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Article

# The spectacle of automation and status aspirations: adoption of automated metro systems around the world, 2000–2020

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## Abstract

Automation's extensive impact on the labor market and economy is well recognized, but the underlying motivations for its adoption remain understudied. To address this gap, we analyze an original dataset covering 1276 cities across 148 countries, using event history analysis to examine the adoption of automated metro systems. Our research suggests that city governments are driven by status competition in their decisions to automate subway systems. We find that high-status cities are more likely to adopt automation. However, this trend diminishes when cities are preparing to host a mega-event such as the Olympics, indicating that lower-status cities use these events as opportunities to adopt automation technologies. Our finding reveals that status-driven aspirations, manifesting in the spectacle of automation, are a significant motivator for adopting automated technologies, prompting further investigation into the socio-economic factors influencing automation and the symbolic importance of technological advancement across various economic sectors.

**Key words:** Automation, Status, Status Competition, Urban Infrastructure, Mega-Events

**JEL classifications:** O18, P50, Q55

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## 1. Introduction

Automation, the introduction of automatic equipment to the production process of goods and services, has garnered significant attention. Research has largely focused on its impact on employment, wages, and work organization (Smith and Anderson, 2014; Frey and Osborne, 2017; Nedelkoska and Quintini, 2018; Benanav, 2020), while also exploring its

broader effects on inequality, politics, work, and housing worldwide (Rosen *et al.*, 2021). Recent scholarly efforts have begun to investigate the sociological aspects of automation, responding to calls for a deeper understanding of the socio-political context surrounding automation (e.g. Spencer, 2017; Wajcman, 2017; McClure, 2018). In line with this, recent studies have examined various factors influencing the adoption and spread of automation, such as the aging labor force (Acemoglu and Restrepo, 2022), immigration dynamics (Liu and Portes, 2021), labor protests (Parolin, 2021; Liu and Zhang, 2022), and national developmental policies (Lei, 2022).

Our study considers automation as an integral part of capitalist urbanization projects. In this framework, cities worldwide showcase their technological prowess as spectacles through infrastructure, projecting an image of future economic prosperity to attract capital and upgrade their status in global competition. This phenomenon aligns with the idea that technological innovation fuels status competition among organizations (Podolny *et al.*, 1996), influences urban governance (McNeill, 2016; Wells *et al.*, 2023), and shapes economic development strategies (Ó Riain, 2000; Lei, 2022). Notably, Lei (2022) shows how local Chinese governments employ automation as part of a political strategy to ‘upgrade’ their economies, reflecting a national aspiration for engaging in capitalist competition by adopting automation technologies. We extend this idea to the urban context, proposing that the urban landscape serves as a neoliberal development project for cities to attract global capital and engage in status competition (Graham and Marvin, 2002; Harvey, 2003; Polillo and Guillen, 2005). Beyond the assumption of utility underlying technological diffusion and efficiency, we interpret automation through the lens of its aesthetic and symbolic value in attracting capital.

Our analysis of automated subways worldwide demonstrates this approach. The selection of this case study is primarily due to the uniqueness and comprehensiveness of our dataset. We compiled this dataset from publicly accessible data on automated metro lines and various city-level variables, enabling comparisons across a vast array of cities over an extended period. Although our dataset focuses specifically on public transit, it compensates for this narrow scope by including a broad geographical range compared to previous studies, facilitating analysis at the urban level. Quantitative research on automation commonly uses data from the International Federation of Robotics (IFR), which includes a variable that measures the ratio of robots to workers. However, a significant limitation of this data source is the small geographical scope (The International Federation of Robotics, 2021). Relatedly, the lack of local-level data in the IFR dataset makes it difficult for researchers to investigate local variations within countries, although recent studies have attempted to resolve this issue by inferring the number of robots in a region based on its employment figures (Acemoglu and Restrepo, 2022; Liu and Zhang, 2022). In contrast, our dataset allows for a direct examination of city-level variations in automation offering broad geographical coverage.

We constructed a novel dataset covering automation events in 1276 cities across 148 countries. Our findings based on event history analysis indicate that cities are more likely to automate their metro systems when they have higher status and in the 5 years leading up to hosting mega-events like the FIFA World Cup, the Olympics and the World’s Fair. Notably, the linear status effect diminishes during the 5-year mega-event window. This finding is replicated even after accounting for city-level fixed effects, suggesting that the trend is not limited to just a handful of rapid-builder cities. Our results also highlight that this effect is not

relegated to constructing new metro lines. We posit that the resource constraints of lower-status cities, despite their ambitions for higher status and capital attraction, restrict their ability to establish automated metro systems that require high costs of initial establishment. However, the status effect is lessened when the city is preparing to host mega-events, as these occasions provide unique opportunities for status elevation and resource acquisition facing a global audience.

This study underscores the importance of empirical research on the ‘spectacle’ of technology, enhancing our understanding of how automation intersects with urbanization by positioning inter-city status competition as a key driver in the adoption of automation technologies. It suggests that technology has capacity to reinforce and further entrench capitalist hierarchies by demonstrating how cities strategize to ascend the status hierarchy and foregrounds the relational and networked diffusion of technological adoption.

## 2. Technological innovation and status competition

Unlike the implicit understanding that automation is primarily driven by reasons of economicism, sociological perspectives highlight the significant confluence of status in economic life. Status, a social estimation of honor and prestige, is not strictly tied to economic capability in the narrow sense but is interlinked with economic resources and advantages (Phillips and Zuckerman, 2001; Bitektine, 2011; Sauder *et al.*, 2012). This hierarchy tends to reproduce itself and is often stable over time despite some possibility of change (Lynn *et al.*, 2009; Podolny, 2005). Actors anticipate the behavior of others based on status positions, shaping their actions and objectives accordingly. In various domains, status hierarchies not only influence behavior but also perpetuate inequalities and establish cultural norms and moral classifications (Ridgeway, 2013; Fourcade and Healy, 2017; Accominotti *et al.*, 2018).

One strategy for actors to maintain or elevate their status is by adopting cutting-edge technologies (Compagni *et al.*, 2015; Pollock *et al.*, 2019). Similar to *distinctive consumption* practices among high-status individuals, which are associated with refined taste (Bourdieu, 1984; Accominotti *et al.*, 2018; Friedman and Reeves, 2020), the use of advanced technology serves as a means for high-status actors to differentiate themselves and preserve their status. Empirical studies show that high-status actors often have more resources and access to adopt innovations earlier than their low-status counterparts (Van den Bulte and Joshi, 2007; Iyengar *et al.*, 2011). This early adoption rewards high-status actors, further consolidating their resource base (Sine *et al.*, 2003; Kim and Rhee, 2016; Correll *et al.*, 2017; Park *et al.*, 2019). Conversely, low-status actors generally face resource constraints and have fewer opportunities to benefit from new technologies, although they are more eager to do so to increase their social status by conveying the image of being innovative if they have enough access and resources for the adoption (Hu and Van den Bulte, 2014; Compagni *et al.*, 2015, pp. 250–251).

In the context of cities, which also participate in status classifications, our study links the concept of status with global city competition. The rising prominence of global capital has shifted focus toward ‘global’ cities, which employ various strategies to actively participate in global capitalism (Sassen, 2001; Schragger, 2016). In the literature on the city growth machine, urban infrastructure, and neoliberalism (Molotch and Logan, 1987; Harvey, 1989; Kirkpatrick and Smith, 2011), fiscal strategies such as tax reduction and

deregulation are identified as key methods for cities to attract capital (Pacewicz, 2016; Rosenberg and Brent, 2020; Wolf, 2022). Competing for global capital, city governments invest in urban renewal projects and define their ‘place identity’ to enhance their attractiveness to global capital, aiming for status distinctions (Florida, 2005; Anttiroiko, 2015). Often supported by national governments, city governments project an identity tied to economic achievement and prosperity (Ong, 2007). Taken together, these city government tendencies mirror the behavior of actors that compete in status hierarchies.

### 3. Urban spectacle and mega-events

We argue that cities utilize spectacles to capture and translate capital into status gains. Spectacle is described by Debord (2020 [1967], p. 12) as ‘images detached from every aspect of life’, which Debord sees as a site of illusion and false consciousness. He elaborates that ‘the fetishistic appearance of pure objectivity in spectacular relationships conceals their true character as relationships between human beings and between classes’ (Debord, 2020 [1967], p. 19). While often linked to mass media and communication technologies, the concept of the spectacle also applies to global cities (e.g. Ley and Olds, 1988; Carter, 2006; Ong, 2011; Shin, 2012). Aihwa Ong (2011), in particular, highlights the significance of skylines and large-scale construction projects in global cities as symbols of political and status ambitions. In the face of a global audience, city governments create spectacles by highlighting their infrastructural amenities (Florida, 2005; Graham and Marvin, 2002; also see Sadowski and Bendor, 2019).

