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Unlocking the Public Value of Data: Key Governance Strategies for the Smart Transportation Systems

Research Report
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Introduction

According to the World Bank, 56% of the world population reside in cities, and this number continues to grow. As our cities become denser, issues like road safety, congestion, and environmental pollution become pervasive challenges for policymakers. Transportation safety is the biggest problem of all: according to the World Health Organization, car accidents are responsible for 1.3 million deaths annually. In 2022, Canada registered 1,934 road deaths, which signifies a staggering 9.4% increase from 2021 and a 4.4% increase compared to 2019. In the United States, car crashes have long been the leading cause of death for people aged 1 to 54.

Municipalities devise various strategies to make the streets safer: from implementing automated traffic management systems to investing in micro-mobility and public transit. In this study, I examine three municipalities that have become a testing ground for new transportation technologies. I analyse the municipal data policies, successful and failed transportation initiatives, and the role of data activism. Each case study draws attention to the economic, social and historical contexts that impact the way these communities handle data.

The report introduces three case studies: Seoul, Boston, and Pittsburgh. Methodologically, the study draws on the Governing Knowledge Commons Theory (GKC), which is a subfield of institutional economics that offers a rich toolset for the study of data governance, data governance policies and the communities that manage shared resources.

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Executive Summary

Key Findings:

- To generate economic and social benefits from mobility data, a municipality needs to become a data steward. When the city does not own or control the data collection and data processing infrastructure, data governance initiatives become too costly and ineffective
- Data-driven transportation initiatives require substantial public funding, yet they bring long-term benefits to the communities
- Commercial transportation solutions often fail to perform as expected and require co-development for each specific city/community
- The municipalities need to attract top talent, including data governance practitioners and social scientists
- Adopting a citizen-first approach may help the cities with the adoption of data-driven public transit

In 2020, computer scientist Casey Fiesler coined the phrase “data is people.” In doing so, she emphasized the fact that data governance raises important legal and political concerns, including those that pertain to privacy, democratic governance, and fair treatment of the data subjects. Governance of the data-driven transportation systems is an even more challenging task. When adopting new transportation solutions, municipalities deal with a plethora of issues: from correctly identifying the mobility needs of citizens to finding reliable vendors with which to partner to incorporating public feedback. As this study shows, the municipalities struggle to obtain mobility data, to implement mobility-related

technological solutions, and to finance them. Investments in the public data infrastructure and iterative approach to digital governance are paramount to successful deployment of new transportation technologies.

In this study, I conceptualize digital governance as the governance of data as well as data collecting and processing infrastructure (i.e., cameras, servers, and data analytics software). While data is essential to understanding and solving transportation issues, my analysis indicates that the adoption of data-driven mobility solutions is most successful when municipal governments exercise control of the data infrastructure.

The case of Boston is illustrative of many governance dilemmas the municipalities face when experimenting with new transportation technologies. Under the last two mayors, Martin J. Walsh and Michelle Wu, the municipality is seeking to address the issues of air pollution, traffic congestion, and equitable access to transportation. The Mayor's Office of New Mechanics has a mandate to partner with transportation researchers and technology vendors to test new solutions, a variety of which have been piloted over the last five years. Examples include digital maps that helped implement traffic reduction policies, new parking apps that introduced performance fees, and smart cameras that automatically ticketed traffic offenders. Many of these pilots faced public pushback and were eventually shut down. The relative lack of success with the data-driven transportation technologies in Boston can be attributed to the fact that Bostonians experienced reduced mobility options and perceived the piloted technologies as penalizing. The City of Boston learned the hard way that limiting the ability of citizens to drive in the city, without providing convenient public transit alternatives, leads to the ride-hailing services replacing personal cars and clogging the streets. The municipality's road safety policies have seen more success.

Through the implementation of Vision Zero, Boston managed to drastically reduce the number of traffic deaths in the city.

The case of Pittsburgh provides other important lessons. A former U.S. steel capital, Pittsburgh has been working to refocus its economy around technology, education, and healthcare. Under Mayor Bill Peduto, the municipality had partnered with university researchers, transit authorities, and ride-hailing companies to launch an open data hub. The city grappled with the issue of public access to transportation and required mobility and parking data to update its policies. Pittsburgh had also invested in the digitalization of public services and partnered with Uber to become the first U.S. city to test self-driving vehicles. However, data governance projects require large public investments and do not immediately generate visible impact. The residents of Pittsburgh protested Uber's self-driving pilot and disapproved of the city's funding of technology-related initiatives. When Peduto left the office, his data-governance initiatives were defunded. Transportation innovation in Pittsburgh continues at the city's flagship universities: Carnegie Mellon University and the University of Pittsburgh.

A story of tremendous success, the case study of Seoul is about a small country that survived a 40-year-long occupation and two wars but managed to build one of the best transportation systems in the world. Unlike Boston and Pittsburgh, Seoul has invested in the data collecting and data processing infrastructure and has been continuously improving its public transit. A data-driven system called TOPIS has been running Seoul's transportation for the last two decades. TOPIS relies on thousands of real-time sensors to collect information about traffic conditions, weather, and emergencies and deploys AI to manage highways. Home to 9.4 million people, Seoul has resolved the problem of traffic congestion, as 53.2% of commuters prefer taking public transit over driving. The

residents of Seoul have many transportation options: self-driving trains, electric buses, electric scooters, bicycles, and ride-hailing services. The Government of Seoul envisions the future of transportation as fully automated. Since 2023, the city has been piloting self-driving night buses. New policies, zoning requirements and technological standards in Seoul prepare for the launch of a fleet of self-driving shuttles and taxi services in 2026.

Methodology

This research report examines the case of institutional design for data-driven transportation governance. The study draws on the Governing Knowledge Commons framework (GKC), developed by Frischmann et al. (2014[1]; 2022[2]; 2023[3]) to study institutional arrangements for overcoming various social dilemmas associated with sharing and producing knowledge, data, and innovation. The GKC has been adapted from Elinor Ostrom's Institutional Analysis and Development (IAD) framework for natural resource commons (Ostrom, 1990)[4] to address the governance of intangible resources.

A Noble Prize winner in economics, Ostrom spent her entire career studying the economy of shared resources. Challenges associated with the governance of fisheries offer iconic representations of the "tragedy of the commons," where individuals refuse to cooperate in pursuit of their own goals (Hardin, 1971).[5] Ostrom's contributions to game theory show that the tragedy of the commons is a solvable issue. Individuals and communities create coordination rules and institutional arrangements that help govern the commons. The GKC extends Ostrom's IAD for the study of various resources, from biomedical research[6] to privacy[7] to smart cities[8].

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[1] https://academic.oup.com/book/36261
[2] https://www.cambridge.org/core/books/governing-privacy-in-knowledge-commons/FA569455669E2CECA25DF0244C62C1A1
[3] https://www.cambridge.org/core/books/governing-smart-cities-as-knowledge-commons/BD2D41AAAB106F43CC328A786224D0DB
[4] https://www.actu-environnement.com/media/pdf/ostrom_1990.pdf
[5] https://pages.mtu.edu/~asmayer/rural_sustain/governance/Hardin%201968.pdf
[6] https://academic.oup.com/book/36261
[7] https://www.cambridge.org/core/books/governing-privacy-in-knowledge-commons/FA569455669E2CECA25DF0244C62C1A1
[8] https://www.cambridge.org/core/books/governing-smart-cities-as-knowledge-commons/BD2D41AAAB106F43CC328A786224D0DB

The GKC framework equips researchers with a set of variables to analyze all kinds of governance arrangements. The external variables include resource characteristics, attributes of the community, and rules-in-use. The internal variables have to do with action situations, social positions of the actors, and possible outcomes. This study is mixed method research: I complement 20 expert interviews, transcribed and coded using OtterAI software, with the analysis of 1,300 pages of policy documents, statistical data, and grassroots reports.

The Case Study of Seoul

With a population of 9.42 million, the capital of South Korea accommodates some 20% of the country's population. Seoul's transportation history is a recent one, and it is a history of tremendous success. The efficacy of South Korea's transportation management rests on three basic principles: extensive data collection, public control over the data infrastructure, and user-centered approach to public transportation.

Seoul offers a variety of mobility options: subway lines, railways, buses, self-driving shuttles, electric bicycles, electric scooters, car-sharing services and licensed taxi services. On the city roads, data-driven traffic signals and automated enforcement help avoid congestion and penalize those who violate the traffic rules. On the highways, algorithms change the speed limits in real time to ensure smooth movement of people and goods at all hours of the day.

Like many other countries, in the 1980s, South Korea witnessed an explosive growth in car ownership. To tackle the issues of traffic congestion and environmental pollution, South Korea has continuously invested in public data infrastructure and high-quality public transit.

In this section, I draw on the GKC framework to analyze the governance of smart transportation in Seoul. My analysis focuses on several questions: what are the biggest challenges for the city? Which resources does the municipality have at its disposal? Who participates in the transportation planning in Seoul? What contested issues/conflicting interests are at stake?

Seoul's Transportation Policies, 1980–2024

Seoul's transportation policies have been continuously developing over the last three decades: from building new roads and highways to accommodating the growing demand for personal automobiles to subsidizing public transit to implementing automated traffic management systems and mobility-as-a-service.[9] There are three key aspects to Seoul's transportation policies: data-driven decision-making, large investments in public data and transportation infrastructure, and developing data-driven transportation as consumer-oriented services. The annual budget of the TOPIS system is KRW 200 billion (approximately USD 200 million).[10]

In the 1970–1980s, Seoul began introducing policies aimed at addressing the issues of congestion, air pollution, and traffic fatalities. In a fast-growing metropolis, where residents relied on private vehicles and taxis for all mobility needs, building new roads and implementing higher fines for traffic violations failed to resolve the city's transportation problems.[11]

Already in that period, the Government of South Korea realized the importance of mobility data, both statistical as well as digital. The Korea Transport Institute (KOTI)[12] was established in 1985 under the auspices of the Office of the Prime Minister to provide evidence-driven policy advice regarding the country's transportation infrastructure. Based on their recommendations, from the 1990s to early 2000s, Seoul implemented many data-driven solutions on the city's roads and highways, including traffic counting sensors (also known as the "loop sensors"

[9] https://www.seoulsolution.kr/en/content/transport-system-management-tsm
[10] https://use.metropolis.org/case-studies/topis-the-control-tower-for-seoul-city-s-transportation-system
[11] https://www.seoulsolution.kr/en/content/guide-transportation-policy-general
[12] As of 2024, KOTI is still operational and provides valuable police research on Korea's transportation issues: https://www.koti.re.kr/eng.do.

placed every 2 km in South Korea), automated traffic management systems, automated highway management systems, and automated bus management systems. In 2004, the integrated data monitoring system called TOPIS was launched, which has connected these multiple digital transportation systems.[13]

The most important goal of TOPIS is to identify factors that contribute to traffic congestion and intervene before a problem occurs. For example, the system may automatically close a highway lane where an accident happened and request the presence of police, ambulances, and maintenance workers. Connected with the weather monitoring and emergency systems, TOPIS sends automated messages to drivers and programs local traffic management systems to reroute traffic in the case of dangerous weather conditions.

In South Korea, the data-driven transportation policies have been incredibly successful. In the 1970s, the Government of Seoul demolished its streetcar network and began working on the first subway line. Over the next three decades, the city built eight subway lines to cover the entire city and developed a railway network that connects Seoul with the small towns of the Seoul Metropolitan Area. Between 1980 and 2002, the subway became the preferred mode of transportation for city commuters.[14] Over the next 20 years, the municipality bought several local bus companies and heavily invested in the bus infrastructure: adding new bus routes, installing bus-only median lanes, and launching new real-time bus management and information systems. These upgrades made Seoul's previously unpopular buses the second-most popular mode of transportation in the city.[15]

[13] https://topis.seoul.go.kr/board/openEngReference.do
[14] https://susa.or.kr/sites/default/files/resources/%EA%B5%90%ED%86%B5_10_TOPIS.pdf
[15] Report by South Korean Ministry of Land, Infrastructure and Transport (2021), https://www.molit.go.kr/USR/NEWS/m_35045/dtl.jsp?lcmspage=1&id=95085966

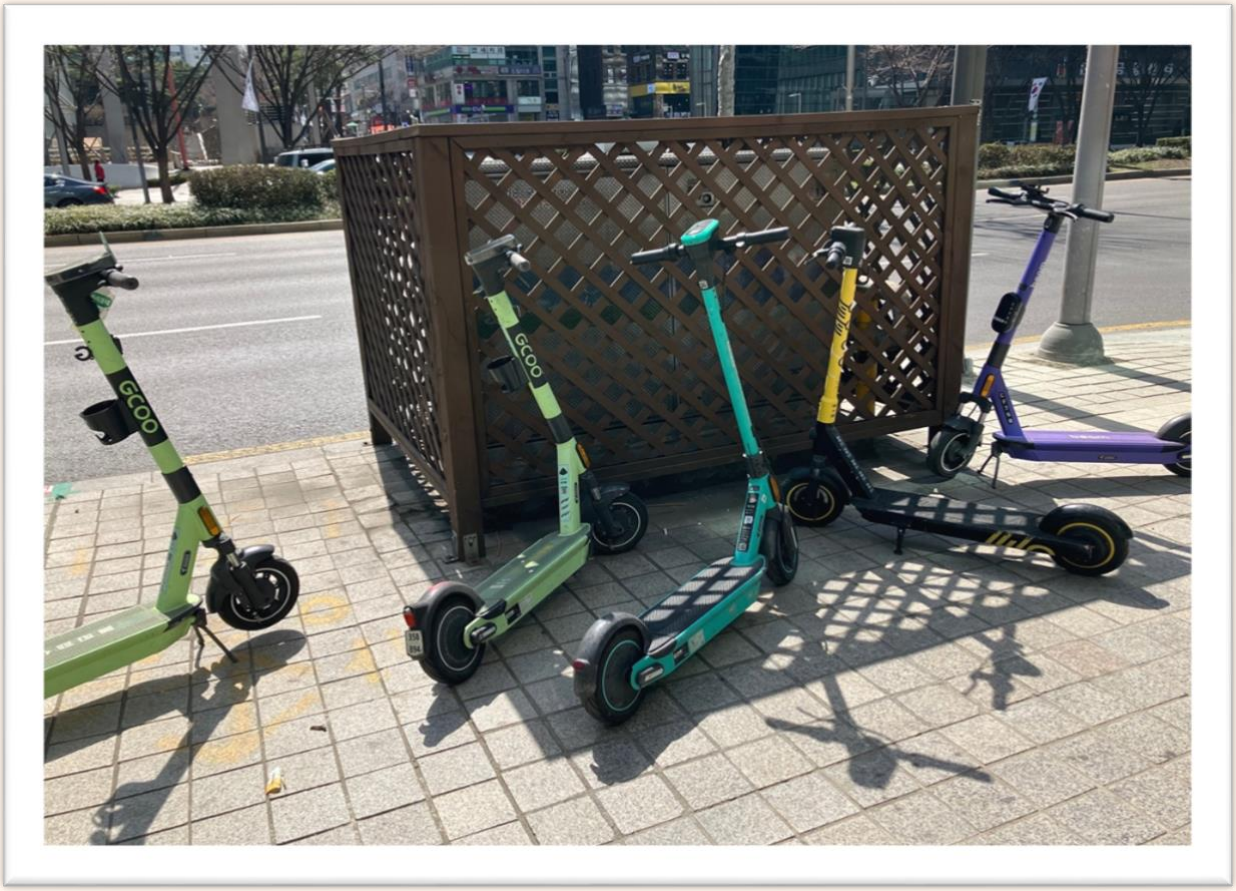


Figure 1. Electric scooters provided by the micro-mobility company GCOO. Seoul, March 2024. Image source: author

In Seoul and across South Korea, intelligent transportation systems (ITSs)[16] deploy CCTV cameras to detect incidents, roads in need of repair, and heavy traffic. Via text messages and smartphone applications, they inform drivers about the traffic conditions. As an added convenience, the ITSs automatically change posted speed limits on highways depending on the level of traffic; this helps get the cars through quickly in anticipation of the next waves of traffic.

