**Block 1 Reading**

# Introduction to Management of Urban Infrastructures

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More than half of the world's population currently lives in urban settlements, and that number will reach two thirds by 2050. This growth will come mostly from emerging countries, precisely where urban living conditions are less developed (UN-Habitat 2012b). Inversely, in industrialized countries where population growth is less pronounced, infrastructures are rapidly aging. Both trends demonstrate the critical importance of managing urban infrastructure systems.

Implementing effective management for the infrastructures of cities is the only way to ensure good living conditions for most people on the planet. This first reading corresponds to the first block of our MOOC "Management Urban Infrastructures" and presents the basic definitions, the main challenges to urban infrastructure systems, their main characteristics, as well as the two most relevant analytical perspectives to approach the management of urban infrastructures. The reading will conclude using the example of challenges faced by Mexico City.

## Definitions

In order to facilitate the understanding of this block's reading, some important concepts need to be defined:

- *Cities* can be seen as large and complex sociotechnical systems composed of two subsystems or layers: a *physical subsystem*, configured by the built environment and the physical infrastructures, and a *human subsystem* configured by the human activities and interactions (Hillier 2012). This particular dual nature of cities classifies them as sociotechnical systems (STS), which are socially constructed both by the economic and social activities and by the institutions (rules) governing the urban system (which in turn conditions the everyday routines of actors). Therefore, when talking about urban areas, bear in mind we are including their physical components (referring to buildings, roads, and electricity distribution networks) as well as the organizational structures, institutional arrangements, and sociocultural meanings and agents inhabiting them (that is, city government, companies, neighborhoods' history and culture, and citizens).

  Cities are heavily dependent upon urban infrastructure systems, which are themselves intrinsically interrelated and interdependent. Urban infrastructure systems rely upon each other and evolve by influencing each other (Graham 2000). For an effective urban infrastructure management, we should be concerned not only about how the infrastructures (seen together as a system, not individually) evolve, but also about the way they interact. Urban infrastructures configure "geographies of enablement and constraint" (Law & Bijker 1992), which are "never truly universal or politically or socially 'neutral'" (Massey 1993 cited in Graham 2000). This means that urban infrastructure management can and should also contribute to a more equal and fair society or, in contradistinction, avoid creating marginalized areas with poor access to basic services. This latter point, added to the previous ones, clearly shows why a multidisciplinary approach transcending the common "engineering" perspective is needed for managing urban infrastructures.

- *Sociotechnical systems* refers to sets of elements interacting and interdependent forming a whole, which include both social (that is, institutions, customs, and habits) and technical components (such as traffic lights and centralized wastewater treatment) (Trist 1981), and implies the "recognition of a recursive (not simultaneous) shaping of abstract social constructs and a technical infrastructure that includes technology's materiality and people's localized responses to it" (Leonardi 2012, p. 27).

- *Urban infrastructures* are sociotechnical systems embedded in the urban areas to which they provide fundamental services such as energy, water, or communications. Urban infrastructure systems can be viewed as "the link between city inhabitants and natural resources" (UN-Habitat 2012b), supporting the critical flow of energy, water, waste, and information into, inside, and out of the city, acting as integrators of the economic and social structures that depend on them (Graham & Marvin 1995).

- *Primary infrastructures and infrastructure services* refers to the infrastructures providing the basic services upon which the city is built. Among primary infrastructures, we can find "electric power, oil and gas, potable and waste water, transportation, and communications," though the list is not definitive and evolves through time (Fulmer 2009). In our approach, we also include housing and green areas as being part of the basic infrastructures.

- *Secondary infrastructures and infrastructure services* build on the primary ones yet constitute another layer. They include, but are not limited to, health infrastructures (such as hospitals), educational infrastructures (such as schools), cultural infrastructures (museums, for example), penal infrastructures (prisons), and others (Fulmer 2009).

- *Efficiency* refers to the ability to avoid wasting a resource (such as energy, money, or time) in doing something or producing a desired result, which can often be measured as the percentage of primary input transformed into the outcome (Oxford University Press 2015). For example, the fraction of the energy contained in the natural gas used to generate electricity reflects the efficiency of a natural gas power plant.

- *Sustainability* is used here as stated by the Brundtland Commission, where sustainable development is "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987, p. 41). Sustainability, according to this definition, has three interrelated components—namely, environmental, economic, and social.

- *Resilience* refers to the "ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure…depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event" (National Infrastructue Advisory Council 2010, p. 15). However, the definition of resilience varies from one discipline to another, with slightly different approaches (Francis & Bekera 2014). Our approach here is a systemic one—that is, we are concerned about the resilience of a complex and dynamic sociotechnical system.

