Driving future mobility for sustainable smart cities

Google

pwc

Contents

Foreword

The COVID-19 pandemic has exposed many vulnerabilities in our society, economy, and environment, including our dependence on activities that generate excessive CO_2 emissions. Global CO_2 emissions declined by 5.8% in 2020 because of the pandemic, but they rebounded by nearly 5% in 2021.[1] The latest Intergovernmental Panel on Climate Change (IPCC) Report provides new estimates of the chances of the global temperature increase exceeding 1.5°C over pre-industrial levels in the next few decades, and finds that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, the goal of limiting warming to close to 1.5°C or even 2°C will be beyond reach.[2] In fact, managing carbon emissions is on the top of many major cites' agendas, and more than 1,049 cities in 67 regions have pledged to halve emissions by 2030.[3]

At both Google and PwC Consulting LLC (hereinafter, PwC Consulting), we believe in building a more sustainable future for everyone to enable well-being, environmental and economic benefits. Therefore, we decided to jointly publish this paper based on the following strategies of both companies:

Google's sustainability efforts are focused on 3 key areas: 1) decarbonizing our energy consumption to operate on carbon-free energy everywhere 24/7, 2) maximize reuse of finite resources across our operations, products and supply chains and enable others to do the same, 3) replenish 120% of the water we consume by 2030 and actively support water security and ecosystems where we operate.[4]

Under the landmark global strategy The New Equation,[5] PwC Consulting LLC's diverse professionals combine human ingenuity with technology to solve important problems such as the impact of disruptive technologies, climate change and geopolitical division.

We hope that this paper will bring new perspectives to stakeholders all over the world and inspire them to develop sustainable smart cities, as well as provide ideas as to how smart mobility will play a role in future smart cities, as the turnaround of mobility is an issue that all cities must address.

Kazuko Abe
Director / Google Japan G.K.

Norio Katayama
Partner / PwC Consulting LLC (Japan)

Chapter 1

Current landscape of cities

1-1

Key challenges surrounding cities

Cities account for more than 50% of the global population, 2/3 of global energy consumption, and more than 70% of annual global carbon emissions.[6] As urbanization and globalization progress, large cities are facing social challenges such as overpopulation, environmental challenges, urban flood damage and other vulnerability against disasters. In addition, large numbers of people and enormous amounts of goods are moving into, out of, and within the populated areas every day. Cities are also facing several imminent challenges in the transportation sector such as emissions, congestion, parking issues, and siloed transportation services to mitigate CO_2 emissions from road traffic.

New York State introduced a new act in 2019 requiring passenger vehicles that enter or remain in New York City's Central Business District to be tolled[7] and New York City also encourages its people to use sustainable transportation such as walking, bicycles, and electric scooters in combination with public transportation to mitigate the chronic traffic congestion that the city faces.

In Tokyo, COVID-19 decreased the number of people using public transportation by half due to an increase in the number of people working from home.[8] The use of e-commerce services also increased, resulting in more frequent delivery of smaller parcels, which in turn led to a shortage of workers in the logistics industry.[9] We believe there is an opportunity to further optimize transportation operations to support the rapidly changing needs of society.

As urbanization accelerates around the world, smart cities have been drawing attention for their utilization of digital technologies such as IoT, 3D maps data, geospatial analytics and satellite images, as methods of solving the various problems that have long faced cities. In the past, the goal of smart cities was to introduce technologies that had been individually optimized for each field and improve the operations of those technologies. The current focus, however, is to provide services for people through collaboration among a broad ecosystem of organizations. This has made it more important to develop sustainable cities with interoperability and scalability in mind.

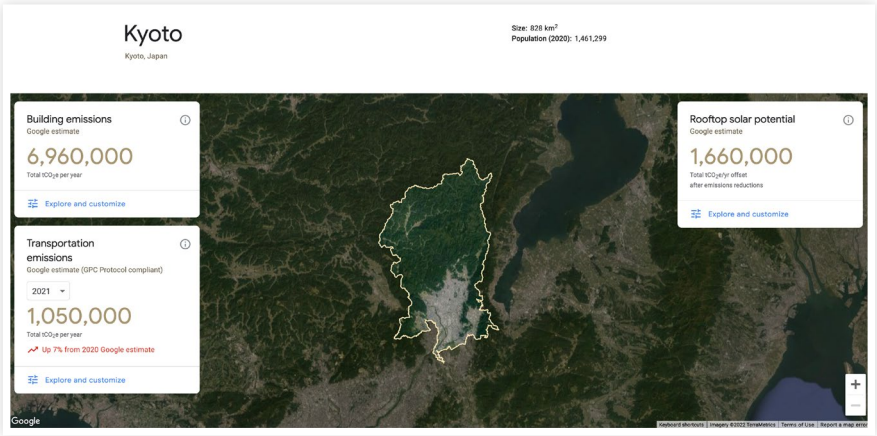
1-2

The importance of sustainability

The United Nations Framework Convention on Climate Change (UNFCCC) initiated a global decarbonization campaign called “Race to Zero”.[10] Its objective was to build momentum around the shift to a decarbonized economy ahead of the 26th UN Climate Change Conference (COP26), where governments were asked to uphold their commitments to the Paris Agreement. This sent governments a resounding signal that business, cities, and investors need to reunite in order to meet the Paris goals and drive a more inclusive and resilient economy. Thanks in part to such global efforts, the Glasgow Climate Pact adopted at COP26 emphasized the importance of the “1.5°C target” (the goal of limiting the global temperature increase to 1.5 degrees Celsius over pre-industrial levels), and both developed and emerging countries manifested concrete actions to achieve the target of net zero carbon emissions. This helped underscore the global importance of sustainability.

Major cities have also set ambitious goals in their climate action plans, which seem hard to achieve without reverting our lifestyles to what they were before the industrial revolution—an unrealistic prospect. However, policies that encourage better land use; more responsible use of energy, water, and waste; and an inclusive economy can make great strides towards reducing our carbon impacts. While we do not believe in technology for technology’s sake, we believe that technology will play a critical role in making processes more efficient, resilient, inclusive, and adaptable.

One of those tools is Environmental Insights Explorer (EIE), which Google launched in 2018. EIE is an online tool available to 40,000 cities globally to help policymakers measure, analyze and identify strategies to reduce CO_2 emissions.



Example: Kyoto

The tool covers key data points including building and transportation emissions, solar rooftop potential, air quality and tree canopy coverage. The goal of these efforts is to enable the cities to take informed actions with high quality data and collectively reduce 1 gigaton of carbon emissions annually by 2030, which equates to the volume of CO_2 emitted from over 120 million homes (based on the US average). One recent example of a city leveraging the EIE tool is from Kyoto, Japan. By leveraging data as a useful reference on solar rooftop potential, they were able to enhance their proposal to secure funding for their solar rooftop platform project. The city is also monitoring the impact of COVID-19 on CO_2 emission volumes resulting from transportation usage trends.

Customer testimonial

"The key advantages of Google's EIE tool are the ability to compare data across multiple cities with a consistent methodology, the ability to customize calculations with parameters and the speed and recency of the data being used".

— Masayuki Fujita, Environmental Policy Department, City of Kyoto.

Even in regions like Asia where access to renewable energy is more difficult, Google is taking the needed steps to advance sustainability. At the end of 2018, we signed a long-term agreement to purchase the output of a 10 MW solar array in Tainan City, Taiwan. This deal was made possible by discussions between Google, industry stakeholders, and the Taiwanese government—which amended Taiwan's Electricity Act in 2017 to allow non-utility companies to directly buy renewable energy and decrease their carbon footprints. This makes Google the first corporate power purchaser to directly buy renewable energy under the change to the Act.

