstanbul Çevre Düzeni Planı Raporu. 2009.

per person was $16,264 in Istanbul, while it was $9,693 in the rest of Turkey[21].

Istanbul, being an economic and cultural center with a dense population and a variety of social and economic activities, has high risk in terms of any external stresses. Istanbul has always had an earthquake risk and the city has experienced very destructive earthquakes and suffered from lack of preparation [18]. In recent years, terror risks have increased in the city, in conjunction with general distress in the Middle East region and Istanbul has faced many terrorist bomb attacks in the last few years[22] because of its pivotal position in Turkey. In addition to these specific stresses, Istanbul also suffers from other natural disasters and the impacts of climate change, such as heat waves, extreme weather events, flooding, as well as others. These examples prove that not only Istanbul but also Turkey would be impacted severely if any climate-based disaster case occurs in Istanbul.

As previously mentioned, climate change risk is one of the most discussed topics globally, and the impacts of such change can be eliminated by local, national and international cooperation, relevant strategies and effective policies. Therefore, these multi-scale efforts take important place in the mitigation and adaptation measures to climate change effects. Increasing the urban resilience is essential for the sustainability of social and economic activities and viability of the city. Even though Istanbul's economic and social structure creates advantages from certain aspects, the vulnerability of it to external stresses is highly critical.

In this study, Istanbul is chosen for the case study because of its geographical location, socio-cultural values, and economic importance in Turkey. Since it is the most important center in terms of economic activity and population, it is urgent that the risk of climate change in Istanbul be considered. Therefore, this study aims to assess the level of risk generated by climate change on urban sectors in Istanbul. The methodology defined by ICLEI [17] has been followed to assess the risk levels. According to the definitions in that guidebook, 11 urban sectors[23] and 25 sub-sectors – planning areas – are identified as shown as *Table 1*. The 11 sectors are defined considering development strategies are likely to be affected by climate-related disasters and critical for economic viability and public health of the city. Related planning areas are defined in the frame of the ICLEI definition, which covers major urban issues and services.

This study is a part of a comprehensive resilience assessment study of the 11 selected urban sectors. The resilience study consists of 3 parts: vulnerability assessment, risk assessment and prioritization assessment[24]. The overall result of these studies will help decision makers to formulate strategies to eliminate the climate change risk, decrease climate-related vulnerabilities and increase urban resilience and adaptive capacity, starting with the most critical sectors.

[21] http://www.turkstat.gov.tr (accessed: 06.05.2020).

[22] http://www.diken.com.tr, "Bir Buçuk Yılda 33 Bombalı Saldırıda 461 Kişi Hayatını Kaybetti" (accessed: 08.02.2018).

[23] ICLEI defines sectors as "any resource, ecological system, species, management area, activity, or other area of interest that may be affected by climate change" [12, p. 5].

[24] The first part has been completed and suggests that the most vulnerable urban systems are urban risk areas, heat, biodiversity, and sea transit followed by energy production, water supply, storm water management, water quality, agricultural land maintenance, public transit, social facilities, disaster response, and historical and cultural heritage. The least vulnerable systems are recycling and waste collection, fire safety, sewage system and urban renewal [5]. In the present study, we evaluate the risks of the same sectors and planning areas. In the last part, which will be the focus of our next study, we will combine the vulnerability and risk assessment results and will present an overall resiliency score for each planning area.