**Key challenges**

Now that we have established a common understanding of the main concepts, let us identify the main challenges that urban infrastructure systems face. We identify five such challenges: (1) demographic, (2) socioeconomic, (3) technological, (4) environmental, and (5) financial. In practice, all of them are interrelated and need to be dealt with in a coherent manner.

1) The *demographic challenge* is related to the dynamics of the urban population. Currently, the growth of urban populations in many areas of the world outpaces the ability of most urban infrastructure managers to expand their systems and provide service to the newcomers. Global urban population has passed from 746 million people in 1950 to 3.9 million people in 2014 (United Nations 2014), and the trend is not expected to change (see Figure 1).

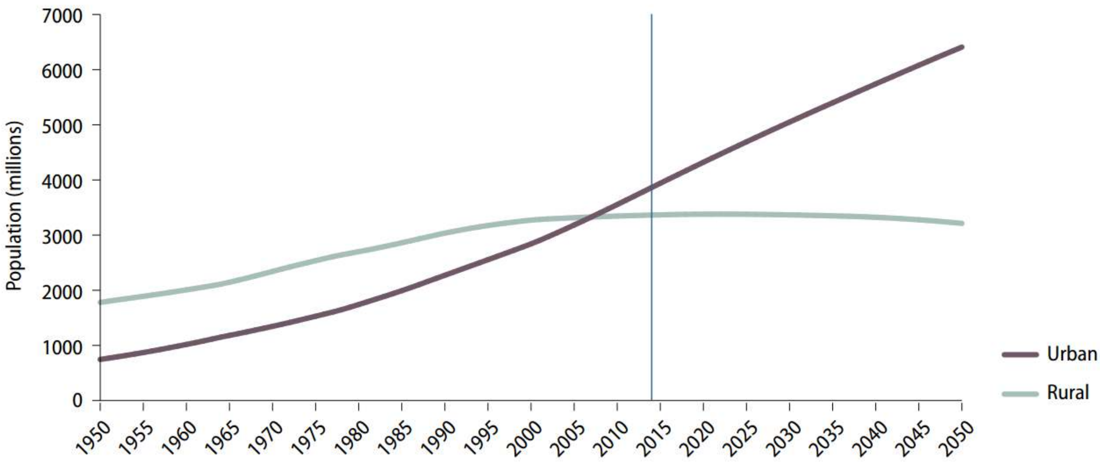


Figure 1: World urban and rural population evolution and forecast.
Adapted from United Nations 2014.

In addition, the increased number of citizens requiring access to the services strains the system and exacerbates the negative effects of inefficiencies. These two consequences of the urban population growth greatly increase the risk of marginalization and expansion of urban slums, where even the most basic services are not delivered properly.

2) The *socioeconomic challenge* is related to the social and economic inequalities in cities. Ensuring adequate living conditions is a key goal of urban infrastructure systems, which has to be inclusive for all people living in urban areas. Several difficulties emerge when trying to achieve this goal, among which are these: (a) providing affordable housing for the diverse inhabitants of the city; (b) providing universal access to safe drinking water;

(c) providing functional waste and wastewater services as a basis for public health; (d) providing adequate and equal mobility alternatives to ensure access to work and leisure opportunities; and (e) providing clean, affordable, and reliable energy to citizens. For example, the share of the population living in slums in developing countries has declined from 46.1 percent in 1990 to 32.7 percent in 2010 (UN-HABITAT 2010). At the same time, the gap between the well-off and the poorer people has grown almost everywhere, including in cities in developed countries (UN-Habitat 2009).

3) The *technological challenge* is related to the increasing complexity in planning and managing urban infrastructure systems. There are, on one hand, the cities with legacy systems, where infrastructures were built in the early twentieth century. Some of these infrastructures are now at risk of collapse and of becoming obsolete; they will have to be upgraded, if not totally renewed. On the other hand, and especially in the emerging countries, new infrastructures are being built from scratch. In both cases, we are facing substantial technological challenges pertaining essentially to their efficiency.

4) The *environmental challenge* mainly pertains to pollution and the effect of climate change on cities. Globally, cities have already become and are further evolving into global environmental forces. For example, urban settlements consume around 75 percent of global primary energy and emit between 50 percent to 60 percent of the total world's annual greenhouse gas emissions (UN-Habitat 2012a). Curbing these emissions is an increasingly pressing task for city managers. Overall, the challenge is to make urban infrastructures more sustainable.

5) The *financial challenge* is related to the limited availability of financial resources to operate and to develop urban infrastructure systems. Establishing an institutional framework capable of ensuring a revenue stream to sustainably support the operation and maintenance of the urban infrastructure is a major challenge for cities. In most cases, urban infrastructure managers are required to provide more and better services with limited (and sometimes decreasing) financial support.