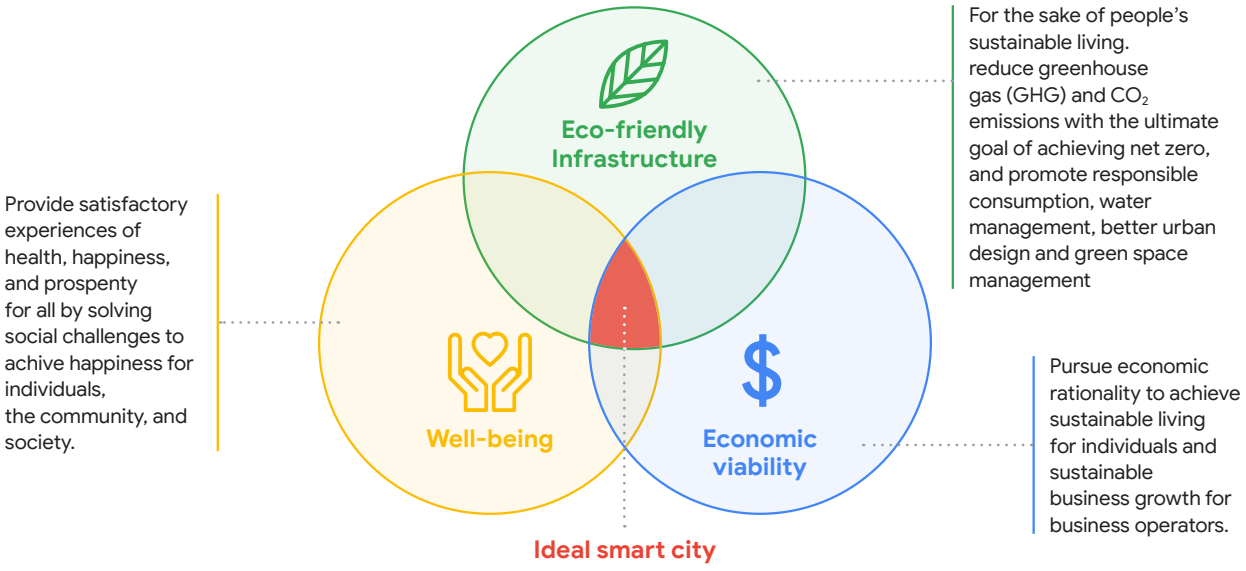
Now, what are some common pitfalls when developing a smart city?

Some smart cities risk becoming commercially unviable due to the overemphasis of environmental aspects or failure to provide sufficient well-being despite being very economical and efficient. These pitfalls occur when developers fail to sufficiently consider the perspective of sustainability. For a smart city to provide social benefits and solve social challenges in addition to contributing to the achievement of the 1.5°C target, it is essential to consider sustainability from a long-term perspective.

What, then, needs to be considered when developing a sustainable smart city?

Various organizations have defined the concept of a smart city in multiple ways, but at Google and PwC Consulting, we believe that a sustainable smart city is defined by the following 3 elements: eco-friendly infrastructure, economic viability, and well-being. By "eco-friendly infrastructure," we mean mechanisms that enable people and organizations to proactively reduce their CO_2 emissions and choose how to reduce their carbon footprint not only for their own day-to-day lives but also for future generations, and that enable companies to improve their operations in view of the entire supply chain in order to achieve long-term carbon neutrality. It also enables responsible consumption, water management, better urban design and green space management. It involves making life supports that ensure an equal, if not better, way of life for future generations. "Economic viability" refers to the pursuit of economic reasonability for both users and providers. For example, when companies provide transportation services that are efficient with respect to both distance per passenger and cost per distance, this can help to streamline their business operations from a total optimization standpoint while also providing more convenient services for users. Finally, "well-being" means providing multifaceted happiness to all people by solving social challenges with respect for diversity in terms of age, language, culture, gender, values, ability, and more to improve mental, physical, and social health.

Three elements of a sustainable smart city



When building a sustainable smart city, it is vital that the city grows by balancing all of these 3 elements, rather than focusing solely on any one. This philosophy of the 3 elements that are vital to the development of a sustainable smart city will serve as the foundation for the subsequent chapters.

Google's sustainability commitment (details)

Google

Commitment

At Google, we remain committed to sustainability and continue to lead and encourage others to join us in improving the health of our planet. We also don't take for granted the privilege of being a company that serves millions of people around the world and continue to strive on our mission to build a better future for everyone. That is why we are approaching sustainability from multiple dimensions across our partners, cities, and individuals.

Operations

In our third decade of climate action, we are going even further to help build a carbon-free future for everyone. Here's how:

- We're eliminating our entire carbon legacy, effective today.
- We are the first major company to make a commitment to operate on 24/7 carbon-free energy in all our data centers and campuses worldwide.
- We're investing in technologies to help our partners and people all over the world make sustainable choices.
- We estimate that the commitments we're making today will directly generate more than 20,000 new jobs in clean energy and associated industries, in America and around the world, by 2025.

Message from leadership

"We firmly believe that every business has the opportunity and obligation to protect our planet. To that end, we're focused on building sustainability into everything that we do- from designing efficient data centers to creating sustainable workplaces to manufacturing better devices and creating more efficient supply chains. But our goal is much bigger: to enable everyone—businesses, policy makers and consumers—to create and live in a more sustainable world." —— Google CFO, Ruth Porat.

PwC's sustainability commitment

Commitment

The PwC global network has made a worldwide science-based commitment to achieve net zero greenhouse gas (GHG) emissions by 2030. This commitment includes supporting our clients in their efforts to reduce their emissions as well as reducing those from the PwC global network's operations and suppliers. PwC has committed to decarbonizing our operations, including our travel footprint, in line with independently validated science-based targets, and neutralizing our remaining climate impact through carbon removal projects. We also engage with our suppliers to help them tackle their climate impact.[11]

Operations

In 2018, the PwC global network joined the RE100, a global corporate renewable energy initiative bringing together large businesses committed to 100% renewable electricity. In July 2021, our targets were independently validated by the Science Based Targets initiative (SBTi). This validation affirms PwC's approach and timeline to achieve its net zero 2030 commitment. Importantly, our targets go beyond direct (scope 1 and 2) emissions to include indirect (scope 3) emissions, which account for the largest segment of our emissions. Additionally, PwC has committed to the United Nations' Race to Zero campaign and Business Ambition for 1.5°C, which aim to build momentum around the shift to a decarbonized economy.[12]

Message from leadership

"As we support our clients and suppliers in transforming their businesses to achieve net zero, we recognize the importance of actively reducing the climate impact of our own operational footprint—including scope 3 emissions."

—— Global Leader for Purpose, Policy and Corporate Responsibility for the PwC global network, Colm Kelly.