Table 1. Sectors and planning areas

Sectors	Planning Areas
Water Resources	Water Supply
	Water Quality
Health	Heat
	Air Quality
Energy	Energy Demand
	Energy Production
Agriculture	Agricultural Land Maintenance
	Crop Diversity
Transportation	Sea Transit
	Road & Bridge Maintenance
	Public Transit
Development & Land Use	Urban Renewal
	Affordable Housing
	Social Facilities
	Urban Planning
Public Safety	Fire Safety
	Urban Risk Areas
	Disaster Response
Infrastructure	Sewage Systems
	Storm Water Management
Ecology & Biodiversity	Biodiversity
	Green Spaces
	Urban Forest Management
Culture	Historical & Cultural Heritage
Materials	Recycling & Waste Collection

3.2. Methodology

ICLEI Guidebook [17] defines risk with two components; the consequences of an impact and its probability or likelihood:

$$Risk = Consequemce \times Probability.$$

The consequence of an impact represents the estimated or known consequences of a particular climate change impact, e.g. the cost and the size of the land area or population affected. In this study, four main types of consequences are investigated: *"economic consequences", "ecological consequences", "social consequences",* and *"cultural consequences"*[25]. The cumulative results of consequences are evaluated as high, medium or low. The likelihood or probability of an impact answers the question *'what is the probability of a projected impact occurrence?"*. Some kinds of climate change impacts are certain and can be observed in the present day, while others are less so. By considering the extent to which such changes affect ongoing problems or generate new problems, the certainty level is determined. The evaluation of the certainty and uncertainty of impacts is ranked as high, medium, and low probability.

[25] Economic consequences are concerned with how costly the damage or repair will be, in addition to the cost of the preventing measures. Ecological consequences refer to how the environment and ecosystem will be affected. Social consequences encompass how citizens will be affected, e.g. whether there is any life-threatening impact, or which group of citizens will be affected. Cultural consequences concern any effect on culture and if present, how it may change cultural behavior.

As a first step, the relevant data on climate change were gathered from institutions and publications[26]. For the next step, in-depth interviews were carried out with 54 interviewees between April and December 2014. The interviewees were determined using snowball sampling methodology among representatives of institutions and companies, experts, academics, scientists, and researchers. The respondents selected by considering most active stakeholders on the specific sector or planning area. From this perspective the interviews were conducted to representative of 42 public institutions, 5 private institutions, 4 academics and 3 NGOs. Public institutions dominate the distribution of interviewees since they are the most important decision makers in İstanbul's urban system. A semi-structured questionnaire as seen in *Table 2* was prepared for the interviews to discover the approaches of the actors and institutions to climate change, the importance of climate change in their agenda, their awareness, their strategic approach to climate change mitigation and adaptation. The interview outputs were used to interpret the risk levels of sectors from the relevant institutions' and actors' perspectives.

The final risk level is evaluated considering both the consequences and probability of impacts using a risk assessment index. In order to combine those results, quantitative scores are given for each. Consequences are scored as 1, 2, and 3 for low, medium, and high results, respectively. Whilst probabilities are also scored as 1, 2, and 3 for low, medium, high probability, respectively. The consequences and probability scores are combined in a matrix in order to score the overall risk level. *Table 3* presents the score matrix of the risk assessment. Risk levels are categorized as high risk (score 6-5), medium risk (score 4) and low risk (score 3-2).

Table 2. Questions of the semi structured questionnaire[27]

Risk Factors		*Which climate-based risks the related urban sector confronts?*
		In which direction do the consequences of the expected climate risks affect the urban system?
Probability		*What is the probability of the occurrence of those risks?*
Consequences	Threats	*Is there any life-threatening situation for citizens?*
		Is there any threat to the ecological balance?
		Is there any threat to the culture?
	Cost	*How costly are the actions that would prevent the risks?*
		How costly is the recovery after any disaster happens?

Table 3. Risk assessment matrix

	High Consequence (3)	Medium Consequence (2)	Low Consequence (1)
High Probability (3)	6 (High Risk)	5 (High Risk)	4 (Medium Risk)
Medium Probability (2)	5 (High Risk)	4 (Medium Risk)	3 (Low Risk)
Low Probability (1)	4 (Medium Risk)	3 (Low Risk)	2 (Low Risk)

[26] The information taken from institutions are: their current programs, policies that may support climate change adaptation or/and mitigation, projections on climate change, future expectations about demographic, structural or economic structures, investments, and plans.

