ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

ENVIRONMENTAL CONCERNS, URBAN MOBILITY AND TRANSPORT: PROMOTING A ROADMAP FOR WATER-BASED PUBLIC TRANSPORTATION IN ISTANBUL

M.Sc. THESIS

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Department of Urban and Regional Planning

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

ÇEVRESEL KAYGILAR, KENTSEL HAREKETLİLİK VE ULAŞIM: İSTANBUL'DA DENİZ ULAŞIMININ DESTEKLENMESİ İÇİN BİR YOL HARİTASI GELİŞTİRİLMESİ

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FOREWORD

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ABBREVIATIONS

AFAD : Disaster and Emergency Management Presidency
AKOM : Disaster Coordination Centre
AKUT : Search & Rescue Association
BRT : Bus rapid transit
EU : European Union
CO_2 : Carbondioxide
CRI : City resilience index
GHG : Greenhouse gas emissions
H_2O : Water vapour
IMM : Istanbul Metropolitan Municipality
IPCC : International Panel on Climate Change
NGOs : Non-governmental organisations
NH_4 : Methane
PIANC : Permanent International Association of Navigation Congress
TURKSTAT : Turkish Statistical Office
UKOME : Transport Coordination Centre
UN : United Nations
UNESCO : United Nations Educational, Scientific and Cultural Organisation
UNFCCC : United Nations Framework Convention on Climate Change

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ENVIRONMENTAL CONCERNS, URBAN MOBILITY AND TRANSPORT: PROMOTING A ROADMAP FOR WATER-BASED PUBLIC TRANSPORTATION IN ISTANBUL

SUMMARY

The environment that we live in offers unlimited opportunities for people to continue their lives. All of these opportunities allow us to create liveable settlements in harmony with the environment. However, the environment contains limits. The unlimited consumption of individuals pushes these limits and even causes them to be exceeded. This concept, which is called planetary boundaries, reveals which planetary boundary we are crossing and at what level. Some concepts have been put forward in the literature to combat this situation and create entirely liveable environments for both existing and future generations. Sustainability is the basis of these concepts. However, sustainability is a concept that has lost its meaning and remained at the policy level. Moreover, it has made failures in tackling climate change and environmental burdens. While the habits of individuals were expected to be changed, consumption levels have been started to increase with an incremental momentum. Therefore, environmental concerns have gained an irreversible dimension.

At this point, resilience is a concept that is introduced based on the failures of sustainability and is essentially derived from sustainability. It is built on the capacity of sustainability to balance against changes. In other words, it refers to the capacity to survive, adapt and develop against unexpected external shocks and stresses. As a result of these unexpected events, the concept of resilience could gain different approaches. In the meantime, with the appearance of the Covid-19 Pandemic, being resistant to the diseases has gained importance. However, climate change, which is faced with irreversible consequences, jumps ahead of all these side effects. In this context, climate resilience has been the most investigated dimension of resilience.

Cities are human-dominated ecosystems consisting of climate, energy flow, communities, mobility and other systems that exist to meet the vital needs of people. Within these ecosystems, individuals meet their basic needs through urban mobility. At this point, urban mobility is an inevitable consumption that reflects people's relationship with time and space, shapes our lives and directs the dynamics of the city. Therefore, urban mobility and transportation have the highest priority and importance. On the other hand, urban mobility and transport, which are at the centre of our daily life, are among the leading reasons for the high carbon footprint. In addition to being a cause of climate change, transportation systems are also one of the most affected systems. As the consequences of climate change occur in an unpredictable way, its effects are also being more devastating. Although the outcomes are unforeseeable, the transportation systems, which are the backbones of cities, must be resistant to these external effects. Thus, the concept of transport resilience comes to the forefront.

In this respect, the approach taken as a basis in the research is climate resilience. However, rather than the resilience of all systems, this study specifically focuses on the resilience of transportation systems. Since the study's primary purpose is to

increase the usage and importance of water-based public transportation, it has been placed in the centre. Water-based public transport has several opportunities to provide resilience. The most important of these is that water-based public transportation uses the natural infrastructure of the water. Therefore, water-based public transportation requires lower unit investment costs. Moreover, the high passenger capacity allows the costs to be even lower. On the other hand, according to the European Union, water-based public transportation is the most resilient form of transportation with the least energy loss and the capacity to substitute environmentally friendly energy resources. In other words, water-based public transportation stands out with its low carbon footprint and its relatively climate-friendly nature. In addition, transferring some load of urban transportation to the sea both relieves road transport and creates safe, calm, peaceful and comfortable options. In this sense, coastal cities with suitable locations and geographies have the opportunity to develop and take advantage of water-based public transportation as a type of public transportation. In this sense, Istanbul stands out among coastal cities with its unique geopolitical location, historical, cultural and natural value, as well as its sea culture from the past to the present. Accordingly, Istanbul is a highly vulnerable city and at the same time has a great potential in terms of water-based public transport, which is considered the most resilient mode of transport by the European Union, to overcome this vulnerability. Water-based public transportation is the only form of transportation that has been continuing since the establishment of Istanbul. Water-based public transport is a culture for Istanbul. In addition to being a form of transport, it is also seen as an activity and a way to relax in the dynamism of the city.

In this context, Istanbul has chosen as the case area within the scope of the thesis. Moreover, the study that aims to understand water-based public transportation's role in terms of resilience and reduce environmental burdens in Istanbul is based on the literature review. The study explores the possibilities of water-based public transportation in coastal cities in combating climate change and its contribution and role in the resilience of transportation systems in line with these opportunities. Within the scope of the research, the analytical hierarchy process, which is a multiple decision-making method, was conducted as a complementary method. In line with the scope of the analytical hierarchy process, a questionnaire has been carried out with a total of nine experts from the Istanbul Metropolitan Municipality and the academy. In the questionnaire, experts were expected to prioritise among the main and sub-criteria in understanding the role of water-based public transportation's resilience in Istanbul. In line with the prioritisation, a roadmap has been proposed to be followed up in Istanbul. The actions included in the roadmap are upper-scale, and the time interval is determined as 2024 for the short term, 2030 for the medium term and 2050 for the long term in line with the commitments of the Istanbul Metropolitan Municipality and the United Nations. However, it is suggested that the action plan be drawn up in detail. Moreover, it has been emphasised that the temporal order of these actions should be reviewed in terms of prioritisation.

On the other hand, some statistical calculations are made in order to analyse whether the results obtained in the questionnaire are applicable to Istanbul. In line with these calculations, although it is seen as important by experts in the fourth place, redundancy has emerged as a parameter that should not be examined about the resilience of water-based public transportation in Istanbul. However, robustness has been the main criterion with the highest importance. On the other hand, during the questionnaire, experts were asked to include potential stakeholders that will play a role in the

realisation of the relevant sub-criteria. Although this section was left as optional in the questionnaire, it has been filled by many experts.

In summary, this research only points out key areas that needed to be considered and reveals the neglected aspects of resilience and climate change. In other words, the thesis focuses on environmental concerns and urban mobility by aiming to be a basis for future studies by emphasising the importance and correlation between urban mobility and environmental concerns from a water-based public transport perspective.

ÇEVRESEL KAYGILAR, KENTSEL HAREKETLİLİK VE ULAŞIM: İSTANBUL'DA DENİZ ULAŞIMININ DESTEKLENMESİ İÇİN BİR YOL HARİTASI GELİŞTİRİLMESİ

ÖZET

Yaşadığımız çevre insanlara yaşamlarını devam ettirebilmeleri için sınırsız imkanlar sunmaktadır. Bu imkanların hepsi yaşanabilir yerleşmeler oluşturmamıza ve çevreyle uyum içerisinde düzenler kurmamıza olanak sağlamaktadır. Ancak, her şeyin olduğu gibi çevrenin de limitleri vardır. Yine bireylerin sınırsız tüketimleri bu limitleri zorlamakta olup kimi zaman aşılmasına da neden olmaktadır. Günümüzde gezegensel sınırlar (planetary boundaries) olarak adlandırılan bu kavram hangi gezegensel limiti hangi düzeyde aştığımızı ve aşmakta olduğumuzu ortaya koymaktadır. Bu durumla mücadele edebilmek ve hem günümüz hem de gelecek nesiller için gerçek anlamda yaşanabilir yerleşmeler oluşturmak adına literatürde bazı kavramlar ortaya atılmıştır. Bu kavramların temelinde sürdürülebilirlik yer almaktadır. Ancak sürdürülebilirlik anlamını yitirmiş ve politika düzeyinde kalmış bir kavramdır. Dahası, iklim değişikliği ve çevresel yüklerle mücadele etme yolunda daha fazla başarısızlıklara imza atmıştır. Bireylerin alışkanlıklarının değişmesi beklenirken Antroposen çağı ile birlikte tüketimler yükselen bir ivme ile artmaya başlamış ve çevresel kaygılar geri dönüşü olmayan bir boyut kazanmıştır.

Dayanıklılık kavramı (resilience), sürdürülebilirliğin hatalarından yola çıkılarak ortaya atılmış ve esasen sürdürülebilirlikten türemiş bir kavramdır. Sürdürülebilirliğin değişimlere karşı denge sağlayabilme 'kapasitesi' üzerine kurulmuştur. Başka bir deyişle, beklenmedik dışsal şok ve streslere karşı ayakta kalabilme, adapte olabilme ve gelişebilme kapasitelerini ifade eder. Yaşanan bu beklenmedik olaylar sonucunda dayanıklılık kavramı farklı yaklaşımlar kazanabilmektedir. Günümüzde Covid-19 salgını ile birlikte salgına karşı dayanıklı olma önem kazanmıştır. Ancak karşı karşıya olunan ve geri dönülemez sonuçlar içeren iklim değişikliği bütün bu yan etkenlerin önüne geçmektedir. Bu kapsamda da iklim direnci dayanıklılığın en çok irdelenen boyutu olmuştur.

Şehirler, insanların yaşamsal ihtiyaçlarını karşılamak için var olan iklim, enerji akışı, topluluklar, hareketlilik ve diğer sistemlerden oluşan insan hakimiyetindeki ekosistemlerdir. Böylelikle insanlar ve şehirler, yaşanabilir çevreler yaratma yönünde birlikte evrilmişlerdir. Ancak zamanla insanoğlunun doğal çevre üzerindeki hakimiyeti artmıştır ve yaşadığımız çevre alarm vermeye başlamıştır. Bu durum, insan kaynaklı çevresel yıkım, başka bir ifadeyle, insan kaynaklı iklim değişikliği olarak adlandırılmaktadır. Öte yandan, şehir ekosistemleri birbirine bağlıdır ve hareketlilikle canlı tutulmaktadır. Bireyler kentsel hareketlilik yoluyla temel ihtiyaçlarını karşılamaktadırlar. Kentsel hareketlilik, insanların zaman ve mekanla ilişkilerini yansıtan, hayatımızı şekillendiren ve şehrin dinamiklerini yönlendiren kaçınılmaz bir tüketimdir. Bu yapı içerisinde, kentsel hareketlilik ve ulaşım, bireylerin yaşamsal ihtiyaçlarını karşılamaları için türetilmiş bir talep olması nedeniyle en üst önem sırasına yerleşmiştir. Günlük hayatımızın merkezinde yer alan kentsel hareketlilik ve

ulaşım, yüksek karbon ayak izinin önde gelen nedenleri arasında yer almaktadır. İklim değişikliğinin bir nedeni olmalarının yanı sıra ulaşım sistemleri aynı zamanda bundan en çok etkilenen sistemlerden biridir. İklim değişikliğinin sonuçları öngörülemeyen bir şekilde meydana geldiğinden, etkileri de daha yıkıcı olmaktadır. Şehirlerin omurgası olan ulaşım sistemleri öngörülemez de olsa bu dış etkilere karşı dayanıklı olmak durumundadır. Bu nedenle ulaşım sistemlerinin dayanıklılığı kavramı ön plana çıkmaktadır.

Yukarıda bahsedilenler doğrultusunda araştırma kapsamında temel alınan yaklaşım iklime karşı dayanıklılıktır. Ancak bütün sistemlerin dayanıklılılığından ziyade bu çalışmada spesifik olarak ulaşım sistemlerinin dayanıklılığı üzerinde durulmaktadır. Çalışmanın temel amacı deniz ulaşımının kullanımını ve önemini artırmak olduğu için deniz ulaşımı merkeze yerleştirilmiştir. Deniz ulaşımı dayanıklılığı sağlamak için çeşitli fırsatlara sahiptir. Bunların başında ise deniz ulaşımın suyun doğal altyapısını kullanıyor olması gelmektedir. Bu nedenle, deniz ulaşımı daha düşük birim yatırım maliyetleri gerektirmektedir. Üstelik yüksek yolcu kapasitesi maliyetlerin daha da düşük olmasına olanak sağlamaktadır. Öte yandan Avrupa Birliği'ne göre deniz ulaşımı, en az derecede enerji kaybına sahip olması ve çevre dostu enerji kaynaklarını ikame etme kapasitesi ile en dayanıklı ulaşım şeklidir. Diğer bir deyişle, deniz ulaşımı, düşük karbon ayak iziyle ve nispeten iklim dostu olmasıyla öne çıkmaktadır. Ayrıca şehir içi ulaşımın bir miktar yükünün denize aktarılması, hem karayolu ulaşımını rahatlatmakta hem de güvenli, sakin, huzurlu ve konforlu seçenekler yaratmaktadır. Bu anlamda uygun lokasyon ve coğrafyalara sahip kıyı kentleri, toplu taşıma türü olarak deniz ulaşımını geliştirme ve bundan avantaj sağlama fırsatına sahiptir. İstanbul ise bu anlamda hem eşsiz jeopolitik konumu hem tarihsel, kültürel ve doğal değeri hem de geçmişten günümüze gelen deniz kültürü ile kıyı kentleri arasında daha öne çıkmaktadır. İstanbul önemli derecede kırılgan olan bir şehirdir ve aynı zamanda da bu kırılganlığın üstesinden gelebilmede Avrupa Birliği tarafından en dayanıklı ulaşım türü olarak kabul edilen deniz ulaşımı açısından büyük bir potansiyele sahiptir. Deniz ulaşımı, İstanbul'un kurulduğu yıllardan beri devamlılığını sürdüren yegane ulaşım şeklidir. Deniz ulaşımı İstanbul için bir kültürdür. Bir ulaşım şekli olmasının yanı sıra bir aktivite aracı ve şehrin dinamizmi içerisinde rahatlamanın bir yolu olarak da görülmektedir.

Bu kapsamda, İstanbul bu tez kapsamında vaka alanı olarak seçilmiştir ve İstanbul'da deniz ulaşımının dayanıklılığının rolünü anlamayı ve çevresel yükleri azaltmayı hedef alan bu çalışma literatür taraması temeline dayalıdır. Çalışma, kıyı alanlarında deniz ulaşımının iklim değişikliği ile mücadelede ne gibi imkanlar sunabileceğini, bu imkanlar doğrultusunda ulaşım sistemlerinin dayanıklılığına katkısını ve rolünü araştırmaktadır. Araştırma kapsamında tamamlayıcı yöntem olarak bir çoklu karar verme yöntemi olan analitik hiyerarşi süreci kullanılmıştır. Analitik hiyerarşi süreci kapsamında İstanbul Büyükşehir Belediyesi ve akademiden toplamda dokuz adet uzman ile bir anket çalışması gerçekleştirilmiştir. Bu anket çalışmasında uzmanların İstanbul'da deniz ulaşımının dayanıklığının rolünü anlamadaki ana ve alt kriterler arasında önceliklendirme yapması beklenmiştir. Yapılan önceliklendirme doğrultusunda İstanbul'da kullanılmak üzere bir yol haritası öne sürülmüştür. Bu yol haritasında yer verilen eylemler üst ölçekli olup İstanbul Büyükşehir Belediyesi ve Birleşmiş Milletler'in taahhütleri doğrultusunda zaman aralığı kısa dönem için 2024, orta vade için 2030 ve uzun vade için 2050 olarak belirlenmiştir. Ancak, eylem planının detaylı bir şekilde çıkartılması önerilmiş ve yapılan önceliklendirme

doğrultusunda bu eylemlerin zamansal sıralamasının tekrar gözden geçirilmesi gerektiği vurgulanmıştır.

Yapılan anket çalışmasında elde edilen sonuçların İstanbul için uygulanabilir olup olmadığını ve uzmanların kendi görüşleri içerisindeki tutarlılıklarını analiz etmek amacıyla bazı istatistiki hesaplamalar gerçekleştirilmiştir. Bu hesaplamalar doğrultusunda uzmanlar tarafından dördüncü sırada önemli görülmesine rağmen tedariklilik (redundany), İstanbul'da deniz ulaşımının dayanıklılığı konusunda irdelenmemesi gereken bir parametre olarak çıkmıştır. Bununla birlikte, dirençlilik (robustness) ise en yüksek önem arz eden ana kriter olmuştur.

Öte yandan, anket çalışması esnasında uzmanlardan ilgili alt kriterlerin gerçekleştirilmesinde rol oynayacak potansiyel paydaşlara yer vermeleri istenmiştir. Bu bölüm anket çalışmasında opsiyonel olarak bırakılmakla beraber pek çok uzman tarafından doldurulan bir bölüm olmuştur. Bu anlamda İstanbul Büyükşehir Belediyesi, sürecin ana aktörlerinden biri olarak belirtilmiştir. Ancak tüm ulaşım türlerinin işletimi İstanbul Büyükşehir Belediyesi bünyesinde olmadığı için Ulaştırma ve Altyapı Bakanlığı da yol haritasına dahil edilmiştir. Ayrıca, Ulaşım Koordinasyon Merkezi (UKOME), ulaştırma ile ilgili karar alma süreçlerinde yetkilidir. Bu nedenle Ulaşım Koordinasyon Merkezi'nin katılımı olmadan bir yol haritası tasarlamak mümkün değildir. Öte yandan akademi, kamu yönetimi, sivil toplum kuruluşları, bakanlıklar, ulaştırma operatörleri ve meslek odaları da yol haritasına dahil edilmiştir. Detaylı güç-çıkar ilişkilerinden oluşan paydaş haritalaması ileriki çalışmalarda yapılacaktır. Belirlenen aktörler, önceliklendirme olmaksızın sadece sektörleri temsil etmektedir. Tabloya dahil edilmemesine rağmen, süreç boyunca halkın katılımı esastır. Diğer bir deyişle, halkın katılımı tüm yol haritasını kapsamaktadır.

Özetle, bu araştırma sadece üzerinde çalışılması gereken temel alanlara işaret etmektedir ve dayanıklılığın, daha geniş anlamda iklim değişikliğinin ihmal edilen yönlerini ortaya koymaktadır. Yalnızca tek bir parametreyi düşünerek iklim değişikliği ile başa çıkmak mümkün değildir. Hepsi birbiriyle bağlantılıdır ve bir bütün olarak, entegre şekilde değerlendirilmelidir. Aksi takdirde aynı sürdürülebilirlik gibi başarısızlıklar ile karşılaşılacak ve iklim değişikliğinin halihazırda yaşanan ağır sonuçları aşılamayacaktır. Kısacası, bu tez çevresel kaygılara ve kentsel hareketliliğe odaklanmaktadır ve deniz ulaşımı perspektifinden kentsel hareketliliğin ve çevresel kaygıların önemini ve ilişkisini vurgulayarak gelecekteki çalışmalar için bir temel oluşturmayı amaçlamaktadır.

1. INTRODUCTION

Sustainability is defined as long-term actions taken for the continuity of systems (Benson & Craig, 2014). According to Agyeman & Evans, sustainability is “the need to ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosysytems” (Agyeman & Evans, 2003, p. 36). With the concept, it has aimed to tackle global warming and ensure equity. Therefore, after the Rio Declaration, sustainability has adopted globally, and global warming has gained importance (Moore & Rees, 2013). Then, sustainability has been integrated into the decision-making processes to deal with the environmental burdens (Ravazzoli & Torricelli, 2017). Some of the integrated sustainability goals were expecting a lot than possible (Benson & Craig, 2014). Therefore, it could not provide the desired percentage of change in behaviours. Thus, a rapid increase in consumptions, unplanned urbanisation, insufficient infrastructures, pandemics, and epidemics have made the situation more difficult and did not pave the way for sustainability. It has emphasised that "...sustainability is not a bad idea" (Benson & Craig, 2014, p. 779), but a failed concept that left behind the idea of what to sustain. Consequently, the need for adaptation and transition of cities has emerged (Resilient Cities Network, n.d.). Thereby, sustainability has lost its significance, and ‘resilience’, a derived concept from sustainability, has emerged (Benson & Craig, 2014).

Resilience stands on sustainability’s idea of having the capacity to balancing the Earth. In other words, the term resilience is described as humanity’s, communities’ or cities’ capacity of adapting, sustaining, surviving, and developing in any kind of shocks and stresses (Carpenter, Walker, Anderies, & Abel, 2001). The idea has been adopted by many planners and policy-makers. With the appearance of the Covid-19 Pandemic, the concept of resilience has acquired one more dimension called the pandemic-resilience. Although in this thesis's scope, the idea of resilience has not been analysed in-depth, the thesis has touched upon the climate resilience.

Along with resilience makes ground, once again, it has unfolded that we consume the World much more than we need, and it already has started to react (Sheth, Sethia, &

Srinivas, 2011). Moreover, those reactions could be even more challenging than our burdens to the environment. We, as humanity, day by day, have put quite a lot of load on the environment (ibid). The reason is that cities are human-dominated ecosystems that consist of climate, energy flow, communities, mobility and other systems that existed in order to fulfil people's living needs (Alberti, 2008). Thereby, the city ecosystems are connected to one another and kept alive by mobility. Humans meet their basic needs via urban mobility. Urban mobility is an unavoidable consumption that reflects people's relations with time and space, which shapes our lives, and drives the city's dynamics (Beyazit, 2013). Within this structure, urban mobility and transport have placed at the top because of being a derived demand for individuals to meet their living needs (Banister, 2008). Therefore, it would not be possible to sustain the World and our lives without changing habits and eliminating environmental burdens. Unfortunately, changing a habit is a very tough issue. Creating awareness and changing perceptions are inadequate for the desired percentage of elimination for the burdens. However, it has been seen that with enforcements and outsource effects, people constrain to change (Mckinsey & Company, 2020). At this point, with regard to the concept of resilience, to be able to change habits, as the infrastructure & environmental dimension of resilience emphasises, more public spaces and fewer roadways could be one of the permanent solutions and supporting ideas (The Rockefeller Foundation; ARUP, 2015).

Public spaces are part of urban mobility patterns (Ravazzoli & Torricelli, 2017). Both terms are interrelated and feed each other (Tranter, 2010). Therefore, since mobility is a social activity, public space means social cohesion and interaction, relaxation, pedestrians and cyclists, liveability, physical and mental health, fresh air, safety, and so forth (Bertolini, 2020). However, the presence of pandemic made us aware that current public spaces are inadequate to let all citizens take a breath during lockdowns. Additionally, the green spaces per person in Istanbul is much less than the standards (Cengiz, Atmiş, & Görmüş, 2019), and parking lots and roadways have occupied a great deal of the land. More roads and parking lots mean increased car dependency and ownership (Börjesson, Hamilton, Näsman, & Papaix, 2015; Naess, Mogridge, & Sandberg, 2001).

Furthermore, globally, roadway transportation emits 82% of the transport's greenhouse gas emissions and around 20% of the European Union's (EU) greenhouse

gas emissions (European Environment Agency, 2018). Although they are a reason for climate change, transportation systems are one of the most vulnerable systems affected by the climate. Since the outcomes of climate change occur unpredictably, its effects are also being damaging. By being the backbone of cities, transportation systems should be resistant to these events, even when they are unforeseeable. Therefore, the term transport resilience comes into prominence.

According to the risk analysis, in Istanbul, it could be seen that most of the roads will be blocked off in the situation of an earthquake or other natural disasters (Bakioğlu & Karaman, 2018). All information above-mentioned concluding that to ensure resilience, the transportation system must not rely on just one backbone - including public transportation. Since the solution is not just cleaner vehicles but also fewer vehicles, the share of other modes should be increased, and dependency on the roadways should be decreased by alternatives. In a sense, what's needed is alternative mobility patterns to follow up instead of roadway transportation.