Technology, as a pivotal aspect of urban infrastructure, has been historically employed to symbolize modernity, closely aligning city development with narratives of modernization rooted in science, technology and standardization (Kaika and Swyngedouw, 2000; Graham and Marvin, 2002). Infrastructural networks often embody a culture of the ‘technological sublime’, glorifying narratives of technological triumph (Jameson, 1991; Graham and Marvin, 2002). Particularly in cities of the global south, governments project and advocate for technological advancements to elevate their status (Ó Riain, 2000; Lei, 2022; Chorev and Ball, 2022). For example, Chorev and Ball (2022) observe that the development studies literature sometimes equates innovation directly with economic growth. Such a fixation on technology can lead to infrastructural projects being pursued irrespective of their efficiency, effectiveness or potential impacts on inequality (Jasanoff and Kim, 2015; Lei, 2022; Wolf, 2022).

We also explore how cities’ status competition is heightened during the spectacle of mega-events. Mega-events, characterized by ‘visitor attractiveness, mediated reach, cost and [urban] transformative impact’ (Müller, 2015), are widely considered as a global showcasing of urban spectacle (Wu *et al.*, 2016). Examples of mega-events include the Olympics, the FIFA World Cup and the World’s Fair. Despite constant political controversies on whether such mega-events benefit everyone in the city (Burbank *et al.*, 2001), cities bid to host mega-events to advance visibility and attract global capital (Hiller, 2000; Schimmel, 2006). Furthermore, cities also have the eventful opportunity to receive funding from federal governments toward infrastructure during mega-events (Zimbalist, 2016). For example, Seoul expedited the construction of line 6 in time for the 2002 World Cup. FIFA officials were shown on television using this newly opened subway line to travel to the opening

ceremony, indicating the importance of the infrastructural images reaching a global audience (KBS News, 2002).

Therefore, we conceptualize mega-events as opportunities for cities to showcase their technological prowess and signal the promise of future economic prosperity. This creates appealing prospects for investment by global capital.

#### 4. Hypotheses

To develop concrete empirical predictions about the role of urban spectacles in automation, we examine automated metro systems. The first completely automated metro system was launched in Kobe, Japan, in 1981, aiming to replace on-board human staff with automated systems. In such systems, operators in a central control room drive trains remotely using computerized systems. The International Association of Public Transport (UITP) in 2018 defined levels of train automation as ‘Grades of Automation’ (GoA), ranging from GoA1 to GoA4. GoA1 includes systems that prevent collisions and manage braking and speed limits, while GoA4 refers to systems where central room staff control all aspects of operation, including train motion, door closing and emergency response (UITP, 2018).

The shift toward automated metro infrastructure, often driven by labor cost considerations, faces high initial investment costs required for automation technology. According to a UITP report, a fully automated system remains more expensive than a conventional one, although the cost disparity is narrowing (UITP, 2019, p. 5). Additionally, the adoption of GoA4 trains does not always eliminate the need for onboard staff. For instance, train attendants were introduced in the Incheon Metro Line 2 in Seoul's metropolitan area following several accidents (MBC News, 2017; Ki-Ho Ilbo, 2022). This raises questions about the cost-efficiency of automated metro systems and complicates the decision-making process for cities considering automation. Despite predictions of 2300 km of automated metro lines by 2025 (UITP, 2018), the majority of metro systems still operate with train operators and sometimes also conductors on board.

We propose that high-status cities are more likely to adopt automated metro systems due to their greater capacity to secure funding and bear initial setup costs. In contrast, lower-status cities might be motivated by the opportunity to enhance their standing, particularly when they are in the global spotlight, such as during mega-events. A case study of such a dynamic is the Doha Metro in Qatar.

Doha revealed its automated metro system in 2019 in preparation for the 2022 World Cup, despite initial hesitation in the early 2010s for a metro system due to low expected usage and high maintenance costs (Qatar General Secretariat for Development Planning, 2011, p. 82). This suggests that substantial construction and infrastructure investments are closely tied to the significance of the mega-event. Around \$229 billion was spent on World Cup infrastructure, including \$36 billion for the Doha Metro and other infrastructural facilities, despite the event itself grossing only \$17 billion (Railway Technology, 2019; Silic, 2022).

International publicity campaigns on the city and the Doha Metro during the World Cup emphasized innovation and futurism, demonstrating the situational opportunity to signal status to a global audience during mega-events. An advertisement in the Wall Street Journal showcased the city's ‘world-class innovation’ demonstrated by its entrepreneurial spirit and substantial investments in research and development. The advertisement read, ‘in

November 2022, Qatar's \$6.5 billion investment in a major soccer tournament placed the region under a global spotlight. ... The megaevent created a halo effect for Qatar. ... What does the region's burgeoning sports sector offer businesses and long-term investors?' ([Wall Street Journal, 2022](#)). In the same time period, Doha Metro decided to use automation technologies after benchmarking the Dubai Metro established in 2010, which is another automated system ([Rizzo, 2013](#)). When construction was completed, CNN published a laudatory article about the Doha Metro, highlighting the speed, automation, and exclusivity of the system: 'It's fast. It's driverless. It has a Gold Class for premium passengers.' The article observed that the metro system's architecture was intentionally designed to convey an image of futurism while also embodying the place-based aesthetics of Qatari traditions ([Sideridis, 2021](#)). As Doha's case suggests, we hypothesize that while high-status cities are generally more likely to adopt automated metro systems, this tendency may lessen when a middle- and lower-status cities are preparing to host a mega-event.

## 5. Methods

### 5.1 Data

Our study utilizes a novel dataset comprising automation events in 1276 cities across 148 countries, spanning from 2000 to 2020. The data for this study consist of the list of metro systems around the world, the list of automated metro systems, country-level data and city-level data, all of which consist of time-varying variables. Notably, because all the variables in the study are time-varying, it limited the scope of data sources. The unit of analysis is a city, or a metropolitan area if the metro system connects multiple adjacent cities. The data frame is from 2000 to 2020, and the time unit of analysis is one-year intervals. We start the analysis from 2000, which is the earliest start date of the city status variable becomes available. The data frame is all cities listed in the *UN World Urbanization Prospects: The 2018 Revision* ([The United Nations, 2019](#)), defined as cities and metropolitan areas with a population of 300 000 or more. We constructed a panel of cities that fit this definition in 2000. The dataset encompasses 26 796 observations (1276 cities over 21 years).

We combined this panel with other data relevant to urban passenger transit with time-varying characteristics. First, we referenced [Ovenden \(2015\)](#), which provides a comprehensive list of global urban train systems up to 2015, including planned and operational metros. We supplemented this list with further research on metro systems starting operations between 2015 and 2020. We limited the data to metro systems, defined as train services operating on heavy railways distinct from road traffic, consistent with the definition that [Ovenden \(2015\)](#) uses in his classification. Based on the list, our research assistants gathered information on each metro system, including its year of operation commencement and subsequent expansions through the addition of lines. As it will be further elaborated below, this is to account for the possibility that rapid-builder metro systems are more inclined to incorporate automated systems simply because they are more prone to building more metro lines in general. For information on the history of each system's expansion, we primarily used official websites when available in English. The research team, equipped with language proficiency in Chinese, Spanish, French, Russian, Turkish, German and Korean accessed websites in these languages as well. In cases where such resources were not available, we referred to private websites such as the UrbanRail.Net (<https://www.urbanrail.net>). The sources of our data have been recorded and are available upon request.

Automation data were sourced from the Observatory of Automated Metros (<http://metroautomation.org>), maintained by the International Association of Public Transport (UITP). This database includes details like the city, the year of automation, and the suppliers for the signaling system and rolling stock.

For city status, we used data published by the Globalization and World Cities Research Network (GaWC) based in the Geography Department of Loughborough University. It measures status through scoring the importance of a city in a network of 100 global firms distributed across 315 cities worldwide (Taylor and Derudder, 2016). It was chosen for its extensive regional and temporal coverage, as well as its popularity in social scientific research (Jacobs *et al.*, 2010; Belderbos *et al.*, 2020; Faure and Lauermaun 2023). Additionally, because this ranking has been updated multiple times since 2000, the time-varying nature of the data helped us match the timing and occurrence of metro automation with the status variable.

