SMART CITY 스마트시티 글로벌 저널 2024

TOP Agenda

Smart City Global Journal 2024

The future of Smart Cities and Advanced Technologies

KAIA Korea Agency for Infrastructure Technology Advancement

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과학기술진흥원

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The Future of Smart City

The Future of Smart City

스마트시티의 미래

Sangho Lee

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ABSTRACT

Smart city is an unfinished future city yet. This paper is about the future of the future city. To understand the smart city that is coming slowly to our daily life, we need to talk about 3 things. First, understanding of the smart city in the historical context of cities that developed since 7,000~8,000 years ago by Homo Sapiens, a modern human, who emerged 200,000 to 300,000 years ago. Then, as the 4th industrial revolution started, the new phenomenon that changed the city, was discussed as a process of completing the smart city. Finally, the people who live in that city were discussed.

The space of city, as hardware, reflects the era, which is the software. The era contains humanity. This paper rethinks the future in point of humanity, times, and space of future smart city with a few questions and answers. Furthermore, it talks about the triggers of the rise and fall of smart city's success in the short and long term. Since it is a city that opens a new civilization, yet not fully developed future city, this paper analyzes and interprets the evidence from the past and current day. This paper is a story about the future of smart cities, drawn by predicted future.

KEYWORDS

Smart City, Future City, Homo Sapiens Humanity, New Era of Smart City, Image of Smart City

초록

스마트시티는 아직 미완성의 미래도시*Future City*이다. 따라서 이 글은 미래도시의 미래에 관한 이야기이다. 천천히 우리의 삶으로 들어오고 있는 스마트시티를 이해하기 위해서는 세 가지를 이야기해야 한다. 먼저, 20~30만 년 전에 등장한 현생 인류, 호모사피엔스*Homo Sapiens*가 기원전 7,000~8,000년부터 일구기 시작한 도시의 역사적 맥락에서 스마트시티를 살펴보았다. 그리고 4차산업혁명이 시작된 이후, 도시를 바꾸어 나가고 있는 새로운 현상들을 스마트시티의 완성 과정으로 이야기했다. 마지막으로 그 도시를 누리고 누비며 활동하는 주체들에 대하여 논의했다.

하드웨어인 도시의 공간상은 소프트웨어인 시대상을 반영한다. 그리고 시대상에는 그 시대를 살아가는 인간상이 담겨 있다. 이 글은 정치, 경제를 포함한 스마트시티의 미래 모습을 인간상, 시대상, 공간상에 대한 몇 가지 문답을 통해 생각해 본다. 또한, 근미래*Short Term*와 먼 미래*Long Term*에 도시 흥망성쇠의 방아쇠가 될 스마트시티의 성공요인을 논의하였다. 새로운 문명을 여는 그러나 아직 완성되지 않은 미래의 도시이기에, 이 글은 과거와 현재의 근거들을 통해 해석하고 미래를 예측하여 그려낸 스마트시티의 미래 모습에 대한 이야기*Stories*이다.

키워드

스마트시티의 미래, 미래도시, 인간상, 시대상, 공간상

The future that has yet to come, but the city we will eventually live in. The smart city is slowly coming into our daily life. Sometimes, quietly as we cannot recognize, but sometimes bringing a big wave to the society. This paper presents a prediction of the future based on the past and present.

The Humanity of **Smart City**

Q1. Will Homo Sapiens still sustainable in the smart city?

Modern humans Homo Sapiens, emerged 200,000~300,000 years ago, will still exist in the smart city. Yuval Harari, the historian, insists that the age of Homo Sapiens will fade, then the age of Homo Deus will rise. It is somewhat provocative. Historian predicts the future to be “As the old Homo Sapiens with lens evolve as cyborg human, Homo Deus will rise”. However, in the eye of urban planner, it seems like “Smart city will work as an efficient Hope System that fulfill the desire of Homo Sapiens as it used to be”. As always, the city, as from the history, are the place where Homo Sapiens ride on equipment like metal·gun·book, and the Hope System that actualize the imagination of human being. The smart city cannot exist without Homo Sapiens. “Smart city is for Homo Sapiens.” It is ‘smart city decision-making principles’ that should be kept in mind in ambiguous future and the road not taken.

Q2. Will avatar rise as another replica of Homo Sapiens?

The avatar that reflects Homo Sapiens’ imagination will rise. Humans imagined and created tools. Then the human and another human came along and collaborated each other. They built a reservoir and stacked up the City of Hope System. They established the City of Desire System, by creating guns and knives to take away accumulated wealth of others. The moat and walled city were created for defense. All these creations were constructed from the imagination of human beings. As an extension of this imagination, avatar is rising. In the movie “Avatar”, the replica of the character takes a war and falls in love in the world of Pandora. In the movie “Surrogates” the avatar robot works as a character’s agency in the real world of character. Furthermore, human like artificial intelligence secretary such as “Bixby” and “Siri” are already presented. Soon the agency will rise, and the avatar will be completed.

Q3. Who will live together with Homo Sapiens?

Human-like Artificial Intelligence will live together with humans. As it can be seen from the history of the city, the features of the city changed along with the subject that live with humans. Humans chose agriculture to overcome hunger and built agricultural cities with living with cattle. Genghis Khan built a city of empire with horses. To refrain from the burden of labor, humans created machines and lived with machines. Then they built an industrial city and lived in it. Humans who lived with cattle, horses, cars and machines, nowadays meet artificial intelligence and robots as their neighbor.

Artificial intelligence and robots that open the age of smart city, become automated and autonomous with innovation of internet and sensor networks infrastructure. It will create a smart city much faster and larger than the scale of previous human companion did to the human being. A city with well-functioning robots and artificial intelligence will be a smart city.

Q4. How the economic system will be in the smart city?

Nowadays, highly connected Platform Economy is leading the economy. Continued by agriculture economy of ancient and medieval era, crafts and commercial economy of modern era, and service and knowledge-based economy of modern, the platform economy is succeeding the history of wealth creation. Also, the city features changed according to the economy of each era, as meadows for agriculture, port city for overseas trade, industrial city for machine operation, and mega city for the service.

Smart city as it is the early stage, information and communication network is building a platform economy, and the technologies making this economy solid are being developed. Soon, from the centralized platform that substitutes market to electronic system, the era of decentralized and open blockchain economy that connects directly with customers and manufacturers will open. Accordingly, the data connected to Internet Data CenterIDC or Cloud System, will be processed faster than before. Furthermore, Quantum Computing, suitable for efficient ledger management based on distributed computing for mutual trust, will become an essential facility.

This platform economy that will be made by the smart city, will be larger, customized and newer than any past eras. The physical boundaries will become blurred, and an expanding economy that crosses the virtual and real world will become generalized.

Q5. Who will gain wealth and political powers in the smart city?

Decentralized Autonomous OrganizationDAO will lead governance and gain wealth in the smart city. According to the inflection point of past era, the flow of political power from ancient king, medieval age's lord and church, and modern age's civil republic, changed the city from castle, church, apartments and factory. As the guild that rose in the medieval era, DAO, the new hierarchy group, will rise. DAO is a hierarchical organization that autonomously unifies and disintegrates to generate profits under transparent rules on a decentralized network. DAO uses platform economy and smart city infrastructures to maximize profit and productivity. Furthermore, DAO will establish a new systems and governance through some kinds of compromise and competition with existing business capitalists and vested interest.

The politic of smart city will be an electronic direct democracy centered on more strengthened form of civil power. May be in the smart city, as it was in period of Yao and Shun, the peaceful era of not knowing who is doing politics. Transparent governance and direct apply of the citizens' opinion are the power of the political system in the smart city. Citizens' opinions are continuously gathered as data, and through this, citizen powers and wills will be constantly reflected in all decisions. Civil data is the key point of the political landscape of smart cities. The citizens are the owner of the data, and the data becomes the basis and means of political power. The republic that rises through the French Revolution by putting Louis XVI to the guillotine, will develop and inherited.

Q6. Where the stage of the smart city will be?

The short-term stage of smart city will be metropolis. The core technology that creates the smart city is based on information and communication technology. Therefore, metropolis, where the infrastructure for information and communication lied in dense, and the highest entropy of knowledge exchange and progress are in, will prosper. It will grow into a vertical city with high density, underground city and sky city. The megalopolis that connects the major cities in the metropolis will expand.

In the long term, the smart city will expand in both physical and theoretical point of view. As Columbus's great voyage widened the view of the world in the medieval age in point of physical view, the future of smart city will expand to the space. Exploration of the moon and Mars has been carried for a while, and the space travel program has already emerged. These are not science fiction stories but predictable future of smart city. Along with these, virtual space will expand the concept of space. Smart cities will have space of expanded physically and theoretically, and all connected as one. Universe earth will expand toward metaverse that create reality and virtual reality.

The Image of **Smart City**

Q7. How will features and behavior change in a smart city?

Smart cities will become complex and professionalized through overcoming physical barriers. The features of space change according to the behavior of humans. Behaviors are actualized by implementing the human imagination into technology. In the future smart city, everyone can gain their wanted service wherever and whenever. Physical barriers are being overcome as it can be seen from working at home through virtual meeting and smart work system, or shopping online, and delivering food to home. Furthermore, digital nomads, those who create wealth online, see all the space as an office and place to live, beyond the physical space called an office. Also, people in the smart city enjoy customized contents, and expand their home ground to space and virtual spaces.

Artificial intelligence and information and communication technology are developed to actualize these imaginations, and these technologies bring innovation to the built environment. In a smart city based on an information and communication network that carries information, the sensor network that carries or senses data is developed. The data of the space is being collected and carried through sensor network, which is the information and communication network. The sensor networks are spread like spider webs underground, under the sea, in buildings, and in the air. It will evolve into 5G, 6G, undersea communication network and space communication network that is capable of handling high-speed, large-capacity information. This data will be carried to the data center and stored. Also, these data will compute in data center or on the terminals themselves, causing buildings and objects to be automated and intelligent. Analog space gets highly efficient through space like smart factories and eco-intelligent spaces.

The land usage of future smart cities will also change. Smart cities will expand from vertical metropolis of near future to air, ground, underground, and virtual spaces of distant future. Space becomes complex, shared, flexible, and intelligent. In the modern industrial city, lands were used according to the division of residential, commercial, industrial, and green areas. Smart cities get vertically and horizontally complexed on land use, like COEX or Azabu Dai Hills. While factories and accommodation got physically separated due to noise and air pollution in the modern age, the sensor controls the noise, smell and vibration caused by mixed use in smart cities. The performance zoning gets generalized. Physical and virtual space is being connected and complex through various sensors and cyber physical system.

As a shared space, the relationship between land and usage changes into one-to-multiple from one-to-one. Through this, time zoning as well as sharing zoning occur, leading that “Less is More” becoming “Flexibility is More” in smart city. Even Urbanism and Mobile Urbanism, which is moving spaces, arises. The space of smart cities will expand to underground and into the air from ground of existing city. Furthermore, it will physically expand into space. Also, virtual space will be added which is different from traditional space. The virtual space and real space are correlated and affect each other.

Physically, smart city is “Now Here City”. In a smart city, everything can be done in one place. Through information and communication technology, people can teleport long distances and walk short distances. Physically, it expands toward the spaces, but the community might return to an ancient or medieval city. As from the ancient or medieval city, it will become a self-sufficient city where all services can be obtained within walking distance. Physically, food, energy, and service self-sufficient will be possible in Now Here City.

The Future of Smart City, **The Trigger of Rise and Fall**

Q8. First Trigger: Innovation

The first trigger that history talks about is innovation. Innovation means changing all the factors from how people work, live, move, play and etc. The way that the island nation Britain became the empire was possible by innovation of the hardware called machine and innovation of software called revolution of policy system. It led to technological innovations to economic innovation, and social-cultural innovation to space innovation. However, there would be a rebound by the innovation. As the Luddite movement in the modern era, smart city might face a movement that destroying robot or artificial intelligence. Walkers, platforms, and robots compete for jobs, and conflicts with vested interests will be carried along with the innovation.

Looking at the process of innovation, it is full of conflict, which seems like war without gunfire. The other name for innovation is illegal. The monarchy is overthrown by a republic, but in the monarchy point of view, the republic is illegal. Libra, the virtual currency that Meta was trying to create, was not be accepted, and Estonia, a small country that recruited world citizens, was under sanctions. As the procedure that the guild become capitalist, those who trying to protect the vested interests and those who trying to innovate in smart city will sometimes form alliances and sometimes fight agist each other as war. This is same context of USA and China in these days. Innovating old practices, policies and governance are the most important key factors of a successful smart city. If there are no innovations, it will fall.

Q9. Second Trigger: Data

Data is an indispensable factor in the smart city. Data is the rich land in the ancient and medieval age, petroleum in modern era, and the seed of the industry. The smart city that can have a system to collect real time data, monitor and predict, and automate and autonomy, will prosper. As in the starting point of smart city, nowadays the importance of data is claimed declaratively. However, as smart cities progress, data acquisition, storage, and artificial intelligence analysis technology become more important. The social agreements on data sovereignty, privacy of personal data, and AI intellectual property rights, have to be met.

As the hardware of smart city, it will start from building a wide-area high-speed information and communications network and an intelligent IoT smart city infrastructure connected to the Internet. The history of railways, roads and harbor in the modern era proves it. Wealth storage will shift from rice storage to internet data center and cloud. The efficient city structure will be made since the robot takes care of manufacturing and distribution. As these smart city infrastructure forms, the smart city with the digital twin related both real data and virtual data, Cyber Physical System CPS that virtual and physical coexist, will naturally open a new era.

Q10. Third Trigger: Energy

Smart cities will require a vast amount of energy. The fate of smart cities will be determined from how to supply cheap and high-quality energy. Historically, the rise and fall of the city is related to the energy. As it shifted from medieval into modern era, the coal mining city for running machine led prosper. Similarly, as the energy source shifted from coal to petroleum, countries and cities that had oil hegemony prospered. Nowadays, a new energy innovation is shaking the world economic landscape. The energy hegemony of climate crisis and fossil fuel abolition, and renewable energy and RE100Renewal Energy 100, is shaking the world economy. The smart city that supports energy efficiently will win the war.

If the blackout happens in the smart city system, smart city will face an enormous disaster. The smart city will stop at once. Through the cut off of electricity and communication system, medical systems will be paralyzed, transportation system will stop, and manufactural facilities will stop operating. Heating system will be stopped, water will cut off, all daily platforms will be paralyzed, and all the system dies in the smart city. One city's blackout will be chained and rippled to another city, eventually causing loss of function in all the city in the world. For the first mile toward sustainable smart city is supply of energy, the last mile will be risk management of energy. Energy supply and management are the necessary and sufficient conditions for smart cities to prosper.

Upcoming
Future of Smart City

Korea is losing its status as Dynamic IT Korea. The communication network is slow, new energy is in short supply, and data or artificial intelligence clouds system are also in short supply. Engineers and scientists are excluded from decision-making, and opaque and outdated practices continue, and the innovation in the field is still illegal or a system that only has responsibility. Everything needs to be changed, and we must make a fresh leap." Just as the name changed from U-City to Smart City, Smart City may be called by a new name in the future. The smart city that will open the new era. Smart city is not a simple city trend, and city that solves the problems of short views. It will be a new standard that divides a new rich and poor country, and citizen and capitalist. As Desire System, the smart city might bring a disaster. The philosophy of smart city for Hope System is needed. Communication, Share and Balance must be found for creating and sharing a new world together. The smart city is the city of Homo Sapiens. This is a fundamental principle to keep in mind when get lost in the process of creating a smart city.

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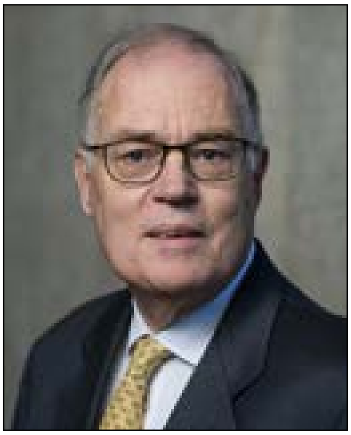
The future of smart cities:

what it means and what it needs

스마트시티의 미래: 그 의미와 필요

Bruno Lanvin



Dr Bruno Lanvin is currently the President of IMD's Smart City Observatory. He held senior positions in the United Nations and at the World Bank. He is the co-founder of four of the most widely used global indices: on technology (Network Readiness Index), innovation (Global Innovation Index), talent (Global Talent Competitiveness Index) and Smart Cities (Smart City Index). He is also the creator of the Future Readiness Economic Index Report FREI. He is co-founder and advisor of Portulans Institute, a thinktank based in Washington DC. He is the founder and president of DL Partners, and of Descartes Institute, two think tanks based in Geneva.

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ABSTRACT

This article argues that smart cities have now reached a critical point after which history will accelerate. It is hence vital to ensure that the promoters, the designers, the managers and the leaders of smart cities are on the right course, and equipped with the right tools.

Three key ingredients will be required to achieve this, namely:

- A fresh definition of smart cities
- Updated ways to measure the performance and impact of smart cities, and
- An ambitious new global urban agenda

KEYWORDS

Smart cities, future readiness, benchmarking, sustainability, inclusion.

초록

본 연구는 현재의 스마트시티가 역사적 가속이 시작될 중대한 지점에 도달했음을 강조하고 있다. 이에 따라 스마트시티를 이끌고, 설계하고, 관리하는 이들이 올바른 방향을 설정하고 적절한 도구를 갖추는 것이 매우 중요하다는 점을 논의하고자 한다.

이를 달성하기 위해서는 다음 세 가지 핵심 요소가 필요하다:

- 스마트시티에 대한 새로운 정의
- 스마트시티의 성과와 영향을 측정하는 최신의 방법
- 새롭고 야심 찬 글로벌 도시 의제 수립

키워드

스마트시티, 미래 대비, 벤치마킹, 지속 가능성, 포용성

Smart cities are the epitome of many fundamental changes in human societies. On one hand they illustrate how humans can improve their ability to live together by leveraging technology and innovation. On the other hand, smart cities show that success cannot rely on technology alone. On both sides of the smart city equation, changes have accelerated exponentially. They are now reaching a critical point.

Why are we on the eve of an acceleration of history? This results from the combination of two trends: on one hand, increasing urbanization rates continue to characterize the growth of human demography, especially in emerging economies; on the other hand, the increasing urgency to solve global issues such as climate change and growing inequalities is matched by the emergence of new tools - in particular artificial intelligence (AI) – that claim to be part of the solution.

One way to summarize the main challenge of to-morrow' cities is the following : how can you be future ready when the future is being constantly redefined at such a rapid pace?

At this particular junction, three vital inputs are urgently needed :

- A fresh definition of smart cities
- Updated ways to measure the performance and impact of smart cities, and
- An ambitious new global urban agenda

We need a fresh definition **of smart cities**

Since the seminal efforts deployed by IBM in the 1990s to promote 'smart solutions'[1)], smart cities approaches have been largely based on the hope that technology could solve urban problems, and make cities a model for future societies. This strong heredity linkage with technology has proved to be both a blessing and a handicap. Whereas better use of sensors and optimization methods undeniably helped reduce traffic congestion, improve waste management and diminish energy consumption per inhabitant, increasing concerns were being voiced about privacy issues, or governance more generally. In some parts of the world, the premises of a 'smart city backlash' have started to be heard.[2)]

Such negative views should not be discarded too lightly, as they often stem from deep concerns by citizens who expect more from their cities a shapers of a desirable future. Because inertia and negative reactions tend to naturally prevail over movement, it is important to offer an updated definition of smart cities, away from its techno-centric roots, and closer to what citizens have the right to expect today and to-morrow. Because this needs to be a positive definition, it is tempting to articulate it around the following acronym :

- **P** eople centric
- **O** pen (attractive)
- **S** ustainable
- **I** nclusive
- **T** ech savvy
- **I** nnovative
- **V** ersatile
- **E** xcellent (brand)

A few words of explanation will make clear why such a definition befits

1) See Palmisano S. (2008)

2) See Green, B. (2019), and Google's decision to abandon its Sidewalk experiment in Toronto in 2023

the needs of the time.

• **People centric** - Largely due to the genesis and history of IBM's 'smart everything' concept, smart cities have often been equated with 'high technology cities'. This sometimes led them to lose sight of citizen's most pressing problems and concerns. As mentioned earlier, examples of cities with 'technological solutions in search of a problem' have sometimes clouded the image of smart cities, and created a visible backlash. Nowadays, people-centricity needs to be put at the top of smart cities' priorities.

• **Open (attractive)** - In today's global economy, smart cities can not be designed or managed in isolation. Cities, regions and innovation clusters have become the new competitiveness hubs that compete to attract and retain talent, investment, tourism and visibility. Historically, this is how most cities have developed, i.e. by becoming exchange focal points. Smart cities need to accelerate their efforts to become to-morrow's global nodes and the testbeds for "*engineered serendipity*"

• **Sustainable** - Climate change mitigation is a priority for mankind. In the next 25 years, 3 billion people (mostly from emerging economies) will be living in cities. If those cities are not smart enough, this urbanization trend will reduce our collective ability to make this planet more liveable and to restore the appropriate balance between growth and sustainability. Smart cities have a unique role to play to show how technology, innovation and human-centricity can generate economic, social, political and environmental sustainability.

• **Inclusive** - Often starting as fairs and trading points, leading cities have traditionally been the places where cultures, ideas, and techniques would converge and combine. Globalization has contributed to reduce distances among people, nations and cities. In that process, traditional values of tolerance and support for minorities have been challenged. Smart cities have the power (and the responsibility) to re-energize our collective ability to fully integrate minorities and other less protected groups. Imaginative and effective policies around diversity, gender balance, and making cities more friendly to the disabled and elderly remain needed in many parts of the world. Smart cities can lead the way by testing, improving and deploying the organizational and technological solutions required.

• **Tech savvy** - Being human-centric does not mean being technophobic. Clearly, smart cities are the ideal testbeds for some of the most advanced technological innovations the world has to offer. They can also be the ideal places to provide the necessary 'reality check' that the wide social adoption of such innovations will require. Citizens need to be placed at the centre of the decision-making and governance apparatus required. Rapidly accelerating reliance on new tools such as artificial intelligence (e.g. through the routine use of digital twins) implies that smart cities should speed up their efforts to deepen their own knowledge and mastery of relevant technologies.

• **Innovative** - In the coming years, smart cities will incarnate some of the most creative strategies to be smarter, and do more with less. They will also be the places where people and organizations will do what has never been done before. Smart cities will spearhead new ways of thinking, designing and governing communities. This means that they need to consider that innovation is not just technological innovation: being socially, politically, organizationally innovative is what will allow smart cities to 'act out of the box' and offer new models for the future. For smart cities, developing their own innovation hubs (clusters), and developing their own innovation districts will be a critical factor of success.

• **Versatile** - For still some time, the global economy will continue to be characterized by its current VUCA traits (volatility, uncertainty, complexity and ambiguity). This maybe an environment in which smart cities can cope and perform better than larger entities such as national economies. To do so, however, they will need to remain flexible enough to prove resilient to external shocks, and to seize new opportunities. One-dimensional smart cities are bound to fail. Examples abound in history of cities that went brutally from prosperity to disaster because they were too narrowly specialized in a single product or production factor (coal, steel, automobiles). Growing, attracting and retaining the right talents will be a vital asset in this regard. As online collaboration increases the ability of workers to contribute anywhere from anywhere, cities that are liveable, safe and fertile in terms of networking and career opportunities will forge ahead of the competition.

• **Excellent**(brand) - Last but not least, smart cities will be competing globally with each other. Investments, talents and technologies will continue to become increasingly fluid, and flow rapidly from one location to another. In such a fast changing environment, excellence and branding will become critical parameters for arbitrations among possible destinations. This means that, for smart cities, offering unique value propositions (to talents, investors, tourists and other key players) will need to be accompanied by strong and imaginative branding strategies. Globally competitive smart cities will be the ones that can gain instant name recognition, and acquire an aura of 'the place to be' or 'the place to operate from'. Hosting major universities, research hubs or global organizations will be part of this effort, as well be the organization of world-resounding events in sports, culture or entertainment.

This positive redefinition of smart cities can also be regarded as a blue print for their future strategies. None of the eight elements highlighted above can be separated from the other seven. Altogether, they constitute the basis of a coherent and ambitious approach. It will need to be customized to the specific economic advantages (current or buildable) of each particular smart city, but also (and most importantly) to its history, culture, geography and demography.

We need to update our tools **to measure the performance and impact of smart cities**

Managing a smart city is a complex endeavour. Doing it in a way that guarantees both the efficient use of available resources and the levels of transparency and accountability needed to engage citizens behind municipal efforts makes it even more so. Gathering and presenting the data that will allow the tracking of on-going efforts and initiatives, and monitoring progress in ways that will allow future improvements is a full time job for many city officials. Adopting good practices in this regard is a critical asset for efficiency and impact. At a higher level, the data collected at the local level must meet recognized international standards if they are to be used for comparisons and benchmarking between cities around the world.

Why measurements are needed

As smart cities spread across all continents, international data become all the more valuable that they are necessary to produce a number of strategic and managerial tools, including :

1. Roadmaps, comparisons, benchmarking exercises : tracking and measuring progress is critically important to enhance current efforts; they are also vital to trigger innovative approaches at the local level, and offer to local citizens and decision makers inspiration from the successes (and sometimes the failures) or other cities,

2. Global indices by which individual cities can assess their own progress relative to other cities around the world : it is important that such indices should not be seen as pure 'medal awarding rituals' (naming the champions and shaming the laggards), but as tools for action, and
3. Case studies, which provide the contextual information necessary to confront the data and indices described above to the everyday reality of living in a smart city and managing it.

What indices exist today : the example of SCI

Since 2019, IMD's Smart City Observatory has made a major contribution to that complex edifice by publishing annually its Smart City Index (SCI)[3], and complementing it with series of case studies.[4] The Smart City Index offers a balanced focus on economic and technological aspects of smart cities on one hand, and "humane dimensions" of smart cities (quality of life, environment, and inclusiveness) on the other. For the last two years, it has benefitted from a partnership with the Seoul-based World Smart Sustainable Cities Organization (WeGO).[5]

This index is mostly based on perceptions: every year, a trusted third-party carries out surveys across representative samples of citizens, leaders and decision makers in relevant cities. The data collected from those surveys is then normalized and aggregated to produce graphs, tables and infographics that will make it usable in various contexts. The example (Figure 1) shows how data relevant to a particular city (in this case the Norwegian city of Oslo, which ranked 2nd in the 2024 edition of SCI) is presented in the

3) The 2024 version of the index covers 142 cities
4) See Bris and al. (2019 and 2021) and Lanvin (2024)
5) See https://we-gov.org

Figure 1

the case of Oslo

Source: Smart City Index Report 2024 (IMD, Smart City Observatory)

report.[6)]

In addition, the same data is routinely summarized through sets of infographics, which facilitates its use by press/media and non specialists. The example of San Francisco (75th in the 2024 edition of SCI) illustrates this approach in the Figure 2.

To allow more detailed analyses, the full data is made public through the use of various tables accessible on line on the SCI dedicated website. From a press and media point of view, however, it is often the 'final' synthetic ranking of smart cities that attracts most attention (see Table 1). Starting in 2024, SCI has been able to offer five-year time series, which will

6) The full annual SCI reports, methodology, data and analyses can be found at https://www.imd.org/smart-city-observatory

Source: : Smart City Index Website 2024 (IMD, Smart City Observatory)

Figure 2
the case of San Francisco

undoubtedly generate significant additional research from urban specialists around the world.

The collection and comparison of SCI data for those five years already allows to draw a number of key lessons, including the following :

• *The global dynamics of cities is changing*. While the trend towards higher urbanization rates continues to affect all parts of the world, different regions fare in contrasted ways in the SCI. For example, this year's report underlined that North American cities have proven to be volatile in their year-on-year positioning. In 2023, most US cities rose in the Index. In 2024, they have fallen. Some explanation can be found in President Biden's Build Back Better policies, which had a positive effect in 2023. In contrast, 2024 being an election year, survey respondents tend to be more critical about areas that need improvement. For the first time since the Index's creation in 2019, there were no North American cities in the Top

City	Rank 2024	Rank 2023	Rank 2021	Rank 2020	Rank 2019
Zurich	1	1	1	1	1
Oslo	2	2	2	2	2
Canberra	3	3	–	–	–
Geneva	4	9	6	8	7
Singapore	5	7	7	7	10
Copenhagen	6	4	5	3	4
Lausanne	7	4	–	–	–
London	8	8	9	5	6
Helsinki	9	8	9	5	6
Abu Dhabi	10	13	12	14	16
Stockholm	11	10	11	9	9
Dubai	12	17	14	19	13
Beijing	13	12	17	22	30
Hamburg	14	11	8	6	–
Prague	15	14	10	4	8

Table 1

SCI Global Rankings 2019-2024

Source: : Smart City Index Report 2024 (IMD, Smart City Observatory) and author's calculations

20 of SCI 2024: all but three of those same 20 cities were Asian or European.[7)]

• From a demographic point of view, *urban change in emerging countries becomes key to the future of the global economy*. As opposed to the evolution of large metropolises in more advanced economies (where they

7) Washington DC and Denver fell by 12 places, and Los Angeles by 11. Meanwhile, San Francisco went down by nine, New York City by seven, and Chicago by four. Adding to North America's woes, Ottawa's three-place tumble and Montreal's nine-spot loss created a setback for Canada, too. The data shows a worsening of infrastructure and safety across North America. On the contrary, overall quality of life has played a positive role in an increasing number of European cities. Zurich, Oslo, Singapore, Abu Dhabi, Beijing, and Seoul are the most consistently high-performing cities in the Top 20 since the Index started in 2019. Sydney, Hong Kong, Shanghai, Tallinn, Riyadh, and Melbourne look likely to enter the Top 20 soon, judging by their momentum across recent years.

tend to shrink) large cities in many emerging countries continue to expand, geographically and demographically. Diseconomies of scale continue to plague the efforts of larger cities (especially in poorer parts of the world) to deploy smart strategies. This is particular clear in the SCI data on safety, air pollution and traffic congestion, for example.

• *In mature economies, second-tier cities (typically cities ranking as No 2 to No 5 within a particular country) are the ones who show the highest performances and the most steady progress in SCI rankings*. These cities (typically with populations between 200,000 and 2 million people) generally prove more dynamic, more agile, and more innovative than their local larger competitors. Examples include those of Geneva or Lausanne in Switzerland, or of Bilbao in Spain.

• *Worldwide, the dominant issue remains affordable housing*, followed by safety and traffic congestion. This is where smart cities have a critical role to play in inventing and implementing innovative solutions to reduce inequalities and foster inclusion.

Moving to the next stage of urban metrics

One main reason to use surveys is the lack of internationally comparable data for cities. Over the last few years, however, renewed efforts have taken place to offer standard methodologies to cities interested in collecting and sharing internationally comparable data. International norms have even been produced to that end. The quality and breadth of such efforts are now bearing fruit, and a critical mass of reliable and comparable data will soon be available.

Integrating this new high-quality data will be only one part of upgrading the metrics of smart cities. The new tools need should also include additional dimensions, especially those related to the impact of urban policies (social, economic, environmental) .

Altogether, this new set of indicators should reflect cities' future readiness. This means that the metrics to be produced should give high importance (and visibility) to the ability of smart cities to adapt to future challenges and uncertainties, and to benefit from the new opportunities that will arise.

We need an ambitious **new global urban agenda**

Cities in general (and smart cities in particular) have a lot to offer to facilitate the transition of the world economy to the next wave of globalization. Building safer, more sustainable and resilient cities will constitute a large part of the planet's agenda in the next few decades. For the world as a whole, this may translate in more stable, less unequal and more tolerant societies.

In addition to the new definition and new metrics required (described in the first two section of this article), we need an innovative and ambitious agenda for cities. That agenda has to be global, because it is not just needed by cities (smart or not) but by the planet as a whole, as our civilization is becoming dominantly an urban one.

This can be illustrated in many different ways. One of them consists of highlighting sustainability issues, which will not be solved without a strong engagement by cities. One could also choose to make this point from the angle of inequalities, as disparities in income and access to basic services (including education and health) are one of the main challenges that accompany the process of urbanization. For the sake of concision, we shall only flag here two of the most urgent reasons why such a global agenda is required : the repeated failures of nation states, and the rapid spread of artificial intelligence.

Smart cities can mitigate the negative effects of nation states' failures

The COVID-19 pandemic showed that wherever central governments are unable (or unwilling) to react quickly and cohesively to address a massive external shock, cities are able to step up to the plate. In some of the largest economies of the world, vaccination campaigns and distribution of protective equipment (masks, gels) have often been organized faster and better at city and local levels than at federal or central ones.

Similarly, in the domain of international trade, as an increasing number of national governments engage in mutually damaging protectionist policies, the collapse of multilateral disciplines translates a pervading erosion of trust in international relations. Yet, trading cities, transport and financial hubs develop imaginative ways to maintain their activities and develop new links across national borders.

The same can be said about university cities and innovation clusters, where cultural and ethnic diversity continue to flourish and nurture future-oriented attitudes, cooperation and discoveries. Those are the places where international trust and cooperation can be re-built.

Among the many ways in which cities can help our civilization to build a better to-morrow, the following seem to deserve priority in the global urban agenda that we now need:

1. Cities must claim (and receive) additional responsibilities (i.e. over those of nation states) to revive multilateral cooperation and re-build trust in international relations,
2. Cities should be seen as key sources of experience to reconcile sustainability and growth: as urbanization continues and gathers momentum, climate issues will become unsolvable in the absence

of a global urban climate agenda,

3. Cities should be the first target of efforts to reconcile prosperity and inclusion: without growth, strategies aimed at inequality reduction may translate in little more than a redistribution of poverty.
4. Cities' human centric strategies and actions should be regarded as a model and source of experience for what the next wave of globalization should be about. BY developing, testing and improving local governance models, cities can open the door to the generalization of such approaches, customized to the specific needs, values and expectations of populations around the world, and
5. Cities should be heralded as the ideal testbeds for innovative approaches and practices: this should not only be the case for technology-based solutions (the example of artificial intelligence will be addressed below), but also for new models of governance, new ways to think about energy, mobility, spatial organization, and sustainability for example.

How cities can use AI to guide many of the choices to be made at the global level

As underlined by Yuval Noah Harari in his latest book (Nexus)[8] '*artificial intelligence is not a tool; it is an agent*'. This implies that the governance and regulation of AI long have to rely on a set of principles rather than precise rules: those will need to retain the degree of flexibility that will allow their progressive refinement. The resulting regulatory and legal frameworks required at global level will hence be the result of experimentations

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8) i.e. a software program that can interact with its environment, collect data, and use the data to perform self-determined tasks to meet predetermined goals. See Harari, N.Y. (2024)

and trial-and-error. The entities that will be the most intensive users of AI will then become the main source of the lessons needed to support that global effort. Cities are well positioned to be among those 'power users', as AI can make significant contributions to several key pillars of urban policies. To name a few, one can think of : urban design, building methods, delivery of public services (health, education, public transport, safety, eg), infrastructure management and optimization (energy grids, transport/mobility), efforts to stimulate and orient growth and innovation, human resources (talent) and citizen engagement, data-driven decision making, sustainability policies and initiatives, approaches and projects to foster inclusion, diversity, and reduce inequalities. AI may also help foster urban resilience/crisis management (alert systems, rescue operations), and enhance their efforts to gain external visibility and attractiveness (e.g. through targeted branding).

Conclusion

With a better and positive (POSITIVE) definition of smart cities, combined with better data and metrics, academia, business and ordinary citizens can give their full dimension to cities as agents of change. By being human-centric and innovation-supportive, smart cities can help solve some of the most important problems of our times. The next wave of globalization will also need its own positive definition. That however, should be the subject of another article.

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The Regenerative Smart City: a New Horizon for Urban Living

재생력을 갖춘 스마트시티: 도시 생활의 새로운 가능성

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ABSTRACT

The rise of smart cities, defined by advanced technology, hyper-connectivity, and data-driven innovation, has reshaped sustainable urban development. Yet, as environmental challenges escalate, a critical question arises: can smart cities evolve beyond sustainability to become truly regenerative? While sustainability seeks to minimise ecological damage, regenerative cities aim to restore and revitalise ecosystems. This shift requires a fundamental transformation of urban systems, focusing on resilience and equity for all.

A regenerative city incorporates principles of diversity, equity, and a just transition to net-zero carbon, rethinking the broader purpose of urban life. Unlike the large-scale infrastructure of smart cities, regenerative urbanism prioritises human-scale developments, echoing Jacob's(1967) vision of urban design centred on local needs and engagement. Lyle's(1999) concept of regenerative design deepens this by integrating circularity into energy, water, and material flows, fostering a balanced relationship between human and natural systems.

Embedding regenerative principles into the smart city paradigm offers an opportunity to reshape urban futures through the creation of regenerative smart cities. Technologies like artificial intelligence (AI) and the Internet of Things (IoT) can support cities in becoming restorative forces. However, challenges exist, such as fragmented data, concerns over privacy, and the complexity of managing interdependent systems. Without robust local governance, there is a risk that cities may evolve into technocratic regimes disconnected from both communities and nature.

For cities to transition from sustainability to smart regeneration, entrenched barriers must be addressed. This article concludes that governance models need rethinking from the ground up, ensuring that technological innovation is matched with inclusivity and ecological stewardship. Only through this integration can smart cities truly regenerate both the planet and the social fabric of urban life.

KEYWORDS

Regenerative, Smart, Just Transition, Localism, Governance

초록

첨단 기술, 초연결성, 데이터 중심 혁신이 특징인 스마트시티의 등장으로 지속 가능한 도시 개발이라는 개념을 재검토하게 되었다. 환경 문제의 심화로 인해 '스마트시티가 지속 가능성을 넘어 진정한 재생형 도시로 나아갈 수 있을까?'와 같은 질문이 제기되고 있기 때문이다. 지속 가능성이 생태계의 피해를 최소화하는 데 초점을 맞추는 반면, 재생형 도시는 생태계를 복원하고 활성화하는 것을 목표로 한다. 이를 위해서는 도시 시스템이 모두를 위한 회복력과 형평성을 중심으로 근본적인 변화를 이뤄야 한다.

재생형 도시는 다양성, 형평성, 탄소 배출 제로 전환을 바탕으로 도시 생활의 목적을 재정의한다. 기존의 스마트시티가 대규모 인프라 중심이라면, 재생형 도시는 인간 중심의 개발을 우선시하며 지역적 요구와 참여를 강조한다. 이는 도시 이론가이자 활동가 제인 제이콥스*Jane Jacobs*의 도시 디자인 비전(1967)을 떠올리게 한다. 건축가 겸 도시계획 설계자인 존 라일*John Lyle*의 재생 설계 개념(1999)은 에너지, 물, 물질 흐름에 순환의 원리를 통합하고, 인간과 자연 시스템 간의 균형 잡힌 관계를 조성함으로써 이를 더욱 심화시켰다.

재생 원칙을 스마트시티 패러다임에 통합하면 재생형 스마트시티의 건설을 통해 도시의 미래를 재편할 기회를 제공할 수 있다. 인공지능*AI*과 사물 인터넷*IoT* 같은 기술은 도시의 회복력을 강화하는 데 기여할 수 있지만, 단편적인 데이터, 개인정보 보호 문제, 상호 의존적인 시스템 관리의 복잡성 등 여러 난제가 존재한다. 따라서 강력한 지역 거버넌스가 뒷받침되지 않으면, 스마트시티는 지역 사회와 자연으로부터 단절된 기술 관료 체제로 전락할 위험이 있다.

도시가 지속 가능성에서 스마트한 재생으로 전환하려면 해결하기 어려운 장벽을 극복해야 한다. 본 논문은 도시 거버넌스 모델의 근본적인 재고로 기술 혁신이 포용성과 생태적 관리와 조화를 이뤄야 한다고 결론짓는다. 이러한 통합만이 스마트시티가 지구 환경뿐 아니라 도시 생활의 사회적 구조까지 완전히 재생할 수 있기 때문이다.

키워드

재생형, 스마트, 공정한 전환, 지역주의, 거버넌스

Introduction, the Illusion of Control: **A Critical Examination of the Smart City Concept**

The celebrated author, E.M. Forster's(1909) short story, *The Machine Stops* presents a prescient vision of a world where humans become utterly dependent on a singular technological platform. In this world, automated systems become so efficient that human-to-human interaction all but disappears. As the machine governs all aspects of life, people lose the ability to maintain or understand it. When it inevitably fails, the knowledge to repair the system is lost, leading to societal collapse. Forster's critique, though penned over a century ago, resonates sharply in today's smart city discourse.

Contemporary urban development often celebrates the smart city for harnessing advanced technologies such as artificial intelligence, the Internet of Things (IoT), and big data to enhance efficiency, convenience, and quality of urban life. Cities are evolving into hyper-connected systems where data flows seamlessly, automating services and managing urban infrastructures with unprecedented precision. However, while this vision of urban progress appears promising, it exposes significant vulnerabilities. Forster's cautionary tale reminds us that dependence on technology can erode human agency, decentralise accountability, and reduce civic life to mere transactions within a vast, unseen machine.

A major consequence of the smart city model is its increasing disconnection from natural systems. As urban environments become more technologically driven, they risk losing touch with the ecological processes that sustain life. Smart cities often approach nature as something to be managed or controlled rather than nurtured and cherished. In *Small is*

Beautiful, Schumacher(1973) warns against this mindset, stating, "modern man talks of the battle with nature, forgetting that if he won the battle, he would find himself on the losing side." In a similar vein, Lovelock's(1979) Gaia hypothesis posits that Earth operates as a self-regulating system where living organisms and their environment collaborate to maintain conditions that support life. Initially critical of technology's impact on the planet, Lovelock later embraced it as a tool for addressing environmental challenges. He argued that while unchecked technological progress could harm Gaia, thoughtful and responsible innovation might help mitigate climate change and restore balance to Earth's systems.

In this context, the smart city's emphasis on artificial systems can distance citizens from the natural world, reinforcing a divide between urban life and the environment. This disconnection can yield cities that are not only unsustainable but also sterile, where ecosystem health becomes an afterthought to technological progress. Lovelock cautioned against overconfidence in humanity's ability to control complex natural processes, stressing that Gaia's systems are unpredictable. While technology can be a double-edged sword, the smart city's trajectory risks exacerbating these challenges rather than resolving them.

The promise of the smart city is rooted in a technocratic ideal where data optimises every facet of urban life — from traffic flow to energy consumption, predictive policing to healthcare services. However, as these systems become more integrated, citizens often find themselves increasingly unaware of the mechanisms behind them. The complexity of smart city systems creates a gap between technology and the people it serves, transforming urban life into algorithmic processes governed by invisible systems, often without public input. This risks rendering citizens passive users of the *city-as-a-service* rather than active participants in urban life.

Moreover, the smart city has drifted from its original civic ideals. Initially envisioned as a platform for local empowerment and community engagement, it has evolved into a vehicle for corporate influence. Corporate-driven smart city models, such as Woven City and Sidewalk Labs, can prioritise private interests over public accountability, raising concerns about who truly benefits from the generated data and resources.

The reliance on digital infrastructure also raises pressing issues of equity and exclusion. While some residents may thrive in these hyper-connected environments, others are left behind, facing digital poverty — defined by a lack of access to reliable internet, digital devices, or the skills to engage with these systems. Conversely, those fully integrated into the digital city may experience hyper-visibility, where the expectation of constant connectivity and productivity fosters burnout and alienation in an increasingly surveilled environment.

Beyond societal implications, the smart city model has become embroiled in the debate over environmental sustainability. Critics argue that smart cities exacerbate the climate crisis, consuming vast amounts of energy to power data centres, 5G networks, and digital infrastructures. The apparent efficiency of smart cities can mask their role as accelerators of resource consumption, perpetuating unsustainable urban growth under the guise of innovation. The growing disconnection from nature —both in the physical design of cities and their operational logic — deepens the ecological crisis, risking the foundations upon which all cities are built.

Forster's *The Machine Stops* highlights the risks inherent in our race towards technological utopia. The allure of convenience and efficiency can foster a dangerous dependency on systems we no longer fully control or understand. The question arises: are smart cities genuinely improving urban life, or are they merely constructing more efficient machines, detached from the needs and aspirations of their citizens and the natural systems that sustain them? If we neglect these concerns, we may, like Forster's characters, find ourselves trapped in a malfunctioning system, unprepared and powerless to repair it.