In the perspective of the above-mentioned facts, with 647 km coastal length (Turkish Marine Research Foundation, 2016) and 109 piers (IMM, 2019b), Istanbul has great potential in water-based public transportation to relieve the ridership of roadway transportation and to reduce environmental burdens. In Istanbul, every year, around 40 million passengers use water-based public transportation on 22 different routes (Sehir Hatlari, n.d.), and water-based transportation is a form of transportation that has existed since the city was first established (Istanbul Planning Agency, 2020). Therefore, it is easier to encourage more people to prefer water-based public transportation. This potential is also based on historical value, feelings of relaxation, fresh air, and the possibility to reduce pollution due to transportation.

1.1 Purpose of Thesis

Climate change is defined as unseasonable changes in the temperature (Schuldt, Konrath, & Schwarz, 2011) and causes a change in the density of gases in the atmosphere. In accordance with United Nations Framework Convention on Climate Change (UNFCCC), climate change is defined as the alteration in the climate different from the natural flow regarding human activities that causes environmental burdens (UN, 1992). It has not the same meaning as global warming. Therefore, the term climate change, which has used to express the climate's current situation, is called

human-induced climate change and is identified as the most significant challenge that humankind has ever seen (Roberts, 2016). In addition, the concept is rather used as climate resilience in order to be discussed at the urbanisation scale. In short, climate change is a hot topic that needs to be addressed urgently.

On the other side, urban mobility and transport occur due to human activities (Banister, 2007). Since human behaviours shape urban mobility and transport, they are both the cause and the solution to climate change. More thoroughly, urban mobility and transport are among the leading reasons for the high carbon footprint (European Environment Agency, 2018). Even if people don't purchase anything during the day, they continue to consume while travelling. Therefore, by reducing consumption or changing the type, the carbon footprint could be diminished, and climate change could be tackled.

In line with the above-mentioned information, if climate change, urban mobility and transport are combined and evaluated as a whole, the way out could be seen as resilience, especially climate and transport resilience. A transportation system could be resilient only by providing power balance in all transportation modes. In other words, in the direction of the concept of climate resilience, public transportation must be interchangeable. (The Rockefeller Foundation; ARUP, 2016a). Therefore, a more capillary structure that supports each other should be created. In this context, in coastal cities, water-based public transportation has the great potential of being at the core of future mobility cultures by being connected. Contrary to most public transportation modes, water-based public transportation could be more climate-resilient by reducing pollution, providing fresh air, and making feel relaxed (Bali, 2021). Within this framework, Istanbul, a coastal city that connects two continents and uses the water for transportation since it was established, has a substantial opportunity to create better integration and capillarity. Accordingly, providing a roadmap has been aimed to bring water-based public transportation into the forefront in Istanbul.

To sum up, as mentioned above, this thesis has been developed within the framework of 'climate resilience', which has gained importance in recent years and is considered an essential component of transportation systems. Therefore, the thesis aims to understand the role of water-based public transport in Istanbul to increase the resilience of transportation systems and decrease the burdens of environmental issues. More thoroughly, it has targeted to determine a roadmap to contribute to the resilience of

public transportation by encouraging the usage and bringing into prominence water-based public transportation in Istanbul. Correspondingly, by the roadmap, it has been sought to address environmental burdens and reduce the carbon footprint. In the direction of the aim, it has predicted that the roadmap will contribute to the total resilience of the transportation systems. Moreover, it has thought that the study will be a base for future studies by emphasising the importance and association of mobility and environmental concerns.

1.2 Scope of the Thesis

In recent years, global warming and climate change raised quite rapidly and became an irreversible problem all around the World. As days pass, they have gained a significant seat in our lives. Yet, in this context, what has neglected is that the environment is not just a landscape. It has few many meanings. Life goes on by the existence of the environment. Cities come into being within the environment and have been planned according to the environment. On the strength of this interrelatedness, the environment has exploited by humanity. There is plenty of reasons that explain this exploitation, and they are still causing rapid growth of those environmental issues. As being at the core of daily life, the transportation sector has a significant share in this situation. Therefore, decreasing the environmental burdens due to transportation is included in the scope of the thesis. Ensuring a climate-resilient transportation system, encouraging the usage and increasing the importance of water-based public transportation by a defined roadmap is also involved within the scope.

The terms of the conceptual framework that the thesis was built around are correlated according to their contribution, description and confliction between each other – see Figure 1.1 below. Since the main goal is to increase usage and importance, water-based public transportation has placed at the core. Climate change and environmental concerns contribute to it, respectively, by resiliency and reduction. The increase in ridership will smooth the way for achieving climate resilience. Therefore, environmental burdens and environmental concerns will be decreased.

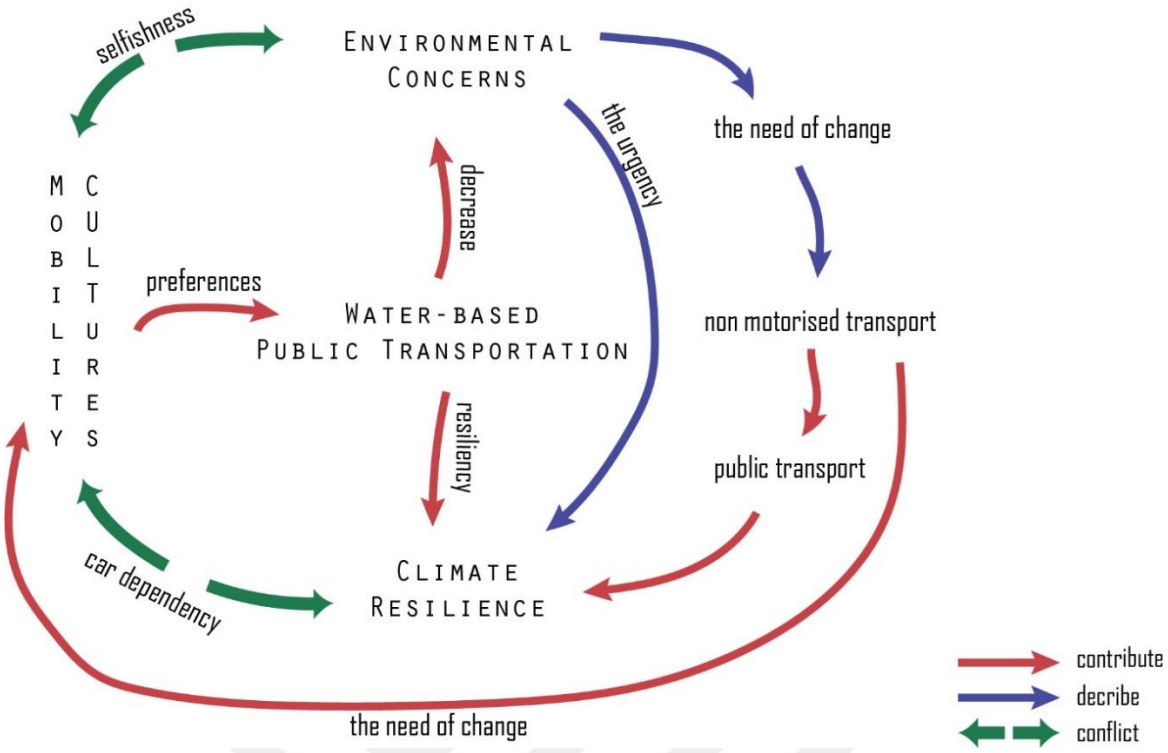


Figure 1.1 : The Conceptual Framework.

Moreover, mobility cultures may influence preferences to change (Cresswell, 2011) in the direction of water-based public transport and facilitate to reach climate resilience. However, since most of the mobility cultures are car-oriented, a conflict occurs. As opposed to car-oriented mobility, the main idea of resilience includes non-motorised transportation. In this context, a need for change come off to provide resilience. Moreover, not having a desire to go out of our comfort zone reveals another conflict between mobility cultures and environmental concerns. Those concerns explain the need for change in mobility cultures and also the urgency of climate resilience.

In addition to the conceptual framework, the thesis has built around a hypothesis: *water-based public transportation is one of the most resilient ways of transport in terms of climate change*.

1.3 Research Questions

Istanbul is a unique coastal city that brings together two continents: Asia and Europe. Thereby, Istanbul has a substantial potential for water-based public transportation. Through this opportunity, contrary to popular opinion, the sea constitutes a strong alternative for the transportation system, not only joy. Therefore, within the scope, to clearly put forward the potentials of water-based public transport, the question of ***to***

what extent water-based public transport may provide opportunities to tackle climate change in coastal cities will be answered.

Ensuring resilience only within water-based public transportation cannot be the solution to reduce environmental burdens. Resilience should be provided holistically. Thus, to see the big picture and understand the role of water-based public transportation therewithin, the answer to ***how far water-based public transportation could contribute to transportation systems' resilience*** is essential.

As Istanbul is the case study area, the ongoing processes about climate change within the city are crucial. In this context, in line with the thesis, ***the role of water-based public transportation in Istanbul's adaptation and mitigation plans*** will be discovered, and **s*patial policies to be developed to promote water-based public transportation*** will be indicated.

Along with the theoretical study, the evaluation of the field study findings and inferences of the analytic hierarchy process-oriented questionnaire will answer the research questions. These responses will be presented in the form of the roadmap, as mentioned above.

1.4 Methodology

"Logic will get you from A to B. Imagination will take you everywhere."

Albert Einstein

The thesis's conceptual and methodological approach has influenced by one of Einstein's statements mentioned above. Therefore, it has aimed to think outside the box. As a result, as the topic is worth discussing, it was intended to conduct the study without traditional approaches as much as possible. Accordingly, the mixed-method approach has carried out in line with the thesis, including the literature review, the case study, and the multi-criteria analytical hierarchy process.

First and foremost, inevitably, in order to have an in-depth understanding of the topics before embarking on the research, a literature review is needed (Race, 2008). Literature review systematically gathers findings from recent and former studies about related topics. Therefore, it has defined as the power of theory development. "By integrating findings and perspectives from many empirical findings, a literature review can address research questions with a power that no single study has." (Snyder, 2019,

p. 333). In this context, in this thesis, the literature review is the basis of the study to address the research's main issue, more than the comprehension of topics. The findings of the literature will directly impact the roadmap and the consequences of the thesis. Furthermore, for the literature review section, some keywords were chosen to be analysed in the direction of the conceptual framework. It has intended to understand the relationship between the keywords that have chosen to form the conceptual framework.

As opposed to the opinion, during the literature review, some obstacles have arisen. As discussed in the waterborne transportation section (2.2.4.), few terms express the transportation system done by water in the literature. However, they mainly refer to the freight shipment. Therefore, having no consensus about the terminology inconvenienced the study and created a need for proposing a new term that will only bring to mind the passenger type of water transportation: "Water-based public transportation".

On the other hand, when human and their perceptions are studied, interpretive and naturalistic approaches are needed, which means qualitative methods (Alvesson & Sköldberg, 2009). In this circumstance, compatible with the aim of the thesis, to address the further research questions, the case study approach is selected. The case study is preferred as a method "…in situations when (1) the main research questions are "how" or "why" questions; (2) a researcher has a little or no control over behavioural events; and (3) the focus of the study is a contemporary (as opposed to entirely historical) phenomenon." (Yin, 2013, p. 2). Furthermore, the case study approach lets researchers sustain individual life cycles' valuable characteristics and is an empirical investigation (ibid). In line with the research, it has intended to see 'how' humans follow a pattern in 'which' directions and 'why'.

With its great potential for water-based public transportation, Istanbul has been chosen as the case study area. The case study covers only inner-city transportation, and the analytic hierarchy process is placed at the core of the study. Apart from the analytic hierarchy process, in line with the case study, ridership data has been analysed. The situation of pre-and during Covid-19 has been compared according to Istanbul Statistical Office's data.

As this thesis focuses on urban mobility, Covid-19 has had a significant impact on data collection and study design. At the very beginning, to complement the case study, in-person interviews were planned to be conducted. However, due to the pandemic, it has thought that in-person interviews will not be meaningful and safe. Alternatively and more complementary, in the direction of the analytic hierarchy process, a questionnaire has been carried out with experts to understand the essential parameters of the resilience of water-based public transportation in Istanbul.

The analytic hierarchy process is a methodological approach suggested by Thomas L. Saaty in the 1970s (T. L. Saaty, 1977). He has proposed the methodology to facilitate multi-criterion decision-making processes and enable equal judgement for each criterion. The approach gives a chance to shape decisions in a hierarchic structure that indicates the most substantial dimensions (T. L. Saaty, 1990). “The analytic hierarchy process (AHP) includes both the rating and comparison methods.” (T. L. Saaty, 1994, p. 19). In other words, it enables to resolve complicated situations/decisions, compare and rank the importance level of inputs (T. L. Saaty, 1990). On the other hand, the analytic hierarchy process is not the traditional decision-making methodology.

As mentioned above, the analytic hierarchy process includes a questionnaire with experts. The questionnaire was designed according to the multi-criteria approach. The criteria were identified according to the literature. As explained in sections 2.2.5 and 3.3., resilience parameters (The Rockefeller Foundation; ARUP, 2016b), transport resilience (Soltani-sobh, Heaslip, Scarlatos, & Kaisar, 2016), the environmental impacts of transport (Gudmundsson, Hall, Marsden, & Zietsman, 2015; Hickman & Banister, 2014; Neves, 2013), mobility indicators, travel pattern, land-use and leisure mobility effects that discussed by David Banister (Banister, 2005), mobility cultures (Beyazit, 2013; Cresswell, 2011; Jensen, 2009b), sustainable mobility (Banister, 2008; Hickman & Banister, 2014), green mobility (Sustainable Mobility for All, 2017), pandemic resilience (Bryant, Edmond, & Langford, 2020), Raworth's Doughnut (Raworth, 2012), waterborne transport (PIANC, 2008) and planetary boundaries (Rockström et al., 2009) have been examined to identify parameters. On the other hand, to prioritise the parameters, the analytic hierarchy process has a specified scale. The ranking consists of successive odd numbers (1, 3, 5, 7, 9) (T. L. Saaty, 1990). Odd numbers are enumerated, ranging from equal to extreme importance, respectively. However, to express intermediate values (2, 4, 6, 8), successive even numbers are also

included within the methodology. Detailed definitions of the scale are given in Table 1.1 below. The same scale is applied within the scope of the thesis. In accordance with the above-mentioned scale, nine experts from the academy and Istanbul Metropolitan Municipality have evaluated main and subcriteria dyadically.

Table 1.1 : The scale of the analytic hierarchy process (T. L. Saaty, 1994, p. 26).

The intensity of importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

After the statistical evaluation of the analytic hierarchy process, the literature and ridership data have been synthesised. By combining the findings, a roadmap for water-based public transportation has been created to be followed up. The roadmap consists of short term, medium-term and long term recommendations towards the resilience of water-based public transportation in Istanbul. According to European Union's and Istanbul Metropolitan Municipality's visions, the timeline of the roadmap has been determined. Within this scope, the short term is specified as 2024, medium-term is 2030, and the long term recommendations point out to 2050.

2. THE LITERATURE REVIEW: ENVIRONMENTAL CONCERNS, URBAN MOBILITY AND TRANSPORT

Without a doubt, it is not possible to replace our living environment. Day by day, human beings have been worsening the wicked problem. Human-oriented designs, plans and actions enable this deterioration. More specifically, the need for urban mobility and transport have been accelerating the collapse and increase the life-threatening outcomes by the high carbon footprint. The natural environment and human beings are intertwined and co-evolved due to personal demands. Since they are an inseparable whole, the thesis has focused on both. The literature is reviewed in two parts within the aim and scope of the thesis: Environmental concerns and urban mobility and transport.

2.1 Environmental Concerns

The environment, comprehensively, could be described as "where we live, work, and play" (Novotny, 2000, p. 24). Our living environment, without questioning, serves all its possessions to humanity to let communities meet their needs. It never allows to be failed; conversely, it helps to be survived.

The intertwined design of the natural environment possesses different loops. Since those loops interact, harm in any loop affects and has affected one another (Brundtland Comission, 1987). Accordingly, harms have turned into burdens increasingly. Over time, these destructions have been dramatically grown up. Therefore, due to rapid growth, thoughtless and redundant behaviours have revealed, as the phrase is, life-threatening environmental concerns.

Constitutively, after the Industrial Revolution, the destruction of the environment has come forward (Neves, 2013). In addition, Anthropocene Epoch (unofficial geologic time that human activities started to have significant impacts on the Earth) also increased consumption, and humanity has become more selfish, more self-indulgent. Moreover, all those behaviours have caused communities to go beyond planetary

boundaries and overshoot the Earth (Brundtland Comission, 1987). That transgression has brought about life-threatening outcomes, which has no escape.

2.1.1 Climate change

Contrary to popular belief, the climate is not just what we expect about the weather. The climate is the cities that lived in, the shape of living quarters, the work that committed, and the mobility that performed. The climate forms all kinds of balances of the World. While the climate makes the Earth liveable, individuals shape climates with the greenhouse gases that arise due to their behaviour. However, greenhouse gases are beneficial when they are in equilibrium (IPCC, 2014a). Though, this does not mean that increasing the number of greenhouse gases is beneficial.

Throughout history, the climate has not been stable. Climates have changed due to natural reasons. Therefore, the Earth has experienced ice age and drought from time to time (Kurnaz, 2019). The Earth moves with a particular inclination of the axis. However, although this inclination is not always constant, it varies between 21° - 24° and creates differences in the sun rays' angle (IPCC, 2007). Consequently, the rate of absorption and reflection of sunlight changes. That causes differences in the Earth's temperature, which results in changes in climates. However, these changes were never sudden; instead, they occurred within a period to which living beings could adapt.

Even though the last natural climate change ended about 12,000 years ago, over time, due to human behaviour, climatic movements started to be experienced again with an accelerated change (Kurnaz, 2019). This alteration, which started from the Industrial Revolution and continues to be experienced harshly today, is defined as human-induced (anthropogenic) climate change (IPCC, 2014a).

If the starting point of human-induced climate change has enlarged upon, the planet we live in has warmed by the natural greenhouse effect (Neves, 2013). Some of the sun's energy to the Earth is absorbed by the greenhouse gases within the atmosphere, bringing the Earth from -18°C to +14 °C (IPCC, 2014a). Greenhouse gases, such as CO_2 (carbon dioxide), NH_4 (methane) and H_2O (water vapour), are in equilibrium in the atmosphere. However, as above-mentioned, changing consumption habits and behaviours have increased the number of greenhouse gases in the atmosphere.

Thereby, the Earth has risen above its ideal temperature, and then anthropogenic climate change has been begun to occur.

As opposed to natural climate change, human-induced climate change has emerged in a flash (Kurnaz, 2019). The abrupt emergence has caused various alterations, which are problematic issues. Ocean acidification, glacial melting, rise in water level, extreme weather events, unusual temperatures, infectious diseases, migration of illnesses, physical and mental health impacts, societal impacts, and economic impacts are some of those consequences (IPCC, 2014a). Since the amount of carbon dioxide emissions already have been exaggerated, even if releases are entirely avoided, it will still take time to bounce back. In a word, overcoming climate change is not that simple. This complexity has brought about environmental collapse, concerns and social and economic disruption. In this context, cities are both reasons and solutions (Balaban, 2020). Therefore, to achieve non-consumptive and balanced use of the environment, some theoretical frameworks have been developed.

2.1.2 The end of sustainability

We, as human beings, have been increasing our population rapidly day by day. More people mean the need for more food, more water and more spaces to live, therefore, more consumption. Simply, to overcome this situation, the term sustainability has arrived on the scene. More profoundly, to respect the environment, to have just and equal developments while ensuring economic growth, 'sustainable development' was offered by the Brundtland Report (Brundtland Comission, 1987). While sustainability is defined as a fair and better-qualified life within the planetary boundaries in every period of time (Agyeman & Evans, 2003), sustainable development has aimed to deal with ecology, equality, and the economy in the same manner (Brundtland Comission, 1987). As mentioned in the Brundtland Report (1987), there are no separate problems; they are all interlinked and one. Nevertheless, independently of each other, economic growth and better quality of life, or the protection of the living environment are placed at the top of sustainability (Campbell, 1996). In other words, every dimension had not had equal stress on it; therefore, practised sustainability consists of conflicts.

On the other hand, historically, the term has been overused, which has caused changes in its meaning (Moore & Rees, 2013). In the meantime, since we live mobile and love not to go out of our comfort zone, our behaviours become more unsustainable instead

(Hickman & Banister, 2014). People have got pissed off at hearing ‘sustainable’ or ‘sustainability’. Thereby, at least in the academy, it has been thought that sustainability is dead (Benson & Craig, 2014); it has become only a term of green-washing (Moore & Rees, 2013). However, what has been forgotten is, losing its originality and assigning only the meaning of ‘something better for nature’ is not enough to unravel the wicked problem.

2.1.3 Planetary boundaries

As mentioned in the previous section, we increasingly consume the Earth's resources day by day; however, the Earth’s resources remain stable. They do not grow. The Earth is overshot every year earlier than before (Global Footprint Network, n.d.). Therefore, to reveal what should be fulfilled to overcome the overshoot day, the term planetary boundaries are proposed as the reconceptualised version of sustainability (Rockström et al., 2009). The boundaries are suggested according to world resources and liveability. As regards the concept, crossing the boundaries means inevitable changes in the environment. In other words, it indicates what the Earth has undergone. Eleven boundaries are defined; however, two of them are not quantified yet (ibid). While climate change, ocean acidification, change in land use, global freshwater use, and phosphorus cycle have started to be crossed, biodiversity loss and the nitrogen cycle have already exceeded – see Figure 2.1 below.

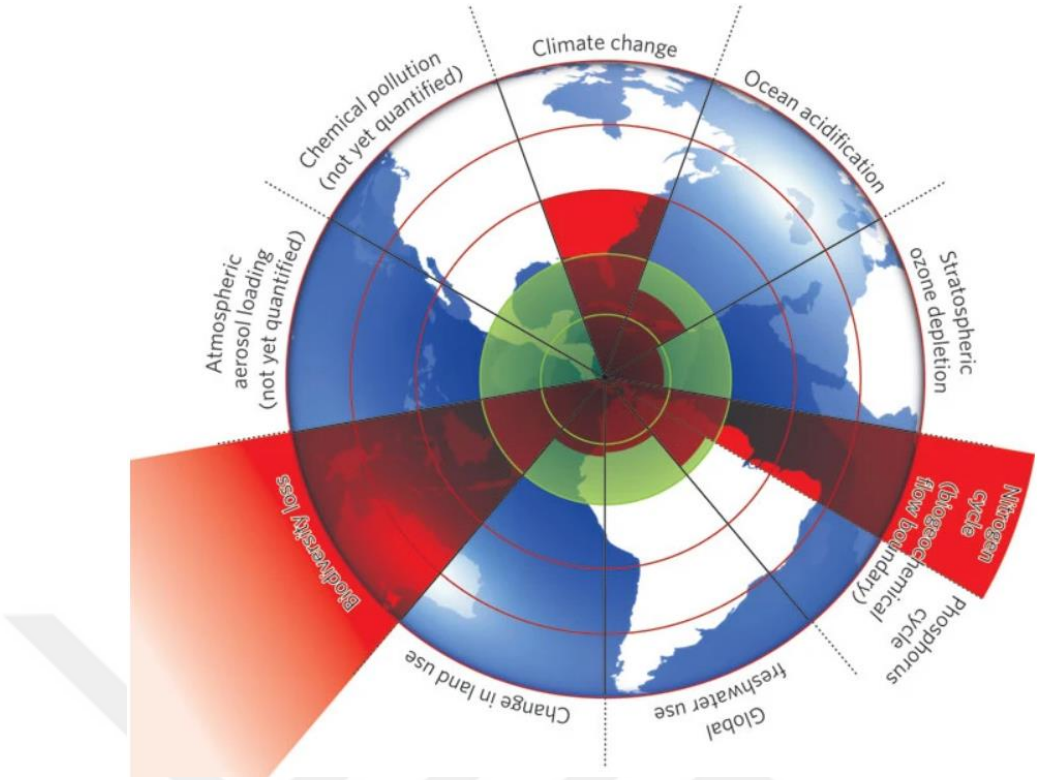


Figure 2.1 : The planetary boundaries (Rockström et al., 2009).

