ISUI Smart City Index 2023

The International Society for Urban Informatics

The Hong Kong Polytechnic University 香港理工大學

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Content

Introduction

Background and Aim

The concept of smart cities can be traced back to utopian works, such as “New Atlantis”, where smart cities were depicted as information-driven cities dominated by technological innovations. The importance of information and communication technologies in urban development was also emphasized by William J. Mitchell in his 1999 publication “Urban life, Jim—but not as we know it”. Recently, especially since the beginning of the post-pandemic era, the idea of smart-city development has evolved from being primarily technology-driven to embracing a people-centric approach to urban development.

Echoing the new trend in smart-city development, we aim to develop a universally applicable, objective, comprehensive, and human-centric Smart City Index fully based on publicly available datasets. By designing the indicator system through human-centric thinking, we are able to unify diverse perspectives of different urban sectors on a city being “smart” to the experience and quality of life of residents.

We hope this index, as an evaluation system on the smart-city development of cities, will help cities explore their current development and ways to become smarter in the future. We also hope the formulation of this index to become an exemplary project of urban informatics, of which the essence is to understand cities and design urban solutions based on a transdisciplinary point of view and new ICT technologies.

The index has been empirically studied in 50 representative cities worldwide. The ranking result and analysis are also present in this report.

Our pursuit of basing this index on publicly available and objective data makes it unavoidably rely on open data. While in some regions of the world, many more cities have opened their data, we did not include all these cities at the moment, considering geographical representativeness. We expect the number of empirically studied cities in future versions of this index to increase, as more city open data becomes available. We also call on the governments and relevant parties to make urban data accessible to help global cities design better smart solutions for cities.

Characteristics of the Index

Universality: balanced consideration in stages of development and cultures of the cities. We thoroughly considered the universality of the evaluation framework by selecting nearly internationally recognized indicators. The index also addresses the variations in the description or usage of certain indicators by applying unified conversions. This approach fully considers the applicability of the index across cities with different stages of development (e.g., in developed, developing, and newly industrialized economies) and cultures, thereby greatly reducing the geographical and cultural bias of the evaluation system.

Objectiveness and repeatability: fully based on publicly available data. All data used in this index is publicly available, requiring no additional permissions. Data sources that involve subjective opinions of data providers are avoided as much as possible to further improve the objectiveness of the index. As a pioneering work in the field of smart city indices, we strive to create a replicable evaluation framework for smart cities that benefits cities in assessing their progress.

Human-centric. We believe that the goal of smart-city development should be human-centric, that is, to improve the citizens' quality of life. Therefore, the indicators and metrics of this index are concentrated on the impact and changes that smart cities bring to the lives of citizens.

Comprehensiveness: six wheels of smart cities. The index comprises 98 indicators for evaluating the cities in six dimensions: Smart Living, Smart Citizens, Smart Environment, Smart Mobility, Smart Economy, and Smart Government. Consistent with the "Six Wheels of Smart City" proposed by Cohen in 1987, this framework is widely recognized as a comprehensive evaluation framework for the development of smart cities.

Smart City Index Framework

Under a human-centric view, our smart city index emphasizes more on the experience of residents than the pure adoption of new technologies or advanced infrastructures. That is, the index evaluates the living experience of residents in the city and how new technologies change their lives.

Smart Mobility

Digital, economical, efficient, safe, and environmentally friendly transportation with the assistance of ICT.

Smart Living

The convenience and satisfaction of urban life, aiming at improving social and digital inclusion, housing conditions, and safety.

Smart Environment

Intelligent equipment as well as Internet technology into urban environmental management and pollution control.

Smart People

Living status of being physically and mentally healthy, receiving good education, and enjoying an equal, culturally affluent, and happy living environment.

Smart Government

Serve the public, operates and manages the city through various smart application systems.

Smart Economy

Technological innovation, resource efficiency, sustainability, and high social welfare.

Smart Mobility

Smart Mobility aims at the realization of digital, economical, efficient, safe, and environmentally friendly transportation solutions with the assistance of information and communication technology (ICT). It is crucial for the efficiency of modern cities as well as people's accessibility to resources for maintaining their quality of life.

Based on the aim of smart mobility and key investments of cities as regards transportation, six development objectives under this dimension are determined to cover the infrastructure, public and private services, shareability, affordability, and use of emerging technologies in transportation.

Objective	Category	Indicator
Mobility infrastructure	Road infrastructure development	Road network coverage
		Bicycle lane coverage
		Fast charging station coverage
	Airport performance	Airport throughput
	Logistics development	Logistics performance index, LPI
Intelligent mobility	Autonomous driving development	Autonomous driving development stage
	Electronic mobility payment development	ETC and Maas development
	Advanced traffic system development	Smart traffic signals development
Public mobility	Public transportation systems	Average waiting time
		Proportion of public transport trips
		The site coverage rate of 500 meters
	Taxi service	Taxi service development
Private mobility	Private vehicle	Number of passenger vehicles per inhabitant
		Proportion of non-fuel vehicles
Shared mobility	Bicycle service	Bicycle sharing
	Car service	Carpooling
Safe and affordable mobility	Traffic accident	Traffic fatality rate
		Traffic injury rate
	Transportation fee	Monthly transportation pass price/cost of living
		One-way ticket/cost of living
		Taxi 1km/cost of living
	Traffic congestion	Time index

Smart Living

Smart Living aims to provide residents with a convenient, comfortable, safe, and healthy living environment. Smart living reflects the actual living conditions of residents, with some emphasis on the improvement of citizens' lives related to the use of new technologies. This dimension is straightforwardly linked to our core people-oriented philosophy. It helps decision-makers directly assess the quality of life of residents and position the direction for improvements.

In this smart city index, Smart Living comprises six development objectives from the perspectives of digital life, healthcare, personal safety, and community inclusiveness. These six aspects are selected according to the living demand of residents.

Objective	Category	Indicator
Communication	ICTs development	Mobile Internet download speed (Mbps)
		Fixed broadband download speed (Mbps)
Housing	Living cost	House price to income ratio
	Living environment	Average per capita living space
	Social equity of living space	Proportion of urban population living in slums, informal settlements, or inadequate housing
Healthcare	Medical availability	Number of beds per 10,000 people
Safe and security	Personal safety and social security	Number of police per 10,000 people
		Crime rate per 10,000 people
	Social security	Urban emergency service level
Social cohesion and equality	Social income equality	Gini coefficient
	Social inclusion of vulnerable groups	Barrier-free facilities construction degree
Culture	Richness of cultural resources	Density of theatres
		Density of galleries

Smart Environment

Smart Environment is an important reflection of urban sustainable development, reflecting the interaction among residents, city, and nature. The assessment in this dimension is conducive to the formulation of urban sustainable development policies and is of great significance to the improvement of urban ecology and habitability.

For Smart Environment, we emphasize the utilization of technological approaches for improving the urban environment. Three development objectives are determined regarding facilities for environment monitoring and treatment, environment status and its improvement via the use of emerging technologies, and environmental administrative strategies.