[27] We constructed the semi-structured questionnaire in 4 parts; the first part attempts to discover climate change risk factors, the second part to evaluate the probability of the risk to occur, the third part to investigate the expected economic, social, ecologic and cultural threats, and finally the last part tries to estimate the cost of the hazards.

3.3. Empirical results

3.3.1. Water resources

Water resources are at risk because of unplanned settlements, unwise land use decisions, and uncontrolled urban development. Climate change will inevitably cause a decrease in rainfall and drought. Increasing temperatures will lead to drops in the water levels of reservoirs through evaporation and water scarcity is thus a very real possible result of climate change. In turn, water resources may become polluted due to leakage, storms, and erosion caused by extreme weather events. Polluted resources create serious costs in treatment and supply. Water is a basic need for human life, and poor water quality and inadequate water service create life threatening risk for citizens. Keeping water resources clean is also very important ecologically. Ecological sustainability depends on water quality and the preservation of resources.

Even today, a decrease in water supply has arisen as a consequence of increasing temperatures. The probability of the impacts on water supply is almost certain. However, climate change has an indirect impact on water quality meaning, the probability is medium (*Table 4)*.

3.3.2. Health

The most obvious climate change impact is an increase in heat and longer summer periods. It is also expected to change the ratio of air components, which will cause an increase in air pollution, a decrease in air quality where it is hotter, and the deterioration of the atmosphere.

Changes in climate will result in increases in respiratory diseases, allergies, skin cancer and asthma even deaths and diseases. An increase in heat will also lead to an extending of disease vectors such as mosquitos around unqualified environment. Climate change and decreasing air quality will create extra health costs. Ecology will also be directly affected by the decreased air quality and increased heat. All citizens will be affected, but elderly, sick people, children and outside workers are at greater risk groups which constitute half of the population. In terms of cultural behavior, slight changes may occur in citizens' daily life habits, and people may spend less time outside We have already observed increased temperatures, especially in summer time, and decreased air quality. As such the projected effects are highly possible (*Table 5)*.

3.3.3. Energy

Turkey depends on external resources of energy as it can only produce 40% of its energy demands. Istanbul has a rapidly growing population generating higher energy demand. Renewable and clean energy resources are not sufficient and fossil fuel is still the main energy resource. Due to climate change, the seasonal energy demand for heating and cooling will change. The demand for cooling energy is expected to increase in summer while the demand for heating will decrease in winter. Energy production will be costly,

Table 4. The risk assessment of water resources

Planning area	Consequence	Probability	Risk Level
Water Supply	High C.(3)	High P.(3)	High R.(6)
Water Quality	High C.(3)	Medium P.(2)	High R.(5)

Table 5. The risk assessment of health

Planning area	Consequence	Probability	Risk Level
Heat	Medium C.(2)	High P.(3)	High R.(5)
Air Quality	High C.(3)	High P.(3)	High R.6)

Table 6. The risk assessment of energy

Planning area	Consequence	Probability	Risk Level
Energy Demand	Medium C.(2)	High P. (3)	High R.(5)
Energy Production	Medium C.(2)	High P.(3)	High R.(5)

with increasing population and demand. More energy consumption will bring more cost for individuals especially. The probability of a climate change effect is high since it can obviously be observed (*Table 6)*.

3.3.4. Agriculture

Climate conditions also affect agricultural productivity. The fertility of each crop may change depending on climate. Climate change will lead to less precipitation and more drought periods. Irrigation systems need more improvements because of the potential water scarcity. Agricultural production in Istanbul is low in comparison to the rest of Turkey. Istanbul is a rapidly growing city, which puts agricultural lands in danger of urbanization. Pollution is another factor that creates risk for agricultural land maintenance. The agricultural production in Istanbul is not sufficient for the population and the population is dependent on the production of other regions of Turkey. The decrease in agricultural activity will cause an increase in dependence. However, this does not create a serious risk for citizens and is not a life-threatening situation. Ecological patterns will change depending on climate conditions, and farmers should adapt to new conditions and learn about compatible crop patterns. Recently, the destructive impacts of climate change have been observed in the agriculture sector which reveals that the probability of the risk is high (*Table 7)*.