Chapter 2

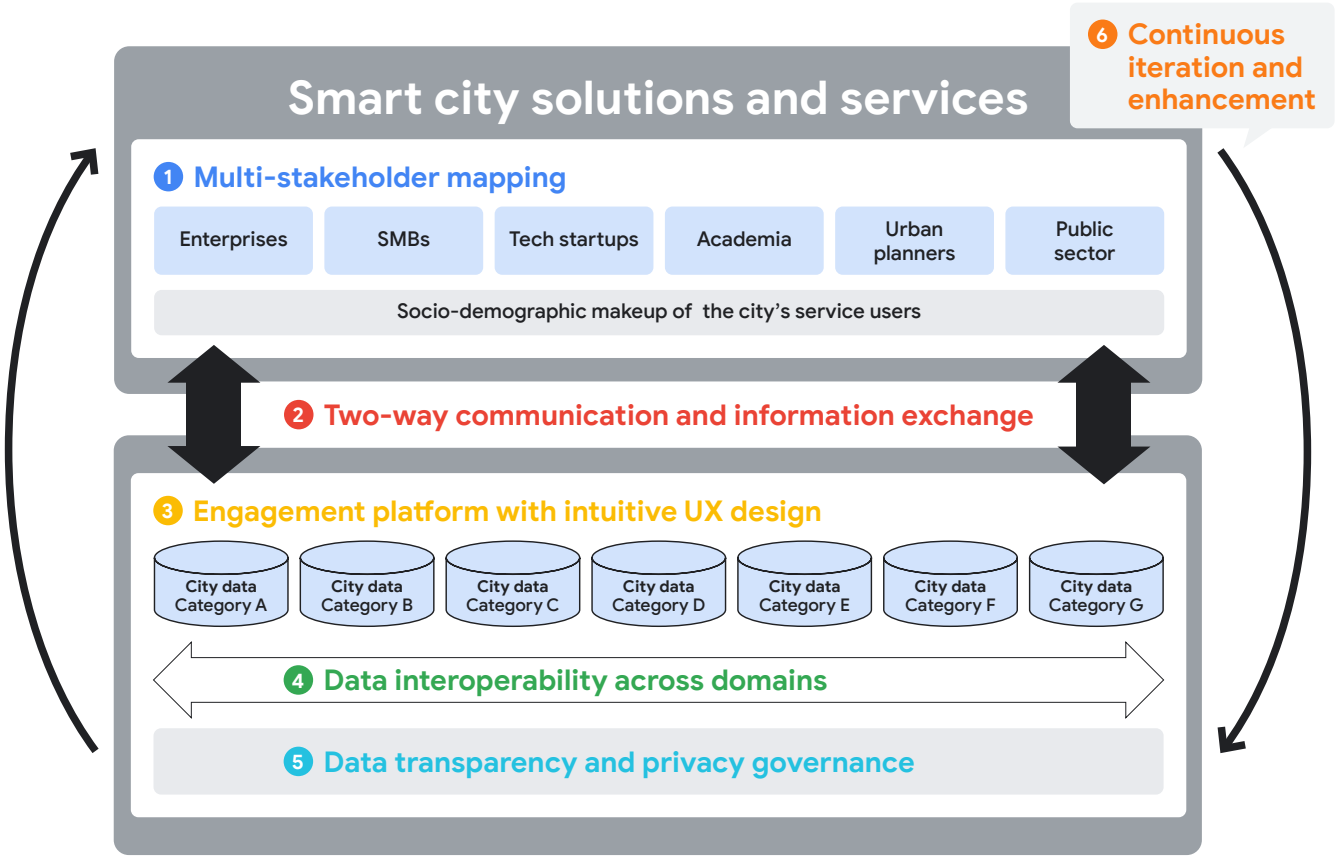
The human-centric approach

2-1
What is the human-centric approach?

At Google, there is a saying that goes “Focus on the user and all else will follow.” While there are many factors that influence a business decision, it is this relentless pursuit to prioritize the values and benefits of end users that enable a successful product or service model. We believe the same approach needs to be applied to smart city initiatives.

As mentioned in the previous chapter, modern technology provides substantial opportunities for smart city use-cases. However, technology-led approaches without the interest of the people who live in, work in, and visit the city (hereinafter collectively referred to as “service users”) in mind are fundamentally flawed and will eventually lead to the demise of any initiative. It is also critical to understand the needs of different communities within the city, not just the most vocal or affluent groups. This is what we refer to as the “human-centric approach” which positions the service users’ needs at the core of every project while engaging all stakeholders in the development process. Below are some of the key building blocks which are fundamental to this approach.

The human-centric approach



1 Multi-stakeholder mapping

Gaining a deep understanding of the makeup of your population is the starting point for any planning. This involves identifying stakeholder categories within your city such as enterprises, small and medium-sized businesses (SMBs), startups, urban planners, the public sector, and academia. It is also important to consider tourists and the role they play in shaping the services needed to attract people from other cities and even countries to maintain a vibrant city economy. Another layer is the socio-demographic composition of the city in terms of age, gender, ethnicity, affluence, education, and other attributes. Once you have developed a map of the population, the next phase is to uncover key trends and challenges the city population is facing, whether those include poverty, healthcare, transportation, or other topics of interest.

2 Two-way communication and information exchange

In order to validate and refine the core challenges and opportunities of your city, it is important to establish a platform or an organized forum to engage in dialogue with your stakeholders. This can be in the form of a city hall or community level discussions, innovation ideathons to involve local service users of all ages, hackathons for entrepreneurs to propose prototype solutions, or the building of a web platform to exchange information and ideas that flow both ways in a virtuous cycle. An inclusive environment that welcomes opinions from all community members, including underrepresented groups, becomes the foundation of trust and engagement when developing smart city initiatives.

3 Engagement platform with intuitive UX design

Without an easy and convenient way to access, analyze and understand these data points, most service users will lose interest in such activities. At the core of the human-centric approach is the need to design a user experience that is intuitive for all service users, including those who are less digitally savvy. This principle should be prioritized across all endeavors including how you engage your stakeholders, how you disclose and share city data and how you design the key services to be provided in your city.

4 Data interoperability across domains

Data can yield deeper and more meaningful insights when cross tabulation is possible. For example, population breakdown by age may be useful as a standalone dataset in some cases, but you can gain even more actionable insights by overlaying data on traffic accidents for correlation analysis. To enable this, we must strengthen data interoperability across multiple domains by using a consistent design for collection, formatting and disclosure.

5 Data transparency and privacy governance

Once you have identified the city stakeholders and the most significant issues to be solved, you need to share data points that are relevant to your community. Whether these are data points on city KPIs, demographics, environment, mobility, energy use, or crimes, this information is meant to help guide discussions and decisions within the community and monitor progress over time. The categories of data that the city can disclose are determined by what has been properly collected and organized in a digestible manner. Data collection and disclosure methods also need to respect that the privacy of individual data subjects is protected, so that data can be accessed and used in a safe and reliable manner.

6 Continuous iteration and enhancement

There is no end stage to the development of a smart city. As the needs of service users and the environment the city operates in will continuously evolve, so will the city's need to adapt to these changes by listening, testing and iterating with new services and solutions. The aforementioned building blocks will enable you to create an ongoing dialogue with the key city stakeholders to co-create a city that continues to grow and adapt in the coming years and decades.

2-2
Humanizing the digital experience for all

Have you ever thought that digital service platforms provided by governments could be easier to use? The quality of a government service website and apps are the basis on which services are provided to service users, and it is for this reason that we at Google and PwC Consulting believe that such websites are an essential component of a sustainable smart city. Furthermore, we believe that applying the human-centric approach to government digital service platforms could make a big difference in the well-being of service users as well as the sustainable growth of the city. In the context of cities, the human-centric approach is a creative approach to problem solving to improve quality of life and experiences for both communities and individuals.

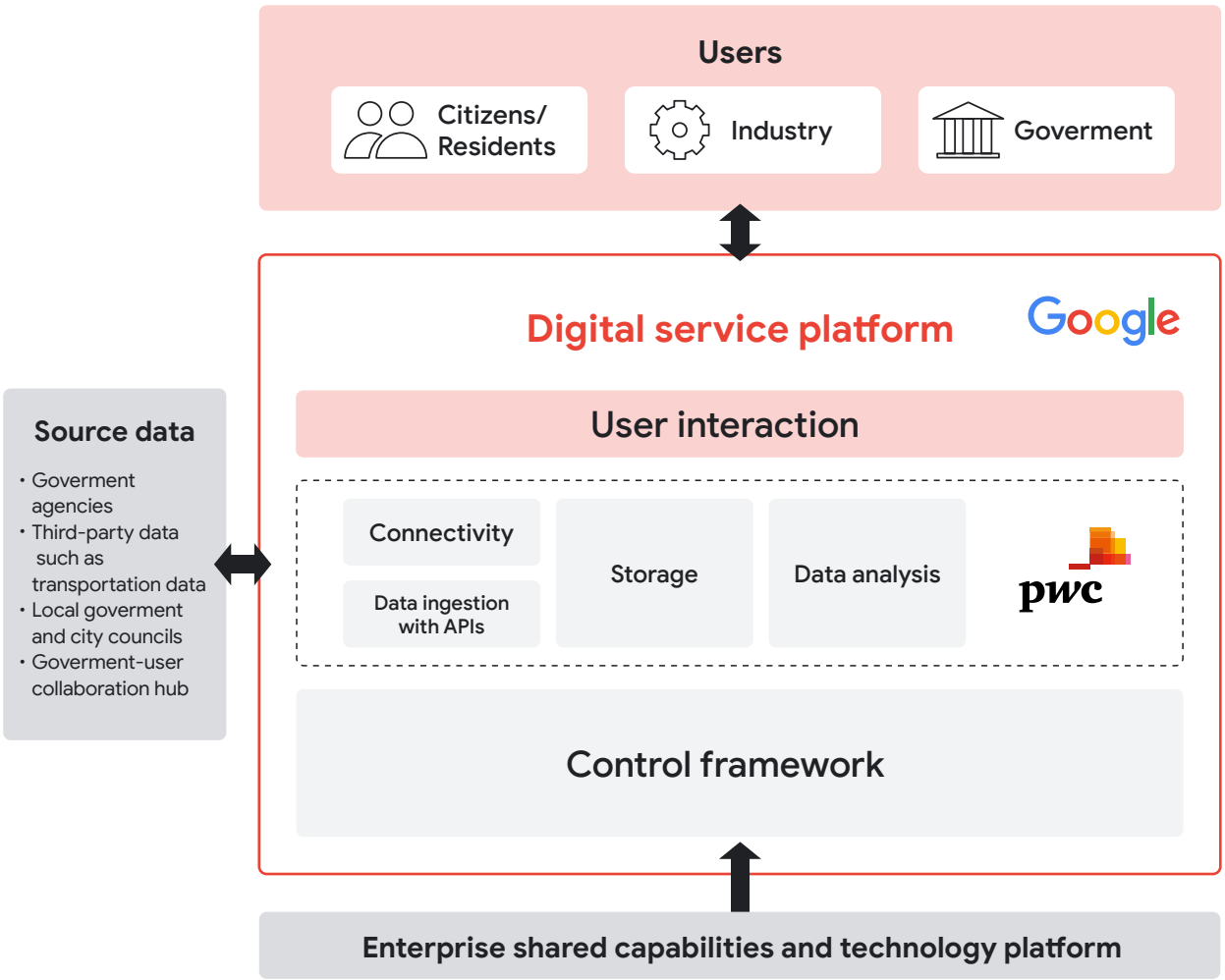
In fact, Google and PwC have just started a joint project in Australia, aimed at helping a public sector department to realize their ambitious vision to become a world leader in user-centric government.