Objective	Category	Indicator
Environmental facilities	Environmental monitoring facilities	Number of real-time air quality monitoring stations per million people
	Sanitary facilities	Number of public toilets per million people
	Pollution control facilities	Number of sewage treatment plants per million people
Environment status	Energy consumption	Electricity consumption per capita
		Share of renewable energy consumption
	Architecture	Number of green-certified projects per million people
		Smart building
	Pollution status	Annual average sulfur dioxide
		Annual average nitrogen dioxide
		Annual average $PM_{2.5}$
		Water consumption per capita
		Wastewater treatment ratio
		Municipal solid waste generation per capita
		Municipal solid waste treatment rate
	Carbon neutral	CO_2 emissions per capita
		Green space per capita
Environmental management	Environmental planning and management	Level of environmental management

Smart People

Smart People refer to the resident's overall living status of being physically and mentally healthy, receiving a good education, and enjoying an equal, culturally affluent, and happy living environment. This concept also pertains to a high potential for the future development of a city, the residents' idea of learning and enterprise, and their pursuit of higher education. Smart People reflects the current material and spiritual level of urban residents and the future development direction. This dimension allows us to evaluate smart cities from the perspective of the cities' users. It is conducive for decision-makers to realize smart-city planning and management from the perspective of achieving convenience for the people and growth of urban potential.

In this smart city index, Smart People is abstracted into three main objectives on human development: residents' ability, physical and mental health, and development environment. The three main objectives are selected by considering the governments' demand for talent development and the direction of social progress as regards population quality. Under these objectives, the Smart People index includes 14 indicators grouped into 7 categories which cover the most concerning issues for policymakers.

Objective	Category	Indicator
Residents' ability development	Primary education	Average education years
		The density of primary schools
		Pupil-teacher ratio
	Advanced education	The level of tertiary attainment
		Number of universities in international academic rankings
	Lifelong learning	Lifelong learning developing status
Physical and mental health	Mental Health/Residents' Well-being	World Happiness Index [1]
	Physical health	Average life expectancy at birth
		Birth rate
		Death rate
Development environment	Equality	Gender Development Index [2]
	Attractiveness of the city	Human Capital Index [3]
		Migration rate
		Population density

Smart Government

A smart government, with the aim to serve the public, operates and manages the city through various smart application systems for key tasks such as government monitoring, information integration, and one-stop government service. In short, Smart Government has three major characteristics: integration, transparency, and cooperation. Smart government services unite various departments, integrate information internally, bring social groups together externally, and provide transparent information for the public to view urban accountability. These enable the city to effectively respond to all social groups and provide high-quality public services without discrimination or barriers.

Smart Government is characterized by a clear theory-first approach, which differs from other aspects of the smart city. It reflects the management ability of the government and the urban development blueprint. This provides us with an evaluation system from the aspect of urban decision-makers. Also, it helps strengthen the ability of the urban system to address issues and produce wider public value as a result.

Objective	Category	Indicator
Integration	Smart city schedules and related policies	Willingness of smart city schedules and policy
		Evaluation of smart city schedules and policy platform
	Government service	Willingness of developing e-government
		Evaluation of e-government platform
Transparency	Urban data	Willingness of developing open data
		Data categories
		Update frequency
		Availability
	Geospatial data	Willingness of developing geospatial data
		Evaluation of geospatial data platform
Collaboration	Inclusiveness of government departments	Electoral quota
		Specialized bodies
		Female parliamentarians
	Communication between citizens and the government	Willingness of developing the smart communication channel
		Collaboration of citizens and the government

Smart Economy

Smart Economy is based on technological innovation, efficiency of human resources usage, sustainability of economic development, and social welfare. It concerns the optimization of industrial structure, knowledge-based economy in which innovation is a key point, and the enhancement of the city's economic strength and competitiveness.

In the context of Smart Economy, technological solutions for the above goals shall be highlighted. Therefore, electronic economy becomes the third objective of this dimension, apart from economic status and economic environment.

Objective	Category	Indicator
Current economic status	Economic strength	GDP per capita
		City product per capita
	Wages and costs	Cost of living
		Time at work needed to afford a Big Mac
Economic environment	Business environment and enterprises status	Stock exchange
		The time needed to start a business
		The number of companies headquartered in this city with revenue above US$5 million
	Employment environment	Unemployment Rate
		Participation rate (labor force aged 15-64 over the population aged 15-64)
Electronic economy	R&D and innovation	The proportion of R&D expenditure in GDP
		PCT patents per million inhabitants
	E-commerce linked with cyber business	Smartphone penetration rate
		Internet penetration rate
		Rate of online access to financial account
		Online shopping (% of total shopping)
	ICT industry status	High-technology exports
		ICT goods exports (% of total goods exports)

Methodology

Selection Criteria of Indicators

We aim to establish a new evaluation framework for smart cities that could extensively assess the development status of smart cities worldwide using objective data, in the selection of indicators that constitute the index, the following principles were adhered to.

- **Independent:** Indicators are independent of each other as far as possible. This ensures the acquisition of more comprehensive and diverse information for evaluating the cities. It also helps avoid the overrepresentation of certain features of the cities which is a source of bias.
- **Comprehensive:** There are 98 indicators covering six dimensions of smart city: Smart Living, Smart Citizens, Smart Environment, Smart Mobility, Smart Economy, and Smart Government.
- **Universal:** The indicators should be applicable to cities in different cultures and at different stages of development. This could enable the usability of the evaluation framework across different cities and reduce the bias of the evaluation result against cities of certain stages of development, culture, or geographical regions. Additionally, the metric of an indicator should be consistent and unified across different regions.
- **Representative:** Indicators that are representative in this field should be selected to capture the essence of the objective being evaluated.
- **Quantifiable:** Indicators can be measured by using actual data, such as the number of facilities per resident, and other tangible measurements.
- **Available:** The data is available from public sources.
- **Objective:** The data is derived from an objective assessment, with an effort made to minimize subjective opinions from the individuals providing the data.
- **Interpretable:** The results are explained and analyzed. The ranking of cities can only

reflect their relative developmental differences. Without appropriate explanations and interpretations, the significance of urban evaluation would be lost.

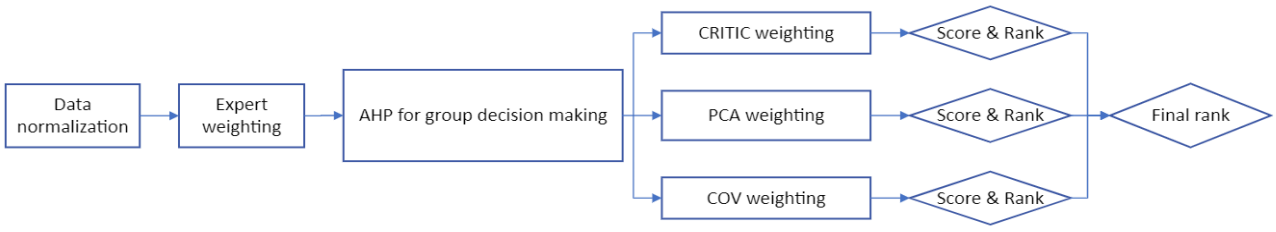
- **Keep updating:** The data for the selected indicators could be updated periodically. Continuous observation and assessment are beneficial for analyzing the implementation status of smart-city development strategies, the impact of specific events on cities, and the condition of urban renewal and recovery.

Data Sources

In this 2023 edition, the index is implemented on 50 worldwide cities entirely based on publicly available data, including official data, user-generated data, widely recognized third-party (e.g., international organizations) data, and official media data. In terms of geographical data, we conducted rigorous verification of official geographic platform data, user-generated data, and statistical data to ensure the rigor of the experiment. The data sources are listed as follows.