3.3.5. Transportation

Istanbul suffers heavily from traffic problems, especially during peak hours. There are different modes of public transportation such as buses, subways, ferries, and. the increase in frequency and severity on extreme weather events as a result of climate change will affect transportation negatively. Roads and bridges will need constant maintenance because of the damage suffered in weather events like heavy rain, snowing and floods. Sea transit is essential for the connection of the two sides of Istanbul. However, its proportion in the transport system is low (2%). Such transit is highly affected by climate conditions. Public transportation is also important in terms of protecting the environment and ecosystems. All citizens are affected, but apart from traffic accidents, the impacts of climate change will not threaten lives in this sector. The probability of climate change effects such as extreme weather conditions are highly possible for Istanbul (*Table 8)*.

Table 7. The risk assessment of agriculture

Planning area	Consequence	Probability	Risk Level
Agricultural Land Maintenance	Medium C.(2)	High P.(3)	High R.5)
Crop Diversity	Medium C.(2)	High P.(3)	High R.(5)

Table 8. The risk assessment of transportation

Planning area	Consequence	Probability	Risk Level
Sea Transit	Low C.(1)	High P.(3)	Medium R.(4)
Road & Bridge Maintenance	Medium C.(2)	High P.(3)	High R.(5)
Public Transit	Low C.(1)	High P.(3)	Medium R.(4)

3.3.6. Development & Land Use

The Istanbul Metropolitan Municipality, District Municipalities and Housing Development Administration produce affordable houses for low income citizens, especially in their proposals to transfer settlements in risk areas. However, it is not possible to transfer all slums and informal settlements into affordable housing. Severe weather events resulting from climate change will cause more damage, especially in risk areas, and as a result the demand for affordable housing is expected to increase. The growing population and migration to the city have also increased the demand for housing. In Istanbul 25,000 buildings are under transformation and it is thus essential to reduce risk and produce higher-quality buildings. After the 1999 earthquake, which inflicted serious damage on Istanbul, the need for higher quality building structures was recognized. Climate change will have more severe impacts on low-qualified buildings. The Istanbul Development Plan includes both strategies that contribute to sustainability and measures to mitigate climate change impacts. Istanbul lacks urban facilities in some districts. The amount of green area per person is less than standard. The plans propose new urban facilities for new development areas. In old and unplanned settlements, the lack of urban facilities is still a problem. Insufficient urban facilities decrease the quality of the environment and of life.

Economically, urban renewal is affordable, and the private sector has taken an active role in such activities. However, building-based transformation cannot eliminate risk totally. The lack of urban facilities and open spaces is a problem for the environment. The sprawl of urban areas threatens the ecology around the city. Low-income groups and people living in urban risk areas would thus be more affected by climate change impacts. Nevertheless, all citizens will be affected by the decisions of the plan, which is insufficient to reduce risk in some settlement areas. Culturally, people's lifestyles may change depending on the architectural style of their houses or neighborhoods.

Affordable housing is continuously produced in the city and there is uncertainty concerning climate change impacts on affordable housing and urban facilities. The impacts of climate change on the urban planning area is certain. Therefore, the probability is medium in planning areas except urban planning that is high (*Table 9)*.

3.3.7. Public safety

Istanbul frequently faces climate-based disasters. Flooding, storms, and drought are frequent climate related disasters occurring in the city and projected to be more so with climate change. Urban risk areas are vulnerable to any climate-based disasters. Unplanned and unofficial settlements where low income people live are located in those risk areas and are habitually exposed to climate disasters like flooding. Climate change will cause more disaster in risk areas like flooding will be more severe and frequent, and storms will be more harmful. Drought and heat cause fires in urban areas and forests.