However, it is also crucial to acknowledge the achievements of the smart city model. Many cities have successfully implemented smart technologies that enhance urban living and promote sustainability. For instance, intelligent transportation systems have improved traffic management, reducing congestion and emissions in cities like Los Angeles and Singapore. Smart grids facilitate more efficient energy distribution and consumption, enabling cities to integrate renewable energy sources and reduce reliance on fossil fuels. Initiatives such as Barcelona's smart lighting and waste management systems have significantly improved resource efficiency, lowering costs and environmental impact.

Moreover, smart cities can foster community engagement through platforms that allow residents to report issues, access services, and contribute to local decision-making. Cities like Amsterdam have developed open data initiatives that empower citizens and organisations to utilise urban data for community-based projects, promoting transparency and collaboration. These examples demonstrate that when implemented with a focus on inclusivity and sustainability, smart city technologies can improve the quality of urban life and contribute to more resilient, adaptive communities.

As the smart city narrative continues to evolve, we must critically examine its trajectory. The city of the future must not only be efficient but also equitable, transparent, and responsive to the needs of its inhabitants. Reconnecting with nature is vital, as a healthy urban environment cannot exist in isolation from surrounding ecosystems. This requires a shift from merely optimising systems to empowering people and restoring natural processes, ensuring that the benefits of technological advancement are shared by all, not just a select few. Otherwise, the promise of the smart city risks becoming its downfall - a machine that serves itself rather than the people and planet it was designed to serve.

The limitations of the smart city model invite a dialogue about what comes next. If its focus on efficiency and technology risks perpetuating unsustainable systems, what alternative urban paradigms can address ecological and social challenges more holistically? The concept of the regenerative city, which seeks not just to sustain but to restore and renew, offers a potential framework for rethinking urban development. Exploring how regenerative principles, emphasising the symbiosis between human systems and nature, complement or evolve the smart city model paves the way for a more sustainable and inclusive urban future.

The Opportunity of **the Regenerative Smart City**

As urban development evolves beyond the limitations of traditional smart city models, the concept of the regenerative smart city emerges as a transformative alternative. This model promises not only sustainability but also urban renewal that actively restores ecosystems and enhances the quality of life for all inhabitants. At its core, the regenerative smart city aims to shift from a linear, resource-extractive model to a circular economy, where waste is minimised, materials are continuously reused, and natural systems are fully integrated into urban life.

Central to this vision is the idea of fostering circular resource flows, allowing cities to function like natural ecosystems that convert waste into valuable inputs. This aligns with Lyle's(1999) principles of regenerative design, advocating for systems that restore rather than degrade the environment.

Lyle's vision promotes a reciprocal relationship between human activities and natural systems through the integration of nature-based solutions, such as urban forests, green roofs, and wetland restoration. These approaches manage organic waste streams while improving biodiversity and enhancing resilience to environmental shocks.

The economic potential of circular practices is significant. The Ellen MacArthur Foundation estimates that integrating circular economy strategies could unlock £1.4 trillion in economic benefits for the UK alone. Beyond financial gains, such practices help reduce environmental degradation, allowing cities to thrive alongside the ecosystems that support them.

However, the transition to a regenerative smart city requires more than technological innovation; it necessitates a rethinking of governance and decision-making processes. Effective governance is crucial for implementing regenerative practices equitably and ensuring benefits are distributed across all communities.

Jane Jacobs, a prominent urbanist, championed the need for cities to be "human in scale", where local communities actively participate in shaping their environment. Her emphasis on community-led urbanism underscores the importance of local engagement in ensuring urban development meets the needs of its inhabitants.

Building a regenerative city therefore calls for an integrated approach involving collaboration across public, private, and civil society sectors. Policies must create the right incentives for circular economy initiatives, fostering a shared commitment to sustainability and resilience. As cities evolve, this shift toward regenerative urbanism presents an opportunity to create environments that not only sustain life but actively regenerate the ecosystems on which life depends.

Identifying Strategic Pathways **for Transformation**

Strategic pathways are needed to facilitate the transition towards regenerative smart cities, recognising the importance of integrating technological, social and environmental systems. This transition calls for a departure from siloed planning approaches toward holistic strategies that align technological innovation with sustainable urban living.

One effective framework for guiding this transition is the Three Horizons Model, which helps stakeholders visualise potential future scenarios. Developed by Sharpe(2013) this model encourages the exploration of three distinct time horizons:

- Horizon 1 focuses on the current systems and practices, emphasising short-term improvements and efficiencies.
- Horizon 2 involves incremental innovations and adaptations that can bridge the gap between current practices and more sustainable approaches.
- Horizon 3 envisions a transformative future characterised by regenerative urban practices that integrate circular economies and ecological resilience.

By using this model, cities can identify key actions and policy measures that align with long-term goals. For instance, cities can assess current practices (Horizon 1) and identify emerging technologies and community initiatives (Horizon 2) that can lead to the desired outcomes of a regenerative smart city (Horizon 3).

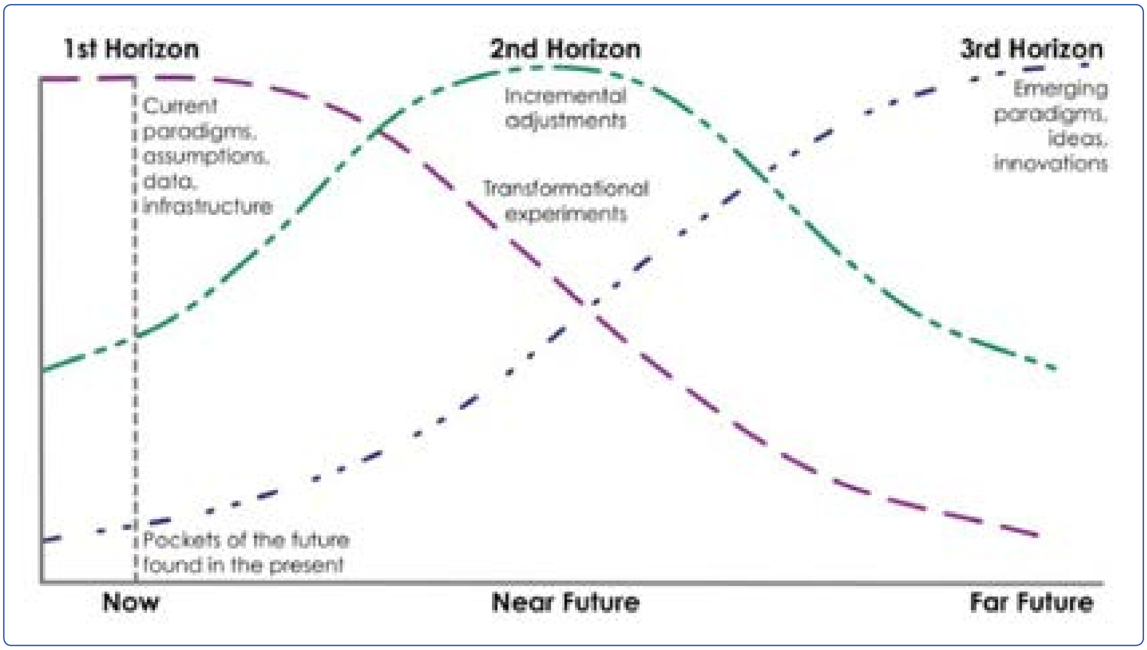

Figure 1

Three Horizons Model

Source: : Three Horizons Framework (ITC)

Applications of **Three Horizons Thinking**

Cities like Barcelona and Amsterdam have successfully integrated sustainable urban mobility and circular economy principles into their strategic planning. In Barcelona, the 2024 Urban Mobility Plan focuses on reducing car dependency while promoting walking, cycling, and public transport. With over 62 key actions and 300 specific measures, the plan aims for 81% of all trips to be made via these sustainable modes, aligning with broader environmental goals such as reducing greenhouse gas emissions.

Amsterdam has adopted a circular economy approach with its Amsterdam Circular Strategy, which outlines the city's ambition to become fully circular by 2050. This strategy features collaborative initiatives that engage local businesses, government, and citizens in efforts to increase resource efficiency and minimise waste.

The City of Bath has utilised Three Horizons thinking to guide Bath Spa University's future relationship with creative technologies. The strategy shifts from a traditional *accelerator* model, which seeks to rapidly scale small businesses, to a propagation model, where these businesses remain small, yet achieve scale through effective peer-to-peer collaboration. This dispersed approach to growth aims to create a local economy that is resilient to global shocks and stresses.

In these examples, a commitment to long-term, transformative change, consistent with the Three Horizons model, is helping to envision a transition from current systems to a more sustainable and regenerative future.

Integrating **Diverse Perspectives**

The Three Horizons Model promotes inclusivity by inviting diverse stakeholders to participate in envisioning and designing the urban future. For example, the EcoDistricts Initiative in Portland continues to advance neighbourhood-scale sustainability efforts by integrating community engagement into urban planning. This initiative fosters local governance structures and sustainability assessments tailored to specific neighborhoods, which enhances community resilience and sustainability. In a recent gathering, the EcoDistricts Institute brought together representatives from multiple cities to share best practices and strategies for implementing sustainability at the neighbourhood level.

This collaborative effort resulted in actionable plans aimed at increasing resource efficiency and minimising waste within communities. Such participatory processes empower residents to express their needs and priorities, ensuring that urban strategies reflect the aspirations of the communities they serve.

Evidence suggests that inclusive governance models improve the resilience of urban systems. The European Commission's Urban Agenda for the EU emphasises the importance of participatory governance in achieving sustainable urban development. Cities that adopt inclusive decision-making processes tend to create policies that are more effective and widely supported by their communities. This alignment between community needs and policy not only enhances environmental sustainability but also fosters a sense of ownership and responsibility amongst residents, reinforcing the interconnectedness of social and ecological well-being.

Challenges and Opportunities **in Urban Governance**

While the Three Horizons Model offers significant potential for fostering smarter urban development, several challenges must be navigated to fully realise its benefits. Traditional governance structures often prioritise immediate economic gains over long-term sustainability, creating barriers to innovative approaches. Additionally, stakeholders accustomed to established practices may resist shifts towards new models of governance and collaboration.

However, these challenges can serve as catalysts for innovation. By prioritising adaptive governance and creating frameworks for collaboration across public, private, and civil society sectors, cities can cultivate a culture of experimentation and learning. For instance, the Living Lab approach, as implemented in cities like Bristol, encourages stakeholders to test and refine urban solutions in real-world settings, facilitating iterative learning and adaptation.

Radical Approaches **to Urban Transformation**

As the climate crisis intensifies, traditional urban governance models are increasingly seen as inadequate. The Intergovernmental Panel on Climate Change (IPCC) has emphasised the need for rapid, transformative strategies to combat global warming, urging cities to implement bold, innovative solutions. Various case studies illustrate how communities are empowered and sustainability is prioritised in these efforts.

One noteworthy initiative is the Fearless Cities Movement, which seeks to transform urban governance through radical democratic practices. Originating in Barcelona, this movement empowers communities to reclaim their cities from corporate control, advocating for citizen-led policies that emphasise social equity and environmental justice. Cities like New York and Toronto have adopted principles from this framework, implementing measures such as participatory budgeting, which allows residents to influence local budget allocations directly. New York's initiative has fostered active citizenship, ensuring community needs are prioritised in urban decision-making.

Barcelona's own Participatory Budgeting initiative exemplifies effective citizen engagement, allocating over €30 million to projects proposed and voted on by residents. This programme has enhanced public spaces and local services while setting a benchmark for transparency and accountability in governance.

C40 Cities also plays a vital role in climate action, providing a platform for urban centres to share best practices and develop innovative strategies. Initiatives such as C40's Waste to Resources programme promote circular economies by encouraging waste reduction and resource recovery. Cities like Amsterdam and London are implementing sustainable waste management systems that engage communities, showcasing how collaborative networks can drive urban resilience amid pressing climate challenges.

Bristol's City Leap Initiative is another bold example, aiming for net-zero carbon emissions by 2030 through a £1 billion investment partnership between the city council and private stakeholders. This programme focuses on renewable energy projects, enhancing energy efficiency in public buildings, and fostering local ownership, thereby addressing climate change while promoting social equity.

Adding to this landscape of transformative urban strategies, Seoul has emerged as a leading example in Asia for innovative urban governance and sustainable development. The city's Seoul 2030 strategy prioritises community involvement in urban regeneration projects, integrating green spaces, affordable housing, and sustainable transport solutions. By engaging residents in the decision-making process, Seoul exemplifies a commitment to participatory governance that aligns with the principles of the Three Horizons Model, addressing immediate urban needs while laying the groundwork for a more resilient future.

Seoul's commitment to public engagement is evident in initiatives like the Citizen Participatory Budgeting Project, which allows residents to directly influence budget allocations for local improvements. This approach has significantly enhanced transparency and community ownership, making it a notable case of participatory governance in action.

The Role of Public **Common Partnerships**

Public Common Partnerships (PCPs) Milburn & Russel(2019) are seen as crucial for the transition to regenerative cities, advocating for collaborative ownership and management of urban resources among diverse stakeholders. This model encourages inclusive governance, allowing citizens a voice in shaping their environments and ensuring accountability in decision-making processes.

PCPs facilitate partnerships that align public objectives with private innovation, pooling resources and knowledge to enhance urban resilience. They support the integration of nature-based solutions, such as green roofs and urban forestry, promoting both environmental sustainability and social cohesion. By fostering a culture of collaboration and innovation, PCPs empower communities and instil a sense of responsibility for shared resources.

Incorporating PCPs into urban governance structures promotes inclusivity, essential as cities grapple with climate change, urbanisation, and social inequality. By prioritising community engagement, these partnerships pave the way for urban environments that are technologically advanced yet socially and ecologically vibrant, meeting the urgent demands of a changing climate.

Conclusion

Reimagining cities as interconnected, regenerative systems is not merely an aspiration; it is an imperative for urban development in the face of pressing global challenges. Traditional urban models are no longer sufficient to address the complexities of climate change, urbanisation, and social inequality. A holistic approach that prioritises the interdependence of social, economic, and ecological systems is essential for fostering resilience and sustainability in our urban environments.

Central to this paradigm shift is the recognition that cities are integral parts of larger ecological networks. By adopting principles of circular economies and enhancing resource management, urban areas can turn waste into valuable inputs and restore degraded ecosystems, thereby closing the loop on resource use. As cities embrace these regenerative practices, they can not only mitigate their environmental impact but also enhance their resilience against future shocks.

Participatory governance and community engagement are crucial in this transformation, empowering residents to shape urban development that is technologically advanced and socially equitable. The evidence from current case studies underscores the potential of collaborative models that leverage local knowledge, fostering a sense of ownership among citizens. Cities that actively engage their communities can harness a wealth of innovative ideas and solutions, making the transition to a regenerative future more achievable.

Networks like C40 Cities demonstrate the power of shared knowledge and collective action in achieving urban resilience. By facilitating the exchange of best practices, these networks bridge the divide between technological innovation and grassroots engagement, underscoring that sustainable urban solutions must emerge from diverse stakeholder collaboration. Movements such as Fearless Cities push the boundaries even further, advocating for radically democratic governance that prioritises community-led initiatives and social justice.

In this envisioned urban landscape, smart technologies will be leveraged to create adaptable, responsive environments that not only enhance quality of life but also nurture natural ecosystems. Data-driven solutions will play a pivotal role in monitoring urban ecological health, guiding decision-making, and promoting transparency. By adopting a regenerative mindset, cities can prioritise ecological integrity and social equity, ensuring that the benefits of technological advancements are distributed fairly among all residents.

The journey toward reimagining smart cities as regenerative is fraught with challenges, yet it promises to create vibrant, resilient urban spaces that endure and thrive over time. By committing to this transformative vision, cities can become active participants in restoring ecological balance while improving the well-being of all inhabitants. Ultimately, transitioning to interconnected, regenerative systems is not just a strategic move, it is the only "smart" choice for cities aiming to thrive in an uncertain future. Embracing this vision for regenerative smart cities will pave the way for a future where urban living and nature coexist in balance, ensuring the sustainability of our planet for generations to come.

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SMART CITY TOP AGENDA 2024

CHAPTER

02

Smart city and Artificial Intelligence

AI-Enabled Smart Cities:

Building Intelligent and Interconnected Urban Infrastructure Through Machine Learning Innovation

AI 기반 스마트시티:

머신 러닝 혁신을 통한 지능적이고
상호 연결된 도시 인프라 구축

Carl Härtlein

Carl Härtlein is an investment professional, CEO, and Founder of Saint Clair Advisory & Capital. He established the Saint Clair Asia Investment Framework to interconnect and strengthen ties between European and Korean investment ecosystems. Through his work with stakeholders on both sides, he facilitates international investment partnerships, particularly in bridging Asian technological innovation with European implementation capabilities. His professional journey of twenty-five years in digital technology combines with an academic background as an Architecte DPLG (French State Certified Architect), providing him with a unique point of view on innovation in the urban context. A truly global citizen in spirit, Carl's purpose is to build bridges that allow us to join forces to tackle the important challenges that our planet faces.

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ABSTRACT

This paper examines the emerging evidence on artificial intelligence integration in urban environments, with a particular focus on digital twin implementation and its implications for city development. The study identifies critical success factors in AI-driven urban transformation while considering economic, environmental, and social implications. It demonstrates that successful AI integration depends not merely on technical sophistication but on the careful orchestration of governance frameworks, implementation strategies, and stakeholder engagement. Key findings suggest that while technical capabilities continue to advance rapidly, from quantum-enhanced sensing to autonomous environmental response systems, successful urban transformation requires institutional arrangements that balance innovation with public interest. Based on evidence from multiple urban centres, the paper provides strategic recommendations for cities considering AI implementation, emphasising the importance of measured, thoughtful approaches to achieve an interconnected, networked urban digital transformation

KEYWORDS

artificial intelligence, digital twins, interconnected smart cities, urban governance, sustainability, social equity

초록

본 논문은 도시 환경에서 인공지능 통합에 대한 새로운 증거를 탐구하며, 특히 디지털 트윈*digital twin*의 구현과 도시 개발에 미치는 영향을 중점적으로 다룬다. 또 경제적, 환경적, 사회적 함의를 고려하면서 AI 기반 도시 변혁*AI-driven urban transformation*에서 중요한 성공 요인들을 규명한다. 이는 성공적인 AI 통합이 단순히 기술적 정교함에만 의존하는 것이 아니라 거버넌스 프레임워크, 시행 전략 및 이해관계자 참여를 신중하게 조율하는 것에 달려 있다는 것을 입증한다. 중요한 것은 양자 기술을 이용한 센서에서부터 자율적 환경 대응 시스템에 이르기까지 기술적 역량이 계속해서 빠르게 발전하고 있지만, 도시 변혁이 성공적으로 이루어지기 위해서는 혁신과 공공 이익을 균형 있게 조절하는 제도적 조치가 필요하다는 것이다. 본 논문은 여러 도시에서의 증거들을 바탕으로, 향후 AI 구현을 고려하는 도시들을 위하여 전략적인 조언을 제시하고, 상호 연결된 도시 네트워크 디지털 혁신을 달성하기 위한 신중하고 사려 깊은 접근 방식의 중요성을 강조한다.

키워드

인공지능, 디지털 트윈, 상호 연결된 스마트시티, 도시 거버넌스, 지속 가능성, 사회적 형평성

Introduction

Integrating artificial intelligence with urban systems marks a fundamental shift in city development and governance. While the rhetoric surrounding Smart Cities often emphasises technological capability, evidence from leading implementations suggests a more nuanced reality: successful urban transformation depends as much on careful governance and social consideration as on technical sophistication.

The convergence of digital twin technology with artificial intelligence might represent the most significant development in urban management since the introduction of computerised systems. These sophisticated virtual replicas, enhanced by quantum sensing and edge computing capabilities, enable unprecedented insight into urban operations. However, their true value emerges not from raw computational power, but from careful integration with governance frameworks and social systems.

The economic implications of this transformation extend well beyond operational efficiency. New markets in urban intelligence have emerged, while traditional infrastructure financing models have evolved to capture the value of digital capabilities. The evolution of cities into regional or global networks supports new business models on top of public services, capable of attracting private investments and generating opportunities for new public-private partnerships.

Environmental applications of these technologies demonstrate particular promise as cities confront mounting climate challenges. Advanced sensing networks combined with sophisticated AI analytics enable a more precise understanding of urban environmental performance. Perhaps most significantly, the social implications of AI integration warrant careful consideration. While early implementations often prioritised technical efficiency, leading cities increasingly demonstrate sophisticated approaches to ensuring equitable benefit distribution and meaningful citizen engagement. This evolution suggests a future where AI technology serves as an enabler of social cohesion rather than a driver of urban fragmentation.

These developments demand strategic responses that balance technological opportunity with social responsibility. As cities worldwide consider AI implementation, evidence increasingly suggests that success depends on careful attention to governance frameworks, implementation sequencing, and stakeholder engagement.

AI in Smart City Development: **Digital Twins and Data Generation**

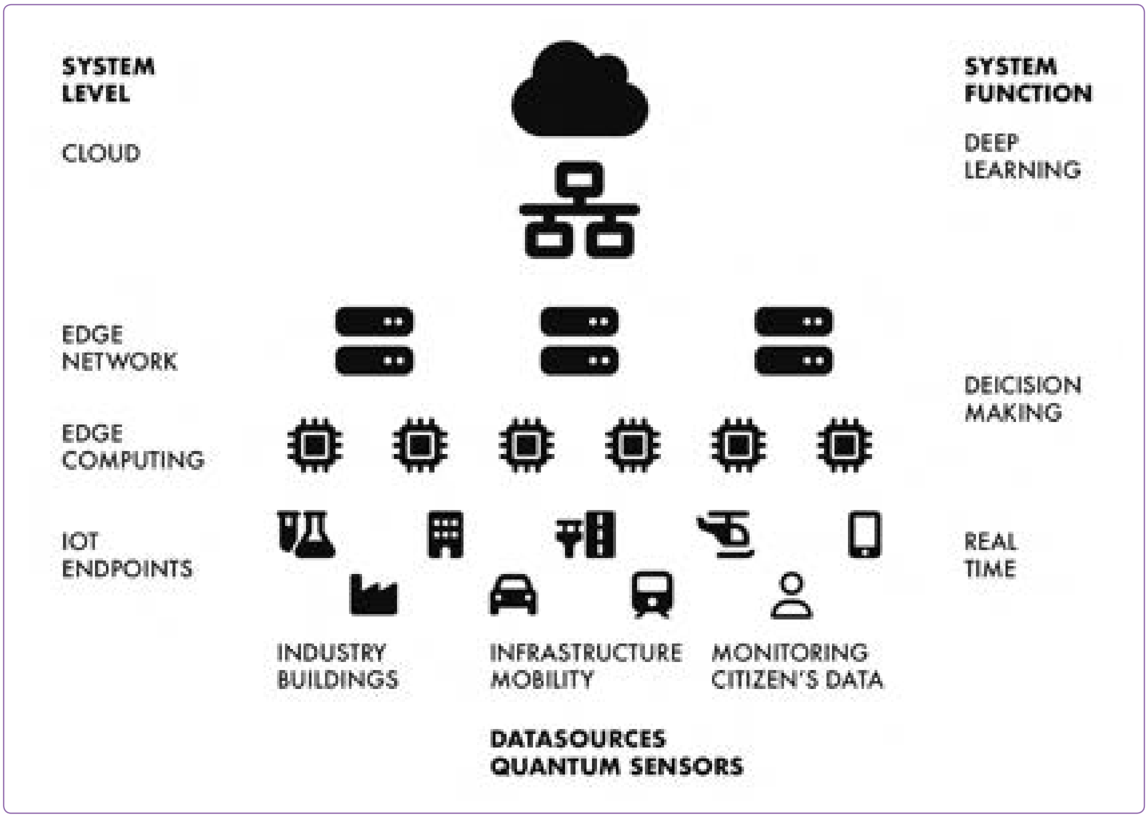
The quiet revolution in Smart City development lies not in the visible transformation of urban landscapes, but in their digital counterparts. Digital twins have emerged as the cornerstone of AI-driven urban planning, offering unprecedented capabilities to simulate, analyse and optimize city operations. These virtual replicas, far more sophisticated than their early predecessors, now serve as the central nervous system of modern urban management.

The Virtual Singapore platform demonstrates the practical impact of this approach. The city-state's digital twin has evolved from a simple visualisation tool to a comprehensive planning platform for urban decision-making. Built over almost 10 years, starting in 2014, Virtual Singapore (Singapore Land Authority, 2014) aims to be an open system that allows third parties to connect and exchange data reserved for public stakeholders in the first phase but to open the platform to businesses and citizens.

The true value of digital twins lies in their ability to generate and process extensive datasets reflecting real-time urban conditions. As cities deploy advanced sensor networks enhanced by recent quantum sensing technology, these platforms capture increasingly granular data across multiple systems—from traffic flows to energy consumption patterns. The integration of edge computing infrastructure, also called “fog computing”, has dramatically reduced latency in data processing, enabling near-instantaneous analysis of urban conditions.

These platforms prove particularly valuable in simulating rare yet consequential scenarios. Rotterdam’s Climate Proof Programme (C40 Cities, 2016) demonstrates how digital twins can enhance flood prediction and mitigation strategies through advanced modelling capabilities. The ability to generate synthetic data for these situations enables AI models to prepare

Figure 1
Edge or Fog Computing Layers in Smart City Digital Twins



for scenarios that occur too infrequently for traditional learning approaches, lacking the necessary data from real extreme events.

This capability extends beyond crisis management to encompass the modelling of subtle shifts in urban dynamics, from changing transportation patterns to evolving energy demands, thanks to the capability to generate complex synthetic scenarios.

Yet perhaps the most transformative development lies in the emergence of autonomous digital twins—systems capable of not only modelling urban environments but independently optimizing their operation. These systems, suggest a future where urban infrastructure could adapt automatically to changing conditions, from adjusting traffic signals in real-time to modifying energy distribution patterns based on predicted demand.

But as the use of digital twins evolves, their importance reaches beyond isolated city systems. The emergence of cross-city digital twin networks, particularly in the European Union's Smart Cities Initiative (European Commission, n.d.), demonstrates the potential for shared learning and collaborative urban intelligence. Cities participating in these networks have reported marked improvements in their ability to address common urban challenges, from traffic management to emergency response.

Economic Impact and **Investment Opportunities in AI-Driven Smart Cities**

This regional or global relevance sparks the emergence of urban data marketplaces (European Commission, n.d.), driving and fuelling the interoperation of Smart Cities in return and representing perhaps the most significant economic development in this sphere. Amsterdam's Smart City (2024) initiative has pioneered platforms for anonymised urban data sharing, creating new economic opportunities. These marketplaces have the potential to attract institutional investors (Moncada Rivera, 2024), suggesting the emergence of urban data as an asset class in its own right.

Public-private partnerships have consequently evolved considerably in response to these technological capabilities. Traditional contractual arrangements are giving way to more sophisticated, performance-based models enabled by AI-driven monitoring systems. Barcelona is at the forefront of the debate, organising global challenges around the topic of public-private collaboration, in particular in the sector of transportation and urban mobility. The Barcelona City OS (Ajuntament de Barcelona, n.d.) constitutes a shared participatory reference framework combining public and private stakeholders. These new partnership models suggest a future where urban services operate with greater efficiency and accountability, introducing the agility and reactivity of private initiatives and through collaboration with startup companies and investors.

The transformation of infrastructure financing through tokenization and Smart City bonds presents another notable development. Singapore's and Switzerlan's recent implementation of blockchain-based infrastructure tokens (Pereire & Yinxin, n.d.) has demonstrated the potential for more liquid and efficient infrastructure investment markets. This approach enables fractional ownership of urban assets while providing real-time performance data to investors, fundamentally altering the risk-return profile of infrastructure investments, and shortening implementation of critical projects in a significant way.

In addition to the new data marketplaces, urban intelligence emerges as an exportable commodity and represents another significant economic opportunity. Cities that invest and successfully implement AI systems often find themselves with valuable expertise and tested solutions as an asset, that can be marketed to other urban centres. Helsinki's Digital Twin Project (Helsinki Digital Twin Project, 2024, Hämäläinen, 2021) demonstrates how cities can develop exportable expertise in Smart City solutions.

The financial implications of environmental impact and, importantly, the need for improved urban resilience appear substantial while harder to quantify. Faced with the challenges and threats of global warming, Cities with advanced AI systems demonstrate markedly better performance in managing both acute crises and chronic stresses, resulting in lower insurance costs and better credit ratings.

Environmental Impact: **AI for Climate Resilience and Sustainability**

The environmental implications of AI integration in urban systems might represent the most consequential aspect of Smart City development, particularly as cities confront increasingly complex challenges related to climate change. Better practices and improved tools for city management and urban development allow reaching beyond the quest for efficiencies, transforming how cities plan their future as part of a greater, often global context.

The emergence of real-time carbon tracking systems marks a significant advancement in urban environmental management. Copenhagen's Solutions Lab (Copenhagen Solutions Lab, 2024) has implemented sophisticated sensors and AI analytics for environmental monitoring, demonstrating new possibilities in urban emission tracking. These systems enable more nuanced approaches to emissions reduction, moving beyond broad policy measures to targeted interventions based on actual performance data.

Water management has emerged as another critical domain for AI applications. At the moment of writing this article, the city of Valencia in the south of Spain is suffering the consequences of catastrophic floods, while the reservoirs providing water to Barcelona's population are at a record low following more than two years of severe drought.

Advanced predictive models now enable cities to anticipate and respond to water stress with remarkable precision. Integrating quantum sensors in water infrastructure provides increasingly granular data about system performance, enabling more sophisticated approaches to conservation and distribution. These systems aggregate diverse data sources to generate more and more accurate predictions of local climate impacts, enabling proactive approaches to adaptation.

The attention to environmental performance data in urban planning processes has begun to transform development practices. AI systems now enable planners to model the environmental impact of proposed projects with unprecedented accuracy, leading to more environmentally conscious design decisions. These capabilities extend beyond immediate environmental impacts to consider long-term climate resilience and adaptation potential.

However, the use of AI goes far beyond support for planning the response to climate stress. The emergence of autonomous environmental response systems again suggests a future where cities can adapt automatically to changing environmental conditions.

Significant technological advances have been realised in edge computing and quantum sensors, enabling real-time operation in areas like autonomous driving. The same technologies are also capable of enabling quick or immediate reactions in an urban environment to trigger coordinated responses involving multiple systems as a result. Early implementations in Barcelona and Tokyo demonstrate the potential for AI systems to modify urban operations in response to environmental stressors, from adjusting

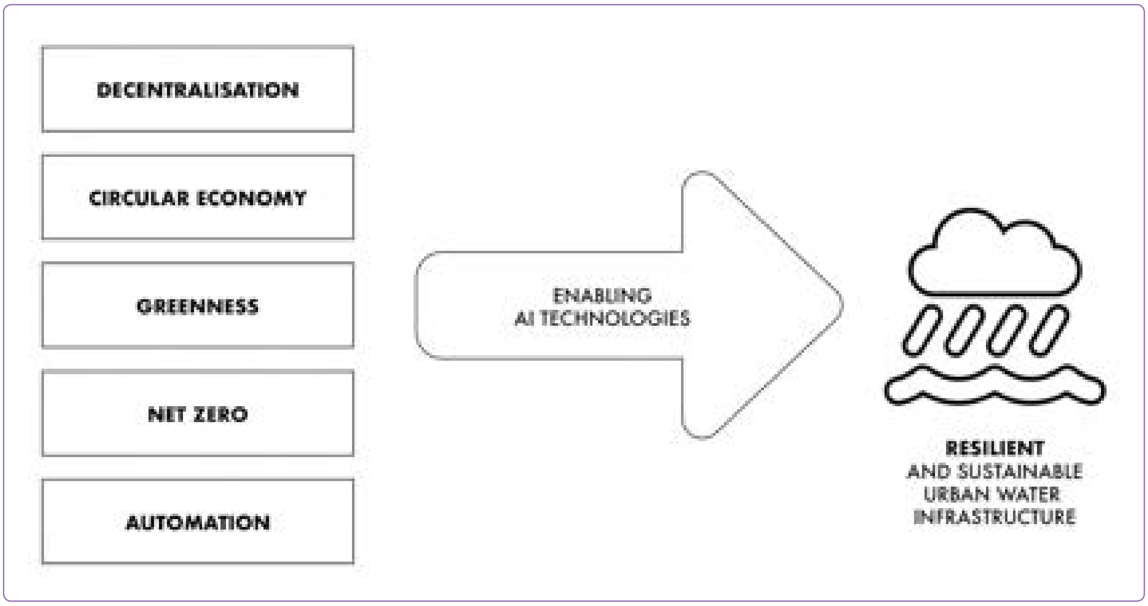


Figure 2

Ingredients for an AI-Enabled Urban Water Infrastructure

building systems during heat waves to optimising drainage networks during intense rainfall events.

The emergence of cross-city environmental intelligence sharing networks again represents a promising development in urban climate action beyond the scope of isolated urban centres. These networks enable cities to learn from each other's experiences while developing more coordinated approaches to shared environmental challenges.

Societal and Social Impact: **Building Inclusive and Diverse Urban Spaces with AI**

AI integration in urban environments also drives a fundamental shift in how citizens interact with their urban environment and how they can exercise their influence, becoming more informed and involved in decision-

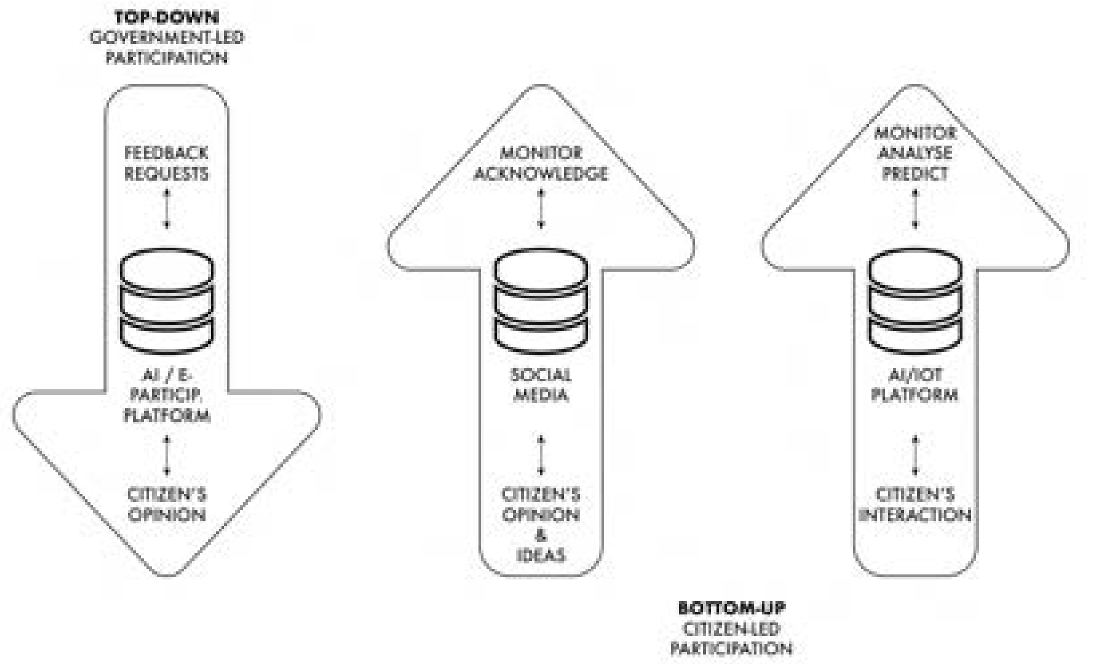


Figure 3

Technology-led Participation Models

making. The use of AI-based systems enhances and supports existing actions that aim at creating more diverse and inclusive urban environments and provides stakeholders with tools that stimulate the development of new initiatives or new ways of valorising social and generational capital in the Smart City context.

The emergence of digital twin interfaces for public consultation marks a significant advancement in participatory urban governance. Cities including Barcelona and Helsinki have developed sophisticated platforms that enable citizens to visualise and comment on proposed urban changes through immersive interfaces. The transformation of public services through AI-enabled personalisation also increases inclusion: cities implementing sophisticated service delivery platforms report increased user satisfaction while reducing administrative overhead, driving efficiencies in the use of public budgets. These systems enable a more informed public discourse and debate while reducing traditional barriers to participation, strengthening the sense of community and reinforcing inclusion.

The development of urban digital identity systems represents another significant, however controversial, social innovation. While raising important privacy considerations, carefully implemented systems demonstrate the potential for improving service delivery while enhancing social inclusion.

The evolution of urban safety systems through AI integration simultaneously presents opportunities and challenges. While advanced systems demonstrate potential for improving public safety, successful implementations typically emphasise transparency and community oversight.

Seoul's Smart City platform implementation (Seoul Metropolitan Government, 2024) demonstrates advancing capabilities in real-time data processing and digital representation. The city government is continuously enhancing the reach of the platform and provides data through their Seoul Open Data Website (Seoul Metropolitan Government, n.d.) not only to businesses and citizens but also to tourists.

Seoul startup White Scan's disaster prevention geographical information system (GIS) constitutes an interesting example of the benefits and, at the same time, the challenges in terms of data security of AI-based security tools. The system uses a big data approach integrating information on cell phone use and mobile payments in combination with real-time footage from Seoul's numerous security cameras to predict crowd dynamics and movements.

Unfortunately, the system was only in the development stage at the moment of the devastating Itaewon Halloween disaster that cost the lives of more than 150 people and left almost 200 injured during the night of October 29th, 2022. However, the startup team was able to use data captured in the area before the event, to demonstrate how their system would have been able to predict, and thus manage the flux of pedestrians in Seoul's Itaewon neighbourhood's narrow streets.

The key to this system's effective use is easy access to the city of Seoul's numerous data sources and generally South Korea's more permissive data protection policies. It would probably be impossible to implement a similar system in Europe, for example, as most of the data needed to train and run White Scan's machine learning model would fall under the EU's strict privacy protection laws.

Strategic Recommendations **for AI-Driven Smart City Success**

Data governance has emerged as perhaps the most critical strategic consideration for Smart City leaders. Cities demonstrating sustained success typically establish clear protocols for data collection, management and sharing before deploying advanced AI systems. These frameworks must balance operational requirements with privacy protection while ensuring sufficient transparency to maintain public trust.

Investment strategies for AI implementation have grown more sophisticated as evidence accumulates about effective approaches. Leading cities increasingly adopt portfolio approaches that balance quick wins with longer-term transformational projects. After initial ambitious, but often poorly sequenced implementations, cities expect more sustainable outcomes with a more measured approach.

The emergence of regional or global cross-city learning networks suggests new possibilities for risk mitigation in AI implementation. Cities participating in structured knowledge exchange programmes typically achieve better outcomes while avoiding common implementation pitfalls.

Investing in quantum technology readiness emerges as an increasingly important strategic consideration. While widespread quantum computing deployment remains distant, cities implementing AI systems must consider quantum security implications in current architecture decisions. This strategic orientation has wide-ranging consequences beyond the technological aspects themselves. Cities must create favourable conditions for companies providing technology and support, show attractivity for a highly qualified workforce, and generally demonstrate their quality as fertile ecosystems for innovation and investment in the field.

Funding models for AI implementation continue to evolve as evidence accumulates about sustainable approaches. Innovation attracts investors, and opening their investment strategies to public-private partnerships provides cities with a more diverse landscape of funding sources. Integrating the innovative approach of tokenisation mentioned before, cities can develop new models where citizens are not only beneficiaries of innovative strategies but also stakeholders with a financial interest in their city's development.

While early implementations often relied heavily on external funding, more sustainable models typically emphasise value capture from system benefits. This approach proves particularly important for maintaining system quality over time. When planning for the integration of AI-based technologies in their development, cities can already anticipate opportunities to monetise their experience with implementing and operating those systems, thanks to the evolution of the Smart City landscape into a connected, networked system.

Conclusion

While technical capabilities continue to advance rapidly, from quantum-enhanced digital twins to sophisticated environmental monitoring systems, sustained success appears to depend primarily on institutional arrangements and implementation strategies that carefully balance competing priorities, rather than a technology-push approach.

Public stakeholders and city planners gain in AI-based technology new powerful tools that allow them not only to gain necessary technological and budget efficiencies, but thanks to a high degree of scalability also open up unprecedented opportunities to interconnect urban systems that have been managed in isolation so far. Coordinating cities existing yet mature legacy, together with new innovative systems enables new ways to match the challenges our cities face.

As an investor, the aspect of interconnection stands out as the most important driver for opportunity: the aforementioned technological scalability translates into financial scalability, turning urban systems into potential sources for attractive returns on investment. Citizens can see themselves becoming stakeholders with a financial interest through tokenisation and gain additional possibilities to influence the evolution of their urban environment.

Finally, regional and even global interconnection emerges as a source of mutual stimulation. Sharing knowledge, experience and data builds an international community of Smart Cities and Smart City professionals that is much bigger than the sum of its constituent parts.

Our cities face unprecedented challenges that exceed their urban territory and sphere of influence. To tackle the challenges our planet and society face, we must use our collective intelligence and the creative, interconnected power that urban communities have harnessed for millennia during our human history.

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SMART CITY TOP AGENDA 2024

AI Smart Cities Operating Systems:

Harnessing Autopoiesis, Collective Intelligence and City DNA as a new model

AI 스마트시티 운영 체제*AI SCOS*:
자기 생성, 집단 지성 및 도시 DNA를 새로운 모델로 활용

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ABSTRACT

This paper proposes a pioneering model for AI-enabled smart city operating systems (AI SCOS) that harnesses autopoiesis, collective intelligence, and the concept of City DNA to reimagine urban management and development. Unlike static frameworks, this model conceptualizes cities as dynamic, evolving systems akin to living organisms—able to self-regulate, adapt, and transform. City DNA, the unique blueprint of each city's spatial, economic, social, and cultural attributes, forms the foundation of this model, encapsulating each city's essence and informing its technological integration and evolution. AI SCOS builds upon this framework by integrating principles of autopoiesis—self-regulation, adaptation, and self-creation—into a system that leverages real-time data to foster situational awareness and adaptive responses.

The AI SCOS acts as a city's "central nervous system," harmonizing interactions among human, technological, and environmental systems to maintain resilience and resource efficiency. Collective intelligence, fueled by inputs from urban functions, sensors, citizen feedback, and environmental data, enables the city to adapt continuously, responding to shifts in real-time while preserving its unique identity. In this way, AI SCOS enables cities to transcend traditional, rigid urban management structures, emerging as self-sustaining, regenerative ecosystems that evolve alongside technological and societal changes.

This paper lays the groundwork for a transformative future where cities operate as self-regulating autopoietic systems—responsive, resilient, and capable of continuous self-organization. By embedding City DNA within AI-driven, adaptive architectures, operating systems will be developed around each city's unique spatial, economic, social, and cultural blueprint, allowing for urban environments that evolve in tandem with technological and societal shifts. South Korea's distinctive blend of advanced technological infrastructure, centralized governance, and cultural cohesion provides an ideal context for piloting Autopoietic Operating Systems.

KEYWORDS

Artificial intelligence, Collective Intelligence, Self-regulating cities, Sustainability, Autopoiesis

초록

본 논문은 자기 생성, 집단 지성과 도시 DNA 개념을 활용하여 도시 관리와 개발을 재구상하는 AI 기반 스마트시티 운영 체제*AI SCOS*를 위한 혁신적인 모델을 제안한다. 정적인 프레임워크와 달리, 이 모델은 도시를 살아있는 유기체와 같은 동적이고 진화하는 시스템으로 개념화했다. 도시의 DNA는 각 도시의 공간적, 경제적, 사회적 및 문화적 특성을 반영한 독특한 청사진으로 이 모델의 기초를 형성하며, 각 도시의 본질을 담고 그 도시의 기술적 통합과 진화에 대한 정보를 제공한다. AI SCOS는 자율적 생성의 원칙, 즉 자율 조절, 적응, 자기 생성을 통합하여 이 프레임워크를 기반으로 구축된다. 이를 통해 실시간 데이터를 활용하여 상황 인식과 적응적 대응을 촉진하는 시스템을 형성한다.