Data sources for ISUI Smart City index
Chargemap
City open geographic data platform
Customer Data Platform
Green Building Information Gateway (GBIG)
IQAir
Macrotrends
NUMBEO
OECD Open Data
Official government announcements
OpenStreetMap
PlugShare
Portulans Institute
QS World University Rankings
SmilarWeb
Socrata
Speendtest
Statistia
Statistical yearbooks
The Meddin Bike-sharing World Map
TomTom
Uber (Service offer official website)
United Nation Statistical Database (UNSD)
World Bank's Data Bank
World Happiness Report based on the Gallup World Poll data

Calculation Method



Flowchart of score and ranking calculations

To integrate the wisdom of smart-city scholars and professionals with the advantage of a data-driven approach, a **subjective-objective** weighting method is used for weighing the indicators during the calculation of index values. The calculation consists of the following steps:

1. Data normalization. The data values of different cities for each indicator of the index are normalized to assure their homogeneity and compatibility.

2. Expert weighting and group decision-making. We collected the opinions of smart-city scholars and professionals on the appropriate weights of different categories of indicators. Then we use the analytic hierarchy process (AHP) method to calculate the expert weights of different categories by using the opinions of these experts. The general idea is that more similar opinions of the experts will contribute more to the weight of the category.

3. Objective weighting. We use three objective weighting methods, namely coefficient of variation (COV) method, principal component analysis (PCA), and criteria importance through inter-criteria correlation (CRITIC), to get the objective weights for each indicator. The general idea for these methods is an indicator with more variations in data is given a higher weight.

4. Calculating scores and ranks. The scores and ranks of the cities in each smart-city dimension are calculated by combining the expert weight of each category of indicators, the objective weights of the indicators under each category, and the normalized data for each indicator. The final rank of a city is based on average results by using three objective weighting methods.

Result

Selection of 50 Cities

The index was empirically studied by selecting 50 representative cities worldwide, according to the following criteria.

- **Geographically,** the selected cities cover most of the world and are representative in terms of nation/region;
- The selected cities have relatively **high levels of data disclosure.** For example, there are official government websites or departments that disclose data; and
- The selected cities cover economies of **different degrees of development and cultures**.

Distribution of Selected Cities

Northern Europe: 4
Eastern Europe: 2
Southern Europe: 4
Western Europe: 2
Central Europe: 4
Southeast Asia: 3
East Asia: 7
South Asia: 4
South America: 4
North America: 6
Africa: 3
Oceania: 2
The Middle East: 5


Helsinki
Copenhagen
Stockholm
Oslo
ST.Petersburg
Moscow
London
Berlin
Warsaw
Paris
Munich
Zurich
Lisbon
Rome
Istanbul
Lagos
Athens
Barcelona
Cairo
Riyadh
Dubai
Karachi
Delhi
Abu Dhabi
Muscat
Mumbai
Dhaka
Beijing
Seoul
Tokyo
Busan
Shanghai
Shenzhen
Hong Kong
Manila
Singapore
Jakarta
Joannesburg
Sydney
Melbourne

Overall Ranking of Cities

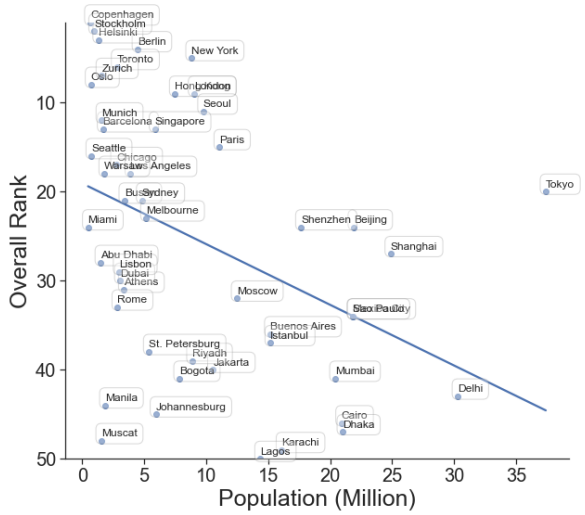
City	Overall ranking
Copenhagen	1
Stockholm	2
Helsinki	3
Berlin	4
New York	5
Toronto	6
Zurich	7
Oslo	8
Hong Kong	9
London	9
Seoul	11
Munich	12
Barcelona	13
Singapore	13
Paris	15
Seattle	16
Chicago	17
Los Angeles	18
Warsaw	18
Tokyo	20
Busan	21
Sydney	21
Melbourne	23
Beijing	24
Miami	24
Shenzhen	24
Shanghai	27
Abu Dhabi	28
Lisbon	29
Dubai	30
Athens	31
Moscow	32
Rome	33
Mexico City	34
Sao Paulo	34
Buenos Aires	36
Istanbul	37
St. Petersburg	38
Riyadh	39

Jakarta	40
Bogota	41
Mumbai	41
Delhi	43
Manila	44
Johannesburg	45
Cairo	46
Dhaka	47
Muscat	48
Karachi	49
Lagos	50

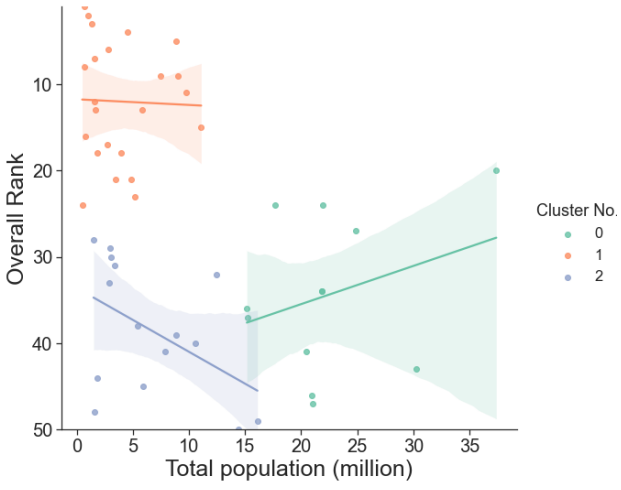
There is a **negative correlation** of approximately -0.41 between the city's overall ranking of smart city index values (for all six dimensions) and city size in terms of population. Further clustering analysis reveals three distinct groups of cities: small city size and high rank; small city size and low rank; large city size and mid-to-low rank. The division line between small and large city sizes in the clustering result is at **15 million** population.

Compared with smaller cities, megacities have several acknowledged difficulties in reaching a high rank of smart-city ranking, especially for this index emphasizing **per-capita** measures in quality of life. Certain urban issues such as congestion are found to scale super linearly with population size, that is, these issues are likely to be severer in megacities even at a per-capita base, which greatly increases the difficulty of city management. The typical large migrations to megacities can also greatly dilute the per-capita ownership of existing urban facilities in all dimensions of smart city. Thus, it is necessary to create a separate ranking of the megacities with populations of 15 million or more.

Relationship between city size and ranking



Clustering result for city size and ranking



*Trend line: y = -0.68x + 30.92; correlation coefficient is -0.41.

Megacity with a population ≥ 15 million	Overall Ranking
Tokyo	1
Beijing	2
Shenzhen	2
Shanghai	4
Mexico City	5
Sao Paulo	6
Buenos Aires	7
Istanbul	8
Mumbai	9
Delhi	10
Cairo	11
Dhaka	12
Karachi	13

Analysis

This section provides the analysis of our ranking result from three perspective cities: top-3 cities in overall ranking, top-3 super-sized cities with populations of over 15 million, and worldwide selected cities in six smart city dimensions in our indicator framework.