Table 9. The risk assessment of development & land use

Planning area	Consequence	Probability	Risk Level
Urban Renewal	Medium C.(2)	Medium P.(2)	Medium R.(4)
Affordable Housing	Medium C.(2)	Medium P.(2)	Medium R.(4)
Social Facilities	Medium C.(2)	Medium P.(2)	Medium R.(4)
Urban Planning	High C.(3)	High P.(3)	High R.(6)

Disasters may have already damaged ecosystems. Citizens, especially those living in risk areas, may face life threatening situations. Renewal is a basic tool to decrease the risk in urban risk areas. Another tool is expropriation, which could be used to wipe out settlements in flood pains and high-risk areas. However, it is not possible to take such precautions in all urban risk areas, and it is very costly where such action is feasible. The city's fire department is well organized and improving. Not all citizens are affected in any fire situation. However, fires may pose a severe threat to people. The probability of occurrence of the risk is high (*Table 10)*.

3.3.8. Infrastructure

Istanbul's storm water system is not sufficient for the dense population needs for example, in any heavy rain event, water overflows from pipelines. Climate change and relational extreme weather events make overflowing more severe and frequent. In some districts of Istanbul, wastewater is discharged into the streams or sea directly. The city's growing population and density may create problems for the system, and so the capacity of the sewage system should be increased. In order to prevent overflows, pipelines should be changed taking into account climate change impacts. Moreover, more penetrable surfaces should be created in the city. Such precautions are costly for the municipal government. Overflows and direct sewage charges may also be ecologically detrimental. They create life threatening situations for citizens, especially for those living in risk areas, flood plains, or slums. In some dense and populated districts, the comfort level may decrease because of insufficient sewage systems. Overflows cause large flooding that leads to deaths and property loss. The risk concerning storm water management can be observed currently. The multiplied effects of climate change will make the risk greater. However, the consequences are not certain for sewage systems (*Table 11)*.

3.3.9. Ecology & biodiversity

In Istanbul, ecologically important areas are confronted by the risks of urbanization, overconsumption, and deterioration due to human activities. Climate change and extreme weather events are detrimental for biodiversity, trees and green areas. Drought is a problem for irrigation and green areas are maintained by the municipality regularly. Climate conditions may damage the design of green areas, plants and parks. The green areas in the city are becoming smaller because of urbanization. Climate change will require more and constant maintenance of green areas. Extreme storms may uproot trees and increase loss of urban forest areas due to these factors and also city expansion are also harmful for ecology and decreases citizens' comfort level, air quality and accessibility to green areas. The habits of people

Table 10. The risk assessment of public safety

Planning area	Consequence	Probability	Risk Level
Fire Safety	Medium C.(2)	High P.(3)	High R.(5)
Urban Risk Areas	Medium C.3)	High P.(3)	High R.(6)
Disaster Response	Medium C.(2)	High P.(3)	High R.(5)

Table 11. The risk assessment of infrastructure

Planning area	Consequence	Probability	Risk Level
Sewage System	Medium C.(2)	Medium P.(2)	Medium R.(4)
Storm Water Management	High C.(3)	High P.(3)	High R.(6)

in green areas may change. The probability of the risk is uncertain for green spaces and urban forest management; however, biodiversity is already at risk in Istanbul (*Table 12)*.

3.3.10. Culture

Climate conditions directly affect historical buildings. Traffic pollution causes darkening of facades, and rain and snow cause cracks in walls. Climate change will negatively affect the city's historical heritage. The damage caused by climate conditions will be multiplied with more frequent and extreme weather conditions. However, since historical buildings are constantly maintained, climate change will not incur extra costs. For citizens, it does not create life-threatening situations. However, for those living in old, historic and registered buildings, climate change may create a risk. Those buildings may need restoration, which may be costly for residents. Climate change will also certainly have an impact on the sector (*Table 13)*.