Over the years, cities have been trying to establish their websites as centralized “one-stop shops” for citizen services. However, people who use these websites often feel frustrated by the confusing and complicated user interfaces, which make it difficult to find the information they are looking for. But although service users are so unsatisfied with these government websites, they have no choice but to use them.

Therefore, with the aim of becoming a service-oriented partner which provides services that people are eager to use at the major milestones of their life, this city embarked upon a project to build a user-centric digital services platform. To do so, they have incorporated the results of research on Australians’ values (which indicated that many Australians highly value inclusiveness and connectedness, leisure, safety, and healthcare), human nature (which is not always logical or rational) and people’s day-to-day experiences using Google (to search and discover and to map and navigate almost every day).

Collaboration between Google and PwC helps to make this ultimate goal possible, thanks to the unique principles of each company. In this context, we aim to deliver a seamless and personalized experience to service users, making information easily searchable and accessible to the public by simplifying complex back-end data flows across multiple government departments and augmenting this with Google's data and services. Service users can customize spatial layers or specific visualization formats, program advanced searches, provide comments and feedback, or pose questions, just like they do when using Google as part of their daily lives. Google and PwC believe that those experiences can build trust between service users and the government and thereby improve service users' life journeys.

Human-centric digital services platform



Chapter 3

Sustainable mobility for all

Mobility, defined as the movement of goods, services and people, is at the core of today's climate change discussions. In major cities where high volumes of people and goods are being transported on a daily basis, local governments and service providers should consider smart mobility solutions to counterbalance their significant carbon emissions impact. In fact, the transportation sector today is still responsible for 27% of CO_2 emissions in the world[13] and is the fastest growing source of greenhouse gas emissions from fossil fuel, which in turn is the largest contributor to climate change. Therefore, when we attempt to solve the mobility challenge in smart cities, we are simultaneously addressing the broader environmental sustainability issue.

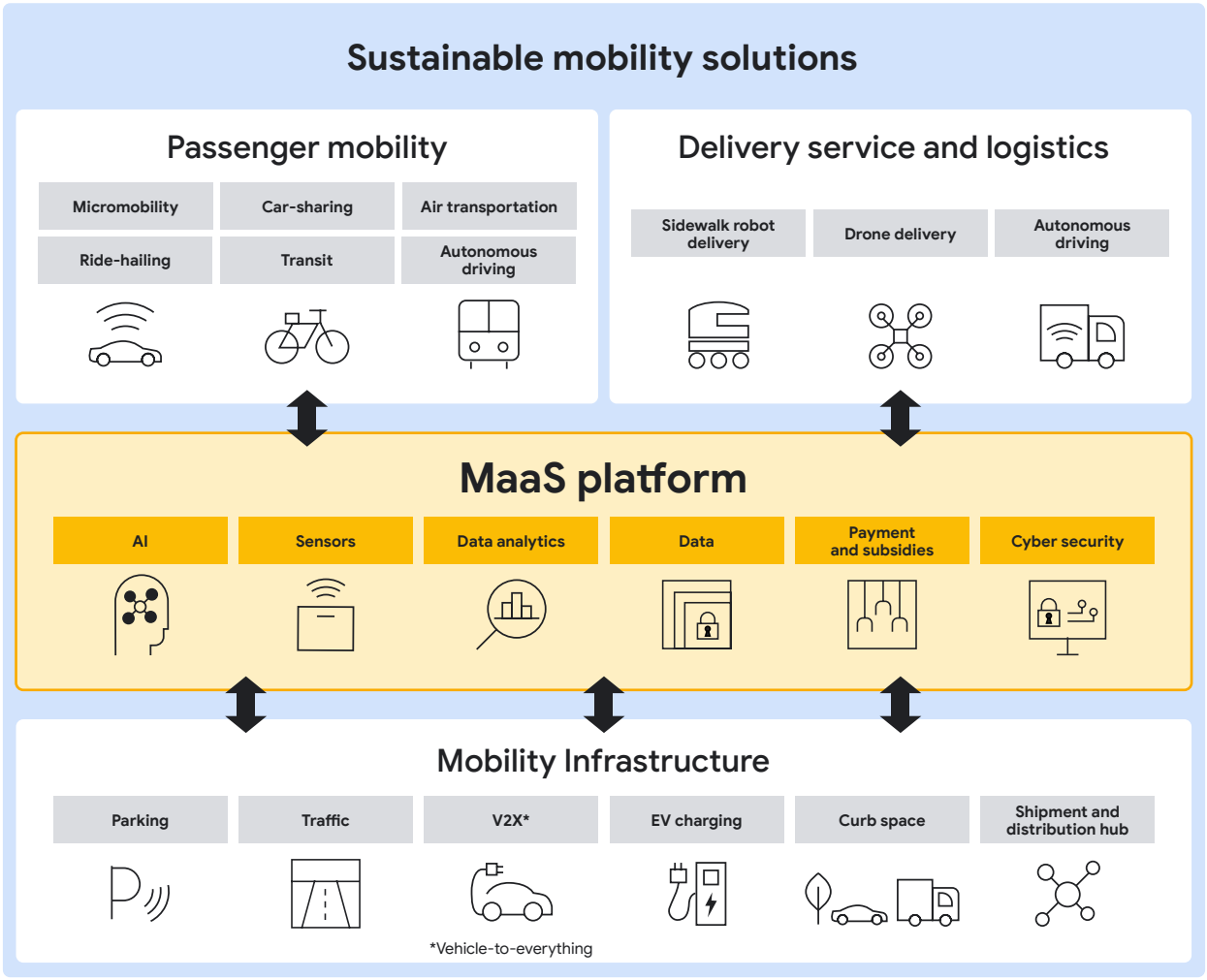
With the progress of modern technology across the fields of new energy vehicles, autonomous technology, and ride-sharing services, mobility has become one of the most promising fields for technology applications to have a direct impact on improving the environment. However, despite all these recent technology advancements to help improve sustainability, accessibility to these newer modes of transportation is still limited in many markets, while conventional means of travel with a high carbon footprint, including gasoline-engine based cars, trucks, and two-wheelers, remain the norm, and continue to generate significant carbon emissions.

Since each individual has their own distinct circumstances to consider when deciding how to move from point A to B, such as time, economic and physical constraints, there is no one-size-fits-all approach to solving mobility issues. For countries where people rely on conventional means of transportation, we need to think of ways to help optimize and reduce travel distance and time to lower overall emissions. For more advanced markets that are experimenting with new mobility solutions, we need to help optimize their operations and enable sustainable business growth and market penetration. For people with disabilities and senior citizens who have different mobility needs, we need to think of solutions for improved accessibility. Taking into account the mobility needs of all citizens echoes our human-centric approach in designing smart cities.