Later on, in 2012, Kate Raworth (2012) has added a social dimension to the concept. Her doughnut-shaped approach has visualised to express sustainability on an environmental and egalitarian scale by integrating with social life (Raworth, 2012). According to Raworth (2017), sustainable development allows humanity to fulfil their needs equally without harming the environment. In other words, sustainability aims to end poverty from an environmental perspective (Raworth, 2017). Therefore, she has identified some boundaries of social issues to indicate what should be conducted to achieve sustainability holistically. The inner circle of the illustration demonstrates vital values that should be fulfilled equally by everyone. On the other hand, the outer-cycle consists of planetary boundaries that should not be exceeded for a living environment, which directly come from Rockström's concept. As can be seen in Figure 2.2, below, in between two boundaries "the safe and just space for humanity" is situated (Raworth, 2012, p. 4).

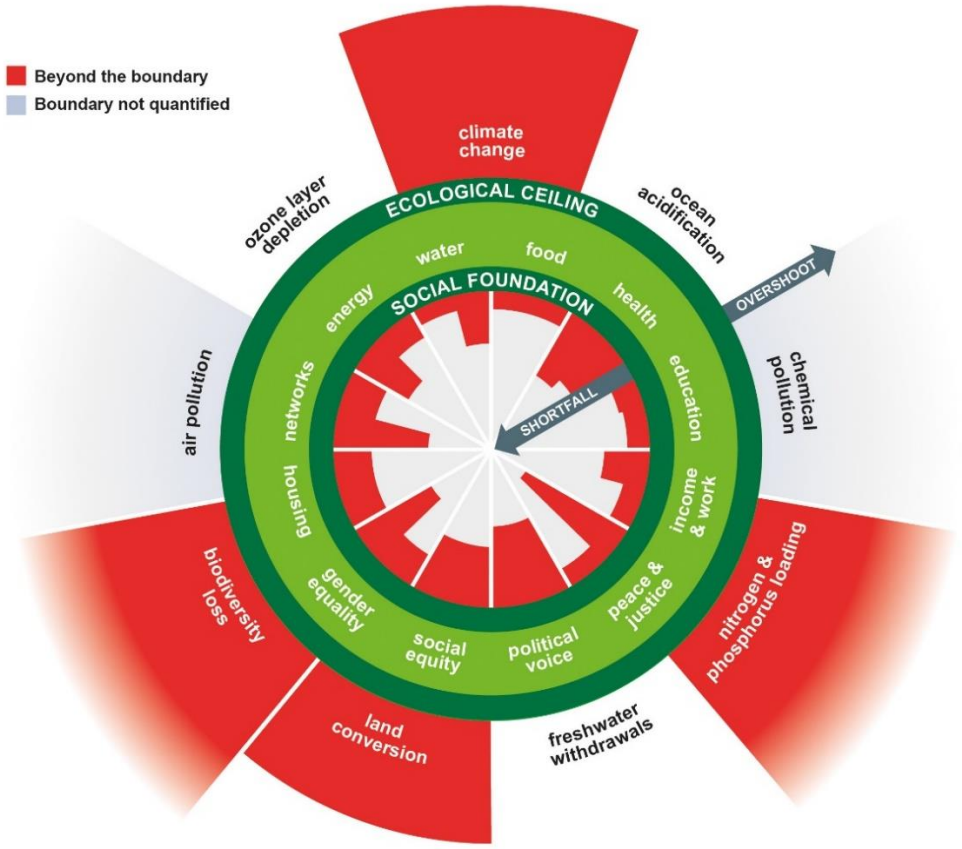


Figure 2.2 : A safe and just space for humanity to thrive in & shortfalls and overshoot in the Doughnut (Raworth, 2017).

Combining social and environmental dimensions demonstrates that humanity's ability to survive is contingent on the Earth's systems, and there is mutual affinity. Moreover, burdens on the environment cause unequal shortfalls in social systems – see Figure 2.2 above. Unfortunately, the Earth does not have a polluter pays system. Those shortfalls mainly occur in vulnerable groups. In this context, to sustain the Earth and humanity, a holistic approach is required. Besides, both environmental and social dimensions should be considered equally.

2.1.4 The term of resilience

As Crawford Stanley Holling (1973) mentions, due to environmental problems, "individuals die, populations disappear, and species become extinct" unexpectedly and irreversibly (Holling, 1973, p. 1). The Earth has a distinctive structure. The ecological systems operate self-sufficiently. However, self-government does not mean not being affected by outsources. On the contrary, naturally, Earth is intensely affected by human interferences (Berkes, Colding, & Folke, 2002). Moreover, external interventions

cause unexpected, inevitable and harsh outcomes. Exceeding planetary boundaries is the most fateful, tangible and newsworthy example of those outcomes. Therefore, to sustain the Earth, protect the boundaries, and eliminate environmental burdens, the term resilience was proposed as a derived term from sustainability (Davoudi et al., 2012). Resilience has been propounded because of the dead-end of sustainability, its failures.

Though resilience, which has been suggested to be used instead of sustainability, is not a new concept. It is a term that originates from Latin and was firstly used by physicists (Davoudi et al., 2012). Over time, accompanied by the increasing importance of system thinking, resilience has come into play in different disciplines. Then by, notwithstanding that engineering and ecology are interconnected, Holling split the term resilience into engineering and ecological resilience (Holling, 1996). He has described engineering resilience as the capability to bounce and revert back towards natural or social disasters.

On the contrary, ecological resilience refuses the idea of bouncing back into the state of the past and having a constant equilibrium (Holling, 1996). In this context, Holling (1973), who has propounded the term into ecological literature, prefers to stand on the meaning of resilience as the ability of resistance, protection, and the adaptation capacity of the systems. Consequentially, due to contradictoriness in itself, the term has lost its originality and meaning, like sustainability. Therefore, in the current situation, there is no consensus about the meaning of resilience (Benson & Craig, 2014). Some researchers have been handling it from the stresses dimension, some from the shocks dimension, and some differentiate by approaching adaptation, mitigation, protection, absorption, and alteration separately rather than holistically. Thereby, the meaning changes depending on the approach. In details, it is both identified as the change that a system can make or the ability to return to the current state of the past (ibid).

On the other hand, more comprehensively, according to 100 Resilient Cities, “resilience is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and thrive no matter what kinds of chronic stresses and acute shocks they experience.” (Greater London Authority, 2020, p. 9). From a different perspective, resilience is the capacity to reorganise and remain functioning in the course of ongoing changes (Walker, Holling, Carpenter, & Kinzig,

2004). Apart from these, in the general framework, there is a consensus about being resilient is quite beneficial (Davoudi et al., 2012).

Despite the uncertainty, many planners and politicians have adopted resilience, and the term has begun to take place in decision-making processes. Though, there was a lot of concern that it is about to remain in theory, rather like sustainability (Benson & Craig, 2014). Nonetheless, after the appearance of Covid-19, resilience has gained its importance once again. In this sense, being pandemic-resilient has become a subbranch term of resilience. By pandemic resilience, it has aimed to reach healthy communities equally and comprehensively (Bryant et al., 2020). Meanwhile, it has targeted to be prepared for all kinds of unexpected health attacks. The presence of the pandemic has evoked authorities the importance of collaboration and participation globally. Moreover, the impossibility of overcoming climate change without a holistic approach has been emphasised over again (Zaytsev, Hasaneini, & Ruina, 2020).

Climate Resilience

As a human-dominated ecosystem, cities differ from natural ecosystems with parameters such as climate, soil, population, energy flow, and other species (Alberti, 2008). More specifically, cities are social-ecological systems that take form according to the relationship between social life and the built environment (Alberti, 2008; Folke, Biggs, Norström, Reyers, & Rockström, 2016). In other words, cities have been designed according to people's behaviours, demands, cultures, beliefs, and relationships in proportion to communities.

On the other hand, cities have a dual relation between human and ecology. Within cities, social systems affect and interplay with nature (Alberti, 2008). To put it another way, humans and ecological systems have coevolved in the way of creating our living environment. Humans are in touch with nature and vice versa, both embedded in each other. However, the evolution of cities in line with humans has caused challenges. People's demands have never ended, just evolved. Accordingly, cities have started to contain unpredictable developments and evolvements.

Nevertheless, even human demands coevolve with both the natural and built environment, it has become challenging to foresee potential issues due to fuzzy tendencies of people and transitions of systems (Friend & Moench, 2013). Furthermore, climate change has complicated the unpredictability further. It has added

insult to injury. Thereby, new uncertainties and hazardous prospects have come into sight. In this context, as an epitome, indirect risks such as flood, drought, fire, and so on could occur due to changes in the climate (IPCC, 2014a). Those disasters implicitly affect the local economy and, subsequently, the global.

Within this context, since the most prominent external threat has seen as climate change, in line with the thesis, the concept of resilience is approached from a climate change perspective. The purpose of the climate resilience approach is to prepare cities against unforeseen threats and achieve an equitable distribution instead of focusing on a single group or region (Tyler & Moench, 2012). In addition, climate resilience has also targeted to come up with solutions apart from climate adaptation strategies and to go beyond the issue. In other words, climate resilience has become prominent as a different way out of climate change.

The City Resilience Framework

If going back to the beginning, even there is no consensus, a framework has been identified to deal with resilience. More deeply, 'The City Resilience Framework' has been prepared by ARUP under the Rockefeller Foundation's support to contribute to the cities' resilience from a common perspective (The Rockefeller Foundation; ARUP, 2015). The Rockefeller Foundation, which is the pioneer of 100 Resilient Cities to built resilient cities all over the World, is a well-accepted foundation that deals with resilience (The Rockefeller Foundation, n.d.). Their framework has applied by 100 cities and continuing to be applied. As a consequence, the City Resilience Framework has chosen to evaluate within the scope of the thesis. The framework handles resilience holistically and comprehensively, yet, the design gives the possibility to focus on the preferred perspective - in this study from the climate resilience perspective. Thereby, within this scope, the framework is evaluated from the perspective of climate resilience.

As stated in the framework, the framework's general objective is to approach cities by analysing their weaknesses, strengths, threats, and potentials within specified dimensions (The Rockefeller Foundation; ARUP, 2015). The framework, which can be seen in Figure 2.3, consists of four dimensions and each dimension contains three drivers.

Figure 2.3 : The City Resilience Framework (City of Chicago, n.d.).

The framework points out that the dimension of 'health and well-being' is associated with local communities to equally meet basic needs (The Rockefeller Foundation; ARUP, 2016a). In addition to satisfying the needs, it also deals with cities' capabilities to serve people and distribute goods and services equally. Supporting livelihoods and employments, decreasing vulnerability, and ensuring public health services constitutes drivers of the dimension. In a time of crisis, especially the climate crisis, cities are of capital importance to enable health and well-being equally (Alberti, 2008). Therefore, the framework calls attention to this dimension to provide a climate-resilient city.

On the other hand, according to the second dimension, since cities and the natural environment coevolved, the order has been affected by the economic tendencies and behaviours of humans (Alberti, 2008). Thus, the dimension of 'economy and society' has incorporated into the framework. While land use, public spaces, cultural and natural heritage, laws and regulations, togetherness, and social consciousness have been included in the scope, collective identity, social sustainability, and supremacy of law account for the drivers of the second dimension (The Rockefeller Foundation; ARUP, 2016a).

Cities are social-ecological systems that ecosystem services and urban facilities' quality are interlinked (Folke et al., 2016). Thereby, as the framework emphasises, the 'infrastructure and environment' constitutes the core of urban resilience (The Rockefeller Foundation; ARUP, 2016a). It engages in the continuity of systems in terms of any outsourcing and unexpected shocks and stresses. In this sense, transportation systems have also been positioned under the third dimension. The robustness of infrastructure and superstructure have seen as crucial with regards to resilience. Therefore, urban facilities' effectiveness, the durability of transportation systems and infrastructure, and decreasing vulnerability have been identified as drivers.

The last dimension, 'leadership and strategy', has been built around knowledge. "A resilient city learns from the past and takes appropriate action based on evidence." (The Rockefeller Foundation; ARUP, 2016a, p. 189). Within the framework's scope, a weight has been given to equally and just design of operations, inclusive developments and stakeholder engagements to whole processes in building resilience, especially in climate resilience. In this sense, to take appropriate actions, effective leadership and collaborative approach, efficient management, and well-developed strategies and plans have been indicated as essential drivers of the fourth dimension.

It has been pointed out that the framework indicates the areas that strategies must be developed to reach resilience. However, achieving resilience and measuring resilience have been uncoupled. Therefore, under the fourth dimension, as shown in Figure 2.4, seven qualities have been identified to measure cities' resilience (The Rockefeller Foundation; ARUP, 2016c). Accordingly, as could be seen in Figure 2.5, a resilient city should be integrated, inclusive, reflective, resourceful, robust, redundant, and flexible (The Rockefeller Foundation; ARUP, 2016b). In details, to be able to shorten the processes, different systems of cities must be integrated. The *integration* enables the flow of information, receiving feedbacks rapidly and producing solutions. Since every city consists of vulnerable communities who have to make more effort to survive, integration contains social integration as well. Considering vulnerable communities, caring about them and including them in planning processes could decrease their susceptibility - which a city cannot be resilient without achieving social justice. In other words, according to the framework, *inclusiveness* is a must of being resilient (ibid).

Figure 2.4 : CRI goals, indicators, and qualities (The Rockefeller Foundation; ARUP, 2016c).

Cities learn and improve themselves by experiencing. However, those experiments are not always being perceived. Thereby, cities should be *reflective* and *flexible* (The Rockefeller Foundation; ARUP, 2016b). To put it another way, as the framework underlies, a resilient city should have the capability of adapting, mitigating, modifying, evolving, practising and learning to be able to play by ear.

Besides all other indicators, in compliance with the framework, a resilient city should have different types of *resources* to be able to serve the city in a time of crisis (The Rockefeller Foundation; ARUP, 2016b). In order to meet basic needs, adequate resources and substitutes are significant. At this point, our living environment offers limitless resources unless used disrespectfully (Alberti, 2008). It has the capacity of when a resource remains incapable; other resources come into play. However, since people continue to consume, the ability of nature is not enough. Cities should also have the same capacity by engaging with nature without causing harm. To be able to engage, at least the characteristics of cities should be understood, which are the reflection of human characteristics (Holling, 1996). In this sense, the existence of multiple ways and *redundancy* paves the way for capacity building, which enables, in the meantime, *robustness* to provide continuance in case of shocks and stresses (The Rockefeller

Foundation; ARUP, 2016b). Within the scope of the framework, infrastructures and superstructures should be durable and should not be relied only on a single backbone. Even though there is a lot of shoulds to ensure resilience, they all serve the same purpose. They all interlinked, and achieving one of the qualities gives a back to meet others needs.

Figure 2.5 : Resilience qualities (The Rockefeller Foundation & ARUP, 2016).

In conclusion, the climate change that the Earth faces have been worsening swiftly. The situation has been evolving in the direction of human behaviours and releases. Environmental burdens due to climate change are not definite, and constant external challenges that resilience struggles with (Berkes et al., 2002). It is more like a process that is ongoing and ever-evolving. Therefore, the defined dimensions, drivers and qualities should be fulfilled to deal with environmental issues with the minimum amount of damage and the best advantage. In line with the study, the above-mentioned dimensions and qualities have discussed as the roadmap parameters in terms of climate resilience.

2.2 Urban Mobility and Transport

Cities are described as complex systems that have a great variety of circumstances from multiple positions. In this complexity, humans shape cities by their activities to meet their needs or to have a better comfort zone (Alberti, 2008). Within this structure, urban mobility and transport have placed at the top because of being a derived demand for individuals to meet their living needs (Banister, 2008). Urban mobility is an unavoidable consumption that reflects people's relations with time and space, which shapes our lives, and drives the city's dynamics. In this manner, urban mobility is

necessary for many essential activities such as education, socialisation, employment, health, shopping, and so on (Beyazit, 2013).

Under these circumstances, cities and urban mobility are important drivers of anthropogenic climate change due to being dynamics designed to respond to individuals' evolving needs (Gehl, 2010). More profoundly, over time, the human-induced design has been ended up in the inability of ecosystems to serve humans needs prompt to thoughtless mobilities. To exemplify, 60% of worldwide travelled distances occur within cities, and those travels mainly take place for short distances (Balaban, 2020). However, every city provides opportunities to prefer public transportation instead. In this context, it could be concluded that with releasing a different amount of greenhouse gas emissions, each performed urban mobility has burdens on the environment - which needs to be minimised (Beyazit, 2013). In other words, human functions have surpassed ecological functions and that have been causing environmental collapse. In this regard, human-induced environmental destruction has created a need to reorganise mobility cultures and patterns to be followed up.

2.2.1 The followed-up ‘urban’ mobilities

Even if it has been using to refer to urban mobility, mobility, in general, is not only vehicles and humans' movement. The term expresses any demand that creates virtual or physical movements (Larsen, Urry, & Axhausen, 2006). On a global scale, people, products, knowledge, money, diseases, problems, vehicles, resources and so on are on the move (Hickman & Banister, 2014; Sheller & Urry, 2006). Commonly, they all cause social interaction. In this direction, within the literature, the types of mobilities are collected under five categories. Physical travel, physical movement, imaginative travel, virtual travel and communicative travel constitute these categories (Larsen et al., 2006). To put it all in simple terms, physical travel refers to urban mobility; physical movement is the products' journey to their users (Urry, 2002). On the other side, imaginative travel and virtual travel do not take place as apparent as others. They do not cover a distance and are, respectively, notional and internet-based. Lastly, communicative travel is both virtual and physical. It comprises written communications. However, the thesis focuses on urban mobility and transport, which is included in the scope of physical travel.

Urban mobility, or broadly transport, has emerged based on the demands of passengers to move beyond the whereabouts (Gudmundsson et al., 2015). In this context, mobility is "... the systematic movements of people for work and family life, for leisure and pleasure, and for politics and protest." (Sheller & Urry, 2006, p. 208). In accordance with these needs, the type of urban mobility varies. However, necessity is not the only determinant that affects the occurrence of mobility. In the meantime, technological advancements, social norms, economic conditions, land-use, the state of individual health, perceptions, individual perspectives, cultures, geographical position of cities, the current transportation services, and so on affect the way mobilities are performed (Beyazit, 2013; Gudmundsson et al., 2015). At this point, the term *mobility cultures* gain importance to understand communal tendencies.

Mobility Cultures and Patterns

Urban mobility is belonging, feeling, and engaging with the environment (Jensen, 2009a). Those interactions, in other respects, the need to move on from one point to another, occur due to social requirements that are shaped according to living conditions (Banister, 2008). While these needs are being met, the focus is not only on the target. Simultaneously, people are also interested in what will happen until the destination is reached; therefore, the route is determined accordingly (Bertolini, 2020). These effects could be named as the need for social interaction, attractiveness, traffic, financial situation, the matter of time, crowd, aesthetic concerns, urban design, accessibility and availability of transportation systems, policies and regulations (Bertolini & le Clercq, 2003; Beyazit, 2013). From an upper scale, social standards, capabilities, identity, belongingness and cultural values (Jensen, 2009b). Concordantly, Jensen (2009b) emphasises that urban mobilities are more than physical activity; they are cultures. However, they are not constant. Since mobility comes into sight because of our beliefs and behaviours, mobility cultures could change in the course of time due to changes in the above-mentioned determinants (Beyazit, 2013). To exemplify, mobility for redundant leisure instead of meeting vital needs has increased dramatically to enhance the poor quality of life. (Banister, 2005). In the literature, the emergence of leisure mobility has identified in the direction of six effects: Security effect, traffic effect, garden effect, storey effect, rendezvous effect and car-living room effect (ibid). These effects indicate that humans tend to go out due to conditions of their living environment, infrastructure and superstructures, namely the built environment. For

instance, people who live in high rise buildings have more tendencies to go out for leisure to engage with ground level. On the contrary, feeling safer in homes leads to less need for outside leisure activities.

Apart from psychological requirements, mobilities differ regarding the mode of transport that preferred. They could be practised by a vehicle or on foot. Distinctness between modes ends up with different mobility cultures; in other words, different mobility 'codes' (Jensen, 2009b). These codes are actions that represent specific cultures. Rather like mobility, mobility codes are ever-evolving. Primarily, they are learnt by cultural norms, and over time, are coevolved by knowledge and experiences (Beyazit, 2013). Rather like psychological requirements, urban planning also considerably affects those mobility codes, cultures and patterns; therefore, the burden on the environment in terms of travel choices. The understanding of urban planning of governments and laws and regulations on transportation from national and international levels direct people to some constant patterns to follow up (Banister, 2005). Those patterns reveal sustainable or unsustainable behaviours and reflect our relationships with time and space. The design of the followed patterns affects preferability. For instance, a pathway that has commercial on both sides, or housing, or industrial usages, or mixed-use designs influences those preferences.

To sum up, David Banister (2005) has divided the influencing factors of mobility cultures into some indicators to understand cultures better. He has split those factors into land-use and travel pattern effects (Banister, 2005). While the size of residential areas, mixed uses, accessibility to public transportation, land-use arrangements sufficiency, positioning of urban facilities and parking conditions constitute land-use indicators, the indicators of travel patterns are travel distances, mode choices, time, frequency, and energy usage (ibid). Both, directly and indirectly, preferences due to these determinants affect the natural environment. Effects could be in a positive or negative manner. However, at present, they constitute the negative. In order to decrease environmental burdens, the above-mentioned factors have been evaluated as a parameter of the roadmap within the scope of the research.

2.2.2 The environmental impacts of urban mobility: Why should the roadway be abandoned?

In different areas, mobility has different types of positive and negative impacts. However, since the environment is "where we live, work, and play" (Novotny, 2000, p. 24), the negative impact on the environment stands out. Every day, plenty of people are on the move to fulfil their daily needs; to live, work, and play. As mentioned in previous sections, their movements occur within the environment; therefore, mobilities directly correlate with the environment (Jensen, 2009a). This correlation causes burdens on the environment, directly or indirectly (Gudmundsson et al., 2015) and creates challenges to transport planning (Banister, 2004). These burdens are listed in Table 2.1 below.

Table 2.1 : Negative impacts of transportation (adapted from (Gudmundsson et al., 2015; Hickman & Banister, 2014; Neves, 2013)).

Negative environmental impacts due to transportation		
Air pollution	Land take & urban sprawl	Depletion of the ozone
Environmental	Global warming	Noise pollution
Water pollution	Soil erosion	Increased toxic substances
Hydrologic impacts	Visual pollution	Biodiversity loss

Within this scope, the concept of 'carbon footprint' is used to measure environmental costs. Carbon footprint is roughly defined as the expression of greenhouse gases emitted by consumptions that cause global warming in terms of carbon dioxide (Wiedmann & Minx, 2007). In this connection, the carbon footprint of the means of transport is affected by several factors. A high carbon footprint basically occurs due to energy, vehicles, and land (Gudmundsson et al., 2015). If energy is handled more profoundly, vehicles with internal combustion engines and energy sources gain importance. For instance, automobiles use approximately 15% of the energy they receive (Kobayashi, Plotkin, & Ribeiro, 2009). The remaining 85% is released directly to the natural environment without transforming into any other types of energy. Besides, using non-renewable energy affects the released amount of greenhouse gases within this percentage (Banister, 2004).

Moreover, the private vehicles' age, the type of the public transportation mode, their occupancy rate, tyre- and brake-wear and the energy source have negative impacts on our living environment (Hickman & Banister, 2014; Transport for London, 2018). Older vehicles release more gases, more passengers in a vehicle leads to decreased carbon footprint per person, and more tyre- and brake-wear cause more emissions. In short, encouraging roadways, increasing car usage and ownership remarkably raises the number of greenhouse gases in the atmosphere (Bertolini & le Clercq, 2003).

Within this context, the general distinctness of transportation's impacts on the environment could be seen in Table 2.2 below, quantitatively. At this point, private car usage directly comes on the heels of domestic flights with a significant share by increasing emissions (Our World in Data, 2020). However, in total, road transportation has the biggest share, and aviation follows it (Neves, 2013).

Table 2.2 : The carbon footprint of transportation modes (Our World in Data, 2020).

