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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Enhancement of City Liveability Model by Examining Sustainability, Resiliency and Smart City Dimensions

Şehirlerde Yaşanabilirlik Modelinin Sürdürülebilirlik, Dayanıklılık ve Akıllı Şehir Boyutları İncelenerek İyileştirilmesi

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Abstract

Liveability models of cities play an important role in many issues such as raising awareness in cities, determining management strategies, and determining and solving criteria that affect human life. However, current liveability models are inadequate in measuring liveability. For this purpose, the currently used EIU The Global Liveability Index model was evaluated and enriched by examining it from 3 aspects and turning it into a more comprehensive index in this article. Since sustainability, resilience and smart city index studies are intertwined with liveability, studies in these areas and their effects on liveability have been utilized. In addition to the equally weighted indicators under the 5 categories within the scope of this enriched model, missing indicators were added. Importance weighting has been done in terms of the impact of these indicators on liveability. This weighting study was carried out with the widely used Analytical Hierarchy Process (AHP) which is a systematic and consistent method. With the enriched index model, data of 6 cities were collected and a comparison study was carried out and applied. Melbourne has become the most liveable city among these cities. The revised liveability index is expected to provide a more comprehensive and reliable measure of the liveability of cities, considering a wide range of factors that can affect the life quality of residents. The enhanced index is expected to be useful for policymakers, urban planners, and researchers in assessing the liveability of cities and identifying areas for improvement. Ultimately, the goal of a liveability index is to provide a more reliable measure of the quality of life in cities, considering a wide range of factors that can affect residents' daily lives.

Keywords: Liveable City Index, Sustainability, Resiliency, Smart City, City Rankings, Liveability Index

Öz

Şehirlerin yaşanabilirlik modelleri, şehirlerde farkındalığın arttırılması, yönetim stratejilerinin belirlenmesi, insan hayatını etkileyen kriterlerin belirlenip çözüm geliştirilmesi gibi birçok konuda önemli rol oynamaktadır. Ancak mevcut yaşanabilirlik modelleri yaşanabilirliğin ölçümünde yetersiz kalmaktadır. Makalemizde bu amaçla halihazırda kullanılan "EIU The Global Liveability Index" modeli 3 açıdan incelenerek zenginleştirilmiş ve daha kapsamlı bir endeks haline getirilmiştir. Sürdürülebilirlik, dayanıklılık ve akıllı şehir endeksi çalışmaları yaşanabilirlik ile iç içe olduğundan bu alanlardaki çalışmalardan ve yaşanabilirliğe etkilerinden faydalanılmıştır. Zenginleştirilen bu model kapsamında 5 kategori altında yer alan eşit ağırlıklı göstergelerin yanı sıra yaşanabilirliğin ölçülmesinde elzem olan ve sonradan eklediğimiz göstergeler de yer almaktadır. Bu göstergelerin yaşanabilirliğe etkisi açısından önem ağırlıklandırması yapılmıştır. Bu ağırlıklandırma çalışması yaygın olarak kullanılan sistematik ve tutarlı bir yöntem olan Analitik Hiyerarşi Süreci (AHP) ile gerçekleştirilmiştir. Zenginleştirilmiş endeks modeli kullanılarak 6 ilin verileri toplanmış ve karşılaştırma çalışması yapılmıştır. Melbourne bu şehirler arasında en yaşanabilir şehir olarak gözlenmiştir. Güncellenen yaşanabilirlik endeksinin, şehir sakinlerinin yaşam kalitesini etkileyebilecek çok çeşitli faktörleri göz önünde bulundurarak şehirlerin yaşanabilirliğine ilişkin daha kapsamlı ve güvenilir bir ölçüm sağlaması beklenmektedir. Yeni endeksin politika yapıcılar, şehir planlamacıları ve araştırmacılar için şehirlerin yaşanabilirliğini değerlendirme ve iyileştirme alanlarını belirleme konusunda faydalı olması amaçlanmıştır. Sonuç olarak güncellenen yaşanabilirlik endeksinin amacı, şehir sakinlerinin günlük yaşamlarını etkileyebilecek çok çeşitli faktörleri göz önünde bulundurarak şehirlerdeki yaşam kalitesinin ölçümünün daha güvenilir bir şekilde yapılmasını sağlamaktır.

Anahtar Kelimeler: Yaşanabilir Şehir Endeksi, Sürdürülebilirlik, Dayanıklılık, Akıllı Şehir, Şehir Sıralaması, Yaşanabilirlik Endeksi

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I. INTRODUCTION

In recent years, the concept of a liveable city has received significant attention as cities struggle with challenges such as climate change, resource scarcity and the need for technological advancement and strive to provide a high life quality to their residents. Achieving liveability requires a comprehensive understanding of the various factors that contribute to a city's overall sustainability, resilience, and smartness. For this reason, the integration of different indices such as the sustainability index, smart city index and city resilience index becomes very important in creating the multidimensional structure of liveability. It is crucial to examine the details of other models to understand the liveability model structure. Three models, presented comprehensively in the literature review section, were used to enrich EIU The Global Liveability as content, and indicators related to liveability were determined.

The sustainability index assesses a city's environmental, social, and economic performance, measuring its ability to use current needs without harming the living standards of future generations. It covers topics such as energy efficiency, waste management, biodiversity, and social inclusion. Sustainability indexes are created worldwide through studies of different dimensions. There have been studies in which countries measured their cities and areas on a national basis. For example, the Sustainable City Index for Malaysia study is a study that measures the sustainability status of Malaysia's major cities [1]. In addition to general sustainability indexes, there are also studies such as Environmental Sustainability Index, Index of Sustainable Economic Welfare and Living Planet Index [2]. These studies particularly focus on the sustainability of designated areas. In this study, the scope was kept wide, and sustainability was examined from a broad perspective, as in the Environmental and Social Sustainability Index study which focuses not only environmental aspects but health and social perspectives [3]. Arcadis, which is a popular and comprehensive sustainability index, was examined. Arcadis index consists of 3 basic headings, and these are people, planet, and profit. With this study, it is aimed to provide a sustainability measurement focused on sustainability of people, nature, and economy.

The smart city index, on the other hand, assesses a city's use of technology and digital infrastructure to improve services, improve governance and foster citizen participation. It considers factors such as digital connectivity, smart transportation systems, e-governance, and innovation ecosystems. In addition to focusing on quality of life, smart cities focus on public safety and security [4]. At the center of this concept is governance and ITC. Governance and ICT are particularly important branches of a mechanism that enables city authorities to communicate with citizens and shape society. The smart city concept is also supported by institutions, organizations and organizations that work closely with city authorities and aim to provide solutions to the problems of cities. It is an inevitable fact that companies focus on this area. Some organizations create frameworks by doing their own work [5].

Finally, the resilient city index focuses on a city's ability to recover from shocks and stresses, including natural disasters, epidemics, and socioeconomic disruptions. It covers aspects such as disaster preparedness, emergency response systems, community engagement and adaptive infrastructure. Apart from the concept of sustainability, the concept of resilience has come to the fore with the increase in crises around the world. Particularly in Spain, where these crises are more visible, resilience studies are focused on this issue [6]. Since resilience also focuses on strategic issues, it has become one of the priority issues of states. There are also studies such as Strategic Resilience Indicators in this field and it has been an important source in determining the topics that will pose problems in the future [7].

While these existing indices provide valuable information on specific aspects of urban development, a more holistic approach is required to comprehensively assess liveability. By integrating the sustainability, smart city and flexible city indices, an improved liveability index can be developed that considers the interdependencies and synergies between these different dimensions. This new index provides a comprehensive framework for evaluating and comparing cities based on their ability to create sustainable, smart, and resilient environments that improve the quality of life of their residents.

The aim of this article is to enhance EIU The Global Liveability Index by synthesizing criteria and indicators from the existing sustainability, smart city, and resilient city indices as seen in Figure 1. A new framework will be proposed by analyzing the components of each index, identifying overlapping criteria, and exploring the potential complementarity of various factors. This framework will provide a comprehensive assessment of a city's liveability, considering its environmental sustainability, technological advances, and resilience to shocks and stresses.