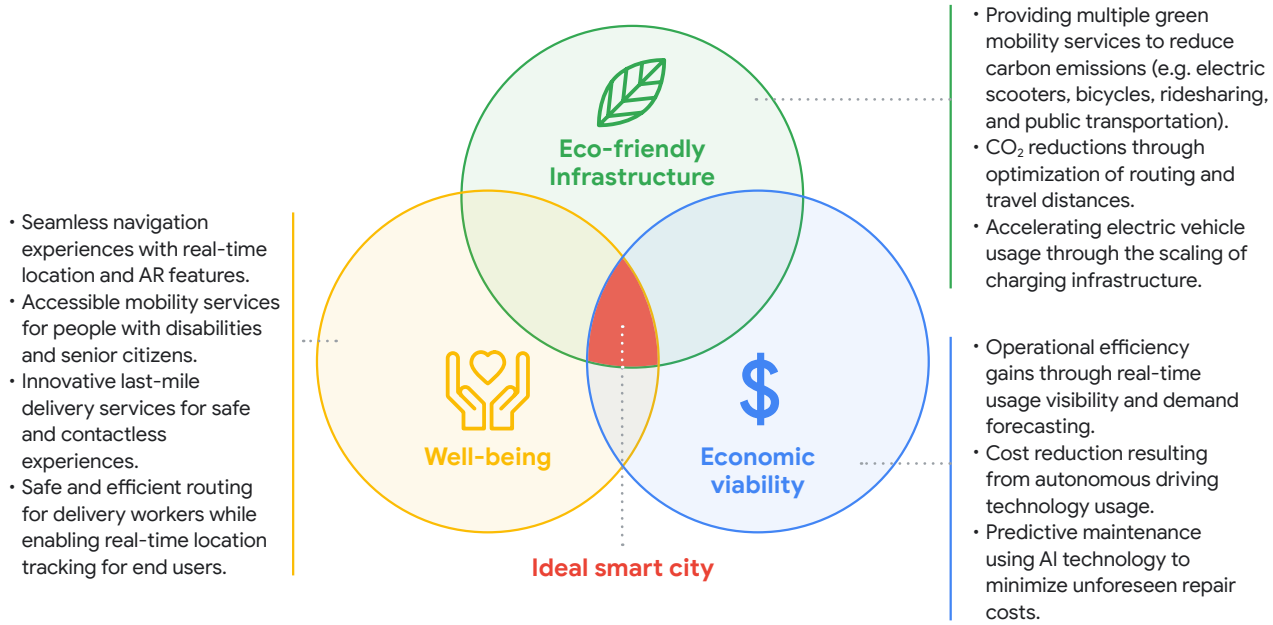
Three categories of mobility

Mobility can be broken down into 3 broad categories: 1) Passenger mobility for the movement of people, 2) parcel delivery and logistics for the movement of goods, and 3) infrastructure that supports the operations of these mobility options. When implementing smart mobility solutions across these categories, it is critical to consider the three elements (eco-friendly infrastructure, economic viability, and well-being) we described in Chapter 1. Furthermore, to enable sustainable smart mobility solutions, we must balance each of the respective elements with ensuring seamless data integration that spans multiple domains.

Sustainable mobility solutions map



Major impact of smart mobility solutions on the three elements



The following section highlights examples of how Google and their key partners are enabling sustainable mobility across multiple dimensions. From advancements in newer mobility solutions to bringing efficiency to conventional modes of transportation, our goal is to showcase different ways that cities can approach mobility based on their local needs.

Passenger mobility

The CASE (connected, autonomous, shared, electrification) revolution is ushering in a new era of mobility solutions aimed at providing more innovative modes of sustainable transportation. In this field, the public and private sectors are collaborating to experiment with solutions that meet the needs of service users while balancing economically viable business models. Conversely, while new mobility solutions continue to receive global attention, public transport plays a critical role in providing reliable mobility with less environmental impact than personally owned gas vehicles. Therefore, technological advancements in public transportation are equally important in achieving sustainable mobility as they contribute to a cleaner environment with reduced traffic, a decrease in oil consumption and improved air quality. Below are a few examples of how Google is collaborating with key partners towards this greener state.

Acciona Mobility

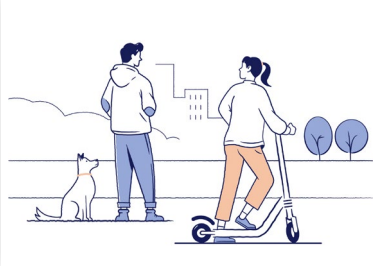
Driving the world toward low-carbon transportation solutions with Google Cloud (details)

Acciona is a Spanish multinational company committed to developing and managing infrastructure and renewable energy. In 2018, they launched a mobility sharing service called Acciona Mobility using e-scooters powered 100% by energy from renewable sources. Users of this service can validate their license, find, reserve, and rent the scooters via app and pay on the basis of minutes spent riding. Since their initial launch in Madrid, their operations required rapid scaling to multiple cities operating over 10,000 scooters with a data-driven strategy to deliver high-quality services to end-users. This includes storing all information related to the service on Google Cloud such as the location of scooters and their availability status on a primary data warehouse to analyze and gain insights on how to optimize supply and demand. They also leverage Google Maps Platform APIs to translate the geographical coordinates of scooters into an easy-to-read address displayed on a visual map. Today, with their continued commitment to lead the transition toward a low-carbon economy, they have serviced well over 3.5 million rides and reduced CO_2 emissions in their operating cities by more than 1,000 tons.

Entur

An end-to-end multi-modal platform service (details)

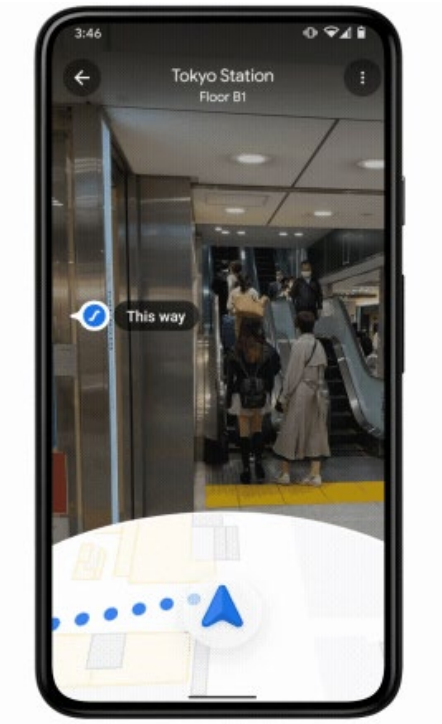
Based in Norway, Entur operates the national registry for all public transport in the country and they've partnered with Google to develop a multi-modal mobility service to connect a range of transportation services for the end-user. This requires the company to collect data from 60 public transportation operators while capturing data from 21,000 daily departures across more than 3,000 routes. They use Google Cloud's AI-analytics solution to gather and analyze information from every transport provider, every route, and every timetable across all mobility options to monitor details such as carriage capacity, seat availability, pricing and even accessibility for disabled riders. More recently, they're working with Google to explore new use-cases such as combining road traffic information with public transportation data to recommend optimal transport service options to its end-users.



JR East

The future of public transportation (details)

East Japan Railways (JR East) is the world's largest railway, with over 13.1 million passengers on 12,000 trains per day. Their business expands across retail, advanced R&D, manufacturing trains, financial services and urban development, as well as "Suica"—the most popular electronic (NFC variant) payment system nationwide. As they grow their lifestyle business and undertake efforts to realize their "Move Up 2027" vision, JR East has strategically stepped forward to connect their broad business domains and develop partnerships for seamless mobility. More recently, they have partnered with Google with real-time and estimated arrival time data on Google Maps to ensure users can plan their trips in advance and make the best use of their time. Additionally, a ticket purchasing function has been added to the interface for an increased convenience factor and enablement of an increasingly seamless customer journey. Furthermore, during transfers at key stations, airports or large public facilities, Google's Indoor Live View technology enables seamless navigation experiences throughout and between different building floors. For example, travelers can find the right train station platforms for transfers—or navigate to one of 150+ ramen stands for a bite to eat. With travel safety as one of the highest priorities for JR East, they have experimented with Google's AI visual inspection technology to identify potential wear and tear on the railroad tracks for preventative maintenance.