Transportation mode	Released emission per person (gr/km)
Domestic Flight	255
Private Automobile (petrol)	192
Private Automobile (diesel)	171
Taxi	150
Car-ferry	130
Hybrid car	109
Bus	105
Motorcycle	103
E-car	53
Petrol Automobile (4 passengers)	48
Diesel Automobile (4 passengers)	43
National Rail	41
Tram and Light Rail	35
Metro	31
Passenger Ferry	19
International Rail	6

On the other hand, over time, with the development of transportation systems, the increased accessibility of transportation and increased vehicle dependency, the travel distances that humans travelled have got longer, and people have tried to reach further (Hickman & Banister, 2014). This behavioural change has caused an increase in the carbon footprint from transportation gradually. According to the European Green Deal, transportation is the sector with the fastest-growing greenhouse gas emissions (European Commission, 2019). It is responsible for a quarter of the European Union's greenhouse gases (Neves, 2013).

In this direction, to deal with environmental impacts holistically, David Banister (2008) has developed the sustainable mobility paradigm as a way out to the confronted ecological issues. He has aimed to emphasise redundant and thoughtless behaviours and the distances covered as an outcome of those behaviours (Beyazit, 2013). In other words, the sustainable mobility approach focuses on reducing burdens caused by the transportation sector, encouraging mode change and shortening the mobility distances (Banister, 2008). Therefore, within the scope, planners and policy-makers have adopted sustainable mobility policies to reduce the high carbon footprint originating from the transportation sector (Hickman & Banister, 2014). The concept contributes positively to individual and societal health and bridges over to create inclusive solutions to be carbon neutral. In this context, encouraging electric transport, strengthening public transport and creating low-carbon societies in an integrated way are emphasised (Holden, Banister, Gössling, Gilpin, & Linnerud, 2020). However, since electricity is produced from coal in most countries, the transition to electric vehicles alone is not enough (Hickman & Banister, 2014). The environment and its issues should be dealt with broadly (Banister, 2004). Additionally, to succeed in sustainable mobility, supplementary practices are needed, not only policies (Givoni & Banister, 2010).

Apart from the need for practice, despite sustainable mobility policies being adopted, car dependence still holds the stage in journeys because of being approached to sustainability from its economic perspective (Hickman & Banister, 2014) and not changing public attitudes (Banister, 2004). The only change has occurred in the type of fuel, and what is worse, using a car has become like a lifestyle. In addition to these facts, although an increase in carbon dioxide release and worsening climate change is considered the most important of the transportation sector’s effects, other above-

mentioned determinants also affect the quality of life and health at least as much as climate change (Gudmundsson et al., 2015). Indeed, they constitute causing drivers of climate change.

Considering all evaluated information, because the term sustainability is dead and open to external risks, giving its name to newer approaches has been causing suspicion. Therefore, aiming to be resilient instead of being sustainable is thought to be a more meaningful and holistic way within this thesis's scope.

Neglected aspects of transport-related environmental burdens

As being a component of the land, streets are one of the key elements of urban mobility. Streets are public spaces where people live, work, socially interact, have fun, relax and shop (Bertolini, 2020). However, the motor traffic dominated order has been causing the streets to lose their public space identity. Additionally, asphalt-covered and vehicle-oriented street planning has made automobile use more attractive, which has increased carbon footprints and provided an accelerated negative contribution to climate change. In other words, more roads mean more car dependency and, consequently, urban sprawl. In the current situation, around 2% of the land is occupied by the transportation sector, and roadway covers 93% of it (Neves, 2013). Nonetheless, streets are "...not designed for the car, and the space is often used for many different purposes, not just traffic." (Hickman & Banister, 2014, p. 23). Thus, loss in green areas and public spaces have become prominent as another environmental burden associated with transportation.

Furthermore, the environmental impacts of transportation do not occur in its origins; on the contrary, it starts to occur in most vulnerable places. Therefore, they cause environmental injustices. And what is worse, "when environmental problems do not appear to affect the people, who cause them, directly, their high-energy lifestyles are more likely to continue." (Bradley, Gunnarsson-Östling, & Isaksson, 2008, p. 70). Moreover, roadway transportation causes much more crashes, which end up in innocent people's death, than other transportation modes due to speed, congestion, and disrespectful behaviours (Hickman & Banister, 2014). To put it in a different way, roadway and individualism-oriented transportation do not only lead to environmental degradation, decreased quality of life, and redundant land occupancy, but also cause social discrimination and injustices.

In line with all the aforementioned, it is not possible to reduce the necessities of a liveable and sustainable environment to certain indicators (Banister, 2004). More profoundly, the way to reduce environmental costs is not only to put forward non-motorised transport, to limit fossil fuels or replace internal combustion engines (Neves, 2013). Contrary to appearances, the problems faced require more comprehensive approaches, solutions by considering the plenty amount of dimensions, situations and different modes and cultures. In addition, those requirements differ regarding handled scale, such as individual, community, national and international levels. In this sense, it bears repeating that instead of approaching economically, discoursing on the environment, equity and economy holistically is far more crucial. That is to say; the term resilience is needed, therefore, comes into prominence.

2.2.3 The common ground: transport resilience

Transportation is seen as a cornerstone in building resilience due to integrating and addressing social issues, economy, health, and land use simultaneously with a single strategy (100 Resilient Cities, 2017). Additionally, transportation is more open to innovations and technology. However, "…transport can be the 'maker and breaker of cities'." (Hickman & Banister, 2014, p. 5). Therefore, how it is handled gains importance in terms of creating sustainable or unsustainable cities, liveable or unliveable environments. At this point, as explained earlier in the previous parts, the solution is not only to reduce the emissions to create sustainable and liveable environments. Therefore, within the scope of the thesis, a great weight is given to transport resiliency to deal with the aforementioned circumstances.

Transport resilience stands for the durability of the transportation systems in case of any external effects, before, during and after any kind of disasters (Soltani-sobh et al., 2016). It also expresses the ability to weather the storm, manage the crisis and quickness. In this sense, Soltani-soch et al. (2016) draw our attention to the circularity of resilience. They identify that circularity in four parts: Normalcy, breakdown, annealing and recovery. The circularity symbolises the life cycle of a system. In this regard, a resilient transportation system should be able to complete all phases successfully in terms of unexpected situations. Within the scope of the thesis, the life cycle of transport resilience has mainly discoursed from environmental aspects, namely from the climate resilience perspective.

Natural disasters and pandemic

Fundamentally, after Hurricane Katrina, transport resiliency is brought to the agenda globally because of its unpredictable, unfair and fatal outcomes (Amdal & Swigart, 2010). After the disaster, plenty of research has done to analyse the reasons for failures. It had concluded that the evacuation before and during the hurricane was made by buses and non-motorised transportation without integration. Railways were not considered as vehicles of evacuation, and the need for education has underlined within those studies (ibid). Moreover, existing plans were not based upon transit. What is worse, evacuation plans that put transit at the core were not contained vulnerable groups evacuation within those plans. Eventually, the need for integration, inclusiveness, reflectiveness, resourcefulness, robustness, redundancy, and flexibility, i.e. resilience, has been comprehended and emphasised (Amdal & Swigart, 2010; The Rockefeller Foundation; ARUP, 2016b). Nonetheless, even resilience stands for more than disasters; this aspect of the term is the most studied one within the literature.

If Istanbul is examined towards disasters, especially starting from 2018, every passing year is being announced as the year that most extreme weather events have been faced (Anadolu Agency, 2019). In 2020, Turkey was confronted with 984 extraordinary weather events (Anadolu Agency, 2021a), which was 935 the year before (Anadolu Agency, 2020). As a result of these events, for instance, the unusual hail that Istanbul was faced in 2017 has obstructed all kinds of transportation modes (IMM, 2018b). The unexpected hail has seriously affected the built environment, the natural environment and people who have caught on foot. If the encountered challenges are elaborated, the water-based transport and aviation were entirely stopped, a crane was toppled in Haydarpaşa Port and caused fire, roadways and underpass were submerged.

As another example, El Niño and La Niña are southern oscillations that highly affect the weather conditions all over the World (WMO, 2021). El Niño warms up the weather while La Niña cools down. 2020 and 2021 years were announced as La Niña years globally. However, in Turkey, 2020 has recorded as one of the warmest years since 1971, even in La Niña (Anadolu Agency, 2021b). Furthermore, an increase in temperature causes irregularity of precipitation and, therefore, drought (Vision 2050, 2020). Drought leads to disruptions in transportation services, especially by preventing energy and water procurements (Güneralp, Güneralp, & Liu, 2015).

According to the Istanbul Earthquake Workshop report conducted by the Istanbul Metropolitan Municipality and the Istanbul Planning Agency, in the event of a 7.5 magnitude earthquake in Istanbul, it is foreseen that 30% of the existing roads will be blocked off (Istanbul Planning Agency, 2019). In addition to the closure of roads, transportation systems may be interrupted after an earthquake due to vehicle damage, energy cuts, coastal depredations. However, transportation systems and accessibility are of advanced importance for both evacuation, rescue efforts, and other post-disaster studies.

On the other side, during the Covid-19 pandemic, in the direction of Istanbul Statistical Office data, it is possible to say that public transportation ridership is highly decreased, and locals have shifted to private car usage due to the risk of infection (Istanbul Statistical Office, 2020b). In line with all the above-mentioned facts, it could be concluded as Istanbul's public transportation system is not resilient due to any kind of disasters, shocks and stresses. In other words, Istanbul is vulnerable to climate change, and its transportation systems are being significantly affected. Therefore, within the scope of the thesis, apart from the climate resilience approach in transport resilience, pandemic and natural disasters are also significant, especially in the case of Istanbul due to Istanbul's vulnerability to earthquakes and being resulted in the road closure and challenges in transport.

Non-motorised transport

Alongside car dependency has not been prevented with sustainability, there is also not yet a technology that will directly reduce the carbon dioxide emissions originating from transportation (Banister, 2004). The only solutions available seen as to change the type of fuel, remove old vehicles from the market, and find a method that can replace the engine systems of vehicles. However, as mentioned earlier, the way out is not the technology. In this direction, United Nations aims to provide a green mobility approach in order to tackle climate change and ensure resilience (Sustainable Mobility for All, 2017). Within this concept, green mobility seeks to provide climate change mitigation and adaptation, decrease noise and air pollution, and increase physical activity, which constitutes burdens of transportation on the environment, listed in the previous section above in Table 2. These achievements require integration and inclusiveness, which means handling all modes, and considering not only a group of people (ibid). Furthermore, on a global scale, adopting concerted actions are necessary.

Organizing mobility to create liveable environments and enabling different types of transportation, perceiving and arranging roads and urban areas as social spaces are very important in terms of environmental concerns, combating climate change, and green mobility (Timur, 2019). Within the scope, non-motorised travel and public transport come into the forefront. Non-motorised transport, also known as active transport, roughly refers to human-powered transportation for both goods and humans, such as walking, cycling, small-wheeled transport (Litman, 2021). In most countries, walking is the predominant mode of transportation for short distances. In addition, bicycles were being extensively used as well (Yedla, 2015). However, the tendency of speeding up has led to bringing into prominence car usage.

Generally, non-motorised means of transport have been seen as a mode of transportation in rural areas and small cities with low income and used for short distances in developed and developing cities (UN-Habitat, 2013). Nonetheless, its advantages are universal. If the benefits of non-motorised transport are elaborated, minimised carbon footprint and environmental burdens, reduced car ownership and congestion, decreased pollutions, encouraging compact designs, increased user convenience, health and pleasure, and saved costs could be counted. (Litman, 2021; UN-Habitat, 2013). However, especially in multi-centred metropolises, non-motorised transportation alone does not have competitive power (Rietveld, 2000). At this point, their integration with other transportation modes gains importance.

Integrated transport

Integration is an overshadowed term that is also a significant dimension of resilience and constitutes one of the cornerstones of sustainability (Givoni & Banister, 2010). The integration enables different opportunities, different patterns to follow up, which also means flexibility of resilience (Gudmundsson et al., 2015). In this context, multi-component organisations require integration to perform effectively. In other words, transportation systems are multi-component organisms that "...need to be integrated to provide an efficient transport system that serves the transport needs of society at a minimal environmental cost" (Givoni & Banister, 2010, p. 2). Moreover, these components could be grouped under six fields in transport planning. Integration between institutions, different transport modes, urban planning, environment, social issues and prosperity, and infrastructure, service and charging are these groups (Hull,

2005). From the upper scale, substantive, methodological, procedural, institutional and policy integration (Givoni & Banister, 2010).

Integrated transportation systems reduce congestion in the city centre, create multi-centeredness, facilitate access to the city and allow different modes of transport to be dispersed effectively (Mees, Nielson, Stone, & Imran, 2010). In addition, it serves the entire city instead of creating many alternatives on the same route. From the transport resilience perspective, integration is located at the core. Not only crucial as a parameter but also between parameters (The Rockefeller Foundation; ARUP, 2016b). More deeply, in terms of shocks and stresses that cities may face, to be able to bounce back, adapt and remain standing, it is vital to be entirely integrated.

2.2.4 Waterborne transport: green and clean

First and foremost, during the literature review, one of the most challenging situations has occurred while researching the transport system that is done by water. It has seen that within the literature, many terms have been used to express the transport system that is done by water. That variety has caused difficulties, and more investigations had required to clarify them. Water transportation, waterborne transportation, inland waterways, inland navigation, waterway, seaway, sea transportation, marine transportation, maritime transportation, and so forth could be given as examples of those usages. However, in most countries, since the primary goal of water is to transport freight, these terms only recall shipping to mind. In addition, having many terms to express the same transport mode creates both challenges and confusions. Therefore, to gather together all terms, the European Union (EU) has described the transportation mode done by water as ‘Waterborne Transportation’. Nonetheless, the proposed term still does not refer to public transport. According to the specialities of geographies, the main usage changes. Therefore, the term should be separated. In Turkey, especially in Istanbul, water is a tool for public transportation and has a significant share. In this context, within this thesis, it is decided and proposed to use ‘water-based public transportation’ as a term, which is a subbranch of waterborne transportation. Nevertheless, since the section is designed top-down, primarily, waterborne transport is investigated.

Transport has an impact upon daily lives from different directions, e.g. economy, social cohesion, societal and individual health and the environment (PIANC, 2008).

Due to global warming and recent crises, sustainable transport, therefore environmental impacts, have gained more importance. Within this direction, waterborne transport is identified as the less harmful mode. Plenty of studies indicate that, globally, waterborne transport constitutes around 2.7% of anthropogenic greenhouse gas emissions (ibid). Although it is stale data, in order to show the difference between percentages, Figure 2.6, which contains the graph of the data for 2010, is attached below. On the other side, roadway transport covers 20% (European Environment Agency, 2018). In a word, it could be concluded that waterborne transport is more environmentally friendly than other transport systems. Therefore, by the EU, waterborne transport is expressed as the smartest, greenest and safest way of transportation (Waterborne EU, n.d.).

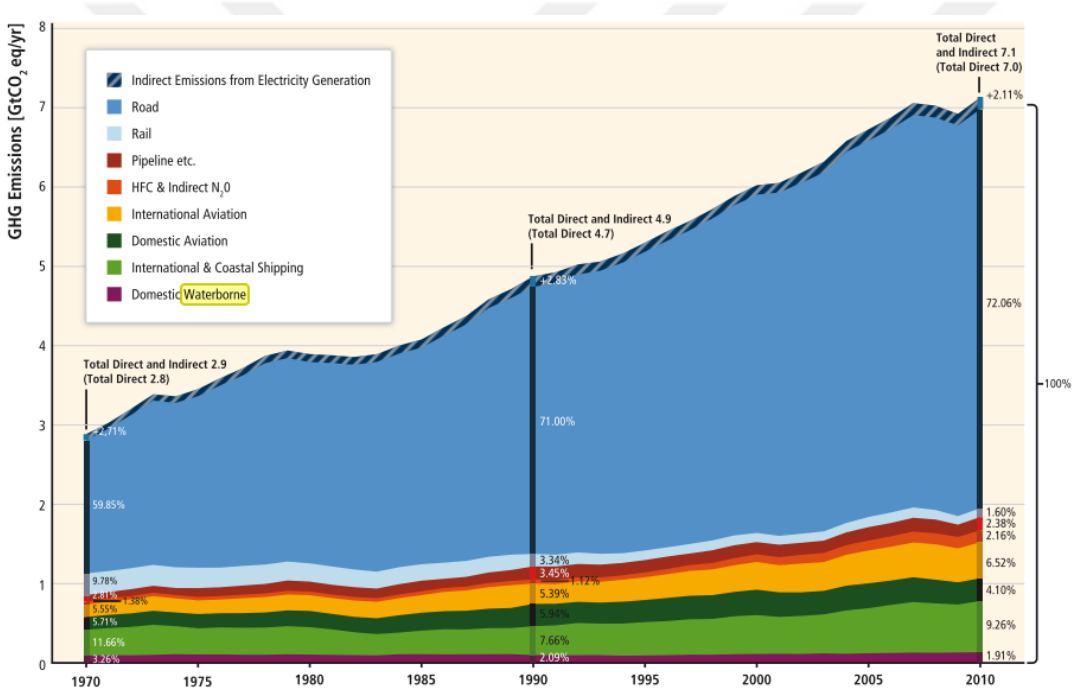


Figure 2.6 : Direct GHG emissions of the transport sector (IPCC, 2014b, p. 606).

In addition to the abovementioned facts, waterborne transport is considerably the most energy-efficient one as opposed to other transport modes (Van den Eede, 2010). It comes to the forefront with its low energy consumption and carbon footprint. Therefore, waterborne transport is described as a relatively climate-friendly mode of transport and an escape way of climate change (PIANC, 2008). Moreover, waterborne transport systems are better adaptable and flexible towards replacing fossil fuels with renewable resources (Gagatsi, Estrup, & Halatsis, 2016). Biofuels, hydrogen, electrification, methanol are some of the more environmentally friendly energy types that could be implemented in waterborne transport (IPCC, 2014b). Within this context,

waterborne transport is a transport mode that inevitably should be integrated with rail, road and non-motorised transport (PIANC, 2008). Besides, increasing the share of waterborne transport and integrating with other modes provide an opportunity to decrease the congestion on the roadway (Van den Eede, 2010). In this sense, IPCC (2014b) suggests a modal shift by displacing roadway through waterborne transport due to its great deal of benefits. Accordingly, the European Union aims to decrease environmental burdens, ensure safer operations, prolong lifecycles and lower down costs, and make innovations in waterborne, by increasing the share of waterborne transport (European Commission, n.d.).

Alongside all benefits, waterborne transport has threats dramatically, mainly due to global warming (Hawkes et al., 2010). Rise in sea levels, tough wind and storm conditions, drastic wave actions, change in coastal hydrodynamics and morphology and sea chemistry, icing and ice melting complicate the carriage, even preclude. However, some researches indicate that due to its potentials, precautions and resiliency, waterborne transport will be the less damaged system by climate change (PIANC, 2008). Furthermore, it has been thought that waterborne transport will be the winner of climate change by remaining standing and increasing its share in overall transportation systems.

Water-based Public Transportation

As abovementioned, water-based public transportation is a subbranch of waterborne transport. The suggested term refers to the public transportation system that is performed by water. The water could be expressed as sea, river, lake, or ocean. By using the natural infrastructure of water, the initial investment unit costs of water-based public transport systems are lower compared to the other modes of transportation (Timur, 2019). This lowness of unit cost is supported by the high passenger capacity of the ferries.

On the other side, water-based public transportation is the safest, cleanest, greenest, and most resilient mode of transport (Meersman et al., 2020; Waterborne EU, n.d.). Even water-based public transportation is sensitive to extreme weather conditions; these effects can also be minimised by technology with low costs (Timur, 2019). Moreover, transferring some load of urban transportation to the sea creates safe, calmy,

peaceful, comfortable, and environmentally friendly options that relieve road transportation (Baykal, 2019).

Coastal cities with suitable locations and geographies have the opportunity to develop water-based transport as a public transport mode and take the abovementioned advantages (Yucel, 2019). More specifically, as referred to in section 3, Istanbul has the great potential to benefit from water-based public transportation.

2.2.5 Parameters associated with the roadmap

In order to determine the essential strategies of the roadmap, first and foremost, all parameters aforementioned in the literature review have been analysed. More profoundly, resilience parameters (The Rockefeller Foundation; ARUP, 2016b), transport resilience (Soltani-sobh et al., 2016), the environmental impacts of transport (Gudmundsson et al., 2015; Hickman & Banister, 2014; Neves, 2013), mobility indicators, travel pattern, land-use and leisure mobility effects that discussed by David Banister (Banister, 2005), mobility cultures (Beyazit, 2013; Cresswell, 2011; Jensen, 2009b), sustainable mobility (Banister, 2008; Hickman & Banister, 2014), green mobility (Sustainable Mobility for All, 2017), pandemic resilience (Bryant et al., 2020), Raworth's Doughnut (Raworth, 2012), waterborne transport (PIANC, 2008) and planetary boundaries (Rockström et al., 2009) have been examined to narrow down parameters and pick the most relevant ones. Accordingly, the first elimination has been done in the direction of the aim of the thesis, and the main problem is identified towards the purpose. Afterwards, within the scope of the thesis, by getting inspired from 100 Resilient Cities and UN-Habitat (The Rockefeller Foundation & ARUP, 2016, 2018; UN-Habitat, 2016), some shocks and stresses that could occur due to global warming, climate change, and other human-induced crises have been identified, to limit the parameters. Then, those shocks and stresses have been grouped, under resilience criteria mentioned in section 2.1.4, by asking, “How we can export resilience considerations to the normal activities of the city?” (UN-Habitat, 2018, p. 45).

If the criteria are elaborated, pandemics and epidemics were added to the seven resilience qualities, and the main criteria were established. As abovementioned, the subcriteria have been identified by evaluating possible shocks and stresses that a city and, more specifically, public transport systems can face. The subcriteria determined

under the main criteria are shown in Figure 2.7 below, and explanations of subcriteria are listed in Table 2.3 below.

	MAIN CRITERIA							
	Flexibility	**Integration**	**Resourcefulness**	**Redundancy**	**Robustness**	**Reflectiveness**	**Inclusiveness**	**Pandemics and Epidemics**
SUB CRITERIA	Unexpected weather conditions	Informing	Low emissions	Frequency of journeys	Urban design	Infrastructure	Equity	The capacity of vehicles
	Urban design	Coordination	Energy efficiency	Accessibility	Infrastructure	Ambience and attractiveness	Fares	Security and safety
	Natural disasters	Urban design	Compatibleness with technology	Infrastructure	Coordination	Compatibleness with technology	Security and safety	Duration of the trip
	Coordination	Accessibility		Coordination	Accessibility		Urban design	Distance of the trip
		Fares						Frequency of journeys
		Continuity						

Figure 2.7 : Subcriteria of parameters.

While unexpected weather conditions refer to the disruptions/problems that may occur in transportation systems due to extraordinary weather events stemming from climate change and global warming, natural disasters represent the problems that may occur in transportation systems because of earthquakes, floods and so on. Since both are unpredictable, public transport systems should be *flexible* to overcome and function properly (Amdal & Swigart, 2010). At this point, urban design and coordination come into prominence. A public transport system could be *flexible* when there is a better connection between different modes and parallel lines (Gudmundsson et al., 2015). Herein, urban design plays a significant role by means of linking up modes.

On the other hand, as opposed to general thought, *integration* is not only linking up multi-components of transport (Givoni & Banister, 2010). It includes both physical and social dimensions. Without informing users about the operation of the public transportation systems, it is not possible to ensure continuity and coordination. However, continuity is more of than connection. It also means intra- and inter-ongoingness of transport modes. Moreover, equal and fair access of all users to public transport systems should be provided for *integration* (The Rockefeller Foundation; ARUP, 2016b). In this sense, the amount that must be paid in order to use the public transport systems makes ground.

Table 2.3 : Definition of subcriteria.

Subcriteria	Definition
Unexpected weather conditions	The disruptions/problems that may occur in transportation systems due to extraordinary weather events stemming from climate change and global warming.

Table 2.3 (continued) : Definition of subcriteria.