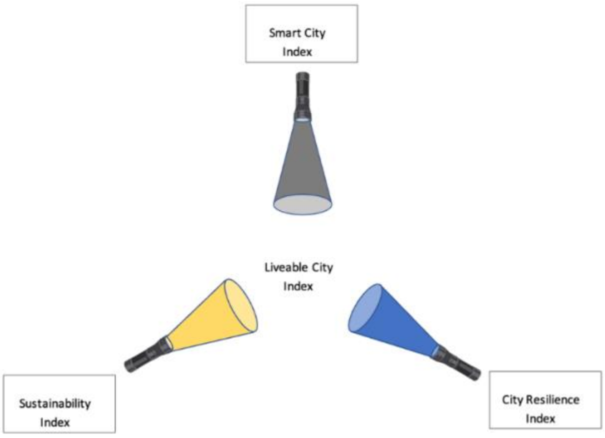

Figure 1. Liveable City Index Based on Sustainability, Resiliency and Smart City Index Dimensions

Moreover, this article aims to highlight the importance of including certain criteria from the resilience index, such as earthquake resistance, and the smart city index, such as response to pandemics, such as COVID-19, in the liveability index. Considering density, which is one of the liveability indicators, it has been observed that low density is safer for COVID-19 [8]. Likewise, the connection between liveable city and disaster management also has an impact on the quality of life [9]. By including these critical dimensions, the developed liveability index will more accurately present a city's ability to provide a high quality of life to its people under various conditions.

Through the enhancement of this liveability index, policymakers, urban planners and stakeholders will have a comprehensive tool to guide their decision-making, policy-making and urban development strategies. This index will contribute to the development of sustainable, smart, and resilient cities that prioritize the well-being and liveability of their citizens.

Liveability is also included in other concepts. Liveability and quality of life are at the forefront of smart city indexes. A significant number of indicators included in smart city indices have a positive impact on liveability [10]. For example, because of the study on green infrastructure, which is accepted as one of the smart city indicators in the USA, it has been observed that the sustainable construction of features such as building materials and water use have a positive effect on liveability [11]. There are also studies emphasizing that cities with low liveability rates can plan these problems for the future based on smart city applications [12].

The relationship between liveability and resilience is also seen in long-term studies. Creating a resilient city is of great importance for the formation of a livable city on a long scale [13]. Sustainability and viability focus on similar areas in many respects. Social life is one of these areas. Social life, which expands from the family size to the size of cities and even countries, shows the connection between liveability and sustainability. For example, neighborhood relations have been evaluated as a subject that affects the quality of life for both concepts. This example can also be evaluated under the subject of social communication in the city dimension [14].

Overall, this article represents an important step towards developing a comprehensive liveability index that integrates the dimensions of sustainability, smart city, and resilient city. By synthesizing these indices and combining specific criteria for liveability, this research aims to contribute to efforts to build more liveable cities that are sustainable, smart, and resilient in the face of future challenges. The added value of this study is to both enrich an existing index study with a broad perspective and ensure that the equally weighted indicators in the existing index are weighted in order of importance by taking expert opinion. In this way, the liveability of cities will be measured with a more accurate and consistent scoring.

In this article, firstly, a comprehensive literature review was conducted under the title of literature on sustainable, liveable, resilient, and smart city index. Secondly, under the heading of methodology, indicators that were observed to improve the liveability-related index were determined and added to index. The liveability categories of stability, healthcare, culture and environment, education and infrastructure were examined, and aimed to improve the existing index by adding relevant indicators. The index indicators have been weighted by experts. Additionally, the Analytic Hierarchy Process (AHP) method was used to weigh the indicators, providing a systematic and consistent approach to assess the liveability of cities. Finally, under the result and discussion heading, six different cities were compared according to the current index and the results were interpreted. Enhancing the Global Liveability Index with current issues and a very comprehensive perspective such as smart city, sustainability and resiliency makes this study different from other indices.

2. LITERATURE REVIEW

When the literature was examined within the scope of the liveability study of cities, it was observed that there were common structures at many points with the concepts of sustainability, resiliency, and smart city. Based on these similarities, we focused on the parts included in these 3 index studies that may have an impact on liveability. For a comprehensive study, four city indexes including liveability, sustainability, resiliency, and smart city were examined in the literature review, and sections related to liveability were identified. The methods used in these index studies were mentioned. Furthermore, the created index study was used for weighting on 6 cities with similar, different cultures and structures. Literature such as standards used in the world and accepted organizational outputs are also explained under this title.

In recent years, urbanization has been spreading rapidly, with more people claiming cities as their living spaces than ever before. As the world becomes more and more urbanized, the concept of "liveable city" has become important for country and city managers, city planners, architects, and researchers alike. The creation of features that increase the quality of life for city residents has brought along large-scale studies created in this context. The Green Agreement of the European Union (EU) and the Inflation Reduction Act (IRA) of the USA can be shown as works aimed at increasing the quality of life as well as creating economic and environmental value.

The concept of liveability encompasses a multidimensional framework that targets the quality of life and well-being of city residents. It aims to take steps for social structure in addition to physical infrastructure, considering social, economic, environmental, and cultural dimensions. Besides obvious issues such as housing or sustainable transportation systems; it is a holistic goal that aims to promote equitable, inclusive, and sustainable urban environments.

Enhancing a liveable city index is the main subject of this article. The index to be compared while doing this study is EIU The Global Liveability Index. The reason for choosing this index is that it is a comprehensive and regularly published study and was created by experienced staff. The methodology was used by experienced teams for qualitative content and from existing external data for quantitative content. It was carried out through benchmarking studies [15].

The Global Liveability index consists of 30 indicators in 5 categories. These indicators are used to measure the liveability of cities and city rankings are made thanks to the surveys made. These five categories were determined as Stability, Healthcare, Culture & Environment, Education, and Infrastructure. Evaluated cities are named as acceptable, tolerable, uncomfortable, undesirable, or intolerable. Qualitative indicators are arranged because of internal evaluation. Quantitative indicators are arranged in line with data from external data sources. According to the calculations, a rating between 1-100 is created. 1 is intolerable and 100 is ideal. The liveability rating is given as points for all categories and indicators. The liveability score is calculated through category weights distributed equally into subcategories. In Table 1, The Global Liveability City Index category and indicators are listed [16]. The indicators shown below are weighted equally in the currently used index. This shows that the importance ranking between the indicators is not achieved. The system was developed by weighting the indicators by taking expert opinions in the categories determined in the methodology section.

The new indicators included in the enriched index are designed to be placed under the relevant 5 categories and shown under the methodology heading. In this study, a weighting study was carried out for the categories that included the added indicators. Other categories were accepted as equally weighted, and no updates were made.

Table 1. EIU The Global Liveability City Index

Category 1: Stability (weight: 25% of total)
Prevalence of petty crime
Prevalence of violent crime
Threat of terror
Threat of military conflict
Threat of civil unrest/conflict
Category 2: Healthcare (weight: 20% of total)
Availability of private healthcare
Quality of private healthcare
Availability of public healthcare
Quality of public healthcare
Availability of over-the-counter drugs
General healthcare indicators

Table 2. EIU The Global Liveability City Index (cont.)

Category 3: Culture and Environment (weight: 25% of total)
Humidity/temperature rating
Discomfort of climate to travelers
Level of corruption
Social or religious restrictions
Level of censorship
Sporting availability
Cultural availability
Food and drink
Consumer goods and services
Category 4: Education (weight: 10% of total)
Availability of private education
Quality of private education
Public education indicators
Category 5: Infrastructure (weight: 20% of total)
Quality of road network
Quality of public transport
Quality of international links
Availability of good quality housing
Quality of energy provision
Quality of water provision

Arcadis is a company that provides consultancy support on issues such as project, management, and design with the aim of improving the quality of life. Arcadis Sustainable Cities Index is one of its studies that has been published periodically since 2015. This index, used in the context of sustainability, was created in a citizen-centric structure. It was designed by experts in the field of indicators and methodology, using previous experience and data [17]. The method used in the Arcadis Sustainability Index report is based on average weighting. Indicators in the subcategory are mostly calculated equally by taking weighted averages. The expert team determined the weights and weighed them [18].

Boyd Cohen Smart City Index was designed by Boyd Cohen, primarily on the creation of a smart city framework for medium-sized cities. Cohen, whose smart city ranking studies started in 2012, created a comprehensive study with the methodology he created in 2014. It ranked the data collected from the specified cities using indicators. He applied the z-score to transform it into standard and meaningful data [19]. Using this study, the way has been paved for the evaluation of different cities within the scope of smart cities [20].