AI SCOS는 도시의 '중추 신경계' 역할을 하며 인간, 기술 및 환경 시스템 간의 상호 작용을 조화롭게 조정하여 회복력과 자원 효율성을 유지한다. 도시 기능, 센서, 시민 피드백, 환경 데이터를 통한 집단 지성은 도시가 지속적으로 적응할 수 있게 하며, 실시간으로 변화에 대응하면서도 고유한 정체성을 유지할 수 있도록 해준다. 이러한 방식으로 AI SCOS는 도시가 전통적이고 경직된 도시 관리 구조를 벗어나 기술 및 사회적 변화에 따라 진화하는 자립적이고 재생 가능한 생태계로 거듭나도록 지원한다.

이 논문은 도시가 자율적이고 지속적인 자기 조직화를 통해, 반응적이고 회복력이 있으며 자율 조절이 가능한 자기 생성 시스템으로 운영되는 변혁적인 미래를 위한 토대를 마련한다. 도시 DNA를 AI 기반 적응형 아키텍처에 통합함으로써, 각 도시의 고유한 공간적, 경제적, 사회적 및 문화적 청사진을 중심으로 운영 체제가 개발되면, 기술적 및 사회적 변화와 함께 진화하는 도시 환경이 가능해질 것이다. 대한민국은 첨단 기술 인프라, 중앙 집권적 거버넌스, 문화적 응집력이 결합되어 있어 자기 생성 운영 체제*Autopoietic Operating Systems*를 시범 운영하기에 이상적인 환경을 갖추고 있다.

키워드

인공지능, 집단 지성, 자율 조절 도시, 지속 가능성, 자기 생성

Introduction

Cities are not static entities; they evolve in a manner akin to living organisms, transforming through adaptation, selection, and emergence into more complex forms. Historically, we have seen civilizations rise and fall in discernible patterns, yet today's cities are embedded within an era of globalization and continuous transformation. As urban centers face mounting challenges—from environmental degradation to rapid population growth—the need to understand cities as evolving, self-sustaining systems has never been more pressing. Only by embracing this perspective can we achieve sustainability and avoid systemic collapse in the face of an uncertain future.

At the heart of this approach is the concept of City DNA, a framework that defines the unique, inherent identity of each city through a combination of its spatial, economic, social, and cultural characteristics. City DNA embodies the foundational essence of each urban environment, shaped by its geography, history, culture, and technological capabilities. Just as biological DNA dictates the genetic makeup of organisms, City DNA provides a blueprint for understanding and nurturing the unique qualities of each city, allowing technology to be seamlessly integrated in ways that resonate with the city's core identity and adapted in an appropriate way for each city's evolution. Yet the complexity of each city's operating systems requires a new intelligence.

The concept of AI Smart City Operating Systems (AI SCOS), introduced in this paper, builds on this understanding by combining the principles of autopoiesis—self-regulation, adaptation, and self-creation—with the power of collective intelligence applied to each city's unique DNA. This approach enables cities to function as self-regulating ecosystems, where human, technological, and natural systems interact harmoniously. Through

AI-driven frameworks, cities can dynamically balance resource allocation, respond to environmental shifts, and foster resilience by continuously learning and evolving in response to real-time data. The AI SCOS thus serves as the city's "central nervous system," processing inputs from real-time urban functions, sensors, citizen feedback, and environmental data among others to maintain a constant state of situational awareness and adaptability.

By leveraging collective intelligence and embedding City DNA within an adaptive, autopoietic architecture, AI SCOS positions cities to transcend traditional rigid operating systems and urban management models. In this framework, cities are not merely collections of infrastructure and services but dynamic, living ecosystems capable of growth and regeneration. AI SCOS brings forth a new paradigm where cities are empowered to thrive as resilient, intelligent environments, fostering a balanced relationship between humans, technology, and nature.

By rethinking urban environments as autopoietic systems—self-sustaining, adaptable, and capable of continuous self-organization—this paper lays the foundation for a future where cities evolve alongside technological advancements and societal changes. In this model, urban life is not just sustained but enriched, with AI SCOS creating a blueprint for cities that are sustainable, responsive, and resilient in an era of rapid global change.

The initial concept of cities as autopoietic, was explored in the author's earlier work *Cybernetic Revisited; Towards a Collective Intelligence; Princeton Press (2011).*

This new cybernetic process will rely on our exponential increase of computational power to process and filter the massive data required to provide a real-time documentation of global activity and resulting behavioral patterns. Each element within our collective biosphere will need to *be carefully tracked, interrelating multiple factors such as geologic and climate conditions, predatory traits, and lifecycles. In this complex and multidimensional data environment, the role of visualization will be key in providing the capacity to recognize the emergent patterns and processes of these phenomena. Visualization will itself become organic, as it will need to adapt to simulate information from a wide spectrum of sources, ranging from micro/organic to macro/planetary states. The role of artificial intelligence will be critical in creating this new cybernetic form of resistance, revealing abnormal trends and anomalies and giving us the ability to utilize resources more effectively and to prevent major catastrophes before they occur.*

The Concept of Autopoiesis **in Urban Systems**

Autopoiesis, from the Greek words "auto" (self) and "poiesis" (creation), describes a system's capacity to self-sustain through internal processes. This concept was introduced by biologists Humberto Maturana and Francisco Varela in 1972 in their seminal work Autopoiesis and Cognition: The Realization of the Living, defining the essential processes that allow living organisms to independently create and maintain all components necessary for survival. Autopoietic systems are thus inherently self-generating entities that manage both structure and function to sustain life.

Maturana and Varela's framework extends to social and organizational systems, with clear applications to urban environments. Here, cities function as complex, evolving systems requiring continuous adaptation and feedback loops to remain resilient. Like living organisms, cities must self-regulate and adapt to environmental shifts—a capability enhanced by AI, which allows cities to dynamically balance resources, monitor environmental variables, and adapt to internal or external changes.

Viewing cities through an autopoietic lens allows us to understand them as real-time, complex systems in which multiple, interconnected subsystems operate in unison. Drawing a parallel to the human body, cities can be seen as "gestalt formations" with interdependent functions, such as circulation, energy flow, and waste management. These functions are informed by real-time data from human, machine, and environmental sources, which provide critical operational insights. Big data, augmented by artificial intelligence (AI), enables these urban systems to filter, analyze, and respond in real-time, promoting cities as self-regulating ecosystems. The challenge lies in integrating each urban subsystem—each with unique operational requirements and response times—into a cohesive, city-wide operating system that spans both human-centric and autonomous intelligence functions.

A defining trait of autopoietic systems is their ability to reshape physical and organizational structures through continuous interaction with their environment. This capacity allows cities to maintain, self-organize, replicate, and adapt by managing their structure and resources while preserving core boundaries.

For example, the concept of structural coupling emphasizes the interaction between urban systems and their surrounding environment. AI strengthens this coupling by delivering real-time insights into factors like climate and resource availability. Meanwhile, resource flows—data, energy, materials—form an "urban metabolism" essential for functionality. AI can assess these flows to optimize efficiency and sustainability, producing a more adaptable urban system.

An AI SCOS encapsulates autopoietic traits that empower it to self-regulate, adapt, and sustain urban ecosystems:

- **Self-Regulation**: AI SCOS autonomously monitors urban functions and processes, adjusting systems to ensure optimized efficiency.
- **Adaptation**: Through machine learning, the AI system evolves based on immediate changes (e.g., extreme weather) and long-term shifts (e.g., population dynamics or resource constraints).
- **Recursion and Feedback Loops**: By reflecting on historical data and making iterative refinements, the system continually progresses toward sustainability.
- **Biomimicry and Sustainability**: Drawing from natural processes, AI SCOS promotes sustainable urban management and operations.
- **Anticipatory System Design**: AI SCOS not only responds to real-time data but also forecasts future trends using predictive analytics, proactively mitigating potential impacts.

In the paper Cities as Autopoietic Operating Systems, the authors developed the following table to define the various characteristics that embody autopoiesis.

Table 1

Traits in AI Autopoietic Smart Cities Operating Systems

Source: Cities as Convergent Autopoietic Systems in Artificial Intelligence, Machine Learning, and Optimization Tools for Smart Cities; Designing for Sustainability, Springer (2022).

Sentience and cognition	Ambient intelligence	Anticipatory capabilities	Structural coupling	Structural determinism
Understanding through experiences and sensing Acquiring knowledge and expanding capabilities	Augmented natural environments Interactive, responsive and anticipatory Ubiquitous, non-physical based intelligence	Predictive capabilities Leading not reacting Agility and resilience Managing systemic risk and complexity	Interrelationship of objects to environment Symbiosis and codependency Adaptation through synergy	Form follows function Perpetual evolutionary mechanisms Continuous perfection & pursuit of optimal states

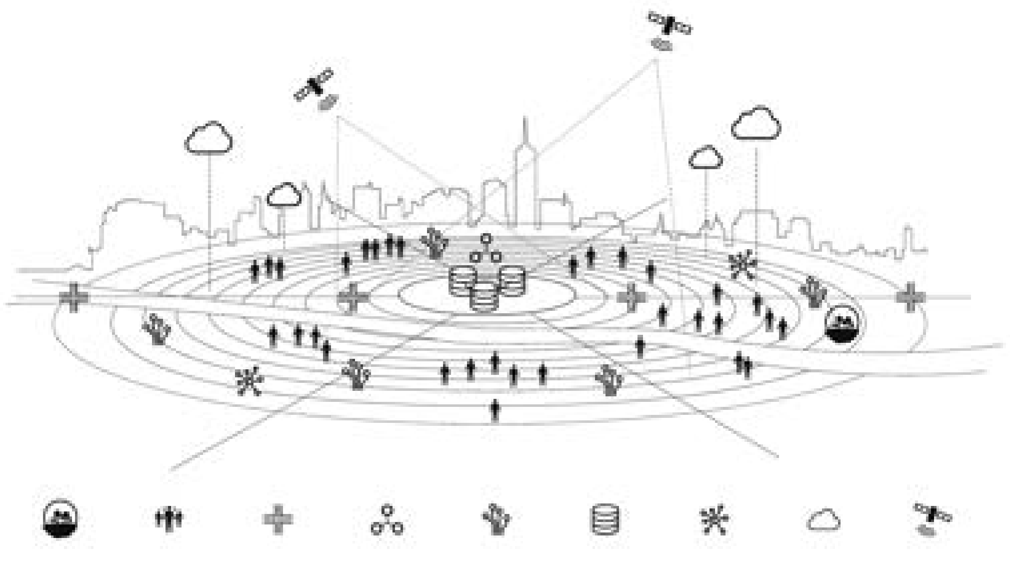
AI Smart City
Operating Systems(AI SCOS)

AI SCOS enable cities to move beyond traditional hierarchical operating system and management structures, allowing them to function in a more organic, agile, and adaptive state. These systems blend autopoietic principles (self-regulation and self-creation) with collective intelligence, fostering urban environments that self-regulate and respond to various urban functions and external factors. Acting as the city's central nervous system, AI continuously processes data from diverse sources—including sensors, smart devices, human inputs, and environmental variables—to maintain a state of constant awareness and adaptability. This setup allows the city to respond to real-time changes, from urban behavioral patterns to emergency needs, creating a city that is not only efficient but also resilient. At

Figure 1

City Eco-System

Source: Smart Cities and Artificial Intelligence: Convergent Systems for Planning, Design, and Operations; Elsevier (2020).



the core, AI SCOS serves as a collective, intelligent decision-making center governing all urban functions This creates a platform where cities can evolve with technological advancements and societal shifts, making them adaptable to unforeseen challenges while ensuring long-term resilience.

Integrating Collective Intelligence with Autonomy: **A hybrid model**

AI SCOS is achieved by balancing collective intelligence with decentralized autonomy across urban subsystems. Collective intelligence here combines human cognition, AI capabilities, and interconnected networks in a continuous decision-making process. This system draws on the wisdom of city leaders, stakeholders, and citizens, in conjunction with AI's computational power, to create cities that are intelligent, adaptive, and responsive to the needs of their inhabitants.

In this model, collective intelligence arises from the synergy between knowledge, software, hardware, and technical expertise. This gestalt perspective—where the whole is greater than the sum of its parts—enhances the understanding and management of complex urban environments. Here, technology optimizes city functions and citizen well-being, with citizens acting as essential, healthy components of the ecosystem. As "epistemic nodes," citizens actively contribute to the city's collective intelligence, reinforcing the system's ability to self-regulate and evolve.

As cities grow more complex, they integrate numerous dynamic systems—from transportation and energy grids to public services and environmental monitoring. AI SCOS fulfills the role of a "brain" capable of managing these subsystems while enabling each to retain its intelligence and autonomy. The hybrid nature of AI SCOS lies in its dual ability to centralize control where needed and to allow distributed autonomy across subsystems, enabling a cohesive yet flexible system incorporating diverse operating systems, applications and solutions that suit each unique urban function.

Beyond processing data, this framework empowers city systems to learn, make predictive decisions, and automate responses. For example, AI SCOS can predict peak energy needs, optimize traffic flow, or detect anomalies in water usage. Each subsystem—whether traffic management, waste processing, or water supply—operates autonomously but in alignment with the central AI. Localized decision-making, enabled by autonomous subsystems, coexists with city-wide objectives set by AI SCOS, such as sustainability targets or disaster preparedness. Through this intelligent coordination, the city functions as a self-regulating organism that adapts as new technologies and environmental factors emerge while aligning with international policies and local regulations.

This hybrid model transforms urban management into a resilient, adaptive process, akin to how the human brain integrates specialized bodily functions while allowing organs to perform independently. SCOS achieves a neural-like integration that enhances operational efficiency and drives the city's continuous evolution. This dual coordination of centralized AI with distributed intelligence creates a responsive, adaptable urban environment where data flows seamlessly, decisions are informed and timely, and actions align with both city-wide goals and localized needs.

In essence, this hybrid framework forms the backbone of future smart cities, combining centralized control with distributed, autonomous subsystems to cultivate urban ecosystems that transcend the sum of their parts. AI SCOS enables cities to be not only technologically advanced but also responsive, adaptable, and in harmony with the needs of their inhabitants and environments while remaining aligned with international policies and local regulations which in themselves are in constant evolution.

The Middle Ground Approach: **Integrating Top-Down and Bottom-Up Perspectives**

A significant challenge in building AI-driven cities lies in the tendency to depend on single-solution technology platforms. Such monolithic systems can overlook the diversity of urban needs and complexities of legacy infrastructure. Given these varied requirements, city managers often need adaptable, flexible platforms that can evolve over time rather than rigid, one-size-fits-all solutions. The AI SCOS framework introduces a middle-ground approach that balances structured, top-down policies with organic, bottom-up citizen engagement. This approach enables the flexible growth of smart city systems that are not only technically sustainable but also inclusive of social, economic, and environmental dimensions.

The Middle Ground concept emphasizes the importance of blending broad policy frameworks, business innovation and grassroots engagement, creating a smart city ecosystem where governments, businesses, and citizens all play vital roles. This multi-tiered involvement allows each group to contribute meaningfully to city operations, ensuring that a combination of urban infrastucture, business ecosystems and localized needs are addressed while achieving total viability and sustainability. AI SCOS facilitates this by acting as a common platform where all stakeholders are actively engaged making it easier to align municipal objectives, business and financial requirements with community aspirations.

The Middle Ground Approach to smart city development consists of three main components:

- **Top-Down Integration**: City managers and policymakers lay out the foundational frameworks and infrastructure necessary for a functional smart city. This includes implementing overarching policies, ensuring regulatory compliance, and creating essential infrastructure like public transportation, energy grids, and connectivity networks.
- **Middle Ground Synergy**: Enterprises, technology platforms, and local communities innovate within these established frameworks, adding decentralized solutions tailored to specific urban functions. These stakeholders work within the structured framework while contributing specific solutions that address localized issues, creating an environment where flexibility and order coexist.
- **Bottom-Up Participation**: Citizens, empowered by digital tools such as mobile apps, social media platforms, and data-sharing systems, actively participate in urban management. Through AI-powered feedback loops, citizens provide real-time data, express their needs, and contribute insights that shape city decisions. In this way, citizens are integral parts of the smart city system, enhancing it with diverse perspectives and local knowledge.

This model fosters a dynamic, interactive relationship between centralized authorities, the business community and decentralized citizen input. With top-down integration, urban managers establish foundational systems while allowing enterprises and communities to build upon them, addressing business requirements and local needs in innovative ways. Meanwhile, digital tools enable citizens to actively participate, creating a reciprocal relationship that enhances both governance and community engagement.

In the context of an AI SCOS, citizens act as "epistemic nodes"—

knowledge hubs that enrich the city's collective intelligence by contributing localized data, ideas, and solutions. Digital platforms such as apps for civic engagement and data-sharing systems provide real-time, community-driven feedback, which is processed and integrated into the city's operating system. By gathering data from diverse communities, the AI SCOS adapts to cultural, environmental, and economic differences across neighborhoods, supporting tailored services that meet localized needs.

For example, in an emergency situation like a flood or power outage, residents can provide immediate, on-the-ground information through citizen apps, which the AI SCOS processes to aid rapid decision-making and resource deployment. Citizens' interactions with these systems allow city managers to understand community trends and concerns, making the city more adaptable and responsive to shifting urban dynamics.

MachineEnhanced Collective Intelligence

AI amplifies the collective intelligence of cities by identifying and analyzing patterns in human behavior, resource usage, and environmental conditions. Machine learning algorithms process and learn from this vast data pool, predicting future trends, proactively managing resources, and boosting the resilience of urban systems against issues like climate change or population growth.

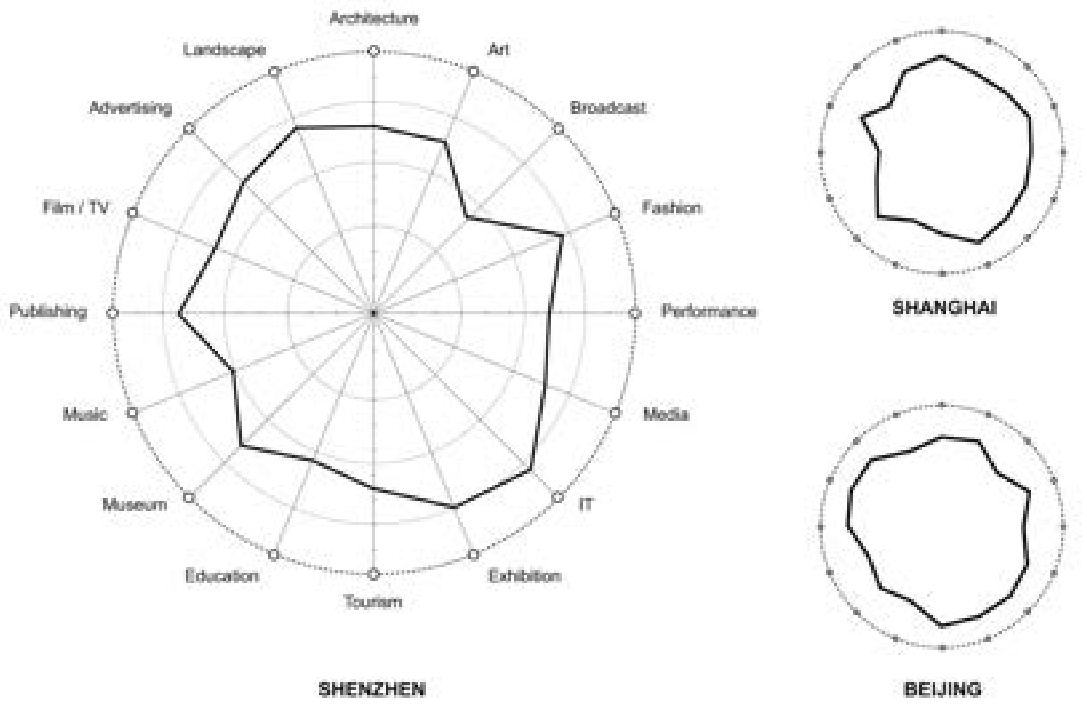
By combining human insights and machine learning, AI SCOS creates a forward-looking system that evolves with emerging needs and crises. This "anticipatory system" continuously learns from historical and real-time data, refining predictions and enhancing resilience. In the case of public health management, for example, an AI SCOS could monitor patterns in health data, detecting potential outbreaks early and enabling preventive measures. Similarly, for energy management, the system can anticipate demand fluctuations and optimize distribution, making the city both efficient and resilient.

The Middle Ground Approach in AI SCOS thus integrates the strengths of structured governance, business enterprises and grassroots creativity, paving the way for cities that are both technologically advanced and human-centered. By combining top-down frameworks with bottom-up engagement with a middle-ground approach, AI SCOS enables smart cities to evolve organically, ensuring that they remain vibrant, adaptable, and truly representative of their inhabitants' needs and aspirations while remaining financially viable.

City DNA: The Blueprint for AI-Driven Urban Identity

Each city is a unique entity, shaped by a complex interplay of spatial, economic, social, and cultural dynamics. To develop an AI-enabled Smart City Operating System (AI SCOS) that is truly adaptive and responsive, it is essential to recognize and integrate the "City DNA" – a concept that encapsulates the distinctive characteristics and underlying identity of each city. City DNA provides a nuanced, structured approach to understanding a city's individual attributes, enabling the development of fit-for-purpose solutions that resonate with its core identity.

City DNA serves as an essential framework for achieving "smart" status by ensuring that each city's unique characteristics, advantages, and constraints are not only acknowledged but actively inform AI-enabled strategies and applications. Similar to human DNA, which encodes genetic information that dictates physical traits, City DNA represents the memetic code of an urban environment. This code comprises a vast array of compo-



Source: Smart Cities and Artificial Intelligence: Convergent Systems for Planning, Design, and Operations; Elsevier (2020).

Figure 2
City DNA

nents—including geography, historical evolution, demographic dynamics, cultural norms, economic structures, and technological adoption patterns. Together, these elements create a “genome” unique to each urban environment, informing every aspect of its governance and development.

The AI SCOS framework leverages City DNA by embedding its principles in generative design processes and functionality of smart city solutions. By analyzing a city’s distinctive characteristics, City DNA offers a blueprint that allows AI SCOS to implement tailored solutions that reflect the city’s inherent identity. This is particularly crucial because smart technologies and management solutions that overlook or misunderstand these foundational attributes risk meeting the local social, economic and technological requirements and potentially lead to inefficiency, resistance, and

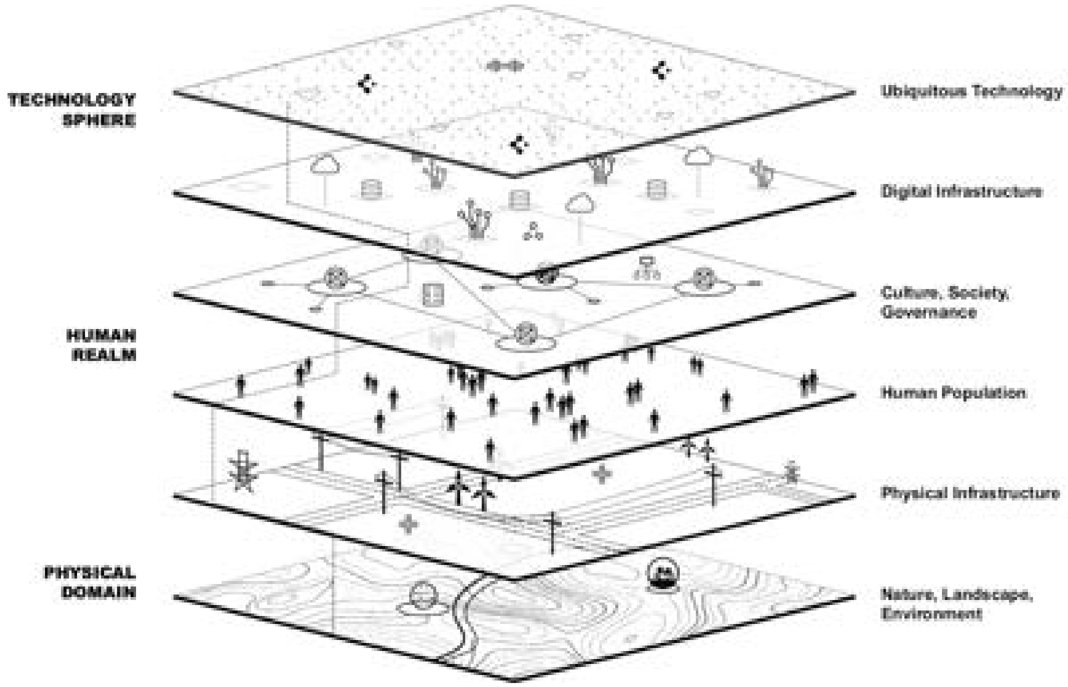


Figure 3

City Dimensions

Source: Smart Cities and Artificial Intelligence: Convergent Systems for Planning, Design, and Operations; Elsevier (2020).

ultimately, project failure.

City DNA factors include:

- **Physical Urban Form, Geographic and Environmental Attributes**: City DNA maps each city's geographic and environmental contexts, from climate patterns and natural resources to urban density and spatial configuration. AI SCOS utilizes these insights to develop sustainable infrastructure, optimize energy consumption, and manage resources in ways that align with environmental realities.
- **Historical and Cultural Identity**: A city's history and cultural heritage are integral to its identity and influence how communities interact with urban spaces. By embedding cultural insights from City DNA, AI SCOS

can design solutions that enhance cultural assets, protect heritage sites, and foster a sense of place. These strategies encourage community buy-in and create a resilient urban identity that evolves in harmony with technological change.

- **Socioeconomic Dynamics**: City DNA includes socio-economic indicators, such as employment patterns, income distribution, and educational levels, all of which inform the specific needs and capabilities of residents. AI SCOS can use this data to develop equitable service distribution, tailor public services to specific community needs, and promote inclusive economic growth. These insights ensure that smart city strategies contribute meaningfully to the well-being of diverse population groups.
- **Technology and Innovation Ecosystem**: Each city has a distinct relationship with technology, from its rate of digital adoption to its existing tech infrastructure and innovation ecosystem. AI SCOS customizes its technological initiatives to reflect these variances, deploying appropriate technologies that respect the city's readiness for AI integration and enhancing connectivity in ways that align with local capabilities.

City DNA as an Evolutionary Code imbedded in the Urban Blockchain

As cities undergo transformations driven by AI and digital technologies, City DNA acts as a dynamic blueprint for evolutionary growth. It enables AI SCOS to go beyond one-size-fits-all models and adopt a "living" framework that adapts and evolves in response to changing conditions. By continuously monitoring and updating City DNA elements, the AI SCOS can anticipate future needs, identify emerging trends, and optimize urban systems for long-term resilience.

For example, AI SCOS can employ predictive analytics to detect shifts in demographic patterns or economic trends, using these insights to proactively adjust services and policies over time. This approach transforms City DNA from a static repository of characteristics into an evolving framework that continuously informs urban adaptation strategies, guiding the city's journey through various developmental stages. In the way, City DNA will become imbedded in the establishment of an Urban Blockchain as the genetic code recording urban evolution.

Integrating City DNA with collective intelligence empowers AI SCOS to harness the knowledge and input of residents, officials, and other stakeholders. By actively involving communities in defining and refining their city's DNA, AI SCOS enables a participatory approach to urban governance. Digital tools and feedback platforms allow citizens to contribute insights into their experiences, needs, and aspirations, which in turn shape City DNA and the strategies derived from it. This citizen-driven feedback loop reinforces the city's identity and fosters a sense of shared responsibility and ownership, aligning smart city developments with local values and needs.

In conclusion, City DNA is not merely a catalog of attributes; it is the foundational narrative that informs and drives AI SCOS. By embedding City DNA into the core of AI-driven strategies, cities can cultivate a symbiotic relationship between technology and identity, ensuring that each advancement in the smart city ecosystem enhances the city's unique essence. The result is a resilient, adaptable urban system that reflects and respects the distinctive identity of its community, ensuring that technological progress enriches rather than disrupts the urban experience.

Applications of AI SCOS in Smart Cities

AI SCOS find practical application in several areas of urban management:

- **Smart Environmental Monitoring**: Through sensors embedded throughout the city, AI SCOS can monitor and adjust environmental conditions, including air and water quality, waste management, and energy consumption. This enables cities to pursue net-zero goals and circular economy practices.

- **AI-Enhanced Mobility Systems**: AI SCOS can transform transportation by managing traffic flow, optimizing public transit systems, and enabling autonomous vehicles. Analyzing commuting patterns ensures smoother, faster, and more environmentally friendly mobility options.
- **Participatory Governance Platforms**: AI-driven platforms facilitate participatory decision-making by allowing citizens to propose ideas, vote on projects, and contribute to urban planning. AI helps ensure that resources are allocated efficiently, keeping the city responsive to its population's evolving needs.
- **City as a Service (CaaS)**: CaaS reimagines urban environments as dynamic platforms that deliver public services on demand, leveraging AI-driven Smart City Operating Systems (AI SCOS). By utilizing real-time data, cities can streamline e-government services such as digital permitting, virtual citizen engagement, and real-time public safety alerts. This approach ensures more responsive governance, improved citizen satisfaction, and enhanced transparency in decision-making, while also adapting to the needs of residents and businesses for a more tailored experience.

The Meta-Architecture **of AI Smart Cities Operating Systems**

The meta-architecture of AI Smart City Operating Systems (AI SCOS) establishes the guiding principles, structural framework, and behavioral rules that drive the city as a living, adaptive entity. This overarching architecture is grounded in the convergence of five core autopoietic characteristics, enabling it to mimic the self-organizing, self-regulating, and evolving properties of biological organisms. Drawing inspiration from human anatomy and the organic behaviors found in nature, the meta-architecture is designed to support recursive interactions, anticipatory control, and adaptive self-regulation. These elements form the basis of a biomimetic system architecture that operates as a dynamic ecosystem, continuously adjusting in response to changes in its environment.

At the core of this meta-architecture is the principle of autopoietic meta-convergence, which seeks to merge the self-sustaining qualities of living systems with the collective intelligence of AI-enabled smart city and the unique city DNA. The AI SCOS meta-architecture enables cities to evolve beyond static infrastructure by incorporating a design language and operational code capable of managing complex states specifically developed for the city in focus (rather than a generic solutions), thereby creating a system that is optimal, efficient, flexible, and adaptable.

Adaptability and MetaDesign Enabling Continuous Evolution

A key requirement for an effective AI SCOS is the ability to adapt, improve, and self-optimize continually. Given the rapid pace of technological and environmental changes, this adaptability is facilitated by an integrated feedback system that allows the AI SCOS to learn and evolve autonomously. In this context, meta-design—a concept closely related to meta-architecture—ensures that the system remains open-ended, designed to accommodate future needs and challenges that may not be fully anticipated during initial development. Meta-design promotes an architecture that is interactive, adaptive, and generative, ensuring that the AI SCOS evolves as a living system alongside the city itself.

For AI SCOS to thrive, its meta-architecture must balance centralized, decentralized, and distributed systems, creating a resilient urban ecosystem that can respond to local and global challenges alike. This hybrid approach allows data to flow freely between central authorities and decentralized networks, integrating transparent and secure technologies such as blockchain to enhance governance. Furthermore, predictive analytics and anticipatory systems within the AI SCOS enable proactive management, allowing cities to foresee and mitigate potential risks before they escalate.

Relevance of Autopoietic Operating Systems to South Korea: **A Strategic Fit**

Developing the concept of AI SCOS in South Korea presents a unique and strategic opportunity. This framework, which aims to integrate theories of self-sustaining systems and AI-enabled smart city design, is particularly suited to the South Korean context due to the nation's advanced IT infrastructure, centralized political system, and unified cultural landscape.

South Korea is renowned for its highly developed IT backbone, boasting some of the world's fastest internet speeds and extensive broadband coverage. This advanced digital infrastructure provides a solid foundation for implementing AOS, which relies on a robust data ecosystem for real-time analysis and decision-making. The integration of AI and IoT within an autopoietic framework can enable South Korean cities to dynamically adapt to changes, optimize resources, and enhance sustainability. The existing digital literacy and widespread adoption of smart technologies by citizens further support the implementation of such complex systems, ensuring a smoother transition and more effective operation.

South Korea's strong centralized political system is another key factor that aligns with the deployment of AI SCOS. Unlike more decentralized or federal systems, South Korea's governance structure allows for uniform policy implementation across the country. This centralization can facilitate coordinated efforts in deploying AOS across multiple urban areas, ensuring that the necessary regulatory frameworks and standards are consistent. Such coordination is essential for the holistic development of smart cities that operate as living systems, where each component interacts seamlessly with the others. It also allows for rapid scaling of successful pilot projects, transforming localized solutions into national standards for smart, sustainable urban living.

The cultural homogeneity and unified language in South Korea contribute significantly to the potential success of AI SCOS. A shared cultural and linguistic context makes it easier to communicate the objectives, benefits, and functionalities of AI SCOS to the public, fostering a collective understanding and adoption of these technologies. The sense of national unity and common purpose can also drive public acceptance and participation, which is crucial for the functioning of autopoietic systems that depend on feedback and interaction with their environment. This alignment enables cities to become true "convergent autopoietic systems," where human, social, and technological components work in synergy towards shared goals like net-zero emissions, resource optimization, and enhanced quality of life.

By developing AI SCOS within this context, South Korea has the opportunity to further solidify its reputation as a global leader in smart city innovation. The convergence of its technological prowess, cohesive governance, and unified social fabric creates an ideal environment for piloting and refining advanced urban systems that could set new benchmarks for sustainable city development worldwide. Additionally, as South Korea seeks to address challenges like urban density, aging infrastructure, and climate change, the AI SCOS framework offers a strategic pathway for transforming these challenges into opportunities for growth and resilience.

South Korea's unique blend of technological infrastructure, centralized governance, and cultural cohesion provides an ideal context for the development of Autopoietic Operating Systems. This synergy enables the creation of dynamic, self-sustaining urban systems that can serve as models for other nations looking to integrate advanced technologies into their city planning and management. The development of AI SCOS in South Korea could represent a pivotal step toward achieving smarter, more sustainable urban living, both regionally and globally.

Conclusion

The fusion of autopoietic principles, collective intelligence and City DNA within the AI SCOS meta-architecture establishes cities as dynamic, self-sustaining systems. Through this integration, cities can operate not only as functional entities but as living systems that respond organically to internal and external stimuli. The AI SCOS becomes more than a tool for urban management; it transforms the city into a responsive, self-regulating ecosystem where technology, human input, and environmental data converge seamlessly.

By harnessing collective intelligence, the AI SCOS enables cities to evolve in tandem with societal needs and technological advancements. Citizens, empowered as "epistemic nodes," contribute local insights, creating a synergistic relationship between technology and community. This self-organizing structure allows AI SCOS to move beyond traditional top-down management, fostering an inclusive environment where the city's evolution is shaped collaboratively by policymakers, businesses and residents.

As AI SCOS frameworks continue to evolve, they will enable urban centers to actively participate in global efforts toward sustainable development. The future of cities lies in their ability to function as living organisms—adapting, evolving, and thriving amidst complexity. In this vision, cities maintain a harmonious balance between human, technology, and nature, integrating advancements in AI and collective intelligence into the fabric of urban life. In this context, South Korea has a competitive advantage to be a global leader in implementing AI Smart City Operating Systems.

Seeing Urban Future Using Generative AI:

A Case Study of MapAI

생성형 AI를 이용한 도시계획: MapAI 개발 사례를 중심으로

Hoon Han

Professor Hoon Han is the first Korean full professor in the field of urban planning in Australia. He has been teaching at the University of New South Wales (UNSW Sydney), ranked 19th in the QS World University Rankings 2024, for 15 years. He currently serves as the director of the Australian Housing Urban Research Institute UNSW Centre (AHURI-UNSW). He was the president of the Korean Scientists and Engineers Association of Australia-New Zealand (2022~2023). Professor Han has published over 150 research papers on urban spatial analysis, which have been cited internationally more than 2,600 times (Google Scholar Hoon Han). Recently, he and his team developed Australia

s first commercialised AI-based property valuation system, which is currently adopted by the Commonwealth Bank of AustraliaCBA, the largest bank in Australia. Recently, he is the Principal of MapAI, a venture company providing geographic information analysis services using generative AI. In recognition of his contributions, he was awarded the Cutting-Edge Research Award, the highest research achievement award by the Australian Planning Institute.

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ABSTRACT

Globally, AI, along with quantum computing, has become one of the core national agenda for R&D. Leading innovation countries, including the Republic of Korea (hereafter Korea), are increasingly adopting AI for urban diagnosis, analysis, and planning. However, AI technologies in urban planning have largely focused on urban design and big data analysis using machine learning and deep learning models. The development and application of generative AI like ChatGPT in Korea is still at a premature stage. This paper introduces MapAI, which utilises generative AI to search, analyse, and visualise various geographic information. Unlike existing geographic information analysis software or programming languages (e.g., ArcGIS, SQL, R), MapAI allows the general public, who may not have expertise in these tools, to easily analyse geospatial information and create thematic maps. Drawing on his experience in founding Australia's first generative AI-based MapAI venture, the author explores the changes generative AI will bring to urban planning in the near future and its impact on the evolution of smart cities in Korea.

KEYWORDS

Generative AI, Machine Learning, City Planning, ArcGIS, Geospatial Data

초록

전 세계에서 AI는 양자컴퓨팅과 더불어 국가 R&D 사업의 핵심 어젠다로 자리매김하고 있다. 최근에는 한국을 비롯한 IT 선도국에서 도시의 진단, 분석 및 계획에 AI를 적극 도입하고 있다. 하지만 도시계획 분야에서 한국의 AI 활용은 대부분 머신러닝, 딥러닝에 기반한 도시설계와 도시 빅데이터 분석에 집중되어 있으며, ChatGPT와 같은 생성형 AI의 개발 및 적용은 매우 미미한 수준이다. 따라서 이 글은 생성형 AI를 이용하여 다양한 지리정보를 검색, 분석, 시각화하는 MapAI의 소개에 초점을 맞추고 있다. 생성형 MapAI는 기존의 지리정보분석 소프트웨어나 프로그램 언어(예: ArcGIS, SQL, R)를 알지 못하는 불특정 다수 일반인이 쉽게 지리정보를 분석하고 원하는 내용을 지도로 만들 수 있게 해준다. 저자는 호주 최초로 생성형 AI 기반의 벤처회사 MapAI를 설립하고 관련 기술을 개발한 경험을 바탕으로, 생성형 AI가 가까운 미래의 도시계획에 어떤 변화를 가져올 것인지 예측하고 한국형 스마트시티의 진화 방향을 짚어 보고자 한다.

키워드

생성형 AI, 기계학습, 도시계획, ArcGIS, 지리정보

Introduction

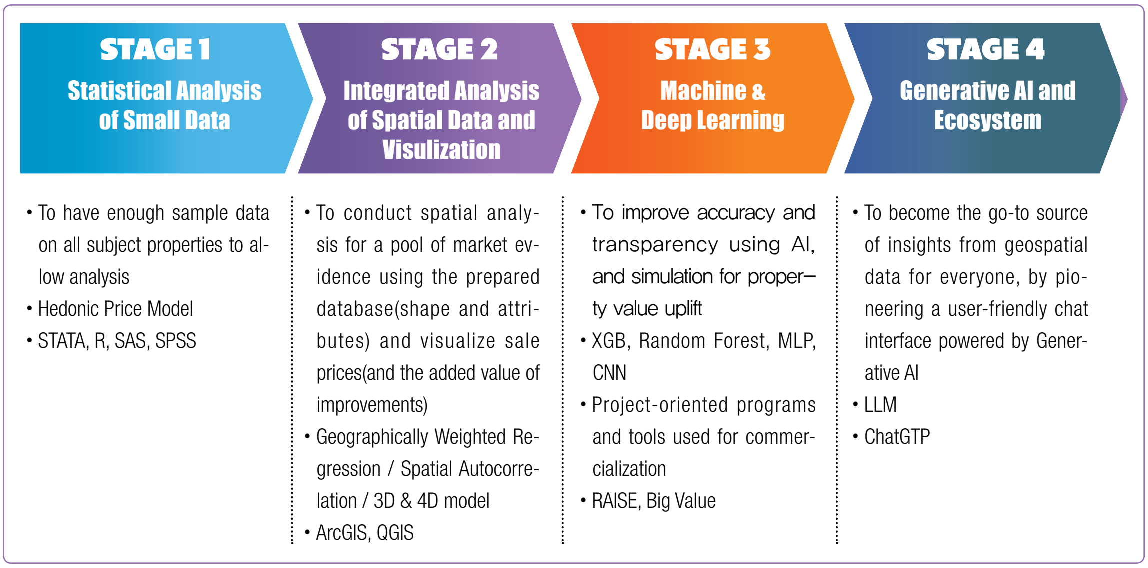
200 years ago, mathematician Carl Friedrich Gauss(1777~1855) created the bell curve (Gaussian curve). Quantitative data analysis based on inferential statistics has been the longstanding research methodology in urban planning, engineering and social sciences over the past two centuries. These statistical methods have evolved into empirical data validation in the areas of medicine and science, providing statistical confidence. Despite statistical assumptions and errors, the quantitative analysis has persisted for over 200 years, which is quite remarkable. However, this quantitative data analysis is undergoing a methodological transformation with the recent data training approach, so-called machine learning and deep learning. Nevertheless, there is still little research on the application of generative AI in urban planning and geospatial data analysis. This article reviews the evolution of geospatial analysis techniques and examines the necessity and precautions of using generative AI in urban planning. The study also discusses the future changes generative AI could bring to smart cities based on the author's experience in establishing the new MapAI venture using generative AI technologies.

How Will Future Methods **for Urban Planning Analysis Evolve?**

For those in their 50s old (born in 1960s and early 1970s) who majored in architecture, urban design, or urban planning, many of those have the experience of manually drawing plans with T-squares before the use of CAD. Similarly, earlier generations used a made-in-Japan Casio calculator before the introduction of statistical software like SPSS and SAS. Today, the computing revolution, often referred to as the Fourth Industrial Revolution, offers numerous project-oriented analysis tools. These tools use various programming languages (R, C++, SAS, STATA, and SQL) depending on the complexity and diversity of the data format (Stage 1 in Fig 1). Around the same time, the geographic information system (GIS) offers to link spatial information, data analysis and visualisation. The GIS software includes ArcGIS and MapInfo, and later provides open-source programs like R and QGIS, lowering the entry barriers (Stage 2). These tools use statistical methods for spatial analysis and have continued to evolve to overcome statistical errors and geographic inconsistencies. For instance, Geographically Weighted Regression (GWR) has been commonly used in spatial analysis. In recent years, the reliability of such statistical analysis results has been significantly improved through AI models like machine learning and deep learning. Various AI models have been developed with Python algorithms for both small and big data, showing superior perfor-

Figure 1
Evolution of Geospatial Data Analysis Techniques

Source: Hoon Han



mance, particularly in image processing with neural network models (Stage 3). However, utilising these AI models remains challenging for both non-experts and urban planning professionals due to the high entry barriers such as Python language. Generative AI, dramatically lowers these barriers for non-experts. Well-known examples like ChatGPT allow anyone familiar with their mother language to conduct analyses, ushering in an era where programming languages like Python are created from spoken languages (Stage 4). Thus, an important question still remains: how can we use generative AI in urban planning and spatial analysis?

Why Is Generative AI Needed in Urban Planning?

Deep learning, a representative approach in AI, excels at analysing big data collected from images or digital sensors, effectively preventing data loss or manipulation during the data cleaning process required by traditional statistical methods (Lee et al., 2024). Machine learning is rapidly replacing quantitative analysis techniques, and significantly lowers errors inherent in statistical assumptions. For example, the property price predictions of traditional regression analysis, hedonic price models, commonly used in real estate appraisals, are far less accurate than AI-based machine learning models (Fig 2; Gao et al., 2022).