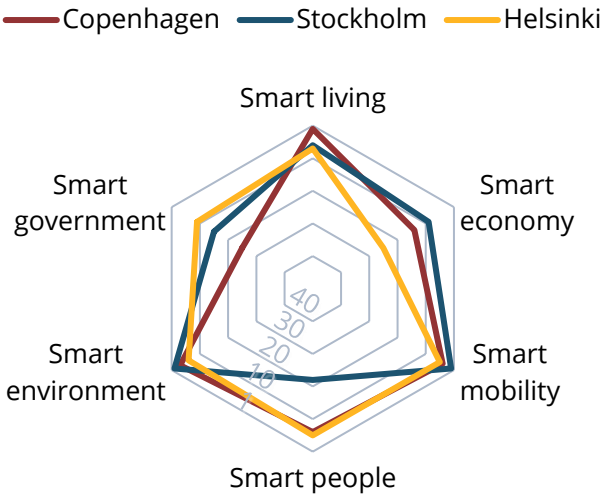
Top-3 cities in Overall Ranking

The top-3 cities in the overall ranking: Copenhagen, Stockholm, and Helsinki, are all located in Northern Europe and have relatively small population sizes. This is understandable since the index emphasizes the quality of life of individual residents, which is closely related to the per-capita resources available. All three cities have high rankings in Smart Mobility, Smart Living, and Smart Economy. In particular, Copenhagen ranks first in Smart Living among all 50 selected cities, while Stockholm ranks first in Smart Mobility and Smart Environment.

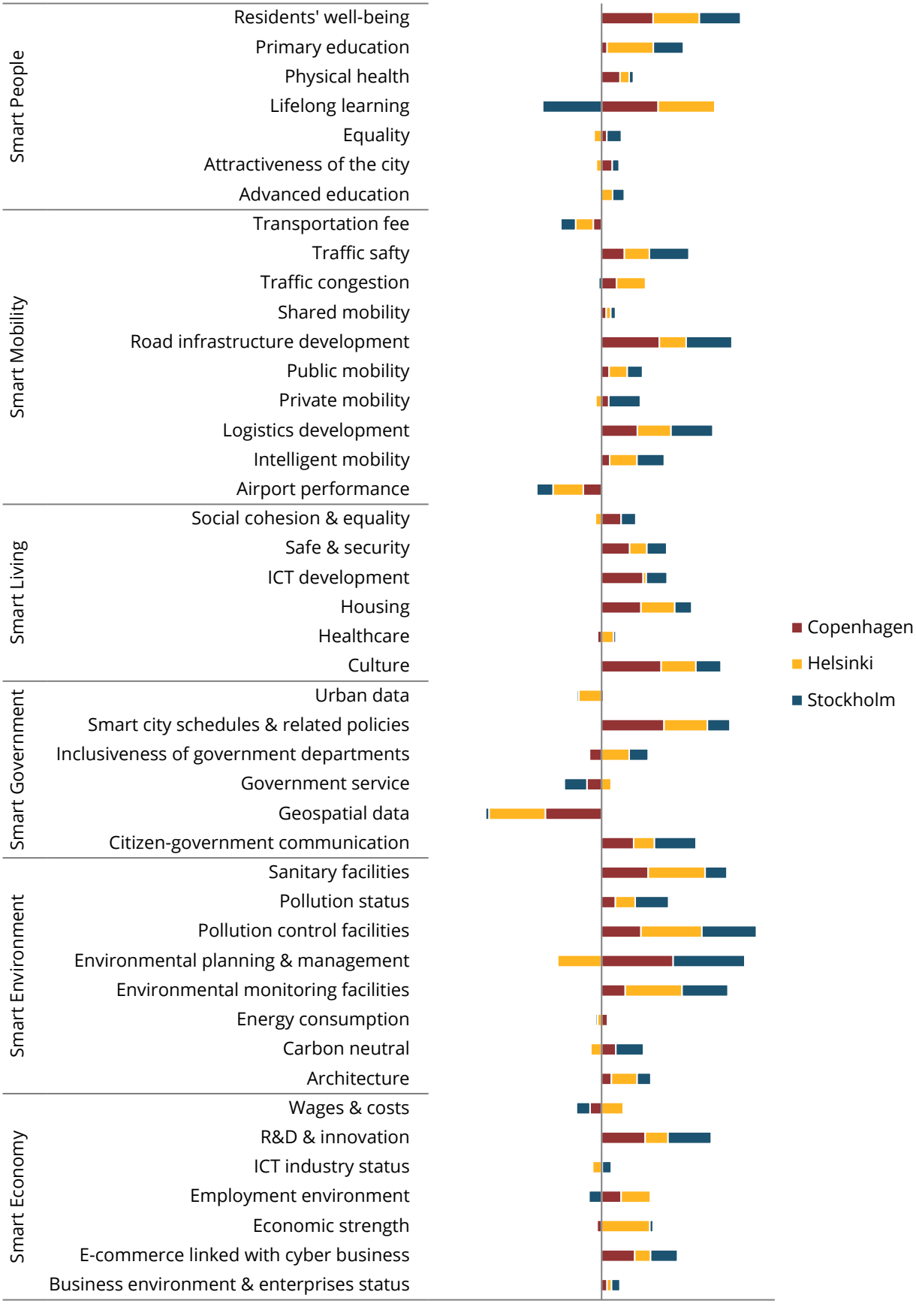
Within each smart city dimension, all three cities have wholesome high performances in every category of indicators under Smart Living except for healthcare. For Smart Mobility, all three cities perform well in road infrastructure development, logistics, intelligent mobility, and private mobility. Their developments in public and shared mobility are also above the average level among the 50 selected cities, even though their demands in these aspects appear to be less pressing than cities with much larger populations. The three cities rank in the front of all selected cities in all indicator categories under Smart Environment, except for an average level of energy consumption, which is inevitable due to the cold climate. All three cities perform excellently in environmental planning and management, showing that their achievement in Smart Environment is far from being primarily due to geographical advantages.

All three cities have high rankings in all dimensions except for one: Smart Government for Copenhagen, Smart People for Stockholm, and Smart Economy for Helsinki. Under Smart Government, Copenhagen is strong in smart city schedules and policies, and communication with citizens. The room for improvement lies in the lower degree of governmental service integration and lack of governmental geospatial data. For Stockholm, its area specifically calling for improvement under Smart People is lifelong learning. Helsinki performs well in electronic economy and R&D innovation but has some drawbacks in overall economic status and business environment, causing an average ranking in Smart Economy.

