Nevşehir Bilim ve Teknoloji Dergisi

dergi web sayfası: http://dergipark.gov.tr/nevbiltek

Makale Doi: **10.17100/nevbiltek.568261**

Geliş tarihi: 21.05.2019 Kabul tarihi: 04.09.2019

Cornerstones of a Smart City: More Sustainable and More Versatile

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Abstract

A smart city finds ways to better serve its citizens, and brings together key urban systems, including energy grids, water management, waste systems, smart mobility and transportation based on the engineering applications. The smart cities should aim to strengthen the socio-economic backbone of the city, so the subject needs to be addressed in multi-dimensional framework. Thus, different disciplines such as engineering, architecture, sociology, economics and urban design are practiced upon in order to design smart technology plans and systems. Even though innovative smart city projects offer sustainable, mobile, digital, safe infrastructures that enable flexibility to different needs still there is no consent about what really forms a city smarter.

This paper considers smart cities as integrated models, and aims at disclosing major catalysts for socioeconomic development in smart city projects. Besides, discusses about the tools for urban development enabled by knowledge-intensive digital applications, the role of open data in smart mobility systems and nature-based solutions. Several dimensions and elements of the smart cities are defined based on the projects of five chosen cities located in different continents. Findings from each project about their critical systems, salient concepts and driving elements are utilized to conclude the study with triggers that can set cities on the path to becoming smart.

Keywords: Smart cities, Smart applications, Innovation, Urban development

Sürdürülebilir ve Çok Yönlü Akıllı Kent Kavramının Temel Taşları

Öz

Konsept olarak akıllı şehirler; mühendislik uygulamalarına dayanan enerji şebekeleri, su yönetimi, atık sistemleri, akıllı mobilite ve akıllı ulaşım dahil olmak üzere önemli kentsel sistemleri bir araya getirerek, vatandaşlarına daha iyi hizmet vermenin yollarını amaçlar. Akıllı şehirler, kentin sosyo-ekonomik bel kemiğini güçlendirmeyi hedeflemelidir, yani akıllı şehirler kavramı çok boyutlu ve multidisipliner bir yaklaşımla ele alınmalıdır. Bu sebepten ötürü akıllı teknoloji planlarını ve sistemlerini tasarlamak için mühendislik, mimarlık, sosyoloji, ekonomi ve kentsel tasarım gibi farklı disiplinler uygulanmaktadır. Yenilikçi akıllı şehir projeleri, farklı ihtiyaçlara esneklik sağlayan sürdürülebilir, mobil, dijital, güvenli altyapılar sunsa da, kenti gerçekten daha akıllı kılan şeyin ne olduğuna dair literatürde karar kılınan tek bir formül yoktur.

Bu çalışma akıllı şehirleri bütünleşik modeller olarak ele almakta ve sosyoekonomik gelişme kapsamında akıllı şehir projelerindeki temel katalizörleri açıklamayı hedeflemektedir. Ayrıca, bilgi yoğun dijital uygulamaların sağladığı kentsel gelişim araçlarını ve akıllı mobilite sistemlerinde doğaya dayalı çözümleri tartışıp, açık verilerin önemini vurgulamaktadır. Akıllı şehirlerin çeşitli boyutları ve unsurları, farklı kıtalarda bulunan beş akıllı kentin projelerine göre tanımlanmaktadır. Her bir projenin kritik sistemleri, göze çarpan konseptleri ve unsurları hakkındaki bulguları ile kentleri akıllı olma yoluna sokabilecek indikatörler paylaşılmıştır.

Anahtar Kelimeler: Akıllı şehirler, Akıllı uygulamalar, İnovasyon, Kentsel gelişim

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Introduction

Today, 55% of the world's population lives in urban environments, between 65% and 70% of humanity is expected to be living by 2050 according to Population Division of the United Nations [1]. Population growth generates extensive challenges in cities in several areas such as air pollution, traffic congestion, waste management, safety, and health care. At this point, smart city concept is especially conceived to face the problems deriving from the increasing urbanization trend [2].

Smart city is an unclear concept that makes implementing it difficult. There are various attempts to standardize smart city models; in 2016, representative of ISO, IEC, ITU, IEEE, CEN-CENELEC and ETSI are gathered at the World Smart City Forum for successful smart city deployment. However, the literature revealed that the meaning of a smart city is multi-faceted [3]. Depending on the expertise of researchers' smart city definitions and its dimensions changed accordingly. Urban architectures, civil engineers, software engineers, sociologists, public administrative etc. have classified smart cities based on their perspectives. Social scientists focus on so-called *'soft'* strategies related to people and governance *(i.e. education, social innovations, culture, human capital etc.)*; on the other hand, engineers interested in the area of Information and Communication Technologies (ICT), smart buildings, smart energy grids, smart mobility etc. that can be defined in so-called *'hard'* strategies [4].