However, applying machine learning and neural network learning remains difficult for the general public who don't learn programming languages like Python or how to access various AI libraries. Additionally, AI algorithms designed to solve specific urban problems often lose their utility after the problem is solved, raising questions about their sustainability. For these reasons, generative AI with fewer limitations should be intro-

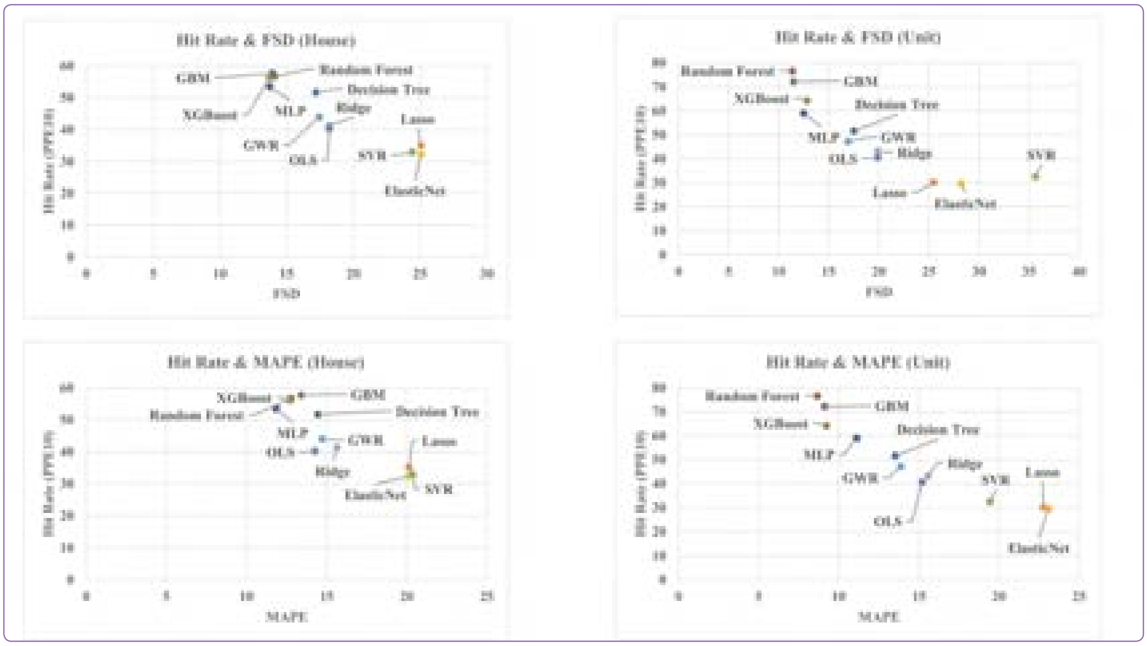


Figure 2

Comparison of the results between AI and statistical models

Q Gao, V Shi, C Pettit, H Han (2022) Property valuation using machine learning algorithms on statistical areas in Greater Sydney, Australia- Land Use Policy, Vol. 123, December 2022, 106409

duced into urban spatial analysis.

Generative AI models like ChatGPT, based on large language models (LLM), can generate user-desired texts regardless of scope and subject areas. This text-based LLM model can also be applied to urban planning. In traditional urban and geographic analysis, the basic elements are geospatial data analysis and visualisation. Software like ArcGIS requires geographic data, including attribute tables and maps (e.g. shape files). With generative AI, spatial data collection, analysis, and visualisation can be performed simultaneously.

This type of generative AI is being applied not only in urban planning but also in neighbouring fields in different ways. For example, in architectural design, generative AI is used to create architectural designs upon big data of various architects' styles and designs. For instance, generative AI might create a design by mixing the architectural styles of Tadao Ando

	Generative AI - MapAI	Existing Geospatial Solutions(ArcGIS)	Emerging Startups	Specialists Approach (Project-oriented tool)
GenAI + Fine tuned location	✓	?	?	✗
Available Now	✓	?	✗	✓
No change to data storage	✓	✓	?	✓
Integrated with existing platforms	✓	✗	✗	✗
Transparent	✓	✗	✗	✓
User Insights	✓	✗	?	✗
Global	✓	✓	✓	✗
Instant Answers	✓	✗	✓	✗

Source: Hoon Han

Table 1

Comparison of services provided by MapAI

(50%), Richard Meier (40%), and Frank Gehry (10%).

The rationale for using generative AI in urban service management lies in the fact that cities form spaces shared by citizens and governments. Citizens from various social strata can access and analyse their city's spatial information and community services without needing to learn specific software like ArcGIS. In the case of generative MapAI, a venture company the author co-developed as the first of its kind in Australia, it allows users to create maps and analyse spatial data anytime and anywhere through a simple chat interface like ChatGPT. Particularly, it allows to explore urban spatial information using open sources, which is more comprehensive and transparent than specific-purpose web-based services. In Table 1, generative AI can search, analyse, and visualise geographic information (map creation) anytime, anywhere, regardless of country, location, or area of interest, offering better efficiency and accessibility than existing geographic information programs. The next chapter will introduce specific cases of how generative MapAI is being utilised.

How to Perform Spatial Data Analysis **Using Generative MapAI?**

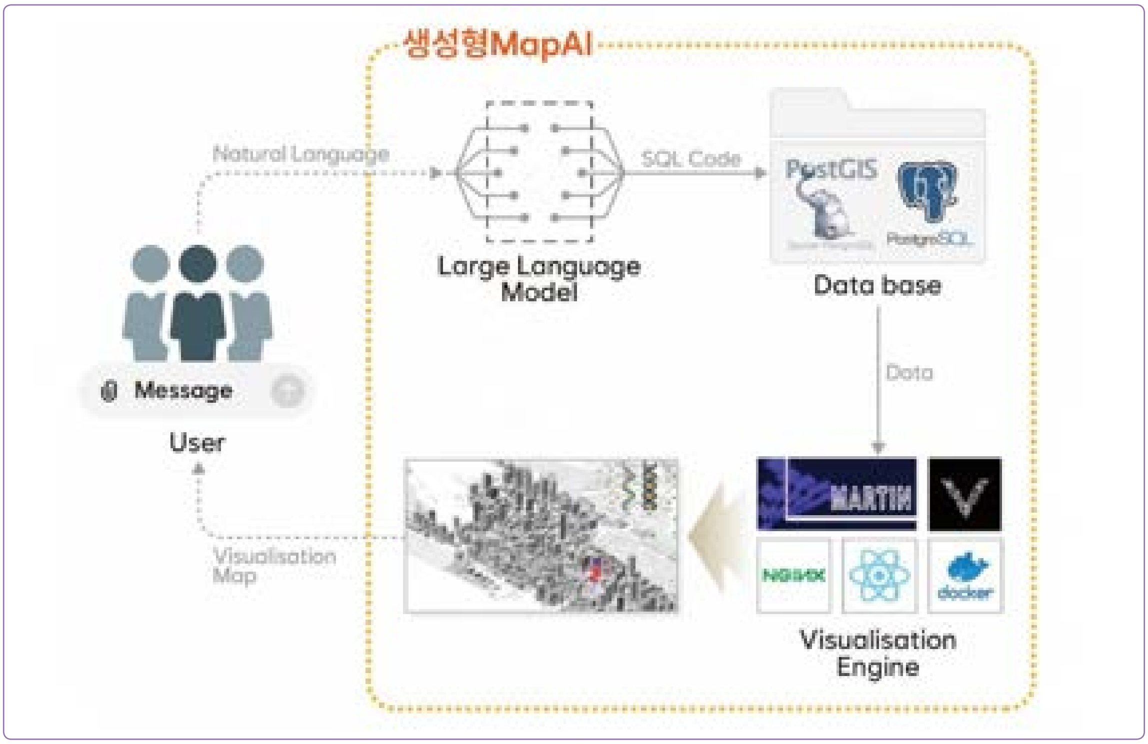
The MapAI aims to generate thematic maps in natural language by end-users. It works by transforming users' questions into programming languages like SQL, R, or Python, and then visualising the results on a map (see Fig 3).

For example, subscribed web services like Airbnb allow users to search for accommodations based on specific conditions like price, location, and housing type, but users can only search within the preset parameters of the website. In contrast, generative MapAI allows for customised searches that meet individual and specific requirements. For instance, a user might input:

"I have school-aged children, and I need a rental with two or more bedrooms, within walking distance to a primary school, in a quiet area safe

Figure 3

MapAI architecture



for women to freely walk at night, and under 1 million won per month in rent."

The generative MapAI can provide a map with the addresses and locations of houses that meet these conditions, and the results can also be delivered as an Excel file.

Figure 4 shows a simple interface with a map and a chat window in MapAI, a user friendly system. Figure 5 demonstrates an example where a chatbot is used to ask MapAI for real-time information on roadside parking availability in Melbourne, Australia. When asking, "Where is roadside parking currently available in the Geelong area?" the user's question is converted into SQL code and visualised on the municipality's street map (refer to Fig 5). Furthermore, when a follow-up question such as "Which location on Yarra Street has the nearest disabled parking?" is asked, the generative AI provides parking information that meets the conditions. This is possible because the parking sensor system managed by the municipality is linked to the MapAI platform.

In MapAI general questions like "Where is the most congested traffic area in LA?" are answered using open-source data like Google, but

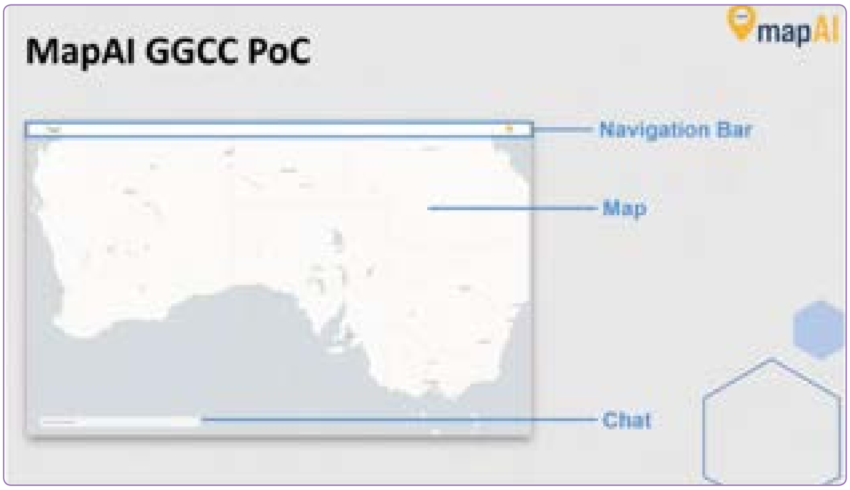


Figure 4
MapAI interface (Source: Phil Delaney, 2024)

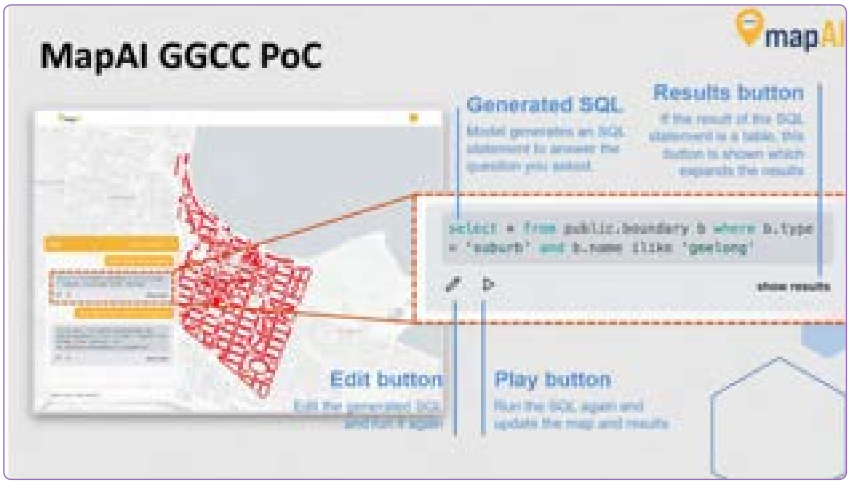


Figure 5

An example of analysis in MapAI (Source: Phil Delaney, 2024)

micro-data analysis and visualisation require data providers to share their platforms. The use of generative AI in a city must be a collaborative effort between citizens, local governments, and AI venture companies. The creative spatial analysis and solutions that arise when various urban services of a smart city are integrated with generative AI are boundless. The next section will explore various business models utilising generative MapAI.

How Will Generative MapAI Evolve?

The future of generative MapAI will be linked with Digital Twin technology. The formula of 'Generative AI + Digital Twin = MapAI-DtW' will become a major asset for urban AI in the future. Our cities are becoming increasingly interconnected and compact. While the management and utilisation of 3D spaces within buildings are key assets of Digital Twin technology, the simulation of various scenarios within a Digital Twin is still in its development stage. Generative AI can replace this 3D spatial analysis

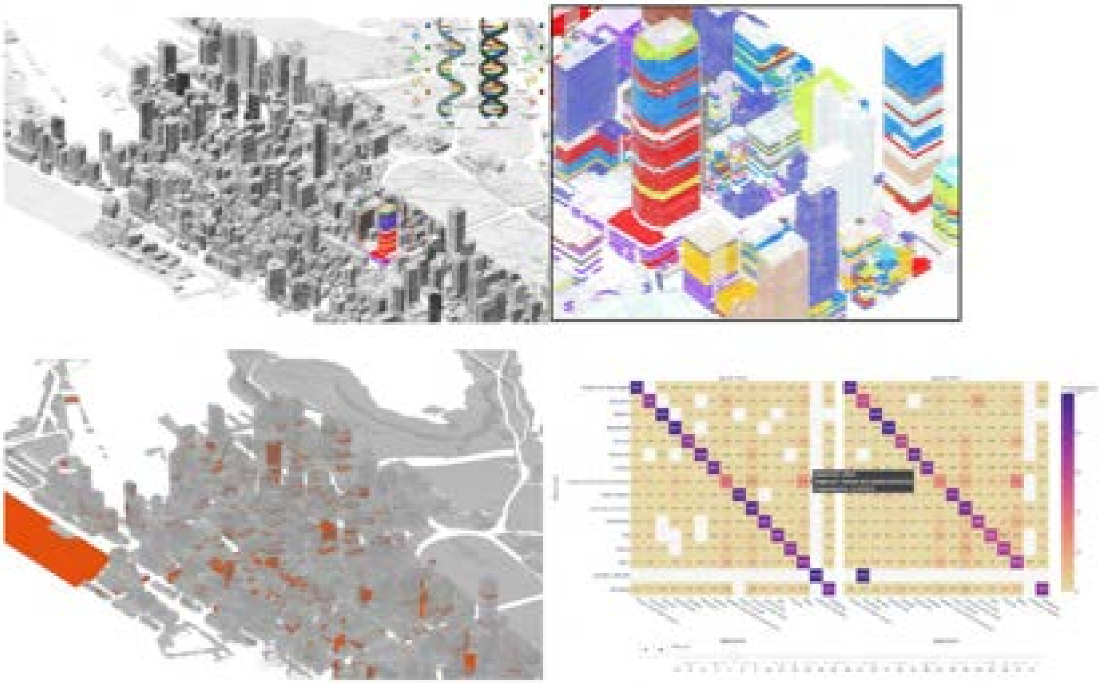


Figure 6

Conversion between generative AI and Digital Twins (Hsu and Han, 2024)

and simulation.

For example, the author created a 3D digital twin of all buildings in downtown Sydney, Australia, using floor plans (big data) for each floor of the buildings (top left of Fig 6). We analysed the types of businesses occupying each floor and section (top right) and identified whether they shared floor space with other types of businesses. This allowed us to simulate the office vacancy risk for certain types of businesses (e.g., retail use) (bottom left, in orange coloured). By visualising the symbiotic (pull) or conflicting (push) relationships between different types of businesses within the building, we created a 3D map of spaces where demand for certain business types is increasing (e.g., co-working spaces) and spaces in decline (e.g., retail) (bottom right). For instance, generative AI can identify the optimal business type to occupy vacant spaces on the 17-19 floors of Building B.

By integrating generative AI with Digital Twin technology, we could pre-emptively simulate potential scenarios for cities like Sejong City, where retail vacancy rates are high.

Conclusion

Generative AI has the potential to become a game-changer in urban planning and geospatial analysis. However, from the perspective of a generative AI developer, the future use of generative AI in urban planning faces the following significant challenges:

First, the hallucination of generative AI. How much can we trust the recreated outcomes or improvised responses produced by generative AI? When we verified the outcomes of the early beta version of MapAI, the accuracy was less than 50%. Similarly, with ChatGPT, numerous questions have been raised about its accuracy and reliability before ChatGPT version 4. Therefore, it is urgent to establish a certified verification system for generative AI. Transparent and objective disclosure of the verification results is also essential, and pre-emptive warnings regarding the reliability of generative AI should be provided, along with international standard certifications (ISO).

Second, the research ethics and integrity for responsible generative AI. Large language models (LLM) like ChatGPT can analyse and even ghostwrite parts of a task. In academia, ChatGPT is widely used for writing reports and completing assignments. Many cases have been reported in which students misuse or over-rely on it for assignments. To verify the use of generative AI, other AI tools are ironically being employed to detect its usage. As a professor, I cannot fully trust the AI tools used to check AI usage rates. In many cases, even when students rewrite tasks based on

ChatGPT outputs, it is hard to identify AI use. Therefore, the ethical and responsible use of generative AI are crucial.

Third, the protection of human rights in generative AI. Generative AI recreates information based on the massive scale of big data. This can lead to serious issues such as the reproduction and leakage of malicious information using personal data. In fact, deepfake technology, which utilises generative AI, has reached a level where it is difficult for the ordinary person to discern what is real. This issue extends beyond the generation of facial images to the creation of personal voice and video, which could be used for crimes such as voice phishing. Sooner or later, it will become increasingly difficult to distinguish between AI-generated products and real-world creations. Just like antique appraisers who authenticate valuable items, in the future, there may be a need for national certification for AI appraisers who can distinguish whether an artwork was created by AI or by a human. A comprehensive and systematic governmental response to the issues of privacy and human rights infringements by AI is urgently needed.

Finally, the equity and democratisation of generative AI. In the past, Korea's U-City was championed under the slogan "anytime, anywhere" access to urban services. I believe that future Korean smart cities will transition to a new vision where generative AI enables "anyone to fairly" access urban services. Regardless of age, technical proficiency, or computer skills, as long as a person can write in Korean, they will be able to access and analyse geospatial information and predictions through AI chatbots. This could reduce the disparity in service access between residents and non-residents of smart cities. Even those unfamiliar with real estate or economics will be able to freely access and visualise spatial information necessary for real estate investment and financial planning. This will lower the barriers to entry in terms of cost and knowledge, just like ChatGPT does.

It will bring us a step closer to the true democratisation of spatial information as open data and open city (from the author's book Open Data Open City).

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SMART CITY TOP AGENDA 2024

AI-Powered Urban Planning Technologies for the Future of Smart Cities

스마트시티를 위한 인공지능 기반 도시계획 기술

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ABSTRACT

Recently, high-density development is being demanded in the reconstruction projects of the first generation new towns due to economic feasibility. The outcome of high-density development through regulatory relaxation may lead to a deterioration of the living environment, which necessitates rational planning. Particularly, the redevelopment of aging cities in the future is likely to involve even greater potential for high-density development, making the need for rational and sustainable planning methodologies critical. High-density development plans that consider the living environment can be achieved through the technologies of AI*Artificial Intelligence*, ECO*Environmental Analysis*, and DT*Digital Twin*. Each of these technologies currently exists, but what is most important is deriving sustainable development scenarios through the integration of these technologies. By utilizing AI design technology and environmental analysis technology in determining regulations and design conditions, it is possible to predict the impact of high-density development on the living environment. Various high-density developments can be examined from an urban perspective using a digital twin platform. There are many other smart analysis technologies for sustainable urban planning beyond the ones introduced in this paper. If these various smart analysis technologies are integrated into the digital twin platform, achieving sustainable smart city planning becomes possible.

KEYWORDS

AI-powered Urban Planning, Habitat Quality, Design Optimization, Digital Twin Models

초록

최근 1기 신도시 재건축 사업은 사업성을 이유로 고밀개발이 요구되고 있다. 법규의 완화를 통한 고밀개발의 결과물은 주거환경의 악화를 가져올 수 있으므로 합리적인 계획이 요구된다. 특히 앞으로의 노후도시 재개발은 더욱 고밀화 가능성을 갖고 있어 합리적이고 지속가능한 계획 방법론이 요구된다.

주거환경을 고려한 고밀개발 계획은 AI인공지능, ECO환경분석, DT디지털트윈 기술로 달성 가능하다. 각각의 기술은 현 시점 존재하는 기술이지만, 중요한 것은 각 기술의 융합을 통한 지속가능 개발 시나리오의 도출이다. 법규와 설계 조건을 결정함에 있어서 인공지능 설계기술과 환경분석 기술을 활용하여 고밀개발이 주거환경에 미치는 영향을 예측할 수 있다. 디지털트윈 플랫폼에서 다양한 고밀개발을 도시적 관점에서 검토할 수 있는 것이다. 지속가능한 도시계획을 위한 스마트 분석기술은 본 글에서 소개하는 기술 외에도 다양하게 존재한다. 다양한 스마트 분석기술이 디지털트윈 플랫폼에 융합된다면 지속가능한 스마트시티 계획을 달성할 수 있을 것이다.

키워드

인공지능 단지설계, 주거환경, 최적화 설계, 디지털트윈

AI-Powered Design Technologies **for Smart City Planning**

Smart cities are a term familiar to the general public. However, it holds a deeper meaning than what is commonly understood. A smart city is a city that serves as a platform utilizing various cutting-edge technologies. Smart cities should consider sustainability across the entire life cycle of the city, including planning, operation, management, and redevelopment, by leveraging various Fourth Industrial Revolution technologies. While many Fourth Industrial Revolution technologies exist, this paper focuses on artificial intelligence technologies from an urban planning perspective and extends the discussion to include the connection with digital twin technology to draw conclusions.

Artificial intelligence technology is being applied across a wide range of fields without limitations, and the productivity enhancements achieved through AI have ushered in an era where it is difficult to disregard AI technology on the grounds of tradition or humanity. All human-produced outcomes are derived by investing labor (or capital) over the dimension of time. Therefore, an increase in productivity signifies a reduction in the required time and labor (or capital). If time were infinite, artificial intelligence might not be necessary. However, achieving high performance within finite time makes AI indispensable, particularly in fields such as urban planning.

Urban planning requires evaluating broader spaces with a greater variety of scenarios compared to architectural planning. When AI technologies are applied, the resulting increase in productivity enables analyses that were previously unattainable. For instance, predicting the number of housing units that could be secured through the redevelopment of an entire first-generation new town would demand significant time and labor (or capital) if conducted manually. By utilizing AI technologies, such tasks can be addressed relatively easily.

Conventional Approaches **to Urban Design**

When carrying out architectural projects, the process typically begins with an initial feasibility study, followed by planning, schematic design, and detailed design stages, involving numerous iterations of design and revisions. The frequency of these iterations is especially high in the early stages of architectural design. During the initial feasibility study phase, it is necessary to evaluate various scenarios. In urban design, the focus extends beyond individual buildings or housing complexes to encompass the design of the entire city.

In other words, while multiple design reviews are conducted even for individual buildings during their early stages, applying such a high frequency of reviews to urban-scale design results in an overwhelming number of design proposals. Therefore, urban design focuses on analyzing the city from a broader perspective and providing strategic direction.

In the urban design stage, the focus is not only on individual buildings but also on various city elements such as transportation, logistics, amenities, education, healthcare, and more, all of which must be considered in an integrated manner. However, since most urban infrastructure is used by people, the projected population (or number of households) becomes a critical urban design indicator. In traditional urban design methods, population predictions were derived based on the floor area ratio (FAR) for each zone. While using FAR to estimate the population can provide a rough approximation, it cannot yield precise predictions, and the following potential issues can arise.

- Floor area ratio (FAR), building coverage ratio (BCR), and number of stories are key factors determining the scale of architectural design, and it may be challenging to achieve the actual FAR based on the values set in urban planning.
- Setting an excessively high floor area ratio (FAR) may lead to the prioritization of project feasibility over marketability in the design of residential layouts, potentially resulting in an inefficient or illogical architectural plan.
- The number of units resulting from the same floor area ratio (FAR) can vary significantly based on the size of individual units.

In order to achieve accurate predictions, it is essential to develop detailed architectural designs for each zone of the city. However, as previously noted, conducting architectural design for every zone within the urban planning framework to estimate population density is not feasible. Given the vast scope of such designs, human capabilities alone are insufficient. Consequently, AI-powered architectural design technologies can efficiently resolve these challenges.

The redevelopment of first-generation new towns, particularly in aging areas, involves increasingly complex challenges. Redevelopment is essential to improve the deteriorating living conditions in these communities. However, the financing of redevelopment projects relies on sales revenue generated from the additional units created through increased floor area ratio (FAR). Specifically, if an apartment complex with a FAR of 200% is redeveloped to achieve a FAR of 300%, the developer can anticipate sales revenue from the additional 100% of units. Additionally, the rising construction costs are further increasing the FAR requirements needed to offset these growing expenses.

The redevelopment market structure inherently calls for high-density development. While high-density development can be effectively achieved through regulatory relaxations, it often results in a decline in residential quality. Key aspects of residential quality, such as sunlight access and view corridors, are frequently compromised in high-density environments. To mitigate these challenges, urban planning must incorporate a holistic assessment of environmental performance, ensuring that development density is balanced with the preservation of livability and quality of life.

Ultimately, all urban planning outcomes should be assessed through a digital twin-based framework. To effectively evaluate key elements such as the urban skyline, landmark placement in various zones, visual impacts in high-density areas, and potential urban imbalances in neighboring residential districts, it is imperative to establish a digital twin platform that integrates 3D modeling with detailed attribute data for each component. Decision-making will, of course, remain a human-driven process, and by leveraging comprehensive analyses, a multidimensional urban model will serve as the cornerstone for developing future smart cities.

Thus, for the planning of smart cities, [precise scale evaluation], [environmental specialization assessment], and [digital twin platform implementation] are essential. When translated into keywords for innovative technologies, this would correspond to AI (Artificial Intelligence), ECO (Environmental Analysis), and DT (Digital Twin).

The individual technologies underlying these innovative solutions already exist within the industry; however, achieving the goals of smart city planning requires the integration of these technologies into a unified platform. Specifically, environmental analysis algorithms must be incorporated into AI-based design solutions, with the resulting data visualized within a digital twin platform. Additionally, the interconnectivity of these technologies should facilitate bidirectional feedback, enabling real-time updates to outcomes as adjustments are made to the urban planning process.

AI : Urban design through Artificial Intelligence-**Powered Design Technologies**

An example of artificial intelligence technology applicable to urban design is BUILDIT, an AI-powered residential complex design solution. BUILDIT automatically generates a range of design alternatives for residential complexes based on user-defined parameters. Notably, the system can integrate architectural regulations and specific design criteria, allowing it to produce design proposals that account for various urban planning conditions.

BUILDIT autonomously retrieves and generates a comprehensive set of data required for residential complex design. These data elements, essential for architectural design and analysis, are typically time-consuming when processed manually using traditional design methods.

- Automated extraction of architectural regulations, including building coverage ratio, floor area ratio, true north sunlight access, daylight plane, setback distances, and site open space, in accordance with zoning requirements.
- Automated extraction of parcel information and the automatic delineation of adjacent property boundaries based on parcel attribute data standards.
- Automated extraction of standards for calculating the required number of parking spaces based on building usage

To implement these automation features, it is crucial to integrate various public data sources, ensuring data completeness and standardizing co-

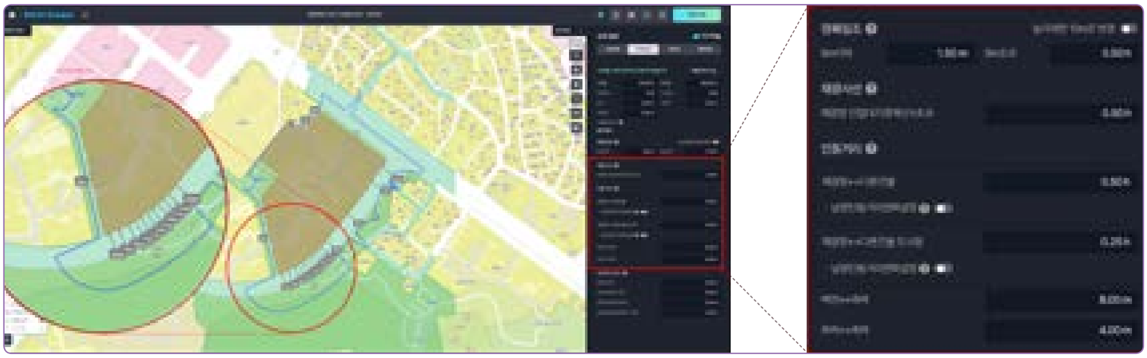

Figure 1

Automated Extraction of Public Data(BULIDIT)

ordinate systems for database creation. In BUILDIT, users can efficiently retrieve public data for a specified area with a single click, initiating automated computations that generate the desired outputs (See Figure 1). These results serve as essential inputs for AI-powered design processes, which, under traditional methods, would require manual data gathering or drafting by personnel.

BUILDIT integrates the following automation features to generate residential complex layout designs autonomously. In traditional design methodologies, such tasks are performed manually using CAD or modeling tools, which results in significant time investment for each layout and variability in design quality depending on the designer. In contrast, the automation technology ensures consistent design quality, enabling standardized evaluations across the entire urban area. This consistency allows the generated layouts to be used as objective evaluation criteria in urban planning processes (See Figure 2).

- Automated regulatory analysis for parameters such as true north sunlight access and setback distances.
- Determination of building height in accordance with regulatory requirements.
- Automated generation of architectural summaries.

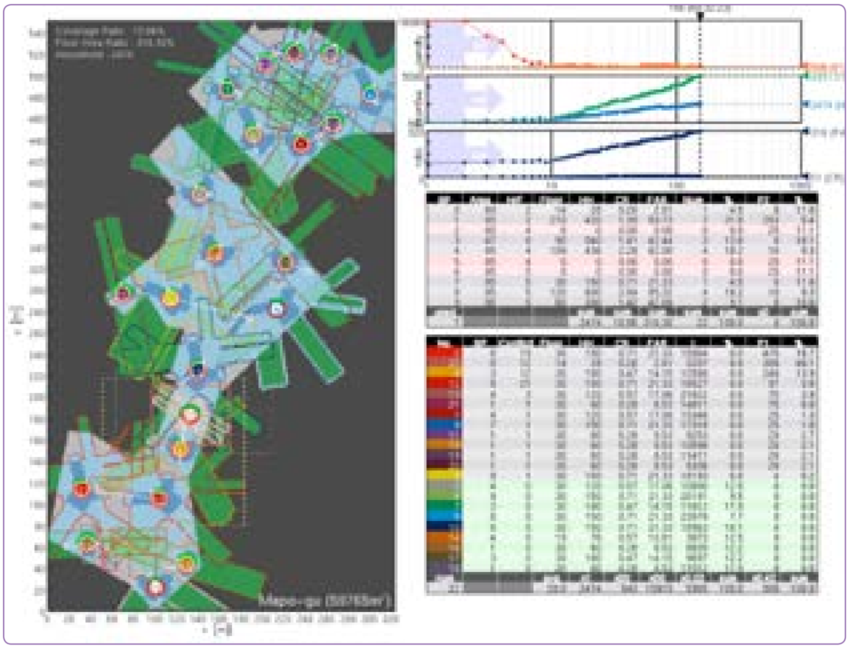

Figure 2

Artificial Intelligence-Powered Layout of the Residential Complex(BUILDIT)

- Automated generation of CAD files based on the site layout.
- Automated 3Dmodeling based on the site layout.
- Automated 3D modeling terrain and surrounding buildings.

BUILDIT is equipped with a range of analytical modules that evaluate the environmental performance of residential complex layouts. These modules enable the quantitative assessment of variations in residential environmental quality across various design scenarios. Given that individual environmental analyses typically require several days to complete, conducting precise environmental evaluations at an urban scale is practically infeasible. However, the integration of AI-Powered design technology with automated environmental analysis modules offers a viable solution to this challenge, facilitating efficient and comprehensive environmental assessments at the urban level.

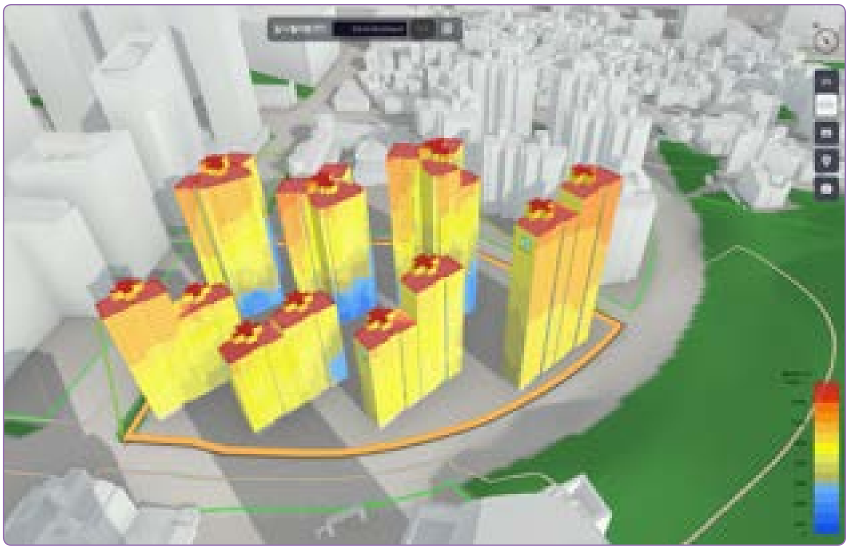

Figure 3

Analysis of Solar Irradiance for Solar Panel Assessment(BUILDIT)

- Automated analysis of daylight access for individual units
- Automated analysis of view quality for individual units
- Real-time analysis of sunlight exposure impact on adjacent schools
- Real-time analysis of landscape changes before and after development
- Real-time analysis of skyline alterations pre- and post-development
- Automated solar radiation analysis for evaluating the feasibility of solar panel integration (See Figure 3)

In a typical architectural office, a rough scale assessment of a residential complex based on design parameters typically requires 3 to 5 days. However, utilizing an AI-powered design solution, this process can be completed in 30 minutes. Moreover, the solution integrates various environmental analysis modules that enable automated 3D modeling and provide precise environmental performance evaluations, such as daylight access and view quality (See Figure 4).

In residential complex design, there is no singular 'correct' solution, as the field allows for a variety of design styles and approaches. As such, the

Figure 4

Illustrative Example of AI-Generated Residential Complex Design Results (Left: Site Layout, Right: 3D Visualization)

solution provides multiple design alternatives, enabling users to choose the most appropriate option based on their preferences and requirements. This process is analogous to the way users interact with AI models, such as ChatGPT, where generated results are evaluated and selectively incorporated into reports or other documentation. (A critical insight arising from the advancement of AI technologies is that while the role of humans may shift, it will not be entirely replaced. AI facilitates the rapid generation of vast data sets, which requires humans to take on the responsibility of interpreting and making decisions based on this information. While tasks that are repetitive or lacking in creativity may be automated, the tasks of selection, synthesis, and creative thinking will continue to rely heavily on human expertise. In this context, the role of human imagination and judgment will become even more central in shaping future outcomes)

The parameters defined during the urban planning phase—such as floor area ratio (FAR), building coverage ratio (BCR), maximum building height, and setback distances—serve as critical determinants in shaping the urban form within architectural design. The accuracy of urban planning is enhanced when these parameters and their impact on the projected urban landscape are rigorously assessed. The application of artificial intelligence design technologies enables rapid evaluation of potential outcomes based on varying parameters, offering immediate insights into possible design scenarios. These insights serve as a crucial foundation for informed deci-

Figure 5
AI-Powered Design Outputs Based on Variations in Setback Distance and Zoning Parameters(BUILDIT)

sion-making, providing key data to support the strategic development of smart city planning.

The Figure 5 is an example of the design outcomes generated by artificial intelligence, demonstrating the effects of changes in setback distances and zoning parameters on the proposed development.

As demonstrated in the above example, variations in key urban planning parameters, such as setback distances and zoning regulations, directly influence the outcomes of AI-generated design proposals. Increasing the setback distance typically results in a decrease in the floor area ratio (FAR) and the number of housing units, while simultaneously improving daylight access. Conversely, changing the zoning designation from a 'General Residential area (Category 3)' to a 'Semi-residential Area' can increase both the FAR and the number of units, while unexpectedly enhancing daylight access. This improvement is likely due to the exclusion of the strict north-facing daylight access regulations in semi-residential zones, which allows for better placement of buildings that benefit from improved sunlight exposure. This analysis suggests that, depending on the site configuration, even when zoning regulations are relaxed, environmental performance can still be enhanced. Therefore, it is essential to leverage AI design technology in urban planning to evaluate and predict the effects of regulatory changes on

Figure 6

AI-Powered Design Outcomes Based on Changes in Maximum Building Height, Floor-to-Floor Height, and Dwelling Unit Typology Standards.(BUILDIT)

environmental performance, tailored to the specific configurations of designated planning zones.

The figure 6 illustrates examples of AI-generated design outcomes based on variations in key urban planning parameters, including maximum building height, floor-to-floor height, and dwelling unit typology, all of which significantly influence the city's skyline and overall form.

An increase in the maximum allowable building height leads to a higher floor area ratio (FAR) and a greater number of residential units. Interestingly, this also results in improved daylight access. This can be attributed to the fact that the higher floors, which typically receive better sunlight exposure, accommodate a larger number of units, thus enhancing the overall average daylight quality across the development.

In the design of unit types, larger units typically result in a reduced total unit count but enhanced daylight access. Conversely, smaller units generally increase the unit count while potentially compromising daylight access. However, as observed in the example above, daylight access can sometimes improve even with smaller units. In this case, the site's specific geometry allowed for the optimal placement of four buildings on the south-facing side, maximizing daylight exposure. This configuration diverges from the usual trend, where an increase in unit count often leads to diminished daylight access. As with earlier examples, this underscores the significant influence of site-specific geometry on the design outcomes and environmental performance of multi-family residential developments

In conclusion, leveraging AI-powered design technologies in urban planning enables the generation of design proposals that reflect various district configurations and constraints, such as floor area ratios, building height limits, and other regulatory parameters. This approach significantly enhances the accuracy of population forecasting, which is a cornerstone of effective urban planning. Moreover, by integrating these design outputs with advanced analytical solutions—such as traffic demand estimation and assessments of required social overhead capital (SOC) infrastructure—planners can develop multidimensional, comprehensive urban plans that address complex and interrelated factors.

ECO : Integrated Design Technology **for Environmental Analysis**

The commonality between urban design and architectural design lies in the fact that their outcomes last for several decades. Additionally, once a building is completed, even a minor adjustment of one meter becomes impossible. This becomes even more challenging at the urban scale. Therefore, various engineering assessments are necessary from the design phase to anticipate the impacts post-construction. These assessments include various types of engineering elements, such as structural analysis, fire prevention, wind flow management, daylight analysis, and solar power generation

Most engineering fields operate on the basis of the design proposal, analyzing it and providing feedback accordingly. Additionally, engineering analyses are typically carried out by specialized firms, introducing both time and cost considerations into the process. This means that the design phase involves executing the design, followed by a period of awaiting feedback from engineering analyses. Given that most projects are subject to strict timelines, achieving a fully optimized design within these constraints is often a significant challenge.

For instance, once the design of a residential complex is finalized, and it is determined that insufficient sunlight is reaching certain areas, adjusting the layout by shifting the buildings would incur significant opportunity costs. While not impossible, such a modification would trigger a series of cascading changes, including adjustments to structural elements, utilities, and underground floor plans, among others.

If the location of the building had been strategically placed in an area with optimal sunlight access during the initial design stage, the issues described above could have been avoided. In other words, the efficiency of engineering optimization increases significantly when it is incorporated during the early stages of design. However, the challenge in the initial design stage is that it involves the evaluation of multiple planning options. Conducing engineering analyses for each of these options, considering both cost and time constraints, can be quite challenging.

Engineering analysis must be preceded by the design process. For instance, to conduct a daylight analysis proposal must first be defined, and then the daylight analysis is carried out based on that design. Any changes made to the design proposal will result in changes to the engineering outcomes. Therefore, the optimization process involves an iterative cycle of design proposal → engineering analysis → design updates → further engineering analysis, and so on.

As highlighted earlier, each stage of the design process incurs both time and opportunity costs. In contrast, if daylight analysis is conducted directly within the architectural firm, these opportunity costs can be minimized, facilitating the possibility of design optimization. Consequently, the integration of design tools with engineering tools becomes a critical requirement. A notable example of such integration can be found in existing parametric design tools, such as Rhino's Grasshopper and Revit's Dynamo. However, these tools necessitate the user to manually develop engineering logic scripts, resulting in relatively low usability. Furthermore, users are required to input complex engineering data, including surrounding topography, climate information, structural parameters, and material properties. Despite the availability of these parametric tools, the practical challenge of achieving design optimization persists due to these inherent limitations.

For the integration of design and engineering, a smart design solution is essential. A smart design solution must possess the following characteristics to effectively address optimization challenges.

- Integration of design tools and engineering tools
- User-friendly interface suitable for direct use by architectural firm
  - Automation of complex data collection for engineering
  - Automation of parameter settings for engineering
- Real-time operation enabling the incorporation of engineering feedback into the design process

The following example demonstrates the application of BUILDIT's smart design solution, utilizing the BUILDIT Designer, an advanced design editing tool, to develop a layout that minimizes sunlight obstruction to surrounding areas(See Figure 7). This solution provides real-time analysis of daylight exposure, coupled with the ability to visualize buildings responsible for any shading. It also integrates essential design review functionalities, including automatic building code compliance checks and real-time updates on floor area ratio (FAR), enabling efficient evaluation and

Figure 7

Optimized Residential Design Process Using Real-Time Daylight Analysis Feature (BUILDIT Designer)

optimization of the design

As demonstrated in the example above, real-time monitoring of surrounding daylight impact allows for immediate adjustments to the design, facilitating the prompt assessment of changes in daylight access. This capability enables the creation of an optimized skyline that minimizes daylight disruption to neighboring areas. The real-time analysis functionality of such 3D modeling provides instant feedback to the designer regarding environmental performance, which is akin to receiving real-time environmental analysis results for design optimization. Therefore, optimization can be achieved without incurring opportunity costs related to communication with engineering firms for environmental analysis. This approach enhances efficiency, enabling the seamless integration of environmental considerations into the design process

The smart design solution, leveraging optimization and integration technologies, can be deployed from the early stages of the design process. This facilitates efficient decision-making at the critical point when opportunity costs are minimized. As a result, it enables the derivation of optimized design outcomes, supporting the development of effective solutions across diverse engineering domains. Furthermore, the application of optimization integration technologies leads to significant improvements in the overall design quality. While the optimization process inherently enhances the quality of the design, the overall improvement extends beyond just the optimized parameters. This is primarily due to the time savings realized throughout the design process. Given the finite nature of design timelines, optimization tools reduce the opportunity costs associated with unnecessary design revisions, allowing more time for deeper creative exploration. In other words, the time saved can be reinvested into refining the design, enhancing its aesthetic appeal, precision, and functionality. As a result, the overall quality of the design is elevated beyond the direct impact of optimization, driving superior design outcomes.

DT : Integrated Platform **for Smart City Planning**

The primary distinction between reality-simulating games and digital twins lies in the broader societal impact of their outcomes. Unlike games, which are designed for entertainment and abstraction, a digital twin is not simply a 3D replica of the physical world. Activities within the digital twin environment carry significant social and economic consequences. As such, the data within a digital twin must adhere to rigorous standards of reliability, which encompass accuracy, timeliness, and consistency. These qualities are paramount to ensuring the trustworthiness of the information, upon which critical decisions are based. For instance, when planning the shape of a building to ensure optimal daylight access while avoiding the shadow impact from adjacent structures, the precise location and form of neighboring buildings become critical data points. A relevant example that underscores the importance of data reliability can be drawn from the use of digi-

Figure 8

Example of Digital Twin Data Timeliness Error

tal map services, such as Google Street View. When searching for a new destination, I often use Street View to visually inspect the area. However, if the photo's time-stamp indicates that the image is outdated, my trust in its accuracy diminishes significantly (See Figure 8). In this analogy, the Street View image functions as a piece of digital twin data, and the time-stamp serves as a proxy for its reliability. Thus, all data utilized within a digital twin environment must adhere to stringent standards of accuracy, timeliness, and standardization. These attributes should be established as foundational criteria, ensuring their application to any subsequent data incorporated into the system. Moreover, integrated analytical modules, including AI-powered design technologies, must rely on trustworthy data drawn from the digital twin framework to operate effectively and produce reliable results.