Rank in different smart city dimensions



Performance compared to average level of all 50 selected cities

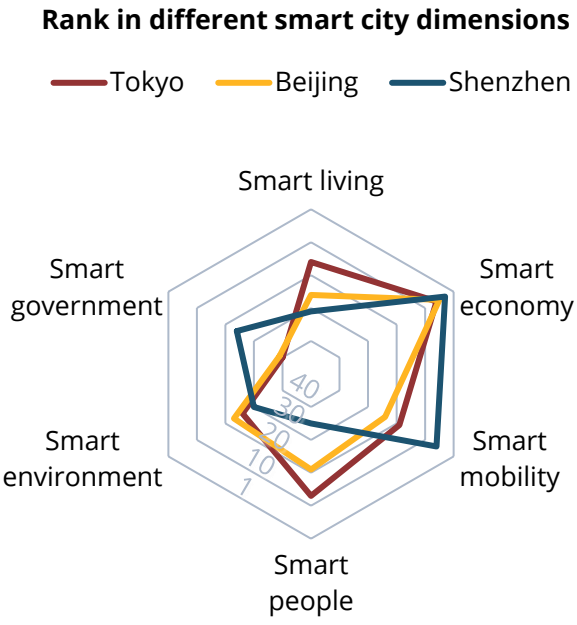


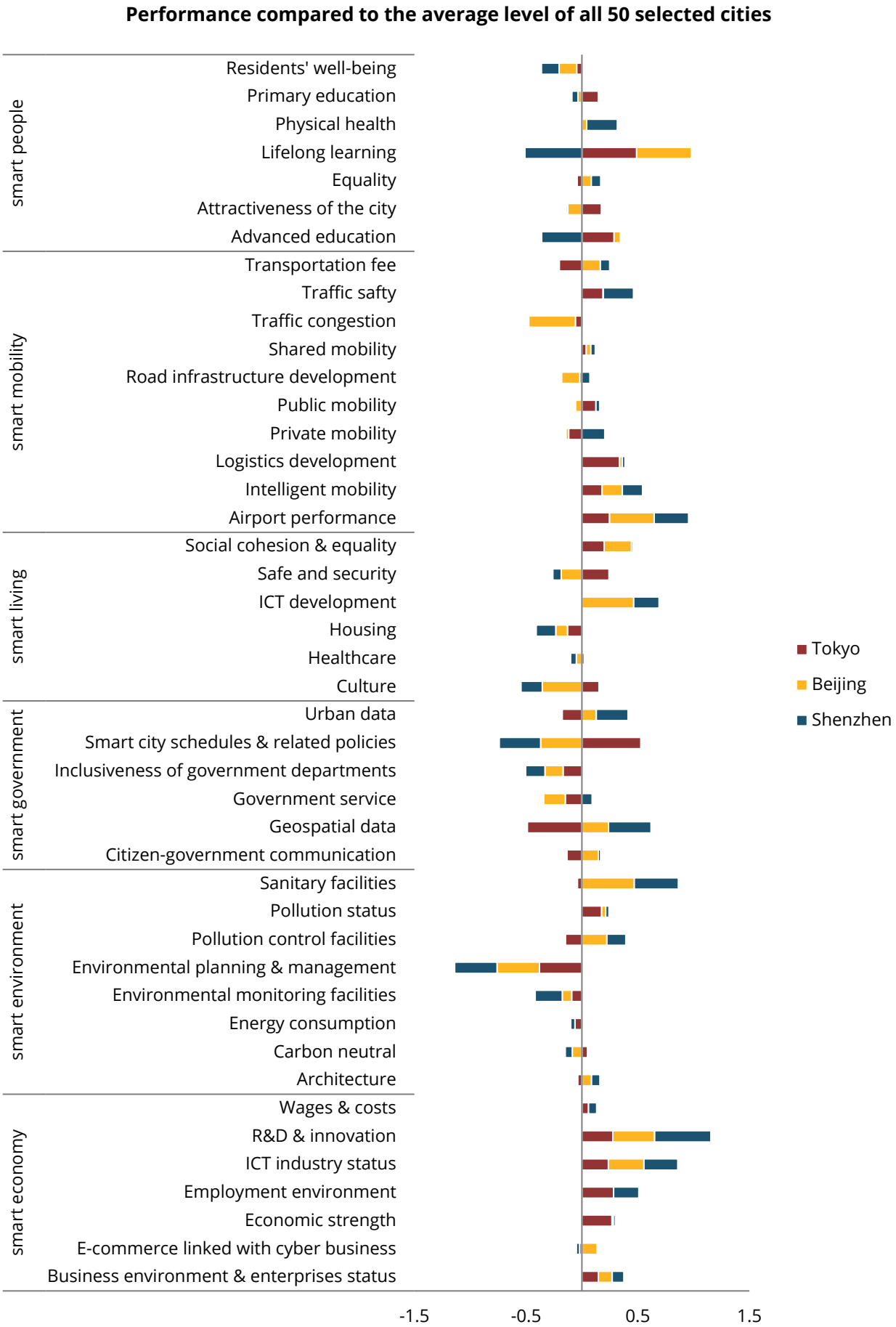
Top-3 Super-sized Cities

The top-3 super-sized cities with a population of over 15 million: Tokyo, Beijing, and Shenzhen, are all located in eastern Asia. All three cities have high rankings in Smart Economy. Apart from their high economic strength, these three cities also possess a substantial high-tech economic capacity and dynamic commercial market. All three cities have high scores in R&D and innovation, ICT exports, and enterprise environment, indicating the similarity of their economic goals.

As shown in the radar map, Tokyo and Beijing have somewhat similar performance in different dimensions of smart cities. Compared with smaller cities ranking at the top among all selected cities, Tokyo and Beijing have lower rankings on Smart Government, Smart Mobility, Smart People, and Smart Environment. Apparently, some specific issues of super-sized cities have greatly added to the difficulty in their pursuit of building smarter cities. For Smart Government, both cities obtain average scores in the integration of online government services. Also, the score of Beijing in establishing a detailed work schedule specifically for smart-city development and the score of Tokyo in open data are average among the selected cities. For Smart Environment, both are below average in environmental facilities and carbon emissions, while over the average in smart buildings. For Smart People, both cities have below-average well-being (happiness) but excellent lifelong learning, reflecting the pressure and enterprising spirit of residents in a highly competitive environment. For Smart Mobility, both cities are advanced in intelligent mobility and airport performance. However, the congestion problem, known to worsen in large cities, is more severe in both cities than average.

Compared with the other two cities, Shenzhen has much higher rankings in Smart Mobility and Smart Government. Shenzhen has a higher density of road infrastructure and less congestion; it also has a more integrated government e-service. However, Shenzhen ranks low in Smart People and Smart Living. In particular, it scores below average in cultural infrastructure, housing conditions, and education. This difference may be related to the history of these cities. Beijing and Tokyo are national capitals and served as ancient capitals for centuries. Shenzhen has been developed only since 1980 as a special economic zone following modern planning ideas. Consequently, Shenzhen encountered much fewer historical development problems such as congestion and disintegrated existing government services. Meanwhile, time is needed for the education resource construction of Shenzhen to keep up with the needs of numerous immigrants which have doubled the city's population in the past 15 years.