3.3.11. Materials

Leakage from storage areas to underground water is a risk for the environment. However, the leakage is prevented by special construction techniques, and methane gas is collected by pipes. Climate change may increase the environmental risk, but necessary controls are performed regularly. Technological improvements are used to protect the environment.

Climate change does not generate considerable risk for this sector, and the consequences are not certain (*Table 14)*.

3.4. The Risk Levels of All Sectors and Planning Areas

In *Table 15*, the summary of the risk assessment is presented, and the risk scores and levels of all sectors are indicated.

The planning areas under risk are determined considering economic impacts and their cost, detrimental ecological impacts, impact on citizens, how many people are affected and whether there is any life-threatening situation and if so, what the impact on the culture will be. The probability of climate impacts is also included. Costly, life threatening, ecologically detrimental, culture-altering impacts and high possibility create high risk in planning areas.

According to the results, *water supply, storm water management, urban planning, air quality, and urban risk areas,* have the highest risk regarding climate change. The planning areas of *biodiversity, energy production, road and bridge maintenance, water quality, disaster response, energy demand, fire safety, crop*

Table 12. The risk assessment of ecology & biodiversity

Planning area	Consequence	Probability	Risk Level
Biodiversity	Medium C.(2)	High P.(3)	High R.(5)
Green Spaces	Medium C.(2)	Medium P.(2)	Medium R.(4)
Urban Forest Management	Medium C.(2)	Medium P.(2)	Medium R.(4)

Table 13. The risk assessment of culture

Planning area	Consequence	Probability	Risk Level
Historical & Cultural Heritage	Medium C.2)	High P.(3)	High R.(5)

Table 14. The risk assessment of materials

Planning area	Consequence	Probability	Risk Level
Waste Collection & Recycling	Low C.(1)	Medium P.(2)	Low R.3)

Table 15. Risk levels of all sectors and planning areas

Sector	Planning Area	Risk Level (Score)	Average Risk Score
Water Resources	Water Supply	High (6)	5.5
	Water Quality	High (5)	
Health	Heat	High (5)	5.5
	Air Quality	High (6)	
Energy	Energy Demand	High (5)	5
	Energy Production	High (5)	
Agriculture	Agricultural Land Maintenance	High (5)	5
	Crop Diversity	High (5)	
Transportation	Sea Transit	Medium (4)	4.3
	Road & Bridge Maintenance	High (5)	
	Public Transit	Medium (4)	
Development & Land Use	Urban Renewal	Medium (4)	4.5
	Affordable Housing	Medium (4)	
	Social Facilities	Medium (4)	
	Urban Planning	High (6)	
Public Safety	Fire Safety	High (5)	5.3
	Urban Risk Areas	High (6)	
	Disaster Response	High (5)	
Infrastructure	Sewage Systems	Medium (4)	5
	Storm Water Management	High (6)	
Ecology & Biodiversity	Biodiversity	High (5)	4.3
	Green Spaces	Medium (4)	
	Urban Forest Management	Medium (4)	
Culture	Historical & Cultural Heritage	High (5)	5
Materials	Recycling & Waste Collection	Low (3)	3

diversity, historical and cultural heritage, heat and agricultural land maintenance also have a high risk. Any impact on those planning areas will negatively affect many people living in the city and may even cause life threatening situations. Recovery or adaptation to such risk is costly in many cases. Climate change also creates ecologically problematic conditions and cultural alterations. The planning areas of *green spaces, sea transit, sewage system, public transit, social facilities, affordable housing, urban forest management and urban renewal* have lower risk. The lowest risk planning area is *recycling & waste collection*. These planning areas have relatively lower risk scores because they don't create life-threatening risk.