Urban design	The impact of city planning on the operation of transportation systems.
Coordination	The connection between transportation systems and parallel
Natural disasters	The problems that may occur in transportation systems because of natural disasters such as earthquakes, floods, etc.
Information	Regularly informing users about the operations
Accessibility	The equal and fair access of all users to public transport
Fares	The amount that must be paid in order to use the public transport systems.
Continuity	The interconnectedness and continuity of public transport
Low emissions	The reduction of greenhouse gas emissions caused by public transport systems.
Energy efficiency	The efficient use of energy required for the operation of public transport systems.
Compatibleness with technology	The adaptation to technological developments for the uninterrupted functioning of public transport systems.
Frequency of journeys	The amount of trips made by public transport modes over a period of time in a day.
Infrastructure	The constructions and investments required for the uninterrupted operation of public transport systems.
Equity	Justice and equity between users.
Security and safety	The sense of confidence or fear that users feel during journeys and when reaching public transport modes.
Ambience and attractiveness	The attractiveness and the emotional state of public transport modes and the routes used to reach them.
The capacity of vehicles	The number of passengers that public transport vehicles can carry at a time.
The duration of the trip	The time for public transport modes to complete the route used.
The distance of the	The distance of the route used by public transport modes.

Transportation, which has one of the most significant shares in causing environmental burdens, brings along high greenhouse gas emissions (European Environment Agency,

2018). This high-order arrive on the scene based on the energy source, efficiency, design of vehicles, and public transport effectiveness. However, on a global scale, greenhouse gas emissions must be decreased immediately to be able to create liveable environments and sustain the Earth (European Commission, 2019). To be able to increase energy efficiency and use renewable resources, technology has a crucial role. More profoundly, public transport systems' ability to adopt those innovations is of prime importance. Being able to adopt different technologies and keeping hold of energy sources are the essential components of resourcefulness.

Moreover, unexpectedness leads to be *redundant*, which means always having backups. Frequency, coordination, accessibility and infrastructures enable creating backups. In other words, if a transport mode is frequent and infrastructures are adequate, it could serve more people in case of shocks and stresses, or trouble in a journey could be easily compensated by a frequent transport mode (The Rockefeller Foundation; ARUP, 2016b). Alternatively, high accessibility to modes and better coordination resolves the problem as well. In addition to *redundancy*, *robust* public transport systems absorb failures by means of well-designed and coordinated layouts with their ports/stops/stations and connections. Urban design, infrastructure, accessibility and urban design have priority and significance under *robustness.*

Cities learn and adapt from past experiences (Bertolini, 2020). The ability to learn and adapt represents the *reflectiveness* of cities and also public transport systems. The need for technology, infrastructures, ambience, and attractiveness – especially for waterborne public transport – reveals according to those experiences. Furthermore, the importance of feeling safe and secure, having just and equal access to transport modes, affordable fares and the effect of urban design comes from experiences as well, which also brings along *inclusiveness* (European Environment Agency, 2021). To quantify *inclusiveness* is tougher; however, since a public transport system cannot be entirely resilient without *inclusiveness*, it should not be neglected.

When it comes to *pandemics and epidemics*, users tend to prefer private and safeguarded travelling due to contamination risks (Bryant et al., 2020). Since social distance gains importance, the capacity and also the design of vehicles come forward. If the vehicle lets users keep the distance, the mode becomes resilient from the point of *pandemics and epidemics*. Moreover, users consider the duration of the trip and the distance of the route used by public transport modes. In addition, in the case of the

crowd, attention is paid to the frequency of journeys, which expresses the number of trips made by public transport modes over a period of time in a day.

To sum up, under the seven qualities of resilience, nineteen subcriteria have been identified to deeply understand the role of water-based public transport within the overall resiliency of public transport systems and how to increase its share, which could be seen in Table 2.4 below.

Table 2.4 : Subcriteria and related main criteria.

Subcriteria	Robustness	Integration	Inclusiveness	Redundancy	Pandemics & Epidemics	Resourcefulness	Flexibility	Reflectiveness
Infrastructure	√			√				√
Security & safety			√		√			
Coordination	√	√		√			√	
Continuity		√						
Accessibility	√	√		√				
Equity			√					
Fares		√	√					
Energy efficiency						√		
Urban design	√	√	√				√	
Natural disasters							√	
Duration of the trip					√			
Compatibleness with technology						√		√
Ambience & attractiveness								√
Frequency of journeys				√	√			
Unexpected weather conditions							√	
The capacity of vessels					√			
Distance of the trip					√			
Information		√						
Low emissions						√		

3. THE CASE STUDY: ISTANBUL

"If the Earth were a single state, Istanbul would be its capital."
Napoléon Bonaparte

The transportation sector is one of the leading reasons for the high carbon footprint, one of the most affected sectors of environmental burdens, and could be a solution to unravel the wicked problem. According to Istanbul Greenhouse Gas Emissions Inventory Report (2019), in 2015, around 28% of greenhouse gas emissions in Istanbul were emitted by the transportation sector. Within this ratio, water-based public transport, railways, and roadway cause 0,2%, 0,3%, and 27,6%, respectively (IMM, 2019c). Aviation is not included in the calculation. Apart from transportation's emissions, the energy sector has caused an additional 41%, as well (ibid). On the other hand, in line with the Istanbul Climate Change Action Plan Final Report (2018), until the projection year 2100, Istanbul could face a 1 to 4.5ºC increase in temperatures, a 12% decrease in precipitation, and an increase of up to 75 cm in sea levels (IMM, 2018b).

In substance, Istanbul, which is the only metropolis in the world that connects two continents, is facing and will face challenges in the near future. However, as like most cities, with its unique historical value, landscape, and geographic position, Istanbul is one of the cities that immediately needs to take action against crises and be entirely resilient. Istanbul is defined as an "outstanding universal value" by UNESCO (UNESCO, n.d.). In line with all these and as an Istanbulite, Istanbul is chosen as the case area within the scope of the thesis.

3.1 The Current Situation of Istanbul's Public Transport System and Plans

Istanbul Metropolitan Municipality provides public services for 15.46 million people in 39 districts (TURKSTAT, 2021a). By this population under pandemic conditions, in 2020, a total of 1.3 billion trips was made via public transport systems across Istanbul (Istanbul Statistical Office, 2021b). In the first three months of 2021, this value is calculated as approximately 300 million, with a 200 million decrease

compared to the previous year (Istanbul Statistical Office, 2021a). When the ridership in 2020 in terms of public transport is examined, it is seen that the shares of water-based public transport, Marmaray[1], Metrobus (BRT), metro/tram and bus are 3.2%, 6.5%, 12.9%, 28.9% and 48.5%, respectively (Istanbul Statistical Office, 2021b). For the first three months of 2021, the same data is calculated as 2.5%, 6.6%, 13.5%, 30.7% and 46.8%, respectively (Istanbul Statistical Office, 2021a, 2021c). In line with these statistics, it is possible to say that, even in public transportation, the most share is in roadways.

Rail transport

Rail transport is the backbone of Istanbul's public transportation system, by constituting metro, Marmaray, tram, light rail train, funicular and cable car (Canitez, Alpkokin, & Kiremitci, 2020). Marmaray has the deepest immersed tube tunnel in the world used by rail systems with a depth of 60.46 meters (Marmaray, n.d.). The system, which has a line length of 76 kilometres, has come into service in 2013 and consists of 43 stations. In addition to Marmaray, Istanbul currently has five tram routes, three funicular lines, two cable car lines and eight metro lines (IMM, 2019b).

As a development, Istanbul Metropolitan Municipality aims to increase the share of the metro even more and have investments accordingly (IMM, 2019a). More profoundly, the Istanbul metro has a 260 km operation length as of 2021 (Metro Istanbul, 2021b). By the end of 2024, Istanbul Metropolitan Municipality aims to add 164 km to the existing system and reach 424 km of access area (Metro Istanbul, 2021a). By the end of 2029, this target is 623 km. Moreover, since the end of August 2019, night rides are started to be operated in the underground as further enhancements. These trips are being performed on six routes and 78 stations and are integrated with eight bus lines (Metro Istanbul, 2019). Night rides are applied between 00.00 and 06.00, and the frequency of the trips is 20 minutes.

[1] Marmaray is a suburban train system serving in Istanbul. The system has been implemented with the construction of the Marmaray Tunnel under the Bosphorus and the modernization of the existing suburban lines between Halkalı Train Station on the European Side and Gebze Train Station on the Anatolian Side. (Marmaray, n.d.)

Road transport

The roadways have a share of approximately 84% in Istanbul's transportation, by including private automobiles, buses, the Metrobus (BRT) system, minibuses, taxis and company buses (Roadmaps for Energy, 2017). In addition, the number of cars per thousand per person is calculated as 195 in 2020 (TURKSTAT, 2021b), which was 158 in 2014 (Canitez et al., 2020). Moreover, the number of motor vehicles registered in Istanbul in 2020 is 4.388.118; approximately 3 million of them are automobiles (TURKSTAT, 2021b).

Apart from private automobiles, currently, IETT provides transportation services to an average of 4 million passengers per day with 774 lines and 6,380 buses (IETT, 2020). In addition to buses, IETT also provides transportation services with Metrobus, consisting of 44 stations in six main and four feeder lines, which came on stream in 2007 (ibid). Furthermore, Metrobus connects the two continents, and the total line length is 52 kilometres.

Non-motorised transport

Non-motorised transport is one of the solutions for environmental burdens and transportation problems if they are supported, especially in short distances (Roadmaps for Energy, 2017). Non-motorised transport enables to decrease the congestion and do sport for individuals while travelling. Therefore, IMM has targeted to develop plans to encourage using bicycles and travelling on foot (IMM, 2019b). In that direction, pedestrianisation studies and the construction of new bicycle paths are being carried out. In the current situation, integration with 23 piers, 20 railway stations, and 2310 bus stops are ensured by bicycle paths (IMM, n.d.). In addition, 50 buses on European Side and 100 buses on the Anatolian side has bicycle parking equipment. Moreover, approximately 90 km of bicycle roads have been constructed in Istanbul, and IMM has planned to reach 1.050 km of bicycle roads in overall (Roadmaps for Energy, 2017).

Water-based public transport

Water-based public transportation is a dominant and preferred type of transportation in coastal cities (Yucel, 2019). As aforementioned, it is far from the adverse effects of road traffic, occupies less land, and offers low cost, highly comfortable and safe travel. With a 647 km coastal length (Turkish Marine Research Foundation, 2016) and 109

piers (IMM, 2019b), Istanbul has great potential in water-based public transportation to relieve roadway transportation ridership and reduce environmental burdens.

As of 2019, as listed in Table 3.1, although there are 109 piers in Istanbul, the number of actively used piers is 82 (IMM, 2019b). In Istanbul, every year, around 40 million passengers use water-based public transportation on 22 different routes (Sehir Hatlari, n.d.). A daily average of 650 trips is organized with 28 ferries by Sehir Hatlari A.S.

According to the Istanbul Metropolitan Municipality's 2020-2024 Strategic Plan, the way of reaching green and sustainable transport system goes by increasing the share of water-based public transport and railways (IMM, 2019a). Therefore, as touched upon in the following section, 3.2., IMM has actualised a significant number of implementations accordingly and proceeding.

Table 3.1 : Water-based public transport statistics of Sehir Hatlari A.S. (IMM, 2019b, p. 127).

	2015	2016	2017	2018	2019
Number of Piers	49	50	80	80	109
Number of Ferry Lines	17	16	19	21	22
Number of Voyages (x1000)	220	197	202	220	224
Number of Vessels	28	28	28	28	28
Number of Rented Vessels	19	19	29	28	29
Number of Rented Car-Ferry	-	-	-	2	2
Annual Ridership (x1000)	45.03		37.670	40.318	42.355
Carried Vehicles (annual)	-	-			649.064

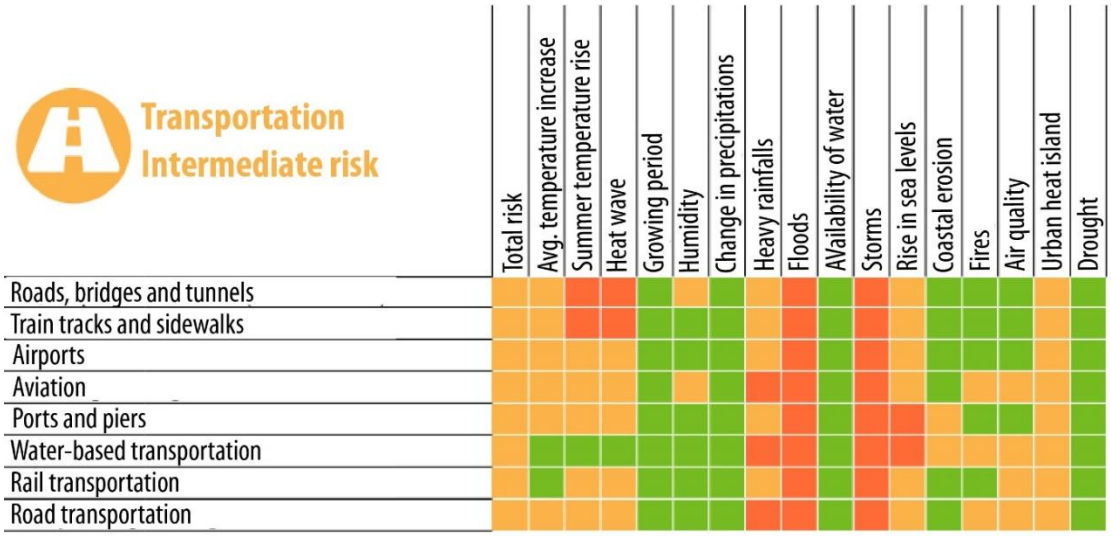
3.2 Ongoing and Upcoming Plans and Investments About Water-Based Public Transport

The time spent on public transportation in a day in Istanbul is approximately 68 minutes (Moovit, n.d.), which also means more than one hour. Moreover, every year, extra 200 hours are being spent on transport in rush hours due to congestion in Istanbul (TomTom, 2020). When this duration is considered, the capacity of public transportation vehicles, accessibility, frequency, sufficiency and efficiency of public transportation comes to the forefront. Furthermore, the importance of public

transportation systems in Istanbul and the necessity of being resistant to climate change and other external shocks and stresses gain prominence (IMM, 2018a). In this context, by Istanbul Metropolitan Municipality (2018a), roads, bridges and tunnels, train tracks and sidewalks, airports, aviation, ports and piers, water-based transport, rail transport and road transport have been identified as critical infrastructures that need to be investigated and strengthened.

Generally, roadway and aviation are the transport modes that pollute the environment at most, while railway and water-based transport are the modes of transport with the least environmental impact. Around 82% of the CO_2 emissions arising in the transportation sector originate from roadways globally (European Environment Agency, 2018). Therefore, Istanbul Metropolitan Municipality puts a high priority and importance on railways and water-based transport in their strategic plans (IMM, 2019b). In this connection, when water-based transport is elaborated, it is possible to say that compared to all components and modes of transport, the least vulnerable mode is water-based transport. In other respects, as seen in Table 3.2, heavy rainfalls, floods, storms and changes in sea level due to climate change are factors that can affect water-based transport at high risk. However, in most, it does not have vital risks to continue operation.

Table 3.2 : Transport sector vulnerability analysis - adapted from (IMM, 2018a, p. 103).



Within this scope, Istanbul Metropolitan Municipality (IMM) has targeted to increase the share and capacity of water-based public transport by ensuring the integration with road and rail systems (IMM, 2019b). In this direction, the importance of water-based

public transport in post-disasters and climate change have been evaluated comprehensively in different studies and workshops. In this connection, the insufficiency of integration and coordination between transport modes, unpredictable reactions in the occurrence of disasters, and the amount of carbon footprint have been determined as threats of water-based public transport (IMM, 2019a). On the other hand, the inadequacy of the share of water-based public transport in the overall transport system, unintegrated transportation-related applications, lack of awareness, instability of infrastructures in the occurrence of disasters have emphasised as weakness of water-based public transport in Istanbul. Therefore, IMM has aimed to overcome, at least minimise, these threats and weaknesses, starting with increasing the awareness of water-based public transport and encouraging usage (Bali, 2021). In line with its new vision, Sehir Hatlari has adopted the goals of creating a modern and environmentally friendly fleet, producing user-oriented solutions, data-based management, digitalisation, and long-term sustainable solutions (Dedetaş, 2019).

If the recent past implementations of water-based public transport are evaluated, starting from 2019, Istanbul Metropolitan Municipality and Sehir Hatlari A.S. have proceeded considerably. First and foremost, at the end of 2019, the application of Sehir Hatlari A.S. has been updated with current price tariffs, routes and timetables (Sehir Hatlari, 2019). Later on, to provide service to all groups of people, the employees of Sehir Hatlari A.S. have been learnt sign language (Sehir Hatlari, 2020b). In line with inclusiveness, to eliminate the gender factor, new women sailors have been employed (Sehir Hatlari, 2020e), and in order to attract the attention of children, as seen in Figure 3.1 below, playgrounds on ferries have been designed to start on April 23, 2020 (Sehir Hatlari, 2020d). After the appearance of the Covid-19 pandemic, ferries have been disinfected periodically with 60 days of persistent materials (Sehir Hatlari, 2020c). Moreover, additional trips have been operated to ensure social distance in ferries (Sehir Hatlari, 2020g).

Figure 3.1 : Playgrounds in ferries (Sehir Hatlari, 2020d).

Apart from social innovations, some educational implementations have been carried out as well. First aid training has held on Kadikoy-Karakoy-Eminonu lines in August 2020 (Sehir Hatlari, 2020h). Along with the training, it has been aimed to create awareness and to be educative. Later on, a contemporary art event has been organized in Halic Shipyard, the oldest living Shipyard in the world, where seven sculptors produced sculptures to be placed in public spaces (Sehir Hatlari, 2020a). On the other hand, to revive the active life that is ignored in daily lives, 15-minute sports exercise activity has been started to be held two days a week in the mornings (Sehir Hatlari, 2020f). Sports instructors have given the event, and passengers were expected to attend the event from their seats, as shown in Figure 3.2 below. The project has started to be implemented on the Beşiktaş-Kadıköy line on Mondays between 08.45-10.15 and on the Üsküdar-Eminönü line on Wednesdays between 09.00-11.05 (Hürriyet Gazetesi, 2020). On the other side, more social responsibility and awareness projects on health are continuing to be carried out. (Bali, 2021).

Figure 3.2 : Sports exercise on ferries (Sehir Hatlari, 2020f).

For Istanbulites, the sea is a culture. Until the end of the 1800s, the only mode of transport in Istanbul was by sea, which led to the creation of the sea culture (Istanbul Planning Agency, 2020). However, as the residential areas moved away from the shore, people moved away, and land-oriented transportation planning has started (Acar, 2019). Therefore, the purpose of Sehir Hatlari and IMM is to create an Istanbul that uses the sea effectively by reviving its cultural memory. In this sense, the decrease in the share of water-based public transport to 3% have prompted the authorities (Bali, 2021). Transport workshops and congresses have been organized to increase ridership. Correspondingly, the first application has been focused on the islands with the instruction of the Mayor of Istanbul, Ekrem Imamoglu. Within the scope of the workshop, 24 hours of operation to the island ferries have been suggested and applied (Euronews, 2019). In addition to the fact that the island ferry is 24 hours a day, Istanbul Metropolitan Municipality has started to provide night service in water-based public transportation after BRT, bus and metro (IMM, 2020a). The application has been implemented in four piers, and passengers have been carrying between the two sides on Friday and Saturday nights. The first night expedition has made on 28 February 2020. Moreover, in order to make water-based transportation widespread and encourage flexible working hours, between June and September 2020, Istanbul Metropolitan Municipality has arranged transport fees as 5 kurus for some trips between 10.00 - 16.00 (IMM, 2020c). The decision has been taken by the Transport Coordination Centre (UKOME) in a meeting that was held in June.

On the other hand, from an environmental perspective, as stated by the general manager of Sehir Hatlari, Sinem Dedetas, electrification projects in the water-based transportation fleet of the Istanbul Metropolitan Municipality have been involved in the vision of Sehir Hatlari (Bali, 2021). Actions on this subject have started with the establishment of a research and development centre. Converting existing vessels to hybrid systems, exhaust emissions, and converting fuel systems are some projects that have been included within the scope.

Last but not least, Istanbul Metropolitan Municipality has planned projects to integrate piers with other transport modes, especially with railways and non-motorised transport. Integration projects, which constitute a key position in transport resilience, have been started with Rumelihisarustu - Asiyan in 2017 (IMM, 2020b). In July 2020, IMM introduced five more lines to be integrated.

The long and the short of the matter, according to the Istanbul Statistical Office data, while a significant decrease has occurred in water-based public transport at the beginning of the pandemic (Istanbul Statistical Office, 2020c), an increase is observed as a result of the above-mentioned studies and incentives carried out by the Istanbul Metropolitan Municipality (Istanbul Statistical Office, 2020a). However, after the end of the decrease in transport fees and the appearance of new lockdowns and peaks in the pandemic, the ridership has decreased once again (Istanbul Statistical Office, 2021c). Therefore, it is possible to say that users are likely to change their choices with effective implementations. Nonetheless, since humans tend to turn back easily, mobility cultures, which needs time and well-rounded applications, should be created instead of temporary changes in choices.

3.3 Specialising Parameters to Istanbul and the Way to Analytic Hierarchy Process

In order to reach more permanent solutions on the roadmap, parameters listed in section 2.2.5 are examined once again to render them more specific and related to Istanbul. To specify parameters, primarily, Istanbul Metropolitan Municipality's 2020-2024 Strategic Plan (2019), Istanbul Greenhouse Gas Emissions Inventory Report (2019), Istanbul Climate Action Plan (2018), Roadmaps for Energy Istanbul (R4E) (2017) and Istanbul Metropolitan Municipality Transportation Master Plan (2011) are evaluated. The plans' fundamental values, principles and objectives are adopted to

better analyse and accommodate parameters towards Istanbul. In this context, to arrange criteria and gather together, four main categories have been designated by getting inspired by PIANC (2020) and Saaty (1994). Subsequently, specified parameters have grouped correspondingly to the necessity of the analytic hierarchy process, outcomes from analysed IMM reports and the main objective of the thesis. The classification could be seen in Figure 3.3 below.

On the other hand, water-based public transport, absolutely, is not seen as the only solution to deal with environmental burdens and crises in Istanbul. However, it could be a tool to minimise impacts. In this context, it is crucial to evaluate and ensure all main criteria. It is not possible to handle them separately. However, in the case of water-based public transport, some may have more priority and importance to provide resilience. Each sub-criterion consists of both pros and cons. At this point, balancing the criteria and tolerating each other's disadvantages is significant. Accordingly, selected sub-criteria have been determined by keeping the balance in mind, and the design of the analytic hierarchy process has been created.

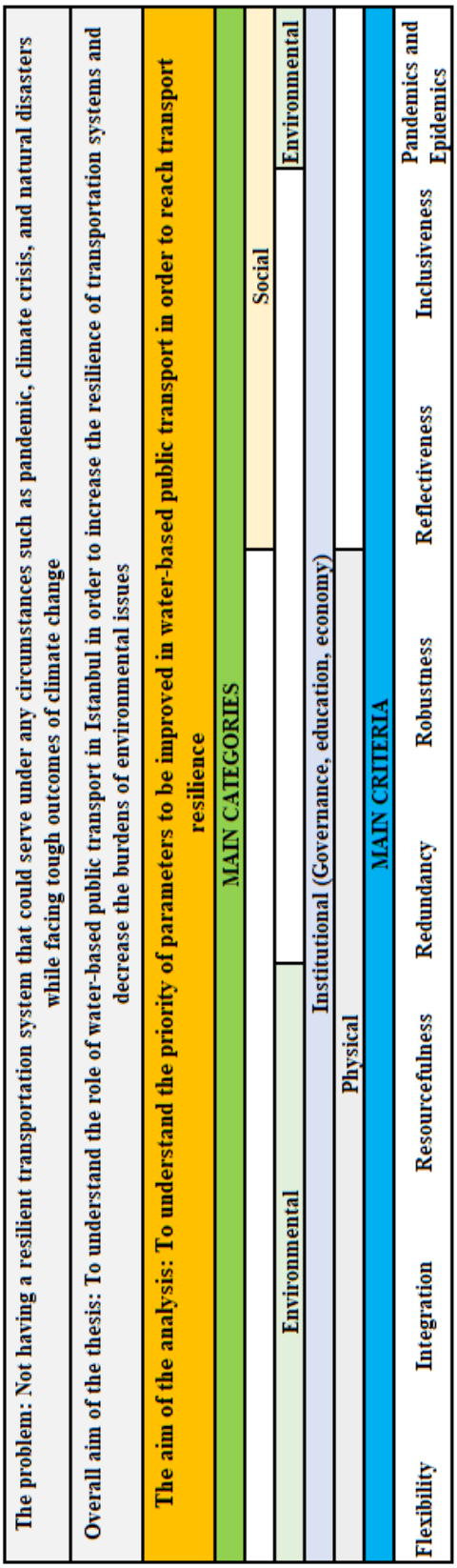


Figure 3.3 : Main categories and criteria for the analytic hierarchy process.