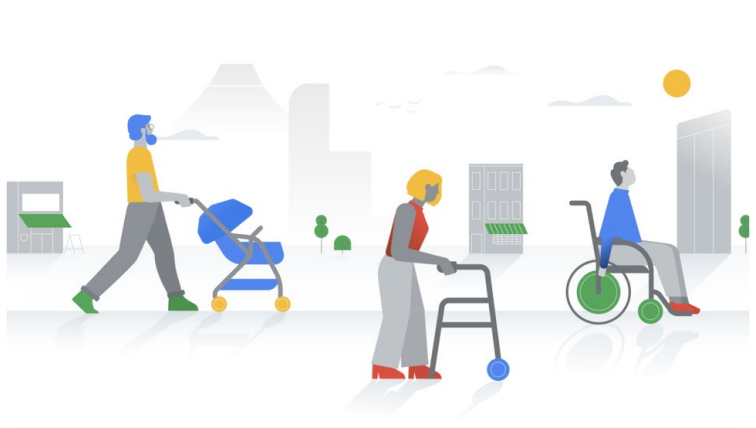
Customer quote

"Our holistic partnership with Google started in May, 2019. By combining the strength of Google's platform and technology with JR East's data and physical infrastructure, we've collaborated on several projects such as business process reengineering and customer digital services. Google is a key partner of ours with a strong culture of innovation that creates advanced and diverse technologies."

Google

Advancing accessible mobility for all (details)

Wheelchair users face many mobility challenges such as stairs or insufficient space when navigating routes within cities. To help combat this problem, Google has enabled Accessible Places, a feature to have wheelchair accessibility information more prominently displayed in Google Maps. When this feature is activated, a wheelchair icon will indicate an accessible entrance and other information such as accessible seating, restrooms or parking. Today, this information covers more than 15 million places around the world and continues to grow. This launch is a milestone in our journey to build a better, more helpful map for everyone which includes recent efforts to help find accessible places, transit routes and walking directions. Additionally, Google Maps has been adding accessible navigation inside train stations. New features provide passengers with more detailed information on accessible routes within the station, helping them make informed choices, plan their trips and travel smoothly. This is live in cities including Tokyo, Sydney, São Paulo, Boston, Prague, and Budapest.



Delivery services and logistics

While transportation for people is a key part of the sustainable mobility equation, it does not address the entire picture. The shipment of goods and services is equally important, especially during the COVID-19 pandemic when the global population relied on it as a lifeline. In fact, freight transportation makes up 8% of global greenhouse gas emissions, and carbon emissions from this sector may double by 2050.[14]

Gojek

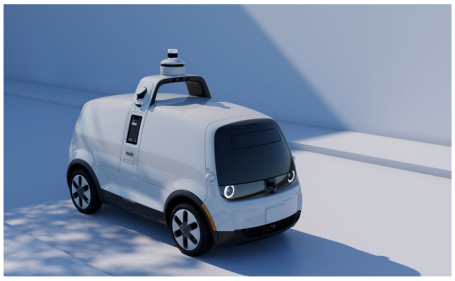
Creating a mobility marketplace with Google Maps Platform (details)

During the pandemic, we witnessed an ever increasing reliance on on-demand delivery services. Gojek is an Indonesian on-demand multi-service platform and digital payment technology group who is driving innovation in this space. They have built a one-stop "super app" platform with more than 20 services, connecting over 190 million users across the APAC region with over 2 million driver-partners and 500,000 merchants. On a daily basis, they match millions of drivers and recipients taking into account optimal pricing, while also prioritizing high-efficiency for mapping and routing for their drivers. To enable this mobility marketplace operation, they have partnered with Google to improve the in-app experience for Gojek consumers and driver partners. With the support of On-demand Rides & Deliveries solution from Google Maps Platform, their drivers are able to use advanced routing and navigation which takes into account the constantly changing road and infrastructure situation in the markets. The solution also enables consumers to track their deliveries, route, and ETA in real time within the app for a seamless delivery experience. Lastly, Gojek is able to monitor delivery request locations to efficiently match them to consumers. Combined together, the data shows that drivers using this technology are 20% more accurate on arrival time.

Nuro

Building the future of autonomous robotics (details)

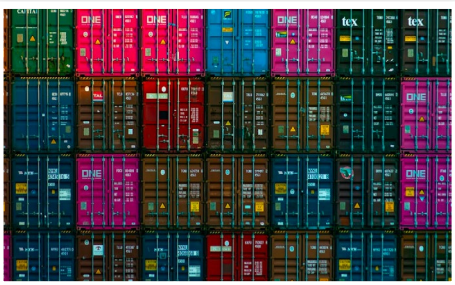
Nuro has a fleet of autonomous vehicles designed to address many of the problems related to last-mile delivery. And every day, these vehicles—and their sensors—generate a lot of data before parking for the night. For Nuro engineers, that data can help them understand the impact of new on-road features, make improvements to their vehicles' software, and ensure even better deliveries for their customers. For Nuro, the key challenge is how to move petabytes of data as quickly, securely, and easily as possible from their edge environments, like vehicle depots, to Google's Cloud Storage. For this delivery effort, Nuro selected Google's Transfer Appliance with its new online transfer capability, now generally available. With these new appliances, Nuro will be able to automate much of their storage transfer needs. When their autonomous vehicles return to the depot, they can move data like software logs, LIDAR data, and sensor data—all ideal fits for Google's Cloud Storage-from parked vehicles to the Transfer Appliance.



Chorus

X's moonshot to improve how we make, move and use the world's goods (details)

Despite trillions of dollars' worth of goods moving through the world's supply chains each year, too many businesses today still lack the tools they need to see where things are in real time. Project Chorus is developing new sensors, software and machine learning tools to radically improve our real-time understanding of where physical goods are located, where they are needed, what state they are in, and how they are used. We've been piloting Chorus technologies with partners around the world. Chorus's sensors were onboard delivery trucks for a number of months and were able to detect patterns and anomalies in delivery times. The insights we collected have been crucial as we develop our technologies and work towards building the tools businesses need to make better decisions, reduce waste and use the assets they have more efficiently and effectively.



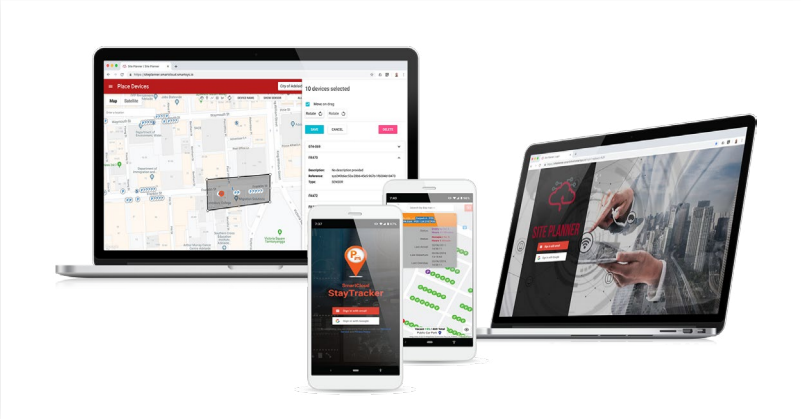
Mobility infrastructure

While the aforementioned examples all contribute to a more sustainable mobility state, transportation infrastructure is the most fundamental element for any given city. In addition to enabling efficient movement of people, goods, and services, it is a core ingredient for basic economic growth and for accelerating efficient use of mobility. Google is working with innovative partners to make advancements in mobility infrastructure which aim to have a lasting impact for years to come.

Smart Parking

Transforming into a data-intelligence business (details)

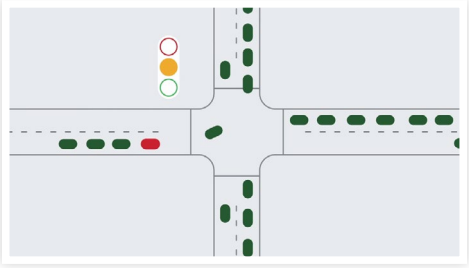
Operating from the UK, Australia and New Zealand, Smart Parking provides an end-to-end smart parking management and smart city solutions for cities. Their service covers various city parking environments including shopping centers, airports and municipal streets using sensor-based systems to register a vehicle's arrival and departure. They provide real-time insights into parking usage to optimize capacity and deliver automated guidance to inform customers on vacancy spaces. Furthermore, they provide data-driven insights to cities and operators on how to adjust and optimize their parking time limits to maximize throughput and increase revenue. Today, they cover more than 70% of production-scale smart parking services globally, and they have partnered with Google to rapidly expand their service footprint. By using Google technology, Smart Parking has been able to reduce IoT installation and operational support effort by more than half and enabled development of a smart cloud IoT platform in just 4 months and operate at city-scale.