Information on cities hosting mega-events was collected from the Bureau International des Expositions (BIE), the International Olympics Committee (IOC), and the Federation Internationale de Football Association (FIFA).

City-level GDP per capita were compiled from OECD.stat (<https://stats.oecd.org>), the CEIC data (<https://www.ceicdata.com/en>) for cities in Brazil, China, India, and Indonesia, and the Metropolis (<https://www.metropolis.org>). The city-level population density variable combined population data published by the *UN World Urbanization Prospects: The 2018 Revision* (The United Nations 2019) with the city land size information from sources like Britannica, DB City (<https://en.db-city.com>), and Google.

Country-level control variables were obtained from the World Bank (2020) and the Global Competitiveness Index published by the World Economic Forum (Schwab, 2019). Country-level data on labor rights and union density came from the Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (ICTWSS), which are annually collected from 55 countries that include all OECD and EU members as well as additional data from G20 countries (Visser 2019). These datasets were merged based on the data frame we constructed for this study.

Due to missing data in certain variables (as shown in Table 2), our complete case analysis was limited to 1934 observations, constituting only 7.2% of the full dataset. To address this issue, we used linear time trend interpolation for cases with at least two data points, avoiding extrapolation outside the data range. After this process, we applied multiple imputation with chained equations (MICE) strategy for remaining missing values as described by Allison (2001). This method iteratively imputes missing data in one variable using other variables with random variances over multiple rounds (ten in our case). This process generated a single imputed dataset, which we replicated 20 times for our analyses. To ensure accuracy, we appropriately adjusted standard errors to account for potential underestimation due to the imputation process.

## 5.2. Variables

The dependent variable of this study is the number of years it takes a city to adopt an automated metro system since 2000 or the last year a city adopted a new metro line. Automation is defined as the introduction or conversion of a metro line into an automated system. We measured automation based on whether the metro system operated an automated train service with a capacity of over 100 people, following the data collection

methodology by the UITP. However, to maintain consistency with our data frame, we excluded automation events of light rails and trams from our analysis. This led to the identification of 36 automation events from 2000 to 2020. Most of these automation events were new line introductions to the system, with only two instances involving the conversion of existing non-automated lines into automated ones (Nuremberg, Germany, in 2009, and Paris, France, in 2012). A detailed overview of these automated metro systems from 2000 to 2020 is presented in [Table 1](#).

Our main independent variable is a city's status. Previous studies measure an economic entity's status based on its connectivity to other high-status entities ([Pollock et al., 2019](#)). Similarly, the GaWC ranks cities by calculating their centrality in intra-corporate networks, assessing the connections between cities through global corporations. We converted the GaWC rankings into percentiles, with 1 representing the highest and 0 the lowest rank. It should be noted that not all cities in our data frame are included in the GaWC ranking. If a city is absent from the GaWC ranking, it is considered to have a lower status than the lowest-ranked city in the GaWC list. For these cities, we assigned a rank of 0. We conducted a supplemental analysis only including cities in the GaWC list and obtained consistent results.

In order to measure city participation in global society, we incorporated an indicator of mega-event hosting. Following [Müller's \(2015\)](#) characterization of mega-events, which includes the World's Fair, Olympic Summer and Winter Games, FIFA World Cup, Asian Games, European Football Championship, Commonwealth Games, Universiade and the Pan American Games, we focused on the World's Fair, Olympic Summer and Winter Games, and FIFA World Cup due to their international prominence, scale, and investment requirements. We used a dummy variable to denote the year a city hosted one of these events and five preceding years to account for preparation (1 = hosted). Given that our data frame extends to 2020, this includes mega-events scheduled through the end of 2025. Additionally, we performed supplemental analyses with varying thresholds of three and four years prior to hosting, yielding consistent results.

We include several control variables at the city level to mitigate the omitted variable bias in estimating the relationship between a city's status in the global competition system, the hosting of mega-events, and the adoption of driverless metro lines. To account for a city's economic characteristics in our analysis, we controlled for city gross domestic product (GDP) per capita, adjusted to constant 2010 US dollars and logged to mitigate the excessive impact of outliers. City population density was included as a proxy for the general demand for public transportation in a city, also logged to reduce the influence of outliers. We controlled for the city's metro infrastructure, specifically the number of preexisting metro lines. This measure aims to reduce the impact of the possibility that a city has saturated its metro line needs. Additionally, we account for the number of automated metro lines to address potential variations in a city's inherent propensity to adopt automation more readily than others.

At the country level, we controlled for country-level status using the Global Competitive Index from the World Economic Forum. The methodology for creating the country-level status variables mirrored those used for city-level ones, considering whether a country is home to the headquarters of companies that produce automated rail signaling systems or automated rolling stock in metro systems. Automation requires an automated rail signaling system (usually CBTC) that communicates the location and movement of the train (the

**Table 1** The list of automated metro systems, 2000–2020

No.	Country	City	Operator	Year
1	Canada	Vancouver	SkyTrain Millenium Line	2002
2	Denmark	Copenhagen	Metroselskabet I/S	2002
3	Singapore	Singapore	SBS Transit Limited	2003
4	Japan	Nagoya	Aichi Rapid Transit	2005
5	Italy	Turin	Gruppo Torinese di trasporti	2006
6	Switzerland	Lausanne	Transports publics de la region Lausannoise	2008
7	Japan	Tokyo	Tokyo Metropolitan Bureau of Transportation	2008
8	Germany	Nuremberg	VAG Nürnberg	2009
9	Canada	Vancouver	Protrans BC	2009
10	Spain	Barcelona	Transports Metropolitans de Barcelona	2009
11	UAE.	Dubai	Serco	2009
12	Singapore	Singapore	SMRT Corporation	2009
13	Brazil	São Paulo	Companhia de Concessoes Rodoviaras S/A	2010
14	Germany	Nuremberg	VAG Nürnberg	2010
15	China	Guangzhou	Guangzhou Metro Corporation	2010
16	UAE.	Dubai	Serco	2011
17	Korea	Seoul	NeoTrans Co. Ltd	2011
18	Korea	Busan	Busan Transportation Corp.	2011
19	France	Paris	RATP	2012
20	Italy	Milan	Azienda Transporti Milanesi s.p.a.	2013
21	Italy	Brescia	Brescia Mobilità	2013
22	Singapore	Singapore	SBS Transit Limited	2013
23	Italy	Rome	ATAC S.p.A. Azienda per la mobilità	2014
24	Korea	Daegu	Daegu Metropolitan Transit Corporation	2015
25	Hungary	Budapest	Budapest Transport Privately Held Corp.	2016
26	Hong Kong	Hong Kong	MTR Corp. Ltd—South Island Line	2016
27	Korea	Seoul	Seoul Metropolitan Rapid Transit Corp.	2016
28	Chile	Santiago	Metro de Santiago	2017
29	Turkey	Istanbul	Metro Istanbul	2017
30	China	Beijing	Beijing MTR Operation Administration Corp.	2018
31	China	Shanghai	Shanghai Keolis	2018
32	Chile	Santiago	Metro de Santiago	2019
33	Qatar	Doha	RKH Qitarat	2019
34	Denmark	Copenhagen	Metro Service A/S	2020
35	Singapore	Singapore	SMRT Corporation	2020
36	Turkey	Istanbul	Metro Istanbul	2020

Source: UITP Observatory of Automated Metros (<https://metroautomation.org/map/>).

Note: A metro system is defined to have an automated line if the line conforms to the GoA4 criteria and each car has a capacity of more than 100 people.

rolling stock). The reasoning behind this choice of variable considers the likelihood that hosting such corporations can provide better access to relevant technology, potentially accelerating automation implementation.