All of these five challenges critically affect the quality of the infrastructure services provided to the cities' inhabitants. Inversely, the way these challenges are addressed and how the urban infrastructures are managed will determine the quality of these services, as graphically represented in Figure 2:

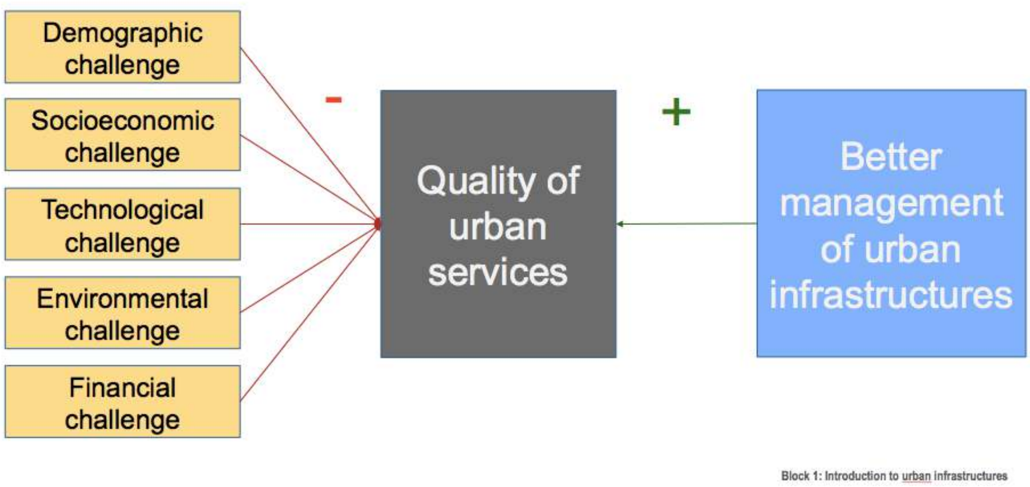


Figure 2: Schematic relation of urban system challenges, its management, and urban services quality.

### Main urban infrastructure systems

Along with the evolution of large human settlements, urban infrastructure systems have grown in scope and complexity, gradually improving and increasing the basic services they provide. From basic transport systems, with several centuries of history, to utility networks with only some decades of age (telecommunications is one example), the picture of urban infrastructure systems is composed of six major systems: (1) transport, (2) housing and green infrastructures, (3) energy, (4) water and wastewater, (5) waste, and (6) communications.

Here is a brief overview of each infrastructure system, along with some considerations about their interrelatedness:

1) The *transport* urban infrastructure system aims at ensuring equitable and easy access for all a city's inhabitants. For doing so, the system is composed of diverse physical mobility components suited for the various means of transport in urban areas. Roads, city roads, and agglomeration roads set the paths for private automobiles to move around in the city. These spaces are also to be shared with other private users such as motorcycles and bicycles, as well as taxi services and public transport (that is, public buses). Some means of transport with fixed tracks, such as train, suburban train, metro, or tram, require special physical infrastructures for their operation, though they often intersect at connection points such as large train and metro stations. Finally, though typically in the outskirts of the cities, airports need to be taken into account because they often condition the development and management of urban transportation systems.

2) The *housing and green infrastructures* systems aim to provide shelter in an adequate built environment and maintain green areas and vegetation within the city. Green areas in the urban environments contribute to the survival of natural ecosystems within the city and contribute to the quality of life for city inhabitants. Urban forests, biological corridors, and parks all need to be properly managed to be sustainable, as is the case with buildings. Maintaining the buildings is indeed indispensable to keeping up a proper urban built environment.

3) The *energy* urban infrastructure system provides (equitable) access to energy services across the city. The physical infrastructure is built around the household and industrial consumers located in the urban areas whose needs strongly condition the development of the system. The generation of electricity traditionally takes place at the outskirts of a city, although one can find electricity backup generation units in the city (such as in hospitals) as well as, increasingly, self-generation (from rooftop solar panels, for example). Electricity and natural gas are delivered to customers through distribution networks that, ideally, reach every corner of the cities and are generally hidden below the streets, even though one can still find overhead wires in some cities.

4) The *water and wastewater* systems supply drinking water and collect waste water from households and industrial facilities and rainwater in some cases. This vital urban infrastructure is generally connected to a river or lake in the surroundings of the city from where the water is extracted and later conditioned for human consumption. Water is then distributed through a pipeline network that ends up in the taps of households. The wastewater system in turn collects the water used in households and industrial facilities and transports it to wastewater treatment plants, after which it is discharged into the groundwater where it again enters the so-called water cycle.

5) The urban *waste* infrastructures pertain to the collection, treatment, and ultimate disposal of the waste generated in the urban area from households and industrial plants. Collection is generally done by trucks, which can be publicly or privately operated, and then transported to treatment and separation plants where it may be destined for recycling, valorized with a waste-derived fuel, composted, or directly incinerated. There is always a remaining fraction (even after incineration) that has to be landfilled.