4. THE ROADMAP FOR WATER-BASED PUBLIC TRANSPORT IN ISTANBUL

In daily life, people encounter complicated situations that should be resolved by deciding, making a selection, or prioritising (T. L. Saaty, 1994). Apart from everyday life, decision making could be a profession or a part of a profession. Decisions are being made according to considerations of benefits, costs and risks. Experiences, social, environmental and political situations affect these preferences. At this point, unlike other methods, the analytical hierarchy process offers both rating and comparison among alternatives (T. L. Saaty, 1994). Therefore, in order to propose a roadmap, the analytical hierarchy process is chosen as a complementary method. In this connection, as mentioned in previous sections, a questionnaire has been conducted with experts within the scope of the analytical hierarchy process. Afterwards, the roadmap has been created by combining the results, the current approaches of the Istanbul Metropolitan Municipality and the literature review.

The analysation of the analytical hierarchy process

The analytical hierarchy process (AHP) is a decision-making method introduced by Thomas L. Saaty that is used in solving multi-criteria problems. The analytical hierarchy process "…facilitates decision making by organizing perceptions, feelings, judgements, and memories into a framework that exhibits the forces that influence a decision." (T. L. Saaty, 1994, p. 21). By the analytical hierarchy process, it is possible to evaluate both intangible and tangible criteria (T. L. Saaty, 2008). The variety of criteria complicates the analysis. However, the method phases out the criteria and compares them in pairs to extinguish the complexity of evaluation (R. Saaty, 1987). Moreover, the binary analysis form of the analytical hierarchy process and the ability to digitise intangible situations prevent biased evaluations.

Even the analytical hierarchy process is not the traditional multi-criteria decision-making tool (T. L. Saaty, 1990), it has applied to a wide variety of fields especially to complex environmental and economic situations (Berrittella, Certa, Enea, & Zito, 2011). Checking the consistency is one of the features that strengths the outcomes of

the method and increases the preferability. Consistency of the criteria is important both in terms of testing the internal consistency of the experts and checking the suitability of the criteria selected within the scope of the study (Aguarón, Escobar, Moreno-Jiménez, & Turòn, 2019).

The analytical hierarchy process consists of three steps: Modelling, valuation, and prioritisation and synthesis (Aguarón et al., 2019). The modelling includes both defining the problem and establishing the hierarchy. AHP approaches the problem as a hierarchy (T. L. Saaty, 1994). Therefore, to create the hierarchy, the main criteria are being determined that each could be a solution in line with tackling the issue. However, the main criteria are not being enough to continue. The method necessitates subcriteria as well. In other words, the hierarchical structure is being established from the main criteria to the subcriteria, see Figure 4.1 below. Thus, a structure is created from the general to the specific. In the meantime, it is crucial to consider the potential stakeholders to be involved in the process and actions to be taken in order to achieve the overall goal (ibid).

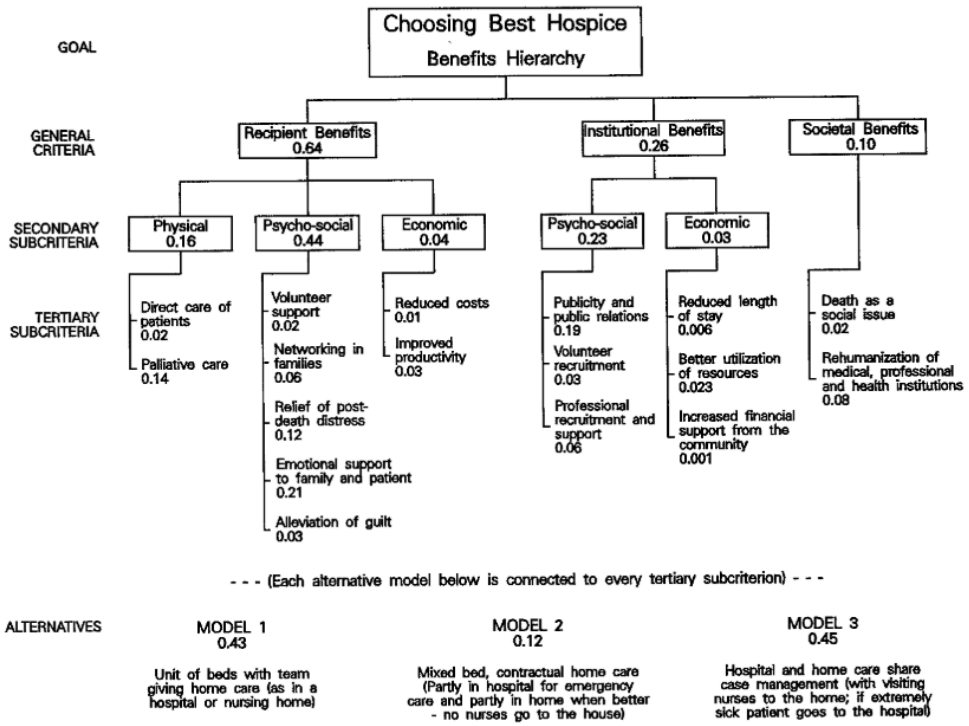


Figure 4.1 : An example of the hierarchy of AHP (T. L. Saaty, 1994)

The next step after determining the hierarchical structure is to determine the priorities of the criteria in the hierarchy. The prioritisation is been made by comparing criteria dyadically, and a pairwise matrix is been created to digitalise inputs (T. L. Saaty,

1990). The criteria are compared according to the priorities of the experts. Each pairwise comparison relatively reveals which criterion is more important for the next higher level item. A nine-point scale, which was identified by Saaty (1977), is used when making these comparisons. The scale underlies that rating should be between 1 – 9 (T. L. Saaty, 1977). Successive odd numbers (1,3,5,7,9) are preferred on this scale. However, it is also possible to choose successive even numbers (2,4,6,8).

Matrices are used when showing these pairwise comparisons. Each criterion in the left column of the matrix is compared with each criterion in the upper row, and the importance value of the criterion in the column is written at the row-column intersection, according to the criterion in the column (Berrittella et al., 2011). Matrix A is an example of a pairwise comparison matrix that is shown in Equation 4.1 below. In matrix A, n represents the number of items being compared, i is the row number in the matrix, j is the column number in the matrix, and a_{ij} is the relative importance of the items being compared. In the diagonal of the matrix, the diagonal values of pairwise comparison matrices are always equal to 1, since the criterion is compared with itself (ibid). If the matrix is created according to an expert's choice survey, then the units of the overall matrix are written by using the geometric mean of experts' choices (T. L. Saaty, 2008).

$$A=\begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & 1 & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}$$

Equation 4.1: An example matrix of the analytic hierarchy process (Berrittella et al., 2011).

Here, if a_{ij} expresses the importance of item i with respect to item j, aji also expresses the importance of item j with respect to item i, and this equality is shown by Equation 4.2 below.

$$a_{ij}>0 \; ; \; a_{ij}=\frac{1}{aji} \; ; \; i, j = 1, 2, \dots, n$$

Equation 4.2: The unit design of the matrix (Berrittella et al., 2011).

With the comparison matrix, the importance levels of the scales are determined relative to each other, but the comparison matrix does not show the importance distributions

of these criteria in the whole. To determine the distribution of priorities, a normalisation matrix should be created using the column vectors of the pairwise comparison matrix (Berrittella et al., 2011) A and their sums. Then, the criteria weights are obtained by dividing the sum of each row vector by the number of criteria. The weights obtained directly reveal the order of importance among the criteria.

If consistency analysis is not performed, prioritisation emerges as a result of normalisation. However, consistency is required in terms of controlling the usability of the data (T. L. Saaty, 1990). It is very difficult to find a perfect match in comparisons. In general, an inconsistency rate of 10% or less is considered acceptable, but in some special circumstances, higher rates may be accepted taking initiatives.

There is also an established method for consistency analysis. In line with this method, it is necessary to create a third matrix. The units of this matrix are obtained by multiplying the units in the pairwise matrix with the criterion weights (T. L. Saaty, 1990). The weighted sum is then calculated for each row vector. The ratios of weighted sums and criteria weights are calculated and the mean value is taken. Thus, $Lambda_{max}(\lambda)$ value is obtained. The obtained values are placed in Equation 4.3 below. Here, the random consistency index is fixed values determined by Saaty, varying according to the number of criteria (see Appendix A.15).

$$Consistency\ Index\ (CI) = \frac{(\lambda - n)}{n - 1}$$

$$Consistency = \frac{CI}{RI}$$

*RI: Random consistency index

Equation 4.3: The equation of consistency (T. L. Saaty, 1990).

Saaty (1977) suggested that while using the AHP method, surveys should be conducted directly with people and their opinions on pairwise comparisons should be obtained. The outcome of the AHP depends entirely on the judgment of the person or persons who will decide (T. L. Saaty, 2008). Therefore, even if the person or persons are not experts on the subject, they should have an opinion on the subject.

To put it simply, the analyse of the analytical hierarchy process is completed by defining the problem and creating a hierarchical structure, creating a comparison

matrix between criteria, determining the importance of criteria, checking the consistency of criterion comparisons, and determining the priority values of the criteria.

The evaluation of the specified analytical hierarchy process

For the analytic hierarchy process, defining the main problem, overall target, the aim of the analytic hierarchy process, main criteria and subcriteria are essential to the flow of the analysis. At this juncture, as a starting point of the evaluation, the main problem is identified as "not having a resilient public transportation system that could serve under any circumstances such as a pandemic, climate crisis, and natural disasters while facing tough outcomes of climate change". As aforementioned in the first section of the thesis, the overall aim of the thesis is determined as "to understand the role of water-based public transport in Istanbul in order to increase the resilience of public transportation systems and decrease the burdens of environmental issues". On the other hand, specifically to the analytic hierarchy process, the aim is stated as "to understand the priority of parameters to be improved in water-based public transport in order to reach transport resilience".

Within this direction, four experts from Istanbul Metropolitan Municipality and five experts from the academy have been filled out the questionnaire by prioritising the parameters. In order to provide input to the roadmap, the data of nine experts have been combined by taking the geometric mean, and a prioritisation matrix has been created (see Table 4.1, below). A consensus is not expected among experts, as the experts filled out the questionnaire in line with their expertise and value judgements, unaware of each other. Therefore, to aggregate outcomes, Saaty (2008) emphasises that "…the geometric mean is the unique way to do that." (T. L. Saaty, 2008, p. 305). The geometric mean offers to gather individual judgements equally.

First and foremost, before gathering expert opinions, consistency analysis was conducted for each expert. As a result of this process, it has seen that the views of all experts were consistent, and the outcomes were combined at the pair-wise matrix by taking the geometric mean. However, the consistency analysis should be done not only for the individual opinions of the experts, but for the aggregation of the data. Thus, the data become clear whether both the main criteria and sub-criteria are suitable and applicable for the purpose of the thesis. Therefore, a consistency analysis was carried

out once again. In compliance with the consistency analysis, the consistency ratio should be equal to or less than 0.10 (T. L. Saaty, 1990). As a consequence of the analysis, the ratio for redundancy is calculated as 0.30, which means that the parameter is inconvenient and inconsistent within the scope of the thesis. Consequently, although it is seen as fourthly important by the experts, redundancy is not included in the roadmap. Apart from all, the detailed version of the analysis has been added to the appendix in order to express how the examination is carried out.

Table 4.1 : The aggregated matrix of expert decisions - main criteria.

PAIR – WISE MATRIX	Flexibility	Integration	Resourcefulness	Redundancy	Robustness	Reflectiveness	Inclusiveness	Pandemics and Epidemics
Flexibility	1.00	0.45	1.44	0.61	0.30	1.22	0.83	1.23
Integration	2.23	1.00	1.80	1.09	0.88	2.24	2.53	2.07
Resourcefulness	0.69	0.56	1.00	1.49	1.00	0.79	0.45	0.50
Redundancy	1.64	0.91	0.67	1.00	1.07	1.71	0.79	0.96
Robustness	3.33	1.14	1.00	0.93	1.00	3.12	1.91	2.43
Reflectiveness	0.82	0.45	1.27	0.59	0.32	1.00	0.69	0.62
Inclusiveness	1.20	0.40	2.21	1.26	0.52	1.45	1.00	1.95
Pandemics and Epidemics	0.81	0.48	2.02	1.04	0.41	1.62	0.51	1.00
TOTAL	11.73	5.38	11.41	8.01	5.51	13.15	8.72	10.76

On the other hand, to determine the prioritisation, a normalisation matrix is created. The normalisation matrix is obtained by dividing each cell by the sum of the column it contains. Then, each row is summed up and divided by the number of parameters. Thus, the criteria weight of each parameter, in other words, the priority order, is determined. In Table 4.2 below, the normalised value of each cell and the criteria weights could be seen. To show the prioritisation between parameters more descriptively, Table 4.3 is created.

Table 4.2 : Normalisation matrix of main criteria.

NORMALISATION	Flexibility	Integration	Resourcefulness	Redundancy	Robustness	Reflectiveness	Inclusiveness	Pandemics and Epidemics	Criteria Weights
Flexibility	0.09	0.08	0.13	0.08	0.05	0.09	0.10	0.11	0.09
Integration	0.19	0.19	0.16	0.14	0.16	0.17	0.29	0.19	0.19
Resourcefulness	0.06	0.10	0.09	0.19	0.18	0.06	0.05	0.05	0.10
Redundancy	0.14	0.17	0.06	0.12	0.19	0.13	0.09	0.09	0.12
Robustness	0.28	0.21	0.09	0.12	0.18	0.24	0.22	0.23	0.20
Reflectiveness	0.07	0.08	0.11	0.07	0.06	0.08	0.08	0.06	0.08
Inclusiveness	0.10	0.07	0.19	0.16	0.09	0.11	0.11	0.18	0.13
Pandemics and Epidemics	0.07	0.09	0.18	0.13	0.07	0.12	0.06	0.09	0.10

According to the prioritisation among the criteria, the most significant parameter for the resilience of water-based public transportation is determined as robustness with 19.5% by experts, as could be seen in criteria weights. With a relatively slight difference, robustness is followed by integration *(*18.5%*)*. Although there is around a 5% difference between integration and inclusiveness, the values of the other parameters are very close to each other. On the other side, the least important is determined as reflectiveness with 7.6%.

Table 4.3 : The prioritisation of main criteria.

Main Criteria	Priorities
Robustness	19.5%
Integration	18.5%
Inclusiveness	12.8%
Redundancy	12.5%
Pandemics and Epidemics	10.2%
Resourcefulness	9.7%
Flexibility	9.1%
Reflectiveness	7.6%

In other respects, similar steps are followed for the sub-criteria as the second stage of the analytical hierarchy process. In this context, both the prioritisation among all sub-criteria has been revealed, and the importance level between the sub-criteria under each main criterion has been determined. According to the prioritisation in subcriteria

done by experts within this scope, the most crucial subcriterion is identified as infrastructure (12.0%) (See Table 4.4, below). This is followed by security and safety (10.1%), coordination (8.2%), and continuity (7.9%). Information (1.8%) and low emissions (1.7%) are considered to be the least important sub-criterion.

On the other hand, when the prioritisation of the main criteria and sub-criteria is examined, interestingly, although the two most important main criteria are robustness and integration, they do not constitute the most important sub-criteria. Infrastructure, which is the sub-criterion of integration, has emerged as the most important sub-criteria. However, the second most important sub-criterion was the security and safety that comes from the fifth important sub-criterion: Pandemics and epidemics.

Table 4.4 : The prioritisation of sub-criteria.

Sub-criteria	Priorities
Infrastructure	12.0%
Security and safety	10.1%
Coordination	8.2%
Continuity	7.9%
Accessibility	6.9%
Equity	5.9%
Fares	5.8%
Energy efficiency	5.1%
Urban design	4.6%
Natural disasters	4.6%
Duration of the trip	4.5%
Compatibleness with technology	4.2%
Ambience and attractiveness	4.1%
Frequency of journeys	4.1%
Unexpected weather conditions	3.7%
The capacity of vehicles	2.8%
Distance of the trip	2.3%
Information	1.8%
Low emission	1.7%

If an examination specific to each main criterion is carried out, robustness is the main criterion that contains four sub-criteria and is chosen as the most crucial parameter within the scope of the study. More thoroughly, the experts' preferences within the scope of robustness are by far in the direction of infrastructure (60.7%, see Table 4.5).

Table 4.5 : Prioritisation for robustness.

Robustness	
Sub-criteria	Priorities
Infrastructure	60.7%
Coordination	18.3%
Accessibility	11.3%
Urban design	9.6%

Alongside robustness is the most prioritised criterion, integration is the main criterion that is positioned as the second. As given in Table 4.6 below, continuity, which represents network integrity, has the highest priority of integration with 36.1%. This is followed by accessibility with 18.7% and coordination with 15.1%.

Table 4.6 : Prioritisation for integration.

Integration	
Sub-criteria	Priorities
Continuity	36.1%
Accessibility	18.7%
Coordination	15.1%
Fares	14.0%
Urban design	8.4%
Information	7.8%

On the other hand, just and equal treatment for all groups of people is more than resilience. It could not be possible to ensure resilience without ensuring equality and justice (The Rockefeller Foundation; ARUP, 2016b). In other words, resilience is not just evacuating a part of people under the circumstances of disasters but also considering the most vulnerable. In this sense, equity (41.4%) becomes prominent. In addition, security and safety, fares and urban design are also crucial. However, urban design (8.9%) have not gained much importance in the experts' choice.

Table 4.7 : Prioritisation for inclusiveness.

Inclusiveness	
Sub-criteria	Priorities
Equity	41.4%
Security and	25.7%
Fares	23.9%
Urban design	8.9%

Even redundancy is not considered in the roadmap, the prioritisation in itself is given in Table 4.8 below. If redundancy were included, the most important sub-criterion would be infrastructure with a very high percentage (51.3%), and the frequency of journeys would have the least importance within the roadmap (11.3%). To have a backup capacity and be redundant, accessibility is crucial. It enables to reach different resources, modes of transport, facilities, knowledge, and so on.

Table 4.8 : Prioritisation for redundancy.

Redundancy	
Sub-criteria	Priorities
Infrastructure	51.3%
Accessibility	20.1%
Coordination	17.3%
Frequency of	11.3%

Pandemics and epidemics is a criterion that is not included in the resilience qualities. The main criterion has come into the forefront after the appearance of the Covid-19 Pandemic. Therefore, it has been decided to add as a parameter within the scope of the study. In this direction, pandemics and epidemics have been placed at the fifth by experts, and since the virus easily infects indoors, the experts' preferences have been naturally on the side of security and safety (41.8%).

Table 4.9 : Prioritisation for pandemics and epidemics.

Pandemics and Epidemics	
Sub-criteria	Priorities
Security and safety	41.8%
Duration of the trip	23.4%
Frequency of journeys	15.8%
Distance of the trip	12.3%
The capacity of vehicles	6.7%

Systems' ability to repurpose resources is considerably crucial under circumstances of shocks and stresses. In this connection, energy efficiency, compatibleness with technology, and low emissions are seen as correlated with a city's resilience by being sub-parameters of resourcefulness. According to the experts' opinion, energy efficiency has the highest priority with almost half of the share (48.7%). As given in

Table 4.10 below, compatibility with technology (36.4%) and low emissions (14.8%) follow energy efficiency.

Table 4.10 : Prioritisation for resourcefulness.

Resourcefulness	
Sub-criteria	Priorities
Energy efficiency	48.7%
Compatibleness with	36.4%
Low emissions	14.8%

Looking at the prioritisation among each main criterion's sub-criteria, as shown in Table 4.11, the most critical parameter for flexibility is natural disasters with 31.1%. In comparison, unexpected weather conditions rank second with a 1.1% difference. Surprisingly, according to experts, urban design (11.5%) is not that correlated with flexibility.

Table 4.11 : Prioritisation for flexibility.

Flexibility	
Sub-criteria	Priorities
Natural disasters	31.1%
Unexpected weather conditions	30.0%
Coordination	27.5%
Urban design	11.5%

A city, or a system, learns from its past experiences and tries to overcome issues in line with those experiments. In line with the questionnaire, the issues where experiences are most important are infrastructure (64.6%) and ambience (33.2%). Interestingly, experts have not thought that the technology is adequately related to learning from the past.

Table 4.12 : Prioritisation for reflectiveness.

Reflectiveness	
Sub-criteria	Priorities
Infrastructure	64.6%
Ambience and	33.2%
Compatibleness with technology	2.2%

The roadmap for water-based public transport in Istanbul

The roadmap proposed in order to increase the ridership of water-based public transport and reduce environmental burdens is significant in promoting water-based public transportation in Istanbul, especially in ensuring its resilience against climate change and other external threats. While creating the roadmap, a detailed literature review was conducted, as emphasised in the previous chapters. The relevant parameters were determined accordingly and then prioritised with expert opinions within the scope of the analytical hierarchy process. The roadmap that is suggested to be followed up consists of an upper scale approach and does not contain detailed action plans. Even though the elaboration of the work is left to further studies, the actions that can be taken within the scope of the resilience of water-based public transportation for each main category, are given below. In addition, some of the given actions are left at the target level. In other words, it is possible to find both actions and targets within the roadmap.

In the direction of determining the time period of the roadmap, the commitments of the United Nations and the Istanbul Metropolitan Municipality have been discussed as time determiners. Accordingly, the short term is specified as 2024, medium-term is 2030, and the long term recommendations are pointed out to 2050. More profoundly, to identify the timeline of the actions, Istanbul Metropolitan Municipality's 2020 – 2024 Strategic Plan (2019), Istanbul Climate Action Plan (2018), London Resilience Strategy (2020), Rome Resilience Strategy (2018) and Bristol Resilience Strategy (2016) have been examined and taken as a guiding light. The relevant table could be seen in Table 4.13, to understand how the mentioned reports are used.

Table 4.13 : The relation of inspired reports and proposed actions.

Main Criterion	Sub Criterion	Action	Timeline	Inspired Action	Inspired Timeline	Inspired Report
Robustness (19.5%)	**Infrastructure (44.4%)**	Increasing the resistance of ferries against external factors such as extreme weather conditions and natural disasters	Medium	Natural capital trust	Medium	Bristol Resilience Strategy

Table 4.13 (continued): The relation of inspired reports and proposed actions.

Robustness (19.5%)	**Urban design (20.2%)**	Encouraging compact designs to shorten distances	Medium	Bristol transport plan	Medium	Bristol Resilience Strategy
	Coordination (19.0%)	Providing collaboration between different modes, authorities, and operators etc.	Short	Adaptive Greater London Authority	Immediate	London Resilience Strategy
	Accessibility (16.4%)	Increasing the accessibility between public transport modes by urban planning	Medium to long	Develop an efficient and economic transport model for people and goods	Medium	Bristol Resilience Strategy, Rome Resilience Strategy
Integration (18.5%)	**Continuity (36.1%)**	Ensuring continuity between water-based public transportation trips	Medium to long	Strengthening integration and continuity between public transportation modes	-	IMM, Bristol Resilience Strategy
	Accessibility (18.7%)	Providing integration between public transport modes	Medium to long	Reorganize the network of public transportation to streamline the mobility system	Short	Bristol Resilience Strategy, Rome Resilience Strategy
	Coordination (15.1%)	Providing collaboration between different modes, authorities, and operators etc.	Short	Adaptive Greater London Authority	Immediate	London Resilience Strategy
	Fares (14.0%)	Ensuring access to all modes with a single ticket	Short	Planning time-fare-route integration by considering other transportation modes	-	IMM

Table 4.13 (continued): The relation of inspired reports and proposed actions.