Between 2015 and 2024, the city has implemented its vision of "human-centred"[17] transportation policies, in which mobility-as-a-service plays a central

[16] https://www.seoulsolution.kr/en/content/6536
[17] https://english.seoul.go.kr/wp-content/uploads/2019/08/TOPIS.pdf

role. Underpinning Seoul's human-centred approach to mobility is the promise to provide commuters with multiple transportation options, support low-carbon technologies, and prepare for the advent of self-driving vehicles. Indeed, the commuters in Seoul have many transportation options, including buses, car-sharing services, electric bicycles and scooters. An integrated payment system allows commuters in Seoul to use multiple modes of transportation with just one card, which also works as a credit card in grocery stores.[18] The goal of these policies is to ensure that Seoul's mobility options operate smoothly as an integrated public transit system.

Since 2021, Seoul has been subsidizing hydrogen and electric buses, aiming to replace 3,000 diesel buses.[19] As of 2023, the Government of Seoul had purchased 2,800 electric buses, 54% of which were Chinese-made.[20] The city also runs informational campaigns on the benefits of walking, aiming to free up more city space for street cafes and child-safe zones.

In 2020, KOTI conducted a survey of public attitudes towards the use of public transit (Figure 2). According to the study, 60% of Koreans still preferred driving their own vehicles over taking public transit, while 29.4% preferred trains and/or buses. In Seoul, however, the proportions were nearly reversed: 53.2% relied on public transit, while 35.2% preferred their own car.

As part of its "Mobility Innovation Roadmap," South Korea envisions self-driving cars as the future of transportation.[21] Preparing for this transition, the government is preparing to launch technical standards for autonomous vehicles and invests in the infrastructure that will support the seamless integration of

[18] https://www.seoulsolution.kr/en/content/one-card-fits-all-integrated-public-transport-fare-system
[19] https://www.seoulsolution.kr/en/content/9444
[20] https://pulsenews.co.kr/view.php?sc=30800028&year=2024&no=65224
[21] https://www.statista.com/topics/12262/autonomous-vehicles-in-south-korea/#editorsPicks

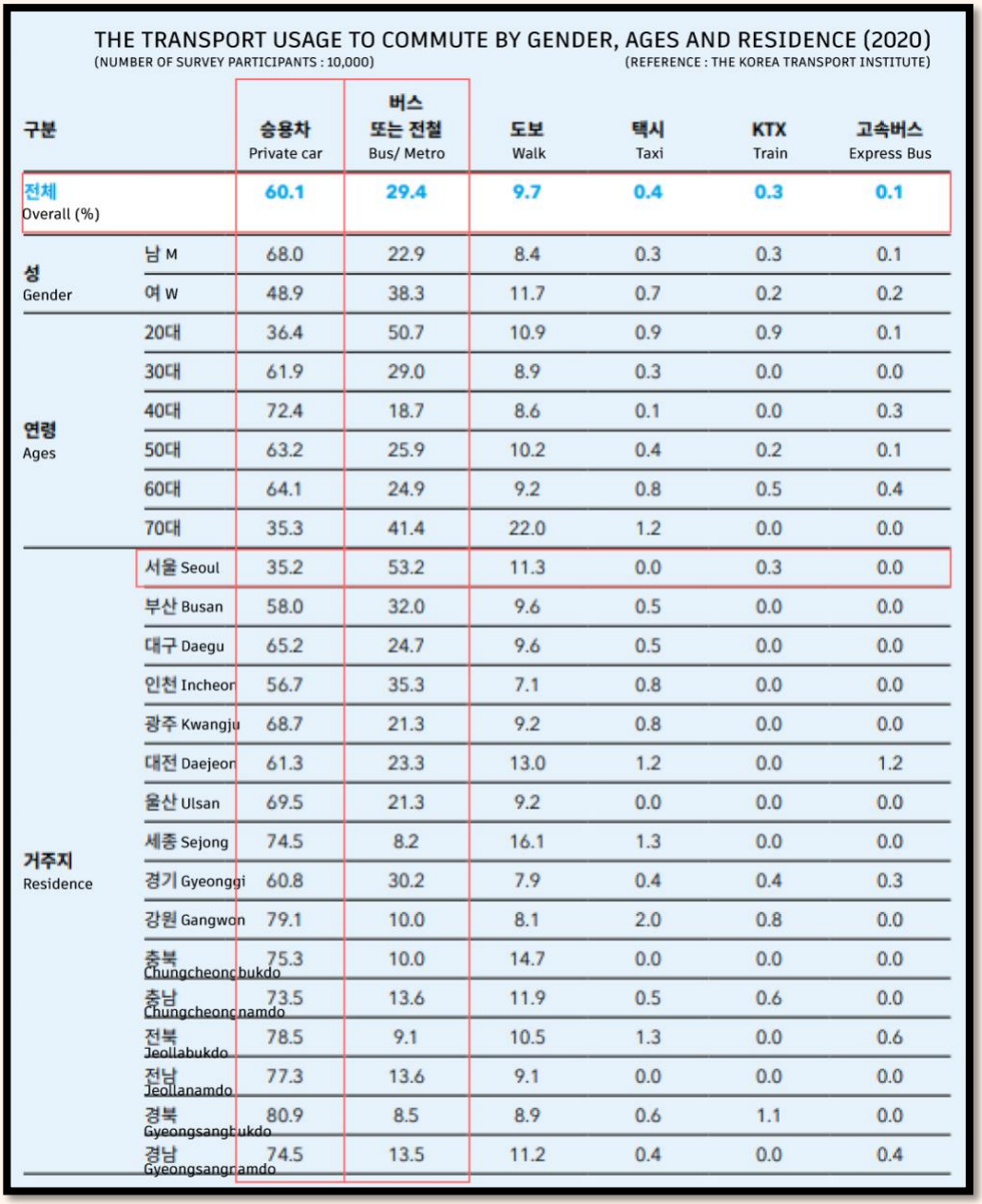
autonomous vehicles with the existing data and transportation systems. Since 2022, Korean automobile makers Hyundai and Kia have been testing autonomous vehicles.[22]

The Government of Seoul has released its own policy roadmap, *Seoul Autonomous Driving Vision 2030*,[23] with the goal of installing city-wide autonomous infrastructure by 2026. The city has experimented with self-driving buses and autonomous taxis. Since December 2023, commuters in Seoul have been riding self-driving night buses.[24]

[22] https://www.iotworldtoday.com/transportation-logistics/hyundai-mobis-plans-major-self-driving-test-in-south-korea

[23] https://english.seoul.go.kr/policy/transportation/seoul-autonomous-driving-vision-2030/

[24] https://www.bbc.com/news/business-68823705



THE TRANSPORT USAGE TO COMMUTE BY GENDER, AGES AND RESIDENCE (2020)

(NUMBER OF SURVEY PARTICIPANTS : 10,000) (REFERENCE : THE KOREA TRANSPORT INSTITUTE)

구분		승용차 Private car	버스 또는 전철 Bus/ Metro	도보 Walk	택시 Taxi	KTX Train	고속버스 Express Bus
전체 Overall (%)		60.1	29.4	9.7	0.4	0.3	0.1
성 Gender	남 M	68.0	22.9	8.4	0.3	0.3	0.1
	여 W	48.9	38.3	11.7	0.7	0.2	0.2
연령 Ages	20대	36.4	50.7	10.9	0.9	0.9	0.1
	30대	61.9	29.0	8.9	0.3	0.0	0.0
	40대	72.4	18.7	8.6	0.1	0.0	0.3
	50대	63.2	25.9	10.2	0.4	0.2	0.1
	60대	64.1	24.9	9.2	0.8	0.5	0.4
	70대	35.3	41.4	22.0	1.2	0.0	0.0
거주지 Residence	서울 Seoul	35.2	53.2	11.3	0.0	0.3	0.0
	부산 Busan	58.0	32.0	9.6	0.5	0.0	0.0
	대구 Daegu	65.2	24.7	9.6	0.5	0.0	0.0
	인천 Incheon	56.7	35.3	7.1	0.8	0.0	0.0
	광주 Kwangju	68.7	21.3	9.2	0.8	0.0	0.0
	대전 Daejeon	61.3	23.3	13.0	1.2	0.0	1.2
	울산 Ulsan	69.5	21.3	9.2	0.0	0.0	0.0
	세종 Sejong	74.5	8.2	16.1	1.3	0.0	0.0
	경기 Gyeonggi	60.8	30.2	7.9	0.4	0.4	0.3
	강원 Gangwon	79.1	10.0	8.1	2.0	0.8	0.0
	충북 Chungcheongbukdo	75.3	10.0	14.7	0.0	0.0	0.0
	충남 Chungcheongnamdo	73.5	13.6	11.9	0.5	0.6	0.0
	전북 Jeollabukdo	78.5	9.1	10.5	1.3	0.0	0.6
	전남 Jeollanamdo	77.3	13.6	9.1	0.0	0.0	0.0
	경북 Gyeongsangbukdo	80.9	8.5	8.9	0.6	1.1	0.0
	경남 Gyeongsangnamdo	74.5	13.5	11.2	0.4	0.0	0.4

Figure 2. A study of transportation use in South Korea. Source: https://nclurbandesign.org/sustainable-transport-system-case-study-of-seoul-south-korea/

The History of Seoul's TOPIS: An Exemplary Smart City

South Korea has often been praised for its safe, convenient, and reliable public transportation. [25] Latest available statistics show that the rates of customer satisfaction for Seoul's public transportation have grown from 58.2%[26] in 2004 to 90% in 2022.[27] Local newspapers describe Seoul's subway as safe, reliable, and comfortable.[28] The driver behind Seoul's transportation management is a data-driven system called TOPIS (Seoul's Transport Operation and Information System).

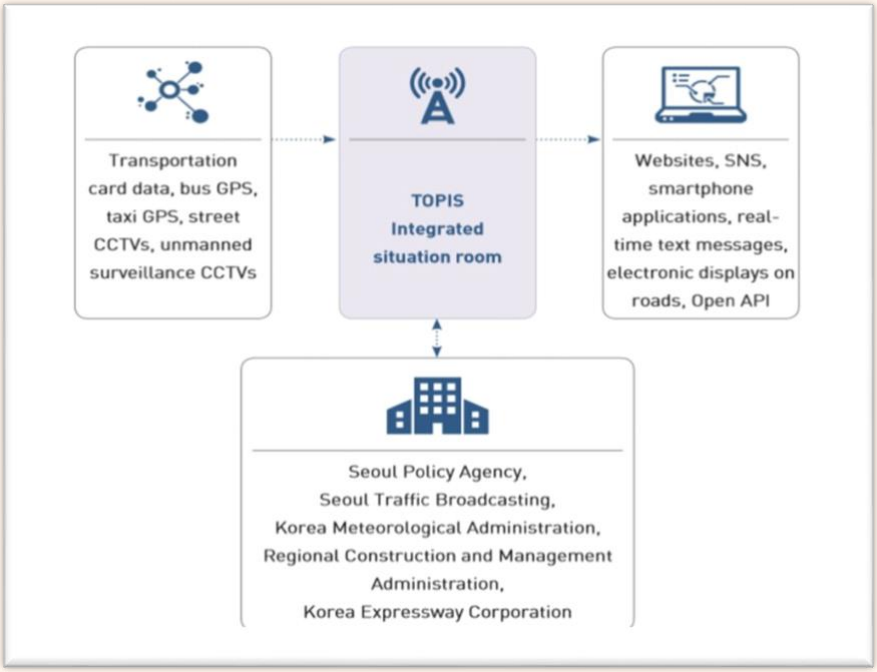


Figure 3. The data flows in TOPIS. Image source: https://topis.seoul.go.kr/openEngIntro.do

TOPIS gathers and analyzes multiple types of information, including GPS data from buses and taxis, payment data, CCTV footage, satellite data, weather

[25] https://www.tomorrow.city/what-makes-the-seoul-subway-system-one-of-the-best-in-the-world/
[26] https://www.metropolis.org/sites/default/files/seoul_public_transportation_english.pdf
[27] https://blog.naver.com/seoul-topis
[28] https://www.koreaherald.com/view.php?ud=20150325000952

information, and emergency systems signals. TOPIS shares the aggregated data and analytics in the form of open data as well as through text messages, real-time message boards, websites, and apps. Through its open API, TOPIS releases some 24 million data points a day. This data informs the work of several government agencies (Figure 3).

The history of transportation in Seoul began in the 1950s, when, during the Korean Civil War, the entire city was destroyed. In 1974, Seoul opened its first subway line (Line 1), which covered the downtown area. In the 1980s, personal automobiles became the most popular mode of transportation in South Korea. With the introduction of mass computers, the municipality began collecting and processing information about traffic flows. Central to the transportation policies of Seoul at the time was the concept of "traffic dispersion." The idea behind this concept was that city population should not rely on one mode of transportation for all mobility needs. The city's attempts to divide traffic flows to avoid clogging the city streets soon proved to be successful. In 1985, Seoul opened three more subway lines and revamped its bus system to create routes and schedules convenient to the commuters. Five years later, the city opened subway Lines 3–8 and imposed fines for the drivers who caused congestion in the streets.

In 1998, Seoul experimented with its first data-driven transportation solution: the Intelligent Traffic System in Namsan district (Figure 4).[29] Tested on a 10.6 km territory of the popular city park surrounding Namsan Mountain, this traffic management technology comprised a network of cameras that collected information about the popular routes and high-traffic times. The Namsan pilot was

[29] https://susa.or.kr/sites/default/files/resources/%EA%B5%90%ED%86%B5_10_TOPIS.pdf

so successful that, already in 2000, Seoul's Intelligent Traffic System was expanded to the city's highways.

Figure 4. The Namsan District, Seoul, March 2024. Image source: author

In 2004, the TOPIS control room was launched:

> The traffic information situation control room, which is an important part of Seoul TOPIS, is sometimes easily mistaken for the entire Seoul TOPIS. However, Seoul TOPIS actually refers to the intangible functional organization that manages Seoul city's ITS [Informational Transportation System], which applies advanced IT to traffic, as a practical department of Seoul city composed of 4 divisions and 90 employees.[30]

In the same year the control room was launched, Seoul introduced its first electronic payment cards. Similar to the 2024 transportation payment cards, which require tap-in and tap-off, those first cards were an important source of mobility data for the city. In 2005, Seoul launched its first "unmanned enforcement system," which uses data from street surveillance cameras to automatically issue tickets to the traffic offenders. Three years later, the city installed a network of bus information terminals that provides real-time updates about bus schedules and wait times. In 2009, a mobile traffic information service was launched, which allows the city to inform drivers and commuters about hazardous driving conditions. Since 2010, Seoul has been sharing mobility data with the public in open-source formats[31] through the official TOPIS website,[32] APIs, and, later, smartphone apps.

Between 2010 and 2013, South Korea adopted national standards for data and data-collecting infrastructure[33] to ensure interoperability between multiple transportation systems (Figure 5). In 2013, when the United Nations' Security Council officially recognized the existence of a nuclear threat to South Korea, the

[30] https://susa.or.kr/sites/default/files/resources/%EA%B5%90%ED%86%B5_10_TOPIS.pdf
[31] https://github.com/SeoulTech/open-data-seoul
[32] https://topis.seoul.go.kr/eng/english.jsp
[33] https://www.mytraffic.com.my/its-vds-vms.html

city of Seoul, which is close to the border with North Korea, began integrating TOPIS with the country's emergency services.