Google

AI for more efficient traffic lights (details)

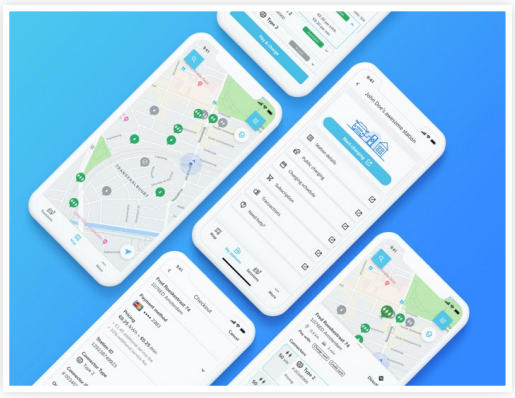
Improving the timing of traffic lights is critical for sustainability because optimized traffic signals can improve fuel consumption, reduce GHG emissions, reduce air pollution and noise pollution, and save valuable time for millions of drivers every day. Google is finding ways to make routes more efficient across an entire city, with early research into using artificial intelligence to optimize the efficiency of traffic lights. We've been piloting this research in Israel to predict traffic conditions and improve the timing of when traffic lights change. So far, we are seeing a 10-20% reduction in fuel consumption and delay time at intersections both in Israel and Rio de Janeiro. We're excited to expand these pilots to more cities across the world.



EVBox

Creating a scalable charging management platform (details)

There are more than one million electric cars registered in Europe, and that number is going up fast along with demand for charging infrastructure. Based in the Netherlands, EVBox launched Everon in October 2019 as a platform-as-a-service (PaaS) solution that companies can customize and use to manage their electric vehicle charging networks. Benefits range from controlling how much power to give each car to creating pricing models and billing customers and optimizing the use of their respective charging networks via smart charging. Using Google Cloud, they monitor their entire operation with over 400,000 charging stations in real time, conduct BI analysis using Google's Big Query solution to develop future pricing models and use Google Maps to connect users with charging stations based on their individual needs. Furthermore, they are able to predict future demand by geography to scale their operational footprint.



Geotab

Turning data from vehicles into actionable insights (details)

Cities are continuously looking for efficient ways of gathering insight to help inform city and road infrastructure planning. With the advancement of technology and IoT devices, local government and private sectors can observe relevant city data at scale. Headquartered in Canada, Geotab is an innovative telematics company that provides connected-transportation solutions to more than 49,000 customers across public and private sectors. Geotab processes and analyzes data from more than 2.6 million connected vehicles that generate over 50 billion data points per day. Every data point is ingested and managed securely and efficiently with Google's BigQuery solution, allowing Geotab to provide AI-driven recommendations, benchmarking and performance assessments while simultaneously allowing its customers to optimize, streamline and scale their fleet's data. With this high data volume and wide geographic coverage, Geotab's platform provides government agencies with key data insights to help solve urban transportation issues such as road congestion, hazardous intersections and deteriorating road conditions.

Chapter 4

Redesigning smart cities

Overall optimization at the city-wide level

As explained in the previous sections, various types of solutions and services can be effective for optimizing mobility and travel, which can in turn contribute to carbon-neutral efforts and ultimately to achieving a sustainable smart city. Improving the efficiency and convenience of individual solutions is therefore essential.

At the same time, there is a natural limit to what can be achieved through individual solutions. To realize a sustainable smart city, further improvements at a city-wide level are also necessary. As we have seen, “sustainable” refers not only to being environmentally friendly but also to ensuring the well-being of service users, and also the viability of the economy. For instance, to achieve the original purpose of mobility, which is to enable access to the things and the services that people need, service providers need to transform and expand the very concept of mobility. This includes, for example, providing options that eliminate or significantly reduce the need to travel through alternative support measures such as online medical care in cooperation with delivery from a local pharmacy. In fact, delivery from hyperlocal premises is becoming the recent trend in some cities.

This transformation requires coordination between mobility solutions and other solutions outside the mobility industry, such as in the healthcare and retail industries as well as city planning and urban design. It is critical, therefore, to redesign the city from a holistic perspective, through overall transformation of the fundamental structures of solutions and services.

Interoperable data management is a key to success

As previously mentioned, interoperability of cross-domain data is essential for local governments to gain a comprehensive view of the city and to interpret the meaning, context, and relevance of the data.

The interoperability of cross-domain city data both from local governments and from private sector sources offers a new wave of opportunities and enables city systems to draw effectively on interoperable data. For example, in the case of online medical care mentioned above, cities can provide a wider variety of services and support options in addition to more efficient

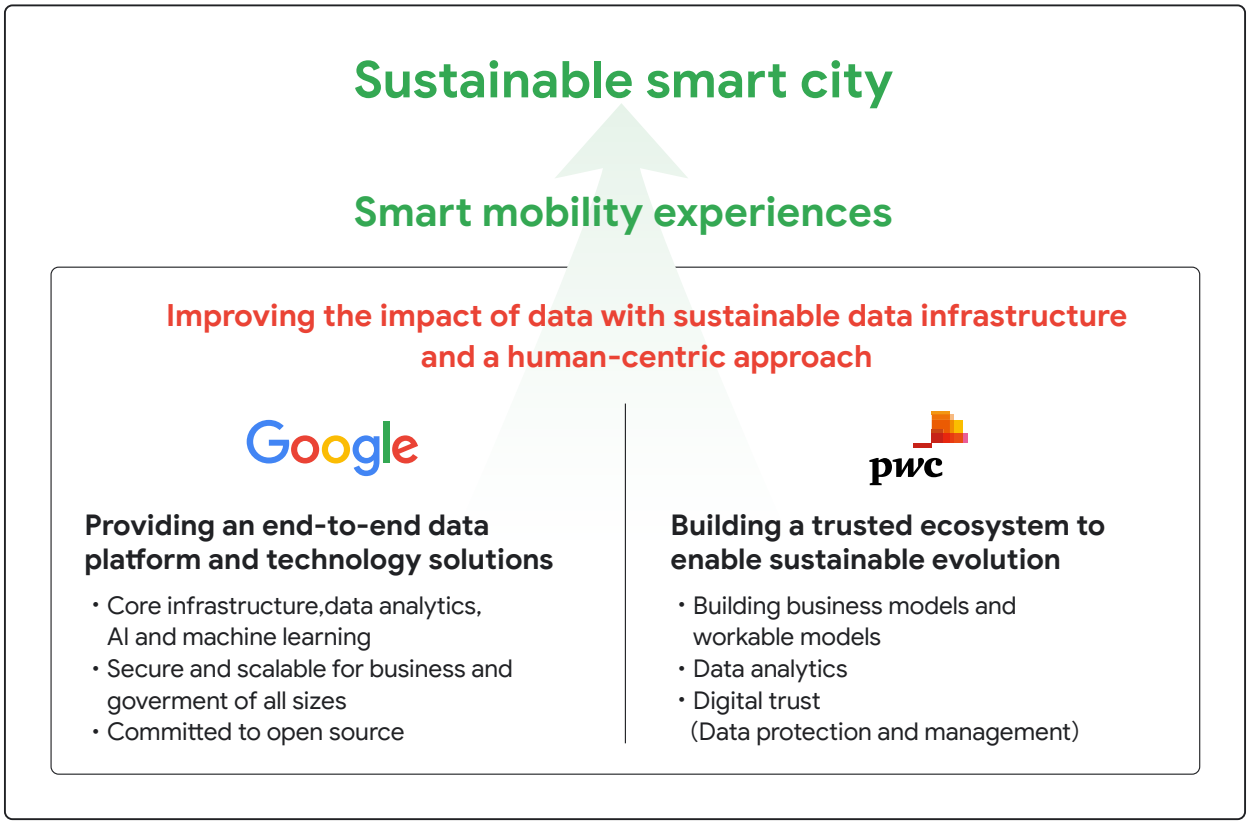
transport, by linking data on public transportation, healthcare backlogs, medical institutions, and pharmacies with personal data, with the patient's consent.