Cities possess a continuous and evolving history, leading to the accumulation of data over time, which serves as a critical foundation for future forecasting and decision-making. As this data grows, its accuracy improves, enabling increasingly refined outcomes from analytical modules that leverage it. For instance, data on various building forms and spatial layouts significantly enhances the quality of artificial intelligence-based design modules utilized in urban planning. Similarly, traffic volume data surrounding residential complexes can provide essential inputs for determining access control zones or evaluating street activation areas within these developments.

The fundamental component of a digital twin is the construction of a 3D model, based on real-world coordinates, to create a virtual representation of the environment. Leveraging a coordinate-based system enables the creation of new layers and the mapping of additional data. This is where the distinction between traditional GIS tools and digital twins becomes evident. The key differentiator of a digital twin lies in its three-dimensionality. The addition of an extra spatial dimension significantly enhances the capabilities and effectiveness from an engineering perspective.

Various analytical solutions are available individually, each designed to perform specific analyses. Typically, these solutions require the input of both target data and environmental parameters, with the analysis results being presented in a report format. To provide the necessary input for these solutions, the extraction of target data from the design is required, a process that is often time-intensive. However, in the context of a digital twin, multiple analyses can be conducted based on a single set of target data, with the integration and management of environmental parameters. This eliminates the need for separate data input, enabling faster and more efficient analyses. Furthermore, such rapid analytical capabilities can be seamlessly integrated with the optimization technologies previously discussed.

Urban environments are characterized by complex, interdependent systems, necessitating the integration of diverse analytical modules for effective optimization in design. In this context, a digital twin platform with an open architecture, capable of seamlessly incorporating new analytical modules, offers significant advantages for smart city planning. Such a platform must be designed with a self-sustaining, ecosystem-oriented

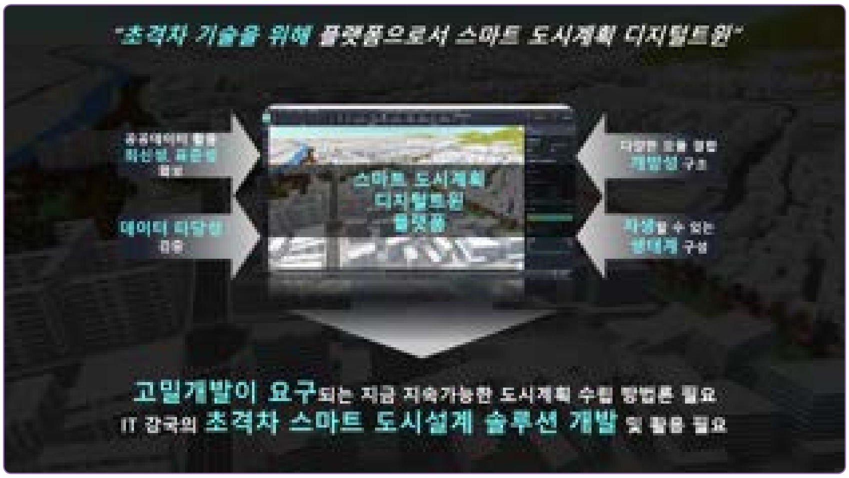

Figure 9

Digital Twin Platform for Advanced Smart City Planning Technology

framework, ensuring its adaptability and scalability to address the dynamic needs and challenges of urban development.

As cities grow organically, smart city planning solutions must also undergo continuous updates and functional development. Relying solely on centralized institutions for development presents challenges in absorbing the vast amounts of data generated across society or addressing all required development needs. Alternatively, if the digital twin space operates as a viable business environment, much like the mobile market where various apps are continuously developed, it can function as a self-sustaining platform, enabling ongoing research and development.

The growing demand for high-density development in recent first-generation new towns highlights the necessity for sustainable urban planning that integrates diverse technological elements. Given South Korea's position as an IT powerhouse, with numerous startups driving innovation, the establishment of a self-sustaining digital twin platform for smart cities could foster the seamless integration of advanced private-sector technologies (See Figure 9). This would facilitate the realization of a robust smart city platform, ultimately positioning the nation at the forefront of global competitiveness in the smart city sector.

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CHAPTER

03

Smart city and Advanced Transportation

Smart City and Advanced Transportation

스마트시티와 첨단교통

Carlo Ratti

Carlo Ratti, architect, engineer, and professor at MIT and Politecnico di Milano, directs the Senseable City Lab and leads CRA-Carlo Ratti Associati, with offices in Turin, New York, and London. A Fulbright Scholar, he holds degrees from Politecnico di Torino, École des Ponts ParisTech, and the University of Cambridge. Among the top ten most-cited urban planning scholars, he has authored 750+ publications, including Atlas of the Senseable City (Yale). His projects, such as the Copenhagen Wheel and Scribit, featured in TIME's "Best Inventions," and his work has appeared at MoMA, La Biennale di Venezia, and more. Curatorial highlights include Expo Milano 2015, the UABB 2019, and Manifesta 14. Named the "Philosopher of the Senseable City" by Bloomberg, Ratti was appointed curator of the 19th International Architecture Exhibition at La Biennale di Venezia in 2025.

ABSTRACT

Cities are quietly evolving as new technologies reshape how we navigate urban life. This paper examines six projects by the MIT Senseable City Lab, directed by Professor Carlo Ratti, that use data to explore solutions to urban mobility challenges. Starting with Real Time Rome, a project that mapped movement during the 2006 World Cup, these projects demonstrate the potential of digital tools to rethink urban life.

The projects are grouped into three themes: sharing, movement, and sensing. HubCab and Unparking investigate shared mobility systems and how autonomous vehicles might ease congestion and free up city space. Behavioral studies like Pointiest Path and US-15 examine the patterns and decisions shaping how people navigate cities, raising important questions about accessibility and urban design. Meanwhile, Good Vibrations and Flatburn reveal how everyday infrastructure, such as bridges or public vehicles, can gather real-time environmental and structural data, creating tools for smarter city management.

These projects don't just focus on moving people more quickly; they aim to rethink mobility systems to serve broader needs, from reducing emissions to reclaiming underutilized urban areas. A concept emerges of a "Moving Web," where diverse forms of transportation are integrated to offer people greater flexibility and choice. This work by the Senseable City Lab offers practical insights into how cities can move beyond traditional transportation models and create systems that are more adaptable, efficient, and responsive to the lives of their residents.

KEYWORDS

Urban Mobility, MIT Senseable City Lab, Real-Time Data, Dynamic Infrastructure, Distributed Sensing

초록

새로운 기술이 도시 생활 방식을 재구성함에 따라 도시는 점진적으로 진화하고 있다. 본 논문은 카를로 라티 교수가 이끄는 MIT 감응형 도시 연구소*MIT Senseable City Lab*에서 수행한 6개 프로젝트를 살펴보며, 데이터 활용을 통해 도시 이동성 문제에 대한 혁신적 솔루션을 탐구한다.

2006년 월드컵 기간 동안 이동성을 추적한 '리얼타임 로마'*Real Time Rome* 프로젝트로 시작된 이 연구들은 디지털 도구를 활용하여 기술이 개인의 도시 생활에 미치는 잠재적 영향을 보여준다.

이 프로젝트는 공유, 이동, 감지라는 세 가지 주제로 나눠진다. HubCab(택시 공유)과 Unparking(주차공간 줄이기)은 공유 이동성 시스템과 자율 주행차가 교통 체증을 완화하고 도시 공간을 확보하는 데 어떻게 기여할 수 있는지 탐구한다. 특히, 유휴 차량을 줄여 주차 인프라를 실질적으로 감소시킬 가능성을 조사한다. Pointiest Path와 US-15는 사람들이 도시를 탐색할 때 길을 선택하는 패턴을 분석하며, 이를 통해 접근성과 도시 설계에 관한 중요한 질문을 제기한다. Good Vibrations와 Flatburn은 교량이나 대중교통 인프라의 실시간 환경 및 구조 데이터를 수집하여 스마트한 도시 관리를 위한 도구를 제시한다. 이 연구들은 단순히 더 빠르게 이동하는 방법만을 고민하지 않는다. 이동성 시스템이 탄소 배출 감소, 활용도가 낮은 도시 지역의 활성화 등 도시의 다양한 요구를 충족하는 데 어떻게 기여할 수 있는지를 탐구한다. 이러한 연구에서 등장한 개념이 바로 'Moving Web'이다. 이는 다양한 교통수단을 통합해 사람들에게 더 큰 유연성과 선택권을 제공하는 미래 도시 이동성 모델이다.

키워드

도시 이동성, MIT 감응형 도시 연구소, 실시간 데이터, 역동적 인프라, 분산형 감지(Distributed Sensing)

Introduction

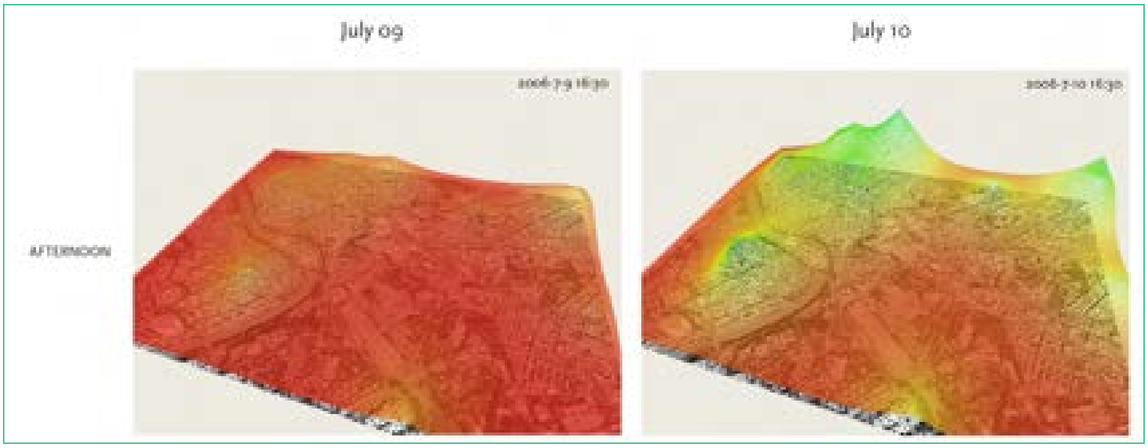
In the summer of 2006, as the World Cup final between Italy and France played out on television screens worldwide, the streets of Rome thrummed with life. Thousands of fans gathered in bars, restaurants, and homes, their collective energy rippling through the city. As Italy claimed victory in a nail-biting penalty shootout, Rome erupted in spontaneous celebrations. The streets filled with honking cars, waving flags, and exuberant chants. But there was another kind of movement beneath the surface—one powered by data.

During the match's halftime, phone lines buzzed as fans called friends, sharing the nervous energy of the tie. And when the final whistle blew, those same phone networks were used to organize rides and parties, guiding the flow of people across the city. For the first time, these invisible currents of communication and movement were being captured and visualized, thanks to an experimental project led by MIT's Senseable City Lab.

The Real Time Rome project, unveiled at the 2006 Venice Biennale, was among the early efforts to show how digital data could help visualize the urban pulse. By tapping into data streams from cell phones, buses, and

Figure 1

Real Time Rome visualization of the afternoon of the day of and the day after the World Cup



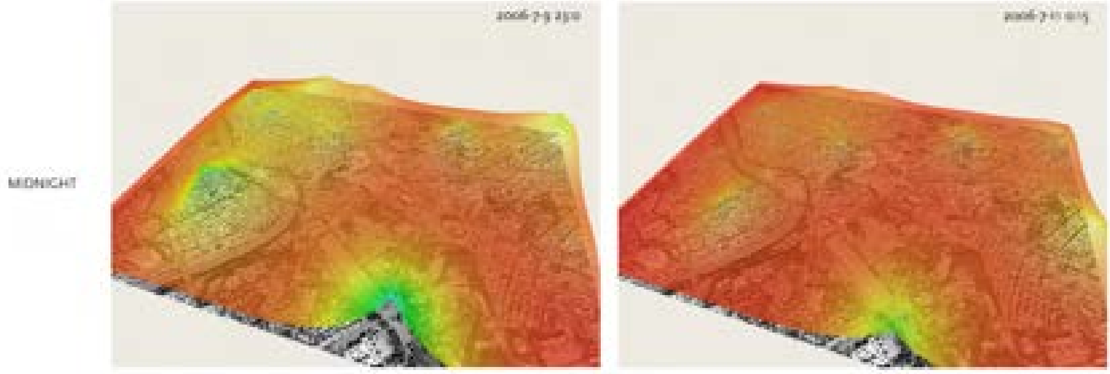
taxis—thanks to TIMs (formerly known as Telecom Italia) Lochness platform—the project painted a real-time picture of mobility in Rome during the World Cup. The result was a vivid map showing how urban life flowed through streets, congregated in neighborhoods, and ebbed after the celebrations subsided (Figure1, 2).

While Real Time Rome marked an important moment for data-driven urban studies, it was just one step in a much broader movement toward understanding cities through digital networks. What seemed innovative at a moment that predated smartphones—tracking city movement through communication networks—has become a cornerstone of modern urban planning. Today, we live in a world where real-time data from apps, sensors, and GPS devices influence everything from transit routes to ride-sharing algorithms, helping cities evolve into smarter, more interconnected ecosystems.

Urban mobility has always been a force shaping cities. From the grid-like roads of ancient Rome to Venice's waterways to the sprawling high-

Figure 2

Real Time Rome visualization of the evening of the day of and the day after the World Cup



The final match of the World Cup was played on July 9, from 8 to 10 pm approximately. Afterwards, people started celebrating around the Circo Massimo, shown in the image. The following day the Italian winning team arrived in Rome and celebrations continued from the afternoon till morning.

ways of the 20th century, the ways we move have dictated the ways we build. "A city made for speed is made for success," Le Corbusier famously said. But the relentless pursuit of speed has often come with costs—traffic congestion, pollution, and the isolation of suburban sprawl.

As cities grapple with these challenges, the focus is shifting toward smarter, more adaptive mobility solutions. The rise of data analytics, artificial intelligence, and real-time tracking is helping planners reimagine how we navigate urban environments. This new approach is turning cities into what some call "living organisms," where infrastructure can adjust dynamically based on real-time information.

The Spanish urban planner and father of modern Barcelona Ildefons Cerdà, in his book "The General Theory of Urbanization[1)]" dreamed of describing the city scientifically. Since the turn of the century, that dream has become a reality. Digital networks and data-driven insights allow us to understand and optimize the built environment in ways Cerdà could never have imagined. We can now see, in real-time, how people move through a city and adjust urban systems to match these patterns.

As cities continue to evolve, the next step in urban life is not just about speed, but about creating environments that are adaptable, efficient, and sustainable. The future of mobility will likely be influenced by how well we can use data to reduce inefficiencies, improve public transport, and make cities more livable. The challenge lies in balancing technological advancements with the need for spaces that prioritize inclusivity and human-centered design.

At MIT's Senseable City Lab, we are proud to have contributed to this field over the years – and at CRA – Carlo Ratti Associati, to help turn re-

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1) Cerdà, I. *The General Theory of Urbanization.*

search into innovative designs. From our early work in Rome to our more recent projects, we've joined a growing community of researchers and practitioners using data to reshape how we experience cities. This article highlights just a few of the key themes we have explored at SCL, which may help shape the future of urban mobility: shared and autonomous transport, the use of mathematical models to uncover patterns in movement, and distributed sensing technologies to support adaptive city systems.

Part 1
Sharing

Sharing mobility is becoming a key principle in the evolution of digitised urban environments. Through pooling resources, from shared taxis to autonomous vehicle fleets, cities can reduce congestion, lower emissions, and make more efficient use of urban space. The projects by the SCL explored in this section—HubCab (2013), and Unparking (2018) showcase how shared mobility systems can transform cities by optimizing transportation networks, reducing the need for private cars, and reimagining how we move through urban environments. These projects offer insights that could inform future efforts to reshape urban mobility in a more sustainable direction. In the subsequent discussion, we will differentiate between ride-sharing—where multiple individuals simultaneously share a single vehicle—and car-sharing, in which the same vehicle is accessed by different users at various times throughout the day.

Sharing – HubCab

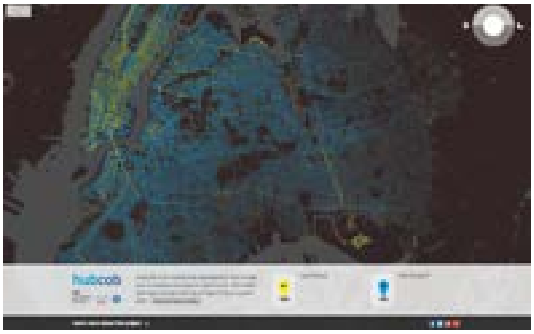
One of earliest our projects that explores this potential is a project we called HubCab, providing insights into how ride-sharing can revolutionize urban transportation. HubCab involved analyzing over 170 million taxi trips in New York City to unveil the complex network of taxi movements. It uses innovative mathematics to generate an interactive visualization that reveals the frequency, location, and timing of taxi trips in granular detail, offering a new perspective on urban mobility that was previously invisible.

HubCab not only maps the travel habits of individuals but highlights the tremendous opportunity for optimizing these trips through ride-sharing. In allowing users to explore where, when, and how people get picked up and dropped off, the project encourages the discovery of potential zones where travel patterns overlap, thus pointing to significant opportunities for sharing. HubCab asks essential questions: How many of these taxi trips could have been shared? How much could ride-sharing reduce the number of trips, traffic congestion, and even fuel consumption? These questions are at the heart of a broader vision of how sharing can reshape urban mobility.

HubCab's interactive interface is powered by a vast real-time urban data set, collected through millions of individual taxi journeys (Figure 3). This data reveals critical patterns that show not only where people are traveling

Figure 3

HubCab visualizing NYC taxi trips and potential sharing



Screenshot of HubCab, showing pickups and drop offs of all 170 million taxi trips over one year in New York City.

Screenshot of HubCab, showing taxi flows and potential taxi sharing benefits between two locations in Manhattan.

to and from but how the city is stitched together by mobility hubs. It allows the user to investigate zones of dense pickup and drop-off activities, which in turn provides key insights into how these areas function as central nodes of urban travel. In understanding these patterns, we can begin to unravel the complexity of urban travel and make cities more efficient by capitalizing on shared mobility solutions.

One of the key contributions of HubCab lies in the development of the novel mathematical approach - shareability networks. This concept, developed in collaboration with network science pioneer Steven Strogatz and published in the Proceedings of the National Academy of Sciences[2)] represents a mathematical framework that models and optimizes the potential for trip-sharing. The results suggest significant potential: HubCab's research indicates that taxi-sharing alone could reduce the number of taxi trips in New York City by 40%, without causing significant inconvenience to passengers.[3)]

Beyond the immediate reduction in trips, the environmental and economic benefits of such a system could be substantial. All other things being equal, fewer trips mean fewer cars on the road, leading to reduced congestion, lower fuel consumption, and a significant reduction in carbon emissions.[4)] In terms of economics, shared trips could result in lower fares for passengers as the cost of each journey would be split between multiple riders. This reduction in fares and traffic creates a more sustainable, af-

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2) P Santi, P., Resta, G., Szell, M., Sobolevsky, S., Strogatz, S., & Ratti, C. (2014). Quantifying the benefits of vehicle pooling with shareability networks. *Proceedings of the National Academy of Sciences (PNAS), 111*(13290–13294).

3) Santi, P., Resta, G., Szell, M., Sobolevsky, S., Strogatz, S., & Ratti, C. (2013). Taxi pooling in New York City: A network-based approach to social sharing problems.

4) Szell, M., & Groß, B. (2013). Hubcab - Taxi-Fahrgemeinschaften, digital erkundet. In D. Offenhuber & C. Ratti (Eds.), *Die Stadt entschlüsseln* (Bauwelt Fundamente). Birkhäuser.

fordable, and efficient transportation system. HubCab's findings extend to tangible environmental savings, showcasing how thousands of kilograms of CO_2 emissions could be eliminated by facilitating shared journeys.[5)]

The implications of this research go far beyond academic curiosity. HubCab's insights helped pave the way for ride-sharing services such as Uber Pool. In fact, when HubCab's shareability research was published, it caught the attention of Uber's CEO, and soon thereafter, MIT began collaborating with Uber to further develop shared mobility solutions. Today, ride-sharing services like Uber Pool, Didi, Grab, and Lyft owe much of their foundational concepts to the work done through HubCab.

HubCab's data-driven approach also shows how the digital world informs the physical world. By studying how people move through cities, we gain insights that can be applied to reimagining the infrastructure that supports mobility. For example, if we know that a significant percentage of taxi trips could be shared, it opens up the possibility of designing cities with fewer roads dedicated to individual vehicles, and more space for pedestrians, cyclists, and public transit. This concept is part of a feedback loop where digital insights lead to physical changes, which in turn can generate new data and new opportunities for design.

Sharing – Unparking

Unparking investigates another type of sharing—car-sharing, and how the adoption of shared and autonomous vehicles can reshape urban mobility and reduce parking demand. Leveraging real-world data from Singapore, the project systematically quantifies the potential reduction in parking spaces required when cities transition from a privately-owned vehicle

5) ibid

model to a shared mobility system, particularly one that incorporates self-driving cars. It proposes two distinct scenarios: the current situation, where each private car requires multiple parking spots throughout the day, and a future scenario where shared, self-driving vehicles are utilized more efficiently and do not need dedicated parking at each destination.

In contemporary urban environments, private cars dominate road infrastructure, occupying a significant portion of parking spaces both at home and at various destinations such as workplaces and shopping centers. Cars typically sit idle for around 95% of their time, requiring substantial infrastructure just to accommodate their presence when not in use.[6)] The project identifies the inefficiency inherent in this model, where a single car often requires at least two parking spots—one at home and another at work—leading to a large amount of valuable urban land being underutilized.

Unparking focuses primarily on home-work commuting patterns, a significant contributor to daily traffic congestion and parking demand. Commuters require dedicated parking spaces at both ends of their journey, resulting in a substantial amount of urban space being reserved for idle vehicles. Through analyzing mobile phone data from over 600,000 commuters in Singapore, the study evaluates the impact of different shared mobility models, particularly focusing on self-driving vehicles. It explores how shared self-driving cars, which can be continuously in use and relocated throughout the day, drastically reduce the need for parking spaces.

The project suggests that a complete transition to a shared, self-driving vehicle model could free up as much as 85% of the parking spaces current-

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6) Kondor, D., Zhang, H., Tachet, R., Santi, P., & Ratti, C. (2018). Estimating savings in parking demand using shared vehicles for home-work commuting. *IEEE Transactions on Intelligent Transportation Systems, 20*(8), 2903–2912.

ly needed in urban areas (Figure 4). The research simulation of Singapore indicates that a fleet of 200,000 autonomous vehicles (AVs) could serve all trips by replacing private vehicles, requiring only 410,000 parking spaces instead of the current 1.37 million—a 70% reduction. Optimized solutions for smaller fleet sizes suggest even more dramatic reductions. For instance, a fleet as small as 90,000 AVs could operate with just 210,000 parking spaces, an 85% reduction in vehicles and parking infrastructure, though this would result in approximately 20% more total distance traveled due to empty AVs rebalancing between trips.[7]

One of the key distinctions made in Unparking is between traditional car-sharing models and shared, self-driving vehicles. Conventional car-sharing, while it offers some benefits, faces challenges such as user anxiety over finding nearby vehicles and the difficulty of rebalancing cars after one-way trips. These logistical issues have limited the adoption of traditional car-sharing systems. However, self-driving vehicles could address these challenges by being more flexible in their operations. Since they do not require human drivers, self-driving vehicles could be constantly re-

Figure 4

Two maps of Singapore comparing the current (left) and projected (right) distribution of parking spaces

7) ibid

routed to meet demand, reducing the time vehicles sit idle and the need for users to park them at specific locations. The flexibility of shared, autonomous vehicles allows for better optimization of parking and routing, meaning that fewer cars can serve a larger population more efficiently.

The study explores the concept of "r_max"[8] which represents the maximum acceptable walking distance to a vehicle. For conventional cars, r_max is typically limited because people prefer to have their vehicles parked close by, which can lead to dissatisfaction if they have to walk too far to reach their parked car. However, for shared, self-driving vehicles, r_max can be more flexible, as users don't need to worry about parking. Instead, the car comes to them when needed, eliminating the stress associated with parking availability. This flexibility in vehicle deployment allows for better overall use of space and time, further reducing the need for parking infrastructure.

The broader implications of "Unparking" could extend beyond parking to urban planning and sustainability. By reducing the need for parking infrastructure, cities could reimagine how space is allocated, potentially transforming areas currently dominated by parking lots into green spaces, public parks, or pedestrian zones. This could contribute to improved urban livability, reduce the urban heat island effect, and create more environmentally sustainable cities. Moreover, fewer cars on the road due to shared mobility systems would lead to reduced traffic congestion, lower emissions, and better air quality, making cities healthier and more attractive places to live.

8) ibid

Part 2
The Laws of Movement

Understanding how people move through cities is key to shaping future urban mobility. While technology and infrastructure provide the framework, individual behaviors drive mobility decisions. The "laws of mobility" reflect patterns, tendencies, and cognitive mechanisms in how people navigate cities, choose routes, and interact with transport networks. Our projects, like Pointiest Path (2021) and US-15 (2024), analyze large-scale data to reveal how factors such as convenience, directional accuracy, and proximity shape movement patterns. These insights guide smarter urban planning, helping cities reduce congestion, improve accessibility, and create more sustainable, livable environments. By focusing on real human behavior rather than assumptions, cities can design systems that are efficient, intuitive, and truly enhance residents' quality of life.

The Laws of Movement – Pointiest Path

Pointiest Path project explores how humans navigate urban environments, revealing that pedestrians often choose routes based on a heuristic called vector-based navigation. This strategy prioritizes paths that point most directly toward the destination from the outset, rather than aiming for the shortest distance.[9] The study, which analyzed GPS data from over half a million pedestrian routes in Boston and San Francisco, found that people frequently deviate from the shortest path, especially over longer distances. However, these deviations are not random. Pedestrians tend to select

9) Bongiorno, C., Zhou, Y., Kryven, M., Theurel, D., Rizzo, A., Santi, P., Tenenbaum, J., & Ratti, C. (2021). Vector-based pedestrian navigation in cities. *Nature Computational Science, 10*(1), 1–8.

“pointy” routes, favoring directional accuracy over pure distance optimization, highlighting how ease of decision-making influences urban movement.

This research illustrates a key cognitive mechanism behind urban navigation: humans rely on approximate heuristics to simplify complex decision-making processes. The brain may opt for “good enough” paths that minimize the cognitive load required for planning, allowing more mental resources to be allocated elsewhere. This tendency mirrors navigation behaviors found in the animal kingdom, where species from insects to primates exhibit similar vector-based strategies to reduce brainpower spent on route planning.

Pointiest Path offers insights into the understanding of the laws of movement that shape human behavior in urban environments. Understanding how and why people choose their routes, city planners and technology developers can design transportation systems and infrastructure that align more closely with human behavior. For instance, integrating vector-based navigation models into urban mobility planning could lead to more efficient pedestrian pathways, public transit routes, and even autonomous vehicle algorithms. These insights could help optimize the flow of people within cities, reducing congestion, and improving accessibility.

This research highlights the value of using real-world data to inform urban design. Analyzing high-resolution GPS data, the study highlights the divergence between human navigation behavior and machine-generated route suggestions (like those from Google Maps), showing that pedestrians prioritize different factors than algorithms. As a result, future urban systems should incorporate these human tendencies to create more intuitive, user-friendly navigation tools. The project highlights the importance of considering human-centric approaches in designing smart mobility solutions, where the cognitive preferences of people play a central role in shaping more efficient and livable urban spaces.

The Laws of Movement – US15

As urban areas account for more than 60% of global greenhouse gas emissions, the need for sustainable, inclusive, and affordable cities is paramount.[10] Central to this challenge is rethinking human mobility, as transportation remains the second-largest energy consumer and the top contributor to greenhouse gas emissions in the United States.[11] This has led to a growing interest in urban models that promote proximity-based living, with a particular focus on the "15-minute city" concept, a model popularized by Carlos Moreno. This urban framework emphasizes that daily necessities should be accessible within a 15-minute walk, aiming to not only cut transportation emissions but also to revitalize community interaction.

US-15 explores the practicalities of this model, focusing on how the proximity of essential amenities impacts mobility behavior. Utilizing GPS data from over 40 million mobile devices, spanning 400 urban areas in the U.S., the project sheds light on how people actually use local amenities. Findings reveal that only 14% of daily consumption-related trips take place within a 15-minute walk from home, indicating that proximity alone does not necessarily lead to local use of amenities.[12] This poses significant questions for the widespread adoption of the 15-minute city model, highlighting that accessibility is only part of the solution.

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10) United Nations. (2012). Generating power. Retrieved from https://www.un.org/en/climatechange/climate-solutions/cities-pollution. Accessed January 19, 2023.

11) U.S. Energy Information Administration. (2021). *International Energy Outlook 2021 (IEO2021)*. Retrieved from https://www.eia.gov/outlooks/ieo/pdf/IEO2021_ReleasePresentation.pdf.

12) U.Abbiasov, T., Heine, C., Sabouri, S., Salazar-Miranda, A., Santi, P., Glaeser, E., & Ratti, C. (2024). The 15-minute city quantified using human mobility data.*Nature Human Behaviour*.

Zoning laws and historical urban planning significantly affect residents' travel behaviors, even in neighborhoods where amenities are nearby. The study suggests that more flexible zoning policies and the promotion of mixed-use developments could enable greater usage of local services. Such policies could not only reduce the need for longer trips but also promote efficient travel behaviors, such as combining multiple errands into one trip. This would encourage more sustainable forms of mobility while helping to reduce transportation-related emissions.

However, the research also uncovers a key social dilemma. In lower-income neighborhoods where reliance on local amenities is higher, there is a noticeable increase in socio-economic segregation. Localizing mobility can lead to fewer interactions between different social and economic groups, potentially deepening divisions in urban communities. This raises important concerns about how cities can avoid these negative social consequences while striving to reduce emissions through localized living.

US-15 underscores that urban planning must account for both the environmental benefits and the social implications of models like the 15-minute city. While reducing transportation distances can significantly contribute to sustainability goals, it is equally critical to consider how these policies might reinforce social isolation in economically divided areas.

Part 3
Distributed Sensing

As urban populations grow, cities face increasing challenges like pollution and traffic congestion, requiring innovative tools for real-time monitoring and responsive policymaking. Distributed sensing, which uses networks of low-cost, mobile sensors embedded in vehicles and public infrastructure, offers a solution by collecting dynamic data on conditions such as air quality, noise, and infrastructure health. Projects like *Good Vibrations* (2018) and *Flatburn* (2023) show how distributed sensing transforms everyday infrastructure into mobile data platforms, providing cities with real-time, actionable insights. This technology enhances environmental monitoring, improves traffic management, and empowers communities to shape their urban environments. Distributed sensing can drive smarter, more sustainable cities by optimizing transportation and resource use.

Distributed Sensing – Good Vibrations

Good Vibrations is a project that leverages smartphones and vehicle-based sensors to create a distributed sensing platform for monitoring the structural health of bridges. Through collecting data from everyday vehicles—whether they be cars, buses, or even e-scooters—equipped with smartphones, this project demonstrates how urban mobility can serve as a tool for large-scale infrastructure maintenance.

The core of Good Vibrations lies in its innovative use of distributed sensing, which bypasses the traditional expensive and specialized sensor networks typically installed on bridges. Instead, the project taps into the vast, readily available network of smartphones that already exist in the pockets of drivers and passengers. These smartphones, with built-in accelerometers and other sensors, can capture vibrations transmitted from the bridge to the vehicle as it passes over, providing insights into the structural dynamics of the bridge.

This concept provides an additional perspective on smart mobility and cities. The routine crossings of bridges by vehicles are turned into data streams that can inform critical infrastructure management. Instead of relying on costly, fixed sensor networks, Good Vibrations reimagines the city's infrastructure as a dynamic, distributed sensor network, with the power to monitor itself in real-time.

The project's early experiments, such as those on the Golden Gate Bridge and the Cadore Bridge, indicate that smartphone-based sensing can provide structural insights with an accuracy of less than 3% error.[13] Such precision demonstrates that distributed sensing has matured to a point where it can play a vital role in maintaining public infrastructure, potentially adding years to the service life of bridges through timely interventions and repairs.

The implications of Good Vibrations extend beyond just bridge monitoring. This project showcases how urban mobility can be harnessed for a variety of purposes. Vehicles equipped with sensors are already a part of the urban landscape, moving throughout cities as part of the daily commute, public transit, or ride-sharing services. Through turning these vehicles into mobile sensors, cities can gather vast amounts of data on the health of their infrastructure, environmental conditions, and even traffic patterns—all without deploying new, costly hardware.

This type of distributed sensing not only reduces the financial burden on municipalities but also could also democratize data collection, turning citizens' everyday movements into a resource that helps improve urban life. Whether through vehicle fleets or individual drivers, the potential for large-scale crowdsourced data collection offers cities a path toward a more resilient and responsive infrastructure system.

Good Vibrations provides an example of how distributed sensing could revolutionize infrastructure monitoring and maintenance. Through the integration of everyday urban mobility into the data-gathering process, it shows how cities can harness the power of movement and connectivity to

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13) Matarazzo, T., Vazifeh, M., Pakza, S., Santi, P., & Ratti, C. (2017). Smartphone data streams for bridge health monitoring. *Procedia Engineering, 966*, 966–971.

contribute to the safety and longevity of their built environment. Through its use of smartphones and vehicles, the project highlights the future of smart cities, where infrastructure itself becomes a part of the sensor network, feeding critical data back to decision-makers to shape a more efficient and sustainable urban future.

Distributed Sensing – Flatburn

Our project Flatburn presents a new approach to air quality management through distributed sensing. Through employing low-cost, open-source sensors, Flatburn enables citizens and local communities to monitor and understand environmental conditions such as air pollution. This project contributes to environmental sensing by making it more accessible and scalable, but it could also play an important role in shaping smart mobility and smart cities by creating an interconnected network of sensors that collect real-time environmental data.

Flatburn sensors can be mounted on vehicles, allowing them to act as mobile data-gathering platforms. These vehicles, whether garbage trucks or personal cars, move through various parts of the city, collecting and transmitting real-time air quality data as they go. This system transforms the urban environment into a dynamic, mobile sensor network, capable of monitoring a wide range of environmental variables like air pollution, noise, and temperature.

The sensor is designed to be easily accessible, allowing anyone to 3D print or assemble the device using inexpensive parts. This makes it possible for community groups, local governments, and even individual citizens to deploy their own air quality monitoring systems. Open-source projects like Flatburn help democratize the process of data collection, encouraging local participation in environmental monitoring and potentially making it easier to address urban air quality issues.

The availability of this technology enables a “bottom-up” approach to urban development. Rather than relying solely on top-down initiatives from city governments or large institutions, Flatburn encourages local participation in the data-gathering process. Doing so, it helps bridge the gap between citizens and urban policymakers, creating feedback loops that can influence policy decisions aimed at improving air quality and overall urban living conditions.

In addition to air quality monitoring, Flatburn’s distributed sensing platform can be extended to other environmental parameters, such as noise levels and temperature, providing a more holistic understanding of the urban environment. This data is could be useful for urban planners and local governments seeking to develop cities that prioritize the well-being of their residents.

Flatburn illustrates how distributed sensing may be influencing the future of smart mobility. Through its open-source design, mobile capabilities, and focus on environmental sensing, it provides a scalable and cost-effective solution for monitoring urban air quality. By enabling citizens to participate in the data collection process, Flatburn not only enhances our understanding of urban environments but also helps create more inclusive and responsive cities, where environmental management is driven by real-time data and community engagement. This approach to distributed sensing highlights the potential for bottom-up innovations to complement and enhance top-down development initiatives, ultimately leading to healthier urban environments.

Conclusion

Since Real Time Rome, we’ve witnessed an ongoing evolution in how we envision and manage urban mobility. The Real Time Rome project of 2006 offered a glimpse into a future of interconnected cities, and today, the technological tools and systems seem increasingly capable of turning that vision into reality. Cities are now on the cusp of evolving into intelligent ecosystems, where the boundaries between modes of transport blur and efficiency is no longer measured by speed alone, but by adaptability, sustainability, and choice.

But what will the future of mobility truly look like? What do these diverse projects reveal about the path forward?

The future may lie in what can be called the "Moving Web"—a dynamic, ever-evolving platform that unifies all transportation modes into a seamless, multimodal network. This Moving Web would go far beyond today's ride-sharing systems, integrating everything from shared autonomous vehicles to e-bikes, autonomous shuttles, and even real-time logistics and data collection. In such a network, transportation becomes fluid: a city where commuters and goods move seamlessly from buses to electric bikes or from autonomous shuttles to e-scooters for the last mile, all coordinated in real time.

The insights gleaned from the projects discussed here suggest a paradigm shift toward this fluid, multimodal mobility. Rather than relying on a single mode of transportation, urban dwellers of the future may access a "mobility portfolio" that allows them to move flexibly between various options, depending on immediate needs and real-time conditions. This shift could drive the adoption of shared micro-mobility solutions like autonomous shuttles and e-scooters, making cities more adaptable to fluctuating demands and environmental conditions.

In this new landscape, the concept of speed as the only marker of success may give way to adaptability, sustainability, and choice. The fusion of technology, human behavior, and urban planning could create a future where mobility is not just about getting from point A to point B but about interacting with the city in a meaningful way.

Smart Mobility Transition and Outlook

스마트모빌리티 전환 및 전망

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ABSTRACT

Transportation solutions have always been a large and important part of smart cities. Over the past 100 years, the transportation sector has been replaced by faster vehicles, but it has not brought about significant changes. However, with the advent of the Fourth Industrial Revolution, the combination of information and communication technologies and transportation has led to the emergence of the concept of smart mobility and a massive revolution in the transportation sector. Smart mobility is not only working as a safer and more convenient service for citizens, but it is also becoming an important means of responding to the climate crisis, which could become a global crisis. The reason why smart mobility is able to bring about a sweeping innovation unlike anything before is that (1) it has laid the foundation for a shift to services from a consumer perspective, (2) is realizing carbon reduction through the introduction of eco-friendly mobility means and (3) efficient traffic management systems, which is enabling optimal distribution between consumers and suppliers by utilizing various big data and platforms. On the other hand, there are still many challenges in order for smart mobility to settle down quickly, and it is especially important to establish an institutional foundation for the application of newly emerging smart mobility means and services in the city and the introduction of new infrastructure in the city.

KEYWORDS

Smart city, smart mobility, consumer perspective shift, carbon reduction, big data

초록

스마트시티에서 교통분야 솔루션은 항상 비중이 높고 중요한 분야이다. 지난 100여 년간 교통 분야는 더 빠른 교통수단으로 대체되기는 하였지만 커다란 변화를 가져오지는 못하였다. 하지만 4차산업혁명 시대의 도래로 정보통신기술들과 교통이 결합하게 되면서 스마트모빌리티라는 개념이 새롭게 등장하고 교통 분야에서도 대규모 혁신이 일어나고 있다. 스마트모빌리티는 시민들에게 보다 안전하고 편리한 서비스로 작동하고 있을 뿐 아니라 전 세계적 위기라 할 수 있는 기후위기에 대응하기 위한 중요한 수단이 되고 있다. 스마트모빌리티가 이전과 다른 전면적 혁신을 가져올 수 있는 이유는 수요자 관점의 서비스로 전환 가능한 기반을 마련하였고, 친환경적 모빌리티 수단의 도입과 효율적 교통관리체계를 통한 탄소 절감을 실현 중에 있으며, 각종 빅데이터 및 플랫폼을 활용하여 수요자와 공급자 간 최적 분배를 가능하게 하였기 때문이다. 반면 스마트모빌리티가 빠르게 정착하기 위해서는 여전히 많은 숙제가 존재하고 있는데, 새롭게 등장하는 스마트모빌리티 수단 및 서비스들이 도시 내에서 잘 적용되기 위한 제도적 기반 마련과 도시 내 신규 기반시설의 도입이 특히 중요하다.

키워드

스마트시티, 스마트모빌리티, 수요자 관점 전환, 탄소 절감, 빅데이터

Introduction

Smart cities are generally recognized as sustainable cities that utilize information and communication technologies to efficiently solve urban problems. Smart cities have been established globally since 2010 as a trend for future cities, and have recently been viewed as a means of not only efficiently solving urban problems but also achieving goals such as responding to climate change, creating a space for the fourth industrial revolution, and securing urban inclusion. The smart city market, which combines various advanced information and communication technologies such as AI, big data, IoT, mobile, digital twin, and blockchain, is rapidly growing as a new market, attracting the attention of both developing and developed countries.

The scope of smart cities encompasses all city functions such as transportation, environment and energy, crime and disaster prevention and so on. And, transportation is the highest portion at 32% in the analysis of smart city service types (Lee et al., 2022).

Transportation is an important in relation to climate crisis response. In Korea, for example, the transportation sector accounts for 16.5% of carbon

Table 1

Growth Prospects for New City Model Market

Source: 4th Smart City Comprehensive Plan(2024-2028), Ministry of Land, Infrastructure, and Transport

Market Research Organization	Expectation
Markets and Markets (2022.11)	The overall market is expected to grow from $511.6 billion in 2022 to $ 1.24 trillion in 2027, at a compound annual growth rate of 14.9%.
Grand View Research (2022.12)	The overall market is expected to grow from $656.8 billion in 2022 to $6.965 trillion in 2030, at a compound annual growth rate of 25.8%.
Insight Partners (2023.02)	The overall market is expected to grow from $1.94trillion in 2022 to $3.11 trillion in 2028, at a compound annual growth rate of 19%.

emissions and 94% of the emissions are caused by automobile use, making it highly relevant to the climate crisis in cities (Seok & Lee, 2013). The smart transportation sector is also gaining importance in the new industrial market, especially as the energy used for transportation is being converted to eco-friendly energy such as electricity and hydrogen to respond to the climate change crisis, and the entire industrial value chain related to transportation is being completely reorganized, resulting in rapid growth not only in the mobility market itself but also in new markets for related industries such as energy.

Smart city transportation solutions, represented by smart mobility, are significantly changing the traditional concept of transportation due to the combination of advanced information and communication technologies, in the same way that smartphones have changed people's daily lives. The traditional concept of transportation refers to the movement of people to places that provide certain activities such as home, work, or shopping Transportation is only a means to achieve the purpose related to people's activities. If movement is only a necessary means for activities, and the movement itself is not of great significance, then it becomes necessary to minimize movement. If movement is an unnecessary derivative demand, progress can be made in ways that minimize travel time per distance. Early humans started by walking, but this changed to faster transportation, such as horses and carriages, which in turn were replaced by faster trains and cars. While the means of transportation has changed to allow for faster travel, it has remained the same until recently in terms of being a secondary means to achieve the goal of getting people to a specific place.

However, faster modes of transportation, such as trains and automobiles, have resulted in the expansion of cities, which has led to a greater dependence on automobiles and a variety of traffic problems. More cars in cities have caused problems such as traffic congestion and parking issues, and have also become a source of environmental pollution in cities and a negative tool for harming human life, such as traffic accidents.

In the traditional view of travel, travel is a derivative demand that is unnecessary to achieve the goal of an activity at a destination and unavoidable to achieve the purpose of reaching a certain area, so to solve the fundamental problem of travel, it is necessary to minimize the means of travel or transform travel itself into a necessary purpose rather than a derivative demand. Fortunately, the limited change over the past 100 years of faster travel, centered on the automobile, has been transformed by advances in information and communication technologies, leading to the emergence of smart mobility, which is characterized by connected, autonomous, shared, and electrification.

Given that the discussion of smart cities has been initiated to solve existing urban problems more efficiently, it is natural that the transportation sector, which is the largest part of urban problems, is important in smart cities. This paper aims to explore the implications of the emerging smart mobility in relation to transportation.

Shifting mobility services **from a provider perspective to a consumer perspective**

The connection of transportation with information and communication technologies has enabled a shift from a provider perspective to a consumer perspective. This shift to a consumer perspective is helping to eliminate inefficiencies related to transportation.