Seoul's data-driven transportation was not intended to be a centralized, top-down system. Instead, it emerged as a constellation of multiple data governance initiatives. The municipality then decided that combining data from multiple transportation systems into one system, which is now called TOPIS, would be immensely useful as a tool to predict future mobility trends. Investments in public data infrastructure were central to the success of TOPIS. According to Taehyung Kim, the head of Seoul's Division for Smart City & Transport, between 2005 and 2015, the government invested in TOPIS USD 2.367 million.[34]

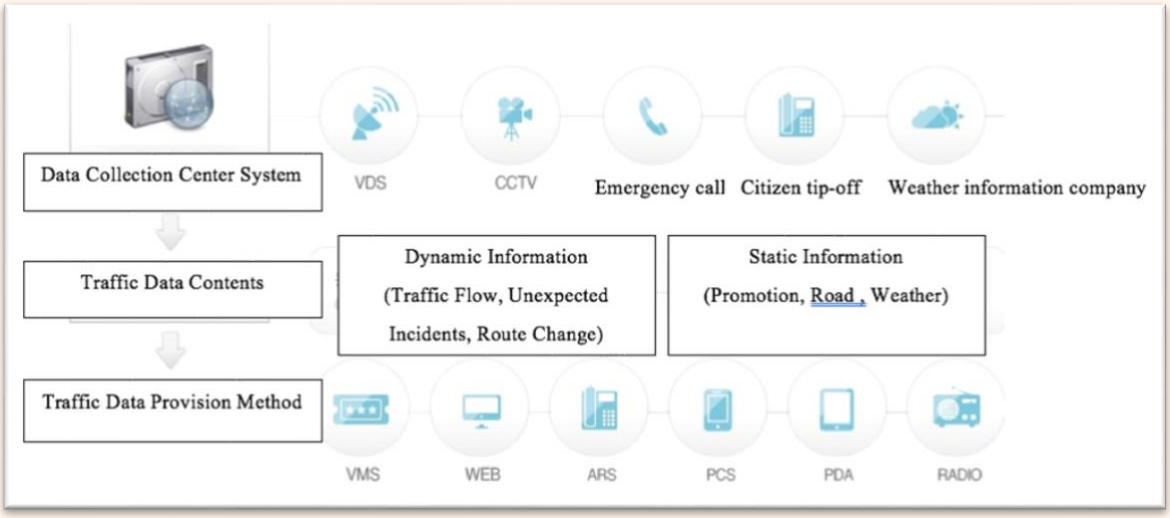


Figure 5. Standardization of Data Collection in South Korea, 2017.

Source: https://www.seoulsolution.kr/en/content/6536

[34] https://events.development.asia/system/files/materials/2019/10/201910-intelligent-transport-system-smart-mobility-korea-lessons-future-direction.pdf

The Issues Data Can Solve

As of 2024, TOPIS integrates eight electronic systems (Figure 14): the Bus System, the Unmanned Enforcement System, the Intelligent Transportation System, the Urban Expressway Traffic Management System, the Advanced Traffic Management System, the Green Traffic Zone System, the Traffic Big Data System, and the Centre System that acts as a "brain" overseeing all other transportation systems.

Each system addresses a particular set of issues. For instance, the Bus System[35] aims to solve two issues: the effective management of bus schedules and the timely communication of these schedules to riders. As a subset of the Bus System, the Bus Management System (BMS) integrates information from the vehicle detection sensors (VDSs)[36] and video footage collected by the variable message systems (VMSs). Inside each bus, a GPS-equipped terminal collects data about the fares, velocity, sudden stops, etc. This real-time data is transferred to the Centre System (Figure 6), which stores this data for future use and communicates updates to the Bus Information System (BIS). The function of the BIS is to inform citizens about arrival times, traffic incidents, and reroutes to ensure the smooth movement of passengers. Riders have access to BIS through a variety of mediums, from the information terminals located inside buses and at bus stops to smartphone apps and text messages. As of 2018 (the latest available statistics), the municipality of Seoul had installed 218.5 km of exclusive bus lanes[37] and operated 50,000 buses.[38]

[35] https://thedocs.worldbank.org/en/doc/fe16467f3f9165aadf561473d0cd7c91-0400012022/original/Final-LUTP-Seoul-Smart-Green-Case-Study-ENG.pdf

[36] https://www.mytraffic.com.my/its-vds-vms.html

[37] https://seoulsolution.kr/en/content/6534

[38] https://asiasociety.org/korea/buses-seoul-long-and-winding-road-innovation

The Unmanned Enforcement System is designed to penalize car drivers who do not adhere to the traffic rules, including parking in no-stop areas and driving in the exclusive bus or bicycle lanes (Figure 7). Street cameras collect license plate data of the vehicles that commit traffic violations; this data is sent to the Centre System, where an algorithm checks the license plate information against the registry of the vehicles maintained by the Korean Ministry of Land and Transportation. Once the name and the address of the vehicle owner have been established, they receive an automated ticket to their home address and cellphone number. As of 2021, TOPIS operates 336 unmanned enforcement sensors.

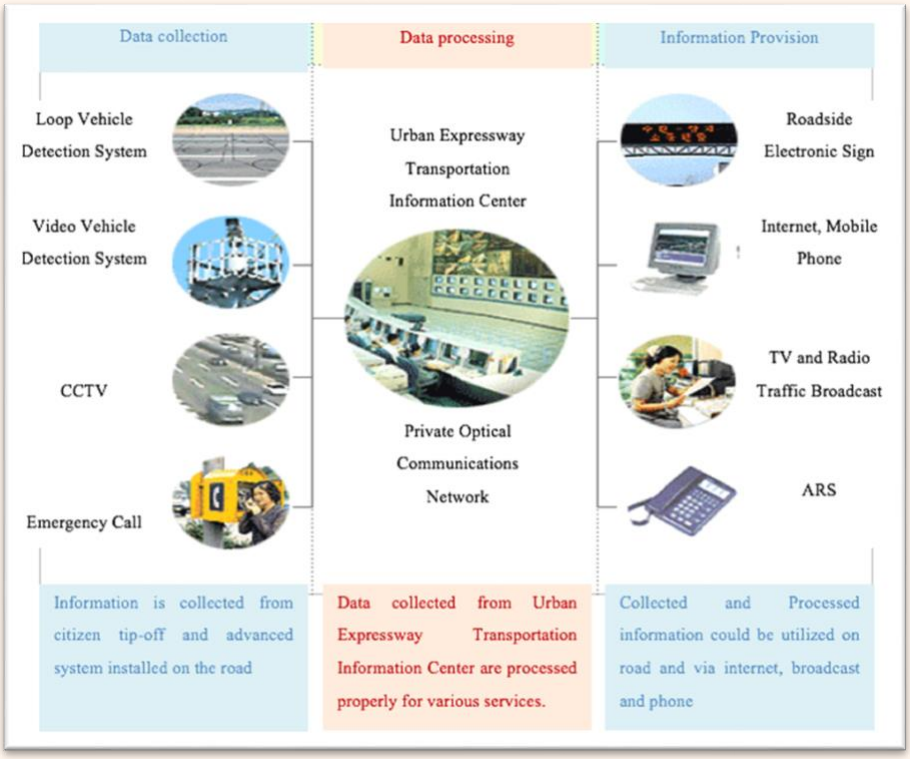


Figure 6. The path of data from the street sensors to TOPIS. Image source: https://www.seoulsolution.kr/en/content/6536

The Intelligent Transportation System integrates and analyses data from two data-driven initiatives: Autonomous Vehicle Testbed and Cooperative Intelligent Transportation System (C-ITS). The Government of South Korea is planning to invest USD 1 billion to develop reliable autonomous vehicles (AV) and build related infrastructure across the country by 2027.[39] In 2020, Seoul ran a driverless car pilot in the Sangam-dong neighbourhood, and the city created joint corporations with Hyundai, Samsung, and several other technology companies to commercialize AV technologies. Since 2023, driverless night buses have been running in Seoul.[40]

The municipality is also testing a technology called C-ITS, which uses 5G networks to connect autonomous vehicles, the city's traffic management system, and TOPIS. The city expects that, by 2027, Seoul's infrastructure will be ready for AVs, allowing driverless cars to seamlessly coordinate with one another and the city's smart transportation. The C-ITS is expected to benefit human drivers by recognizing and communicating information about traffic hazards. Currently, the C-ITS is being installed on the major roads and priority bus lanes in Seoul.

Underneath the C-ITS are the V2X communication technologies, which stands for "vehicle to everything." A form of Internet of Things technologies, V2X bridges multiple devices that normally do not connect to one another (i.e., CCTVs, driver assistance software, speed limit cameras, etc.). The Government of Seoul is establishing the world's fastest 5G-connected public traffic system, which will rely on a variety of new communication and data formats (e.g., VTV and C-V2X).[41]

[39] https://www.bbc.com/news/business-68823705
[40] https://youtu.be/7kGocLqHxHA?si=stMfeR672otOQV3i
[41] https://topis.seoul.go.kr/openEngCits.do

The Urban Expressway Traffic Management System (UETMS) and the Advanced Traffic Management System (ATMS) monitor traffic on Seoul's expressways and provide real-time data to city officials and drivers.[42] These two highway management systems were piloted in the mid-1990s and implemented in the 2000s and have been regularly upgraded since then. The UETMS collects data using sensors installed under the roadway, which count the number of vehicles passing over them; CCTV; satellite imagery; emergency phone calls; and other reports made by drivers. The ATMS merges data from the UETMS with other data points, including taxi GPS data, weather alerts, and automated traffic signal systems. Both the UETMS and the ATMS process information by analyzing traffic congestion, planning alternative routes, and conducting real-time speed monitoring. During the high-traffic periods, the systems may decide to raise the allowed minimum speed on certain roads to avoid delays and congestion. The traffic management systems provide real-time data to drivers through the TOPIS website, APIs, smartphone apps, and text messages.

[42] https://thedocs.worldbank.org/en/doc/fe16467f3f9165aadf561473d0cd7c91-0400012022/original/Final-LUTP-Seoul-Smart-Green-Case-Study-ENG.pdf

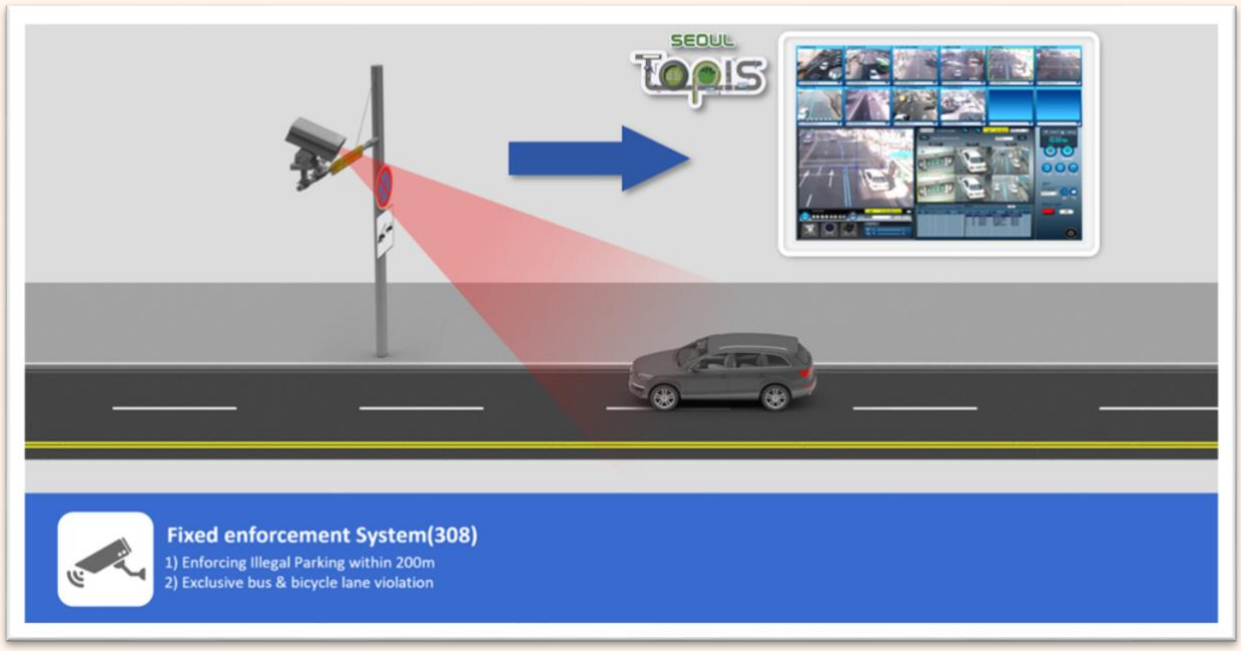


Figure 7. Unmanned traffic enforcement. Image source: https://topis.seoul.go.kr/openEngUnmanned.do

The Green Traffic Zone System was established in 2019 as a way to lower greenhouse emissions in Seoul. The automated enforcement system relies on 45 sensors to monitor the incoming traffic in downtown Seoul (Figure 7). The license plate data is sent to TOPIS's Centre System; if the Centre System detects a gas-powered vehicle released before 1987 or a diesel vehicle produced before July 2002, the driver will be automatically fined. The latest upgrade saw the Green Traffic Zone equipped with a deep learning technology that recognizes number plates and erases personal information in the messages, which are being transmitted between the systems. Recent studies show that Seoul's push for green vehicles has helped significantly reduce the level of air pollution in the city.[43]

[43] https://www.mdpi.com/1660-4601/19/22/15314

The Traffic Big Data System is yet another part of TOPIS. The data aggregated and analyzed by the Big Data System includes transportation card data, GPS taxi data, and speed and traffic volume data. The transportation card data is created every time a person taps their card, and approximately 85 million data points[44] are being collected in Seoul every day. Some 26 million data points per day come from the GPS devices mounted on buses and taxis. Over 100 million data points of speed and traffic volume data are being collected daily.

The Integrated Centre System oversees all other systems in TOPIS. In a control room all data is monitored by administrators, who have been trained to make swift decisions in the case of emergencies, traffic incidents, and extreme weather situations. According to the official TOPIS website,[45] Seoul currently manages 1,955 traffic volume cameras, 849 CCTV cameras, 341 VMS sensors, and 95 lane control systems. The administrators can remotely program CCTV cameras, traffic signals, and other on-site communication devices. The Centre System also oversees data sharing arrangements, to connect different public agencies around the issues that need intervention.

[44] https://topis.seoul.go.kr/openEngBigData.do
[45] https://topis.seoul.go.kr/eng/english.jsp

South Korea's Railway System: A Human-Centred Approach

Korea built its railway system under the Japanese colonial government between 1910 and 1945. Understanding the high value of transportation infrastructure, South Korea has turned its old railway system into a smart transportation system. The entire country is covered with a dense network of high-speed trains, subway trains and light-rail trains (Figure 8). As I found out during my trip to South Korea, one can travel via train to any part of the country in a 15-minute to 2-hour trip. For example, in March 2024, it took me 40 minutes to get from Seoul to the town of Sejong, located 121 km to the south.[46] For many Koreans, trains are the primary mode of transportation, as they commute to Seoul or another large city for work.

Seoul's subway, which is called "Metro," operates 10 lines and, according to the latest available statistics (2018), moves 8 million passengers a day.[47] Metro serves the capital city, Seoul, and the provinces of Gyeonggi, Incheon, and South Chungcheong. It has 302 stations and stretches 327.1 km, including 290 km of underground tracks. Three public corporations operate the subway lines: Korail (Korea National Railroad), Seoul Metropolitan Rapid Transit (SMRT), and Metro 9. Korail has been running Line 1 since its inception in 1974, and now the agency manages Lines 1–4. The SMRT corporation was launched in 1994 and operates Lines 5–8. The driverless Line 9 is operated by a private vendor, Metro 9 (a subsidiary of Veolia Transport), and connects Gimpo Airport with southeastern Seoul. Line 9 was opened in 2009 and serves 38 stations.

[46] The Government of South Korea has been moving its operations and staff to Sejong to avoid a potential nuclear attack from North Korea.

[47] https://english.seoul.go.kr/wp-content/uploads/2019/08/TOPIS.pdf

Figure 8. A high-speed train leaves a railway station. Seoul, March 2024. Image source: author

The driverless train system operates subway trains and controls departures, stops, and the opening and closing of doors without human supervision. CCTV cameras provide 24-hour monitoring of the subway tunnels and stations, and subway workers use the cameras to detect potential issues. It is expected that, in the near future, driverless trains will be able to run computer diagnostics of the railway systems (e.g., the safety of the tracks) and notify subway workers about the issues.