Integration (18.5%)	**Urban design (8.4%)**	Providing integration of urban planning and water-based transport	Medium	Bristol transport plan	Medium	Bristol Resilience Strategy
		Providing the connection of piers with non-motorized transportation modes	Short to long	Active and healthy aging	Short to long	Bristol Resilience Strategy
		Creating an opeation and management centre	Short	Create an operation and managem ent centre	Long	Rome Resilience Strategy
	Informing (7.8%)	Establishing a resilience office	Short	Establish a resilience office	Short	Rome Resilience Strategy
		Ensuring the better use of ICT and AFC Systems	Short to medium	Bristol is open	-	Bristol Resilience Strategy
Inclusiveness (12.8%)	**Equity (41.4%)**	Supporting the involvement of different actors and stakeholders	Short to long	City knowledg e exchange platform	Long	Bristol Resilience Strategy
		Providing communities with the resources and capacity to take action to deal with shocks and stresses	Short to long	Equality charter	Short	Bristol Resilience Strategy
		Providing accessibility to ferries to vulnerable groups	Short to long	Equality charter	Short	Bristol Resilience Strategy
	Security and safety (25.7%)	Ensuring door-to-door safety	Medium to long	Safe & resilient spaces	Long	London Resilience Strategy
	Fares (23.9%)	Keeping the ticket and transfer fees at an amount that the public can afford, and providing incentives in certain periods	Short to medium	Free bus travel for under 16s	Short to medium	Bristol Resilience Strategy

Table 4.13 (continued): The relation of inspired reports and proposed actions.

Inclusiveness (12.8%)	**Urban design (8.9%)**	Arranging piers design within the scope of equal and fair access	Medium	Urban integrated diagnostics	Short	Bristol Resilience Strategy
	Security and safety (41.8%)	Developing newer ventilation systems that are dependable and useful under the circumstances of pandemics and epidemics	Short	Innovative data use for infrastructure	Medium to long	London Resilience Strategy
	The duration of the trip (23.4%)	Shortening the duration of journey of ferries by using technology	Long	Increasing smart transportation systems and transportation infrastructure applications	-	IMM
Pandemics and epidemics (10.2%)	**The frequency of trips (15.8%)**	Being able to increase frequency in terms of shocks and stresses	Medium to long	Ongoing implementations of IMM and Sehir Hatlari A.S.	-	IMM
		Adding additional trips to avoid the crowd at peak hours	Medium	Ongoing implementations of IMM and Sehir Hatlari A.S.	-	IMM
	The distance of the trip (12.3%)	Shortening the distance of journeys via urban planning	Long	Increasing smart transportation systems and transportation infrastructure applications	-	IMM

Table 4.13 (continued): The relation of inspired reports and proposed actions

Pandemics and epidemics (10.2%)	**The capacity of vessels (6.7%)**	Arranging seatings to provide social distance and limiting the number of users at each journey	Short	Ongoing implementations of IMM and Sehir Hatlari A.S.	-	IMM
		Adding additional trips to avoid the crowd at peak hours	Medium	Ongoing implementations of IMM and Sehir Hatlari A.S.	-	IMM
Resourcefulness (9.7%)	**Energy efficiency (48.7%)**	Replacing old vessels	Short to long	Resilient & zero carbon infrastructure	Medium	London & Rome Resilience Strategy
		Making use of environmentally friendly energy sources	Medium to long	Climate strategy and energy framework	Medium to long	Bristol & Rome Resilience Strategy
	Compatibleness with technology (36.4%)	Shortening the duration of journey of ferries by using technology	Long	Increasing smart transportation systems and transportation infrastructure applications	-	IMM
	Low emissions (14.8%)	Making use of environmentally friendly energy sources	Medium to long	Climate strategy and energy framework	Medium to long	Bristol & Rome Resilience Strategy
		Using electric, hybrid or hydrojen vessels	Medium to long	Climate strategy and energy framework	Medium to long	Bristol & Rome Resilience Strategy
		Providing the connection of piers with non-motorized transportation modes	Short to long	Active and healthy aging	Short to long	Bristol & Rome Resilience Strategy
Flexibility (9.1%)	**Natural disasters (31.1%)**	Providing adaptation to natural disasters via use of technology and past experiences	Medium to long	Manage our future flood risk & Climate adaptatin plan	Medium/short	Bristol Resilience Strategy

Table 4.13 (continued): The relation of inspired reports and proposed actions.

Flexibility (9.1%)	**Natural disasters (31.1%)**	Increasing the resistance of ferries against external factors such as extreme weather conditions and natural disasters	Medium	Natural capital trust	Medium	Bristol & London Resilience Strategy
	Unexpected weather conditions (30.0%)	Providing adaptation to extreme weather events via use of technology and past experiences	Medium to long	Manage our future flood risk & Climate change adaptation plan	Medium/short	Bristol Resilience Strategy
		Increasing the resistance of ferries against external factors such as extreme weather conditions and natural disasters	Medium to long	Natural capital trust	Medium	Bristol Resilience Strategy
	Coordination (27.5%)	Providing parallel public transportation opportunities to water-based public transportation	Medium to long	Reorganize the network of public transportation to streamline the mobility system	Short	Bristol & Rome Resilience Strategy
	Urban design (11.5%)	Encouraging compact designs to shorten distances	Medium	Bristol transport plan	Medium	Bristol Resilience Strategy
Reflectiveness (7.6%)	**Infrastructure (64.6%)**	Strengthening ferries and piers that are specifically vulnerable to shock and stress	Medium	Resilience impact assessment	Short	Bristol Resilience Strategy
	Ambience and attractiveness (33.2%)	Increasing social activities on ferries and preserving sea culture	Short to long	Ongoing implementations of IMM and Sehir Hatlari A.S.	-	IMM
	Compatibleness with technology (2.2%)	Developing the current technological capacity	Short to long	Bristol is open	-	Bristol Resilience Strategy
		Horizon scanning and promoting secure technology	Short to long	Horizon scanning	Short to medium	Bristol Resilience Strategy

Rome's resilience strategy was more specific and pointing out the preservation of heritage (The Rockefeller Foundation & ARUP, 2018). Therefore, it has been used in fewer actions of the roadmap. Similarly, London's focus was not very much on transportation. It was more comprehensive and concentrated on the use of technology, air quality and societal well-being (Greater London Authority, 2020). IMM's reports and Bristol's Resilience Strategy were the most relevant studies in terms of the scope of the roadmap. It has seen that in terms of ensuring resilience, Bristol's strategies mostly covered the medium term, London focused on the short term, Rome and IMM targeted the medium and long terms (Greater London Authority, 2020; IMM, 2018b, 2019a; The Rockefeller Foundation & ARUP, 2016, 2018).

Accordingly, within the roadmap that could be seen in Table 4.14 below, it is possible to find short term, medium term, long term, short to medium, short to long and medium to long term planning horizons. These timeframes refer to the due date of the realisation of the action. On the other hand, short to medium, short to long, and medium to the long term mean that the action will actualise in between two planning horizons or take place in both.

Table 4.14 : The proposed roadmap for water-based public transport.

Main Criterion	Sub Criterion	Action	Stakeholders	Timeline
Robustness (19.5%)	Infrastructure (60.7%)	Increasing the resistance of ferries against external factors such as extreme weather conditions and natural disasters	IMM, public administration	Medium
	Coordination (18.3%)	Providing collaboration between different modes, authorities, and operators etc.	IMM, governorship, public administration, private sector	Short
	Accessibility (11.3%)	Increasing the accessibility between public transport modes by urban planning	IMM, Sehir Hatlari A.S. and other related transport operators, Ministry of Transport and Infrastructure	Medium to long
	Urban design (9.6%)	Encouraging compact designs to shorten distances	IMM, academy, trade associations, public administration, private sector	Medium
Integration (18.5%)	Continuity (36.1%)	Ensuring continuity between water-based public transportation trips	IMM	Medium to long

Table 4.14 (continued): The proposed roadmap for water-based public transport.

Main Criterion	Sub Criterion	Action	Stakeholders	Timeline
Integration (18.5%)	Accessibility (18.7%)	Providing integration between public transport modes	IMM, TCDD, Sehir Hatlari A.S., Metro A.S. and other related transport operators, public administration, Ministry of Transport and Infrastructure	Medium to long
	Coordination (15.1%)	Providing collaboration between different modes, authorities, and operators etc.	IMM, public administration, governorship, district municipalities	Short
	Fares (14.0%)	Ensuring access to all modes with a single ticket	IMM, UKOME, municipal council, public administration, Ministry of Transport and Infrastructure	Short
	Urban design (8.4%)	Providing integration of urban planning and water-based transport	IMM, academy, trade associations, private sector, NGOs	Medium
	Urban design (8.4%)	Providing the connection of piers with non-motorized transportation modes		Short to long
	Information (7.8%)	Creating an operation and management centre	IMM, related transport operators	Short
		Establishing a resilience office		Short
		Ensuring the better use of ICT and AFC Systems	IMM, related transport operators	Short to medium
Inclusiveness (12.8%)	Equity (41.4%)	Supporting the involvement of different actors and stakeholders	IMM, NGOs	Short to long
		Providing communities with the resources and capacity to take action to deal with shocks and stresses		Short to long
		Providing accessibility to ferries to vulnerable groups		Short to long
	Security and safety (25.7%)	Ensuring door-to-door safety	IMM, Sehir Hatlari A.S., public administration, governorship, security directorate	Medium to long
	Fares (23.9%)	Keeping the ticket and transfer fees at an amount that the public can afford and providing incentives in certain periods	IMM, UKOME, municipal council	Short to medium
	Urban design (8.9%)	Arranging piers design within the scope of equal and fair access	IMM, public administration, NGOs, private sector	Medium

Table 4.14 (continued): The proposed roadmap for water-based public transport.

Main Criterion	Sub Criterion	Action	Stakeholders	Timeline
Pandemics and epidemics (10.2%)	Security and safety (41.8%)	Developing newer ventilation systems that are dependable and useful under the circumstances of pandemics and epidemics	IMM, Sehir Hatlari A.S., public administration	Short
	The duration of the trip (23.4%)	Shortening the duration of journey of ferries by using technology	IMM, Sehir Hatlari A.S.	Long
	The frequency of trips (15.8%)	Being able to increase the frequency in terms of shocks and stresses	IMM, AFAD, AKOM	Medium to long
		Adding additional trips to avoid the crowd at peak hours	IMM	Medium
	The distance of the trip (12.3%)	Shortening the distance of journeys via urban planning	IMM, Sehir Hatlari A.S., private sector, ministries	Long
	The capacity of vessels (6.7%)	Arranging seatings to provide social distance and limiting the number of users at each journey	Related transport operator	Short
		Adding additional trips to avoid the crowd at peak hours	IMM	Medium
Resourcefulness (9.7%)	Energy efficiency (48.7%)	Replacing old vessels	IMM, public administration, Ministry of Environment and Urbanisation, Ministry of Transport and Infrastructure, private sector	Short to long
		Making use of environmentally friendly energy sources		Medium to long
	Compatibleness with technology (36.4%)	Shortening the duration of journey of ferries by using technology	IMM, public administration, Ministry of Industry and Technology, private sector	Long
		Making use of environmentally friendly energy sources		Medium to long
	Low emissions (14.8%)	Using electric, hybrid or hydrogen vessels	IMM, public administration, Ministry of Environment and Urbanisation, Ministry of Transport and Infrastructure, UKOME, private sector	Medium to long
		Providing the connection of piers with non-motorized transportation modes		Short to long

Table 4.14 (continued): The proposed roadmap for water-based public transport.

Main Criterion	Sub Criterion	Action	Stakeholders	Timeline
Flexibility (9.1%)	Natural disasters (31.1%)	Providing adaptation to natural disasters via use of technology and past experiences	AFAD, IMM, NGOs, AKUT (Search & Rescue Association)	Medium to long
		Increasing the resistance of ferries against external factors such as extreme weather conditions and natural disasters		Medium
	Unexpected weather conditions (30.0%)	Providing adaptation to extreme weather events via use of technology and past experiences	AKOM, AFAD, IMM, UKOME	Medium to long
		Increasing the resistance of ferries against external factors such as extreme weather conditions and natural disasters		Medium to long
	Coordination (27.5%)	Providing parallel public transportation opportunities to water-based public transportation	AKOM, Sehir Hatlari A.S., IMM, Ministry of Transport and Infrastructure, governorship	Medium to long
	Urban design (11.5%)	Encouraging compact designs to shorten distances	IMM, academy, trade associations, public administration, NGOs, private sector	Medium
Reflectiveness (7.6%)	Infrastructure (64.6%)	Strengthening ferries and piers that are specifically vulnerable to shock and stress	IMM, public administration	Medium
	Ambience and attractiveness (33.2%)	Increasing social activities on ferries and preserving sea culture	IMM	Short to long
	Compatibleness with technology (2.2%)	Developing the current technological capacity	IMM, private sector	Short to long
		Horizon scanning and promoting secure technology	IMM, public administration	Short to long

Within the scope of the analytical hierarchy process, potential stakeholders for each sub-criterion have been stated by experts. Thus, in light of that information and evaluation of current plans, the related stakeholders have been identified for each action. In this sense, IMM has been specified as one of the main actors within the process. However, since the operation of all transportation modes is not under IMM, the Ministry of Transport and Infrastructure is also included in the roadmap. Moreover, Transport Coordination Centre (UKOME) is entitled to decision making processes of transportation. Therefore, it is not possible to design a roadmap without UKOME's participation. On the other hand, the academy, public administration, NGOs,

ministries, transport operators and associations have been included within the roadmap. The stakeholder mapping, which consists of detailed power-interest relationships, will be carried out in further studies. The identified actors only represent sectors, without prioritisation. Although not included in the table, public participation is essential throughout the process. In other words, public participation covers the whole roadmap.

To be comprehensible, the roadmap is visualised (see Figure 4.2). By the visualisation, it has aimed to pave the way for the implementation phases. Therefore, in the visual form, actions are grouped according to their content and impact area to show the field of application. In this sense, ticket arrangements, urban planning, legislative regulations, capacity building, participation, technological enhancements, and decarbonisation are designated as implementation areas. Additionally, the visual is designed towards the results of the analytical hierarchy process. The actions' priorities are gathered by calculating geometric means. Within this framework, ticket arrangements have the most priority and decarbonisation has the least. The colouring of the visual indicates the starting and ending dates of the timeline. More thoroughly, light colours mean that the implementation is just started and dark colours mean that it is about the end. On the other hand, some actions take part within the whole timeline. However, some of them take place only in specified time periods.

To sum up, as part of the roadmap, the first two main criteria that stand out with values close to each other are robustness and integration. Although there are no high differences between the other six criteria, the least important is reflectiveness. Redundancy is seen as inconvenient within the scope of this thesis. In this direction, priority should be given to robustness in order to ensure the resilience of water-based public transportation in Istanbul. Therefore, while following up the roadmap, the priorities should be taken into consideration. Detailed action plans should be determined in line with the prioritisation, and the timing should be rearranged accordingly. However, it is also possible to say that to ensure resilience especially in water-based public transportation, it is crucial to consider all parameters holistically, not only paying attention to robustness and integration. Moreover, it is significant to ensure integration not only between public transportation modes, but also integration among social, environmental, institutional and physical systems.

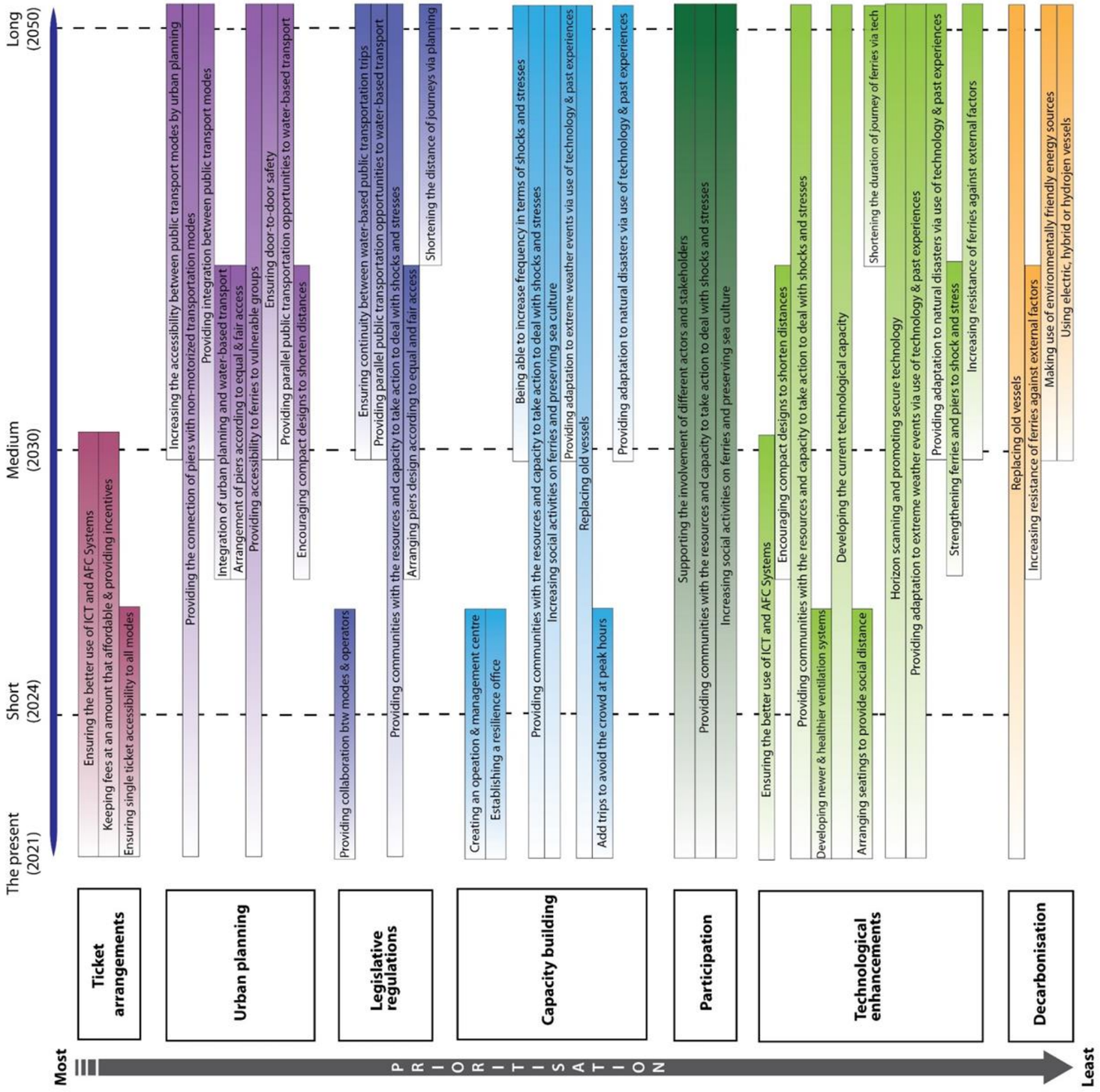


Figure 4.2 : The Visualised Version of the Roadmap.

5. CONCLUSION

As emphasised many times within the thesis, the environment is “where we live, work, and play” (Novotny, 2000, p. 24). Moreover, since we, as human beings, are always on the move by our mobility preferences, we leave traces on the environment. The outcomes of these traces differ as regards the vulnerability of places or systems. Accordingly, the capacity of resistance also varies. Therefore, plenty of terms have been proposed to deal with either these abilities and vulnerabilities within the literature. When one of those terms fail, the other comes into play. Now, it is the round of resilience.

Resilience stands on sustainability’s idea of having the capacity to balancing the Earth (Carpenter et al., 2001). In other words, resilience is the capacity and ability of people, systems, cities, countries, and so on to sustain, adapt and develop, in terms of shocks and stresses (Greater London Authority, 2020). These shocks and stresses are mainly external and unexpected. Therefore, the term gains new dimensions over time while facing challenges. Livingly, after the appearance of the Covid-19 pandemic, the term pandemic-resilience has come to the forefront. However, the wicked problem that we are facing is vital and more compeller than all other dimensions. Thus, climate resilience is the perspective that the thesis handles.

Cities are human-dominated ecosystems that consist of climate, energy flow, communities, mobility and other systems that are existed in order to fulfil people’s living needs (Alberti, 2008). Thereby, humans and cities are coevolved in the direction of creating liveable environments. They both embedded in each other. However, over time the dominance of human beings have gotten over the natural environment, and it has started to be alerted. This situation is called as human-induced environmental destruction, or namely, human-induced climate change.

On the other hand, the city ecosystems are connected to one another and kept alive by mobility. Humans fulfil their basic needs via urban mobility. Urban mobility is an unavoidable consumption that reflects people's relations with time and space, which

shapes our lives, and drives the city's dynamics (Beyazit, 2013). Within this structure, urban mobility and transport have placed at the top because of being a derived demand for individuals to meet their living needs (Banister, 2008).

As being at the core of our daily lives, urban mobility and transport are among the leading reasons for the high carbon footprint (European Environment Agency, 2018). Although they are a reason for climate change, transportation systems are one of the most vulnerable systems affected by the climate. Since the outcomes of climate change occur unpredictably, its effects are also being damaging. By being the backbone of cities, transportation systems should be resistant to these events, even they are unforeseeable. Therefore, the term transport resilience comes into prominence.

Water-based public transportation, or more broadly waterborne transportation, has different types of opportunities in order to ensure transport resilience. First and foremost, water-based public transportation uses the natural infrastructure of water. Therefore, it requires lower initial investment unit costs (Timur, 2019). Moreover, high passenger capacity, even more, lowers down the costs. On the other hand, according to the EU, water-based public transportation is the most resilient mode of transport by having minimum energy loss and the capacity of replacing environmentally friendly energy sources (Meersman et al., 2020; Waterborne EU, n.d.). In other words, water-based public transportation comes to the forefront by being relatively climate-friendly with a low carbon footprint. Furthermore, transferring some load of urban transportation to the sea creates safe, calmy, peaceful, and comfortable options that relieve road transportation. In this sense, coastal cities with suitable locations and geographies have the opportunity to develop water-based transport as a public transport mode and take the abovementioned advantages. Therefore, as a coastal city, Istanbul is chosen as the case area because of being vulnerable to climate change in the current situation and also having great potential to overcome this vulnerability by encouraging water-based transportation.

In line with the thesis, the role of water-based public transportation in terms of transport resilience is evaluated from eight dimensions: Integration, flexibility, redundancy, resourcefulness, reflectiveness, inclusiveness, pandemics, and epidemics. Except for pandemics and epidemics, other dimensions are city resilience measures (The Rockefeller Foundation; ARUP, 2016b). To understand the importance of these parameters in increasing the ridership of water-based public transportation in Istanbul

and reducing environmental burdens, an analytical hierarchy process questionnaire has been conducted within the scope of the thesis.

According to the questionnaire, it has seen that nine experts from both academy and IMM thought that redundancy is an important measure in order to tackle climate change. However, their prioritisation has revealed that it is an inconsistent parameter to work with. Therefore, it is not included within the roadmap. On the other side, the highest priority is seen on robustness and integration. It is understandable to have robustness and integration at the top. Not only integration between modes but also integration among social, physical, institutional and environmental systems are crucial. In this sense, while following up the roadmap, it is essential to give priority to robustness and integration and design the detailed timeline according to these prioritisations. Within the scope of this study, the action plan offered is from an upper scale. Therefore, its timeline only represents a time frame. For the detailed action plan for Istanbul's water-based public transportation system, the timeline should be revised by considering both prioritisations made by experts and the participation. The study only points out the essential areas to work with and propounds the neglected aspects of resilience, more broadly, climate change. It could not be possible to deal with climate change only by considering one parameter. They all are interlinked and must be evaluated as integrated as a whole. Otherwise, the same sustainability failures will be faced, and the harsh outcomes of climate change could not be overcome. In a word, this thesis focuses on environmental concerns and urban mobility and has aimed to be a base for future studies by emphasising the importance and association of urban mobility and environmental concerns from a water-based public transportation perspective.