**Table 2** Descriptive statistics ( $n = 26\,796$ )

Variables	Measurement	Number of obs.	Missing rate, %	Mean	S.D.
Automation	GoA4 level of automation	26 796	0	0.001	0.037
City-level variables:					
GaWC rank	A city's percentile of the GaWC rank	26 796	0	0.000	30.016
Excluded from the GaWC rank	Whether the city was excluded from the rank	26 796	0	0.679	0.467
Mega-event	Up to 5 years prior to a mega-event	26 796	0	0.004	0.063
City GDP per capita (log)	Natural log of city's GDP per capita (unit: \$1000)	5321	80.1	3.503	0.543
City population density (log)	Natural log of 1000 people per square km	26 796	0	2.324	13.735
Metro system history	The number of metro lines prior to the year	26 796	0	0.388	1.632
Automation history	The number of automated lines prior to the year	26 796	0	0.016	0.169
Country-level control variables:					
World Economic Forum rank <sup>†</sup>	A country's percentile of the WEF rank	11 809	55.9	34.884	22.240
Automation technology	Having a company with automation technology	26 796	0	0.149	0.356
Labor rights <sup>‡</sup>	Average of ICTWSS labor rights scores	13 406	50.0	1.678	0.658
Union density <sup>‡</sup>	Union members (% of wage and salary earners)	12 595	53.0	19.631	11.079
GDP per capita (log) <sup>‡</sup>	Natural log of GDP per capita (unit: \$1000)	18 908	29.4	1.940	1.016
Size of manufacture industry <sup>‡</sup>	Size of manufacture industry relative to GDP	18 548	30.8	17.821	9.070
Mobile subscription rate <sup>‡</sup>	Mobile subscriptions per 100 000 people	18 941	29.3	0.708	0.445
Export of ICT goods <sup>‡</sup>	ICT goods exports (% of total goods exports)	18 041	32.7	11.061	11.824
Renewable energy <sup>‡</sup>	Renewable energy relative to total consumption	17 955	33.0	25.304	21.460
CO <sub>2</sub> emission per capita <sup>‡</sup>	Metric tons of CO <sub>2</sub> equivalent per capita	17 955	33.0	1.091	1.060
International tourism receipt <sup>‡</sup>	International tourism, receipts (% of total exports)	13 867	48.2	6.935	6.829

<sup>†</sup>In 2020, the WEF only listed analyzed countries without publishing the rank of the general 'competitiveness' of the countries.

<sup>‡</sup>Missing values in the noted variables were interpolated according to the linear time trend when there are at least two data points, and the missing rates are reported after this process.

Moreover, utilizing the ICTWSS data, we evaluated labor rights on a 0–3 scale (0 = no rights, 1 = rights with major restrictions, 2 = rights with minor restrictions and 3 = full rights), covering the right to association, right to collectively bargain, and the right to strike. These metrics, differentiated between private and public sectors, were averaged to create a composite measure of labor rights. The ICTWSS data calculates union density by dividing the number of union members by the total number of wage and salary earners. This variable serves as a country-level indicator of labor's associational power (Wright, 2000; Silver, 2003). These variables were included as controls because it is plausible that labor rights and power may influence the adoption of driverless metro lines.

Additional country-level control variables included the logged gross domestic product (GDP) per capita (constant 2010 US dollars), the ratio of the manufacturing industry to overall GDP, mobile subscriptions per 100 people, and the proportion of high-technology goods in total manufactured exports. Environmental considerations were factored in with variables like the percentage of renewable energy in total energy consumption and tons of CO<sub>2</sub> emission per capita. International tourism's economic impact was also included, measured as the dollar value of tourism relative to total exports. Descriptive statistics of these variables are presented in Table 2.

### 5.3. Models

The primary analytic strategy of this study is event history analysis, which examines the timeframe within which a city's metro system adopts an automated metro line. The key dependent variable in this model is the duration, the number of years from either 2000 or the year of a metro system's initial establishment (if later than 2000) until the year of automation, or 2020 for cities that have not adopted automation. Event history analysis is particularly suitable for this study because it censors data after the automation event, thereby avoiding the spurious correlation between independent variables and automation after the year of adoption. This approach mitigates concerns that a city's status improves as a result of adopting automated metro lines. Consequently, this method provides robust and rigorous evidence that any observed association between city status and automation adoption is attributable to the former's influence on the latter, rather than vice versa.

To mitigate the potential bias from left censoring, we use a discrete-time model in our concrete regression. Left censoring poses a bias risk because certain cities might have a different exposure to the likelihood of adopting automation. For instance, cities that implemented automated metro lines before 2000 might have a reduced need for further automation, potentially lowering their automation risk. Ignoring this 'saturation' effect could lead to skewed results. A key advantage of our data is that, even though our data frame begins in 2000 due to the availability of city status variables, we possess records of metro line establishment and automation events prior to 2000. This comprehensive data allows us to accurately determine known start times and effectively use the discrete-time model to address left censoring issues (Guo, 1993). Additionally, we control for the number of metro lines and the number of automated metro lines, including data preceding 2000. These methods reduce the potential biases arising from starting the data frame in the year 2000.

We used a cause-specific model (Kalbfleisch and Prentice, 2002) to evaluate the likelihood of cities adding automated metro lines, as opposed to expanding with non-automated lines or not expanding at all. This model functions similarly to a regular discrete-time model

but differs in how it handles competing events. If a city adds a non-automated line, that city is then censored in the analysis for any subsequent potential addition of an automated line. This is to address the methodological concern that some cities are more predisposed to add any metro lines, automated or not, simply due to their general propensity for metro expansion. We refrained from using the competing risks model developed by [Fine and Gray \(1999\)](#), despite its popularity in commonly used statistical packages (e.g. *strcrreg* in Stata) based on critiques by [Allison \(2018\)](#).

In instances where a city adopts automated lines, on more than one occasion, we conduct a repeated events model. In this model, each time a city implements automation in its metro system, the duration from either its start or the year 2000 to the year of automation is recorded as an event spell. Because the same city can introduce automation in other lines in subsequent years, the city re-enters the risk set with the year of the first automation as the starting point for another event spell. This means that a city can have multiple spells in the dataset. To address potential biases arising from this methodological approach, we report analysis results both with and without city fixed effects. Incorporating city fixed effects allows for comparisons of the same city, effectively holding (time-constant) unobserved city characteristics constant.

## 6. Results

To present the findings, we begin with descriptive statistics. [Table 3](#) displays the distribution of event spells by the city's hosting of mega-events and the city's status (shown categorically for clear presentation). Up to five years before hosting mega-events, six automated metro lines were established in 23 instances, or spells (26.1%). This rate is notably higher compared to other periods, which saw 30 automated lines across 1535 spells (2.0%). Additionally, during the period of hosting a mega-event, low-status cities were more likely to establish automated metro lines (50.0%) than high-status cities (15.4%). In contrast, outside of mega-event hosting periods, high-status cities had a higher likelihood of adopting automated metro lines (14.0%) compared to low-status cities (2.4%).

Prior to executing comprehensive regression analyses with control variables, we assessed the most suitable functional form for our data. [Table 4](#) presents the results based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Our comparison of regression models focused on whether to include a quadratic term for status, since previous studies suggest that, given access and resources, middle-status actors are more likely to innovate compared to high-status and low-status actors to achieve higher social status ([Hu and Van den Bulte, 2014](#)). Moreover, we examined whether incorporating an interaction variable between status and the mega-event variable would enhance model fit. The BIC criterion indicated that a quadratic status term resulted in poorer model fit and provided inconclusive evidence on the interaction between status and mega-events. Conversely, the AIC criterion supported the inclusion of the interaction term for improved model fit. Based on this finding, we consequently decided to proceed with the regression model using the linear term of status and its interaction with the mega-events variable.

There are a few potential reasons for why the quadratic term does not demonstrate improved fit, as indicated by the BIC. First, adopting automated metro systems may require higher resources compared to other automated systems, such as commercial kits of genetic engineering ([Hu and Van den Bulte, 2014](#)). This could highlight resource limitations more

**Table 3** Modes of metro operation by city status and mega-events<sup>†</sup>

Panel A: Up to 5 years before hosting mega-events				
Category <sup>‡</sup>	No new lines	Non-automation	Automation	Total
Excluded	0 spell (0.0%)	2 spells (100.0%)	0 spell (0.0%)	2 spells (100%)
Low status	1 spell (12.5%)	3 spells (37.5%)	4 spells (50.0%)	8 spells (100%)
High Status	4 spells (30.8%)	7 spells (53.8%)	2 spells (15.4%)	13 spells (100%)
Total	5 spells (21.7%)	12 spells (52.2%)	6 spells (26.1%)	23 spells (100%)
Panel B: The other years				
Category <sup>‡</sup>	No new lines	Non-Automation	Automation	Total
Excluded	912 spells (93.8%)	57 spells (5.9%)	3 spells (0.3%)	972 spells (100%)
Low status	292 spells (65.0%)	146 spells (32.5%)	11 spells (2.4%)	449 spells (100%)
High status	40 spells (35.1%)	58 spells (50.9%)	16 spells (14.0%)	114 spells (100%)
Total	1244 spells (81.0%)	261 spells (17.0%)	30 spells (2.0%)	1535 spells (100%)

<sup>†</sup>It should be noted that a city can have multiple spells (see the Methods section). Six spells in the automation column in Panel A, for example, means that six new driverless lines were established and began operating up to 5 years before hosting mega-events.