Performance compared to the average level of all 50 selected cities
smart people
Residents' well-being
Primary education
Physical health
Lifelong learning
Equality
Attractiveness of the city
Advanced education
smart mobility
Transportation fee
Traffic safty
Traffic congestion
Shared mobility
Road infrastructure development
Public mobility
Private mobility
Logistics development
Intelligent mobility
Airport performance
smart living
Social cohesion & equality
Safe and security
ICT development
Housing
Healthcare
Culture
smart government
Urban data
Smart city schedules & related policies
Inclusiveness of government departments
Government service
Geospatial data
Citizen-government communication
smart environment
Sanitary facilities
Pollution status
Pollution control facilities
Environmental planning & management
Environmental monitoring facilities
Energy consumption
Carbon neutral
Architecture
smart economy
Wages & costs
R&D & innovation
ICT industry status
Employment environment
Economic strength
E-commerce linked with cyber business
Business environment & enterprises status
-1.5
-0.5
0.5
1.5
Tokyo
Beijing
Shenzhen

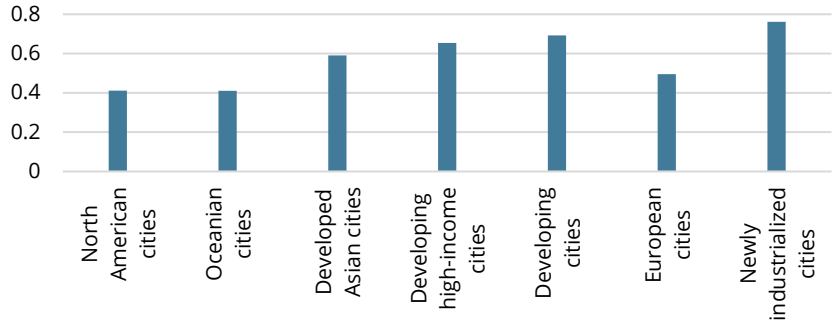
Smart Mobility

The Smart Mobility dimension of this index considers both citizens' travel experience and transportation infrastructure. Overall, the cities' efforts for the development and application of high-tech in smart transportation can be clearly observed in selected cities worldwide. More than half of the selected cities have made substantial progress in developing autonomous driving, intelligent transportation systems, and electronic payment systems for transportation.

The selected cities with a higher degree of urbanization, such as European and US cities, not only have higher coverage of infrastructure such as roads and fast charging stations but perform even better in the service level of public transport and logistics. However, transportation costs, even after adjustment by cost of living, generally pose a greater burden for the residents in these cities. For cities in newly industrialized economies, their average level of adoption of high-tech and shared mobility is equally good as that of developed cities. However, their public and private transportation service levels, as well as the congestion situation, call for improvement.

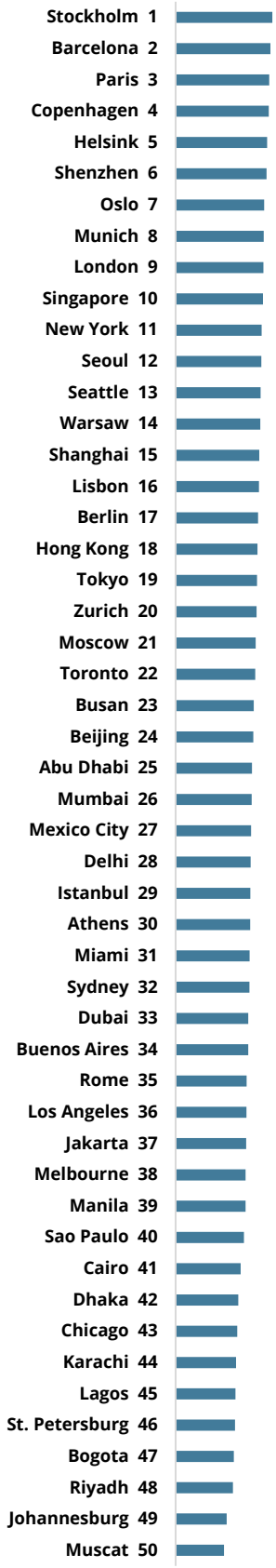
It is of note that the evaluation of transport infrastructure, despite its necessity, would unavoidably disadvantage cities with a large proportion of area unsuitable for infrastructure development. For example, Hong Kong is a mountainous city and conservative lands take 40% of its area. Although Hong Kong has one of the world's most densely populated built areas, the built area of the city only covers 25% of its land, leading to a road network coverage that is at the bottom among all selected cities. This situation lowers the Smart Mobility ranking of Hong Kong to 18th, even though its ranking in terms of efficiency should be higher. For highly urbanized cities on plain terrain, such as Copenhagen, the road network coverage reaches 73%.

Standardized score of transportation fee



* Lower scores mean higher relative costs.
* The data presented in this figure refer to the 50 selected cities only.

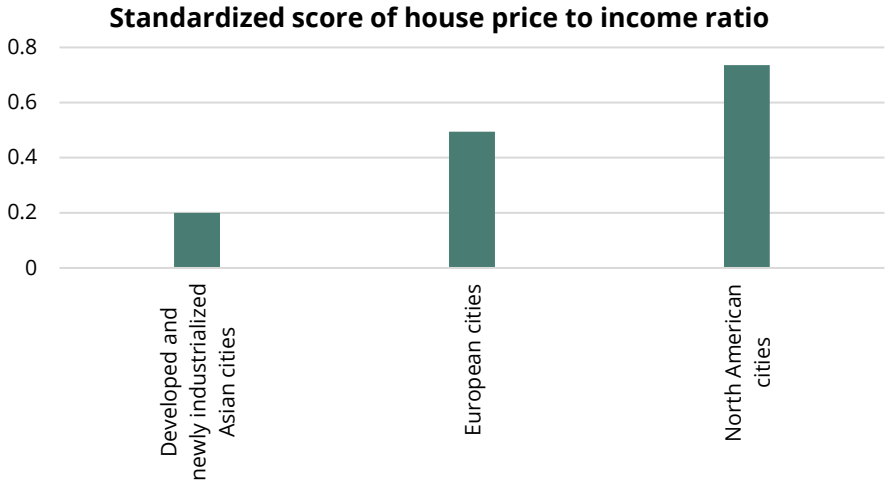
Standardized score in Smart Mobility



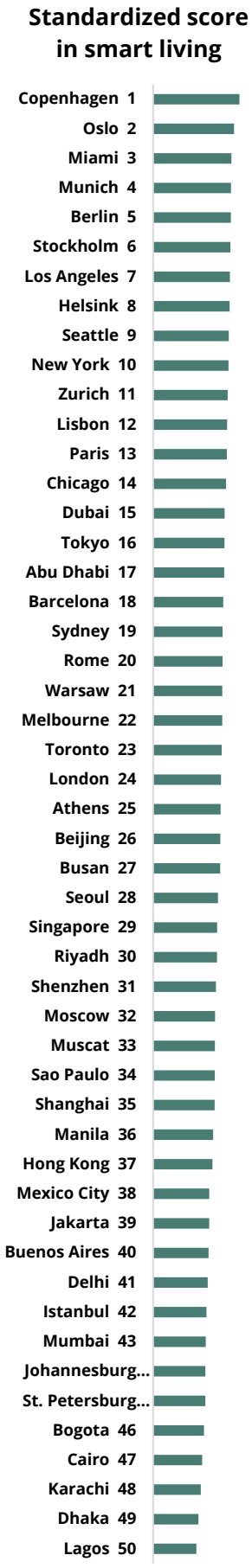
Smart Living

Among the selected cities, European cities perform better than other regions in Smart Living, for example, Copenhagen ranks 1st, Oslo ranks 2nd, Munich ranks 4th, and Berlin ranks 5th in this dimension. Apart from their high degree of development and great effort in improving citizens' quality of life, these cities have relatively small populations and low population density, resulting in some advantages in the provision of facilities and housing. According to the United Nations' World Urbanization Prospects Report [9], the population density of most built-up areas in large cities is 4,000–10,000 persons/Km^2, which is typical in parts of Asia, Africa, and South America. Urban areas with lower densities are mainly located in Europe, North America, and Oceania.