The Resilience Index is a framework created in 2014 as a joint effort by Arup and the Rockefeller Foundation [21]. There are 12 indicators in this framework created for the evaluation of cities. City data obtained according to this framework is analyzed. In this context, quantitative data were converted into numerical numbers and the World Council for City Data reporting on the International Organization for Standardization (ISO): 37120 standard was used for performance measurement. Based on available data, hypothetical profiles from 1 to 10 were created. A Standard distribution has formed between very poor performance and great performance. After then, a study was conducted with 12 external experts and 10 Arup industry experts to validate the approach established [22].

This study presents a comprehensive liveability index enriched with the liveability aspects of sustainability, resilience, and smart city dimensions. Therefore, information about these dimensions is given in the following subsections.

2.1. Sustainability and Sustainable City Indicators

Sustainability has become a topic of increasing popularity as concerns about the future begin to increase. Problems affecting the balance of the world such as climate change, air pollution, rapid population growth and the need to build a better future encourage societies to take different measures. Establishing sustainable living spaces is one of the priority targets in this context. The rapid increase in the human population and the fact that a large part of this population lives in cities increases the importance of sustainability even more. The urban population, which was 55% in 2018, is estimated to be 65% in 2050 [23]. The increase in population and density in urban areas also brings various social, economic, and environmental effects. Some of the effects observed in recent years can be given as examples such as income inequality, poverty, lack of education, and inability to access resources [24]. Organizations such as the United Nations take some measures to minimize these effects and to build a sustainable world. The goals established for Sustainable Development are one of them. It is aimed to create a sustainable and resilient world with 169 goals created under 17 headings, thanks to objectives such as hunger, peace, education quality and gender equality [25].

It is necessary to define the concepts of sustainability and sustainable development to better understand these structures. Although sustainability is such a broad and comprehensive concept that it cannot be expressed with a single explanation, different institutions/organizations have explained it with similar definitions. According to the definition of the World Bank, sustainability has been defined as the basis of this generation and it is a requirement to potentially transfer the quality of life to all future generations [26]. On the other hand, a definition made by the International Union for Conservation of Nature (IUCN)/ United Nations Environment Programme (UNEP)/ World Wide Fund (WWF) is as follows: "Sustainability is improving the quality of human life while living within the carrying capacity of supporting eco-systems" [27]. One of the common points of the definitions is to focus on what needs to be done to create a livable place for future generations. The relationship between the concept of liveability and sustainability will be examined in detail in the following titles.

Although sustainability and sustainable development are stated as similar concepts in some sources, different definitions are also made. Since sustainable development is a comprehensive process, it can be defined as the work done to ensure sustainability. Another definition of sustainable development is: "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [28]. United Nations Educational, Scientific and Cultural Organization (UNESCO) has defined sustainability as a long-term goal for all people, cities, and countries [29].

Index studies can be used to determine different characteristics of cities. In addition to liveability, resiliency and smart city indexes, sustainable cities index are the indexes to be focused on in this article. The sustainability index consists of 3 subheadings. The pillars of people (social), planet (environmental) and profit (economic) form the basis of sustainability. There is a comprehensive list of indicators under each heading [30]. With the announcement of the United Nations' Sustainable Development Goals call for action, an infrastructure was created that supports the national plans of governments for sustainable development. The evaluation of cities by index studies of institutions is also in line with these purposes. For instance, an index study was conducted for Mexican cities, considering the UN SDGs [31]. Likewise, in a study called "China Urban Sustainability Index", cities in the range of 200,000 – 2,000,000 people were evaluated within the scope of the index [32]. As a comprehensive city index study, Arcadis the Sustainable Cities Index measured 100 different cities with people (social), planet (environment) and profit (economic), which form the basis of sustainability. The important outcomes of this index study include the long-term contribution of profit pillars to sustainability, the need for performance improvement in mid-level cities in all areas, and the importance of digitalization in the services provided by cities [30]. In this study, Arcadis's framework will be used as a sustainable city index. While creating the index, indicators were determined under 3 main headings. These indicators are also weighted with the determined methodology.

In the Sustainable Cities Index, a three-stage averaging process was used. Some indicators are composite, meaning they average over their component sub-indicators. The three sub-indices are calculated by taking the weighted averages of the component indicators, and the total score is calculated using the simple average of the three sub-indices [17].

2.2. Resiliency and Resilient City Indicators

The concept of resilient city, like the other concepts mentioned earlier, is a subject defined by different organizations with their own work. Organizations such as the United Nations, The Organization for Economic Co-operation and Development (OECD) and The Rockefeller Foundation have made definitions and created infrastructure and index studies for cities to have a resilient structure. It is important to establish an integrated management and a durable structure between countries. Many countries have created their own resilient plans. Countries that create resilient plans on many subjects such as economies, societies, institutions, environment, natural disaster attach importance to different titles according to their internal structures [33].

Resilience was used as an ecology term in the 1970s but has recently emerged as a broad definition. City Resilience Index study definition is as follows: "City resilience describes the capacity of cities to function, so that the people living and working in cities – particularly the poor and vulnerable – survive and thrive no matter what stresses or shocks they encounter" [34].

According to the definition of the United Nations, resilience focuses on the ability of a system or structure exposed to hazards to quickly and effectively resist, absorb, adapt, and recover from the effects of that hazard, while preserving its essential properties and functions [35]. Because resilience is considered as a process, plans and effects are created for long periods of time. As stated in the definition, resilience against natural disasters is an important criterion for cities. For city-sized systems, the purpose of natural disaster resilience is the survival of these Urban Systems for a long time of periods [36].

City Resilience Index of The Rockefeller Foundation - Arup was chosen as the Resilient City index to enhance the liveability index in this article. This index is a comprehensive study that contributes to the comparison and development of cities. Although the even distribution of indicator weightings may seem problematic in terms of focusing on high priority issues, it is a valuable and educational study for city managers [37]. Qualitative and quantitative perspectives were used in the study. Under the 4 main pillars, 12 goals, 52 indicators and 156 sub-indicators were created. With these indicators, quantitative data are collected. It is also evaluated under the 7 qualities of a resilient system where the quantitative structure is determined for each indicator question. The 7 pillars used to evaluate cities in terms of their qualities are given below.

- Reflectivity
- Resourcefulness
- Robustness
- Redundancy
- Flexibility
- Inclusivity
- Integration

In Resilience Index, quantitative data were converted into numerical numbers and the World Council for City Data reporting on ISO: 37120 standard was used for performance measurement. Based on available data, hypothetical profiles from 1 to 10 were created. A Standard distribution has formed between very poor performance and great performance. After then, a study was conducted with 12 external experts and 10 Arup industry experts to validate the approach established [22].

2.3. Smart City and Smart City Indicators

Cities have been evaluated in many different contexts in recent years. Popular concepts such as 'Connected City', 'Calm City', 'Green City', 'Sustainable City', 'Brand City', 'Innovative City' and 'Digital City' are defined for cities. With these concepts, cities aim to attract investments, increase tourism income, and prevent unemployment by providing employment. Although all these concepts create a movement in the cities, none of these concepts fully express the city and its inhabitants. This is where the concept of the smart city comes to the fore. It includes inter-object communication, sustainability, innovation and digitality in cities.

Before explaining what, a smart city is, it would be helpful to explain what a smart city is not. Smart parking systems, smart streetlights, the expansion of the Wi-Fi network in the city and smart agriculture applications are city projects, but they do not represent the smart city when applied alone. It is a limited and incomplete approach to see the definition of smart city as the creation of livable cities by combining information technologies with city management studies. Since the concept of Smart City is a new and changing concept, it is possible to talk about many definitions. Cities, institutions, organizations, and companies that make the definitions bring different definitions to the Smart City according to their own perspectives. Smart City definitions of some institutions and organizations are given below.

European Commission (EC) defines the concept as a place where traditional structures are made more efficient by using digital solutions to meet the demands of citizens and the business world [38].

Republic of Turkey Ministry of Environment, Urbanization and Climate Change's definition is "Smart City is defined as an approach that ensures that interoperable systems developed with cooperation between stakeholders meet expectations and problems with future foresight based on data and expertise" [39]. Purposes of smart cities are listed in national Smart City Strategy as:

- Construct the expectations and needs of cities as a triggering mechanism in all structures of the city,
- Advance the structure with three legs: physical, social, and digital,
- Comprehensively anticipate, identify, and resolve emerging difficulties,
- Create conditions suitable for development by ensuring communication of the structures in the city.