<sup>‡</sup>Although the regression models in this study use a continuous measure of city status according to the GaWC (see Table 5), this table uses a categorical measure for clearer presentation. The categories are measured as 'excluded' if the city was excluded from the list, 'low status' if the city was categorized 'Sufficiency' to 'Beta+', and 'high status' if the city was classified into 'Alpha' categories. Although the exact threshold varies by year, 'Alpha' cities are generally within the top 10% of the cities included in the ranking. The excluded category is coded as 0% for the GaWC rank. See: <https://www.lboro.ac.uk/microsites/geography/gawc/gawcworlds.html>.

**Table 4** Model fits by various specifications of the status variable

Model	AIC	BIC
M1: City status + Mega-event	415.910	440.498
M2: City status + (City status) <sup>2</sup> + Mega-event	416.452	449.236
M3: City status x Mega-event	407.890	440.674
M4: (City status + (City status) <sup>2</sup> ) × Mega-event	404.013	453.189

*Note:* The model fits were obtained from cause-specific repeated-events discrete-time regressions before control variables are included. A plus sign indicates that only linear terms were included in the regression, and a multiplication sign indicates that interaction terms as well as linear terms were added.

for cities of middle and low status during adoption, irrespective of their latent aspirations for status, thus resulting in a linear relationship between status and adoption rates. However, when resource constraints are eased by hosting mega-events, middle-status cities might exhibit a greater propensity for automation compared to their high-status and low-status counterparts, particularly to showcase innovation and more aggressively align with the capitalistic hierarchy of global city status. Since mega-events seldom occur in low-status cities, the model struggles to distinguish between the likelihood of automation in middle-status and low-status cities using a quadratic term.

Table 5 presents the results of the cause-specific repeated-events discrete-time regression analysis for metro automation. In Model 1, which shows the estimation results excluding city-level fixed effects, the findings indicate that a unit increase of the percentile rank of GaWC status is associated with a 0.0549 times increase in the likelihood of automation, provided the city is not hosting a mega-event within the next 5 years ( $P < 0.001$ ). If this effect is linearly approximated, a unit increase of GaWC status is associated with a 5.3% increase in the probability of automation on average. This suggests that higher status cities are more likely to adopt automated metro lines compared to building non-automated metro lines or opting not to expand at all. This trend persists even after controlling for various country-level characteristics, including logged city population and the historical development of the city's metro system. This inclination of high-status cities toward automation may be attributed to their greater capacity to adopt novel technologies and manage the higher initial costs.

However, this tendency is significantly diminished when a city is hosting a mega-event. The analysis shows that a unit increase in a city's GaWC percentile rank in status shows almost no association with the likelihood of automation if the city is hosting a mega-event within the next five years ( $p < 0.01$ ). This represents a 96% decrease in the estimated effect of city status on automation adoption compared to periods when the city is not preparing for a mega-event.

The analysis reveals a significant influence of mega-events on automation likelihood, varying by status rankings. For a city with a 50% ranking in the GaWC, hosting a mega-event correlates with a 27.2-fold increase in the likelihood of automation. This increase is even more pronounced, at 364.3 times, for cities at the lowest possible status (0% in the GaWC rank), and diminishes to 1.2 times for cities at the highest status (100% rank). These results suggest that cities, particularly those with lower status, are significantly more likely to adopt automated lines when hosting mega-events. Overall, the findings from Model 1 are consistent with our hypotheses and remain robust with the inclusion of city-level fixed effects, as indicated by the results in Model 2.

An alternative explanation is that the observed trends are attributable to some cities being more active in constructing metro lines in general, rather than specifically automated ones. To explore this possibility, we conducted a regression analysis to model the time to expansion by adding non-automated metro lines, using the same set of independent variables as in Models 1 and 2. The results are presented as Models 3 and 4. While these results are broadly consistent with Models 1 and 2, the significance of the main independent variables disappears at the 5% significance level after including city-level fixed effects. This indicates that high-builder cities construct non-automated metro lines in general, which confounds the effect of status and mega-events. With and without fixed effects, city-level population density significantly influences the likelihood of adding non-automated metro

**Table 5** Estimation results from cause-specific repeated-events discrete-time regressions

	Automated lines		Non-automated lines	
	No city FEs	City FEs	No city FEs	City FEs
	(Model 1)	(Model 2)	(Model 3)	(Model 4)
GaWC rank <sup>†</sup>	0.0534*** (0.0130)	0.2563* (0.1111)	0.0395*** (0.0037)	0.0106 (0.0082)
Mega-event	3.3407*** (0.7431)	9.4314* (3.8825)	1.8504*** (0.4335)	10.9756 (5.7926)
GaWC rank <sup>†</sup> * Mega-event	-0.0512** (0.0185)	-0.2123* (0.0899)	-0.0399*** (0.0103)	-0.2177 (0.1259)
City-level controls				
GDP per capita (log)	-0.1133 (0.7197)	-0.6498 (1.7830)	-0.3127 (0.3906)	-0.0769 (0.4279)
Population density (log)	0.2849 (0.1741)	9.6691 (6.6353)	0.1925** (0.0648)	7.1399*** (1.3518)
Prior metro lines	-0.0492 (0.0540)	-0.2203 (0.4906)	0.0284 (0.0291)	-0.4724*** (0.0789)
Prior automated lines	-0.0449 (0.2581)	-4.8855*** (1.3785)	-1.1041*** (0.2766)	-0.5012 (0.5476)
Country-level controls				
WEF-GCI rank	-0.0005 (0.0230)	-0.0175 (0.0476)	0.0211* (0.0084)	0.0001 (0.0116)
Automation technology	0.8342 (0.4671)	1.2075 (2.0443)	0.8358*** (0.2352)	1.6278*** (0.4200)
Labor rights	-0.7430 (0.9341)	-0.6580 (2.7462)	-1.0398** (0.3890)	0.0307 (0.6921)
Union density	<0.0000 (0.0191)	-0.0229 (0.0796)	0.0348** (0.0113)	0.0282 (0.0168)
GDP per capita (log)	0.7307 (0.5072)	-1.2112 (2.0001)	-0.7767*** (0.2095)	-0.1931 (0.5432)
Size of manufacture Ind.	-0.0122 (0.0363)	-0.0032 (0.1097)	0.0012 (0.0170)	-0.0078 (0.0287)
Mobile subscription	1.2805 (0.7069)	5.9559 (3.1429)	0.7819** (0.2503)	-0.2878 (0.5146)
Export of ICT goods	0.0056 (0.0461)	-0.0066 (0.0947)	-0.0155 (0.0208)	0.0266 (0.0394)
Renewable energy	0.0232 (0.0199)	0.0012 (0.0769)	0.0014 (0.0083)	-0.0019 (0.0134)
CO <sub>2</sub> emission per capita	-0.3043 (0.2741)	-0.3717 (0.7824)	-0.1043 (0.1042)	0.1327 (0.1988)
Intl' tourism receipt	-0.0368 (0.0523)	-0.0603 (0.1435)	-0.0437 (0.0260)	-0.0244 (0.0321)
Constant	-10.1548** (3.6561)		-1.7753 (1.4589)	
Duration dummy	Included	Included	Included	Included
Number of cities	1276	26	1276	118
Number of spells	1558	107	1558	388
Number of observations	26 796	567	26 796	2583

Note: \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

<sup>†</sup>The GaWC rank is centered at 50% for the regressions.

lines. The analysis suggests that the need to manage high population density drives the establishment of non-automated metro lines, a trend less evident with automated metro lines. These differences further indicate that the adoption of automated metro lines is not solely driven by utilitarian purposes or a city's general propensity to construct new metro lines.

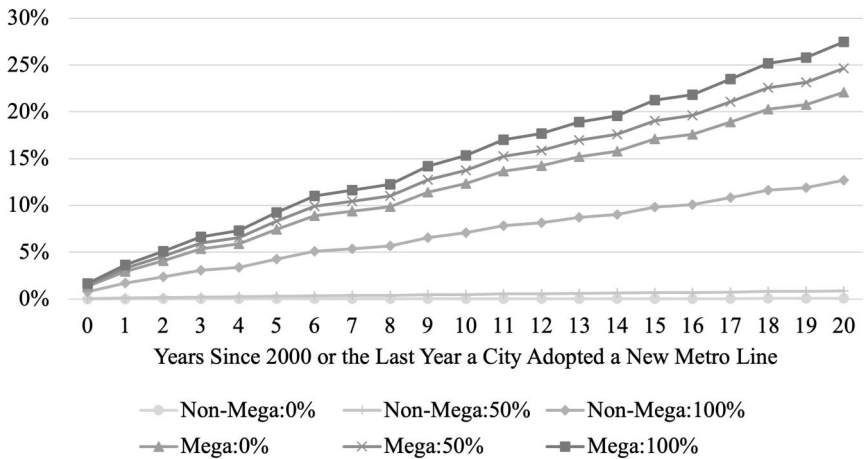
Other country-level control variables demonstrated minimal explanatory power. As previously outlined in the variables section, these control variables were included to reflect each country's economic ability, general interest in technology, and environmental considerations. However, almost none of these variables consistently yielded statistically significant results at the 5% level. The lack of significance might be attributed to the fact that city-level factors are more relevant to explaining the reasons behind the establishment of metro lines.