Before the 1990s, when information and communication technology was not connected to transportation, citizens could only wait at the bus stop for public transportation to arrive. However, since the year 2000, the Bus Information SystemBIS has been introduced, and the inconvenience of waiting for a bus has been eliminated. BIS has also brought economic benefits to local governments, which previously had no way to track the location of buses. For example, if there are four buses per hour, a bus should arrive every 15 minutes mathematically, but before the system was introduced, it was common for four buses to arrive at the bus stop at the same time after an hour had passed, and there were even cases of cheating, such as overpaying public transportation subsidies by operating only two buses when they were supposed to operate four buses per hour. However, these problems were solved when the bus information system made it possible to check real-time bus operation information, which means that buses arrive exactly at the appointed time and can be checked in advance, which not only increased the convenience of passengers, but also eliminated the problem of paying public transportation subsidies in a clumsy manner and had a positive effect on reducing tax waste for local governments.

However, although the bus information system has increased the convenience of citizens, it is difficult to say that it is a demand-centered public transportation. The introduction of demand-responsive public transportationDRT is the beginning of a full-fledged public transportation from the perspective of the user. DRT is a form of public transportation in which citizens decide where they want to get on and where they want to get off and call the bus by app. There are many cases where buses run empty during the day on weekdays when there is not enough passenger demand outside of the metropolitan area, and even though buses must pass through fixed stops, it often happens that no one waits at the bus stop. If this problem persists, bus routes will have to be set up to go through more bus stops or the number of buses will have to be reduced to make the bus service more economical. From the passengers' point of view, they feel that the buses make too many trips, or they have to accept the inconvenience that the buses do not come frequently. DRT recognized this problem and allowed buses to travel only to bus stops with people instead of following fixed routes, reducing waiting time and travel time for passengers and allowing bus operators to operate buses in a more efficient way rather than running empty buses. Reducing wait times and travel time for passengers naturally helps reduce carbon emissions. In addition, the ridership data accumulated from the continuous operation of the DRT allows us to identify which areas have high ridership and when, which allows us to better plan the operation of the DRT, which allows us to provide service in a more efficient manner as the DRT runs longer. The DRT service from the perspective of the consumer, who is looking for passengers on fixed routes provided unilaterally by the provider, was made possible by the competition between information and communication technology that identifies passenger locations in real time and AI technology that creates bus routes in real time.

Another transportation solution that has expanded consumer choice is mobility-as-a-serviceMaaS. MaaS connects different transportation modes on a single platform to provide information and pay for them, allowing citizens to decide what combination of modes they want to use to get where they want to go. It is a new mobility service that allows people to connect different modes of transportation depending on whether it is important for them to move quickly or to move at the lowest cost, which is a typical service from a consumer perspective. MaaS creates greater synergy when various transportation modes are combined. Platforms such as MaaS, which combine various stakeholders such as shared mobility for the first/last mile, public transportation such as buses and subways, and long-distance transportation such as railroads, are inevitably based on governance among stakeholders, so when combined with technologies such as blockchain, stakeholder trust can be strengthened.

Consumer-oriented solutions are also expanding in the use of transportation-related facilities. For example, providing citizens with information on the cost and location of parking lots to expand their choices is a consumer-oriented solution. In particular, smart parking solutions can reduce the number of vehicles wandering around in search of parking lots, reducing traffic congestion and emissions in urban centers. In recent years, robotic parking has been introduced in commercial areas in urban centers where there is an absolute shortage of parking lots, allowing more vehicles to be parked in the same area.

Demand-side solutions seek to accurately identify the needs of consumers and provide the supply to meet those needs at the right place and time, which can only be provided in an environment where real-time data is available.

Evolving mobility solutions **to address the climate crisis**

The demand for achieving carbon reduction targets is rapidly expanding as major countries around the world have declared Net Zero by 2050 and announced carbon reduction targets by 2030. Korea has also set a national GHG reduction target of 40% reduction in 2030 compared to 2018 (Joint Ministry of Environment, March 2023). Of the total national GHG emissions, GHGs from the transportation sector account for 13.5% (Ministry of Environment, Korea Greenhouse Gas Information Center, 2020).

As a means of carbon reduction, the Korean government is proposing transportation demand management as the first measure to curb the ever-increasing passenger vehicle traffic. The number of registered cars in Korea is expected to increase by about 5 million units to about 27 million in 2030 compared to the baseline year of 2018, and the government aims to supply 4.5 million electric and hydrogen vehicles by 2030, reduce the total mileage of cars by 4.5%, and reduce passenger car traffic by 15% by 2050 (Joint Ministry of Environment, 2021.10.18). To achieve this, measures such as promoting decarbonized personal transportation such as bicycles, strengthening congestion pricing, and expanding public transit-only zones are being proposed, but it is essential to think about smart mobility solutions.

The European Green Deal, announced in 2019, includes the development of a sustainable and smart mobility strategy. The Smart Mobility Strategy (2020.12) was categorized into two types of sustainable mobility systems and smart mobility systems, and five detailed strategies were prepared and announced. The sustainable mobility system focuses on promoting the introduction of transportation infrastructure for carbon-free transportation, while the smart mobility system focuses on promoting the use of MaaS, data, and AI as an important means of mobility.

As can be seen from the sustainable and smart mobility strategies, there are two main types of mobility solutions to respond to the climate crisis. The first is to create a comprehensive change in the energy sector to reduce carbon emissions, and the second is to reduce carbon emissions by minimizing travel through MaaS and promoting the use of data and AI.

The first is to make transport system more environment friendly. In particular, the widespread use of eco-friendly mobility vehicles such as electric and hydrogen vehicles is the most effective means of responding to the climate crisis, and it is being promoted as a government policy in both domestic and developing countries, including Europe. Most developed countries are aiming to fully transition to eco-friendly vehicles around 2035, and Korea has also set a target of 4.5 million electric and hydrogen vehicles by 2030 (16.7% of all vehicles), of which 500,000 business vehicles will be converted to zero-emission vehicles first. To this end, the government is focusing on maintaining purchase subsidies and laying the foundation for financial support to make eco-friendly vehicles more competitive in price. However, there are difficulties because a complete reorganization to go green presupposes a complete transformation of urban infrastructure. The spread of electric charging infrastructure is still not keeping up with the growth rate of electric vehicles, and the construction cost of a hydrogen charging station is up to 2.5 billion to 3 billion won, compared to about 50 million won to 100 million won for an electric charging station. The spread and expansion of infrastructure is perhaps the most urgent issue that needs to be addressed in relation to the complete reorganization of the mobility system itself to become more environmentally friendly.

Second, minimizing travel will be a way to optimize the distribution of transportation supply and demand based on information and communication technology. The intelligent transportation systemITS, is to improve the overall transportation efficiency, which can result in the saving of energy resources and the reduction of carbon emissions. From a driver's point of view, ITS can reduce unnecessary travel by providing the best route to a destination through navigation and other means. In recent years, real-time information on road conditions such as traffic accidents and traffic congestion has also been provided to help drivers streamline their routes. For example, if a driver is provided with real-time traffic information through a navigation system, he or she can know in advance which roads are congested, and if he or she can avoid the congested roads and use a detour to reach the destination faster, most drivers will choose to use the detour to reach the destination faster. This saves drivers time, but when you look at the overall road conditions, congestion can be cleared faster because fewer drivers are entering the congested roadway, and detours can be utilized more efficiently because drivers are using detours that were not being used.

In other words, it is possible to optimize the distribution of vehicles to reduce the use of busy roads and increase the use of less busy roads, thereby increasing the utilization of both busy and less busy roads.

This is because we can understand the real-time situation of the road through navigation. In recent years, not only information related to traveling, but also real-time status information related to parking has been provided, contributing to the reduction of congestion in urban centers as mentioned earlier. As AI and data technologies advance, traffic distribution will become more efficient, which will play a big role in reducing traffic congestion and carbon reduction. As mentioned earlier, service solutions like MaaS can help reduce the use of private cars by expanding people's transportation options. Travel optimization and convenience based on MaaS can reduce car traffic, solve traffic congestion and parking problems, and reduce carbon emissions.

Institutionalization and **infrastructure transformation for mobility adoption**

Even with autonomous vehicles equipped with the same advanced technology, some cities experience very rapid adoption while others experience very slow adoption.

This has a lot to do with the level of institutionalization and infrastructure in the urban area.

One of the biggest obstacles to the demonstration of advanced technologies in cities is the variety of regulations in cities. To address this, regulatory sandboxes are being actively adopted in Korea and abroad, which exempt new forms, new technologies, and new services from regulations for a period of time. Regulatory sandboxes were launched in the UK in 2016 to foster the fintech industry.

In the United States, Arizona introduced a regulatory sandbox for fintech in 2018 and is expanding and promoting it to Wyoming, Kentucky, and other states. In addition, various countries such as Japan and China are competitively promoting the introduction of regulatory sandboxes.

In Korea, regulatory sandboxes have been prepared and promoted by the Ministry of Trade, Industry and Energy, the Financial Services Commission, the Ministry of Science and ICT, the Ministry of Land, Infrastructure, and Transport, and the Ministry of SMEs since 2018.

The activation of the regulatory deferral system in cities has enabled various demonstration projects related to smart cities to be successfully promoted, and in particular, it has helped new items such as demand-responsive mobility and autonomous vehicles to quickly settle in cities. Regulatory deferrals such as regulatory sandboxes are essential for the rapid settlement of new innovative industries and solutions in cities, especially in the case of regulatory sandbox systems based on local innovation, which are often based on mobility. The Ministry of Land, Infrastructure, and Transport has approved a total of 51 smart city regulatory sandbox projects to date, and most of them are directly or indirectly related to mobility, such as demand-responsive mobility, autonomous driving service-related solutions, and drone-related solutions. In Japan, the regulatory sandbox is limited to autonomous driving and drones. Since most mobility means are related to human life, they are highly regulated. Naturally, there will be a difference in the introduction of smart mobility solutions between cities that implement a regulatory sandbox and those that do not.

The existence of infrastructure facilities that can accommodate new mobility solutions also greatly influences the adoption of new mobility solutions in a city. For example, the nation's first wide-area autonomous bus was able to travel a total of 32.2 kilometers from Sejong Express Bus Terminal through Osong Station to Banseok Station because there is a dedicated bus lane in the area that is uninterrupted and inaccessible to other vehicles.

It is easier to introduce mobility solutions in a region with infrastructure facilities that can easily accommodate new mobility methods. It is very important to secure the infrastructure facilities in the city that support new mobility solutions as well as their deployment and operation.

Platform-Based Mobility, **The Value of Data at a Glance**

It is estimated that if global automobile manufacturing revenue is KRW 250 trillion, the value of the data-driven mobility ecosystem is about KRW 700 trillion. It is also estimated that if the automobile manufacturing profit is 130 trillion won, the service revenue profit is estimated to be 2,100 trillion won, more than 10 times higher (Junsung Kim, 2020). The annual global data generation has increased by more than 20 times compared to 10 years ago and is expected to increase by more than 10 times again in the next 10 years.

Mobility big data includes vehicle navigation data related to vehicle movements, mobile data and credit card data related to human movements, and public transportation card data to understand the movements of public transportation users. This mobility big data will first of all enable real-time understanding of the demand for mobility services and the available supply, and will be essential for providing solutions in a way that optimizes demand and supply. Both the aforementioned shift to a consumer perspective and minimizing travel in response to the climate crisis are goals that can be achieved through real-time data to optimize demand and supply.

As the period of operation of various urban mobility demonstration projects increases, more real-time data is continuously accumulated, which can be used for more efficient mobility-related operation planning and necessary infrastructure planning by enabling prediction of mobility usage in specific areas and at specific times.

Mobility big data is the most fundamental element for building an efficient mobility system because it enables optimal distribution of supply and demand in real time, and even spatial and temporal predictions of mobility demand, and these mobility big data can be operationalized when they are interconnected under a platform.

Looking to the future **of mobility**

We are in the midst of a major transformation of mobility, which hasn't changed much in more than 100 years. While mobility has been approached only in a way to increase the speed of transportation, various methods of optimally distributing supply and demand in real time are now being introduced, and a breakthrough in energy is also being made to completely revamp carbon-emitting mobility.

As AI and autonomous vehicles continue to advance, the future of mobility will be even more platform-oriented and based on real-time data. In the era of autonomous vehicles that no longer require human intervention, autonomous platforms will be able to analyze the entire traffic volume through AI and specify the best route for each individual vehicle to take to reach its destination, which in turn will allow for optimal management of the entire traffic volume in the city by specifying the best traffic routes for individual vehicles. In addition to this, it will be possible to reduce the surplus of vehicles in the city by ensuring that the number of vehicles available matches the demand within the city.

In the future, if we can easily summon the nearest autonomous vehicle in real time when we need to move, the need for personal vehicles will be eliminated, and the inefficient urban infrastructure that comes with owning a personal vehicle, such as parking lots for storing cars, will be reduced, and the proportion of roads in the city will decrease, as the overall traffic can be optimally managed and road efficiency will increase.

The arrival of autonomous vehicles and the rise of AI-powered urban traffic analytics platforms will greatly improve the convenience of individual vehicles and optimize traffic flow from a city-wide perspective, while significantly reducing unnecessary resources and reducing carbon emissions.

There is still a long way to go, we believe that the ongoing integration of the individual technological advancements in smart mobility will enable us to achieve the goals of improving the convenience of citizens, optimizing the distribution of resources in cities, and reducing carbon emissions.

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The Role of Autonomous Vehicles in Completing Smart Cities

스마트시티 완성을 위한 자율주행자동차의 역할

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ABSTRACT

Mobility innovation is one of the critical factors in the success of creating smart cities, and autonomous driving is at the center of it. Without a significant improvement in the satisfaction with the transportation system (especially the acceptance of accidents related to safety), the public would not feel the city is smart enough. Currently, Advanced Driver Assistance Systems (ADAS), which are now commonplace, have made a significant contribution to reducing the damage of traffic accidents, but given that there is still a risk of driver malfunction or misuse of the technology, the introduction of autonomous driving technology is necessary for ultimate traffic safety. In this article, we will look at how related policies and laws (safety standards) are being prepared to secure the safety of autonomous vehicles and promote their services as a prerequisite for the introduction of smart cities.

KEYWORDS

Mobility Services, Cybersecurity, Autonomous Vehicle Safety Policies and Systems, Autonomous Vehicle Pilot Operation Zone, Autonomous Vehicle Performance Certification System

초록

스마트시티 구현에 있어서 모빌리티 혁신은 중요한 성공 요인이고 그 중심에 자율주행이 있다 해도 과언이 아니다. 무엇보다도 교통시스템에 대한 만족도(특히, 안전사고와 관련된 수용성)를 획기적으로 개선하지 않는다면 스마트시티에 대한 체감도는 낮을 수밖에 없을 것이다. 현재 보편화된 첨단 운전자지원장치*Advanced Driver Assistance System*는 사고피해 저감에 적지 않은 기여를 하고 있지만, 운전자의 오작동 또는 기술의 오남용으로 인한 위험성은 여전히 존재한다는 것을 감안하면 궁극적인 교통안전을 위해서는 자율주행 기술의 도입이 필요하다. 본 고에서는 스마트시티 도입을 위한 선결과제로서, 자율주행자동차의 안전성을 확보하고 서비스를 촉진하기 위한 관련 정책과 법규(안전기준)가 어떻게 준비되고 있는지 살펴보고자 한다.

키워드

모빌리티 서비스, 사이버보안, 자율주행자동차 안전 정책과 제도, 자율주행자동차 시범운행지구, 자율주행자동차 성능인증제도

Autonomous driving as a key **to future mobility**

Smart future Mobility

Smart (future) mobility is not only used to improve the efficiency and sustainability of cities and the quality of life of citizens as a key means to realize smart cities, but it is also a very important factor to create a transportation system innovation through data-driven transportation efficiency beyond the scope of transportation.

Smart mobility typically requires Internet of ThingsIoT, Intelligent Transportation SystemsITS, real-time data analytics, artificial intelligenceAI, data communications, and cloud/edge computing technologies and their integration and management, many of which have many similarities to autonomous driving technologies that are already being implemented.

Autonomous Driving

Autonomous driving technology is categorized into six levels, ranging from Level 0 to Level 5, with Level 3 and above considered to be the practical level of autonomous driving. Level 3 autonomous driving technology, by definition, requires a driver's response (precisely, when the system is outside the designed driving range or is no longer operational) and is currently being commercialized on a highway basis due to practical and technical limitations. Therefore, from the perspective of smart city and technology combination, the realization of smart mobility through networking with infrastructure data is closer to level 4 or higher autonomous driving.

So, what is the role of autonomous driving in enabling smart mobility?

Currently, it is still possible to implement the concept of smart mobility by C-ITSCooperative Intelligent Transport System and DASDriver Assistance System, and it is known that shared mobility by ordinary cars was already introduced in the early 2010s and contributed to the reduction of traffic in cities to some extent.

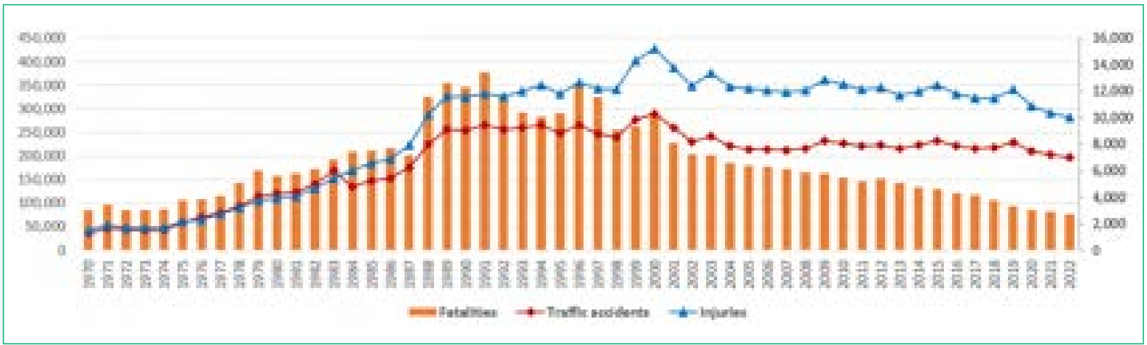
Furthermore, when autonomous driving is introduced, based on the technological core of real-time data analysis, judgment, and control by AI, traffic efficiency can be maximized by order and cooperation among vehicles operating within the boundaries of law, and dramatic improvements in traffic efficiency can be expected in terms of time and space utilization, such as shared services and autonomous parking. In addition, it has the absolute advantage of securing traffic safety by eliminating driver factors that account for more than 90% of accidents.

Autonomous Driving Enabling Accident Zero Smart Cities

Europe's "Vision Zero" policy, which started in Sweden in 1997 and is now spreading across Europe, aims to reduce the number of traffic fatalities and serious injuries by 50% by 2030 and eliminate traffic fatalities completely by 2050. Other countries such as the United States, Australia, Japan, and Canada are promoting similar traffic safety policies, and Korea is also implementing policies and campaigns to reduce traffic accidents at both national level (Ministry of Land, Infrastructure, and Transport) and local

Figure 1

Traffic Accident Status (Korea)



level such as Incheon City and Sejong City.

Korea's traffic accident statistics show that the number of vehicle registrations has increased more than 10 times from 2 million in the 1980s to 24 million in 2022, and the number of traffic accidents has not decreased in any meaningful way, even though the number of fatalities has decreased steadily (5,500 in 2010 → 2,700 in 2022).

The decrease in the number of fatalities can be attributed to the introduction of various advanced driver assistance systemsADAS by traffic safety policies since the 2000s. However, as the recent accident trends show, it is difficult to dramatically reduce the number of traffic accidents by using advanced driver assistance systems that require driver intervention alone, as 90% of accidents are caused by human error. For this reason, the introduction of autonomous vehicles is necessary to ultimately complete a smart city without traffic accidents.

Challenges of **autonomous driving**

The commercialization of autonomous vehicles is a prerequisite for the successful implementation of smart mobility. There are many technical issues, such as safety assessment and data communications. as well as social consensus and policy decisions that need to be addressed.

Standardized Smart Infrastructure

First of all, the implementation of widespread data-driven mobility requires cooperation with infrastructure, and it is necessary to improve and standardize the existing physical infrastructure (road geometry, pavement, shape, transportation facilities, etc.) and digital infrastructure (positioning, communication, precision maps, traffic information, communication etc.) to facilitate the implementation of autonomous driving technology. To this end, efforts are underway to define and standardize infrastructure support levels for automated driving ('Road Infrastructure Support Levels for Automated Driving', 25th ITS World Congress, Copenhagen, 2018), but in reality, infrastructure is dependent on road traffic conditions and operated by each country, so it is more difficult to standardize it by international consensus than in the automotive sector.

Privacy and data security

The implementation of smart mobility means having control over traffic conditions through large-scale data, and for this, it is important to secure a safe and reliable data management system. In particular, in the case of autonomous driving, location information, travel routes, surrounding vehicle and pedestrian information, etc. must be collected, processed, analyzed, and utilized in real time by the on-board system of the vehicle, and privacy and data security issues become very important issues in this process.

Although institutional barriers continue to be lowered, such as the recent revision of the Personal Information Protection Act (2022), which allows the collection of surrounding traffic information from mobile video processing devices, there is always the fundamental possibility that the collected information will be combined with other information and may infringe on a person's privacy, so it is not easy to derive an "adequate" level of privacy protection for all of them, and especially in a networked environment, it is more likely to be exposed to security threats such as hacking.

In response, the United Nations Economic Commission for EuropeUNECE derived international standards to prepare for cybersecurity in 2020, and Korea has amended a related law (Motor Vehicle Management Act), which is scheduled to be enforced in August 2025. However, if the vehicle control system is maliciously manipulated due to hacking, it can cause large-scale traffic disruptions and even serious human casualties, so it is necessary to apply strong encryption technology to autonomous driving systems and strengthen network security protocols.

Social and ethical guidelines

Unlike human drivers, autonomous systems sometimes have difficulty deciding how to behave in certain situations that require clear and rapid decision-making. This includes situations where obeying the law can seriously impair traffic efficiency, or when the roadway is occupied by parked cars in front of the vehicle on a one-way street, or when an accident is inevitable and a decision must be made whether to prioritize the safety of passengers or pedestrians (the Trolley Dilemma).

At a minimum, there should be some guidance on what decisions autonomous driving algorithms should make in these socio-ethical dilemmas. Even if there is no right answer, there needs to be an ongoing discussion about how decision-making algorithms in autonomous vehicles will reflect social consensus and ethical standards, and if there is no social consensus or different standards in different countries, the adoption of autonomous technology will be more difficult.

Social inequality and access to technology

Smart cities and autonomous driving technologies are revolutionary in their own right, but their benefits may not be equitably distributed across all social classes. In London, for example, a study found that autonomous ride-sharing services were concentrated in wealthier neighborhoods and did not improve access to transportation in poorer areas ("The Opportunity of Shared Autonomous Vehicles to Improve Spatial Equity in Accessibility," European

Transport Research Review, 2023). This is a problem in the early stages of technology adoption, and the high cost of autonomous vehicles may be a factor in driving this inequality.

According to a World Bank report ("From Gridlock to Green Transport: Supporting Electric Mobility to Meet the Demand for Passenger Transport", World Bank Report, 2024), the initial investment for owning an autonomous vehicle is more than 50% higher than for a conventional vehicle. This means that access to public technologies may not be equitably available depending on income level, so governments and companies will need to work together to support the diffusion of the technology and its integration into public transportation systems if they want to realize the public benefits of autonomous driving.

Preparing society for smart mobility

In addition, many legal and institutional preparations are required for autonomous driving technology to be introduced into everyday life, and Korea is taking steps to support the development of autonomous driving technology and services through various policies. In addition, citizens' awareness and education are necessary for autonomous vehicles to become part of everyday life, and resolving anxiety and misunderstandings about innovative technologies and having a firm perception of their utility will contribute to increasing social acceptance.

Autonomous vehicle safety policies **and systems**

The primary gateway to the successful adoption of autonomous vehicles is safety. According to the results of a consumer survey on the safety of autonomous vehicles ("2020 Global Automotive Consumer Study: Is consumer interest in advanced vehicle technology warning?", Deloitte Insights, 2020), Koreans and Japanese are less confident in the safety of autonomous vehicles compared to the US (42%) and Europe (50-55%). As a result, the UN and governments are actively promoting policies to ensure the safety of autonomous vehicles and expand the use of autonomous vehicle services, and the main points are as follows

Domestic policy trends

In 2015, Korea amended the Motor Vehicle Management Act to establish a legal definition of autonomous vehicles and actively promote policies to support autonomous vehicle technology development. In February 2016, the "Temporary Operation Permit System for Autonomous Vehicles" was implemented to allow the operation of autonomous vehicles on public roads for technology development, and in April 2019, the Act on the Promotion of and Support for Commercialization of Autonomous Vehicles was enacted to allow paid passenger and cargo transportation services using autonomous vehicles. In addition, in December 2019, the safety standards for Level 3 autonomous vehicles were established to meet international standards, and from 2025, the "Autonomous Vehicle Performance Certification System" will be implemented to allow inter-company transactions of Level 4 autonomous vehicles.

① Temporary Operating Permits

Data collection and learning through public road operation is essential for the development of autonomous vehicle technology. Since February 2016, the Ministry of Land, Infrastructure, and TransportMOLIT has implemented a temporary operation permit system for autonomous vehicles for testing and research, allowing them to operate on public roads for up to five years

Figure 2

Classification of autonomous vehicles by type

if minimum safety requirements are met. Considering that it was previously impossible for autonomous vehicles to operate on public roads, the implementation of the temporary operation permit system became an opportunity to promote the development of autonomous vehicle technology in Korea and became the starting point for autonomous vehicles to be recognized within the legal system. Since then, 442 autonomous vehicles (as of August 2024) of 65 organizations have obtained licenses and are currently in operation, and the technologies applied to mobility are diversifying, including driverless shuttles (B-type autonomous vehicles) and autonomous vehicles without human passengers (C-type autonomous vehicles). (Kyung Chan Min, Autonomous Vehicle Convergence Future Forum Issue Brief, 2023)

② Autonomous Vehicle Pilot Operation Zone

There are some difficulties in applying existing automobile safety standards to autonomous vehicles. Items designed with the driver in mind, such as field of vision, rearview mirror, and braking system performance, are a few examples. Therefore, the emergence of new forms of mobility requires revisions to the existing legal system, such as NURO, a representative unmanned delivery vehicle in the United States, which took about 18 months to receive an exemption from the driver-related items of the Federal Motor Vehicle Safety StandardsFMVSS. In response, the Ministry of Land, Infrastructure, and TransportMOLIT enacted the Act on the Promotion of and Support for Commercialization of Autonomous Vehicles in

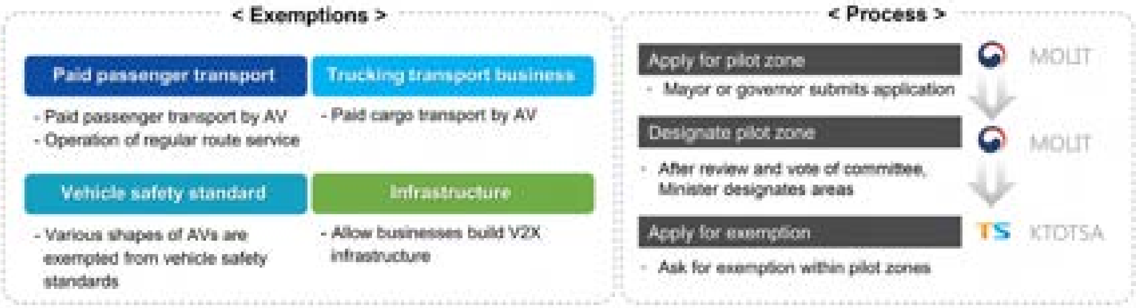


Figure 3
Overview of the autonomous vehicle pilot operation zone

2019 to develop various types of autonomous vehicles and expand the application of new mobility concepts. This has enabled the development of various types of autonomous vehicles by exempting some of the automobile safety standards in areas designated as "autonomous vehicle pilot operation zones," and laid the foundation for a mobility ecosystem in which developed technologies are connected to transportation services. Currently, 36 (as of December 2023) pilot zones have been designated in 17 local governments nationwide, providing a variety of autonomous mobility services.

③ Autonomous Vehicle Safety Regulations

In order to freely utilize autonomous vehicles for the purpose of operation rather than temporary operation, it is necessary to register the vehicle, which must be manufactured in accordance with the Rules on Performance and Standards for Motor Vehicles and their Components. Such a system is similarly applied in most countries and is the most basic element for the application of autonomous driving technology.

Korea has established Level 3 autonomous vehicle safety standards (December 2019), laying the institutional foundation for the era of autonomous vehicles, and is continuously maintaining related standards in line with the development level of autonomous vehicle technology and changes in international standards (UNECE Regulations).

	Level 3 autonomous vehicle safety standards		Remarks
	Current	Revisions	
Applicable Vehicles	Passenger cars	Passenger cars, buses, and trucks	Same with international regulations
Operating Speed	Follow the speed limit	Follow the speed limit* * 60 km/h limit when MRM lane change is not available	
Features	Keep in Lane	Lane keeping and lane change* * Passenger vehicles and trucks weighing 3.5 tons or less	

Table 1

Level 3 autonomous vehicle safety standard status

Meanwhile, international standards for Level 4 autonomous vehicles are expected to be established after 2027. Accordingly, a separate certification system (Performance Certification System, amendment to the Act on the Promotion of and Support for Commercialization of Autonomous Vehicles) has been established to allow the sales of Level 4 autonomous vehicles (business-to-business transactions) to promote technology development and create a related industrial ecosystem, and is expected to be implemented in 2025.

International policy trends

Governments have established and implemented various policies to secure the safety of autonomous vehicles and expand their distribution. The UN has launched various expert technical groups to establish international safety standards for Level 4 autonomous vehicles, and the EU and Germany respectively have established and are operating their own systems for Level 4 autonomous vehicles, similar to Korea's Performance Certification System.

① United Nations

The UN World Forum for the Harmonization of Vehicle regulations (also

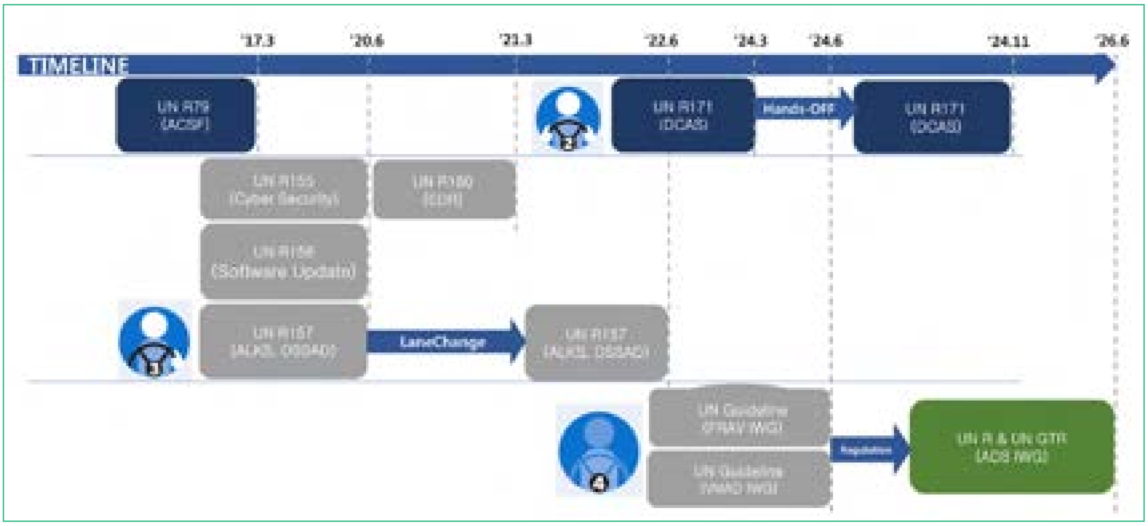


Figure 4

International standard adoption schedule

known as WP.29) launched the Working Party on Automated/Autonomous and Connected VehiclesGRVA in September 2018 to respond to technological changes. In addition, the Working Party has established sub-expert groups for driving safety, cybersecurity, and data storage for autonomous vehicles, and is working to establish international standards for Level 4 autonomous vehicles.

② European Union

In August 2022, the European Union enacted a type approval regulation for Level 4 autonomous vehicles. It aims to apply uniform procedures and technical regulations for type approval in each country in the EU and stipulates the scope of application, technical requirements, and administrative regulations for type approval of autonomous vehicles. This regulation is significant in that it provides manufacturers with goals for the development of autonomous vehicle technology and provides a unified Level 4 autonomous vehicle certification process within the EU member states. (EU 2018/858, 2022)

Korea's Mobility Innovation Roadmap(2022)

The implementation of smart cities varies from country to country. However, the common concept of smart cities can be summarized as using Information and Communications TechnologyICT to efficiently use limited resources and infrastructure to solve urban problems caused by high population density and transport related social exclusion. In particular, the biggest problems in most of the large cities are the damage to life and property caused by traffic accidents and the increasing social costs of traffic congestion and energy problems. Accordingly, many countries have classified smart transportation as a core element of smart cities and have established various policies (Smart City, Hwang Gunwook, 2018). The Korean government (Ministry of Land, Infrastructure, and Transport) also announced the "Mobility Innovation Roadmap" in 2022, the main contents of which are as follows.

Proliferation of ondemand mobility services

Combined with smart transportation infrastructure, autonomous vehicles can transform transportation services by utilizing real-time data. Through the convergence of existing transportation systems and ICT, it is possible to provide demand-driven transportation services, eliminating time and place restrictions and dramatically changing the transportation system. This means a change from a transportation system that operates according to a fixed time and route to a customized transportation service that can change in real time and meet consumer needs. The K-MaaSMobility as a Service project will integrate autonomous vehicles and AI-based mobility data to link various transportation methods and information, guide the optimal route on a single platform, and integrate reservations and payments to dramatically improve consumer mobility convenience.

Provide a safe transportation environment

Autonomous vehicles can be the most reliable way to realize zero traffic accidents as well as convenience of transportation. For this, the safety of autonomous vehicles must be secured first, and the United Nations is considering various measures to do so, and is focusing on securing safety by establishing a software verification system for the safety of autonomous driving functions as well as a verification evaluation of the risks that may occur during operation in the actual driving environment. In addition, a reporting system between the government and manufacturers is being established to verify risks that may occur during driving. These safety management measures will help ensure the safety of autonomous vehicles with enhanced safety management policies compared to conventional cars, and will be a driving force for autonomous vehicles to grow as a pillar of safe mobility.

Convergence of mobility and cities

The integration of various transportation infrastructure and mobility functions, such as traffic lights, parking lots, and public transportation systems, will enhance the completeness of smart cities. Demand-responsive transportation systems will guarantee the right to travel fast and safe, and optimal route prediction and unmanned delivery systems using AI will lead to logistics innovation, creating a new industrial ecosystem in the city. To this end, the government will create specialized cities for the demonstration of new mobility services such as autonomous vehicles and drones, and these efforts will ultimately lead to the success of smart cities.

SMART CITY

TOP

AGENDA

2024

Advanced Air Mobility in Smart Cities

스마트시티의 미래항공모빌리티

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ABSTRACT

This article discusses the impact that the introduction of future air mobility, including urban air mobility*UAM* and drones, will have on cities and transportation systems in the context of smart cities. UAM is gaining attention as an innovative mode of transportation that can sustainably alleviate urban congestion by utilizing eco-friendly, electric-powered vertical take-off and landing aircraft. Meanwhile, drones have the potential to enhance last-mile logistics, maximizing delivery efficiency. For these technologies to be successfully introduced, legal and institutional improvements, as well as safety validation, must be prioritized. Additionally, the necessary infrastructure—such as vertiports integrated with ground transportation at key points in city centers and automated collection facilities for drone logistics—must be developed. In the long term, integrating future air mobility into urban design from the city planning stage will enhance the transportation efficiency of smart cities and, in turn, improve the quality of life for urban residents.

KEYWORDS

Advanced Air Mobility, Smart City, Urban Air Mobility, Drone, Vertiport

초록

본 글은 스마트시티에서 도심항공교통*Urban Air Mobility: UAM*과 드론을 포함한 미래항공모빌리티의 도입이 도시와 교통체계에 미칠 영향을 분석한다. UAM은 친환경 전기동력 수직이착륙기를 활용해 도심 내 교통혼잡 문제를 지속 가능하게 해결할 수 있는 혁신적 교통수단으로 주목받고 있으며, 드론은 물류의 라스트 마일 문제를 개선해 배송 효율성을 극대화할 수 있다. 이러한 기술이 성공적으로 도입되기 위해서는 법적 · 제도적 개선뿐만 아니라 안전성 검증이 우선되어야 하며, 도심 내 주요 지점에 지상교통과 연계된 버티포트*vertiport* 설치와 드론 물류를 위한 자동화된 집하시설 등 필수 인프라 구축이 뒷받침되어야 한다. 장기적으로는 도시 계획 단계에서부터 미래항공모빌리티를 염두에 둔 통합적 도시 설계를 통해 스마트시티의 교통 효율성을 높이고, 나아가 도시민의 삶의 질을 향상시키는 데 기여할 수 있을 것이다.

키워드

미래항공모빌리티, 스마트시티, 도심항공교통, 드론, 버티포트

Introduction

According to the Standard Korean Language Dictionary of the National Institute of Korean Language, transportation is defined as the movement of people or goods by cars, trains, ships, or airplanes. Similarly, the Cambridge Dictionary defines transportation as the movement of people or goods from one place to another. That is, transportation involves the movement of people and goods, and its path can be categorized into land, sea, and air routes. While transportation encompasses various modes, this article focuses on air transportation. Air transportation, unlike ground transportation, is not a commonly used mode of transportation in daily life. Aircraft, air transport vehicles, typically require a long runway and generate significant noise during takeoff and landing. As a result, air transportation is generally confined to a specific place (i.e., an airport), and most major airports in the world are located far from city centers. Therefore, air transportation is primarily used for long-distance travel, which would be time-consuming via ground transportation. However, recent advances in electric motor and battery technologies are expanding the applications and usage of air transportation. In the near future, it is expected that air transportation will become more integrated with ground transportation, bringing it closer to the daily life of citizens. This article explores the anticipated changes that Advanced Air MobilityAAM will bring to the movement of people and goods in smart cities.

Urban Air Mobility in Smart Cities – **Vertiports as a Multimodal Hub**

In a bustling metropolis like Seoul, Republic of Korea, ground transportation is frequently congested, leading to increased travel time and costs. According to the 2021 Traffic Congestion Cost Estimates released by the Korea Transport Institute, the cost of congestion in Seoul is estimated at KRW 14.6 trillion, and KRW 65 trillion nationwide, amounting to about 3% of Korea's GDP (Cheon, 2023). To alleviate such ground congestion, efforts to utilize the city's airspace are materializing in the form of Urban Air MobilityUAM. The Korean UAM Concept of Operations version 1.0 defines UAM as a new air transportation system that employs eco-friendly electric vertical takeoff and landingeVTOL aircraft, capable of operating in urban areas. UAM is expected to be integrated with other modes of transportation to move passengers or cargo efficiently within urban areas.

Since 2018, NASA has been conducting a National Campaign to demonstrate the safe and integrated operations of new aircraft like eVTOLs in the national airspace. In 2023, Korea also launched the first phase of the K-UAM Grand Challenge to validate the safety of UAM operations. Europe, too, is in the process of revolutionizing its urban transportation system through Innovative Air MobilityIAM. Both the AAM and IAM concepts include not only UAM but also small drones for cargo delivery. However, this article will first focus on the future city shaped by UAM for passenger transportation.

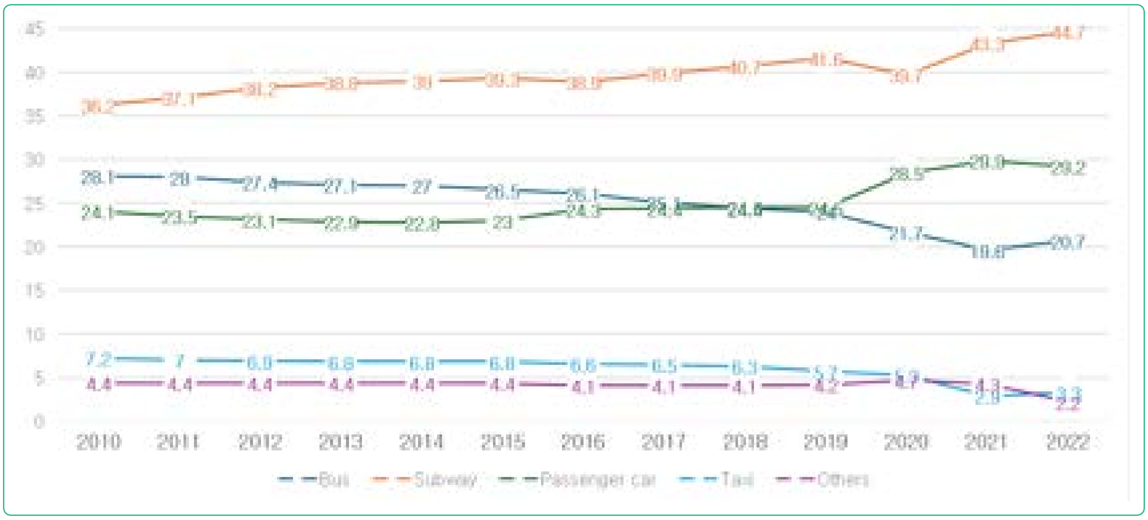
The most common type of aircraft considered for UAM services is eVTOL aircraft. Since eVTOL aircraft use electric motors instead of jet engines that burn aviation fuel, they are significantly more environmentally friendly and quieter. Additionally, their distributed propulsion system, which uses multiple motors to generate lift and thrust, increases the safety of UAM operations. Unlike conventional fixed-wing aircraft, eVTOLs can take off and land vertically, eliminating the need for large runways and allowing them to operate in relatively small (and limited) urban areas. As a result, vertiports can be constructed even in dense city centers, dramatically improving the accessibility and frequency of air transportation while helping to reduce ground congestion.

Before the introduction of eVTOLs, air transportation services using helicopters to connect city centers to their outskirts could be considered an early form of UAM. However, helicopters are noisy and expensive to operate, limiting such services to high-income customers in a few cities like New York City. In contrast, UAM aims to offer affordable fares. According to Korea's UAM technology roadmap, the projected fare is KRW 1,300 per person per kilometer by 2035 when the UAM service is fully mature. For example, the straight-line distance from Gangnam Station to Incheon International Airport Terminal 1 is approximately 51 kilometers. Assuming

Figure 1

mode share in Seoul

Source: Seoul Metropolitan City 2024



UAM detours about 20% of the distance to consider takeoff and landing routes and airspace availability, the one-way fare would be around KRW 80,000 per passenger, which is similar to the current taxi fare for the same route.

The figure 1 shows the mode share of buses, subways, passenger cars, and taxis in Seoul from 2010 to 2022 (Seoul, 2024). While the taxi mode share decreased somewhat after 2021, taxis still accounted for about 6% of trips in Seoul. Travel cost and time are the key factors influencing mode share, and UAM can significantly reduce travel times compared to ground transportation. Therefore, if UAM fares are competitive with taxi fares, it is likely that UAM will capture a larger mode share than taxis where they are available.

However, UAM can only take off and land at designated locations (i.e., vertiports), limiting their accessibility compared to taxis. While eVTOL aircraft, which will be primarily used for UAM, are capable of vertical takeoff and landing, they cannot do so just anywhere. In 2022, the U.S. Federal Aviation AdministrationFAA released Engineering Brief No. 105 on Vertiport Design. It states that vertiports must have multiple clear departure and arrival paths, similar to a traditional heliport. The European Aviation Safety AgencyEASA has proposed slightly more flexible requirements for departure and arrival paths, as shown in the figure 2 (EASA, 2022). Even with these more lenient European standards, UAM is still restricted to taking off and landing only at vertiports.