Seoul's driverless subway line project has been so successful that, in 2020, Hyundai Rotem received a $416.5 million contract to supply 62 self-driving trains

to Singapore.[48] In 2023, Korail piloted a driverless system for its locomotives in the Korean town of Jecheon. In the pilot phase, the software operates 25 trains and 200 wagons per day, with the option for Korail workers to operate the locomotives remotely. Korail plans to expand the pilot to 10 more locations in 2024.[49]

To support and improve Metro, the Government of Seoul uses a mix of public and private funding. The Metro 9 corporation, which had developed the driverless subway line, is controlled by the French company Veolia Transport through its Korean subsidiary and will run it for 10 years.[50] The contract for development of the driverless trains for Line 9 was awarded to the South Korean company Hyundai Rotem, a subsidiary of Hyundai Motors. The Macquarie Korea Infrastructure Fund (MKIF) has invested in Seoul's subway system in the form of equity and subordinated loans.[51] Starting in 2009, MKIF has a concession term of 30 years. The defining feature of Korea's public transit is that it is consumer-oriented service. As the Government of South Korea postulated back in 2016, the aim of the nation's smart transportation policies has been to build a human-centred mobility infrastructure.[52]

[48] https://ca.sports.yahoo.com/news/62-koreabuilt-driverless-trains-to-ply-jurong-region-line-074834067.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAJgbKFenkMHCSYI1EVabzP3i-djWZUqTcd-rW-FmqdadNniDsLWrHujT_8nPZR5LCRLWFAJD0ul67vPFzX1yIBnJqBI_iLBQP1FVToyDCXE1HMQY725fKLANBnPKoG8HSAdBX-RYrk0xrQ5700E0zGB6H8WOXGJuD-dGK_ezdukj

[49] https://www.railjournal.com/technology/korail-introduces-driverless-shunting/

[50] https://www.railway-technology.com/projects/seoul-metro/?cf-view&cf-closed

[51] A private investment company, MKIF invests its clients' money in infrastructure assets (i.e., toll roads, marine ports, and bridges).

[52] https://english.seoul.go.kr/wp-content/uploads/2019/08/TOPIS.pdf

Figure 19. A lounge zone for passengers at the train station in Sejong. March 2024. Image source: author

Indeed, Korean commuters enjoy travelling by trains. With their vast shopping facilities, comfortable lounge spaces, and cozy little cafes, Korean railway stations and subway stops resemble Seoul's high-end malls (Figure 9). Metro is the place where Korean commuters have lunch, meet with friends, and do shopping (Figure 10). All trains and subway stations provide free and fast Wi-Fi, and riders on long commutes spend time watching movies.

Figure 10. Coffee shops, boulangeries, and fast-food restaurants exist at every transit station. Image source: author

Seoul's transportation facilities accommodate all types of users: from accessible train cars to seats reserved for the elderly and people with special mobility needs. Subway stations are also places where one will find a quiet spot for rest, reading, and meditation. For instance, the green spaces at Seoul's downtown subway stations have been created for transit riders who need a moment for themselves (Figure 11). Seoul's subway is but one illustration of South Korea's approach to public transit, where customer satisfaction is the primary evaluation criterion. Public agencies in charge of the nation's smart transportation initiatives regularly run customer satisfaction surveys and aim to achieve the highest rates.

Figure 11. Commons in Seoul's subway. Image source: author

Every technology deployed in the streets and highways of Seoul is meant to make the commute more convenient and offer residents additional mobility options. For instance, the real-time bus information system provides updates about bus arrivals with 96% accuracy; the city's railway system has been integrated with the bus management system to allow for smooth connections. Unlike Boston, commuters in Seoul never protested the city's automated traffic enforcement systems.

The Case Study of Boston

With its rich political history and high concentration of world-leading research universities, Boston is a landmark North American city. In her famous study, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* anthropologist AnnaLee Saxenian (2006) explored Boston and San Francisco as two leading U.S. technology hubs and found out that Boston was rather conservative in matters of technology, governance, and business culture. As I discuss in the following sections, Boston's conservative culture manifests both as a catalyst and a barrier in the field of transportation innovation.

In this report, I draw on the Governing Knowledge Commons (GKC) framework to analyze the City of Boston's governance of digital technologies in transportation. My study addresses several questions: What are the key challenges for the city? Which shared resources does the municipality manage? Which actors participate in the governance of data-driven mobility solutions in Boston? What are the manifested goals and values of these actors? What are the controversies/conflicting interests at stake?

Boston's Scarce Resources: Space and Mobility Data

When it comes to transportation, Boston faces the same challenges as Vancouver, Toronto, Chicago and many other North American cities that struggle to accommodate the mobility needs of their growing populations. Traffic congestion has been an issue in Boston for more than a decade (Figure 1). In 2022, the Global INRIX Traffic report[53] named Boston as one of the five most congested

[53] https://inrix.com/scorecard/

cities in the world, stating that commuters in Boston spent a staggering 134 hours a year in traffic. INRIX also estimated that in the same year, drivers in the Greater Boston area were losing an average of $2,270 in gas and wasted time. In 2019, a report from the Massachusetts Transportation Authority[54] confirmed that all types of commuters suffered from traffic: between 2008 and 2017, the average bus trip duration increased by 17% during peak travel times; between 2013 and 2017, peak travel times have increased on most roads around Greater Boston. Local press and residents reported issues with traffic in 2017[55] and 2013.[56]

There are three factors that contribute to the city's traffic problem: explosive population growth, lack of physical space, and the car-centred lifestyle that currently prevails among the residents of Greater Boston. According to the United Nations, population of Boston has been growing since the 1950s (Figure 12). Between 2000 and 2023, Boston added 367,000 new residents. The lack of physical space in the old city and its ad hoc planning also play a role here. Boston emerged from several Puritan settlements, developed into a busy town around a seaport, and was chartered as a city in 1822 when it became a large industrial center. The key planning decisions in relation to mobility were made in the 1970s when Boston planners proposed building several new highways to accommodate the growing demand for private cars in the city.

[54] https://www.masslive.com/news/2019/08/how-bad-is-massachusetts-traffic-and-what-can-be-done-about-it.html

[55] https://www.bostonmagazine.com/news/2017/04/30/boston-traffic/

[56] https://www.bostonherald.com/2013/05/06/boston-traffic-ranked-10th-worst-in-us/

Figure 12. Traffic in the streets of Boston, August 2023. Image source: author

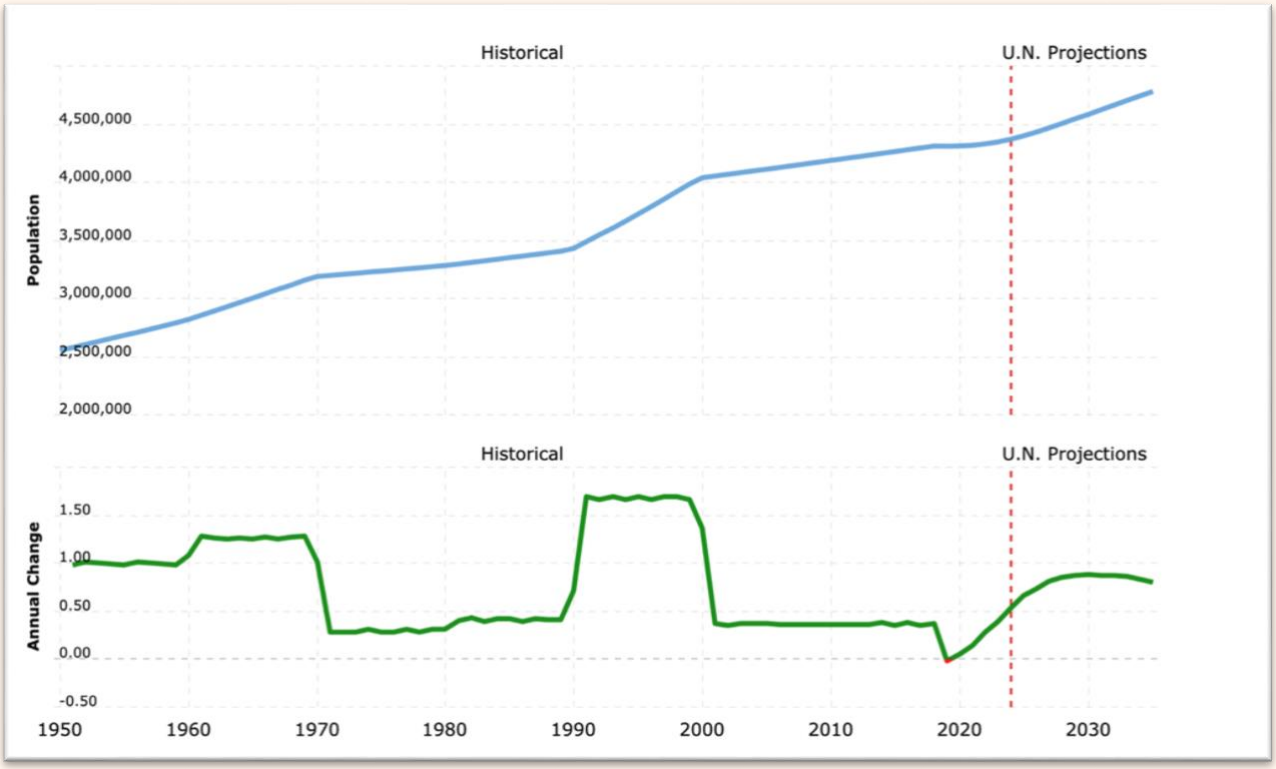


Figure 13. Boston population trends, according to the United Nations (1950–2030). Image source: https://www.macrotrends.net/cities/22939/boston/population

Residents of the southern neighbourhoods, predominantly recent immigrants (Figure 14), campaigned against the project and won. Instead of highways, the land was used by the Massachusetts Bay Transportation Authority (MBTA) [57] to build two new subway tracks (the Orange Line), the MBTA's Needham Line Commuter Rail and a 52-acre park.

By 2013, the MBTA's transit system was failing to accommodate the fast-growing number of commuters (Figure 13). Boston's infrastructure was strained by the number of cars and trucks that circulated within the city and required additional road space and parking. The city administration wanted to collect digital data to

[57] Massachusetts Bay Transportation Authority administers public transit in the Greater Boston Area.

help design new public transit routes, yet accessing mobility data proved to be an issue.

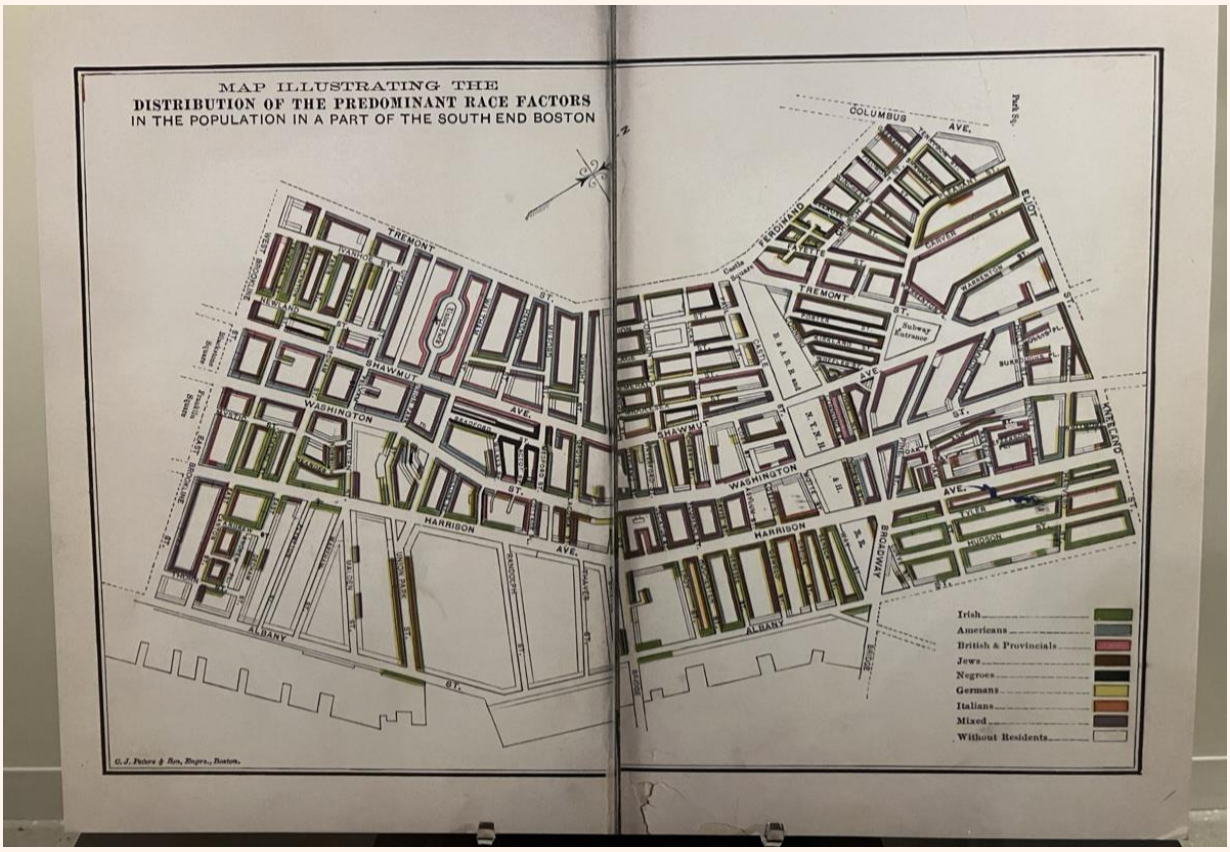


Figure 14. A 1979 map illustrating the demographics of the South End, Boston. Image rights: Boston Public Library

Many public sector organizations at the city and state levels collect information about commuting in the form of exhaust data from their primary services. This means this data cannot be shared or reused by the municipality, researchers or other organizations. MBTA is a prime example. In 2015, the agency revealed that it did not have information about the number of commuters using its buses and trains.[58] The same year, MIT researcher Raphaël A. Dumas analyzed[59] data from transit payment cards to confirm reports about African American

[58] https://www.bostonmagazine.com/news/2015/05/06/mbta-count-commuter-rail-passengers/
[59] https://radumas.info/thesis/raw_thesis/Thesis%20Final.pdf

commuters facing longer travel times[60] on MBTA compared to other transit riders. Dumas' study was unable to prove or refute these reports, because MBTA did not track ticket data on some of its routs, including the neighborhoods where Boston's African American populations predominantly reside.

In 2020, the City of Boston partnered with a non-profit organization, called Shared Streets to use mobility data to address the congestion issue.[61] Shared Streets was a joint initiative by Uber and Lift, which quality transportation data to municipalities. Boston was one of the few U.S. cities that benefitted from this collaboration: Uber and Lyft provided them with granular data about traffic, optimal delivery routes, and curb occupancy. Unfortunately, the Shared Streets initiative was shut down during the pandemic, leaving Boston to once again scramble for data.

Even when Boston finds another data sharing partner, mobility data is often of the wrong type or of a lesser quality than needed. The state of Massachusetts requires ridesharing companies to provide statistical data on the number of rides per city.[62] We learn from these reports that Uber and Lyft were losing customers in 2020 and 2021, and 2022 shows a hike in the number of requested rides and deliveries.[63] Unfortunately, this bird's-eye view of rideshare trips across Massachusetts is of little use to the City of Boston.