A noteworthy finding is the lack of statistical significance in labor-related control variables at the 5% level. This contrasts with previous research, such as [Liu and Zhang \(2022\)](#), which suggested that labor rights protests in China contributed to increased robotization. The difference in our findings could be attributed to several factors. First, the difference in the measurement of labor power might account for the discrepancy. While protests about labor rights could prompt organizations to automate for the purpose of circumventing conflict, strong labor unions might have well-established and institutionalized bargaining channels that influence economic decisions. Secondly, the specificity of labor relations in China or the characteristics of public transit might account for the different results in our study. We considered including additional variables, such as the number of strikes and the number of work stoppage days due to strikes and lockouts, from the ICTWSS data and data from the ILO, to further explore this issue. However, these variables did not yield significant results, likely due to the high missing data (exceeding 60% for both variables). Future research could explore this topic further by obtaining more fine-grained data such as the presence of labor unions in the metro system.

[Figure 1](#) presents the predicted probabilities of automation adoption, based on the findings from Model 1. The Y-axis represents the cumulative hazard rate of automation, which indicates the sum of all hazard rates up to the year at the X-axis. The hazard rate is the likelihood of a city adopting an automated metro line in a given year assuming it has not done so previously. When a mega-event is not forthcoming within five years, the chance of a city with the lowest GaWC rank (0%) adopting automated lines remains nearly zero for the entire duration, while a city at the mid-point rank (50%) has just under a 1% chance. In contrast, a city with the highest GaWC rank (100%) has a predicted 12.7% chance of adoption within the analysis window. However, when a mega-event is imminent, these probabilities increase to 22.1%, 24.7% and 27.5%, respectively. This suggests that cities hosting mega-events are more inclined to adopt automation and that the status-based disparities in adoption likelihood narrow significantly. These findings align closely with the descriptive pattern outlined in [Table 3](#).

## 7. Discussion and conclusions

In this article, we provide empirical evidence on the drivers of automation through an event history analysis of automated metro systems from 2000 to 2020. Our findings highlight the significance of city status in adopting automation technologies in metro systems, supporting the hypothesis of distinctive consumption. However, during mega-events, which place cities



**Figure 1** The predicted probability of automation by mega-events and the GaWC percentage.

*Note:* The predicted probability here indicates the cumulative hazard rate. It is the conditional probability that a city adopts a driverless metro line in a certain year, given that the city has not adopted a driverless metro line until the year that is cumulated over time. We calculated the predicted probabilities by using the results presented in Model 1 of Table 4. The values of the control variables were fixed at their means for the predicted probabilities.

in the global spotlight, the influence of high-status diminishes. Lower-status cities are also proactive in constructing automated lines during mega-events. A key factor behind this trend is how considerations for status motivate cities to signal technological prowess, particularly during high-visibility occasions of spectacle. Our study indicates that the impetus for automation in subways extends beyond mere economic and utilitarian considerations. Rather, it is primarily driven by status competition, as opposed to commonly attributed factors like resources availability, labor rights, environmental concerns or infrastructural utility.

A measure of city status varies widely depending on domain and methodology, which may pose some limitations on interpreting the findings of this study (Carter *et al.*, 2010; Brandtner, 2017). To this point, future research should consider the issue of city status measures as a standalone research agenda, examining the differential impacts of these measures on automation decisions, including in different domains of city infrastructure. Additionally, exploring the theoretical implications of potential differences between these measures can get at a more comprehensive understanding of the subject.

These findings have implications for several fields, including the literature on automation, the sociology of urban development, and economic sociology. Primarily, this study enriches the sociological understanding of automation and its diffusion process. By examining automation decisions over a 20-year span worldwide, we demonstrate the influence of highly sociological phenomena on these decisions. In doing so, we expand upon the existing scholarship of automation that highlights the importance of status and spectacle, incorporating an urban perspective by examining how status competition and concern for economic development among cities during spectacular events influence technological adoption.

Research on organizations and technological change has traditionally focused on the behavioral, organizational, and societal impacts of technological adoption (Chandler, 1977; Barley, 1990; 2020; Barley and Bechky, 1994; Orlikowski and Scott, 2008). This study extends theoretical discussions surrounding the socio-materiality of technology by examining early motivations for adopting technology, rather than focusing solely on the implementation phase. It remains to be clarified whether automotive transportation technologies constitute a simple substitution of tasks (such as robots in manufacturing, as described in Liu and Zhang, 2022) or signify a more profound infrastructural shift (such as gig-work, as discussed by Wells *et al.*, 2023), and how status and spectacle clarify their revolutionary potential (Barley, 2020). This ambiguity underscores the need for further qualitative and situated research of automotive vehicles and driving systems (Levy, 2022) to fully understand the material, networked and ideational consequences of transportation systems.

We also build on urban studies scholarship that explores the networked impact of globalization on urban development (Alderson and Beckfield, 2004; Polillo and Guillen, 2005). Beyond the purely relational and networked dynamics of global city regions, the study paves the way for future research to further explore dynamics of status and spectacle on global city networks (Sassen, 2001). Bridging the study of status dynamics inherent in the socio-materiality of technological change and urban development has many promising arenas for future empirical research, especially as scholarly attention turns to algorithmic systems and artificial intelligence.

Furthermore, this study makes a significant contribution to economic sociology by bridging the literature on status competition with urban studies. Economic sociological research, such as the work of Lee and Strang (2006) and David (1985) emphasized the role of imitation and mutual influence in the diffusion of norms and policies. Our investigation into the adoption of innovative urban infrastructure examines how a fetishization of technology, often evident in managerial ‘hype,’ intersects with status competition to drive innovation diffusion. This approach suggests that city governments’ behavior in adopting new technologies is influenced not just by practical utility or isomorphism, but also by a desire to compete for status and prestige during moments of global attention.

Our analysis, while specific to the urban passenger transportation sector known for high capital costs and public governance, suggests that status competition could similarly influence automation in the private sector and in other economic areas among actors motivated by status. This underscores the need for technological innovation accounts to seriously consider the symbolic meaning of technology. By doing so, we can better understand the durability and impact of technological diffusion particularly in terms of its wider implications for inequality and the world of work.

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## References

- Accominotti, F., Khan, S. R. and Storer, A. (2018) 'How Cultural Capital Emerged in Gilded Age America: Musical Purification and Cross-Class Inclusion at the New York Philharmonic', *American Journal of Sociology*, **123**, 1743–1783.
- Acemoglu, D. and Restrepo, P. (2022) 'Demographics and Automation', *The Review of Economic Studies*, **89**, 1–44.
- Alderson, A. S. and Beckfield, J. (2004) 'Power and Position in the World City System', *American Journal of Sociology*, **109**, 811–851.
- Allison, P. D. (2001) *Missing Data*, Thousand Oaks, Sage.
- Allison, P. D. (2018) 'For Causal Analysis of Competing Risks, Don't Use Fine & Gray's Subdistribution Method', accessed at <https://statisticalhorizons.com/for-causal-analysis-of-competing-risks> on May 29, 2021.
- Anttiroiko, A.-V. (2015) 'City Branding as a Response to Global Intercity Competition', *Growth and Change*, **46**, 233–252.
- Barley, S. (1990) 'The Alignment of Technology and Structure through Roles and Networks', *Administrative Science Quarterly*, **35**, 61–103.
- Barley, S. (2020) *Work and Technological Change*, Oxford, Oxford University Press.
- Barley, S. R. and Bechky, B. A. (1994) 'In the Backrooms of Science: The Work of Technicians in Science Labs', *Work and Occupations*, **21**, 85–126.
- Belderbos, R., Du, H. S. and Slangen, A. (2020) 'When Do Firms Choose Global Cities as Foreign Investment Locations within Countries? The Roles of Contextual Distance, Knowledge Intensity, and Target-Country Experience', *Journal of World Business*, **55**, 101022.
- Benanav, A. (2020) *Automation and the Future of Work*, London, Verso.
- Bitektine, A. (2011) 'Toward a Theory of Social Judgments of Organizations: The Case of Legitimacy, Reputation, and Status', *Academy of Management Review*, **36**, 151–179.
- Bourdieu, P. (1984) 'Distinction: A Social Critique of the Judgement of Taste', *Translated by Richard Nice*, Cambridge, MA, Harvard University Press.
- Brandtner, C. (2017) 'Putting the World in Orders: Plurality in Organizational Evaluation', *Sociological Theory*, **35**, 200–227.
- Burbank, M., Andranovich, G. and Heying, C. H. (2001) *Olympic Dreams: The Impact of Mega-Events on Local Politics*, Boulder, CO, Lynne Rienner Publishers.
- Carter, T. F. (2006) 'Introduction: The Sport of Cities Spectacle and the Economy of Appearances', *City & Society*, **18**, 151–158.
- Carter, C., Clegg, S. and Kornberger, M. (2010) 'Re-Framing Strategy: Power, Politics and Accounting', *Accounting, Auditing & Accountability Journal*, **23**, 573–594.
- Chandler, A. (1977) *The Visible Hand: The Managerial Revolution in American Business*, Boston, Harvard University Press.
- Chorey, N. and Ball, A. C. (2022) 'The Knowledge-Based Economy and the Global South', *Annual Review of Sociology*, **48**, 171–191.
- Compagni, A., Mele, V. and Ravasi, D. (2015) 'How Early Implementations Influence Later Adoptions of Innovation: Social Positioning and Skill Reproduction in the Diffusion of Robotic Surgery', *Academy of Management Journal*, **58**, 242–278.