The International Telecommunication Union (ITU) uses the term smart sustainable city in its definitions. The main idea of the concept is a city that uses information and communication technologies (ICT) and many different tools to increase the quality of life, urban management and efficiency and competitiveness, while also meeting the needs of current and future generations without harming economic, social, environmental, and cultural values [40].

OECD's approach to the smart cities is that emphasizing that digitalization-enabled approaches should be created to create collaborative, multi-stakeholder and inclusive urban structures that increase the well-being of citizens [41]. For The British Standards Institution (BSI) smart city is important that the systems that design a sustainable, prosperous, and inclusive future for their citizens should be effectively integrated into the environments [42].

Smart city indices are evaluated in different scopes and formed according to the dynamics of institutions and countries. Indicators and titles created by the change of cities and city management styles may change. Looking at the definitions of smart cities, it is seen that the concept of ICT has a common denominator. Digitization and data are also evaluated in this context.

Organizations such as the UN, Smart City Council, EU, ISO, and companies such as Frost & Sullivan experienced consultancy company in the field of smart city have created various functional areas. Frost & Sullivan created a measurement model for the Smart City on eight parameters. Cities are measured with these parameters listed as smart governance, smart energy, smart building, smart mobility, smart infrastructure, smart technology, smart healthcare, and smart citizen [43].

The cities of 28 countries that are members of the EU are examined within the scope of six functional areas created for smart city indicators. According to the EU, these are Smart Governance, Smart People, Smart Living, Smart Mobility, Smart Economy, and Smart Environment. In the document named "Mapping Smart Cities in the EU" published by the European Union in 2014, the smart city foundations and the functional areas where smart city maturity can be founded [44].

Giffinger developed one of the most prominent parameters of smart cities and Boyd Cohen improved the idea and created Smart Cities Wheel [45]. In this article, Boyd Cohen's smart city study was used to establish the connection with liveability. 6 smart city characteristics are described which are smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. To rank the cities, Giffinger described 74 indicators under the 6 characteristics [46]. European cities generally ranked high in the outcomes of this study. The sum of the pillar values of each city gives the evaluation result of that city. There are cities with some low pillar values but a high total smart city ranking. For instance, Luxembourg ranked first among mid-sized cities with populations ranging from 100,000 to 500,000. While the smart economy is Luxembourg's strongest feature, creativity and flexibility are below average. Ruse is the last city on the list, although some of the pillars. The city ranks 53rd out of 70 cities in the smart economy rankings. However, it ranks last because it received lower scores compared to other cities in other pillars [46]. Looking at these examples, cities need to consider the indicators included in each pillar to improve their rankings in the smart city index.

A detailed study has been done at the smart city pillar level and the categories are well defined. Smart Governance is defined as the management of all services and interactions that enable the communication of public, private, civil society, and European Union institutions so that the city can work effectively. Smart Economy includes online business and e-commerce, high productivity rate, ICT-oriented production and services, and the creation of new business models. It also builds smart clusters and eco-systems. Smart Mobility encompasses ICT-based and integrated logistics and transportation systems. The Smart Environment pillar focuses on efficient energy sources, smart energy networks, measurement, control and monitoring, inspections and renewal of facilities, green buildings, and efficient use of green city needs. Smart People covers topics such as ICT-based work, access to education and training, adapting to human resources and capacity management, with the aim of creating an inclusive society that fosters creativity and supports innovation. Smart Living focuses on lifestyles, behaviors and consumption habits created with ICT supported solutions [42].

In Smart City Index, a set of indicators has been assigned to measure the six components of Dr. Boyd Cohen's Smart Cities Wheel. Each component consists of 3 indicators, a total of 19 sub-indicators. There are 62 indicators under these indicators. It has been simplified by selecting 400 indicators from different sources and reducing it to 62. 16 of these indicators target the new sustainable cities ISO standard (ISO 37120). The index created was evaluated for 120 cities, but the data of 11 cities could be collected. Data from each of the 11 cities was optimized using a mathematical formula called the z-score. Each of the 6 components was weighted to assign a maximum of 15 points. It was ensured that the city, which is the leader in each component, can be ranked in such a way that it can get a maximum of 90 points [47].

In the index studies described in the literature review, indicators that were seen to be linked to liveability and were predicted to contribute to liveability were determined. These indicators are 6 in total, 2 from the smart city index, 2 from the city resiliency index and 2 from the sustainability index. The positioning of these indicators in the liveability index, their explanations, and the category they fall into are explained in the methodology section.

After this section, the methodology where the method to be used for the index is explained in detail.

III. METHODOLOGY

In this section, existing index studies are evaluated in many contexts and the methods and processes necessary to further develop The Global Liveability Index study are mentioned. Some revisions were made to enrich The Global Liveability Index model detailed in the literature review. Thus, this current index to be used for the measurement of cities has been made understandable and easy to apply.

As mentioned in Table 1, it has been decided under which heading the relevant indicators included in the index consisting of 5 categories should be positioned. However, it has been observed that some indicators do not fit into existing categories. In this context, the title of the 3rd category, designated as "Culture and Environment", is considered under “3.1 Culture” and “3.2 Environment”. Hence, the "Culture and Environment" category, which has a weight of 25% in the total index, is divided equally and the "Culture" category is designed as 12.5% and the "Environment" category is designed as 12.5%.

There are 6 indicators recommended in the Global Liveability Index to prevent deficiencies arising from existing risks and negativities. Work-Life Balance, Effective mechanism for communities to engage with government, Green Space per Capita, Ease of Doing Business, Density, Supportive Financing Mechanism indicators are in the categories specified in the Table 2 below. Correct implementation of the weight of these indicators and their compatibility with other indicators are necessary for the accuracy of the index.

The process of weighting indicators within the Liveability Index is a crucial step that requires careful consideration. Several methodologies can be employed to assign appropriate weights to the diverse indicators from each dimension. When enhancing a new index for a livable city, it's important to employ robust survey methods to gather reliable and comprehensive data. Assessment of liveability index requires professionals and experts in relevant fields such as urban planning, architecture, sustainability, transportation, and social welfare. While creating existing indexes, the weighting of the indicators is done by experts. In the index study, which was enriched in the same way, a similar weighting was made by using the opinions of the people. The information shared by these experts can contribute to the determination of weights for different indicators in the index. To identify relevant experts, specific areas related to the liveability index were agreed. These are chosen from among urban planners, architecture, sustainability experts, transportation experts, experts in the fields of social welfare, environmental studies, and public health. Experts were determined according to their qualifications, experience, and knowledge in the relevant fields. Various expert groups are targeted to provide a comprehensive perspective.

A questionnaire was prepared focusing on different areas that are related to the dimensions of liveability. This survey contains a list of indicators or factors that contribute to liveability. A weight was assigned to each indicator and experts were asked to rate the importance of each indicator on a determined scale.

A rigorous and versatile methodological approach were used to design the liveability index that reflects the intertwined dimensions of sustainability, resilience, and smart city indicators. In this approach, the Analytical Hierarchy Process (AHP) decision making method was used. AHP method is used for measurement of cities from different perspective. “Measuring liveability of cities is an important task as it provides useful information to the people who would like to choose the best place to live” [48].

The indicators that contribute to the liveability index by progressing through common points and that are included in other indexes are given in Table 2 and explained afterward. The added indicators are positioned under the most appropriate categories.

Table 3. Indicators Selected from Sustainability, Smart City, and Resilience Indexes included in Liveability Index

Indicator- Category			
C1. Stability	**C3.1. Culture**	**C3.2. Environment**	**Index**
Work-Life Balance			*Sustainability Index*
Ease of Doing Business			*Sustainability Index*
Supportive Financing Mechanism			*Resilience Index*
	Effective mechanism for communities to engage with government		*Resilience Index*
		Green Space per Capita	*Smart City Index*
		Density	*Smart City Index*

3.1. Identification of included indicators

Below, the specified indicators are explained and why they are included in the index is explained.

3.1.1. Work-Life balance

The "Work-Life Balance" indicator in the Arcadis Sustainability Index is closely related to the concept of liveability and can significantly influence the overall assessment of a city's liveability. Work-life balance refers to the equilibrium between one's professional and personal life, ensuring that work commitments do not overly encroach on personal time, well-being, and leisure activities. In this context, the best Work-Life balance 2019 index was prepared, considering workload, corporate support, and liveability parameters. Global crises such as covid have reshaped the work-life balance. Occupational branches whose infrastructure and business scope are suitable for this have tried to overcome this crisis with methods such as remote working. It has become important for employers and employees to have an infrastructure in this regard. On the other hand, remote working conditions that are not properly planned result in increased working hours. All these factors are important for work-life balance [17].