[60] https://trid.trb.org/view/1289630
[61] https://sharedstreets.io/
[62] https://www.mass.gov/info-details/2017-municipal-rideshare-fund-report
[63] https://www.mass.gov/info-details/2022-rideshare-data-report

The City's Long-Term Vision for Transportation Planning

In 2017, the City of Boston released *Go Boston 2030.*[64] In this ambitious plan, city administration proposed to reduce the amount of car travel within the city, invest in new public transit routes, build more bike lanes, reduce the number of traffic fatalities, and reduce the overall level of greenhouse emissions. As of 2023, many of these goals have been achieved. After the Vision Zero policy has been implemented, the number of traffic collisions in Boston fell by 30%.[65] The municipality installed new traffic signals[66] that prioritize bicyclists and pedestrians, and the MBTA implemented new dedicated bus lanes.[67] Yet the number of traffic fatalities in Boston remains alarmingly high.[68]

In 2021, the mayor of Boston approved new guidelines for developers, which limited the number of parking spots that can be built in the neighbourhoods where transit options are available.[69]

Several of my respondents shared their experiences working on the Performance Parking Pilot that ran in the Back Bay neighbourhood in 2017.[70] The ParkBoston and Ticketzen apps[71] were developed for the pilot, which helped drivers pay for parking using their mobile phones. The city also experimented with smart parking meters and occupancy sensors, which collected data on parking usage and could be programmed remotely. Between 2017 and 2023, Boston expanded the pilot into two more neighbourhoods.

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[64] https://www.boston.gov/news/go-boston-2030-vision-and-action-plan-released
[65] https://mass.streetsblog.org/2023/10/12/halfway-to-2030-hows-go-boston-going
[66] https://mass.streetsblog.org/2023/06/15/guest-column-why-bostons-new-traffic-signal-policy-is-a-big-deal
[67] https://www.mbta.com/projects/bus-transit-priority
[68] https://mass.streetsblog.org/2023/01/03/2022-was-another-record-breaking-year-for-deaths-on-massachusetts-roadways
[69] https://www.boston.gov/departments/transportation/maximum-parking-ratios
[70] https://www.boston.gov/sites/default/files/embed/p/performance_parking_final_report_-_web_1.pdf
[71] After the pilot ended, these apps were replaced with the Boston PayTix app, which is still in use.

With the help of the smart parking meters, the city significantly raised parking fees. In some locations, the flat fees were tripled. In others, performance rates were introduced: if the block or a parking garage had high occupancy, the city would raise the fee by 25 or 50 cents; when the occupancy was low, the price would go down. In addition, the city sent a public worker to collect data about the usage of the parking spaces and violations. Adding this manually collected data to the digital data proved to be very beneficial since it revealed significant blind spots of the tested technologies (e.g., some sensors failed to identify disability tags). The pilot faced significant pushback. Local small business owners complained that, because of the new parking policies, they were losing customers and had to pay more for deliveries. For this reason, the Performance Parking Pilot did not get support at the state level and was eventually shut down.

In 2020, the City of Boston planned to partner with a non-profit organization called *Open Mobility Foundation* (OMF)[72] to introduce data specifications and new data-sharing standards for alternative transportation methods like scooters and electric bicycles. Unfortunately, this initiative has been sidelined during the pandemic.

In August 2023, when I arrived in Boston, the easiest way to park anywhere in the city was to obtain a resident parking permit from a hotel or an individual Boston resident (Figure 15). Public parking lots were rare, and in the few places in the city where there existed, most of the spots would be reserved for employees and visitors of a particular organization (Figure 16).

[72] https://www.openmobilityfoundation.org/

Figure 15. Resident parking in the Back Bay, Boston, 2023. Image source: author

Figure 16. Public parking in downtown, Boston 2023. Image source: author

Several of my respondents shared that, because of the lack of public parking, they were not able to drive in the city. One would use ridesharing apps to get around the city, while their personal car remains parked in a residential parking spot. These reports have been confirmed by the latest statistical data released by the state of Massachusetts.[73] Since the municipality began limiting parking within the city, Uber and Lyft have seen a growing demand for their services. In 2022, residents of Boston made 28.7 million trips via ridesharing apps, which is a 56% increase since 2021.

As part of its green transportation agenda, the municipality continues to invest in the cycling infrastructure. As of 2023, the City of Boston installed 95 km of off-street bike paths, 28 km of separated bike lanes, and 12.8 km of neighbourhood bike routes.[74] Unfortunately, cycling in Boston remains extremely unsafe. Every year 300 people get injured while cycling in Boston. A 2021 survey conducted by MassINC Polling Group indicated that 50% of Boston residents would consider biking more if the city built separated bike lanes in their neighbourhoods.[75] The demand for protected bike lanes isn't surprising: a 13-year study of ten U.S. cities showed that separated bike lanes made streets safer for cyclists, pedestrians, and drivers.[76] Cycling in Boston is also inconvenient: the existing bike paths are not connected and the city offers few bike parking spots.

[73] https://www.mass.gov/info-details/2022-rideshare-data-report
[74] https://storymaps.arcgis.com/stories/a90bff933db94496b6c4214caf17c706
[75] https://files.constantcontact.com/e6e14db6301/a2fd95a5-a8bc-4ea5-bea2-23b845ead887.pdf
[76] https://www.sciencedaily.com/releases/2019/05/190529113036.htm

Attributes of the Community

Historically, Boston has a strong culture of citizen engagement. In the interviews, some city officials pointed out that Boston's distinctive political culture contributes to what they called a "slow [technology] governance." This means that it may take several iterations and several different providers for a given solution to start working for the benefit of the community, and some technologies will be rejected even if they function properly.

Indeed, as we have seen with the Performance Parking Pilot, it is not an easy task for the City of Boston to adopt a new technology. Boston's residents often raise concerns about new policies and new technological solutions deployed in the city. In Roxbury, a southern neighbourhood where in 1979 the city wanted to install a multi-lane highway, a big sign reminds the residents of the importance of community activism: "If it wasn't for community activism, you'd be on a highway right now" (Figure 17).

The City of Boston is responsible for many core functions, including housing, mobility, and addiction services. Unlike other cities, which often rush into agreements with technology vendors[77] and have no in-house experts to evaluate the technological solutions they deploy,[78] Boston has created the Mayor's Office of New Urban Mechanics[79] to explore how technological solutions can help address the city's biggest challenges.

[77] https://spacing.ca/toronto/2020/07/27/why-is-city-of-toronto-sole-sourcing-key-digital-infrastructure/
[78] https://mitpress.mit.edu/9780262538961/the-smart-enough-city/
[79] https://content.boston.gov/fr/departments/new-urban-mechanics

Figure 17. The placard in Roxbury, Boston, 2023. Image source: author

The Mayor's Office of New Urban Mechanics (MONUM)[80] was created in 2010 with the goal to partner with MIT researchers and implement new technologies. Like all other North American cities, Boston officials have been relentlessly lobbied by the technology vendors. MONUM is authorized to spend up to $10,000 to test any solution. Thanks to this policy, the city has run various pilots over the past thirteen years: from smart traffic signals to parking apps to an engagement center for homeless people. When a test is successful, MONUM

[80] https://www.boston.gov/departments/new-urban-mechanics

collaborates with other city departments to implement the chosen solution on a long-term basis. Road safety and access to transportation, for people who live outside of the city core, have been the latest priorities for MONUM.

Boston's transportation department[81] is another innovative actor in the city. The issues they address include illegal parking, curb management, and access to public transit. In 2022–23, the department had partnered with a technology company to test an automated traffic enforcement system [name of the vendor has been removed for privacy reasons]. Smart cameras had been installed in several locations around the city; they automatically alert the police when a driver forgot to pay their parking fee and help parking enforcement officers navigate their way to the offenders' vehicles. This system proved to be quite efficient since it limited the amount of time the officers spent patrolling the parking lots. The city is considering a full-scale adoption of this technology.

Curb management is another duty fulfilled by Boston's transportation department. The city aims to allocate more space for walking and cycling, including such measures as turning parking spots into restaurant patios, creating new public spaces, and building an interconnected network of dedicated bike lanes. The transportation department has created digital maps, in which Boston streets and segments of the curb have been encoded and receive different traffic management regimes. These maps allow for the seamless integration between the municipal policies and public and private software deployed in the city. For example, the city introduced strict requirements for delivery trucks to reduce the amount of air pollution in Boston. The city's digital maps, paired with an

[81] https://www.boston.gov/departments/transportation

automated enforcement system, automatically charge vehicles that do not comply with the new requirements.

In the 2022 U.S. census,[82] 48.6% of the population in Boston identified as Caucasian, 22.5% as African American, 19.6% as Hispanic or Latino, 0.3% as Asian, and 9% as mixed race. Similar to the 1970s, the non-Caucasian populations predominantly reside in the southern parts of the city. Connecting these communities to jobs and educational institutions has been a long-term priority for the city administration. Local grassroots organizations play an enormous role in ensuring Boston's transit system is equitable, accessible and reliable.

The Livable Streets Alliance is one of the three biggest grassroots organizations in Boston, which help the city collect feedback on its policies. In 2019, Alliance published a report called *64 Hours: Closing the Bus Equity Gap*.[83] Drawing on travel journals and interviews with commuters, the study showed that African American residents of Greater Boston spent 64 hours longer on the MBTA buses annually than White residents. The *Keeping Pace* report, which the Alliance has prepared jointly with the Institute for Transportation & Development Policy (ITDP), shows that the current bus fleet of 1200 buses is insufficient to accommodate the growing demand for public transit in the new neighbourhoods of Boston.[84]

The Boston Cyclists Union (Figure 18)[85] is second non-profit that works with the City of Boston to help make roads safer for cyclists. Since 2017, the Union has campaigned for the municipality to increase its cycling infrastructure budget.

[82] https://www.census.gov/quickfacts/fact/table/bostoncitymassachusetts/PST045222
[83] https://www.livablestreets.info/64_hours_report
[84] https://www.livablestreets.info/keeping_pace_report
[85] https://bostoncyclistsunion.org/policy

Figure 18. *The office of the Boston Cyclists Union, Boston, 2023. Image source: author*

Thanks to the efforts of the Boston Cyclists Union, the city doubled its bike budget in 2020. The Union has also advocated for introducing Vision Zero in Boston, which has helped reduce the number of collisions and fatalities in the city and won the campaign against distracted driving, which led to the city passing new laws forbidding the use of hand-held communication devices while driving. As part of its campaign for equitable transportation, the Union has advocated for the inclusion of electric bicycles in the city's bike rental, to help elderly people start biking.

WalkBoston is yet another successful grassroots organization in Boston. After thirty years of functioning at the city level, the non-profit has changed its name to "WalkMassachusetts" and plans to expand its operations outside the city. This non-profit advocates on several issues: walkable communities, pedestrian safety, age-friendly walking, transit connection, and walkable street design. The most impactful policy work conducted by WalkMassachusetts is their monthly "crash reports,"[86] which analyze the patterns revealed by data and help the City of Boston design policies to reduce the number of collisions and traffic fatalities.

WalkMassachusetts helps ensure the city's development projects create complete communities, ensuring, for instance, that all traffic stops have safe road crossings. Its employees conduct safe streets and traffic signal audits, ensuring that dangerous parts of the city quickly become the focus of new policies. Together with the Boston Cyclists Union, WalkMassachusetts successfully advocated for the implementation of Vision Zero in Boston. WalkMassachusetts also created the Age-Friendly Walking Framework to help the planners in the City of Boston (and beyond) design cities that are accessible to elderly people.[87] Educating citizens

[86] https://walkmass.org/monthly-crash-review/
[87] https://walkmass.org/what-we-do/age-friendly-walking/

about the health benefits of walking is yet another big part of the organization's mandate.

Contested Issues in Boston's Transportation Policies

Both the literature review and the interviews I conducted with city officials and activists indicate that traffic congestion is the topic of hottest debates in the city. Overwhelmed by the number of cars that stall Boston's narrow streets, the municipality encourages residents to switch to public transit. To make the transition easier, city administration has invested in buses and dedicated bus lanes.

Sadly, Boston's public transit falls short of fulfilling the mobility demands of its population. As of 2023, the city needs 1,000 more buses and 740 new bus drivers to address the demand for bus services in the Greater Boston Area.[88] A growing number of crimes committed on the MBTA trains[89] contribute to the decline in daily commuters using these trains. A recent poll shows that 70% of the population consider MBTA trains to be unsafe.[90]

Despite the impressive work of city officials and grassroots organizations, Boston is still a car-centred city. Every person I interviewed mentioned that the residents of Boston have been dissatisfied with the policies that made driving in the city less convenient. In the absence of reliable transportation alternatives, the city's latest policies contributed to the reduced mobility options for residents. Some Bostonians consider new transportation polices to be costly for their businesses,

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[88] https://www.livablestreets.info/new_report_greater_boston_s_population_doubled_as_mbta_bus_fleet_decreased_the_same_over_the_past_fifty_years

[89] https://www.boston.com/community/readers-say/why-readers-are-scared-to-ride-the-t/

[90] https://www.trains.com/trn/news-reviews/news-wire/mbta-is-unsafe-and-service-isnt-great-either-says-poll/

others are not in the habit of cycling, and yet others simply prefer driving over taking public transit.

Among the key interest groups with conflicting interests in Boston transportation are small businesses vs. cyclists, small businesses vs. the city's environmental protection plan, and car owners vs. cyclists. The loss of public parking spaces has become a challenge for both individual residents and local vendors. Most recently, in Cambridge, a coalition of small business owners insisted on an additional review of the proposed cycling infrastructure. Some of the city's transportation initiatives were shut down by the state government, because of the intense lobbying from the local businesses.

Key Players: Their Values and Goals

My respondents emphasize that Boston is a conservative city. But what does this mean in relation to the governance of data-driven technologies in transportation? In 2008, AnnaLee Saxsenian[91] argued that Boston's conservative culture was a barrier to innovation, which had led to Boston losing its competitive advantage to Silicon Valley. Nevertheless, as I discussed in the previous sections, the City of Boston's work in relation to digital technology is quite impressive. From the establishment of the Mayor's Office of New Mechanics to partnering with Uber and Lyft to use data in planning to the automated traffic enforcement pilot, Boston has been actively experimenting with new technologies.

Boston's political climate manifests in its strong culture of public engagement, which prevents the municipality from imposing policies and

[91] https://www.hup.harvard.edu/books/9780674753402

technological solutions that do not bring clear advantages to the citizens. What some respondents see as a "slow adoption"[92] of digital technologies, in practice, is a well-balanced, iterative process that helps weed out the solutions that are flawed or do not serve the public interest.

Boston is a distinctly American city that, over the decades, became car-centred, and where car ownership is still considered to be a sign of good social standing. The city administration, which nudges the residents to switch to public transit, finds itself at the crossroads of four interest groups: residents who are enraged because of the limited mobility options in the city; residents who express disappointment with the reliability and safety of the existing public transit system; small businesses that protest high parking fees and automated enforcement systems; small and big businesses that protest new cycling infrastructure. While the local grassroots organizations support municipal investments in public transit and cycling infrastructure, Boston's businesses actively lobby against these policies at the city and state levels.

Another policy roadblock in Boston's transportation planning is that many of its public interest initiatives do not have clear evaluation criteria. This makes implementing policies and technological solutions that cause inconvenience to the residents extremely difficult. Securing funding for innovative transportation solutions is yet another challenge. Boston's transportation budget depends on the funding from the state of Massachusetts, and local policies do not always receive support from the state legislators.

[92] Some academic studies argue that "slow governance" may be the best way to adopt any digital technology without facing public resistance, privacy issues, or vendor lock in. https://policyreview.info/articles/analysis/slow-governance-smart-cities-empirical-study-smart-intersection-implementation

The Rules-in-Use

The biggest issue with data-driven transportation technologies is that they collect sensitive information, including the drivers' locations, routes, and licence plate data. The software that monitors parking can be easily deployed to track vehicles and their owners. To address these potential threats, the city has implemented new data- and privacy-protecting policies.

In 2020, the City of Boston passed the Ordinance on Surveillance Oversight and Information Sharing,[93] which defines surveillance technology as "any device, hardware, or software that is capable of collecting, capturing, recording, retaining, processing, intercepting, analyzing, monitoring, or sharing audio, visual, digital, location, thermal, biometric, associational, or similar information specifically associated with, or capable of being associated with, any identifiable individual or group; or any system, device, or vehicle that is equipped with an electronic surveillance device, hardware, or software." The ordinance has introduced strict rules regarding the use of surveillance technologies and provides guidance in respect with data sharing. For example, the ordinance prohibits public schools from sharing any information about their students. The Surveillance Oversight Advisory Board was created by the surveillance ordinance to represent the voices of the community. It is comprised of the president of the city council, members of the Massachusetts American Civil Liberties Union, academic researchers, and the Boston police commissioner. After receiving feedback from the board, city mayor submits an updated policy for the council's approval.