In this paper, the modelling approaches of smart cities are compared systematically. Based on comparison a framework with dimensions and elements are developed to evaluate five representative smart cities located in different continents, and outcomes are extrapolated from this comparison.

The remainder of this paper is structured as follows: next section provides an analysis of existing smart city frameworks and benchmarking approaches; then a new framework and indicators is introduced and apply for five existing smart cities to compare. The final section discusses findings and future thoughts.

1. Material and Method

A smart city framework is designed to provide a comprehensive view of a people-centered smart city's three cross- sectoral goals; economic growth, sustainability and quality of life [5]. The many definitions for the smart city concept make it difficult for researchers and authorities to decide which framework is the best for analysis of smartness. Therefore, a framework that constitutes on dimensions are generated. Also, each of dimensions is broken down into several elements, and each element is the result of the aggregation of several indicators.

In order to determine the dimensions of a smart city various smart cities reported in [3], [6] - [9] are deeply analyzed. Key characteristics are justified from a very broad concept and finally these key elements shown in Table 1 are shaped by technology utilization, social and economic factors, efficiency, renewable energy usage, transportation, health care and public safety.

Based on this table, smart city dimensions are generated namely smart economy, smart governance, smart mobility, smart environment, smart people and smart living, respectively. The offered framework shown in Figure 1, overlaps with some approaches like in Giffinger's [8] and Manville's [6] studies to develop indicators and smart city development strategies.

Table 1. Common key elements of smart cities

	Key Elements
1	Economic development, employment opportunities
2	Transparency and community participation in decision making
3	Importance should be given to public transport
4	Efficiency and sustainability, renewables usage, green technology
5	Diversity, creativity and participation in public life, proper facilities for entertainment, education
6	Improving lives and livelihoods of residents, social infrastructure like parks, gardens, community halls, livable, health and safety

In this study, each dimension is classified into four levels of success to compare the smartness levels of the cities. Here, fundamental, mediocre, advanced and progressive labels show the level of implementation undertaken at five cities.

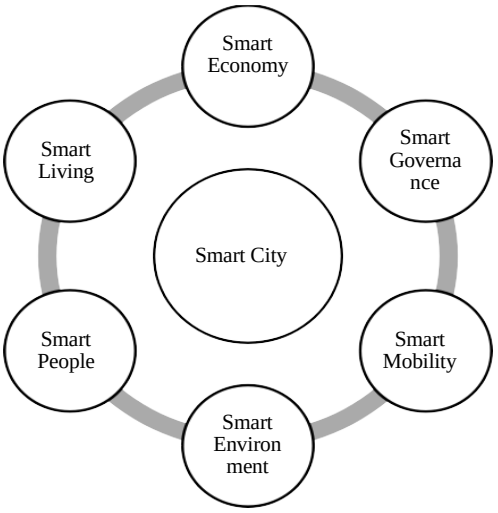

Figure 1. Smart City Framework

The smart economy concept represents the new economy in an innovative, sustainable and eco-economic approach. Descriptive indicators that are generated in this study are given in Table 2 in order to score the smartness of cities in terms of economy.

Table 2. Summary of Smart Economy levels and descriptive

Fundamental	Policies that support the specific labor market (infrastructure, facilities, economic support system)
Mediocre	Policies that are designed to support the entrepreneur, GDP per employed person
Advanced	Policies based on entrepreneurship and innovation, flexibility of labor market, innovative economic growth
Progressive	Employment rate in knowledge-intensive sectors, ICT based economic entrepreneurial behavior

Smart governance implies using technology to facilitate and support better planning and decision making, improving democratic processes and transforming the ways that public services are delivered. Table 3 summarizes the smart governance measurement levels.

Table 3. Summary of Smart Governance levels and descriptive

Fundamental	Provision of basic public and social services
Mediocre	Participation in decision-making
Advanced	Public and social services
Progressive	Transparent governance with ICT that provides real-time policy conveyance

Smart mobility covers public accessibility to real-time information; which improves services by reducing CO_2 emissions, saving time, money and gas [10]. Smartness level increases with offering alternatives to private car and using smart control management tools to reduce traffic congestion. Smartness performance measurement levels for mobility are given in Table 4.