3.1.2. Ease of doing business
Quality of life is an important factor in attracting and retaining talent or professionals, especially given working conditions. The "Ease of Doing Business" indicator in the Arcadis Sustainability Index relates to the business-friendly and regulatory environment of a city or country. It evaluates factors such as ease of starting and operating a business, obtaining permits, access to credit, protecting investors and enforcing contracts. There are important indirect links between "Ease of Doing Business" and "Liveability". The high number of procedures can cause unnecessary expenses for a large part of people's work. Good management of these processes can improve the quality of life [17].

3.1.3. Supportive financing mechanisms
The "Supportive Financing Mechanisms" indicator in the Resilience City Index refers to the availability and effectiveness of financial tools and mechanisms that support sustainable development and improve the quality of life in a city. Therefore, while there is no direct information that states the relativity of the "Supportive Financing Mechanisms" indicator with liveability, quality of life, and liveable city index, there is evidence to suggest that supportive financing mechanisms can affect economic growth, which is a crucial factor in determining the liveability of a city [29].

3.1.4. Effective mechanisms for communities to engage with government
The "Effective Mechanisms for Communities to Engage with Government" indicator in the Resilience City Index is closely related to the concept of liveability and has a significant impact on the overall assessment of a city's quality of life. Well-being is a dimension of liveability that is constantly concerned with community participation and social interaction. In this context, participation and, accordingly, governance has an important place in improving people's quality of life [29].

3.1.5. Green space per capita
Access to green spaces, such as parks, gardens, and natural areas, has been consistently linked to improved physical and mental well-being. Green spaces offer opportunities for exercise, relaxation, and stress reduction, which contribute to residents' overall health and quality of life. Urban green spaces offer people more livable environmental conditions thanks to their refreshing and ecological benefits [49]. Organizations like the World Health Organization (WHO) and urban planning associations consistently highlight the positive impact of green spaces on residents' well-being [50].

3.1.6. Density
The "Density" indicator in the Arcadis Sustainability Index refers to the population density of a city, which is the number of people living per unit of land area. While there isn't a straightforward or universally agreed-upon relationship between density and liveability, there are complex and multifaceted dynamics that influence how density can impact a city's quality of life. One of the biggest problems in an earthquake is that it is difficult to reach places with high density and to take aid. At the same time, major problems can occur if infrastructures such as electricity, water and natural gas are disrupted in places where there is a dense population [50].

The proposed index is shown in Table 3 below. This table includes indicators that are compatible with liveability in other index studies and are included in the newly created index. The sections highlighted in bold under the categories are the newly added indicators. No changes were made as no indicators were added to other categories. The final version of the updated index is given in Table 9. Moreover, the importance weights of the main categories which already exist in the current index are not changed. The revision is only made for the categories including the added indicators. All the indicators within the related categories as seen in Table 3 are considered and AHP is applied to determine the local importance weights of them.

Table 4. The proposed Liveability Indicators with their descriptions

Category 1: Stability (Weight: 25% of total)	**Definition**
Prevalence of petty crime	Simple amount of crime (theft, extortion, etc.)
Prevalence of violent crime	The amount of violent crime (murder, stabbing, etc.)
Threat of terror	Cities with terrorist threat experience security and peace problems that reduce the quality of life.
Threat of military conflict	Military conflict is a major security issue
Threat of civil unrest/conflict	Civil conflict/unrest is an issue that negatively affects the quality of life.
Work-life Balance	**Balance between the amount of time spent at work and time spent in private life**
Ease of doing business	**The importance of the regulatory and financial environment that facilitates the smooth running of business**
Supportive financing mechanisms	**Finance structure that allows businesses to adapt to changing circumstances and leverage contingencies against shocks.**
Category 3.1: Culture (Weight: 12.5% of total)	**Definition**
Level of corruption	Abuse of entrusted management authority for private gain
Social or religious restrictions	Presence of masses who are subject to religious and social discrimination in society
Level of censorship	Social and cultural censorship
Sporting availability	Availability of accessible sports infrastructure in the city
Cultural availability	Presence of historical and cultural infrastructure (museum, theater, cultural play, dance, etc.) in the city
Food and drink	Access to healthy food, presence of access to cultural food types
Consumer goods and services	Level of access to consumer products and services
Effective mechanisms for communities to engage with government	**Collective structure for communication and coordination between authorized institution and citizens.**
Category 3.2: Environment (Weight: 12.5% of total)	**Definition**
Humidity/temperature rating	Climatic conditions of the city (humidity, temperature) affect liveability positively or negatively.
Discomfort of climate to travellers	The city's life challenges for travelers (tourists, short-term visitors) are considered
Density	**Density of people in cities (km2/100,000 people)**
Green space per capita	**The ratio of green areas in the city to the sum of active and passive green areas (protected zones, military areas, forests, etc.)**

3.2. AHP Methodology

The Analytic Hierarchy Process (AHP) is a decision-making methodology that helps prioritize alternatives based on a set of criteria. It is a structured approach that helps prioritize and make decisions based on a set of criteria and alternatives. The AHP method is widely used in various fields, including engineering, management, and social sciences. The AHP method is based on the principle that complex decisions can be broken down into smaller and more manageable parts. The method involves dividing a decision problem into a hierarchy of criteria and sub-criteria, and then comparing the importance of each criterion and sub-criteria relative to each other. The AHP method uses pairwise comparisons to determine the relative importance of each criterion and sub-criterion. Pairwise comparisons are then used to calculate the weights of each criterion and sub-criteria used to make the final decision. The AHP method is a flexible and adaptable methodology that can be used to solve a wide variety of decision-making problems. To use the methodology, it is necessary to establish the general purpose and determine the weights of importance in the criteria [50].

The formulation proceeds in the following order. A matrix as shown in Table 3 is formed from the survey results obtained. This matrix is called the A matrix and is used as a pairwise comparison matrix. The main right eigenvector of matrix A is determined as 'w' [51].

Positive and reversed matrix equation 1 and equation 2 is shown:

$$e^{T} = (1,1,\ldots\ldots 1) \quad (1)$$

$$w = \lim_{k\to\infty} \frac{A^{k}.e}{e^{T}.A^{k}.e} \quad (2)$$

The pairwise comparison matrix with n objectives is an n × n matrix $A = \{a_{ij}\}$. In case of an incompatible matrix, the calculation must be repeated several times to solve the problem. To convert w to meaningful absolute values and normalized weight with the result, following equation 3, equation 4, equation 5, and equation 6 is used:

$$w = \lambda_{max}\, w, \qquad \lambda_{max} \geq n \tag{3}$$

$$\lambda_{max} = \frac{\sum a_j w_j - n}{w_1} \tag{4}$$

$$A = \{a_{ij}\} \quad a_{ij} = \frac{1}{a_{ij}} \tag{5}$$

- A: Pair wise comparison
- w: Normalized weight vector
- λ_{max} : Maximum Eigen value of matrix
- A a_{ij}: Numerical comparison between the values i and j
- In the next step, another formula $CR = CI/RI$ is used to validate the AHP results.
- CR: Consistency ratio
- CI: Consistency index

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

The purpose of using this formula is to determine that the results are measured consistently. Inconsistency ratio should be less than 0.10 for a healthy result [53].

3.3. Data collection

In this study, AHP, one of the multi-criteria decision making methods, was applied to measure global needs and problems and their impact on liveability. Due to its nature, AHP is an appropriate method in urban-scale regional planning in terms of both qualitative and quantitative indicator measurement. It is an important method to measure the liveability of cities. In addition, it can give advice to city managers to increase liveability [48].

The weighting was created through a pairwise comparison survey. All indicators are weighted by pairwise comparison with other indicators within their categories. The survey was conducted with experts who are highly aware of liveability in different areas. The experts who completed the survey are as follows, sustainability expert, smart city consultant, sociology professor, corporate consultant, economics professor, architect, and landscape architect. This study aimed to make a consistent weighting by taking the opinions of experts with different perspectives.