[93] https://codelibrary.amlegal.com/codes/boston/latest/boston_ma/0-0-0-18988

There exist a few exceptions to Boston's surveillance ordinance. Office software, parking enforcement devices, and cameras mounted on and in police cars are exempt from the regulations.

In 2021, the City Council approved another ordinance which banned all city officials from using facial recognition technologies or accessing third-party facial recognition data.[94] The same year, the State of Massachusetts banned police from using facial recognition software.[95]

Under the new policies, all city departments must submit annual surveillance reports to the mayor's office. These reports contain information about the technological solutions deployed or tested by the departments, employees who have had access to them, and the data-sharing arrangements around these technologies. In 2023, the mayor's office released surveillance use policies for each city department, pending approval by the city council.

[94] https://www.boston.gov/sites/default/files/file/2021/02/Boston-City-Council-face-surveillance-ban.pdf
[95] https://www.npr.org/2021/05/07/982709480/massachusetts-pioneers-rules-for-police-use-of-facial-recognition-tech

The Case Study of Pittsburgh

An old industrial town working to reinvent itself as a technology hub, Pittsburgh struggles with a lack of public transit, low levels of digitalization, outdated infrastructure, and rampant economic inequality. Pittsburgh's experiments with data-driven transportation have never been consistent or particularly successful.

In this section, I rely on the Governing Knowledge Commons (GKC) framework to analyse recent data governance initiatives launched by the City of Pittsburgh, local transit authorities, and academic researchers. The empirical data from this case highlights four important findings. First, implementing data-driven transportation solutions at the municipal level requires significant public funding. Second, commercialization of these solutions is not an easy and straightforward task. Third, smart transportation must provide additional mobility options to the citizens as opposed to limiting them. Fourth, technological solutions cannot be used as a remedy for the social ills.

The following subsections address several questions: what are the city's key challenges? Which policies and data-driven transportation initiatives have been tested in Pittsburgh? What are the outcomes of these projects? Who participates in the governance of transportation in Pittsburgh? What can be said about their goals and values? Which controversies and points of contestation exist between these actors?

Reinventing Pittsburgh: From the "Steel City" to the "Smart City"

The first steel mill was established in Pittsburgh in the 1880s. Situated at the intersection of three rivers, the town of Pittsburgh provided unique opportunities in terms of extraction volumes and easy steel transportation. By 1910, local manufacturing produced 25 million ton of steel annually.[96] By the 1940s, Pittsburgh had become the largest steel producer in the world.[97] In the 1950s, Pittsburgh was the steel capital of the United States, responsible for half of the nation's steel. In the 1970–80s, the U.S. steel industry went into steep decline.[98] As the country went from one recession to another, Pittsburgh was hit especially hard. In less than a decade, the "steel town" saw both the core of its tax base and its entire labour market wiped out. This economic downturn continued for three decades, with Pittsburgh attempting to revitalize its business environment and rebuild its economy around the "eds and meds"—that is, research and educational institutions and biotechnology. According to the latest labour statistics (Figure 19), the city's unemployment rate continues to rise.

Over the course of its history, Pittsburgh has suffered from four major ills: social inequality, economic inequality, environmental pollution, and weak public administration. All these issues have roots in the town's industrial past. The first attempts at evidence-based policymaking were made by Pittsburgh business elites in reaction to the famous *Pittsburgh Survey* conducted in 1908–1914.[99] The socio-economic study, funded by the Russell Sage Foundation, was published by a team of sociologists in New York and Chicago as a series of articles about the "typical

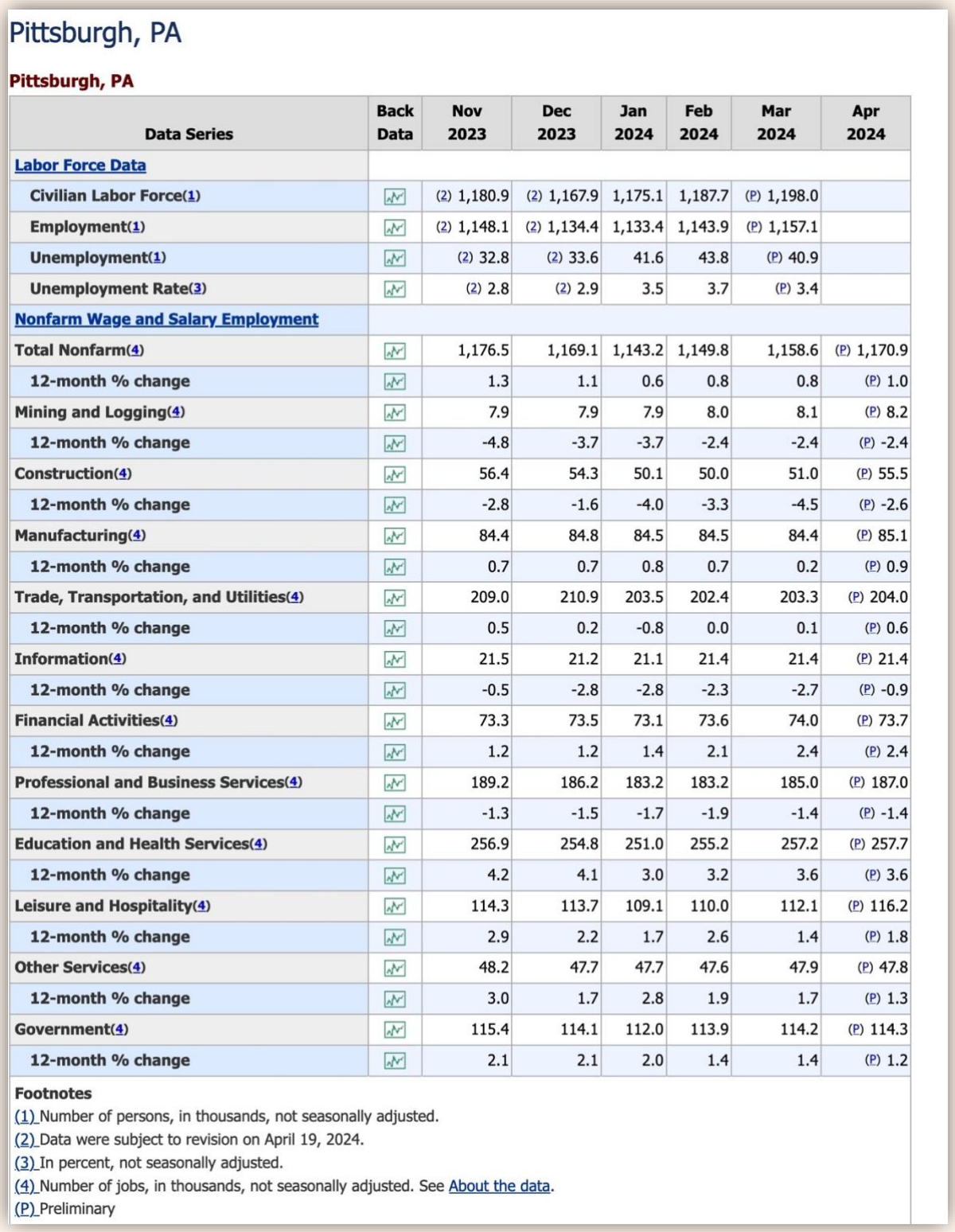
[96] https://pittsburghquarterly.com/articles/a-very-brief-history-of-pittsburgh/
[97] https://www.pittsburghbeautiful.com/2023/02/01/pittsburgh-steel-industry/
[98] https://storymaps.arcgis.com/stories/193c7822ffbf42e1bc3be7a463f69054
[99] https://www.amazon.ca/Pittsburgh-Surveyed-Science-Twentieth-Century/dp/0822956101

American industrial city." The survey painted a grim picture of the abject poverty of Pittsburgh steel workers in scattered communities along the Allegheny River and the Ohio River in poorly managed housing provided by the manufacturing plants. The study also referred to Pittsburgh as the "Smoky City" on the account of constant fires and smoke, which made the city's air visibly dirty.[100] The survey generated volumes of statistical and observational data and had a clear progressive agenda of improving the living conditions and social standing of workers, many of whom were immigrants. The progressive components of the survey were largely ignored by city leaders, and up until the 1940s, Pittsburgh remained divided along economic, social, and racial lines.

Some improvements to the steel workers' material conditions were made between the 1920s and 1950s, when Pittsburgh doubled in population and became a rich industrial city. Pittsburgh's business elite led the gentrification and revitalization of the city: downtown Pittsburgh was rebuilt, the poorest neighborhoods were torn down, and the city received a new steel-roofed concert hall called the Civic Auditorium (Figure 20). The city established its own public health institutions, and the rivers were cleaned. This could be seen as the birth of the local culture of philanthropy, which eventually became the key governance factor in the city.[101] The families of Andrew Carnegie, Andrew Mellon, Henry Clay Frick, and Howard Heinz were among those who invested in Pittsburgh, commissioning architects and urban planners from New York to redevelop their city.

[100] Pittsburgh had long struggled with environmental issues. In the 1960s, when the town's economy was dominated by the iron industry, one traveller referred to Pittsburgh as "hell with the lid taken off." The quote is found in Madison, M. (2012), Contrasts in innovation: Pittsburgh then and now, in M. Carpenter (Ed.), *Entrepreneurship and innovation in evolving economies* (pp. 144–82), Cheltenham: Edward Elgar. https://doi.org/10.4337/9780857934703.00013

[101] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4097059



Pittsburgh, PA

Pittsburgh, PA

Data Series	Back Data	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024	Apr 2024
Labor Force Data							
Civilian Labor Force(1)		(2) 1,180.9	(2) 1,167.9	1,175.1	1,187.7	(P) 1,198.0	
Employment(1)		(2) 1,148.1	(2) 1,134.4	1,133.4	1,143.9	(P) 1,157.1	
Unemployment(1)		(2) 32.8	(2) 33.6	41.6	43.8	(P) 40.9	
Unemployment Rate(3)		(2) 2.8	(2) 2.9	3.5	3.7	(P) 3.4	
Nonfarm Wage and Salary Employment							
Total Nonfarm(4)		1,176.5	1,169.1	1,143.2	1,149.8	1,158.6	(P) 1,170.9
12-month % change		1.3	1.1	0.6	0.8	0.8	(P) 1.0
Mining and Logging(4)		7.9	7.9	7.9	8.0	8.1	(P) 8.2
12-month % change		-4.8	-3.7	-3.7	-2.4	-2.4	(P) -2.4
Construction(4)		56.4	54.3	50.1	50.0	51.0	(P) 55.5
12-month % change		-2.8	-1.6	-4.0	-3.3	-4.5	(P) -2.6
Manufacturing(4)		84.4	84.8	84.5	84.5	84.4	(P) 85.1
12-month % change		0.7	0.7	0.8	0.7	0.2	(P) 0.9
Trade, Transportation, and Utilities(4)		209.0	210.9	203.5	202.4	203.3	(P) 204.0
12-month % change		0.5	0.2	-0.8	0.0	0.1	(P) 0.6
Information(4)		21.5	21.2	21.1	21.4	21.4	(P) 21.4
12-month % change		-0.5	-2.8	-2.8	-2.3	-2.7	(P) -0.9
Financial Activities(4)		73.3	73.5	73.1	73.6	74.0	(P) 73.7
12-month % change		1.2	1.2	1.4	2.1	2.4	(P) 2.4
Professional and Business Services(4)		189.2	186.2	183.2	183.2	185.0	(P) 187.0
12-month % change		-1.3	-1.5	-1.7	-1.9	-1.4	(P) -1.4
Education and Health Services(4)		256.9	254.8	251.0	255.2	257.2	(P) 257.7
12-month % change		4.2	4.1	3.0	3.2	3.6	(P) 3.6
Leisure and Hospitality(4)		114.3	113.7	109.1	110.0	112.1	(P) 116.2
12-month % change		2.9	2.2	1.7	2.6	1.4	(P) 1.8
Other Services(4)		48.2	47.7	47.7	47.6	47.9	(P) 47.8
12-month % change		3.0	1.7	2.8	1.9	1.7	(P) 1.3
Government(4)		115.4	114.1	112.0	113.9	114.2	(P) 114.3
12-month % change		2.1	2.1	2.0	1.4	1.4	(P) 1.2

Footnotes
(1) Number of persons, in thousands, not seasonally adjusted.
(2) Data were subject to revision on April 19, 2024.
(3) In percent, not seasonally adjusted.
(4) Number of jobs, in thousands, not seasonally adjusted. See About the data.
(P) Preliminary

Figure 19. *The Pittsburgh labour market in 2024 (source: U.S. Bureau of Labor Statistics, https://www.bls.gov/eag/eag.pa_pittsburgh_msa.htm)*

Between the 1920s and 1970s, Pittsburgh went through several iterations of revitalization. By the mid-century, Pittsburgh businesses had formed the Allegheny Conference on Community Development (ACCD), a non-profit corporation that helped direct private funding into city planning, social services, and public–private partnerships. The ACCD, which exists to this day, is a philanthropic endeavor. It also helps shape city policies in a direction that benefits local entrepreneurs.

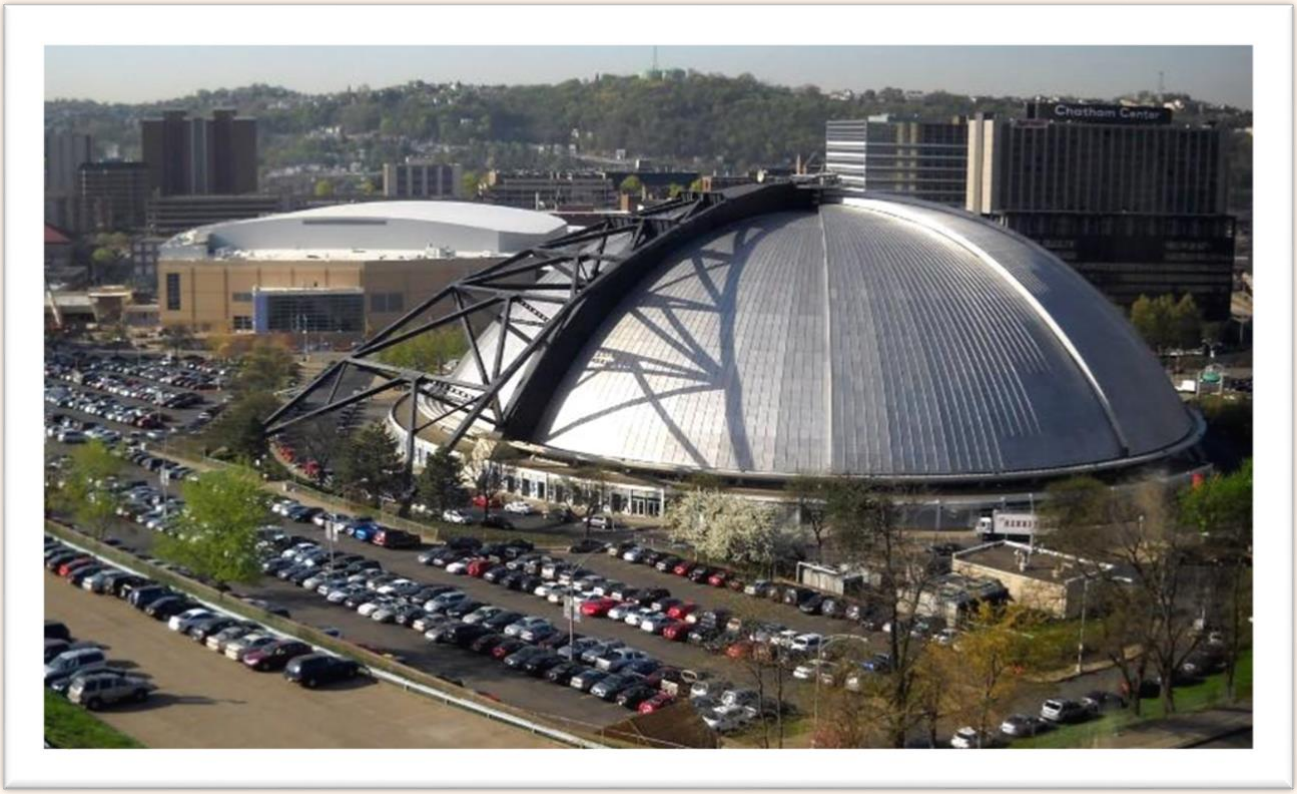


Figure 20. *The Civic Arena with retractable steel roof, built in 1961 and demolished in 2018, was a symbol of Pittsburgh's revitalization (source: https://www.brooklineconnection.com/history/Facts/Arena.html)*

Around the same time that the *Pittsburgh Survey* was conducted, city officials commissioned a study of the city's transportation infrastructure, *Pittsburgh Transportation Problem*. This 1910 study addressed the lack of transportation infrastructure to connect different communities in the city. Pittsburgh has a peculiar geography: different parts of the city are separated by

hills and rivers, and the communities that form the Pittsburgh metropolitan area around the steel mines are barely connected. Between the 1920s and 1940s, the city built a network of streetcar routes that, for a time, helped connect various communities. In the 1960s, the streetcar tracks were demolished and replaced by automobile roads and highways. As of 2024, Pittsburgh offers limited options for public transit, and commuting between geographically disconnected neighborhoods remains a daunting task.