The performance of a city in individual indicator categories is related to complex factors, for example, the stage of urban development and related development strategies, city size, and culture. For example, European cities generally perform well in all categories of indicators but Internet communication. Cities in North America, developed Asia, mainland China, and the United Arab Emirates score higher in this category, indicating their emphasis on urban efficiency in smart-city development goals. The developed and higher-income developing cities in Asia generally have a much lower per-capita share of culture and emergency facilities than Western cities, which should be related to the huge population of these Asian cities. Also, the house price to income ratio is generally highest in Asian developed and newly industrialized cities, followed by European cities, and is relatively low in North American cities. This reflects the marked difference in the importance placed on house ownership in the cultures of different regions.



* Lower score means a higher ratio or less affordable houses.
*The data presented in this figure refer to the 50 selected cities only.

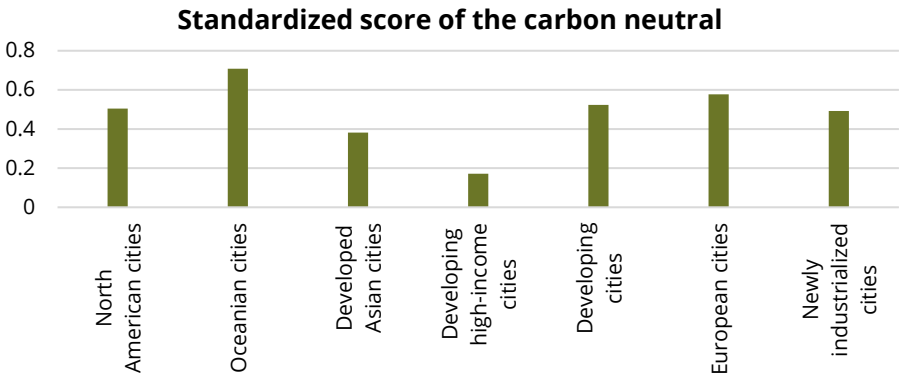


Smart Environment

Through the evaluation on the dimension of Smart Environment, the selected worldwide cities have demonstrated significant concern and effort on sustainable development. Out of the 50 selected cities, 44 have constructed smart buildings that are energy-saving and environmentally friendly, 47 have practiced green certification projects, and 35 have a renewable energy consumption rate of 20% or above.

Developed economies tend to rank high in this dimension. Understandably, cities in developing economies face greater pressure of maintaining economic growth and infrastructure development, as well as supporting great numbers of immigrants. In practice, sustainable development has to be balanced with these contradicting objectives of city development. Yet several selected cities in newly industrialized economies also obtain relatively good rankings. In particular, they have a high rate of sewage and solid waste treatment. They also progress well in constructing green buildings, showing that they have been working hard to improve the environment with new technologies. However, these cities tend to fall behind the more developed cities in terms of CO2 emission and air quality.

The performances of developed economies in different aspects of Smart Environment seem to be related to their different focuses on sustainable development. The selected US cities are advantageous in the number of green certification projects and smart buildings, which may be related to the high concern of the US on sustainable development via better energy utilization. The US Congress passed the Energy Independence and Security Act in 2007 to further support renewable energy and energy efficiency. Cities in western and northern Europe, in contrast, feature low emission of CO_2 and air pollutants, reflecting their focus on achieving carbon neutrality. The European Union implemented the European Green Deal in 2020, aiming to achieve a carbon neutrality goal by 2050.



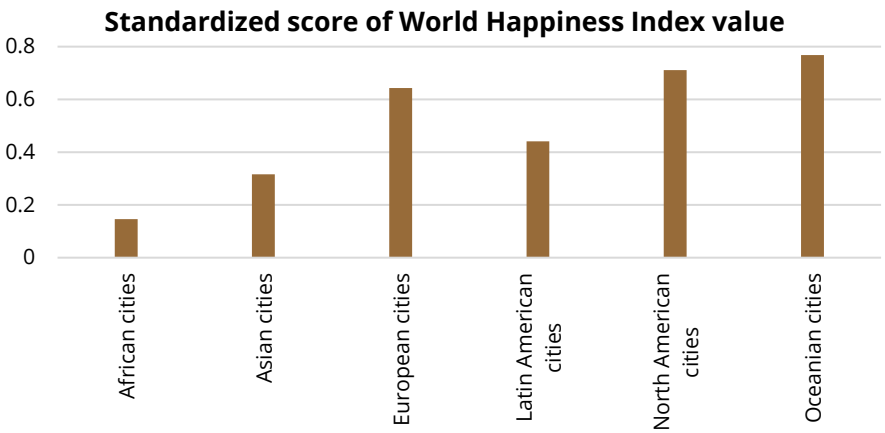
* The data presented in this figure refer to the 50 selected cities only.

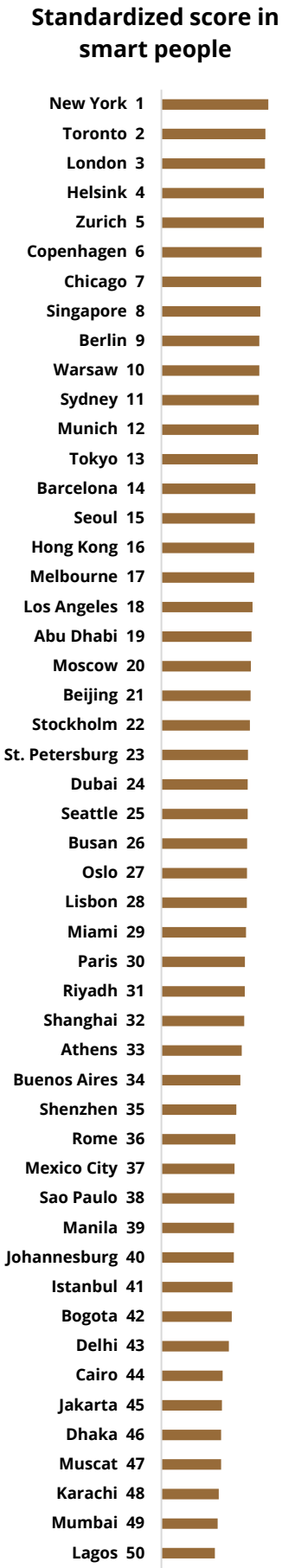
Smart People

The Smart People dimension of this index mainly evaluates the citizens' educational level, physical health and well-being, and development potential. Overall, European and American cities have a higher per-capita level of education, followed by Asian cities. In the Middle East, due to cultural influences, there are significant gender differences in education levels among urban citizens.

In many cities of developed or newly industrialized economies, the concept and implementation of lifelong education are relatively mature, with complete strategic plans and related project support. For example, Beijing has systematically established learning centers and multi-functional halls in the communities. It also actively promotes vocational education and encourages enterprises to conduct internal training and skills competitions. Meanwhile, in some less developed cities, the concept of lifelong learning has been established only recently with the help of international organizations, such as UNESCO via its Global Network of Learning Cities.

Most selected cities have relatively homogenous performances in the indicators of physical health, showing that most cities have invested great effort to improve this most basic condition of the citizens. However, there is a significant difference in happiness levels among the cities. Oceania cities have a higher average happiness level, followed by North American cities. The happiness level in Asian cities is relatively low, particularly in fast-developing East Asian cities.