The experiences of seven experts were used to determine the importance weights of the indicators. The properties of the experts are as follows:

- A professor whose area of expertise is sustainable finance,
- An engineer with smart city and sustainability consultancy experience,
- An associate professor working on urban sociology,
- An architect specialized in his field,
- An experienced landscape architect,
- An institute director working on livable environments,
- An experienced consultant on city strategy

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between). Category weighting has remained stable as determined by The Global Liveability Index. Category 3 weighting is designed as a sub-category with equal weights as environment and culture.

3.4. City Ranking

As a result of the weightings created, 6 cities selected from different regions of the world are ranked among themselves in this index study. The selected cities were obtained from various index data, research results and reports. Among the indicators under each category, those with data from all cities participated in the evaluation. Indicators with no or missing data are not included in the weighting. When choosing cities, their location, cultural, economic, and environmental differences were taken into consideration. The purpose of this is to measure the liveability of different continents and cultures and to demonstrate that the index can be used on a global scale. Cities participating in the Index weighting are London, Montreal, Bogota, Kuala Lumpur, Melbourne, and Istanbul.

To apply normalization, the methods shown in equation 7 were used and the values of the cities on the indicator and category scale were transformed into logical values. Equation 8, 9, 10, and 11 are the definitions of normalization used. Minimum-maximum normalization is a technique used to transform the range of numerical values of a data set for a given range [52]. This range will generally be between 0-1, but it can also be created between different ranges. In this study, values between 1 and 10 were set to make city comparisons understandable.

Xnew=(xi−min(x))/((max(x)−min(x)) **(7)**

Xnew = The revised value of the dataset **(8)**

X = Old value **(9)**

Max (X) = Maximum dataset number **(10)**

Min (X) = Minimum dataset number **(11)**

IV. RESULTS AND DISCUSSION

The aim of this article is to improve the liveability index by adding six new indicators to the old version. These indicators are Work-Life Balance, Ease of doing Business, Supportive Financing Mechanisms, Effective Mechanisms for Communities to Engage with Government, Green Space per Capita, and Density. Weighting was carried out by experts by including these indicators that were added later. The overall weighting of the index was determined by seven experts who gave weight to each indicator.

In Global Liveability Index, indicators are weighted equally. To improve results, experts' weights were applied to categories which have current indicators. In category Stability, Culture and Environment, current weighting was used. The weighting of indicators outside these three categories was kept as in the existing index, and no updates were made. Overall, for every expert pairwise comparisons have been applied to all indicators. Each expert weighs every indicator of determined category and come up with a result. As an example, the first expert stability category pairwise comparison steps are shown in in Table 4. Instead of the weighting made by all experts for each category, all steps of the first expert's weighting for the Stability category are shown. However, other expert and category data are shared in Table 7.

Table 5. Pairwise Comparison Matrix for Stability Category (Expert 1)

Indicators	Indc.1	Indc.2	Indc.3	Indc.4	Indc.5	Indc.6	Indc.7	Indc.8
Indc.1	1	0.17	0.13	0.11	0.14	0.33	0.25	1
Indc.2	6	1	0.25	0.20	0.33	3.00	2.00	3.00
Indc.3	8	4	1	0.50	2	5	4	6
Indc.4	9	5	2	1	3	7	6	7
Indc.5	7	3	0.50	0.33	1	4	3	3
Indc.6	3	0.33	0.20	0.14	0.25	1	0.50	2
Indc.7	4	0.50	0.25	0.17	0.33	2	1	2
Indc.8	1	0.33	0.17	0.14	0.33	0.50	0.50	1

In Table 5, the normalized matrix was obtained by adding all the rows and dividing them by themselves.

Table 6. Normalized Pairwise Matrix for Stability Category (Expert 1)

Indicators	Indc.1	Indc.2	Indc.3	Indc.4	Indc.5	Indc.6	Indc.7	Indc.8
Indc.1	0.08	0.08	0.07	0.08	0.07	0.13	0.14	0.13
Indc.2	0.17	0.16	0.22	0.12	0.13	0.16	0.19	0.19
Indc.3	0.25	0.16	0.22	0.25	0.26	0.19	0.19	0.19
Indc.4	0.25	0.32	0.22	0.25	0.26	0.16	0.19	0.25
Indc.5	0.17	0.16	0.11	0.12	0.13	0.13	0.14	0.13
Indc.6	0.02	0.03	0.04	0.05	0.03	0.03	0.02	0.02
Indc.7	0.03	0.04	0.05	0.06	0.04	0.10	0.05	0.03
Indc.8	0.04	0.05	0.07	0.06	0.07	0.10	0.09	0.06

The weights are calculated by averaging all the elements of each row in the normalized matrix. All the elements were summed up and divided to indicator number which is 8 in Table 6.

Table 7. Weight of Indicators for Stability Category (Expert 1)

Indicators	**Indc.1**	**Indc.2**	**Indc.3**	**Indc.4**	**Indc.5**	**Indc.6**	**Indc.7**	**Indc.8**
Expert 1	0.10	0.17	0.21	0.24	0.14	0.03	0.05	0.07

All the experts' weightings were completed using the weighting data collected in Table 7.

Table 8. Expert Weighting for Each Indicator

Expert - Category (S=Stability, C=Culture, E=Environment)							
	Expert1	**Expert2**	**Expert3**	**Expert4**	**Expert5**	**Expert6**	**Expert7**
S1	0.1	0.02	0.03	0.06	0.09	0.08	0.05
S2	0.17	0.1	0.1	0.09	0.14	0.13	0.09
S3	0.21	0.23	0.19	0.22	0.24	0.24	0.25
S4	0.24	0.34	0.25	0.22	0.24	0.19	0.25
S5	0.14	0.15	0.25	0.22	0.14	0.21	0.15
S6	0.03	0.05	0.04	0.05	0.06	0.05	0.05
S7	0.05	0.07	0.07	0.05	0.05	0.05	0.09
S8	0.07	0.03	0.07	0.09	0.05	0.05	0.06
C1	0.25	0.31	0.31	0.24	0.28	0.27	0.31
C2	0.24	0.17	0.21	0.16	0.16	0.21	0.17
C3	0.1	0.18	0.15	0.19	0.17	0.17	0.18
C4	0.08	0.07	0.06	0.06	0.08	0.09	0.07
C5	0.08	0.07	0.1	0.05	0.08	0.05	0.07
C6	0.04	0.05	0.09	0.05	0.08	0.05	0.05
C7	0.04	0.1	0.05	0.09	0.08	0.05	0.1
C8	0.17	0.04	0.03	0.13	0.08	0.1	0.04
E1	0.37	0.1	0.14	0.11	0.18	0.19	0.19
E2	0.09	0.16	0.14	0.11	0.14	0.1	0.12
E3	0.38	0.28	0.26	0.3	0.36	0.37	0.42
E4	0.15	0.47	0.45	0.48	0.32	0.35	0.27

With this method, the outputs of all experts were calculated, and the weighting of the stability category was obtained in Table 8.

Table 9. Stability Category Overall Weighting

Indicators	**Indc.1**	**Indc.2**	**Indc.3**	**Indc.4**	**Indc.5**	**Indc.6**	**Indc.7**	**Indc.8**
Total Weight	0.06	0.12	0.23	0.25	0.18	0.05	0.06	0.06

The revised importance weights of the indicators are provided in Table 9. The related weights are local weights of the indicators within the main categories. The global weight of each indicator can be found via the multiplication of its local weight by the main category's importance weight. The percentages are rounded.

Table 10. Revised liveability indicator benchmark

Category 1: Stability	**Definition**
Prevalence of petty crime	6.1%
Prevalence of violent crime	11.7%
Threat of terror	22.6%
Threat of military conflict	24.7%
Threat of civil unrest/conflict	18.0%
Work-life Balance	4.7%
Ease of doing business	6.1%
Supportive financing mechanisms	6%

Table 11. Revised liveability indicator benchmark (cont.)

Category 3.1: Culture	Definition
Level of corruption	28.5%
Social or religious restrictions	19.0%
Level of censorship	16.3%
Sporting availability	7.4%
Cultural availability	7.2%
Food and drink	5.9%
Consumer goods and services	7.3%
Effective mechanisms for communities to engage with government	8.5%
Category 3.2: Environment	**Definition**
Humidity/temperature rating	18%
Discomfort of climate to travellers	12%
Density	34%
Green space per capita	36%

To use the AHP method properly, the inconsistency ratio must also be evaluated to be able to have valid result. As calculated above, pairwise comparison matrix shown in Table 4 is used. Each of the columns are multiplied with associated indicator weights calculated in Table 6. The result of the inconsistency index values is shown in Table 10. Then, row values are summed up and divided to indicator weights. Average of these result gives the λmax which is calculated as 8.3266 as shown in equation 4. As the next step, equation 6 was used for CI which is 0.0466.