Table 4. Summary of Smart Mobility levels and descriptive

Fundamental	Basic transportation and local accessibility
Mediocre	Full accessibility, sustainable, innovative and safe transport systems
Advanced	Payment integrated in multimodal transport system
Progressive	ICT in traffic control, international accessibility, sustainable, innovative and safe transport systems with ICT infrastructure

A city's environmental smartness include promoting renewable energy and electric vehicles, establishing smart grids, recycling water, and monitoring leaks and emissions [10]. Table 5 shows the assessment criteria for smart environment.

Table 5. Summary of Smart Environment levels and descriptive

Fundamental	Safe and clean environment
Mediocre	Environmental protection, efficiency in energy
Advanced	Sustainable resource management system, efficiency in water consumption
Progressive	Monitoring and reducing atmospheric emissions, usage of ICT in the sustainable environmental management system

Smart people aim at providing high level of education to citizens, vocational training, lifelong learning for all age groups and demographics, the quality of social interactions regarding integration and public life. Smartness levels for people dimensions are listed in Table 6.

Table 6. Summary of Smart People levels and descriptive

Fundamental	Fundamental level of infrastructure and programs for the training and education
Mediocre	Improved access to educational resources, increased environmental awareness, improved digital literacy, affinity to lifelong learning
Advanced	Research and investment in innovation and creativity, advanced technological features for the advancement of knowledge, skills
Progressive	ICT and technology driven educational and training

Smart Living focuses on improving healthcare, safety, housing conditions, smart buildings, social and digital inclusion *(i.e. the use of electronic services, connectivity, and social platforms)*.

Table 7. Summary of Smart Living levels and descriptive

Fundamental	Fundamental cultural facilities and social cohesion
Mediocre	Critical infrastructure and resources to boost efficiency, availability, and resilience, diversity and social cohesion, green urban planning, green energy
Advanced	Connected planning, awareness building, and capacity development, fostering readiness
Progressive	ICT based integrated smart, and sustainable urban areas, health, safety, social cohesion, diversity, green buildings

According to this study's aim timeframe and data accessibility were the most decisive criteria for the selection of a city sample. Thus, the comparison as for reasons of data availability is done between San Francisco, Amsterdam, Seoul, Milan, and Shanghai. Each city's dynamics are given below in Table 8. In order to calculate the scores and determine the smartness level of each city, relevant information is taken from databases published by international organizations and scientific papers.

Table 8. Selected five cities' dynamics

	San Francisco	**Amsterdam**	**Seoul**	**Milan**	**Shanghai**
Population	884.363	821.752	9,9 million	1,35 million	26,32 million
Total Area (km^2)	606,6	220	605,21	181,8	6.340
Households	780.971	373.182	4.241.547	731.091	5.416.200
Population density (people per km^2)	7.230	4.908	17.000	7.200	46.100
Innovation Cities Index (2018)	3rd	18th	12th	40th	35th

In the smartness ranking analysis each descriptive under dimensions have value of 1, 2, 3 and 4; 1 (fundamental) means city shows the existence of fundamental services, 2 (mediocre) means some improvement related to smartness is achieved, 3 (advanced) means advanced progress of smart implementations is being made in the city, and 4 (progressive) indicates the city has integrated ICT systems and ranked at progressive level.

2. Research Findings and Discussion

After smartness performance measurement, it can be concluded that all analyzed cities are aiming to improve the quality of life of their taking into consideration their culture, needs, and features of their cities based on geographical areas and countries.

Figure 2 shows the radar chart that shows the comparison of chosen smart cities under six different dimensions. It is observed that none of the cities lead in the smartness under all six dimensions. However, all cities except Shanghai have shown at least one progressive smartness level, while all cities are ranked in advanced level of smartness at least once.

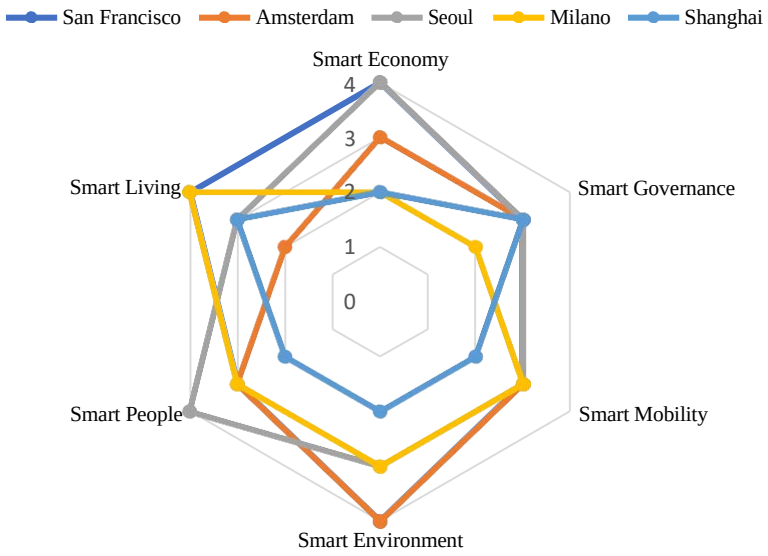

Figure 2. Comparison chart of chosen cities

San Francisco and Seoul show the progressive level of implementation of high-productivity economy, competition, economic prosperity, innovation, sustainable jobs, digital economy.