Despite the considerable potential of city data, some current smart city initiatives mainly address data platforms as individual and unconnected ICT development projects, and do not sufficiently consider all stakeholders and their data needs. Consequently, such initiatives are sometimes vulnerable to failure due to insufficient stakeholder input, failure to meet requirements, and information fragmentation and overload.

How we can drive change in smart cities

This is where the strengths of Google and PwC Consulting come in. Both the data platform provided by Google and the ecosystem created by PwC Consulting are essential elements to enabling innovation for sustainable smart cities.

Sustainable data infrastructure for smart cities



As the platform and the ecosystem need to work in synergy with one another, both incorporate the following five aspects based on our core value of human-centricity.

Five aspects of sustainable smart cities

1 User focus	• Focus on the collective benefits to service users, communities, and societies • Ease of participation for all stakeholders • Evaluation of user attitudes and enthusiasm
2 Flexibility	• Development of a solution and an ecosystem that is open, scalable, and interoperable with various stakeholders, based on unique characteristics of communities and needs of individual cities, which differ from city to city and evolve over time
3 Innovation	• Incorporation of an open and adaptable culture, reflecting innovation in technologies and business models • Provision of fast, accurate, and high-quality technologies with consideration for adaptability
4 Responsibility	• Trustworthy, secure, and transparent data management • Creation of appropriate governance structures in compliance with relevant laws and regulations • Assessment of, compliance with, and clearance of legal requirements • Pursuit of security and safety through risk analysis
5 Feasibility	• Evaluation of business and economic feasibility as well as continuity based on a combination of business models, operational structures, and financials • Development of practical operation and technical capability to provide services and generate revenue • Identification of those who will bear the cost of services and other critical stakeholders

We believe that the most important aspect of a smart city is that the platform, services, and technologies provide solutions to the users' actual needs, as services provide value only when they are used.

Therefore, technologies should not only be deployed, but should be monitored and analyzed through a data platform and ecosystem that can verify the degree to which they are actually being used and integrated into the lives of users.

No two cities have the exact same issues and data. Therefore, it is essential to build an appropriate infrastructure that can evolve as those needs change.

A way forward

Driving change to realize sustainable smart cities with mobility

In the fast-changing environment of the 2020s, sustainability is a more important objective and responsibility than ever before at all levels of society. And it is now critical to collaborate and bring sustainability efforts together at the city, town, or village level in order to make those activities more precise and impactful at the same time.

As this report states, it is important to build a smart city foundation which bridges all relevant data together. However, technology solutions alone will not provide a solution for the many challenges at hand. Such a solution requires involvement and collaboration from all key stakeholders including individuals, businesses, policy makers, urban designers, and academia.

On top of this foundation, we believe mobility will play a significant role in driving wider city collaboration to address climate change-related needs, as it is a fundamental element within cities which intersects with multiple domains. Once mobility is connected with other data and services, it will become possible to create more sustainable services involving other industries and areas.

Google and PwC have experience engaging in various smart city projects around the world. We understand that pursuing sustainability at the city-wide level is not an easy and short path, but rather a long and challenging road. However, we are confident that it is feasible if all stakeholders come together to jointly confront those initiatives that are important for pursuing sustainability.

At Google and PwC, we believe that the most important step is for all related parties to commit, to set a goal, and to start working on it, even if those first steps are small ones. And Google and PwC Consulting are committed to supporting these steps as a platform provider and an ecosystem enhancer, respectfully, maximizing the efforts of all the participants in order to utilize data and technologies for a bigger and more impactful movement.

References and endnotes

1 IEA. “Global Energy Review 2021.” (https://www.iea.org/reports/global-energy-review-2021/co2-emissions)

2 IPCC. “Climate change widespread, rapid, and intensifying”(https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/)

3 The United Nations Framework Convention on Climate Change (UNFCC). “Race To Zero Campaign.” (https://unfccc.int/climate-action/race-to-zero-campaign)

4 Google. “Our comittment to sustainability - Google sutainability”(https://sustainability.google/commitments/)

5 PwC. “The New Equation.” (https://www.pwc.com/gx/en/the-new-equation/the-new-equation-strategy.html#:~:text=The%20New%20Equation%20focuses%20on,first%20is%20to%20build%20trust)

6 The World Bank. “Urban Development.” (https://www.worldbank.org/en/topic/urbandevelopment/overview#1)

7 The New York State Senate. Vehicle & Traffic (VAT) Chapter 71, Title 8, Article 44-C, Section 1704, “Establishment of central business district tolling program.”(https://www.nysenate.gov/legislation/laws/VAT/1704)

8 East Japan Railway Company. “News: Analysis and investigation of changes in station usage due to the influence of COVID-19 using Suica data.” (https://www.jreast.co.jp/press/2021/20211104_ho04.pdf)

9 Logistics Policy Division, Ministry of Land, Infrastructure, Transport and Tourism. “About recent logistics policy.” (https://www.mlit.go.jp/common/001388194.pdf)

10 The United Nations Framework Convention on Climate Change(UNFCC) (https://unfccc.int/climate-action/race-to-zero-campaign)

11 PwC. “Corporate responsibility.” (https://www.pwc.com/gx/en/about/corporate-responsibility.html)

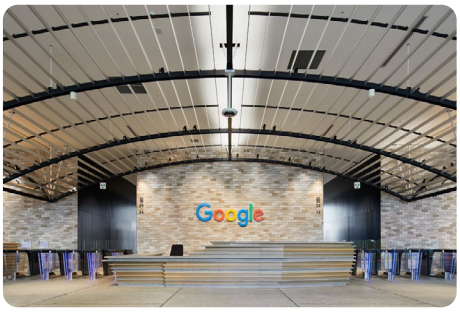
12 PwC. “Committing to Net Zero by 2030.”(https://www.pwc.com/gx/en/about/net-zero.html)

13 IEA. “Greenhouse Gas Emissions From Energy Data Explorer.” (https://www.iea.org/articles/greenhouse-gas-emissions-from-energy-data-explorer)

14 Moseman, Andrew, feat. Josué Velázquez Martínez. “Ask MIT Climate: How can carbon emissions from freight be reduced?” MIT Climate Portal. (https://climate.mit.edu/ask-mit/how-can-carbon-emissions-freight-be-reduced)

Contacts

for inquiries on business partnership opportunities



Google

Google Japan G.K.

smartcity-mobility@google.com

PwC

PwC Consulting LLC (Japan)

jp_llc_pr-mbx@pwc.com

Key contributors

Kazuko Abe
Director
Google Japan G.K.

Leo Osako
Head of Automotive
APAC Partnership Solutions

Mikiko Ujihara
Cross-Google Partner Manager
APAC Partnership Solutions

Naomi Gaskell
Strategic Partner Development Manager
Geo Product Partnerships

Paula White
Customer Engineer
Google Cloud

Willa Ng
Partnerships and Strategy Lead
Pebble @ Sidewalk Labs

Tomomi Matsuoka
JAPAC Regional Lead
Google Earth Outreach

Norio Katayama
Partner
PwC Consulting LLC
(Japan)

Akira Yasuda
Director
PwC Consulting LLC
(Japan)

Yuji Fujita
Director
PwC Consulting LLC
(Japan)

Kentaro Abe
Director
PwC Consulting LLC
(Japan)

Akira Naito
Senior Manager
PwC Consulting LLC
(Japan)

Miki Edamoto
Senior Manager
PwC Consulting LLC
(Japan)

Kazuyoshi Mori
Manager
PwC Consulting LLC
(Japan)

Hazem Galal
Partner & Global Leader for Cities & Local
PwC Middle East

Carlos Aggio
Partner
PwC Australia

PwC refers to the PwC network member firms and/or their specified subsidiaries in Japan (including PwC Consulting LLC), and may sometimes refer to the PwC network. Each of such firms and subsidiaries is a separate legal entity. Please see www.pwc.com/structure for further details.