Pittsburgh first articulated its ambitions to become a technology hub in the 1990s. Mayor Tom Murphy, who served the City of Pittsburgh between 1994 and 2006, planned to rebuild the city economy around data and technology. He introduced a legislation to create the Ben Franklin Technology Partnership (BFTP). The BFTP invested in early-stage technology firms and forged career opportunities for the local workforce. Murphy initiated operational modernization and digitization of the municipal services.

The mayor's focus on technology had not been well received by his constituents, who expressed concerns about the city's budgetary deficits. In 2003, the City of Pittsburgh designated itself as "distressed," which meant that it could not fulfil its financial obligations. For the next fifteen years, supporting the city's infrastructure, educational institutions, and social welfare became the primary concerns of the policymakers. In 2018, Pittsburgh retracted its distressed status.

Pittsburgh took on a label of the "smart city" under the next mayor, Bill Peduto. In 2014, Peduto ordered to digitalize the department of licensing, invited researchers from Carnegie Mellon University (CMU) to advise his office on new transportation policies, and equipped the maintenance department with tablets for better coordination. In 2015, the Western Pennsylvania Data Center (WPDC) was established. Designed to operate as a data fiduciary, the WPDC combined data

from multiple public actors, including the City of Pittsburgh, Allegheny County, and Port Authority. Responding to these developments, CMU established a research centre called Metro21: Smart Cities Institute. The goal of the institute has been to provide the policymakers with evidence-based research, particularly in the field of transportation. Under its first director, Bob Gradek, the institute conducted several studies of Pittsburgh's mobility issues, including access to public transit by the city's vulnerable populations, traffic congestion issues, and emergency routes. Under the new executive team of Director Raj Kumar and Executive Director Karen Lightman, Metro21 has been forging partnerships with out-of-state universities and industry players, focusing on goals such as enhancing rural mobility options and promoting energy saving technologies.[102] In 2023, Kumar was appointed as an advisor to the U.S. Transportation Department, and Lightman became an advisor to the Allegheny Country transportation committee.[103]

In many recent ratings, Pittsburgh has been listed as one of ten American "smart cities."[104] In 2023, when I was interviewing Pittsburgh's data and transportation experts, many of the local data governance initiatives had been shut down, citing a lack of commercial success and changing political climate. The new mayor, Ed Gainey has pivoted away from the smart city agenda.

[102] https://www.cmu.edu/metro21/projects/safe-mobility/doe-rural-mobility.html; https://www.cmu.edu/metro21/projects/net-zero-energy/doe-zero-emissions.html

[103] https://www.cmu.edu/metro21/news/news-articles/news-articles-2024/index.html

[104] https://www.visitpittsburgh.com/about-pittsburgh/technology-in-pittsburgh/

Smart Transportation Initiatives in Pittsburgh

In a book chapter The Kind of Solution a Smart City Is,[105] law professor Michael Madison provides a list of twelve projects designated as Pittsburgh's smart city projects. For instance, these include a local initiative to provide broadband connectivity across the Pittsburgh metropolitan area, a real-time transit information board, and a mobility-as-a-service initiative. A thorough look at the city's smart transportation initiatives reveals that many of them did not last past the pilot phase.

The University of Pittsburgh's *PittSmartLiving* project was awarded $1.44 million in 2017 and quietly shut down in 2022. The project aimed to inform commuters about the traffic conditions, encourage the use of municipal buses, and trial flexible pricing options for public transit. The Allegheny County Port Authority had donated an unspecified amount of mobility data to PittSmartLiving, and this data was to be combined with the information scrapped from Google Maps and provided by local weather stations. Information about the project's output is scarce. The passenger app had been trialed with a limited group of users and never publicly released, and the project's website and multiple social media accounts went silent between 2019 and 2023.

Move PGH was a Mobility-as-a-Service (MaaS) initiative that had been trialed in Pittsburgh between 2021 and 2023.[106] The project emerged from the Micromobility Collective public consultation, which the City of Pittsburgh had run between 2019 and 2020. The consultation revealed that a growing number of Pittsburgh families could not afford a car and suffered from a lack of reliable public transit. *Move PGH* was funded through a public-private partnership and encouraged Pittsburgh residents to use micromobility and public transit options

[105] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4097059
[106] https://engage.pittsburghpa.gov/move-pgh

through the Transit app and the Ready2Ride app. The smartphone applications helped commuters customise their routes using a variety of mobility options, including municipal and inter-city buses, electric bicycles, scooters, car-sharing, and carpooling. The applications also worked as payment apps. Real-time data on bus routes and schedules was provided to *Move PGH* by the Port Authority of Allegheny County. Transportation partners of *Move PGH* were given exclusive rights to operate in the city. Some of these firms provided discounts to the commuters who rely on social assistance. In 2022, the City of Pittsburgh released a mid-term report that detailed key demographics of the project and explored the role of the partnering organizations.[107] The final report detailing the results of the pilot was expected in October 2023, but it was never released.[108]

Between 2016 and 2018, Uber was testing autonomous vehicles (AVs) in Pittsburgh. Several local parks in Pittsburgh had to be demolished to accommodate a new AV-proofed road. Residents protested the trials because they did not want to lose their parks and were concerned about the safety of the AV technologies.[109] Uber halted its pilot in Pittsburgh after a fatal traffic incident involving an Uber AV car in Phoenix. From 2018 to 2023, the City of Pittsburgh took part in the Knight Foundation's $5.2 million AV initiative. Along with other U.S. cities like Detroit, San Jose, and Miami, Pittsburgh had been chosen as a site for design and manufacturing of AVs. The project aimed to engage residents in the development and testing of AVs and expected to create new local technology businesses. As part of this initiative, Pittsburgh tested locally produced sidewalk delivery robots.[110]

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[107] https://apps.pittsburghpa.gov/redtail/images/19169_Move_PGH_Mid_Pilot_Report_[FINAL]_v2.pdf

[108] https://engage.pittsburghpa.gov/move-pgh

[109] https://www.witf.org/2019/07/26/after_three_years_pittsburgh_takes_up_the_questions_of_an_autonomous_future/

[110] https://knightfoundation.org/reports/piloting-sidewalk-delivery-robots-in-pittsburgh-miami-dade-county-detroit-and-san-jose-knight-autonomous-vehicle-initiative/

In 2023, Pittsburgh AV companies reported record losses and complained about insufficient venture funding.[111] Some companies went bankrupt, and others pivoted to manufacturing AV trucks.[112]

I have been able to find an ongoing smart transportation initiative in Pittsburgh, a public–private partnership between CMU and Fujitsu Limited. [113] In 2022, the partnership began developing a digital twin technology that helps predict traffic patterns. A privacy-preserving tool, the software converts images from CCTV cameras into 3D models of streets and highways and predicts the traffic patterns. In 2024, the partnership began testing this technology in the streets of Pittsburgh.

[111] https://www.publicsource.org/pittsburgh-autonomous-driverless-vehicles-robot-cars-argo-aurora-locomation/

[112] https://triblive.com/local/regional/self-driving-vehicle-testing-in-pittsburgh-area-shifting-gears-to-focus-on-trucking-industry/

[113] https://www.iotinsider.com/smart-world/ai-powered-social-digital-twin-technology-with-traffic-data-from-pittsburgh/

Data Repositories in Pittsburgh and the People Who Support Them

Researchers observe that the data governance community in Pittsburgh is small and close-knit.[114] Local data governance initiatives rely on interpersonal relationships rather than any formal institutions. Some of the Pittsburgh's smart transportation projects ended, when the individuals who had initiated them changed jobs.

In 2014, the City of Pittsburgh passed an ordinance, which created an open data repository called the **Western Pennsylvania Regional Data Center (WPRDC)**.[115] The ordinance was in line with Mayor Peduto's vision that digitalization of public services contributes to transparency and accountability of the government. All municipal agencies were obligated to contribute data related to matters of public interest to the WPRDC. Initially, the WPRDC was a partnership between the city administration, Allegheny County, the Port Authority of Allegheny County, and the University of Pittsburgh. One of Pittsburgh's steel families had underwritten the costs of data storage and staff salaries.

Robert Gradeck was the founding member and director of the open data repository.[116] His connections to the mayor's office, Pittsburgh's city council, and the social welfare services of Allegheny County made it possible for diverse actors to support the WPRDC. Research conducted by the WPRDC drew on data about Pittsburgh's public transit, weather, and crime rates and helped shape the city's policies. The first WPRDC use case was a study on the city's parking needs (Figure 21). The data on times, locations and payment transactions had been contributed by Pittsburgh's parking authority.

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[114] https://www.cambridge.org/core/books/governing-smart-cities-as-knowledge-commons/kind-of-solution-a-smart-city-is/5CEFBD5B817F872512C65724423B8080

[115] https://data.wprdc.org/dataset/

[116] https://ucsur.pitt.edu/staff_gradeck.php

The parking pilot was so successful that, from 2014 to 2018, Pittsburgh city council relied on the WPRDC analytics to update parking policies. [117] A second public agency to trust the WPRDC with their data was the Port Authority of Allegheny County. The transportation agency intended to better understand its ridership patterns and monthly performance through an analysis of the number of rides per route.[118] Over the course of its existence, the WPRDC accepted and analysed various types of data, including Pittsburgh's weather readings,

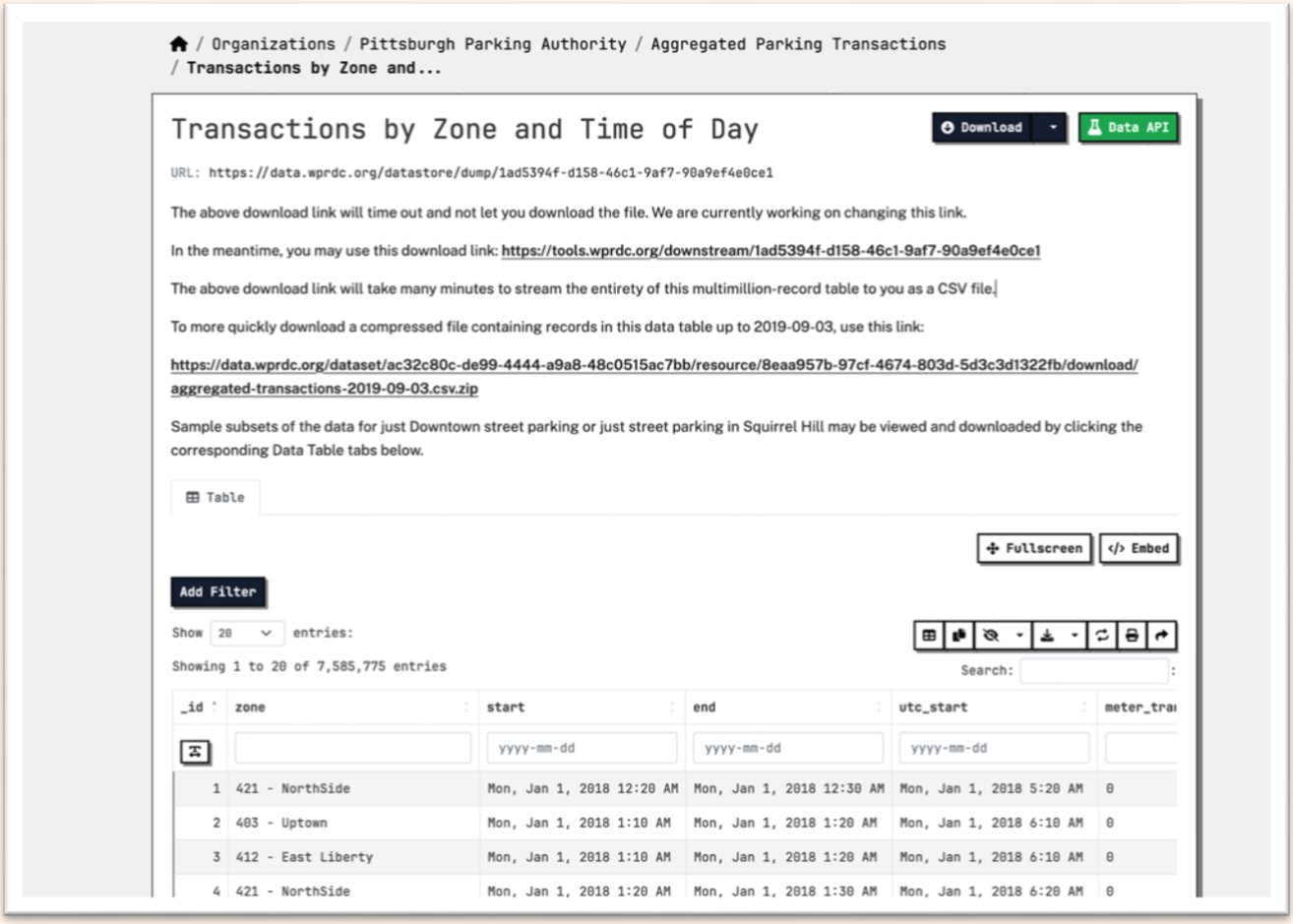

Figure 21. *Parking data on the WPRDC (last accessed by author in May 2024)*

[117] https://data.wprdc.org/dataset/parking-transactions/resource/1ad5394f-d158-46c1-9af7-90a9ef4e0ce1
[118] https://data.wprdc.org/dataset/port-authority-monthly-average-on-time-performance-by-route

jail performance reports, and crime statistics. Local grassroots organizations used open data from the WPRDC to conduct their own research, for example, on cycling patterns in Pittsburgh.

When collaborating with the WPRDC, vendors devise their own data-sharing contracts. Some vendors insist on a sunset clause, which means that the data should be erased by a certain deadline; in other cases, the datasets get anonymized or redacted. For researchers and activists, the WPRDC has been an excellent source of data on different aspects of the city's economy.[119]

The issues with the WPRDC began in 2018, when the Port Authority moved its data to another repository, citing minor errors in the WPRDC's data processing techniques. The city itself was not in compliance with the open data ordinance, and the WPRDC struggled to attract and retain data from other contributors. In 2021, the WPRDC declined to accept and host a dataset from Allegheny County because the data was not sufficiently anonymized. This incident formed a crack in the previously strong partnership between the data repository and the county. The repository's last publicly funded project was *Move PGH,* which was wound down in 2022.

Since 2022, the WPRDC has significantly downsized its operations. Some contributors stopped updating their files, and others removed their data from the WPRDC. As of 2024, the WPRDC is supported by modest funding provided by the University of Pittsburgh. A small team consisting of Robert Gradeck, three software developers and a project manager ensure that the repository stays operational.