All selected cities have some form of smart government since they use e-government, open data, and provide information with open access to citizens. However, progressive level in smart governance is not achieved by any selected cities. Also, except Milan all cities have advanced level of public services, meaning greater efficiency, community leadership, mobile working and continuous improvement through innovation

Like smart governance, smart mobility also is not achieved in progressive level. Except Shanghai, all cities have reached an advanced level for transportation. All cities need to plan their traffic systems to transport with lower emissions and noise pollution. Also, all cities have shown efforts to exploit open data with local companies creating mobile applications based on parking and transportation.

Smartness performance of San Francisco and Amsterdam on environment are sharing a progressive level which means green buildings, renewable energy usage, green urban management, efficiency, waste management are given great importance.

Only the city of Seoul shows progressive level in terms of smart people solutions that support the creation of an accessible and inclusive environment to increase prosperity and innovation within the city and community.

In smartness measurement on living San Francisco and Milan cities reach a progressive level. These cities are encouraged connected communities through constructing green areas, innovating in health care and security, and using data to monitor social programs.

Shanghai shows fundamental level of smartness 4 out of 6 dimensions. This result can be thought an outcome of having a very wide terrain, high population and high number of households. However, Seoul shows only advanced and

progressive performance even though it has very similar dynamics with Shanghai. This dissimilitude can be explained by a deep involvement of Seoul citizens both in governing smart cities and in participating in its implementation.

Both Amsterdam and Milan that conditioned by historical buildings and infrastructures, have narrow territory which seems to be a weakness against greenfield opportunities and ease of mobility. However, both cities did a good job for implementing smart city strategies in bottom-up approach. A large use of ICT, governance and policies improve their smartness performance.

3. Results and Suggestions

It becomes clear that researchers come up with many proposals regarding the smart city definitions, but still there is no commonly accepted definition, and the indicators of the smartness of a city are still arguable. Here, it is aimed to compare different smart cities scattered around the world in terms of smartness level. A conceptual framework with six dimensions is generated, and its indicators for each dimension are classified into four smartness levels.

This paper has shown that this method can be applied to assess various elements of smartness; such as the governance of cities, environment, mobility etc. As a conclusion, this kind of comparisons can serve as an index identifying gaps and areas where improvement is needed in cities' smart planning and development. The measurement of the smartness level allows public administrative and urban developers to assess the effectiveness of actions they take for improving the quality of life, which is the aim of smart cities.

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Genişletilmiş Özet

Giriş

Bugün, dünya nüfusunun %55'i kentlerde yaşıyor ve Birleşmiş Milletlerin çalışmasına [1] göre 2050 yılına kadar % 65 ila % 70'i kentlerde yaşayacak. Şehirlerdeki bu kontrolsüz nüfus artışı; hava kirliliği, trafik sıkışıklığı, atık yönetimi, güvenlik ve sağlık gibi çeşitli alanlarda büyük zorluklar yaratmaktadır. Bu noktada, artan kentleşme eğiliminden kaynaklanan problemlerle yüzleşmek için akıllı kent kavramı çözüm olarak düşünülmektedir [2].

Akıllı kent konsepti, hala tanımı net olmayan bir modeldir. Bu modeli standartlaştırmak için çeşitli girişimler olmasına rağmen literatür akıllı kent kavramının çok yönlü olduğunu ortaya koymuştur [3]. Kent mimarileri, inşaat mühendisleri, yazılım mühendisleri, sosyologlar, kamu yöneticileri gibi uzmanlar; akıllı şehirleri kendi perspektiflerine göre tanımlamışlardır. Sosyal bilimciler daha çok eğitim, sosyal yenilikler, kültür, insan sermayesi gibi konulara odaklanırlarken; fen bilimciler ise Bilgi ve İletişim Teknolojileri (BİT), akıllı binalar, akıllı enerji şebekeleri, akıllı mobilite gibi alanlara odaklanmışlardır. Tanımı uzmanlık alanlarına göre değişiklik gösteren akıllı kent modellerinde tek bir standart model oluşmamıştır.