Table 12. Stability Category Inconsistency Calculation (Expert 1)

Indicators	Indc.1	Indc.2	Indc.3	Indc.4	Indc.5	Indc.6	Indc.7	Indc.8
Indc.1	0.10	0.09	0.07	0.08	0.07	0.12	0.15	0.14
Indc.2	0.20	0.17	0.21	0.12	0.14	0.15	0.20	0.21
Indc.3	0.30	0.17	0.21	0.24	0.28	0.18	0.20	0.21
Indc.4	0.30	0.34	0.21	0.24	0.28	0.15	0.20	0.28
Indc.5	0.20	0.17	0.11	0.12	0.14	0.12	0.15	0.14
Indc.6	0.03	0.03	0.04	0.05	0.04	0.03	0.02	0.02
Indc.7	0.03	0.04	0.05	0.06	0.05	0.09	0.05	0.04
Indc.8	0.05	0.06	0.07	0.06	0.07	0.09	0.10	0.07

By using $CR = CI/RI$ equation, CR is calculated as 0.0330. In Table 11, experts' CR scores were calculated. Since all values are below 10% for consistency, no revisions were required.

Table 13. CR Score of Experts

CR(%)	Stability	Culture	Environment
Expert 1	3.3	2	6.5
Expert 2	3.6	2.8	1.1
Expert 3	3	4.3	0.4
Expert 4	0.6	2	5.6
Expert 5	1	0.4	4.3
Expert 6	1	1.3	0.4
Expert 7	1	0.8	2.6

In the stability category, work-life balance, ease of doing business, and supportive financing mechanisms were found to be as important as the prevalence of petty crime. Their weighting within the category is 5%, 6% and 6%, respectively. This is very close to the weight of prevalence of petty crime, which is 6%. Based on this data, work and doing business coverage has a similar impact as minor crimes. Here, it shows that employment opportunities and work-related opportunities other than private life have an impact on liveability. In the environment category, density, and green space per capita were identified as very important for people's quality of life. Considering the environment category, density and green space indicators are much more prominent than other environmental factors. The density of cities greatly affects the quality of life. It has been observed that the measurement of liveability in residential areas with high population density and low amount of green space has also changed. In the culture category, effective mechanisms for communities to engage with government were found to be as important as cultural and social availability. In the culture category, the indicator Effective mechanisms for communities to engage with government is above the importance weights of indicators such as food and drink, emphasizing that the harmony of city governments with citizens affects the quality of life. The development of a comprehensive liveability index that considers these factors can help policymakers, urban planners, and researchers identify problems for improvement and make informed decisions about how to improve the quality of life in cities. The Global Liveable Cities Index and other similar indices provide a useful starting point for developing a comprehensive liveability index that considers a wide range of factors.

Data analysis in this area was limited since the data of 6 cities was not accessible for the following indicators.

- "Threat of military conflict" and "Supportive financing mechanisms" indicators under the 1. Stability category.
- “Quality of private healthcare” and “Availability of over-the-counter drugs” indicators under the 2. Healthcare category.
- “Humidity/temperature rating” and “Discomfort of climate to travelers” indicators under the 3.1. Environment category
- “Sporting availability”, “Cultural availability”, “Food and drink” and, “Effective mechanisms for communities to engage with government” indicators under the 3.1. Culture category
- “Quality of international links” and “Quality of energy provision” indicators under the 5. Infrastructure category.

Tables 12-17 which contain the data of each city are shown below. Especially in developing countries, accessibility of city-scale data is limited. Therefore, in indicators where city data is not available, country data is taken as the source.

Table 14. Stability Category City Indicator Data

Category 1: Stability (weight: 25% of total)							
Indicator #	London (Europe-UK)	Montreal (N. America Canada)	Bogota (S. America-Colombia)	Kuala Lumpur (Asia-Malesia)	Melbourne (Australia)	Istanbul (Europe-Turkey)	Weight
In_1	6.40	10.00	1.00	3.52	1.09	1.54	6.1%
In_2	9.91	9.55	1.00	10.00	10.00	9.37	11.7%
In_3	5.50	7.03	1.00	10.00	8.47	2.53	22.6%
In_4	N/A	N/A	N/A	N/A	N/A	N/A	24.7%
In_5	6.85	7.75	1.00	9.64	10.00	2.62	18.0%
In_6	9.10	8.92	6.13	1.00	10.00	3.97	4.7%
In_7	10.00	7.75	1.00	9.37	9.10	6.22	6.1%
In_8	1.00	1,00	1.00	1.00	1.00	1.00	6%

Table 15. Healthcare Category City Indicator Data

Category 2: Healthcare (weight: 20% of total)							
Indicator #	London (Europe-UK)	Montreal (N. America Canada)	Bogota (S. America-Colombia)	Kuala Lumpur (Asia-Malesia)	Melbourne (Australia)	Istanbul (Europe-Turkey)	Weight
In_1	1.31	10.00	1.00	4.07	8.17	1.23	1/6
In_2	N/A	N/A	N/A	N/A	N/A	N/A	1/6
In_3	10.00	10.00	1.00	10.00	10.00	8.74	1/6
In_4	8.04	9.22	1.47	1.00	10.08	4.76	1/6
In_5	N/A	N/A	N/A	N/A	N/A	N/A	1/6
In_6	9.95	9.42	4.79	1.00	10.00	3.34	1/6

Table 16. Environment Category City Indicator Data

Category 3.1: Culture and Environment (weight: 12.5% of total)							
Indicator #	London (Europe-UK)	Montreal (N. America Canada)	Bogota (S. America-Colombia)	Kuala Lumpur (Asia-Malesia)	Melbourne (Australia)	Istanbul (Europe-Turkey)	Weight
In_1	N/A	N/A	N/A	N/A	N/A	N/A	18%
In_2	N/A	N/A	N/A	N/A	N/A	N/A	12%
In_3	2.82	4.34	4.63	1.00	10.00	2.82	34%
In_4	5.53	7.79	1.00	2.85	10.00	5.53	36%

Table 17. Culture Category City Indicator Data

Category 3.2: Culture and Environment (weight: 12.5% of total)							
Indicator #	London (Europe-UK)	Montreal (N. America Canada)	Bogota (S. America-Colombia)	Kuala Lumpur (Asia-Malesia)	Melbourne (Australia)	Istanbul (Europe-Turkey)	Weight
In_1	9.54	9.77	1.69	3.54	10.00	1.00	28.5%
In_2	6.00	10.00	9.00	1.00	9.00	2.00	19.0%
In_3	10.00	10.00	10.00	2.50	8.50	1.00	16.3%
In_4	N/A	N/A	N/A	N/A	N/A	N/A	7.4%
In_5	N/A	N/A	N/A	N/A	N/A	N/A	7.2%
In_6	N/A	N/A	N/A	N/A	N/A	N/A	5.9%
In_7	10.00	10.00	1.00	1.00	10.00	5.50	7.3%
In_8	N/A	N/A	N/A	N/A	N/A	N/A	8.5%

Table 18. Education Category City Indicator Data

Category 4: Education (weight: 10% of total)							
Indicator #	London (Europe-UK)	Montreal (N. America Canada)	Bogota (S. America-Colombia)	Kuala Lumpur (Asia-Malesia)	Melbourne (Australia)	Istanbul (Europe-Turkey)	Weight
In_1	10.00	1.23	2.85	1.00	6.54	10.00	1/3
In_2	6.19	1.35	1.69	10.09	1.00	6.19	1/3
In_3	9.64	8.92	1.00	2.44	10.00	9.64	1/3

Table 19. Infrastructure Category City Indicator Data

Category 5: Infrastructure (weight: 20% of total)							
Indicator #	London (Europe-UK)	Montreal (N. America Canada)	Bogota (S. America-Colombia)	Kuala Lumpur (Asia-Malesia)	Melbourne (Australia)	Istanbul (Europe-Turkey)	Weight
In_1	8.11	8.58	1.00	10.00	8.11	8.11	1/7
In_2	10.00	5.82	1.00	8.31	7.26	10.00	1/7
In_3	N/A	N/A	N/A	N/A	N/A	N/A	1/7
In_4	9.18	8.36	1.00	9.18	10.00	9.18	1/7
In_5	N/A	N/A	N/A	N/A	N/A	N/A	1/7
In_6	10.00	7.37	1.88	1.00	7.15	10.00	1/7
In_7	10.00	5.33	1.00	6.00	9.00	10.00	1/7