The average risk scores of each sector has also been calculated using the risk scores of planning areas and assuming all planning areas within a sector have the same impact on sector's risk level. In terms of sectors in the assessment, *health and water resources* has the highest risk with a score of 5.5 followed by *public safety* with 5.3 and *energy, agriculture, infrastructure and culture* with a score of 5. The *development and land use* sector has medium risk with a score of 4.5, and the *transportation* and *ecology and biodiversity* sectors have a score of 4.3. The *materials* sector has the lowest risk score with 3. As a result, out of 25 planning areas, 5 have the highest risk score (6), 11 have a high-risk score (5), 8 have a medium risk score (4), and 1 has a low risk score (3). The sectors have highest risk scores should have priority in planning practice.

Concluding remarks

The resilience level of a city is based on its vulnerabilities and the risks that the city is expected to confront. Therefore, while moving

towards a resilient development, risk assessment has great importance. The risks should be determined and expected impacts on the city system should be measured. The determination of risks and expected consequences is important in reducing uncertainty. On the other hand, knowing the vulnerabilities of sectors is critical in assessing the resiliency of an urban system. A study on the vulnerability assessment of those sectors was recently completed by Aygün and Baycan [5] as a part of a more comprehensive resilience study. According to this vulnerability study, the most vulnerable planning areas are *biodiversity, heat, urban risk areas and sea transit*. Other high-level vulnerable planning areas are *historical and cultural heritage, water quality, energy production, disaster response, water supply, social facilities, public transit, storm water management*, *agricultural land maintenance*. When we probe the highest scores in both studies, it is obvious that the vulnerable and risky planning areas are mostly overlapping. It can be claimed that high vulnerability creates high risk for a sector, while high risk creates high vulnerability as well. These two concepts are interrelated and inseparable in the field of resilience.

The results of the study clearly indicate that Istanbul's urban development process over time and the current settlement pattern are the main causes of climate-related risk in the city. The rapid migration and as a result rapid urbanization formed urban development in risk areas such as river basins or geologically unsuitable areas most of which are informal settlements. The Urban Heat Island effect increases due to dense settlement pattern, lack of green areas and wind corridors. As a result, the vulnerability of the settlements to heat, heat waves and extreme weathers increase. Moreover, ecology and water resources are at risk due to the pressure on natural areas and resources caused by sprawling urban settlements to peripheral areas and increasing population. Furthermore, the city suffers from an insufficient infrastructure system especially in old and dense neighborhoods. It is not sufficient for the population or any extreme precipitation. The major problem that revealed in this study is that the city is lacking the balance between capacity of the urban system such as resources, infrastructure, facilities, management abilities, etc., and the density of population, settlements, and demand.

This study is a starting point for resilient development in Istanbul. Future studies can be constructed on the results of this study. The results address the weaknesses and opportunities of the city system in a comprehensive way which can also direct future actions toward resilience. The starting point of resilient development is critically important for decision makers because it is a long-term process that should be started from the right spot immediately. The climate change impacts have already been observed, and its negative effects have harmed risky and vulnerable sectors. The requirement for preparedness is urgent. It is important that academics contribute to the research and pathways on this top topic.

Climate change research is a new topic in Turkey, therefore, we confronted difficulties finding data for the risk assessment study. The institutions were not able to give relevant information and lacked effective coordination and data collection systems. The climate change concerned studies were very limited in institutions. Therefore, during the in-depth interviews, we needed to combine their point of views on risk with climate change. In Turkey, it is obvious that effective data collection systems, coordination between institutions, and an increased awareness of climate change are primarily necessary.

Since 2014, when these in-depth interviews were conducted, the awareness of climate change has increased in institutional level in Istanbul. In 2018 "Istanbul Climate Change Action Plan" prepared together with 'GHG Inventory Report', 'Climate Change Scenarios Report', and 'Climate Change Risk, Opportunities and Vulnerabilities Assessment Report'[27]. These assessment reports significantly address the same risks and vulnerabilities with this study. However, the regional development plans or local implementation plans still don't consider climate change impacts and risk reduction strategies. Therefore, the climate change risk levels of sectors defined in this study remain the same, even in 2020.