- Correll, S. J., Ridgeway, C. L., Zuckerman, E. W., Jank, S., Jordan-Bloch, S. and Nakagawa, S. (2017) 'It's the Conventional Thought That Counts: How Third-Order Inference Produces Status Advantage', *American Sociological Review*, **82**, 297–327.
- David, P. A. (1985) 'Clio and the Economics of QWERTY', *The American Economic Review*, **75**, 332–337.
- Debord, G. [2020 (1967)] *The Society of the Spectacle*. Nicholson-Smith Donald (tr), Princeton, Princeton University Press.
- Faure, A. and Lauermaun, J. (2023) 'Are Mega-Events Only for Global Cities? Analyzing Host Cities through the Global and World Cities Framework, 1990–2020', *Journal of Olympic Studies*, **4**, 31–55.
- Fine, J. P. and Gray, R. J. (1999) 'A Proportional Hazards Model for the Subdistribution of a Competing Risk', *Journal of the American Statistical Association*, **94**, 496–509.
- Florida, R. (2005) *Cities and the Creative Class*, New York, Routledge.
- Fourcade, M. and Healy, K. (2017) 'Seeing like a Market', *Socio-Economic Review*, **15**, 9–29.
- Frey, C. B. and Osborne, M. (2017) 'The Future of Employment: How Susceptible Are Jobs to Computerisation?', *Technological Forecasting and Social Change*, **114**, 254–280.
- Friedman, S. and Reeves, A. (2020) 'From Aristocratic to Ordinary: Shifting Modes of Elite Distinction', *American Sociological Review*, **85**, 323–350.
- Graham, S. and Marvin, S. (2002). *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition*, New York, Routledge.
- Guo, G. (1993) 'Event-History Analysis for Left-Truncated Data', *Sociological Methodology*, **23**, 217–243.
- Harvey, D. (1989) 'From Managerialism to Entrepreneurialism: The Transformation in Urban Governance in Late Capitalism', *Human Geography*, **71**, 3–17.
- Harvey, D. (2003) 'The Fetish of Technology: Causes and Consequences', *Macalester International*, **13**, 3–30.
- Hiller, H. H. (2000) 'Mega-Events, Urban Boosterism and Growth Strategies: An Analysis of the Objectives and Legitimations of the Cape Town 2004 Olympic Bid', *International Journal of Urban and Regional Research*, **24**, 449–458.
- Hu, Y. and Van den Bulte, C. (2014) 'Nonmonotonic Status Effects in New Product Adoption', *Marketing Science*, **33**, 509–533.
- Iyengar, R., Van den Bulte, C. and Valente, T. W. (2011) 'Rejoinder—Further Reflections on Studying Social Influence in New Product Diffusion', *Marketing Science*, **30**, 230–232.
- Jacobs, W., Ducruet, C. and De Langen, P. (2010) 'Integrating World Cities into Production Networks: The Case of Port Cities', *Global Networks*, **10**, 92–113.
- Jameson, F. (1991) *Postmodernism, or the Cultural Logic of Late Capitalism*, Durham, NC, Duke University Press.
- Jasanoff, S. and Kim, S.-H. (eds) (2015) *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago, IL: University of Chicago Press.
- Kaika, M. and Swyngedouw, E. (2000) 'Fetishizing the Modern City: The Phantasmagoria of Urban Technological Networks', *International Journal of Urban and Regional Research*, **24**, 120–138.
- Kalbfleisch, J. D. and Prentice, R. L. (2002) *The Statistical Analysis of Failure Data*. Hoboken, NJ, John Wiley & Sons.
- KBS News (2002) 'World Cup—FIFA Key Figures Attend the Opening Ceremony via Subway', May 30th, accessed at <https://news.kbs.co.kr/news/pc/view/view.do?ncd=1015105> on January 7, 2023. (In Korean)
- Ki-Ho Ilbo (2022) 'It's Unnerving to Have "Unmanned Subway" on Incheon Subway Line 2', January 21st, accessed at <https://www.kihoilbo.co.kr/news/articleView.html?idxno=964202> on January 7, 2023. (In Korean)

- Kim, T. and Rhee, M. (2017) 'Structural and Behavioral Antecedents of Change: Status, Distinctiveness, and Relative Performance', *Journal of Management*, 43(3), 716–741.
- Kirkpatrick, L. O. and Smith, M. P. (2011) 'The Infrastructural Limits to Growth: Rethinking the Urban Growth Machine in Times of Fiscal Crisis', *International Journal of Urban and Regional Research*, 35, 477–503.
- Lee, C. K. and Strang, D. (2006) 'The International Diffusion of Public-Sector Downsizing: Network Emulation and Theory-Driven Learning', *International Organization*, 60, 883–909.
- Lei, Y.-W. (2022) 'Upgrading China through Automation: Manufacturers, Workers and the Techno-Developmental State', *Work, Employment and Society*, 36(6): 1078–1096.
- Levy, K. (2022) *Data Driven: Truckers, Technology, and the New Workplace Surveillance*, Princeton, Princeton University Press.
- Ley, D. and Olds, K. (1988) 'Landscape as Spectacle: World's Fairs and the Culture of Heroic Consumption', *Environment and Planning D: Society and Space*, 6, 191–212.
- Liu, L. and Portes, A. (2021) 'Immigration and Robots: Is the Absence of Immigrants Linked to the Rise of Automation?', *Ethnic and Racial Studies*, 44, 2723–2751.
- Liu, L. and Zhang, H. (2022) 'Robots and Protest: Does Increased Protest among Chinese Workers Result in More Automation?', *Socio-Economic Review*, 21, 1751–1772.
- Lynn, F. B., Podolny, J. M. and Tao, L. (2009) 'A Sociological (De)Construction of the Relationship between Status and Quality', *American Journal of Sociology*, 115, 755–804.
- MBC News (2017) 'What is the Problem with the "Unmanned" Incheon Subway?', May 19th. Accessed at [https://imnews.imbc.com/replay/2017/nwdesk/article/4313628\\_30212.html](https://imnews.imbc.com/replay/2017/nwdesk/article/4313628_30212.html) on January 7, 2023. (In Korean)
- McClure, P. K. (2018) 'You're Fired,' Says the Robot: The Rise of Automation in the Workplace, Technophobes, and Fears of Unemployment', *Social Science Computer Review*, 36, 139–156.
- McNeill, D. (2016) 'Governing a City of Unicorns: Technology Capital and the Urban Politics of San Francisco', *Urban Geography*, 37, 494–513.
- Molotch, H. L. and Logan, J. R., 1987. *Urban Fortunes: The Political Economy of Place*. Berkeley, Los Angeles, London, University of California Press.
- Müller, M. (2015) 'Assemblages and Actor-Networks: Rethinking Socio-Material Power, Politics and Space', *Geography Compass*, 9, 27–41.
- Nedelkoska, L., and Quintini, G. (2018) *Automation, Skills Use and Training*, OECD Social, Employment and Migration Working Papers, No. 202, Paris, OECD.
- Ó Riain, S. (2000) 'The Flexible Developmental State: Globalization, Information Technology and the "Celtic Tiger"', *Politics & Society*, 28, 157–193.
- Ong, A. (2007) 'Please Stay: Pied-A-Terre Subjects in the Megacity', *Citizenship Studies*, 11, 83–93.
- Ong, A. (2011) 'Hyperbuilding: Spectacle, Speculation, and the Hyperspace of Sovereignty'. In: Roy, A. and Ong, A. (eds) *Worlding Cities: Asian Experiments and the Art of Being Global*, Chichester, West Sussex; Malden, MA, Wiley-Blackwell, pp. 205–226.
- Orlikowski, W. and Scott, S. V. (2008) 'Sociomateriality: Challenging the Separation of Technology, Work and Organization', *Academy of Management Annals*, 2, 433–474.
- Ovenden, M. (2015) *Transit Maps of the World*, New York, Penguin Random House
- Pacewicz, J. (2016) 'The City as a Fiscal Derivative: Financialization, Urban Development, and the Politics of Earmarking', *City & Community*, 15, 264–288.
- Park, S., Daegy, Y., Hyeonjin, C. and Seobin, P. (2020) 'The Halo Effect and Social Evaluation: How Organizational Status Shapes Audience Perceptions on Corporate Environmental Reputation', *Organization & Environment*, 33(3), 464–482.
- Parolin, Z. (2021) 'Automation, Occupational Earnings Trends, and the Moderating Role of Organized Labor', *Social Forces*, 99, 921–946.