To apply normalization, the methods shown in equation 7 were used and the values of the cities on the indicator and category scale were transformed into logical values. Equation 8, 9, 10, and 11 are the definitions of normalization used. Minimum-maximum normalization is a technique used to transform the range of numerical values of a data set for a given range [54]. This range will generally be between 0-1, but it can also be created between different ranges. In this study, values between 1 and 10 were set to make city comparisons understandable.

$$Xnew=(xi-\min(x))/(\max(x)-\min(x)) \quad (7)$$

Xnew = The revised value of the dataset **(8)**

X = Old Value **(9)**

Max (X) = Maximum dataset number **(10)**

Min (X) = Minimum dataset number **(11)**

When comparing cities, normalization was arranged to rank them between values 1-10. In Figure 2, among the cities compared, Melbourne had the highest liveability index with a score of 8.93. It is followed by Montreal with 7.96, London with 7.87, Kuala Lumpur with 5.45, Istanbul with 4.19, and Bogota with 2.25. These rankings give a general idea about the liveability of these cities with the revised index.

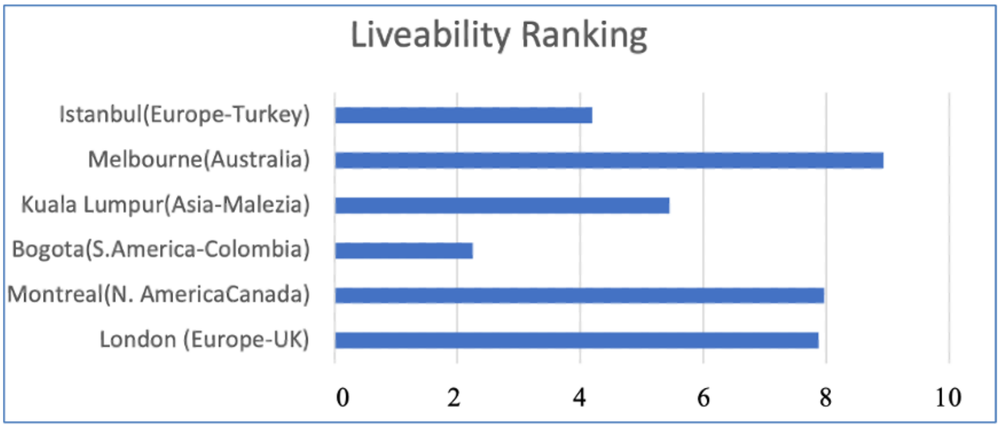

Figure 2. Revised Index Liveability Ranking of Cities

When the results of the existing index and the revised index are compared, a difference emerges. Cities are compared using the indicators and weight percentages of the existing index in Table 18 below.

Table 20. Current Index City Overall Ranking

Category Distribution							
Category	London	Montreal	Bogota	Kuala Lumpur	Melbourne	Istanbul	Weight
Stability	7.17	7.17	7.17	7.17	7.17	7.17	25%
Healthcare	7.33	9.66	2.06	4.02	9.56	4.52	20%
Culture and Environment	8.88	9.94	5.42	2.01	9.38	2.38	25%
Education	8.61	3.83	1.85	4.51	5.85	3.07	10%
Infrastructure	9.46	7.09	1.18	6.90	8.30	5.49	20%

In Figure 3, among the cities compared, Melbourne has a score of 7.12 which is same with London. Montreal, Kuala Lumpur, Istanbul, and Bogota received 6.77, 4.68, 4.40, and 3.30 points respectively. These rankings give a general idea about the liveability of these cities of current Index.

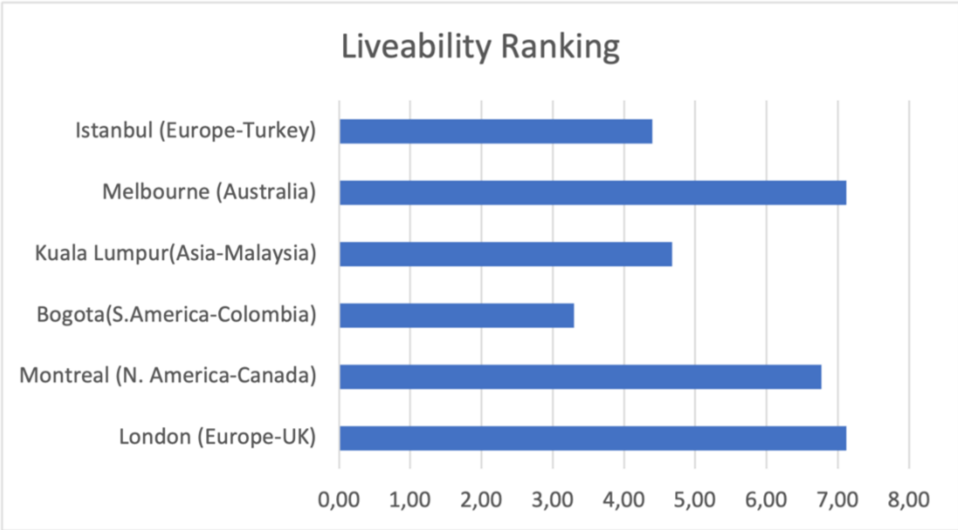

Figure 3. Current Index Liveability Ranking of Cities

V. CONCLUSION

The assessment of city liveability examined by sustainability, resiliency, and smart city dimensions is a complex and multidimensional task. This article aimed to enhance the Global Liveability Index that lacks factors such as work-life balance, ease of doing business, supportive financing mechanisms, density, green space per capita, and effective mechanisms for communities to engage with government. The results of this study show that these factors are crucial for the liveability of cities. It was observed because of the survey that the other indicators added to the current index are at least as important as the existing indicators.

The selected 6 cities were ranked with the updated liveability index model. The difference between this index and the old version is being more comprehensive. Especially in terms of environmental impact, density and green area ratio contribute to the ranking of environment category. Working integrated with the government has been shown to affect cultural liveability. Work life balance, ease of doing business and access to finance are also designed under the heading of Stability. When cities are evaluated on a category scale, Melbourne ranks first in the stability ranking with 9.49, while Bogota ranks last with an index score of 1.61. Crime, terrorism, and civil unrest indicators were seen as the main reasons for Bogota's low rankings. While Montreal had the highest score in the Healthcare category with 9.66, Bogota again ranked last. While it achieved the highest score in the Environment category, Kuala Lumpur ranked last with the lowest score of 1.94. Newly added indicators in this category, density, and green space per capita, affected the ranking. When evaluated in the culture category, Istanbul ranks last with a ranking of 1.87, while Melbourne ranks first. In the culture category, censorship, corruption, and restrictions were included in the evaluation. Food availability, sports and cultural activity data were not included in the evaluation because they were not accessible. In the education category, London ranked first with a score of 8.61, while Bogota ranked last with a score of 1.85. Finally, in the infrastructure category, London was the city with the best infrastructure service with 9.46, while Bogota ranked last with 1.18.

When looking at the difference between the existing index and the revised index, a few points attract attention. In Figure 3, the current index result is shown. Although both indexes are evaluated out of 10 points, the scores vary greatly. For example, the difference between Istanbul and Melbourne was higher in the revised index calculation. In addition, when the revised index was used, Montreal was calculated to be a more liveable city than London, but the opposite was calculated in the existing index. In the existing index, London and Melbourne received the same score. Considering this difference, updating the index study affects both the rankings and the city performance scores.

In conclusion, the enhanced liveability index proposed in this article can provide a more reliable measure of the quality of life in cities, considering a wide range of factors that can affect residents' daily lives. The recommendations provided in this article can guide policymakers, urban planners, and researchers in developing strategies to improve the liveability of cities and promote sustainable development. Thanks to this index, the liveability of world cities can be ranked by using data from other cities. However, with this data, the index can be strengthened by using techniques other than the AHP such as ANP, DEMATEL methods and can be improved with fuzzy logic approach. The way for more comprehensive studies will be paved with the development of cities' data accessibility and open data portals. Finally, comparative studies can be applied with the existing approaches and the validation of the proposed index can be provided based on the field surveys.

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