Therefore, to make UAM more accessible in future cities, vertiports will need to be strategically located at key points within the city, and these vertiports must be seamlessly connected to ground transportation. In other words, like traditional air transportation, UAM cannot function as a standalone mode of transportation; it must be integrated into a broader Mobility as a ServiceMaaS system. The concept of UAM as part of MaaS can be

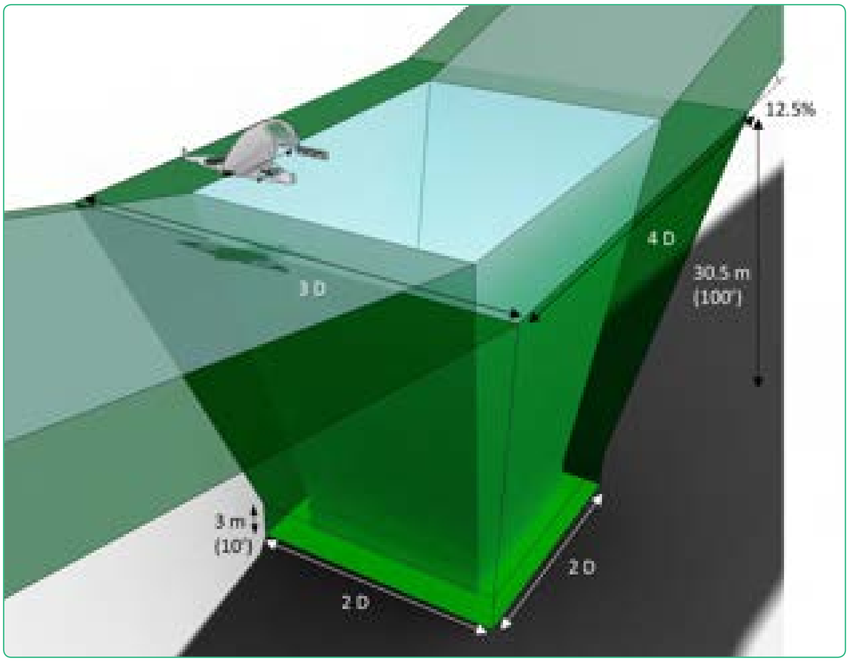


Figure 2
Vertiport Take-off and Landing Reference Volume

Source: EASA, 2022

traced back to a presentation by Uber Elevate in 2019, one of the early pioneers in the UAM market. The figure 3 illustrates Uber Elevate's business model, where passengers arrive at a vertiport via personal mobility or ground transportation to board a UAM for their journey. MaaS providers offer a comprehensive travel solution, connecting the first, middle, and last legs of a passenger's trip within their services, enabling efficient movement from origin to destination.

To effectively utilize new transportation modes like UAM to ease traffic in and around cities—and to leverage the associated time and cost savings to improve urban life—MaaS systems, including UAM, must be integrated with city design, structure, and operations. As mentioned earlier, UAM can only operate at vertiports, so it's crucial to locate vertiports in optimal locations around cities. The "optimal" location should consider not only the individual vertiport's operation but also the performance of the entire vertiport network. Since UAM must be integrated with ground transportation, they need to complement each other. Each vertiport has a catchment area, which is the maximum distance within which it can effectively serve passengers. Ground transportation's structure and operational characteristics will determine the actual catchment area of each vertiport. A previous study on optimal vertiport locations in the Seoul metropolitan area shows that UAM traffic volume and mode share vary depending on the size of vertiport catchment area (Kim et al., 2024). Moreover, even the same vertiport may have different "practical" catchment areas depending on ground transportation situations. For example, during peak traffic congestion, passengers might be willing to travel farther to reach a vertiport because UAM can move long distances quickly. Conversely, when ground traffic flows smoothly, it may be more efficient for passengers to use ground transportation instead of traveling to a vertiport to board a UAM. Therefore, to maximize the effectiveness of UAM in urban areas, real-time updates on overall traffic conditions and transportation demand in urban areas are essential.

Additionally, when designing central business districts and large residential areas, vertiports should be included in the city plan as multimodal

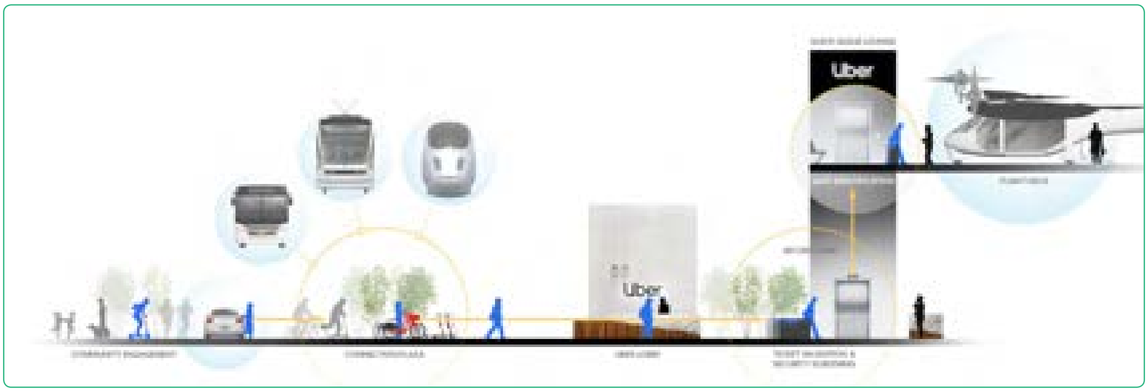


Figure 3

Uber Elevate's Conceptualization of UAM within MaaS Framework

Source: Uber Elevate, 2019

hubs that serve as central points for both UAM and ground transportation. Although much smaller than airports, vertiports still require adequate space and must be large enough to accommodate various connecting modes of ground transportation. Also, the placement of tall buildings should not obstruct UAM takeoff and landing paths, making it important to incorporate vertiport design into urban planning early on.

Air Logistics in Smart Cities – **A Last-Meter Challenge for Drone Delivery**

In addition to passenger transportation, UAM can also be used for logistics. Most UAM aircraft currently in development are designed to carry between two and four passengers or a similar amount of cargo. Meanwhile, both the AAM and IAM concepts include small cargo delivery by drones, which are much smaller than UAM aircraft. Korea's Drone Industry Master Plan has also identified drone delivery services as a major application area of drones.

Amazon, the global logistics giant, is piloting a drone delivery service called Amazon Prime Air, while Korea is also advancing the commercialization of drone delivery through its Drone Demonstration City project. Drones are expected to play a crucial role in the logistics process, particularly in the 'last mile' of delivering goods to the end consumer. According to Samsung Securities(figure 4), more than half of all logistics costs are incurred during this last mile (Samsung Securities, 2020).

A major reason for the high cost of last-mile delivery is the difficulty of achieving economies of scale. Large airlines and logistics companies typically use a Hub-and-Spoke network, as shown in the figure 5. This net-

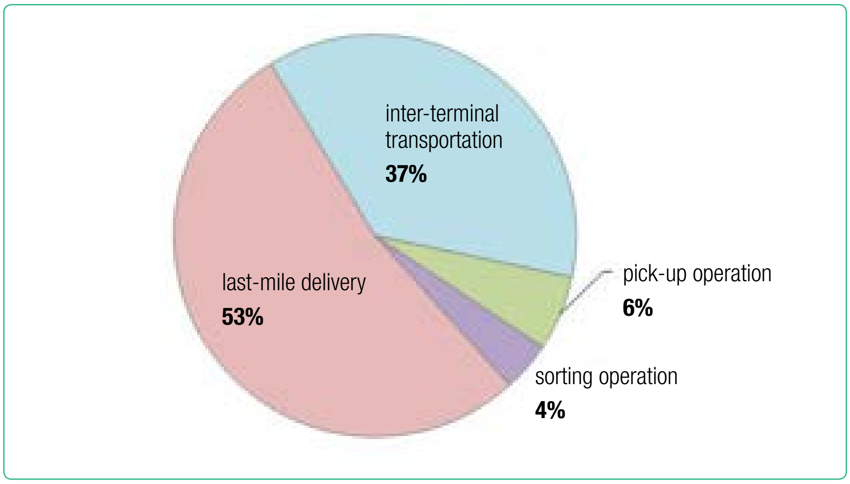


Figure 4

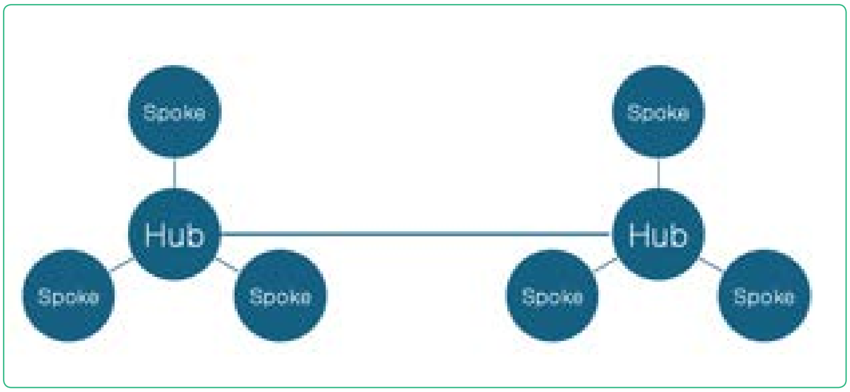
Costs composition by logistics step

Source: Samsung Securities, 2020

work structure allows them to connect all locations with fewer routes compared to a Point-to-Point network, which directly connects each location. As a result, transportation between hub airports or cargo terminals can be efficiently managed using high-capacity vehicles such as large aircraft or trucks. In contrast, end consumers are dispersed across various locations, and the number of shipments per destination is relatively small, making the logistics journey longer and more complex. FedEx, a global logistics company, has identified three key challenges to last-mile delivery.

1. Customers expect fast delivery times
2. High cost of last mile delivery
3. Increasing demands of special shipping services

Using drones for last-mile delivery enables multiple simultaneous deliveries by relatively inexpensive units, providing faster service to more customers. However, drone delivery has a significant limitation: drones are small and cannot fly long distances, making them effective only for delivering small, lightweight items over short distances. While adding fixed



Source: Sang hyun Kim

Figure 5

Hub-and-Spoke Network

wings can increase payload capacity and extend flight range, the small size of drones remains a fundamental constraint.

Another challenge arises when considering drone delivery in urban areas. While drones may increase the efficiency of last-mile logistics, they introduce a unique problem that traditional logistics processes do not face: how to deliver goods directly to the end consumer, which is called a last-meter challenge. McKinsey & Company, a global consulting firm, identifies this last-meter challenge as a critical hurdle for making drone delivery a reality (Cornell, Miller, & Riedel, 2023). Even if the physical limitations of payload capacity and flight distance are overcome, the method for safely delivering goods to the end consumer is not fully developed. For instance, Amazon has demonstrated placing a specific marker on the ground for drones to drop packages, as shown in the figure 6. However, in a country like Korea, where the majority of the population lives in high-rise condos, this method would require special facilities on top of residential buildings.

Therefore, to enable drone delivery in large cities in Korea, drone delivery collection facilities will need to be installed on the rooftops of major buildings. While only basic collection facilities may be installed on existing buildings, newly planned smart cities should incorporate a comprehen-

Figure 6

Amazon's
Drone Delivery Marker

Source: amazon

sive system that automatically identifies items delivered by drones, transfers them to individualized storage spaces (e.g., unmanned delivery boxes), and alerts recipients. In other words, a system that is seamlessly integrated into the smart city infrastructure is essential for drone delivery to become a reality.

Closing Thoughts – **Challenges for Air Mobility in Future Cities**

Advances in various technologies will fundamentally reshape the structure of future cities and the daily lives of their citizens. In particular, advancements in aviation technology have the potential to extend three-dimensional travel, currently available only in limited areas, to much larger spaces. These changes will not only reduce traffic congestion and increase travel efficiency but also enable more efficient use of urban space. However, several preparations and issues must be addressed before this can be realized. The most urgent and critical issue is the legal and institutional framework. For new air transportation modes, such as advanced air mobility, to become commercially viable, safety must be ensured, requiring updates to relevant laws and regulations. Various legal concerns—including safety regulations, flight rules, and vertiport requirements in urban areas—must be resolved before UAM and drone services can operate safely in cities. In particular, regulations related to unmanned aircraft and automatic/autonomous flight must be developed alongside technological advancements.

In this article, we have discussed the necessary steps to ensure the successful integration of new air transportation modes, such as UAM and drones, into smart cities, provided that the underlying technologies are thoroughly tested and deemed safe. As previously mentioned, these new technologies cannot function independently but require support from relevant infrastructure. Vertiports, drone delivery depots, and integration into existing transportation systems are crucial. Moreover, designing future cities involves not only addressing current issues but also planning for future transportation and infrastructure needs. Flexible designs that accommodate the growth and evolution of cities, infrastructure development for the seamless operation of UAM and drones, and the introduction of intelligent transportation systems that facilitate easy access to these new modes of transportation are essential. Urban planners and policymakers must anticipate these changes and envision future smart cities where technology and urban infrastructure are closely interconnected.

Ultimately, future air mobility will enhance convenience and efficiency in our daily lives in cities and play a key role in building sustainable urban environments. For these technological innovations to succeed, we must begin preparing now, and this can only be achieved through convergence with smart cities.

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SMART CITY TOP AGENDA 2024

CHAPTER 04

Smartcity and Citizen' life

Power to the people and districts as laboratories:

Urban innovation pattern language [uiPL] as performance-based approach for future-proof cities

시민에게 권한을, 지역을 실험실로:
미래가 보장된 도시를 위한 성과 기반 접근법으로서의
도시 혁신 패턴 언어

Steffen Braun

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ABSTRACT

With ongoing urbanization to a projected 9 billion people in cities by the end of the century, the existing global urban system, including all underlying infrastructure, is expected to double in size - within today's unsustainable paradigms. Technological progress in urban systems as predominant habitats and economic domains of our global society has become highly relevant in our time. Although the emergence and diffusion of technical innovations have played an increasing role in the urban system since early industrialization, there are still hardly practical approaches that enable a systematic handling or a strategic foresight of future technological potentials. The paper pursues the systematization of cooperative innovation and diffusion processes between cities in the context of urban transformation and sustainable urban development from a global perspective. With qualitative and quantitative research methods of knowledge discovery in databases, previous co-innovation processes of urban systems are analyzed exploratively, and recurring characteristics as patterns are identified and validated.

The objective has been the prototypical development and validation of a first universal pattern language set based on the theories in Software Engineering to organize identified proven solutions, operationalize them in an understandable form and thereby strengthen cooperation between those involved in the application of strategic innovation management in urban systems - a common language between science, industry, politics, and public authorities. For smart, citizen-centric, or carbon-neutral cities of the future, it becomes evident that a new understanding of the versatility or adaptivity of cities as complex systems is key to success. With a performance-based approach coded into a unique set of 35 urban innovation patterns, systemic innovation capacities for public stakeholders in smart cities can be specifically addressed and unlocked.

KEYWORDS

co-evolution, urban innovation, pattern language, future-proof cities, smart districts

초록

지속적인 도시화로 21세기 말까지 도시 인구가 90억 명에 달할 것으로 예상되는 가운데, 현재의 지속 불가능한 패러다임 내에서 모든 기반 시설을 포함한 기존 글로벌 도시 시스템의 규모가 두 배로 커질 것으로 예상된다. 따라서 오늘날 글로벌 사회의 주요 거주지이자 경제 영역인 도시 시스템의 기술 발전은 우리 시대에 더욱 중요해지고 있다. 초기 산업화 이후 기술 혁신의 출현과 확산이 도시 시스템에서 점점 더 중요한 역할을 담당했지만, 미래 기술 잠재력을 체계적으로 다루거나 전략적으로 예측할 수 있는 실용적인 접근 방식은 여전히 찾아보기 힘들다. 본 논문은 글로벌 관점에서 도시 변환과 지속 가능한 도시 개발의 맥락에서 도시 간 협력적 혁신과 확산 과정을 체계화하는 것을 목표로 하고 있다. 데이터베이스에서 지식 발견의 정성적, 정량적 연구 방법을 모색함으로써 지금까지 시행되어 온 도시 시스템의 공동 혁신 과정을 탐색적으로 분석하고 반복되는 특성을 패턴으로 식별하고 검증하고자 한다.

목표는 소프트웨어 엔지니어링 이론을 기반으로 한 보편적 패턴 언어 세트의 초기 프로토타입을 개발하고 검증하는 것이다. 이를 통해 입증된 솔루션을 체계화하고 이해하기 쉬운 형태로 구현하여, 도시 시스템의 전략적 혁신 관리에 참여자들 간의 협력을 강화하고자 한다. 즉 과학, 산업, 정치 및 공공 기관 간의 공통 언어를 개발하는 것이다. 스마트하고 시민 중심적이며 탄소 중립적인 미래 도시를 위해서는 복잡한 시스템으로서 도시의 다양성과 적응성을 새롭게 이해하는 것이야말로 성공의 핵심이기 때문이다. 이러한 성과 기반 접근 방식을 35개 도시의 각기 다른 혁신 패턴으로 프로그래밍하면, 스마트 도시와 관련된 공공의 이해 관계자들을 위한 체계적 혁신 역량을 밝혀내어 구체적으로 다룰 수 있다.

키워드

협력적 진화, 도시 혁신, 패턴 언어, 미래 보장 도시, 스마트 도시

Introduction

There is a quote from Wellington Webb, the former mayor of the City of Denver, who defined the 19th century as the age of empires, the 20th century as the age of nations, and the 21st century as the age of cities. Cities and their future-oriented development or better transformation nowadays are crucial in understanding our role as mankind on planet Earth - especially in times of unprecedented climate change. From ancient history on, mankind would never have evolved without cities and urban technology at that time.

Until today cities have always enabled the structural accumulation of social values, economic wealth and workforce, culture, and education. So there has been a constant mutual co-evolution of our civilization together with the concept of the city as versatile 'multi-tool' on the path of technological evolution and population growth until today. With new technologies, our cities changed as well, like a software or hardware update when looking at the analogy of a product.

To frame the current state of discussion it is helpful to have an introductory retrospect on the matter of smart sustainable cities for the 21st century:

- 1992 can be described as a decisive year for recent urban development, as it marked the beginning of two approaches that were completely separate from each other, but which have recently been increasingly converging, sometimes making it difficult to draw a clear line between them. The role this plays in today's spatial planning practice will be examined later. On the one hand, some 10,000 delegates and experts gathered in Rio de Janeiro for the first global United Nations Conference on Environment and Development to discuss environmental issues in a global context and to agree on joint action. Twenty years after the first UN Conference on the Human Environment in Stockholm in 1972, Agenda 21 was adopted for the first time as one of the most important outcomes, providing a common basis for long-term, country-specific action for sustainable global development [United Nations, 1992].

• In addition to the significant climate protection initiative that captured public attention, another groundbreaking publication emerged in the same year: "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks" by David Gibson et al. established the scientific groundwork for the concept of the "smart city" which, over thirty years later, is still being addressed with greater practical specificity than ever before [Gibson, 1992]. As evidenced by the title, the text focuses on the examination of the Greek terms "techne" and "polis" within the context of an increasingly information and communication technology-permeated society. It is not by accident that the world's first web browser had only been released a year earlier (1991), marking the advent of a new era of networked information society. First initial conceptualizations in the form of a "ubiquitous city" (u-city) emerged in South Korea during the mid-to-late 1990s with the development of Songdo International City in Incheon, South Korea, which pursued advanced approaches in the domain of integrated (ubiquitous) information and communication networks to regulate local processes [O'Connell, 2005].

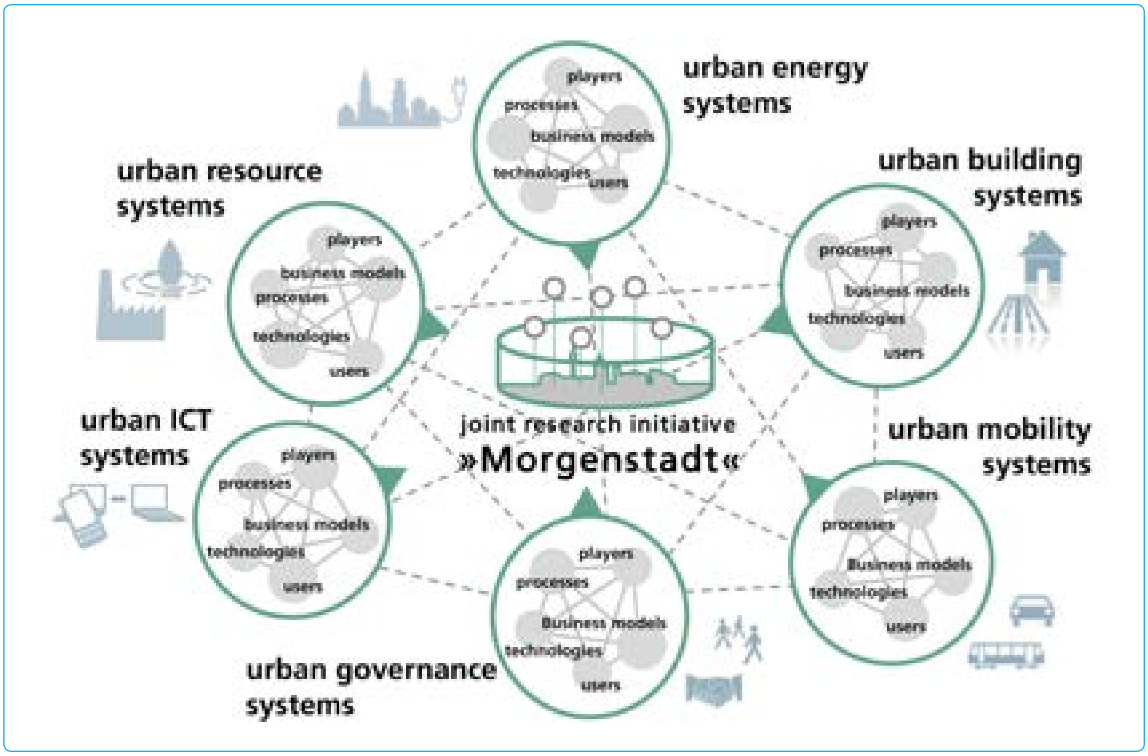
Referencing these trajectories in younger history, it can be stated that the platonic idea of smart sustainable cities is still unfolding and will heavily define humanity's future on a highly urbanized planet earth in the 21st century. Again, former UN secretary-general Ban-Ki Moon said: "Our struggle for global sustainability will be won or lost in cities." The key question for shaping citizens' lives in smart cities should be how to increase the speed of innovation and transformation in heavily regulated frameworks and many inhibitory factors for public stakeholders.

Evolution of urban systems: **From horse trams and robo-taxis**

To introduce the concept of urban systems evolution it might be helpful to reduce the complex configuration of a city with social, technical, economic, ecological, and cultural components as a kind of complex machine - composed of different parts or subsystems which are conjoined and work synergetically. So the urban system in general can be split into a set of 13 subsystems composing the modern city in the 21st century [Braun, 2024]. Each of these systems has its primary function to provide city operations and its own set of underlying technologies [Pumain, 2004]. This is from the author's point of perspective important to highlight due to the common fact, that most Smart City strategies in many countries ignore the aspect of evolution and only focus on the next technology layer without a systemic understanding of urban innovation.

The Fraunhofer Morgenstadt initiative, which has been engaged in applied research and the advancement of system innovations for the city of tomorrow since 2012, has identified several subsystems and their climate-neutral transformation as a core research area (see Figure 1):

Therefore, the proposed definition of urban systems as socio-technological subcomponents shapes each subsystem with a different legacy in the historical development of modern cities up to now. Some urban systems and their key principles regarding technologies, business models or processes are very established and stable (e.g. landscape), and some are newer



Source: Bauer, 2012

Figure 1

Identification of the most important urban sub-systems as relevant drivers for sustainable cities

"to the game" and yet unfolding (e.g. waste). Others might have been part of the urban system in the past, but have been 'outsourced' due to paradigm shifts and are on their way back to the urban domain (e.g. Food) - or transformed its physical form into the digital realm (e.g. security). After intensive screening of scientific literature, the following systems in a specific time interval have been identified:

1. **system: Mobility** - horse-drawn streetcars to robo-taxis (1662 - 2016)
2. **system: Energy** - oil lamps to power-to-gas (1662 - 2015)
3. **system: Buildings** - half-timbered houses to micro-housing (1849 - 2017)
4. **system: Communication** - Telegraph to Internet of Things (1837 - 2022)

5. **system: Water -** aqueducts to vacuum sewer system (1804 - 2017)
6. **system: Security** - city walls to predictive policing (1766 - 2014)
7. **system: Economy -** Cameralistics to Robocoins (1762 - 2014)
8. **system: Workforce -** Manufactories to micro-factories (1769 - 2014)
9. **system: Food -** poor gardens to vertical farming (1746 - 2015)
10. **system: Landscape** - public parks to animal-aided design (1637 - 2019)
11. **system: Waste -** refuse to cleaning robots (1874 - 2016)
12. **system: Logistics -** pneumatic tube to delivery drones (1761 - 2019)
13. **system: Governance -** Ideal city to virtual city twin (1699 - 2021)

The modern origins - or better the beginning of urban technological evolution - of these systems can mostly be traced back to the 17th to the 19th century in European cities - from there, along with global urbanization, they have been replicated and adapted to cities all over the world, from North America to Asia and Africa. Building on a comprehensive data set of 135 selected urban innovations with 1.629 entries (ID, time, and location) of 118 cities, it can be stated, that urban systems are an evolutionary concept on the one hand side, and on the other side, show a high level of standardization up to now - e.g. a subway in Stuttgart, Germany, functions pretty much the same way like in Seoul, Korea, or in Buenos Aires, Argentina. The future outlook on the evolution of urban innovation will be interesting to see unfold having completely new urban paradigms on the horizon (e.g. zero-gravity urbanism in 'The Line', Saudi Arabia).

A significant proportion of the identified urban innovations can be geographically assigned to one specific city in which the underlying invention or initial piloting originated (city zero). The following diagram(Figure 2) shows this spatial distribution of the synthesized cases of urban innova-

Figure 2

Worldwide spatial distribution of identified urban innovations (N = 135)

tions (N=135) between the years 1750 to 2020 with some concentrations in Europe and the USA:

To illustrate the concept of urban systems the evolution of the mobility system can be summarized shortly (modelled on 58 enabling innovations in the analyzed time interval):

• Before the year 1662, the transportation means for inhabitants in every city consisted of muddy roads, ox carts, or horse carriages. Then, famous mathematician Blaise Pascal introduced the world´s first public transport system in Paris/France called 'Cinque Carrosses' which ran successfully for some years. But it has not been adopted by other cities for the next century.

• In 1817 Carl Freiherr von Drais invented the bicycle in Karlsruhe/Germany after the 'year without summer', long before the automobile.

• The Liverpool and Manchester Railway in the UK, which opened in 1830, was the first modern interurban railroad with steam locomotives and as a public carrier of both passengers and freight.

• In 1863 a breakthrough took place in London/UK with the world´s first subway line, utilizing tunnel-digging technologies and being run with coal-powered locomotives until the age of electrification.

• The pioneering of electric trams only happened in 1881 for Berlin-Lichterfelde/Germany by Werner von Siemens (Founder of Siemens AG) and five years later (1886) the first Automobile as a motorized coach appeared in the streets of Stuttgart/Germany - in retrospect a world-changing technology highly influential to all cities, for the better and the worse.

• The 20th century brought along a variety of car-fostering innovations like underground tunnels (1896, Stuttgart), electric traffic lights (1914, Cleveland), Parkuhren (1935, Oklahoma City), and zebra crossing (1948, London).

• Since the publication of 'limits of growth' (Meadows, 1972) glimpses of a new mobility paradigm with better public transport (Bus Rapid Transit Systems BRT in 1974, Curitiba), more regulation (first pricing scheme ALS in 1975, Singapore), first commercial bike and car-sharing (e.g. Bycyklen in 1995, Copenhagen) and the commercial introduction of autonomous vehicles (Connexxion in 1999, Rotterdam) arrived - but a lot is still under development. The rest in the 21st century is common knowledge providing a heterogeneous field for the transition towards carbon-neutrality.

It is worth mentioning that each urban system evolution like the described mobility domain has mostly been isolated in its early development; but over time it has been more connected to and profitted from other urban systems (e.g. energy infrastructure). Lately, with the upcoming of smart or connected cities in the age of information technology beginning in the 1990s and early 2000s (see Introduction) the entanglement and interdependencies of urban systems have become a new paradigm - with an unprecedented increasing speed of innovation within the last decades. By systematically measuring the innovation and adoption rate between urban systems

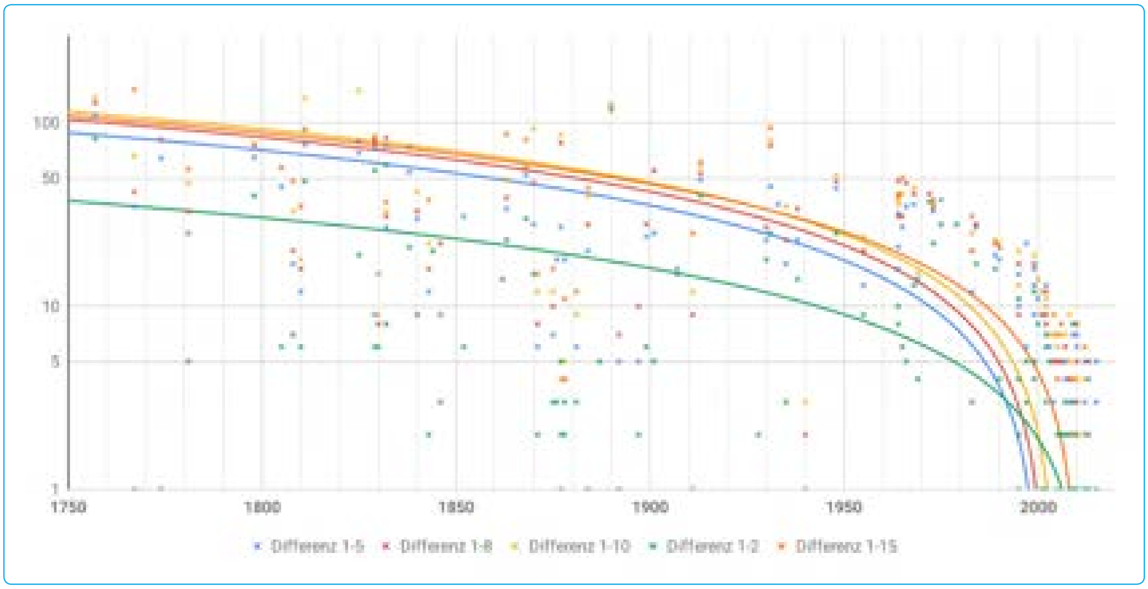


Figure 3

innovation cycles of urban innovation in different intervals along the y-axis (N = 135)

and cities the following diagram (see Figure 3) can be generated. On the y-axis, it displays the amount of years for a specific urban innovation (UI) it took from first urban pilot (e.g. the subway 1863 in London) to successful diffusion in a specific group of other cities as early adopters (e.g. to the tenth city with a subway in operation).

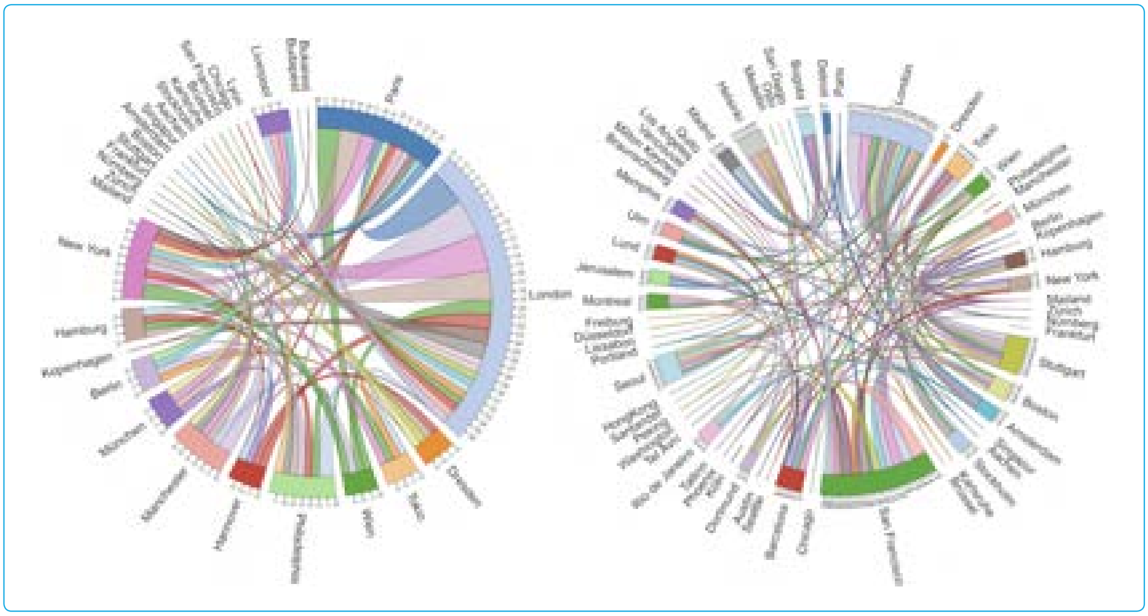
A clear pattern can be recognized over time with a continuously increasing of urban innovation diffusion speed among cities since modern times. When an urban innovation in the 19th century took about 34 years to diffuse to the tenth city, in the 21st century it increased to less than five years. The rapid pace of urban innovation has repeatedly outpaced the planning cycles of the present era - it seems therefore necessary to adopt a new paradigm [Popescu, 2020].

From London to San Francisco - **who is leading the race of urban innovation?**

In order to facilitate quantitative measurement in urban systems, it is necessary to introduce a new factor that is based on a comprehensive empiricism of previous innovation diffusion over a defined time interval. In order to achieve this, the UI factor is proposed as a means of determining the innovation performance of a city. This is achieved through a weighted innovation analysis, which allows for the description of a city's single innovation performance in relation to the entire innovation system of cities [Braun, 2024].

The raw data, comprising time, location, and type, along with the resulting diffusion curves (N = 135 urban innovations in the introduced 13 urban systems), are used to weight each city (UI_{1-x}) for the initial first ten data points of each UI. In the event that a city is the world´s first to pilot UI_1 on a global scale, it is accorded the rank of no. 1. The subsequent rank is then assigned in descending order, with the second city to achieve UI_1 being ranked no. 2, the third city no. 3, and so forth. With this indicator it is possible to determine leaders of urban innovation on a global level which, on the one hand, are pushing the breakthroughs of urban technologies for others to follow and, on the other hand, are early Adopters or even late movers in terms of replicating proven solutions for global urban progress. Against this background, the data show that these long-term interdependencies between cities are a fluid situation changing over time [Smith, 2013].

A comparison of two characteristic intervals (see Figure 4) provides de-



Source: Braun, 2024

Figure 4

chord diagram for the interval before the year 1850 (on the left) and the interval since the year 2000 (on the right) between 50 cities

tailed snapshots of this global innovation ecosystem of cities for a specific era:

In a manner analogous to a long-term photographic exposure in a subsequent time-lapse, the dynamics, relationships, and weightings for both observation periods become visible in a flashlight-like manner. The interpretation elucidates the manner in which the role or dominance of individual cities in the innovation system can undergo a shift over time. While the left-hand diagram (up to 1850) depicts the city of London as the dominant player (most No. 1 innovations pioneered at that time), followed by Paris and approximately a dozen similar cities, the right-hand diagram illustrates a markedly more heterogeneous network structure in the 21st century. Nowadays, the city of London has relinquished its pioneering role to San Francisco, and there is a considerably larger number of cities that are also piloting and adopting No. 1 innovations. The “playing field”, the rules of the game, and the tactics for urban innovations have become much broader and more open [Thompson, 2018].

Concept of 'Urban Innovation Pattern Language' - **what is the 'DNA' of an innovative city?**

How does one identify the underlying patterns which are critical to success for creating or adopting urban innovations in cities over time? The discipline of thinking in patterns and pattern languages is a relatively recent addition to the developing body of knowledge within the modern knowledge society. It emerged concurrently with the work of the 'Club of Rome', modern systems sciences, and the 'Whole Earth Catalogue' [Turner, 2008]. In the process, the approach of pattern languages is that of structuring and at the same time open configuration in the context of incipient digitalization. They serve to structure knowledge and form the basis for communication across different disciplines [Leitner, 2015]. The term 'design pattern', as it is used today in various engineering and technology domains, was originally coined in the 1970s by the architect Christopher Alexander in the field of house construction and urban planning [Buschmann et al, 2000]. Accordingly, a pattern describes the proven solution to a problem that frequently occurs in a specific context in abstract form, whereby conceptual knowledge, 'know-how', and 'best practices' can be generalized.

Based on a theoretical coding method for each diffusion process in the analyzed urban systems, a positive influence can be defined for some 25 urban innovation patterns. For each of the identified patterns (see table 1) several instances of urban innovation diffusion could be demonstrated. The most frequent occurrence is the pattern 'Urban Life Quality' (ULQ), with 40 instances (detected in 29.6% of all UI cases), while the lowest occurrence is the pattern 'Special Event Trigger' (SET), with 9 instances (detected in 6.6% of all UI cases). In addition to the data-based and exploratory identification of the patterns in the data set, they were also verified by an expert-supported verification survey of over 50 smart city experts from Germany, in which the application and practical relevance were simultaneously checked. The evaluation of all 25 patterns shows a very positive feedback for general purpose, with rated plausibility values all in the upper third of the scale between 65 and 88%.

As one practical example, the urban innovation pattern DWC (Don't waste a good crisis) addresses the aspect of external crises as moments of opportunity for urban innovation, where experts see an increasing relevance for municipal decision-makers by +10% in the next decade.

Each of these patterns is defined by additional descriptive indicators and attributes like type, centrality (among other patterns), most frequent era, av-

Table 1

Overview of 35 urban innovation patterns organized in 7 classes, each pattern has its own acronym

Class 1 Conditional patterns [C]	Class 2 Spatial patterns [S]
• Special Event Trigger [SET]	• Backyards and Niches [BAN]
• Don't waste a good crisis [DWC]	• New Spatial Expansion [NSX]
• Performative De/Regulation [PDR]	• District as Laboratory [DAL]
• Choke Point Opportunity [CPO]	• Modular Matrjoschka [MOM]
• Small Guinea Pig [SMA]	• Urban Quality Improvement [UQI]

Class 3 Relational patterns [T]

- Innovation Culture + Agencies [ICA]
- Citizen Crowdfunding [CIC]
- Power to the People [PTP]
- Political Leadership Expertise [PLX]
- Local Science Push [LSP]
- Enterprise Innovation Push [EIP]

Class 4 Evolutionary patterns [E]

- Paradigm Shifting [PAS]
- Technology Evolution Anticipation [TEA]
- Combine two technologies [CTT]
- Familiar Re-Interpretation [FRI]
- Old Legacy Detachment [OLD]

Class 5 Operational patterns [O]

- Start with Premium [SWP]
- One Zero Off [OZO]
- User experience first [UEF]
- Public-Private Innovation Partnership [PPI]
- Free Access for All [FAA]

Class 6 Subjective patterns [S]

- Urban Innovation Acceleration [UIA]
- London Powerhouse [LOP]
- New York Next [NYX]
- Munich Shuffle [MUS]
- San Francisco Gambit [SFG]

Class 7 Anti-patterns [A]

- Legal Framework Idleness [LFI]
- Social Technology Scepticism [STS]
- Short Viable Product [SVP]
- Missing Urban Interfaces [MUI]

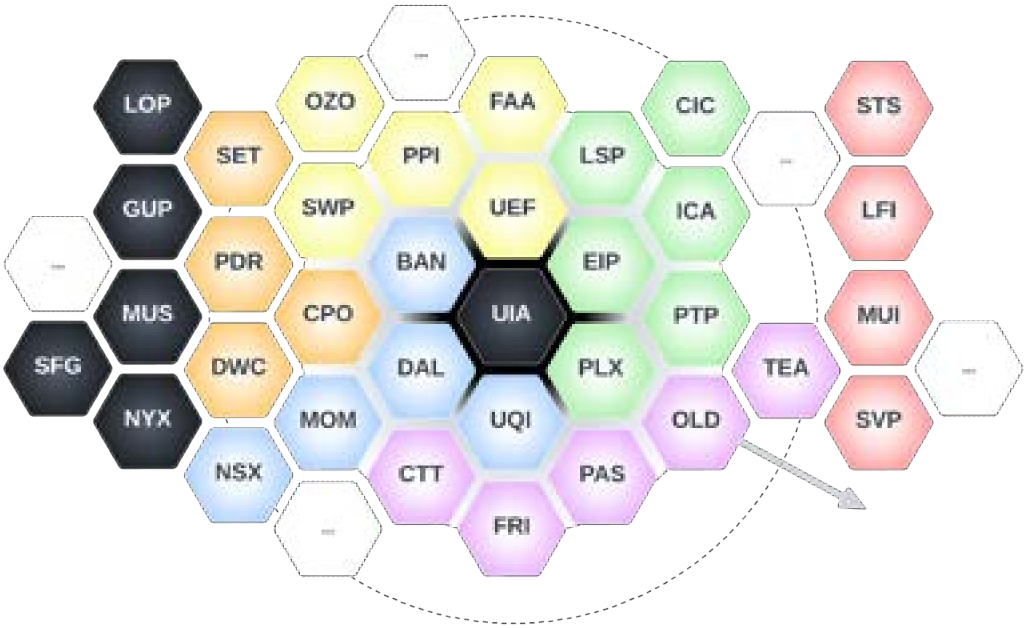


Figure 5

Arrangement of the individual 35 patterns as open urban innovation pattern language [ui.PL], pattern UIA (urban innovation acceleration) as centered origin

erage speed, related city size, and others. Based on the evaluative review of the expert survey, a visual organization scheme for 25 original patterns (class 1-5) and 9 secondary patterns (class 6-7) is presented above (see Figure 5) as an individual and a coherent representation of all patterns (comparable to the Periodic Table of Elements in Chemistry). The aim is to improve the application through clear identification, including formative performance indicators, and for practical use by Smart City experts.

In the case of the urban innovation patterns discussed here, several characteristics of a pattern language are evident. According to the literature, as introduced at the beginning, a pattern language exists when there are relationships between the patterns and these can be considered in a differentiated way. With that open approach, more patterns can be added in the future depending on the classification (indicated).

Outlook: innovating for citizens' lives in future districts

What do urban innovation patterns have to do with citizen's lives in smart cities of the future? In retrospective, cities as innovators or adopters of new technologies have never created urban innovations in some secret laboratories or away from public opinion. They always co-created technological progress in public spaces and had high interaction with the public. Technology acceptance of users or residents is critical when it comes to successful pilots and up-scaling of urban innovations - this is i.e. anchored in the anti-pattern STS (social technology scepticism) based on empirical evidence where a multitude of urban innovations in history suffered from scepticism - sometimes unjustly fuelled by negative press or the establishment.

Another universal innovation pattern is DAL (district as laboratories) which essentially describes the role of newly emerging or redeveloping urban neighbourhoods as experimental test and experimental laboratories for the whole surrounding city and the urban society - as a kind of 'pars pro toto'. This recurring principle can be found in many cities across the history of urban innovation and development from the industrial age to the newest smart city developments all over the world. Since 2022, the Fraunhofer innovation network 'Morgenstadt: Future District Alliance' has supported numerous innovation-oriented district and campus developments in cities across Germany with applied research, some of which are being developed over a period of ten to twenty years. What they have in common is the ambition to be pioneers and real-world laboratories for developing and testing new approaches to forward-looking neighbourhood development. The focus is on developing new, future-proof solutions to current challenges such as social and demographic change and the design of climate-neutral, sustainable neighbourhood structures (Braun, 2024b).

For that, the pattern PTP (power to the people) describes the strategy of involving citizens at a very early stage, or even of enabling or promoting innovations directly from society. This approach is often preceded by an 'appropriation' or experimentation phase in specific districts or urban areas, in which social or technical innovations are tolerated or tested for some time. After such a phase, positive experiences can then be analysed and scaled-up in the long term. An outstanding example of this pattern was the Suwon Ecomobility Festival in South Korea in 2013, where over 5,000 people travelled emission-free for a month (ICLEI, 2018).

In summary, the relevance of a universal urban innovation pattern language seems very high, especially for Governments in the urban millenium. By facilitating a minimal yet essential level of common principles, universal patterns can pave the way for faster innovation cycles and the development of a cohesive global market and collaboration for smart, citizen-centric and carbon-neutral cities - centered around solutions, services, and data.