Vulnerabilities and risks may change over time, and strategies may work or fail. A fixed tracking system is thus a necessity. New technological improvements, economic conditions, changing demands are important factors in the risk levels of urban systems. Non-climatic alterations may also negatively or positively impact a system's risk level. Therefore, the reassessment of risk levels of the sectors is inevitable over time. The next step should be developing policies and strategies to decrease risk and increase resilience. The most vulnerable urban systems and risk factors should be considered carefully by decision makers. At the same time, the risk reduction strategies should be integrated into development and implementation plans. Citizens also have a critical role in a resilience development. They should be informed, educated and involved in sustained collaboration. Any action without the participation of citizens would be meaningless in an urban system.

References

1. Tompkins E.L., Adger W.N. Does adaptive management of natural resources enhance resilience to climate change? *Ecology and society*, 2004, no. 9(2): 10.
2. Evans J.P. Resilience, ecology and adaptation in the experimental city. *Transactions of the institute of British Geographers*, 2011, no. 36(2), pp. 223–237.
3. Norman B. *A Low Carbon and Resilient Urban Future: An Integrated Approach to Planning for Climate Change*, 2010.
4. Pamukcu K. *Turkey's Post-Kyoto Climate Change Policy*. University of Phoenix-Chicago, 2010.
5. Aygün A., Baycan T. Istanbul's vulnerability to climate change: An urban sectors' based assessment. In: *Handbook of Climate Change Communication*. Vol. 3. Springer, Cham, 2018. Pp. 361–383. ISBN: 978-3-319-70478-4
6. Wamsler C., Brink E., Rivera C. Planning for climate change in urban areas: From theory to practice. *Journal of Cleaner Production*, 2013, no. 50, pp. 68–81.
7. Wisner B. et al. *The Challenge of Disasters and our Approach. At Risk: Natural Hazards, People's Vulnerability and Disasters*. 2nd ed. London: Routledge, 2004. Pp. 3–48.
8. Hansen J. et al. Global surface temperature change. *Rev. Geophys.*, 2010, no. 48, RG4004. DOI:10.1029/2010RG000345.
9. Carter, J. G., et al. Climate change and the city: Building capacity for urban adaptation. *Progress in Planning*, 2015, no. 95, pp. 1–66.
10. Jabareen Y. Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. *Cities*, 2013, no. 31, pp. 220–229.

[27] http://www. iklim.istanbul, date retrieved 06.05.2020.

11. Meerow S., Newell J.P., Stults M. Defining urban resilience: A review. *Landscape and Urban Planning*, 2016, no. 147, pp. 38–49.
12. Cannon T., Müller D. Vulnerability, resilience and development discourses in context of climate change. Natural *Hazards*, 2010, no. 55(3), pp. 621–635.
13. Morss R.E. et al. Improving societal outcomes of extreme weather in a changing climate: an integrated perspective. *Annual Review of Environment and Resources*, 2011, no. 36, pp. 1–25.
14. Rosenzweig C. et al. (ed.). *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network*. Cambridge University Press, 2011.
15. Coppola D.P. *Introduction to International Disaster Management*. Elsevier, 2006.
16. Gallina V. et al. A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment. *Journal of Environmental Management*, 2016, no. 168, pp. 123–132.
17. Snover A.K. et al. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*, 2007.
18. Gündüz A. et al. How imminent is the earthquake expected in Istanbul? And how potentially deadly? *The Journal of Academic Emergency Medicine*, 2015, no. 14(2), pp. 99–102.

Information about the Authors

Aysun Aygün – PhD Candidate, Research Assistant, Istanbul Technical University (34437, Turkey, Istanbul, Sisli, Taksim, Taskisla; e-mail: aaygun@pau.edu.tr), Pamukkale University (20160, Turkey, Denizli, Pamukkale, Kınıklı Campus)

Tüzin Baycan – PhD, Full Professor, Istanbul Technical University (34437, Turkey, Istanbul, Sisli, Taksim, Taskisla; e-mail: tbaycan@itu.edu.tr)

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