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APPENDICES

APPENDIX A

Table A.1 : The questionnaire – questions of main criteria

Intensity of Importance		Definition
1	Equal Importance	Both factors are equally important.
3	Moderate Importance	One factor is slightly more important than the other.
5	Strong Importance	One factor is strongly more important than another.
7	Very Strong Importance	One factor is highly important than the other.
9	Extreme Importance	One factor is extremely important than the other.
2,4,6,8	Intermediate Values	When choosing between two factors, they are the values between the above.

1st Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to flexibility ?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Flexibility																		Integration
Flexibility																		Resourcefulness
Flexibility																		Redundancy
Flexibility																		Robustness
Flexibility																		Reflectiveness
Flexibility																		Inclusiveness
Flexibility																		Pandemics and epidemics

2nd Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to integration?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Integration																		Resourcefulness
Integration																		Redundancy
Integration																		Robustness
Integration																		Reflectiveness
Integration																		Inclusiveness
Integration																		Pandemics and epidemics

Table A.2 : The questionnaire – questions of main criteria

3rd Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to resourcefulness?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Resourcefulness																		Resourcefulness
Resourcefulness																		Redundancy
Resourcefulness																		Reflectiveness
Resourcefulness																		Inclusiveness
Resourcefulness																		Pandemics and epidemics

4th Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to redundancy?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Redundancy																		Redundancy
Redundancy																		Reflectiveness
Redundancy																		Inclusiveness
Redundancy																		Pandemics and epidemics

5th Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to robustness?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Robustness																		Reflectiveness
Robustness																		Inclusiveness
Robustness																		Pandemics and epidemics

6th Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to reflectiveness?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Reflectiveness																		Inclusiveness
Reflectiveness																		Pandemics and epidemics

7th Question: While increasing the share of water-based public transport in the resilience of transportation systems, which criterion is more important than the other resilience criteria compared to inclusiveness?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Inclusiveness																		Pandemics and epidemics

Table A.3 : The questionnaire – questions of sub-criteria

Intensity of Importance		Definition
1	Equal Importance	Both factors are equally important.
3	Moderate Importance	One factor is slightly more important than the other.
5	Strong Importance	One factor is strongly more important than another.
7	Very Strong Importance	One factor is highly important than the other.
9	Extreme Importance	One factor is extremely important than the other.
2,4,6,8	Intermediate Values	When choosing between two factors, they are the values between the above.

1st Question: Which criterion is more important than another in terms of flexibility while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Unexpected weather conditions																		Urban design
Unexpected weather conditions																		Natural disasters
Unexpected weather conditions																		Coordination
Urban design																		Coordination
Urban design																		Natural disasters
Coordination																		Natural disasters

2nd Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Unexpected weather conditions	
Urban design	
Natural Disasters	
Koordinasyon	

3rd Question: Which criterion is more important than another in terms of integration while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Informing																		Coordination
Informing																		Urban design
Informing																		Accessibility
Informing																		Fares
Informing																		Continuity
Coordination																		Urban design
Coordination																		Accessibility
Coordination																		Fares
Coordination																		Continuity
Urban design																		Accessibility
Urban design																		Fares
Urban design																		Devamlılık
Accessibility																		Fares
Accessibility																		Continuity
Fares																		Continuity

4th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Informing	
Coordination	
Urban design	
Accessibility	
Fares	
Continuity	

Table A.4 : The questionnaire – questions of sub-criteria

5th Question: Which criterion is more important than another in terms of resourcefulness while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Low emissions																		Energy efficiency
Low emissions																		Compatibleness with technology
Energy efficiency																		Compatibleness with technology

6th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Low emissions	
Energy efficiency	
Compatibleness with technology	

7th Question: Which criterion is more important than another in terms of redundancy while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Frequency of journeys																		Accessibility
Frequency of journeys																		Infrastructure
Frequency of journeys																		Coordination
Accessibility																		Infrastructure
Accessibility																		Coordination
Infrastructure																		Coordination

8th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Frequency of journeys	
Accessibility	
Infrastructure	
Coordination	

9th Question: Which criterion is more important than another in terms of robustness while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Urban design																		Infrastructure
Urban design																		Coordination
Urban design																		Accessibility
Infrastructure																		Coordination
Infrastructure																		Accessibility
Coordination																		Accessibility

10th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Urban design	
Infrastructure	
Coordination	
Accessibility	

11th Question: Which criterion is more important than another in terms of reflectiveness while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Infrastructure																		Compatibleness with technology
Infrastructure																		Ambience and attractiveness
Compatibleness with technology																		Ambience and attractiveness

12th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Table A.5 : The questionnaire – questions of sub-criteria

Infrastructure	
Teknolojiye uyum	
Ambience and attractiveness	

13th Question: Which criterion is more important than another in terms of inclusiveness while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Equity																		Fares
Equity																		Security and safety
Equity																		Urban design
Fares																		Security and safety
Fares																		Urban design
Security and safety																		Urban design

14th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

Equity	
Fares	
Security and safety	
Urban design	

15th Question: Which criterion is more important than another in terms of pandemics and epidemics while increasing the share of water-based public transport in the resilience of transportation systems?

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
The capacity of vehicles																		Security and safety
The capacity of vehicles																		Duration of the trip
The capacity of vehicles																		Distance of the trip
The capacity of vehicles																		Frequency of journeys
Security and safety																		Duration of the trip
Security and safety																		Distance of the trip
Security and safety																		Frequency of journeys
Duration of the trip																		Distance of the trip
Duration of the trip																		Frequency of journeys
Distance of the trip																		Frequency of journeys

16th Question (OPTIONAL): Who are the relevant stakeholders that can take part in the actions to be developed in line with the specified parameters?

The capacity of vehicles	
Security and safety	
Duration of the trip	
Distance of the trip	
Frequency of journeys	

Table A.6 : Detailed version of the analytical hierarchy process – main criteria

PAIR-WISE MATRIX	Flexibility	Integration	Resourcefulness	Redundancy	Robustness	Reflectiveness	Inclusiveness	Pandemics and Epidemics
Flexibility	1.00	0.45	1.44	0.61	0.30	1.22	0.83	1.23
Integration	2.23	1.00	1.80	1.09	0.88	2.24	2.53	2.07
Resourcefulness	0.69	0.56	1.00	1.49	1.00	0.79	0.45	0.50
Redundancy	1.64	0.91	0.67	1.00	1.07	1.71	0.79	0.96
Robustness	3.33	1.14	1.00	0.93	1.00	3.12	1.91	2.43
Reflectiveness	0.82	0.45	1.27	0.59	0.32	1.00	0.69	0.62
Inclusiveness	1.20	0.40	2.21	1.26	0.52	1.45	1.00	1.95
Pandemics and Epidemics	0.81	0.48	2.02	1.04	0.41	1.62	0.51	1.00
TOTAL	11.73	5.38	11.41	8.01	5.51	13.15	8.72	10.76

NORMALISATION	Flexibility	Integration	Resourcefulness	Redundancy	Robustness	Reflectiveness	Inclusiveness	Pandemics and Epidemics	Criteria Weights
Flexibility	0.09	0.08	0.13	0.08	0.05	0.09	0.10	0.11	0.09
Integration	0.19	0.19	0.16	0.14	0.16	0.17	0.29	0.19	0.19
Resourcefulness	0.06	0.10	0.09	0.19	0.18	0.06	0.05	0.05	0.10
Redundancy	0.14	0.17	0.06	0.12	0.19	0.13	0.09	0.09	0.12
Robustness	0.28	0.21	0.09	0.12	0.18	0.24	0.22	0.23	0.20
Reflectiveness	0.07	0.08	0.11	0.07	0.06	0.08	0.08	0.06	0.08
Inclusiveness	0.10	0.07	0.19	0.16	0.09	0.11	0.11	0.18	0.13
Pandemics and Epidemics	0.07	0.09	0.18	0.13	0.07	0.12	0.06	0.09	0.10
TOTAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

	Flexibility	Integration	Resourcefulness	Redundancy	Robustness	Reflectiveness	Inclusiveness	Pandemics and Epidemics	Weighted Sum Value
Flexibility	0.09	0.08	0.14	0.08	0.06	0.09	0.11	0.13	0.77
Integration	0.20	0.19	0.17	0.14	0.17	0.17	0.33	0.21	1.58
Resourcefulness	0.06	0.10	0.10	0.19	0.20	0.06	0.06	0.05	0.81
Redundancy	0.15	0.17	0.07	0.12	0.21	0.13	0.10	0.10	1.05
Robustness	0.30	0.21	0.10	0.12	0.20	0.24	0.25	0.25	1.65
Reflectiveness	0.07	0.08	0.12	0.07	0.06	0.08	0.09	0.06	0.64
Inclusiveness	0.11	0.07	0.21	0.16	0.10	0.11	0.13	0.20	1.09
Pandemics and Epidemics	0.07	0.09	0.20	0.13	0.08	0.12	0.07	0.10	0.86

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lambda max
0.77	0.09	8.50	8.46	8.46
1.58	0.19	8.51		
0.81	0.10	8.39		
1.05	0.12	8.40		
1.65	0.20	8.46		
0.64	0.08	8.47		
1.09	0.13	8.51		
0.86	0.10	8.44		

Consistency index =	(Lambda max-n)/(n-1) =	0.07	
Consistency =	Consistency index/random consistency index =		0.05
			<0.10
Random consistency index =	1.404		

Table A.7 : Detailed version of the analytical hierarchy process – sub-criteria/robustness.

ROBUSTNESS	Urban design	Infrastructure	Coordination	Accessibility
Urban design	**1.00**	0.19	0.42	0.84
Infrastructure	5.14	**1.00**	4.25	5.29
Coordination	2.39	0.24	**1.00**	1.61
Accessibility	1.19	0.19	0.62	**1.00**
TOTAL	9.72	1.62	6.29	8.74

NORMALISATION	Urban design	Infrastructure	Coordination	Accessibility	Criteria Weights
Urban design	**0.10**	0.12	0.07	0.10	0.10
Infrastructure	0.53	**0.62**	0.68	0.61	0.61
Coordination	0.25	0.15	**0.16**	0.18	0.18
Accessibility	0.12	0.12	0.10	**0.11**	**0.11**

	Urban design	Infrastructure	Coordination	Accessibility	Weighted Sum Value
Urban design	**0.10**	0.12	0.08	0.10	0.39
Infrastructure	0.50	**0.61**	0.78	0.60	2.48
Coordination	0.23	0.14	**0.18**	0.18	0.74
Accessibility	0.11	0.11	0.11	**0.11**	**0.46**

Weighted Sum Value (t)	Criteria Weights (c)	t/c	Mean of t/c	Lambda max
0.39	0.10	4.01	**4.04**	**4.04**
2.48	0.61	4.09		
0.74	0.18	4.02		
0.46	0.11	4.04		

Consistency index =	**(Lambda max-n)/(n-1) =**	0.013	
Consistency =	Consistency index/random consistency index =		**0.015**
			<0.10
Random consistency index =	0.9		

Table A.8 : Detailed version of the analytical hierarchy process – sub-criteria/integration

INTEGRATION	Informing	Coordination	Urban design	Accessibility	Fares	Continuity
Informing	**1.00**	0.60	0.72	0.43	0.52	**0.28**
Coordination	1.66	**1.00**	2.41	0.57	0.70	0.69
Urban design	1.38	0.42	**1.00**	0.40	0.85	0.20
Accessibility	2.32	1.75	2.53	**1.00**	1.58	0.28
Fares	1.92	1.44	1.18	0.63	**1.00**	0.39
Continuity	3.53	1.44	5.07	3.62	2.59	**1.00**
TOTAL	**11.82**	6.64	12.91	6.65	**7.24**	**2.84**

NORMALISATION	Informing	Coordination	Urban design	Accessibility	Fares	Continuity	Criteria Weights
Informing	**0.08**	0.09	0.06	0.06	0.07	**0.10**	**0.08**
Coordination	0.14	**0.15**	0.19	0.09	0.10	0.24	**0.15**
Urban design	0.12	0.06	**0.08**	0.06	0.12	0.07	**0.08**
Accessibility	0.20	0.26	0.20	**0.15**	0.22	0.10	**0.19**
Fares	0.16	0.22	0.09	0.09	**0.14**	0.14	**0.14**
Continuity	0.30	0.22	0.39	0.54	0.36	**0.35**	**0.36**

	Informing	Coordination	Urban design	Accessibility	Fares	Continuity	Weighted Sum Value
Informing	0.08	0.09	0.06	0.08	0.07	**0.10**	**0.48**
Coordination	0.13	0.15	0.20	0.11	0.10	0.25	**0.94**
Urban design	0.11	0.06	0.08	0.07	0.12	0.07	**0.52**
Accessibility	0.18	0.26	0.21	0.19	0.22	0.10	**1.16**
Fares	0.15	0.22	0.10	0.12	0.14	0.14	**0.86**
Continuity	0.28	0.22	0.43	0.68	0.36	0.36	**2.32**

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lambda max
0.48	0.08	6.22	**6.24**	**6.24**
0.94	0.15	6.21		
0.52	0.08	6.18		
1.16	0.19	6.23		
0.86	0.14	6.16		
2.32	0.36	6.43		

Consistency index =	**(Lambda max-n)/(n-1) =**	0.048	
Consistency =	Consistency index/random consistency index =		**0.038**
			<0.10
Random consistency index =	1.24		

Table A.9 : Detailed version of the analytical hierarchy process – sub-criteria/inclusiveness

INCLUSIVENESS	Equity	Fares	Security and safety	Urban design
Equity	**1.00**	2.30	1.99	3.27
Fares	0.43	**1.00**	1.67	2.28
Security and safety	0.50	0.60	**1.00**	5.54
Urban design	0.31	0.44	0.18	**1.00**
TOTAL	2.24	4.34	4.83	12.09

NORMALISATION	Equity	Fares	Security and safety	Urban design	Criteria Weights
Equity	0.45	0.53	0.41	0.27	**0.41**
Fares	0.19	0.23	0.34	0.19	**0.24**
Security and safety	0.22	0.14	0.21	0.46	**0.26**
Urban design	0.14	0.10	0.04	0.08	**0.09**

	Equity	Fares	Security and safety	Urban design	Weighted Sum Value
Equity	0.41	0.55	0.51	0.29	**1.77**
Fares	0.18	0.24	0.43	0.20	**1.05**
Security and safety	0.21	0.14	0.26	0.50	**1.10**
Urban design	0.13	0.11	0.05	0.09	**0.37**

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lambda max
1.77	**0.41**	**4.27**	**4.27**	**4.27**
1.05	**0.24**	**4.39**		
1.10	**0.26**	**4.30**		
0.37	**0.09**	**4.11**		

Consistency index =	**(Lambda max-n)/(n-1) =**	0.089	
Consistency =	Consistency index/random consistency index =		**0.099**
			<0.10
Random consistency ir	0.9		

Table A.10 : Detailed version of the analytical hierarchy process – sub-criteria/redundancy

REDUNDANCY	Frequency of journeys	Accessibility	Infrastructure	Coordination
Frequency of journeys	**1.00**	0.83	0.34	0.32
Accessibility	1.20	**1.00**	0.16	3.81
Infrastructure	2.91	6.14	**1.00**	3.38
Coordination	3.11	0.26	0.30	**1.00**
TOTAL	8.22	8.23	1.80	8.51

NORMALISATION	Frequency of journeys	Accessibility	Infrastructure	Coordination	Criteria Weights
Frequency of journeys	**0.12**	0.10	0.19	0.04	**0.11**
Accessibility	0.15	**0.12**	0.09	0.45	**0.20**
Infrastructure	0.35	0.75	**0.55**	0.40	**0.51**
Coordination	0.38	0.03	0.16	**0.12**	**0.17**

	Frequency of journeys	Accessibility	Infrastructure	Coordination	Weighted Sum Value
Frequency of journeys	**0.11**	0.17	0.18	0.06	**0.51**
Accessibility	0.14	**0.20**	0.08	0.66	**1.08**
Infrastructure	0.33	1.24	**0.51**	0.58	**2.66**
Coordination	0.35	0.05	0.15	**0.17**	**0.73**

Weighted Sum Value (t)	Criteria Weights (c)	t/c	Mean of t/c	Lambda max
0.51	**0.11**	**4.54**	**4.82**	**4.82**
1.08	**0.20**	**5.36**		
2.66	**0.51**	**5.19**		
0.73	**0.17**	**4.21**		

Consistency index =	**(Lambda max-n)/(n-1) =**	0.275	
Consistency =	Consistency index/random consistency index =		**0.31**
			<0.10
Random consistency index =	0.9		

Table A.11 : Detailed version of the analytical hierarchy process – sub-criteria/pandemics and epidemics

PANDEMICS & EPIDEMICS	The capacity of vehicles	Security and safety	Duration of the trip	Distance of the trip	Frequency of journeys
The capacity of vehicles	**1.00**	0.18	0.43	0.46	0.29
Security and safety	5.69	**1.00**	2.29	2.48	3.47
Duration of the trip	2.32	0.44	**1.00**	2.59	2.13
Distance of the trip	2.16	0.40	0.39	**1.00**	**0.64**
Frequency of journeys	3.47	0.29	0.47	1.55	1.00
TOTAL	**14.65**	**2.30**	**4.58**	**8.09**	**7.53**

NORMALISATION	The capacity of vehicles	Security and safety	Duration of the trip	Distance of the trip	Frequency of journeys	Criteria Weights
The capacity of vehicles	0.07	0.08	0.09	0.06	0.04	**0.07**
Security and safety	0.39	0.43	0.50	0.31	0.46	**0.42**
Duration of the trip	0.16	0.19	0.22	0.32	0.28	**0.23**
Distance of the trip	0.15	0.17	0.08	0.12	0.09	**0.12**
Frequency of journeys	0.24	0.13	0.10	0.19	0.13	**0.16**

	The capacity of vehicles	Security and safety	Duration of the trip	Distance of the trip	Frequency of journeys	Weighted Sum Value
The capacity of vehicles	0.07	0.07	0.10	0.06	0.05	**0.34**
Security and safety	0.38	0.42	0.54	0.31	0.55	**2.19**
Duration of the trip	0.16	0.18	0.23	0.32	0.34	**1.23**
Distance of the trip	0.14	0.17	0.09	0.12	0.10	**0.63**
Frequency of journeys	0.23	0.12	0.11	0.19	0.16	**0.81**

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lambda max
0.34	**0.07**	**5.14**	**5.17**	5.1713
2.19	**0.42**	**5.23**		
1.23	**0.23**	**5.25**		
0.63	**0.12**	**5.10**		
0.81	**0.16**	**5.14**		

Consistency index =	**(Lambda max-n)/(n-1)** = 0.043	
Consistency =	Consistency index/random consistency	**0.04** <0.10
Random consistency index =	1.12	

Table A.12 : Detailed version of the analytical hierarchy process – sub-criteria/resourcefulness

RESOURCEFULNESS	Low emissions	Energy efficiency	Compatibleness with technology
Low emissions	**1.00**	0.35	0.35
Energy efficiency	2.88	**1.00**	1.54
Compatibleness with technol	2.82	0.65	**1.00**
TOTAL	**6.71**	**2.00**	**2.89**

NORMALISATION	Low emissions	Energy efficiency	Compatibleness with technology	Criteria Weights
Low emissions	0.15	0.17	0.12	**0.15**
Energy efficiency	0.43	0.50	0.53	**0.49**
Compatibleness with technol	0.42	0.33	0.35	**0.36**

	Low emissions	Energy efficiency	Compatibleness with technology	Weighted Sum Value
Low emissions	0.15	0.17	0.13	**0.45**
Energy efficiency	0.43	0.49	0.56	**1.48**
Compatibleness with technol	0.42	0.32	0.36	**1.10**

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lamda max
0.45	**0.15**	**3.01**	**3.02**	**3.02**
1.48	**0.49**	**3.03**		
1.10	**0.36**	**3.02**		

Consistency index =	**(Lambda max-n)/(n-1)** = 0.009	
Consistency =	Consistency index/random consistency index =	**0.02** <0.10
Random consistency index =	0.58	

Table A.13 : Detailed version of the analytical hierarchy process – sub-criteria/flexibility

FLEXIBILITY	Unexpected weather conditions	Urban design	Natural disasters	Coordination
Unexpected weather conditions	**1.00**	2.59	0.69	1.53
Urban design	0.39	**1.00**	0.33	0.51
Natural disasters	1.44	3.03	**1.00**	**0.70**
Coordination	**0.65**	**1.97**	**1.43**	**1.00**
TOTAL	**3.48**	**8.59**	**3.45**	**3.73**

NORMALISATION	Unexpected weather conditions	Urban design	Natural disasters	Coordination	Criteria Weights
Unexpected weather conditions	0.29	0.30	0.20	0.41	**0.30**
Urban design	0.11	0.12	0.10	0.14	**0.11**
Natural disasters	0.41	0.35	0.29	0.19	**0.31**
Coordination	0.19	0.23	0.41	0.27	**0.27**

	Unexpected weather conditions	Urban design	Natural disasters	Coordination	Weighted Sum Value
Unexpected weather conditions	0.30	0.30	0.22	0.42	**1.23**
Urban design	0.12	0.11	0.10	0.14	**0.47**
Natural disasters	0.43	0.35	0.31	0.19	**1.28**
Coordination	0.20	0.23	0.44	0.27	**1.14**

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lamda max
1.23	**0.30**	**4.11**	**4.13**	**4.13**
0.47	**0.11**	**4.12**		
1.28	**0.31**	**4.13**		
1.14	**0.27**	**4.15**		

Consistency index =	**(Lambda max-n)/(n-1) =** 0.043	
Consistency =	Consistency index/random consistency index =	**0.05**
		<0.10
Random consistency index =	0.9	

Table A.14 : Detailed version of the analytical hierarchy process – sub-criteria/reflectiveness

REFLECTIVENESS	Infrastructure	Ambience and attractiveness	Compatibleness with technology
Infrastructure	**1.00**	2.52	23.37
Ambience and attractiveness	0.40	**1.00**	19.08
Compatibleness with technology	0.04	0.05	**1.00**
TOTAL	**1.44**	**3.57**	**43.45**

NORMALISATION	Infrastructure	Ambience and attractiveness	Compatibleness with technology	Criteria Weights
Infrastructure	0.69	0.71	0.54	**0.65**
Ambience and attractiveness	0.28	0.28	0.44	**0.33**
Compatibleness with technology	0.03	0.01	0.02	**0.02**

	Infrastructure	Ambience and attractiveness	Compatibleness with technology	Weighted Sum Value
Infrastructure	0.65	0.84	0.53	**2.01**
Ambience and attractiveness	0.26	0.33	0.43	**1.02**
Compatibleness with technology	0.03	0.02	0.02	**0.07**

Weighted Sum Value (t)	Criteria Weights	t/c	Mean of t/c	Lamda max
2.01	**0.65**	**3.11**	**3.06**	**3.06**
1.02	**0.33**	**3.07**		
0.07	**0.02**	**3.00**		

Consistency index =	**(Lambda max-n)/(n-1) =**	0.029	
Consistency =	Consistency index/random consistency index =		**0.05**
			<0.10
Random consistency index =	0.58		

Table A.15 : The determined values of random consistency index (T. L. Saaty, 1977)

Scale	Order of matrix													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1–5	0.000	0.244	0.335	0.472	0.479	0.527	0.580	0.577	0.611	0.591	0.623	0.632	0.641	0.629
1–7	0.000	0.515	0.504	0.708	0.798	0.827	0.922	0.961	0.968	1.012	1.019	1.054	1.052	1.052
1–9	0.000	0.416	0.851	1.115	1.150	1.345	1.334	1.315	1.420	1.395	1.482	1.491	1.470	1.466
1–15	0.000	0.705	1.733	2.024	2.416	2.349	2.351	2.525	2.674	2.749	2.693	2.804	2.827	2.806
1–20	0.000	1.326	2.044	2.948	3.354	3.428	3.598	3.709	3.807	3.719	3.899	3.888	3.895	3.971
1–90	0.000	3.206	10.411	15.452	16.096	17.603	17.454	18.580	19.110	18.747	19.695	19.857	19.990	20.052

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- **Beyazıt İnce, E., Şen, İ., Yargıç, İ., Sadeghpour, M., & Baran, Y.** (2020). *İklim Değişikliği Bağlamında Hareketlilik ve Aktif Yaşam*. (The report is prepared under IstanbulON Urban Mobility Lab)
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