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SMART CITY

TOP

AGENDA

2024

Barcelona Superblock, a new life in the city for the many, not the few

바르셀로나 슈퍼블록, 소수가 아닌 다수를 위한 도시의
새로운 삶을 제공하는 도시계획 프로젝트

Janet Sanz

As Mayor Deputy of Barcelona for eight years (2015~2023), Janet Sanz has been the main architect of an ambitious agenda for an affordable and healthy city. Notorious for an ironclad advocacy for social rights in front of the interests of global capital, she built the Superblock project and imposed on big landlords a 30% mandatory affordable housing. She is recognized for being the first in the world to limit and degrowth short-term rental and tourist apartments, sanctioning digital platforms like Airbnb. In addition to these initiatives, Sanz championed extensive improvements in public transport, expanding bike lanes and promoting sustainable mobility to reduce carbon emissions. She also initiated community-driven urban regeneration projects, enhancing old housing, green spaces and biodiversity throughout the city. Sanz's efforts to create participatory budgeting processes allowed residents to have a direct say in local spending, further strengthening community engagement and resilience.

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ABSTRACT

Barcelona is at a pivotal moment in urban transformation, driven by the recognition of interlinked housing, health, and climate crises exacerbated by the pandemic. The city's response—embodied in the Superblock initiative—aims to address these challenges through a radical reimagining of urban space, prioritizing pedestrian mobility and sustainability. The Superblock model seeks to reclaim public space, emphasizing community needs and social equity, especially for marginalized groups. It challenges the historically male-dominated urban planning paradigms, advocating for a city designed for all. Initiated in 2016, Superblocks are designed to reduce vehicular traffic, increase green spaces, and enhance public health, contributing to a significant reduction in pollution and improved living conditions. The initiative has inspired cities worldwide, establishing Barcelona as a benchmark for eco-social urban strategies. It promotes an inclusive urban agenda that confronts structural inequalities and fosters collective resilience against the climate emergency.

Barcelona's Superblock is more than an aesthetic change; it is a commitment to sustainable urban living, addressing urgent socio-environmental issues while enhancing community ties. By transforming streets into pedestrian-friendly spaces, the initiative empowers citizens, making the city a more livable, equitable, and vibrant place. The Superblock model exemplifies a forward-thinking urban vision, responding to present realities while laying the groundwork for a sustainable future. It is a call to prioritize care, interdependence, and social justice, illustrating that the path to a better urban life is possible through collective action and innovative policies. In essence, Superblock Barcelona serves as a tangible assertion of life and hope in the face of pressing global challenges.

KEYWORDS

Barcelona, Superblock, pandemic, crisis, innovation, urbanism, streets, neighborhoods, climate, justice, mobility, housing, pollution, community, gentrification, health, tactics, feminism, inequality, participation, future

초록

바르셀로나는 코로나 팬데믹으로 인해 가구 간 상호 연결, 건강, 기후 위기가 악화됨으로써 도시가 변화의 중요한 순간에 처해 있음을 인식하게 되었다. 슈퍼블록 계획에 구현된 도시의 대응 목표는 보행자 이동성과 지속 가능성을 우선시하는 도시 공간의 급진적 재구성을 통해 이러한 과제를 해결하는 것이다. 슈퍼블록 모델은 특히 소외 계층을 위한 지역사회의 요구와 사회적 형평성을 강조하는 도시 공간을 회복하고자 한다. 이 모델은 역사적으로 남성이 주도하던 도시 계획 패러다임에 과감히 이의를 제기하며 모든 사람을 위한 도시 설계를 지향한다. 2016년에 시작된 슈퍼블록은 차량 통행량을 줄이고, 녹지 공간을 늘리며, 공중 보건을 강화하여 오염을 크게 줄이고 생활 조건을 개선하는 데 기여하도록 설계되었다. 이 계획이 전 세계 도시에 영감을 줌으로써 바르셀로나는 생태-사회적 도시 전략*eco-social urban strategies*의 벤치마크 대상으로 자리매김하게 되었다. 이 계획은 기후 비상사태를 대비해 집단 회복력을 증진하고 구조적 불평등에 맞서는 등의 포괄적인 도시 의제를 장려하였다.

바르셀로나의 슈퍼블록은 단순히 도시를 아름답게 변화시키는 것 이상이다. 지속 가능한 도시 생활에 대한 약속이며, 지역사회의 유대감을 강화하면서 긴급한 사회-환경적 문제를 해결하고자 한다. 거리를 보행자 친화적인 공간으로 전환함으로써, 시민에게 권한을 부여하고 도시를 더 살기 좋고 공평하며 활기찬 곳으로 만들고자 한다. 슈퍼블록은 미래 지향적인 도시 비전을 보여주는 도시 계획 모델이자 현재에 대응하고 지속 가능한 미래를 위한 토대를 마련하기 위한 것이다. 이는 배려, 상호 의존, 사회 정의를 우선시하라는 요구이며, 더 나은 도시 생활로 가는 길은 집단적 행동과 혁신적인 정책을 통해 가능하다는 것을 보여준다. 본질적으로, 슈퍼블록 바르셀로나는 우리를 압박하는 세계적 도전에 맞서 생명과 희망을 구체적으로 드러내 보인다.

키워드

바르셀로나, 슈퍼블록, 코로나 팬데믹, 위기, 혁신, 도시주의, 거리, 이웃, 기후, 정의, 이동성, 주택, 오염, 커뮤니티, 젠트리피케이션, 건강, 전략, 페미니즘, 불평등, 참여, 미래

Barcelona is going through a transcendental moment, a pioneering path for many cities in the world. The recent pandemic has disclosed the fact that cities will gather massive communities in the future, risking great dangers in the making. This crisis has triggered the hidden seams of a housing, health and climate crises that are now chronic. But they have also produced great momentum for a range of innovations that worked towards a prosperous future for all. Without these crises, in previous times these innovations had been put aside.

To summarize the struggles of our times, let me say bluntly that opportunities to opt for a job position cannot escape a generalized precariousness. There are big strains in accessing basic rights such as housing or quality public health. And there is a palpable climate emergency that will have aggressive consequences for the majority of people in cities.

In many countries, nationwide surveys or debates tend to indicate there is still a big opposition to any change that may answer to these crises. However, cities in general, and Barcelona in particular, have found a strong consensus on the need to face up this triple crisis with political ambition.

Like so many cities with strong beliefs in their civic rights, Barcelona is the result of many hands, many voices, many colors and, above all, many struggles. It is also the result of a longing for a metropolitan and welcoming city, which overflows its borders in a process of constant adaptation and transformation. Barcelona is desire and revolution. We have neighborhoods steeped in history, which preserve identity and collective memory. Each layer of the city is a testament to the people who lived erecting the city. There are testimonies of a citizen's belief in the future in every spot. They are visible from the old city to its walls, from industrial complexes to worker towns, from shanty towns and slums up to the tight and electrifying Expansion Plan of Cerdà. We see it every time we do construction work:

cobblestones, roads, walls, irrigation systems and farmhouses emerge from under the asphalt.

Ten years ago, people stood against a way of governing that relied on a sort of autopilot mode in urban planning and democratic decision. It seemed like for 40 years, voters had remained numb, and that City hall didn't want to risk their power with any bold move that might face critical problems with pollution in an unaffordable city. Protests brought Democracy right in front of a mirror, revealing its deformations, incapable of generating responses to the challenges we were facing. It was a resounding rejection of the existing political and institutional architecture that facilitated the construction of a new political subject, ambitious movements full of projects for the future. An important part of these movements made a big leap into government, with the victory of Barcelona en Comú and the appointment in May 2015 of Ada Colau as the first female mayor of the city.

We found an economy that bet its future on an extractive and gentrifying activity: tourism. Popular struggles wanted to recover the city, from public space to housing, and social movements had been weaving communities, networks, and spaces of resistance. The mainstream economic model of Barcelona in 2015 showed a giant flaw with its 15% unemployment rate, the issue that most concerned its citizens. Tourism was out without a leash, consuming the city with short-term rentals and hotels. Car traffic dominated 60% of public land and European sanctions were being applied on the city for a non-compliance with the "Air Quality Directive". Traffic on pollution rates posed a danger to public health, especially for the most vulnerable groups, such as children, pregnant women and the elderly.

Perhaps for the first time, the consequences of climate change had a priority place on the public agenda, and a new common sense began to emerge among citizens, demanding radical changes. Concern about rising temperatures or greenhouse gas emissions was no longer perceived as an incomprehensible reality on a human scale, an extravagant idea coming from minority environmental and anti-system groups. On the contrary, the climate emergency began to be felt as an everyday problem. This had to do with the possibility of children being able to open school windows, older people suffering premature deaths, or the disproportionate increase in the number of tropical nights. Hence, Barcelona declared a climate emergency in January 2019, and did so as a comprehensive response to the serious situation of planetary crisis under the capitalist drives. It was not just a proposal to decarbonize mobility and put the eco label on an unsustainable model of urban growth.

The objectives we set ourselves were very ambitious. Before 2030, Barcelona had to increase 1 m^2 of green space per person; reduce 20% the use of private motor vehicles; refurbish 20% of buildings to be more energy efficient; ensure that no citizen was cut from electricity because of poverty; reduce drinking water consumption; and, of course, being carbon-neutral by 2050. The list of objectives is much longer and more precise, but these examples emphasize that the declaration of a climate emergency did not only aim to convey scientific consensus to the institutions. Its aim was, above all, to lay the foundations for an eco-social transformation of the urban model, which would demonstrate the fact that social injustices could not be reversed.

The fundamental tool for achieving this change in the urban model is an international benchmark that is now being replicated in Los Angeles, Bogotá and Vienna: SuperBlock Barcelona (*Superblock Barcelona*). An eco-feminist urban planning strategy that aims to recover one million square meters of public space, place pedestrians and sustainable mobility at the center of urban design and ensure that one in three streets in Barcelona's urban fabric is green. Obviously, it is not just about replacing gas cars with electric cars, but about claiming the right to the city for everyone, altering the hierarchies – of gender, class, origin – that have historically determined the configuration of the streets. The previous urban model emerged from the alliance between capital and patriarchy, a city tailored for male, white, functional, upper-class subjects, a man who works in urban centers and commutes by car: a gray city tailored for "the gray man". Superblock Barcelona corrects the structural inequalities that have contributed to the social and environmental degradation of urban environments.

How is a Superblock done? Firstly, by making women, children, and the elderly the main characters of the new streets and squares, that is, by taking interdependence seriously as a fundamental value of urban design. Streets with a single platform, more accessible, where pedestrians are the protagonists and cars are mere guests. Changing the lighting, to adapt it to the passage of people, instead of being designed to facilitate the passage of vehicles. Removing asphalt and making cityscapes work like a sponge, with sustainable draining systems, changing asphalt and cement for more absorbent materials with less carbon footprint, like natural stone. Multiplying the green surface of the streets, with a prepared subsoil that facilitates the growth of roots and allows for the planting of more bushes, more flowers and trees, gaining shade spaces and reducing the heat island effect. Placing quality urban furniture: benches, chairs, tables, children's play areas, ping-pong tables, chessboards.

In terms of urbanization, Superblock is a leap in scale, a strategy that reaches all neighborhoods. The idea of a "superblock" is not new. The original concept can be traced back to the 1930s, when GATPACGroup of Catalan Architects and Technicians for the Progress of Contemporary Architecture dreamed of adapting Le Corbusier's garden city ideals to the urban layout of Barcelona, recovering the utopian spirit of the Cerdà Expansion

Plan based on a basic idea: diverting traffic around a block to free up car crossings and recover that space for pedestrians. That initial idea, which was never implemented, was the one that was taken up much later by the Urban Ecology Agency in the 1990s, and which we finally began to implement with tactical urban planning in 2016. First in Poblenou district, in the perimeter formed by the streets of Badajoz, Pallars, Llacuna and Tánger, and then it was successfully extended to other districts, such as Sant Antoni, Horta or Hostafrancs. The case of Sant Antoni is where this success is most evident.

The new squares were first developed with tactical urbanism, showing that with little amounts of money the city model could change drastically. We painted the ground with yellow, orange and blue colors, with large planters and wooden benches, have become a symbol of recovered public space. Where there used to be cars, driving and parked, now there are children playing in the middle of the street, families strolling, older people playing chess, birthday celebrations, people reading or sunbathing.

But it is not just an aesthetic change, a modification of leisure in the city and body movements. Superblock has impacted the living conditions of the environment in a very material aspect. Data shows that pollution has been reduced by 40%, that traffic has decreased by 17% throughout the neighborhood, that there are 4 decibels less noise and that 200 local shops have opened in the past five years. For all these reasons, in 2019 we decided to apply this model to the entire city: creating 21 green axes and 21 new squares in the Eixample district, the core of XIX century's Ildefons Cerda Expansion Plan. We also wanted to pacify urban motorways such as the Meridiana Avenue, the Diagonal Avenue or the Via Laietana Street, as well as converting old industrial areas into green neighborhoods: the Marina, the Montjuïc Mountain the Besòs River industrial areas. Many large parks were created out of the blue in these neighborhoods, such as Glòries Park, Can Batlló Park or the former Colònia Castells Park.

In the past, Barcelona's relationship with its metropolitan area has lacked investment in public transport. We promoted important measures to restrict the transit of private vehicles, limit the entry of the most polluting vehicles and promote public and sustainable transport. The network of bicycle lanes has been doubled, more than 60 km of bus lanes have been created, we have frozen and subsidized 50% of transportation fares. Above all, we have started the Tramway connection in the heart of Barcelona, enabling a metropolitan connection that will link 9 metropolitan cities, 4 metro lines and 13 bus lines.

Something began to change, and now Barcelona is the largest city in the state where fewer people use the car to go to work or study. However, there is still much room for growth: 70% of the journeys made by private vehicle are within the coverage area of the metro and the tram. And to take advantage of all this potential, we need to unlock investments and work to improve the metro, railway, and freight transport networks. The good news is that Barcelona's innovations in recent years has forced other public administrations to speed up. Work has already begun to expand regular and high-speed train stations.

Every time a street is pacified, traffic lanes are reduced, or new bike lanes are created, many people have feared the collapse of the city, instead of seeing a more diverse, more sustainable mobility centered on public transport. Urban planner Janette Sadik-Khan uses old futuristic representations of flying cars to show to what extent the new technological imagery remains anchored in an individualistic and inefficient mobility model that perpetuates the spatial injustice of contemporary cities.

For this reason, the Superblock model is and will necessarily be linked to the battle for a new urban common sense. Superblock is a model of positive innovation, a pioneering policy that not only generates resistance to change, but also pride in the city. In contrast to the pessimism of "nothing is possible" and "everything is lost", Superblock proposes a viable eco-socialist policy of repossession of that which is common. It is a cry for action, for mobilization, where every green crack opened in the asphalt counts; every tree pit in which we plant a tree; every new species that returns to the city; every decibel of noise that is reduced; every polluting car that does not enter the city; every centimeter of cycle lane and every carriage of public transport.

Superblock Barcelona looks to the future, but speaks to us of the present: it is an everyday utopia, a rebellion against collapse and nihilism. It is an effective strategy both on a material and symbolic level. It provides a quantitative response to the climate emergency (reducing emissions, reducing consumption, improving energy efficiency, increasing urban greenery, etc.). It corrects historical injustices in access to public space, health and affordable housing, and, at the same time, it is a plea for hope, for the construction of a city that makes life easier for its inhabitants and offers an alternative to a neoliberal and predatory system of greed over urban land that is incompatible with life today. In the face of the climate and social emergency, it demonstrates with facts that there are not only possible, alternative futures: there are also better presents.

Judith Butler says that "We are all born into a condition of radical dependence, and that is what makes us equal". Superblock Barcelona wants to claim the right to the city for all and improve the quality of interdependence links. Because what is needed now is to put life and care at the center, while recognizing these relationships of dependence as the indispensable foundation on which to build a livable future . We need an urban planning that leaves behind the fantasy of growth for growth's sake and that understands that care is not an extravagant policy.

The sustainability of life must permeate public action, not as a form of corporate responsibility, but as a design principle. The spaces should adapt to the needs of the people, and not the people to the conditions of the spaces. Placing care in the center means facilitating a type of travel - on foot, by public transport, by bicycle - or transforming certain spaces in the city to make them safer and healthier. But it also means making structural policies, which determine what kind of uses and resources cities consume. In the midst of a climate emergency, we cannot continue to think about temporality on a human scale if we want to avoid extinction.

Superblock Barcelona looks to the future, but tells us about the present: it is an everyday utopia, a rebellion against collapse and nihilism. Because as Yayo Herrero reminds us, thinking of the great collapse, the great cataclysm, as something to come, is a very patriarchal and anthropocentric way of thinking about the climate emergency: there are already many collapsed lives today.

Many people suffer from natural disasters, extinct species, deaths in heat waves, diseases caused by pollution. Faced with this situation, Superblock is a policy of repair and regeneration, which starts from the material reality of the city to transform it. It is a shock strategy towards the protection of life, in the face of the uncertainty. It is the profound change that our societies need.

Superblock Barcelona is an assertion of life, the construction of an ecofeminist, caring city that puts interdependence at the center. But also, and no less important, the explosion of a landscape that demonstrates with facts that there are not only possible futures: there are better presents.

Beyond the Rationalist City of Reason, to a Smart City of Monism

이성의 합리주의 도시를 넘어, 기일원론의 스마트시티로

Lim, Kitaek

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ABSTRACT

The fundamental goal and center of a smart city is not technology, but life together with people's lives and the operation (dynamics) of nature. Smart cities are just a concept that follows naturally in relation to such movements (practices). Ultimately, it is desirable for all technology to focus on human life and being sensitive to the strictly operating characteristics of nature and living together in accordance with the changes and flows of nature. Smart city technical solutions should set these basic goals and should make them follow secondary goals. Technology is bound to quickly become helpless and be eliminated in the face of advanced technology. Rather than focusing on the development of technology itself and making money, we should stick to the fundamental goal of how it can benefit the life and happiness of the human community. When that happens, smart cities should be revealed naturally by combining technologies of contemporary value. This means that smart cities should not be the goal. In that respect, a smart city is not simply an objectified technology, but a city that flexibly satisfies needs and can change according to changes in energy (material, unconscious). It is a city that is fundamental to the community, the flow of energy, and human life. It should be a structure that can improve satisfaction.

KEYWORDS

Smart City, Monism, Community, Qi, Movement of Climate

초록

스마트시티의 근본적인 목표와 중심은 기술에 있지 않고, 사람의 삶과 자연의 운행과 함께하는 삶에 있다. 스마트시티는 그러한 실행과 관련하여 자연스럽게 따라오는 개념일 뿐이다. 모든 기술은 결국 인간의 인간다운 삶과 엄정하게 운행하는 자연을 민감하게 느끼며 자연의 변화와 흐름에 맞추어 함께 살아가는 것에 초점이 맞추어지는 것이 바람직하다. 스마트시티의 기술적인 해결 방법들은 이러한 기본 목표가 설정되고 부차적으로 따라오게 만들어야 한다. 기술 그 자체의 발전과 돈벌이에 집중하기보다는 '그것을 통해 내가 인간 공동체의 삶과 행복에 어떠한 유익을 줄 수 있을 것인가?'의 근본적인 목적에 충실해야 한다. 그렇게 될 때 스마트시티는 동시대적인 가치의 기술과 접목되어 자연스럽게 드러나게 될 것이다. 스마트시티가 목적이 되어서는 안 된다는 의미이다. 스마트시티는 그러한 측면에서 단순히 대상화된 기술이 아니라 기(물질, 무의식)의 변화에 따라 유연하게 그 니즈를 만족시키고 변화할 수 있는 도시, 그것이 공동체와 기의 흐름, 그리고 근본적인 삶의 만족을 향상시킬 수 있는 구조가 되어야 할 것이다.

키워드

스마트시티, 기일원론, 공동체, 기, 기의 흐름

Introduction

The fundamental goal and center of a smart city is not technology, but life together with people's lives and the operation (dynamics) of nature. Smart cities are just a concept that follows naturally in relation to such movements (practices). Ultimately, it is desirable for all technology to focus on human life and being sensitive to the strictly operating characteristics of nature and living together in accordance with the changes and flows of nature. Smart city technical solutions should set these basic goals and should make them follow secondary goals. Various Ubiquitous City technologies, which were once the subject of a significant portion of the Ministry of Land, Infrastructure and Transport's R&D, disappeared in an instant when Steve Jobs' smartphone came out. Technology is bound to quickly become helpless and be eliminated in the face of advanced technology. Rather than focusing on the development of technology itself and making money, we should stick to the fundamental goal of how it can benefit the life and happiness of the human community. When that happens, smart cities should be revealed naturally by combining technologies of contemporary value. This means that smart cities should not be the goal. If convenient technology is focused on oppressing and controlling rather than making life rich and happy, the development of technology may result in the exact opposite of the purpose of realizing a happy life for humans.

The characteristics of AI remind us of Lao Tzu's Tao. For example, let's say you're using navigation to pass through a congested area during rush hour. Artificial intelligence sets and distributes routes according to real-time road conditions, thereby achieving overall balance and harmony. Like the concept of 'Best Virtue is like Water (上善若水)', it is a natural law that water flows from top to bottom, so it must be followed. Likewise, today's

AI helps to clear blockages, create circulation, and appropriately adjust excesses to achieve smooth operation in a state of equilibrium from an overall perspective. By following the real-time navigation system, you can get the best results under the traffic conditions. It can be said that this is the principle (道) of the world's operation being put into practice. The concept of 'smart city' also shows similar characteristics to these conditions.

This 'control' ability to actively respond to external variables and have resilience is an empirical perspective that is centered on responding appropriately to the situation and creating the best equilibrium result, rather than an ideological method of setting and promoting ideological (Idea) values. There is a strong tendency to be linked to the philosophy of. It symbolizes various changes and combinations of external variables and elements. We must think of a fundamentally different approach from the way we are accustomed to modern and Western perspectives. In a city of ideological (IDEA) values and rational reason, we must respect the value of a city where the unconscious can be freely expressed, permitted, and reconciled. It is necessary to think about it from a Deleuzean perspective, the value of monism in Northeast Asia, and the perspective of Choi Han-ki in Korea.

Virtuality of combining Deleuze's discourse **with the values of monism**

As we enter the 21st century, one of the biggest social changes will be the transition to a full-fledged digital age. In the 1990s, there was remarkable development and growth in terms of performance and price to the extent that PCs could be distributed to each home, and the installation of optical speed communication networks became common, creating an environment where the world could be connected and communicate in real time. In order to acquire comparative advantage in production capacity under better conditions, business players relocated their factories to third world countries, including China, which claims to be the world's factory, and the volume of trade increased dramatically due to the development of various means of communication and transportation. World capital has expanded and developed rapidly in conjunction with the development of communication networks and the globalization of the stock market. This has freed up the situation where large amounts of capital can quickly accumulate in areas where there is virtuality for profit and then quickly withdraw when profits are realized. The so-called 'global neoliberal world' has emerged. A situation emerged where the scale and speed of mergers and acquisitions (M&A) for profit were being reorganized and disbanded at a faster rate than in previous times. Through this, mankind has been able to experience a variety of sweet fruits created by the development of capital, which rapidly lives and dies. In proportion to this, we also experienced the negative effects of rapid concentration and development of capital, excessive consumption, and environmental destruction. We experienced the emergence of the so-called global neo-liberal world and its characteristics and harmful effects.

The philosophical thought that can best explain the mechanisms of late capitalist society, especially the mechanisms of the neoliberal era and the digital era, was Deleuze's philosophy. His discourses makes it possible to explain the circulation relationship and change of capital in a new way through 'compound', the concept of the endless combination and aggregation of each element and complex. At the same time, it explains well how it is driven by the unconscious. Representative philosophers who influenced Deleuze can be said to be Spinoza, Nietzsche, and Bergson. For Deleuze, it shows a perspective that escapes the dichotomous structure of a thinking subject and an object that is the object of judgment. To him, 'Being' consists of 'events', 'movements', and 'effects'. He believes that the events and effects created by the relationships between the elements that make up the world are the only movements that create the subject in each situation. When thinking about the constantly changing world, various psychological elements behind visible phenomena create something new by causing chemical reactions through mutual relationships and the drive of desires. At that time, what is created as each element meets and reacts occurs through an 'event' called a meeting of relationships, which creates an 'effect'. The subject at that moment is a newly created subject, and the subject is continuously renewed and newly 'created' as a new subject by the relationships and encounters of other elements and events. When it meets other elements, another subject is created. Through this, Deleuze preaches the concept of 'rhizome', which is like a sweet potato rhizome networked by the relationships between each element.

The subject at that moment is a newly created subject, and the subject is continuously renewed and newly 'created' as a new subject by the relationships and encounters of other elements and events. When it meets other elements, another subject is created. Through this, Deleuze disseminates the concept of 'rhizome', which is like a sweet potato rhizome under the soil, networked by the relationships between each element.

The temporary result created as each element meets and mixes and becomes compound becomes a 'Machine' that projects desire or desires by the unconscious driving force that the elements desire. When another element is added to the Machine, it becomes a different Machine through the driving force of another desire. Different modes and modes that appear in different forms create differences depending on the purpose of desire. Concepts such as 'War Machines' and 'Abstract Machines' for waging war are such that in the neoliberal world, capital is accumulated in an instant, investment and development occur, and once the purpose (accumulation of capital) is achieved, capital is recovered in an instant. It is an appropriate concept to explain the characteristic of forming and falling away, leaving only an empty shell.

The field of urban architecture is an easy field to explain Deleuze's thoughts in a practical way. Let's consider the redevelopment process of a declining area. In architecture, when the time for change is ripe, the virtual waits until development becomes easy according to the flow of capital, and then the virtual is realized in earnest and revealed to the eye, and it is firmly realized as a building in a short period of time. In order to make the building a reality, the benefits of development are planned behind the scenes, the relevant parties move, and the work progresses through appropriate mutual supplementation. As the work progresses, active construction activities occur before our eyes in a relatively small period of time. It becomes a reality while doing so.

After Deleuze, Zizek's thinking focuses on Hegel's dialectics and spiritual phenomenology. And along with the temporal progress of development, Lacan's unconscious is simultaneously thinking about the potential reaction of analytical elements and the part that is revealed as political reality. He focuses on the gap between how the unconscious operates. Deleuze's thinking focuses on the aspect of constant change driven by the driving force of unconscious desire, and is a philosophical discourse suitable to explain the somewhat ruthless characteristics of neoliberalism. On the other hand, Zizek's thinking focuses on the mechanism of 'structuring' what is revealed and what is not revealed, and how the unconscious elements that reveal achieve social 'subjectification' in political and social aspects. Badiou's thinking is also an extension of the flow of post-structuralist thinking, but based on rigor like set theory in mathematics, the concept of 'fidelity' refers to the social repercussions created by the event after the event and how the remaining influence continues. focus on. He believes that he is a 'rare subject' who has a great influence on the world and that influence continues and changes in future generations. These thoughts, called 'philosophy of becoming,' 'philosophy of events,' and 'Nomadism', are all names for French progressive philosophies.

Possibility of combining the value of **Northeast Asian monism with post-structuralism**

In the philosophy of Northeast Asian Taoism, Lao Tzu's concept of 'Tao (道)' refers to the law of the world in which yang and yin circulate in harmony, achieve balance (moderation mode), and operate. If you look at Northeast Asian thinking, the journey to the absolute spirit (Hegel's) has similar aspects of the movement and movement of the Tao. The difference is that the movement of the Tao does not have any reason or purpose, just as nature does on its own. This is how nature operates, and it only circulates according to its own laws. Qi monism explains the occurrence and development of phenomena in all things in the world from the movement of 'Qi' while the world operates by the action of Li and Qi. Qi monism is in conflict with Li monism and believes that material 'Qi' forms the basis of the world. Li is something that appears as qi is created and moves, and is seen as nothing more than a secondary law inherent when 'qi' moves. Qi monists explain everything through the magnetic movement of material 'Qi'. It is believed that all things are created, operated, and developed through the interaction of yang and yin. To them, our perception is also seen as something that comes from the gathering of energy and they place emphasis on experience and observation, similar to British empiricism. The Sadanchiljeong controversy during the Joseon Dynasty also began with this controversy. Periodic theory, which emphasizes the movement of energy and matter, looks at the world centered on energy, but energy alone cannot explain the movement, and as energy moves, li follows, so in a way, it can be said to be interdependent. This is a difference in which part of the focus is placed on how the world operates, and is also used as a partisan point of view.

Qi monism disseminates the concepts that Qi flows and creates world, as if unclogging a blood vessel. It is created by the relationship between elements, and like a diagram, it considers the aspect created through the connection of various forces. Qi monists believe that revealing Li through the movement of Qi is a kind of ethics. The structure in which series create relationships through events is newly created, added, and changed by other forces, and in that it is very similar which is operated by the human mind (unconsciousness), and that is mostly related to monism. For Deleuze, virtual is countless folds, and is created as it unfolds and moves. If you think about it in Deleuze's way, the movement of large and small singularities of event-meaning unfolds. The events, meanings, actions, and concepts of Northeast Asia's 'Book of Change' are similar to thinking about the pattern of change in which these folds unfold, and are also connected to the Buddistic theory of causality, which thinks about the impermanence of parts that are constantly changing. It can ultimately be linked to modern thinking about change and creation as a genealogy of monism. Although Western studies have generally become differentiated since modern times, poststructuralist thinking and Northeast Asian thinking are important in terms of synthesizing the whole.

Behind the structure, Apeiron is at work vividly, capable of destroying the created structure and creating a new one. Badiou values the role of groups (publics) that can guarantee 'fidelity' that continues to influence the event after the event if the event created by the movement of creation is to be elevated to the level of truth by the subject. The 'rare subject' is thus a faithful executor of connection. It is accompanied by a structure that is created in a field of difference rather than the reality of an immutable idea. The fact that elements showing differences create a variety is similar to the composition of Choi Han-ki's Qi monism.

For Bergson, consciousness is pure activity and acts outward. The outside is a field. The phenomenological reduction that gives meaning to consciousness is also the activity of consciousness. That activity inevitably results in each person's 'experience', which is linked to and reduced to the unconscious. The structure created in response to the drive behind it is the central theme of structuralist philosophy.

What creates meaning is a pure signifier, and it is determined and varies depending on its position in the structure. Changes in the mind depend on the changes and movements of these structures. Unlike Western modern philosophy, which assumes that there is a clear 'subject,' the philosophy of becoming and Northeast Asian Qi monism share something similar in that they dismantle the a priori subject. The unconscious mind that operates the mind is the level of creation related to desire. As a result of creation, a structure is revealed, and that structure changes again according to the operation of the unconscious. When recognizing a structure, the Western ‘subject’ that recognizes it is already standing outside that structure. It unfolds into folds as it folds the outside into itself. Those folds are ultimately the unfolding of creation and change. In order to overcome its own contradictions, the West is paying attention to the immanence nature of Northeast Asia and practicing change. The thinking for its immanence is influenced by the ideas and worldview of Northeast Asia, represented by Lao Zhuang Thought.

The West moved east to the East, and the East moved west to the West through the forced transplantation of Western ideas, technology, and culture by the imperialist powers during the modern era, evolving on its own and now meeting in the center to develop its own strengths. It has become an era of expansion and competition between the two. It is an important point in time to overcome the shortcomings of Northeast Asian thinking and take on the things of the West while at the same time overcoming what the West does not have with an independent perspective.

Architectural attitude of living as one with nature and **ecological architectural planning methodology**

We learn how to live together with the climate of the universe (movement of Qi), focusing on the attitude of respecting ‘nature’, which is me, you, him, us, the universe, and the world itself, with respect for the ‘true me (atman)’. ‘You have to get used to it.’ Such an attitude is the spirit of unity of Brahman and Atman and the unity of heaven and man. The genealogy of the philosophy of Northeast Asia's immanence reached the Joseon Dynasty and sublimated these values into 'ethical aspects', aiming for a life in which the Tao of nature was properly realized and applied to the level of daily life and political governance. In today's busy metropolitan life where capital is at the center, it would be impossible to apply such an attitude to daily life and live a life of strict ethical standards. However, at least being close to nature, living together for a long time, reacting sensitively to nature and the weather, and enjoying the sense of change are essential. Eco-architecture's solution to this problem is mainly based on the attitude of viewing architecture and cities as one object and trying to solve problems, so there is a possibility that it will follow the harmful effects of Western objectification.

Based on this recognition, alternative methods that can be considered are an eco-architectural methodology that makes the most of natural light in the planning stage and an architectural methodology that reduces the energy heating and cooling load as much as possible by using natural ventilation of the microclimate. It is important to apply a sloping roof, louver, and 'brise-soleil' system that selectively admits or blocks daylight according to the high altitude in summer and the low altitude in winter. Also, at the planning stage, it is necessary to plan as passively as possible by considering the double skin methodology and skyline parapet design for microclimate control. In other words, a planning methodology and details are needed to maximize the application of passive energy-saving architectural solutions that do not require energy input. In the case of envelopes and insulation or structural elements, energy consumption (including carbon emissions savings) is high during the initial stages of production and construction, but energy savings (including carbon emissions savings) once built are also encouraged. When used for a long period of time, you should choose an option whose energy savings are relatively much higher compared to the lifespan of use. However, this solution itself is only the result of an targeted technology and is an energy-saving methodology that is different from the attitude of living with nature. If the life and attitude of becoming one with nature is prioritized and plans are made to improve the value of life in the community, these passive solutions will naturally follow as a necessity. As mentioned earlier, in the sentence, 'We must become accustomed to living with the energy of the universe with a mind that respects me and with an attitude of respect for nature, the universe and the world itself', our life, unity between Brahman and Atman, is mentioned in the sentence. the attitude of life of unity of heaven and humanity reminds us of the wisdom of life pursued by our ancestors along with Northeast Asian values.

As mentioned earlier, life in metropolitan cities, which have developed with an emphasis on the division of labor and efficiency of capital, is composed of the artificial natural environment of buildings and landscaping surrounded by a high-density artificial environment. The skyscraper metropolis, which was created with the advancement of structure, equipment, and envelope technology by emphasizing efficiency and technical aspects, has shown various problems. The destruction of the surrounding nature and the mass production of artificial facility plans that run counter to the flow of energy have led to a separation from nature. The problems of the existing modernist architecture were accelerated by the uniform and violent plan that increased the energy consumption of facilities and accelerated the deterioration of the local microclimate due to heat emissions.

Contemporary urban and architectural solutions that can coexist with nature as much as possible are linked to a methodology that can create a microclimate while reducing the harshness of the flow of energy (weather), a major external variable in the region. From an urban design perspective, when creating a residential environment to create a microclimate, it is not desirable to simply consist of box-shaped functional masses and arrange them geometrically like a military barracks. Rather, it is necessary to plan to surround each building with 4 to 5 stories of various layers and create a landscaped area with somewhat irregular external spaces. To facilitate the flow of energy, the easiest and best way is to actively use the convection phenomenon, where the wind enters a low place on one side and goes out to a high place on the other side. An appropriate combination of the outer protrusions and inner recesses of the mass can stimulate air circulation and allow it to flow smoothly. Appropriate use of external protruding and retreating elements such as bay windows and balconies creates a space where one can view the outside nature and feel the energy of the outside. It is advisable to appropriately combine internal Ssamzie Park, patios, etc. so that each area of the internal block can feel a mild microclimate. On the outside of the first floor, a non-magnetic gray space can be created by appropriately applying eaves protrusions, and it is desirable to apply elements such as a Korean-style pavilion connected to the interior to connect the inside and outside and create a space where you can enjoy nature. The advantage of this multi-functional gray space is that it can be used as a neutral space in that the inside and outside are not clear, but the inside and outside can be enjoyed stably while feeling the changes in nature, and if necessary, the outside can be used as if it were an inside space. there is. In particular, it is desirable to make the most of the useful advantages of Korean architecture due to its non-self-directed characteristics. The double-skinned shutter window, which acts as an intuitive and immediately responsive filter between the inside and the outside, can be used as a semi-exterior space or an area that shows the characteristics of a gray space when connected to a balcony. Even in the case of modern Korean apartments where the yard space is internalized as an internal living room, it would be good to combine this balcony area with appropriate variable windows to use it as a creative gray space and an external area where you can fully feel the outdoor air of nature. It will have the effect of expanding the feeling of life outside to the inside and give a sense of outside nature becoming one with life. What is important here is that these windows must be intuitive, easy to use, and easy to manage. In addition, it must be able to be opened and closed as needed and must also have excellent thermal and soundproofing effects. When this happens, you can use it conveniently at the right time, adapt sensitively to changes in nature, and enjoy the sensation of changes in energy.

In addition, a planning methodology is needed to maintain good relationships with neighbors by harmonizing public, reflective, and private relaxation spaces with landscaping areas while ensuring natural lighting and ventilation. In order to become one with nature, we need to elaborate an architectural planning methodology that allows our senses to respond sensitively to the natural weather, that is, the flow of energy (climate), and allows us to work with external nature for as long a time as possible. There is. In order to approach the realization that neighbors and I are one when we go to a deeper level, like the concept of 'public domain' in Buddhism, and that the macrocosm and the flow of energy itself are one, based on the aspects that Northeast Asian Confucianism, Buddhism, and Taoism value, There is a need to rethink nature and the surrounding built environment.

If you use the gray space in the first floor area appropriately by using the entrance, veranda, and arcades around the shopping center, you can create a gray area in the private, semi-private, and semi-public areas, or a buffer. You can create space. These spaces can become areas for communication. This uncertain buffer space can be used in rainy and snowy weather or as a space to avoid sunlight, and can also be used as an external area such as a cafe. Rather than using technology that consumes energy, it should be possible to increase outdoor activities and enhance community through detailed planning using microclimate at the planning stage. Ultimately, the purpose should be to connect with nature (unity of all people, unity of all people) and to improve the community of family and neighbors and further civic consciousness. This is a very important part. In these spaces, the sense of community can be expanded by utilizing elements such as the main hall, veranda, or pavilion, which are connected to the yard of Korean architecture. On the upper floors, as the balconies and other windows open, the interior and exterior space is transformed into a buffer space or gray space where one can enjoy nature and smoothly feel the outside air. In order to feel the ever-changing sensation of external energy, it will be possible to immediately convert and use it. This point is important. Like the open windows and window frames covered with window paper in Korean architecture, applying contemporary Korean windows with an appropriate combination of shutters, louvers, sliding doors, and screens will create a window and air circulation structure with the Korean atmosphere of our ancient ancestors. In big cities, it is often difficult to view Mother Nature from the first floor, terrace, or balcony. Therefore, it is desirable to provide a landscaping space, a resting area, and a plan to smoothly view the sky in each area of each building. There is a need to actively utilize natural elements that allow people to experience nature comprehensively and to consider a harmonious artificial environment as nature so that they can feel the flow and changes of nature in a stable atmosphere. The combination of various outdoor spaces and surrounding natural elements will awaken the feeling of living with nature and a sense of changes in climate.

Natural elements should be brought in as much as possible to the external space of each building in the complex to create harmony. Seeing majestic landscapes in the distance may be the best option, but this may not be possible in metropolitan cities. In times like these, the design must be planned to naturally harmonize as part of the urban environment by appropriately using the green space of trees and water space. If that happens, we can create a harmonious microcosm with sufficiently artificial nature and enjoy a life that is integrated with nature to some extent. Of course, the most direct way to live with nature is to plan nearby so that you can feel the mountains and nature directly. The best life would be to climb a mountain like a natural person and feel the changes in nature. It is necessary to have a 'body sense' that can appropriately respond to the patterns and cycles of Qi (climate) flow. In principle, it would be desirable for the composition and form of cities and architecture to be eco-friendly, economical, built with fewer resources, and consume less energy. Sometimes, it is necessary to control the variables of the harsh external air to create a microclimate that is as mild as possible than the surroundings, thereby enabling smooth outdoor activities and to live a life in which the flow of energy can be embodied through the senses of the body. In order to create a living and working space and surrounding environment, it is necessary to construct a small, surrounding building that can naturally create a microclimate. Complex planning requires a structure that reduces exposure to strong winds and sun while requiring less maintenance, and an architectural planning methodology that reduces artificial heating and cooling(active planning) as much as possible. However, as mentioned earlier, the focus should not be limited to the technical efficiency of heating and cooling, but spatial structures, expressions, and methodologies that can awaken a sense of climate change and achieve positive community should be prioritized. That is the ethical aspect of microclimate.

Since each region is different in terms of climate conditions, especially outdoor air conditions, which are the most important external variables in each region, architectural solutions tailored to the needs of lighting and ventilation are needed. A methodology is needed to alleviate the extreme outdoor conditions so that people can spend as much time as possible outside or semi-exterior or inside connected to the outside. An area surrounded by blocks forms a microclimate that is somewhat protected from strong wind and sun, and remains relatively stable compared to the surrounding harsh climate of hot and cold weather. This is similar to the fact that a relatively diverse range of life forms exists in tidal flats, silver, and spaces with a lot of cover. In areas protected by a mild microclimate, human outdoor activities naturally increase. This means that the time spent with nature increases. Through this, the sense of community can be improved as communication with neighbors increases. During the hot part of the day, a relatively lower temperature is maintained than the outside, and a microclimate area is formed that maintains a higher temperature than the cold temperature at night. Our ancestors prioritized finding a place in a stable hilly area with a mild microclimate to make their home. This was also the most basic effort to secure a mild microclimate and stable drinking water. It is like a scene where a fetus in the womb is safely settled and sleeping peacefully.

In general, the more time residents spend in the external area of the house, the easier it will be to establish territoriality and control over that external area. However, rather than a block surrounded by each house in a uniform grid, planning with an irregular external space and mass configuration that deviates from the grid to a certain extent actually increases the activity of the external area. This means that a stable microclimate will be improved. At this time, when the roof is a sloping roof and the central masses are placed slightly lower than the exterior, the outside wind flows in and out relatively gently, helping to form a mild microclimate. The sloping roof is also advantageous for lighting. It can improve the sense of openness when looking at the sky outside. The irregular plan of each building in the complex and the diagonal mass that deviates from the grid in a certain part of the central part are conducive to the microclimate and can create a public area that is good for daylighting. Between the high-rise masses, strong building-style wind is created and deep shadows are cast, which interferes with the formation of a mild microclimate and a comfortable outdoor space. In areas with a pleasant microclimate, the possibility of becoming one with nature increases while enjoying the microclimate on balconies and semi-outdoor areas open to the outside. It is necessary to appropriately use methodologies that can create a mild microclimate, improve the sense of belonging to the community, and live with the changes in nature's energy.

On the way out

Everyone would agree on the premise that the composition and form of cities and architecture should be as eco-friendly as possible, reducing energy consumption and pollution, and saving natural resources and materials. However, rather than the technical aspect of passively restoring ethics through resource and energy saving solutions, a different humanistic and life-ethical direction is needed. In other words, we must pursue a life that can create a smooth community by cooperating with the changes of nature as much as possible and adapting to the flow of natural weather (climate). This attitude will naturally lead to building cities and architecture in the necessary way, and as a result, cities and architecture suitable for that life will follow. The concept of resilience is also a concept that responds to contemporary demands that require a flexible ability to maintain equilibrium in response to changes in nature. Ultimately, the construction of the built environment surrounding us is a matter of thought and attitude. The ideology and culture of Zen Buddhism, which has the characteristic of sinking inward and its close connection with the entire world, has been linked to a culture that values the spirit of the unity of heaven and man. However, there is a risk that such communality can easily degenerate into totalitarian characteristics, and because the non-homogeneous ideological characteristic emphasizes the connection between oneself and the conceptual world, it is difficult to think about the interests of civil society and the community as a whole and appropriate social compromise with members. There is a difficult downside. When viewed as a characteristic of modernity that objectifies cities, the harmful effects that have emerged have created a history that clearly reveals its shortcomings. Humanity has strived to create complementary cities and built environments. Urban space centered on phenomenological values created by considering the area surrounding the community and external variables, structuralism's efforts to melt and realize the humanistic values of the fundamental structure of the city by studying the fundamental structure, and contemporary historical and semantic values of the public. Postmodernism, which sought to dissolve the values of the excluded, oppressed, and alienated unconscious, and poststructuralism, which sought to reconcile them by correctly revealing them in reality, were all efforts to create the best urban space and the best smart space by the standards of the time. It was. In that respect, a smart city is not simply an objectified technology, but a city that flexibly satisfies needs and can change according to changes in energy (material, unconscious). It is a city that is fundamental to the community, the flow of energy, and human life. It should be a structure that can improve satisfaction.

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