[119] https://ucsur.pitt.edu/files/center/Bicycle_Pedestrian_Transit_PA_2018.pdf

The Allegheny County Data Warehouse was established in 1999 as part of a larger restructuring of the county's social service departments after the tragic death of a child in care of the country's social welfare system. That year, Allegheny County created the Department of Human Services and the data warehouse that served its needs. Similar to other data governance initiatives in Pittsburgh, the funding for this project came from local philanthropists. Initially, the warehouse worked only as an internal management tool. During the first decade of its existence, the warehouse began partnering with other government agencies to support decision making and case management. Eventually, the data warehouse became an important policymaking tool at the county, municipal, and state levels.

Data managed by the data warehouse comes from multiple sources, including the Allegheny County court system, Pittsburgh Public Schools, local housing authorities, and the Allegheny County jail system. The data warehouse entered into cooperative agreements with these organizations to merge and conduct analysis of their datasets. In 2013, Allegheny County launched a campaign called "Be There" to examine correlations between the youth missing school and the need for social services intervention. Since 2016, the data warehouse has been using the Allegheny Family Screening Tool (AFST), a predictive analytics software that helps allocate social support to vulnerable children in the community. The tool received harsh criticism in the 2019 book by Virginia Eubanks, *Automating Inequality*, yet its perception in Allegheny County has been rather favourable.[120]

Similar to the case of the WPRDC, success of the data warehouse can be attributed to the work of specific people who managed to secure funding for the project, forged collaborations with public organizations, and developed useful

[120] https://us.macmillan.com/books/9781250074317/automatinginequality

insights from data. In the case of the data warehouse these were Allegheny County public servants Marc Cherna and Erin Dalton.

Data and Transportation Activism in Pittsburgh

Pittsburghers for Public Transit is a union and a grassroots organization that unites transit workers, transit riders, and Pittsburgh residents who live in the vicinity of local transportation infrastructure. The union has a research committee, which prepares reports and policy papers to provide feedback to the City of Pittsburgh and other levels of government. Committee leader Bonnie Fan is in charge of this research and policy work. The union collaborates with the WPRDC to conduct studies on the state of Pittsburgh's public transit, the city's cycling infrastructure, and equity concerns expressed by the residents.

The union's report called *Representing Our Routes: The State of Public Transit and How the City Can Improve It* provides a useful breakdown of the statistical data on what percentage of people depends on public transit and how reliable the bus routes in different Pittsburgh communities are.[121] The report provides an in-depth picture of the city, where 20–50% of residents in each district rely on buses to get to work and access healthcare services. Another report prepared by the union explains why Pittsburgh residents had opposed the development of the Mon-Oakland Connector, a pilot testing program for autonomous shuttles.[122] The report called *A People's Audit of the Mon-Oakland Connector: Why Shuttles (With or Without Drivers) in the Mon-Oakland Corridor*

[121] https://www.pittsburghforpublictransit.org/wp-content/uploads/2023/02/PPTs-Representing-Our-Routes_Feb-22.pdf

[122] https://www.pittsburghforpublictransit.org/wp-content/uploads/2020/04/PPT-Mon-Oakland-Final-Report.pdf

Are Not a Mass Transportation reveals that, even if the project proved financially viable, it would have been unaffordable for the residents. The residents proposed an alternative plan: to add a weekend service for route 39, which is very popular among the residents. Additionally, in 2023, the union ran a campaign to inform the new mayor about the transit needs of the citizens.[123] In 2024, the union advocates for an appointment of a pro-transit Allegheny County executive.

[123] https://www.pittsburghforpublictransit.org/votetransit-county-executive-candidate-qa/

Implementing Data-Driven Transportation in Canada: Existing Regulations

The existing regime of data and artificial intelligence regulation in Canada is expected to change in the coming years, with the standardisation of automated decision-making rules (Directive on Automated Decision-Making), the introduction of comprehensive AI legislation (AIDA), and the roll-out of new trade agreements with Canada's key partners.[124] Currently, Canada's technology industry is regulated by a piecemeal combination of existing privacy law, tort law, human rights law, and intellectual property (IP) law.

Artificial intelligence poses significant risks to the rights of Canadians guaranteed by Canada's Charter of Rights and Freedoms, the Canadian Human Rights Act, and various provincial statutes. Specifically, AI may infringe on mobility rights, the right to equal treatment with regards to employment, and democratic rights. A 2024 class action suit claims that the ArriveCan app violated the rights of Canadians by denying them access at the border and mistakenly sending them to quarantine.[125] The use of AI in recruitment often results in discriminatory hiring practices based on gender, age, race, color, and personality traits.[126] In 2024, two US recruiting companies faced AI discrimination lawsuits as their algorithms allegedly screened out qualified candidates based on race or age.[127]

[124] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4507114
[125] https://www.ctvnews.ca/politics/arrivecan-technical-issues-violated-charter-rights-alleges-new-class-action-application-1.6778004
[126] https://www.nature.com/articles/s41599-023-02079-x
[127] https://www.forbes.com/sites/karadennison/2024/03/21/could-lawsuits-against-ai-lead-to-a-shift-in-job-searching/?sh=1b7ef1473d86

In 2019, the Government of Canada released the *Directive on Automated Decision-Making (DADM)*[128], a guiding document for public agencies seeking to deploy automated decision-making systems in their administrative processes (excluding internal digital systems).

The functioning of automated decision-making systems may be skewed by bias; furthermore, they may operate on incomplete information, leading to discrimination against individual applicants and groups. The directive outlines several principles of responsible AI governance in the public sector: transparency, accountability, legality, and procedural fairness. The DADM's key objectives[129] are to ensure that all systems deployed by the government are subject to internal impact assessments and that affected citizens are informed about the technologies and data used in processing their documents. The DADM complies with the principles of responsible AI governance proposed by the Organisation for Economic Co-operation and Development (OECD),[130] i.e., human-centered values, fairness, transparency, robustness, security, and safety. In 2023, the Treasury Board of Canada concluded its three-stage review of the DADM. The feedback[131] collected from multiple stakeholders included a suggestion to extend the DADM's applicability to all public digital systems excluding the ones that protect national security; a requirement for external impact assessments and comprehensive review of the datasets; a recommendation to make the system reviews periodical; and a requirement to provide detailed information to citizens who have been denied

[128] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3722192
[129] https://www.statcan.gc.ca/en/data-science/network/automated-systems
[130] https://oecd.ai/en/dashboards/policy-initiatives/http:%2F%2Faipo.oecd.org%2F2021-data-policyInitiatives-24240
[131] https://wiki.gccollab.ca/images/3/33/3rd_review_of_the_Directive_on_Automated_Decision-Making_-_2nd_What_We_Heard_Report_(EN).pdf

social benefits or public services regarding the level to which the process was automated and the criteria used to make a decision.

As of May 2024, the status of the DADM is unclear. The page on the DADM has been deleted from the Government of Canada website.

The *Artificial Intelligence and Data Act* (*AIDA, Bill C-27*)[132] was tabled in the House of Commons in 2022. If passed, the AIDA will become the first Canadian comprehensive AI regulation. In its original version,[133] AIDA applied only to the high-risk AI systems, which the bill did not define; it also proposed establishing a new office of the data and artificial intelligence commissioner, which came without budget and staff. Instead, the commissioner was proposed to be a staffer in the Ministry of Innovation, Science and Economic Development (ISED).[134] The AIDA received significant pushback: critics pointed to the lack of clarity regarding the scope and the enforcement powers of the legislation,[135] the inevitable conflict of interest between the ISED and the new commissioner, [136] and the absence of meaningful public consultations on the draft bill.[137]

In response to these criticisms, in November 2023, the ISED proposed amendments to Bill C-27.[138] The amendments include an updated definition of "artificial intelligence systems" adapted from the 2023 OECD definition of AI, as well as some criteria for defining algorithmic systems as high-risk or general-purpose AI. AIDA now defines AI as "a system that, using a model, makes

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[132] https://www.parl.ca/legisinfo/en/bill/44-1/c-27

[133] https://cbr.cba.org/index.php/cbr/article/view/4817

[134] https://www.ourcommons.ca/Content/Committee/441/INDU/Brief/BR12711886/br-external/ArtyushinaAnna-10810464-f.pdf

[135] https://www.cigionline.org/articles/ai-regulation-should-not-be-a-blank-cheque-for-government/

[136] https://www.cigionline.org/articles/proposed-changes-to-canadas-bill-c-27-do-little-to-mitigate-ai-harms/?utm_medium=organic

[137] https://thelogic.co/news/digital-rights-advocates-say-ottawas-ai-law-still-needs-work-or-a-do-over/

[138] https://www.ourcommons.ca/content/Committee/441/INDU/WebDoc/WD12751351/12751351/MinisterOfInnovationScienceAndIndustry-2023-11-28-Combined-e.pdf

inferences in order to generate output, including predictions, recommendations or decisions." This definition is foundational to AIDA, as it specifies that the legislation will apply only to systems that make inferences -- not all computational systems. In its latest version, the AIDA provides nationwide requirements for companies designing, developing, and deploying AI regardless of whether the technologies were created in Canada or imported.[139] Companies must provide assessments of the severity of harms or adverse impacts caused by algorithms and inform the Commissioner whether it is possible to opt out from the system, practically and legally; furthermore, companies must establish measures to identify and mitigate the risks of harm or biased output generated by AI.

High-risk systems have been defined as technologies used in healthcare and emergency services; technologies used by courts, social services, and administrative bodies to decide on individual's rights, responsibilities, and priority of service provision; technologies used to process biometric information; technologies used in content moderation; technologies deployed by law enforcement agencies; and technologies used for employment purposes. Developers and operators of high-impact AI have significant obligations: they must inform clients/users when an AI system is used and for what purposes, publish a plain-language explanation for clients/users detailing what kind of data the AI system collects and processes and how it operates, define whether their system is high-risk or general-purpose, conduct impact assessments prior to the release of AI systems to ensure they do not pose significant risks, and undergo audits by the AI and Data Commissioner along with external audits (if required). AI systems that do not qualify as high-impact systems (the general-purpose

139 https://www.ourcommons.ca/content/Committee/441/INDU/WebDoc/WD12751351/12751351/MinisterOfInnovationScienceAndIndustry-2023-11-28-Combined-e.pdf

systems under AIDA) are subject to less stringent requirements. Companies must watermark the content generated by algorithms and inform clients/users in plain language how the system is working, the designers and developers of these systems are required to take measure to assess and mitigate potential harms, and human oversight is required to review the work of the system during its life course.

If an AI system does not comply with the regulations, it will be required to shut down until the issues have been addressed by responsible parties. If the problems persist, it will be required to stop operating permanently. An important change to the AIDA enforcement practices is that the legislation now requires companies to name individuals responsible for design, development, and deployment of AI systems. In this case, it is impossible for businesses to avoid responsibility for the actions of the technologies they create or deploy.

Since AI systems require large amounts of data to train and operate, nearly every use of AI raises privacy concerns. In Canada, the collection, processing, and disclosure of personal information by businesses is regulated by the federal Personal Information Protection and Electronic Documents Act (PIPEDA) and substantially similar provincial legislation in Alberta, British Columbia, and Québec. PIPEDA emphasises informed consent as a mandatory requirement for all instances in which personal information is collected, shared, transferred, or disclosed. AI developers should be aware of the obligations mandated by PIPEDA, and Canada's data privacy regulators have authority to investigate if a company uses data without acquiring proper consent. In 2023, privacy authorities from Alberta, British Columbia, and Quebec joined the federal privacy commissioner to launch an investigation into the data sharing practices of OpenAI, the company responsible for ChatGPT.

Existing intellectual property (IP) legislation in Canada does not directly address issues caused by AI, including when chatbots generate written texts or images that could be considered intellectual property. However, the decision of the Canadian Intellectual Property Office (CIPO) in the DABUS case envisions the possibility of designating IP rights to the outputs generated by chatbots. In November 2021, CIPO issued a compliance notice, stating that a patent application designating an AI system (DABUS) as an inventor was not compliant with Canada's Patent Act.[140] However, CIPO suggested that the owner of DABUS may identify themselves as the legal representative of the inventor and claim legal rights to the AI-generated works. The case has yet to be resolved.

The Government of Canada suggested multiple approaches[141] to protecting AI-generated outputs under the Copyright Act, given that, under Canadian law, an author must be a natural person: from attributing authorship only to humans, to applying authorship to the persons who arrange for an AI system to do a job, to creating a new set of rights for AI-generated works. These suggestions, however, have not been included in AIDA, and attributing rights to AI-generated outputs remains a significant issue.

Tort law[142] is another source of protection for Canadians when dealing with AI and data-driven technologies. While the issue has yet to be explored by Canadian courts, the common law of negligence will likely apply in instances where parties have been harmed by AI systems. Activities that give rise to negligence claims or illegal activities remain negligent and illegal even if

[140] https://www.nortonrosefulbright.com/en-ca/knowledge/publications/5881ba46/ai-inventorship-on-the-horizon-dabus-comes-to-canada

[141] https://ised-isde.canada.ca/site/strategic-policy-sector/en/marketplace-framework-policy/copyright-policy/consultation-modern-copyright-framework-artificial-intelligence-and-internet-things-0

[142] https://www.torys.com/en/our-latest-thinking/publications/2023/04/guide-to-artificial-intelligence-regulation-in-canada#comparisons

conducted through AI systems. Canada's tort law will likely be useful in cases involving identity fraud, duplication of images and voices, and non-consensual distribution of intimate images (e.g., deepfakes). In British Columbia, the Intimate Images Protection Act prohibits dissemination of intimate images without obtaining the consent of individuals depicted in the images. Though liability can certainly be assigned when an AI system has conducted fraudulent activities, Canadian law has yet to address the problem of multiple stakeholders involved in the development and use of AI.

The human rights law in Canada, including the provisions against discrimination and discriminatory practices in the Canadian Human Rights Act and the provincial statutes, provides certain protections to individuals whose rights been affected by AI. For example, an AI system may unintentionally perpetuate the underrepresentation of a marginalised group that was present in the training data. Developers and users of AI systems should consider these risks and take precautions to ensure that AI systems do not discriminate against any types of users or clients. In December 2023, federal, provincial, and territorial privacy authorities launched a set of principles to support the responsible and privacy-protective development and use of generative AI technologies in Canada.[143] These guidelines urge companies that create and deploy AI to minimise the use of personal and sensitive data, inform Canadians in plain language about the work of their AI systems, and ensure that the systems are compliant with existing law and available for public oversight.

[143] https://www.priv.gc.ca/en/privacy-topics/technology/artificial-intelligence/gd_principles_ai/

Policy Recommendations

As this report shows, cities are in dire need of the following resources:

- mobility data
- public data collection and data processing infrastructure
- funding for smart transportation projects
- employees with expertise in data governance and social sciences.

My three primary case studies— Seoul, Boston, and Pittsburgh, highlight the importance of digital governance (i.e., governance of data and data infrastructure) in transportation management. To generate economic and social benefits from mobility data, a municipality needs to become a data steward. When the city does not own or control data infrastructure, data-driven transportation initiatives become too costly and ineffective.

When deployed properly, public transit solves many contemporary urban problems: from road safety to equity to environmental care. However, persuading residents that the city needs a public transit system can be a serious challenge for the policymakers. As this study shows, deploying data-driven solutions to prevent citizens from using personal vehicles may not be the best strategy. In Boston, this policy had backfired to the city administration and worsened the traffic situation. In Pittsburgh, a progressive mayor's data-driven transportation initiatives had been met with public pushback, as collapsing bridges indicated the need to reorient municipal budgets to the city infrastructure. An alternative approach is to make public transit attractive to the citizens. In Seoul, commuters have a choice of mobility options, and the government continuously works to improve the competitiveness of the public transit.

In a 2023 article "Slow governance in smart cities: An empirical study of smart intersection implementation in four US college towns," lawyers Madelyn Sanfilippo and Brett Frischmann provide important use cases for the study of smart transportation governance. Four American college towns experimented with smart intersection technologies and found that there was no one-size-fits-all traffic management solution. It requires a slow and iterative approach for the community to find a technology that performs well and aligns with its goals. For city governments, adopting a user-centered approach is key to the successful deployment of data-driven transportation solutions. Public transit, however smart, should provide added benefits for commuters.