- Phillips, D. J. and Zuckerman, E. W. (2001) 'Middle-Status Conformity: Theoretical Restatement and Empirical Demonstration in Two Markets', *American Journal of Sociology*, **107**, 379–429.
- Podolny, J. M., Stuart, T. E. and Hannan, M. T. (1996) 'Networks, Knowledge, and Niches: Competition in the Worldwide Semiconductor Industry, 1984–1991', *American Journal of Sociology*, **102**, 659–689.
- Podolny, J. M. (2005) *Status Signals: A Sociological Study of Market Competition*. Princeton, NJ: Princeton University Press.
- Polillo, S. and Guillen, M. F. (2005) 'Globalization Pressures and the State: The Worldwide Spread of Central Bank Independence', *American Journal of Sociology*, **110**, 1764–1802.
- Pollock, T. G., Kisha, L., Rindova, V. P. and Jung-Hoon, H. (2019) 'Which of These Things Are Not like the Others? Comparing the Rational, Emotional, and Moral Aspects of Reputation, Status, Celebrity, and Stigma', *Academy of Management Annals*, **13**, 444–478.
- Qatar General Secretariat for Development Planning (2011) *Qatar National Development Strategy 2011–2016*, Doha, Gulf Publishing and Printing Company.
- Railway Technology (2019) Doha Metro, Qatar, July 12, accessed at <https://www.railway-technology.com/projects/doha-metro/> on January 14, 2024.
- Ridgeway, C. L. (2013) 'Why Status Matters for Inequality', *American Sociological Review*, **79**, 1–16.
- Rizzo, A. (2013) 'Metro Doha', *Cities*, **31**, 533–543.
- Rosen, E., Garboden, P. M. E. and Cossyleon, J. E. (2021) 'Racial Discrimination in Housing: How Landlords Use Algorithms and Home Visits to Screen Tenants', *American Sociological Review*, **86**, 787–822.
- Rosenberg, L. and Brent, A. (2020) 'Infrastructure Disruption in "Silicon Savannah": Exploring the Idea of the Creative Class and Their Relation to Quality of Place in Nairobi, Kenya', *International Journal of Urban and Regional Research*, **44**, 809–820.
- Sadowski, J. and Bendor, R. (2019) 'Selling Smartness: Corporate Narratives and the Smart City as a Sociotechnical Imaginary', *Science, Technology, & Human Values*, **44**, 540–563.
- Sassen, S. (2001) *The Global City: New York, London, Tokyo*, 2nd edn, Princeton, NJ, Princeton University Press.
- Sauder, M., Lynn, F. and Podolny, J. M. (2012) 'Status: Insights from Organizational Sociology', *Annual Review of Sociology*, **38**, 267–283.
- Schimmel, K. S. (2006) 'Deep Play: Sports Mega-Events and Urban Social Conditions in the USA', *The Sociological Review*, **54**, 160–174.
- Schragger, R. (2016) *City Power: Urban Governance in a Global Age*, New York, Oxford University Press.
- Shin, H. B. (2012) 'Unequal Cities of Spectacle and Mega-Events in China', *City*, **16**, 728–744.
- Sideridis, D. (2021) 'Exploring the Doha Metro: Qatar's Futuristic Rail Network', CNN, May 5, accessed at <https://edition.cnn.com/travel/article/qatar-doha-metro/index.html> on January 14, 2024.
- Silic, D. (2022) "'Is the FIFA World Cup 2022 in Qatar Profitable?'" Swiss School of Business and Management Geneva, accessed at <https://www.ssbm.ch/is-the-fifa-world-cup-2022-in-qatar-profitable/> on January 10, 2024.
- Silver, B. (2003) *Forces of Labor: Workers' Movements and Globalization since 1870*, Cambridge, Cambridge University Press.
- Sine, W. D., Shane, S. and Gregorio, D. D. (2003) 'The Halo Effect and Technology Licensing: The Influence of Institutional Prestige on the Licensing of University Inventions', *Management Science*, **49**, 478–496.

- Smith, A. and Anderson, J., 2014. 'AI, Robotics, and the Future of Jobs. Pew Research Center: Internet, Science & Tech', August 6, accessed at <http://www.pewinternet.org/2014/08/06/future-of-jobs/> on June 14, 2021
- Spencer, D. (2017) 'Work in and beyond the Second Machine Age: The Politics of Production and Digital Technologies', *Work, Employment and Society*, 31, 142–152.
- Taylor, P. J. and Derudder, B. (2016) *World City Network: A Global Urban Analysis*, 2nd Ed, Abingdon, Routledge.
- UITP (The International Association of Public Transport) (2018) *World Report on Metro Automation*, Brussels, UITP.
- UITP (The International Association of Public Transport) (2019). *The Benefits of Full Metro Automation*, Brussels, UITP.
- UITP (The International Association of Public Transport) (2020) 'Observatory of Automated Metros', accessed at <http://metroautomation.org> on February 11, 2022.
- The United Nations, Department of Economic and Social Affairs, Population Division (2019) *World Urbanization Prospects: The 2018 Revision*, New York, The United Nations.
- The World Bank (2020) "World Development Indicators", [Data file] Washington, D.C., The World Bank, accessed at <https://data.worldbank.org/> on October 5, 2021.
- Schwab, K. (2019) *The Global Competitiveness Report*, Geneva, Switzerland, The World Economic Forum.
- Van den Bulte, C. and Joshi, Y. V. (2007) 'New Product Diffusion with Influentials and Imitators', *Marketing Science*, 26, 400–421.
- Visser, J. (2019) "ICTWSS Data Base. Version 6.1." [Data File], Amsterdam, Amsterdam Institute for Advanced Labour Studies. Accessed on November 29, 2019. <https://www.ictwss.org/downloads>.
- Wajcman, J. (2017) 'Automation: Is It Really Different This Time?', *The British Journal of Sociology*, 68, 119–127.
- Wall Street Journal (2022) "Shaping the Future of Sports Innovation", accessed at <https://partners.wsj.com/invest-qatar/eye-on/shaping-the-future-of-sports-innovation/> on January 7, 2023.
- Wells, K. J., Attoh, K. and Cullen, D. (2023) *Disrupting D.C: The Rise of Uber and the Fall of the City*, Princeton, Princeton University Press.
- Wolf, A. (2022) 'City Power in the Age of Silicon Valley: Evaluating Municipal Regulatory Response to the Entry of Uber to the American City', *City & Community*, 21, 290–313.
- Wright, E. O. (2000) 'Working Class Power, Capitalist-Class Interests and Class Compromise', *American Journal of Sociology*, 105, 957–1002.
- Wu, Y., Li, X. and Lin, G. C. S. (2016) 'Reproducing the City of the Spectacle: Mega-Events, Local Debts, and Infrastructure-Led Urbanization in China', *Cities*, 53, 51–60.
- Zimbalist, A. (2016) *Circus Maximus: The Economic Gamble behind Hosting the Olympics and the World Cup*, Washington, D.C., Brookings Institution Press. [In Korean]