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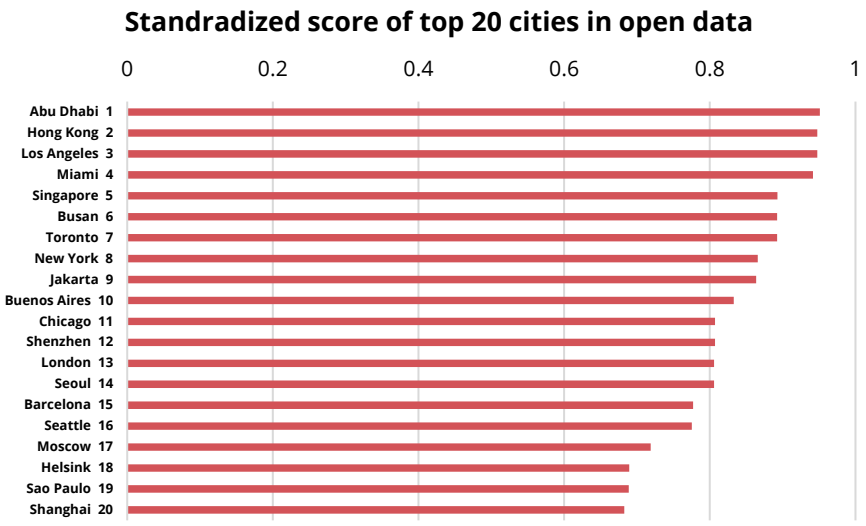
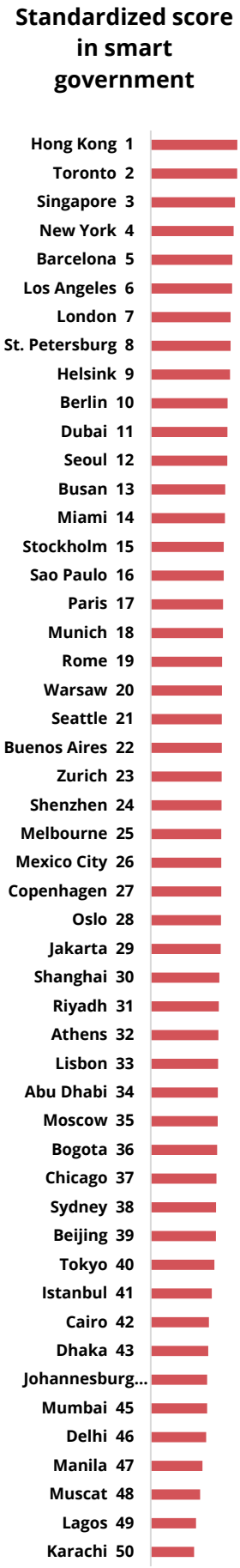
Smart Government

In terms of Smart Government, e-government and open data seems to be the current development focuses. While only 12 out of the 50 selected cities are found to have strong and clarified policies and schedules for systematic smart-city development, 40 and 33 cities have been developing e-government platforms and open data. Regarding the actual status of development, developed cities in general and several cities in newly industrialized economies performed well in e-government. However, among the dozen developed European cities in this study, only London, Moscow, and Helsinki rank top 20 in open data. The other cities fall behind not only other developed cities (e.g., US cities, Hong Kong, and Singapore) but also some cities in newly industrialized economies. Nevertheless, this may be related to the relatively small size of some selected European cities.

Two Asian cities, Hong Kong and Singapore, rank 1st and 3rd in this dimension, respectively. These successes may also reflect the stronger role played by Asian governments in smart-city development, and, further, the cultural differences between Asia and the Western world. Hofstede's cultural dimensions theory suggests that Asian cultures tend to prioritize collectivism over individualism. In contrast, Western cultures tend to emphasize individualism and personal freedom, leading to more decentralized and participatory governance where decisions are made through a process of public consultation and consensus-building. This difference may enable the former to achieve higher efficiency in realizing government initiatives. Both Hong Kong and Singapore have government offices (Hong Kong: Office of the Government Chief Information Officer; Singapore: Smart Nation and Digital Government Office) directly related to smart-city development, which benefits clearer leadership and more systematic development of smart cities.



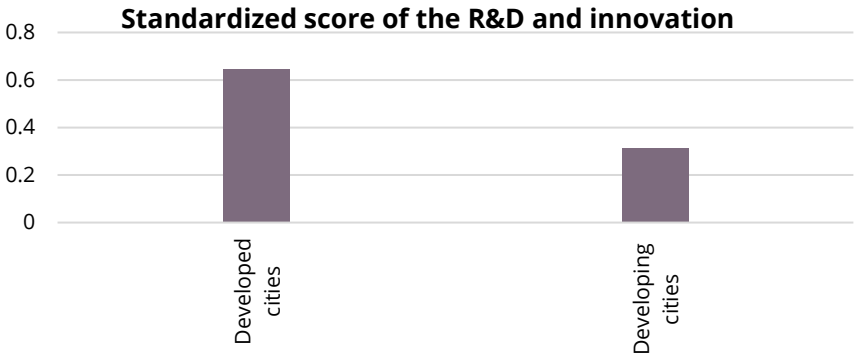


Smart Economy

Asian developed cities and cities in newly industrialized economies (particularly China) obtained very high score in Smart Economy, taking eight out of the top-10 in this dimension. On one hand, these cities rank high in the business environment and enterprise status, similar to the developed Western world. They also rank high in ICT exports, comparable with US cities and surpassing most European cities. On the other hand, these cities tend to have lower costs of living relative to wages, compared with the Western world.

The top-ranked cities, including Singapore, Hong Kong, Seoul, and Shenzhen, share similar characteristics: a high degree of openness to foreign investment, a high proportion of the service industry, and rapid development of high-tech industries. According to the government economic development plans of the four cities [5-8], they are all committed to the development of innovative technologies, especially in the areas of new information technologies, new energy, and intelligent manufacturing. All four cities are also committed to strengthening international cooperation, and their strategic locations are all gateways for national and foreign investment cooperation.

Among different indicator categories under Smart Economy, the largest gaps between the developed and developing cities lie in R&D and innovation as well as e-commerce. The average normalized score for R&D and innovation (including R&D expenditure and patents) of the selected developed cities exceeds twice that of those developing ones. The average rates of online shopping and online finance popularity in these developed cities both exceed 50%, indicating the arrival of the era of the digital economy.



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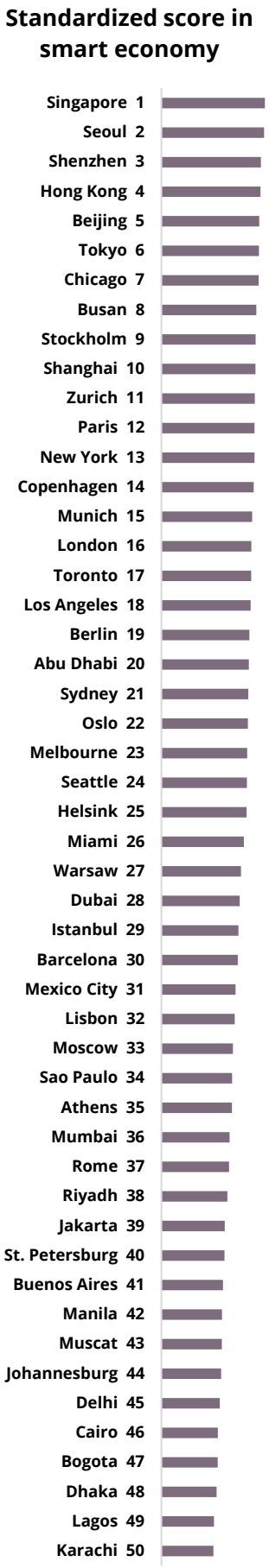

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