Bu çalışmada, çeşitli akıllı şehirlerin modelleme yaklaşımları sistematik olarak karşılaştırılmıştır. Karşılaştırmaya dayanarak, farklı kıtalarda bulunan beş temsili akıllı kenti değerlendirmek için boyutlar ve unsurlar içeren bir çerçeve geliştirildi ve karşılaştırma sonuçları sunulmuştur.

Yöntem

Bu çalışmada, akıllı şehrin boyutlarını belirlemek için [3], [6] - [9] 'da sunulan çeşitli modeller incelenmiştir. Çalışmalardaki örnek kentlerin temel ortak özellikleri çıkarılmış ve tüm bu öğeler teknoloji kullanımı, sosyal ve ekonomik faktörler, verimlilik, yenilenebilir enerji kullanımı, ulaşım, sağlık ve kamu güvenliği ile kümelendirilmiştir. Bu şekilde oluşturulan akıllı kentlerin ortak temel öğeleri ve bu öğelere karşılık gelen akıllı şehir boyutları Tablo 1'de sunulmuştur. Ayrıca bu tablo, Giffinger'in [8] ve Manville'in [6] akıllı şehir geliştirme stratejileri çalışmalarıyla örtüşmektedir.

Tablo 1. Akıllı şehirlerin ortak temel öğeleri ve bunlara karşılık gelen akıllı şehir boyutları

	Temel Öğeler	**Akıllı Şehir Boyutları**
1	Ekonomik gelişme, istihdam fırsatları	Akıllı Ekonomi
2	Şeffaflık ve karar alma sürecine toplumun katılımı	Akıllı Yönetişim
3	Toplu taşımaya verilen önem	Akıllı Mobilite
4	Verimlilik ve sürdürülebilirlik, yenilenebilir enerji kullanımı, yeşil teknoloji	Akıllı Çevre
5	Çeşitlilik, yaratıcılık ve kamusal hayata katılım, eğlence için uygun olanaklar, eğitim	Akıllı Insan
6	Sakinlerin yaşam ve geçim kaynaklarının iyileştirilmesi, parklar, bahçeler gibi sosyal altyapı, topluluk salonları, sağlık hizmetleri ve güvenlik	Akıllı Yaşam

Bu araştırmada, akıllı kent örneklemindeki en belirleyici faktör veri erişilebilirliğidir. Bu yüzden akıllı kent karşılaştırması San Francisco, Amsterdam, Seul, Milano ve Şangay arasında yapılmıştır. Her bir kentin puanlarını hesaplamak ve her bir şehrin akıllılık seviyesini belirlemek için, bilimsel makaleler ve uluslararası kuruluşlar tarafından yayınlanan veritabanlarından ilgili bilgiler çekilmiştir.

Sonuç

Araştırmacıların akıllı şehir tanımlarıyla ilgili birçok öneri sundukları, ancak hala yaygın olarak kabul edilen bir tanım olmadığı ve bir kentin akıllılığının göstergelerinin hala tartışmalı olduğu açıktır. Burada, dünyanın çeşitli bölgelerindeki farklı akıllı şehirleri akıllılık seviyesi açısından karşılaştırılması yapılmıştır. Altı boyutlu kavramsal bir çerçeve oluşturulmuş ve her bir boyut için göstergeler incelenip, değerlendirilmiştir.

Seçilen akıllı şehirlerin altı farklı boyutta karşılaştırılması yapılmıştır. Akıllılık performans ölçümünden sonra, analiz edilen tüm şehirlerin, coğrafi alanlara ve ülkelere dayanarak şehirlerinin kültürlerini, ihtiyaçlarını ve özelliklerini dikkate alarak yaşam kalitelerini iyileştirmeyi amaçladıkları sonucuna varılabilir. Her kentin problemi ve vatandaşlarının beklentisi ve öncelikleri farklı olmasından ötürü karşılaştırılması yapılan kentler bazı boyutlarda iyi performans gösterirken, bazılarında ise yeterli puan alamadığı görülmüştür.

Sonuç olarak, bu tür karşılaştırmalar kentlerin akıllı planlama ve geliştirmelerinde iyileştirmenin gerekli olduğu boşlukları ve alanları belirleyen bir endeks görevi görebilir. Akıllılık seviyesinin ölçümü, kamu yöneticilerinin ve şehir geliştiricilerin akıllı şehirlerin amacı olan yaşam kalitesini iyileştirmek için yaptıkları eylemlerin etkinliğini değerlendirmelerini sağlayacaktır.