6) The *communications* infrastructure mainly aims at offering access to phone and Internet services. Despite its relative youth, the communications infrastructure has become an essential component of urban infrastructures with a physical network of copper cables and, more recently, fiber optic cables. Mobile communications services are delivered by way of mobile towers, public Wi-Fi stations, and WiMAX.

There are strong interdependencies among urban infrastructure systems with substantial implications for their management. Urban infrastructures do indeed share spaces, such as the city surface (using roads, buildings, and green areas) and underground tunnels (for trains, such as copper cable, electrical network, and fiber optic). But beyond the spatial interdependence, the services provided and the needs covered by the different systems are deeply reliant on each other (such as traffic lights and energy, waste and transport, communications and energy). For the city to satisfy the needs of the citizens living in it, the correct, simultaneous functioning of all systems is required. Hence, an integrated urban infrastructure management approach is the only way for guaranteeing it.

## The characteristics of urban infrastructure systems

We have already distinguished between primary and secondary infrastructures, in the previous discussion. The *primary infrastructures* are the focus of this course and are composed of the six infrastructure systems introduced in the previous section and whose performance is measured in terms of efficiency, sustainability, and resilience. On addition to these infrastructures, *secondary infrastructures* deliver more elaborate services, such as education, health care, nutrition, culture, justice, and others. The combination of primary and secondary urban infrastructures ultimately leads to three indicators—namely, the quality of life in cities and the attractiveness and the competitiveness of the city.

To effectively manage urban infrastructure systems, the following five characteristics have to be considered.

1) The *technical characteristics* of urban infrastructure systems refers to the technical elements and technologies present in the various urban infrastructures (for example, energy, transport, and communications). Generally, a distinction is made between lines (line technologies, such as cables, roads, tracks) and nodes (node technologies, such as transformers, substations, and exchanges). These physical components constitute the basis upon which services to citizens and customers (of transportation services or electricity) can and will be delivered. These services may also have a technical dimension with corresponding characteristics, such as is the case for transport vehicles, telephone devices, and others.

2) The *economic characteristics* refers to the economic nature of urban infrastructure systems. Obviously, urban infrastructures have a cost, both for building and for operating them. First and foremost, (urban) infrastructures are characterized by so-called sunk costs,

and these would be expenditures that cannot be recovered once made. From this follows that (urban) infrastructure services display significant economies of scale (and sometimes scope). In other words, once an infrastructure exists, the additional (marginal) per unit price of using it is very low. Once an infrastructure exists, it is thus rational to use it to the maximum, rather than to build a second one, something which, in economic terms, tends to lead to so-called market power or even monopolies. Finally, many (urban) infrastructures deliver so-called public goods (these would be services whose usage does not diminish those goods of others or consume it (for example, a nonrivalry) and whose usage cannot be restricted (for example, nonexcludability), as is the case with street lighting).

3) The *jurisdictional characteristics* refers to the geographic dimension of the infrastructures and their operations, in particular to the fact that the geographic and the political boundaries of cities or rather agglomerations coincide less and less. In other words, urban infrastructure systems are generally much bigger in scope than the political boundaries of a given city. Rather, agglomerations are composed of several political cities. This creates particular problems of interconnectivity, interoperability, and joint system management and significantly defines the quality of the services received by the citizens. Let us take the case of greater Mexico City, discussed below, which covers the so-called Federal District plus 41 adjacent municipalities, each with different jurisdictions and decision power over the urban infrastructures (SEDESOL et al. 2012). Urban infrastructure management requires substantial coordination efforts.

4) The *social characteristics* refers to the impact infrastructures inevitably have on society and citizens. The key concern here pertains to equity in access to the services, but also to the quality of the services delivered to the different parts of a city (with different types of populations inhabiting it). Typically, less well-off communities have less access to transport, electricity, and other services and suffer lower-quality services (for example with poorer drinking water quality, electricity cuts, and others). Disenfranchised communities in cities also tend to be more polluted.

5) The *environmental characteristics* refers to the interaction of urban infrastructures with their natural surroundings. The impact of urban infrastructure systems in the environment can be either negative (such as $CO_2$ emissions, noise, pollutants, and changes of land use) or positive (such as integrated, green infrastructures and renewable energies). But in any case, urban infrastructures do affect the urban environment, generally negatively.

Figure 3 illustrates how these five characteristics are related to each other. While the technological, economic, and jurisdictional characteristics are directly related to each other (for example, interoperability, costs), the social and environmental characteristics are pervasive in that they cut across these three dimensions. All five characteristics or dimensions make up the city as a complex sociotechnical system, requiring an intrinsically multidisciplinary approach for managing it. The way this system (and its subsystems) is managed will directly determine its efficiency, sustainability, and resilience. And indirectly all this will affect the quality of life, the attractiveness, and the competitiveness of a city or agglomeration.

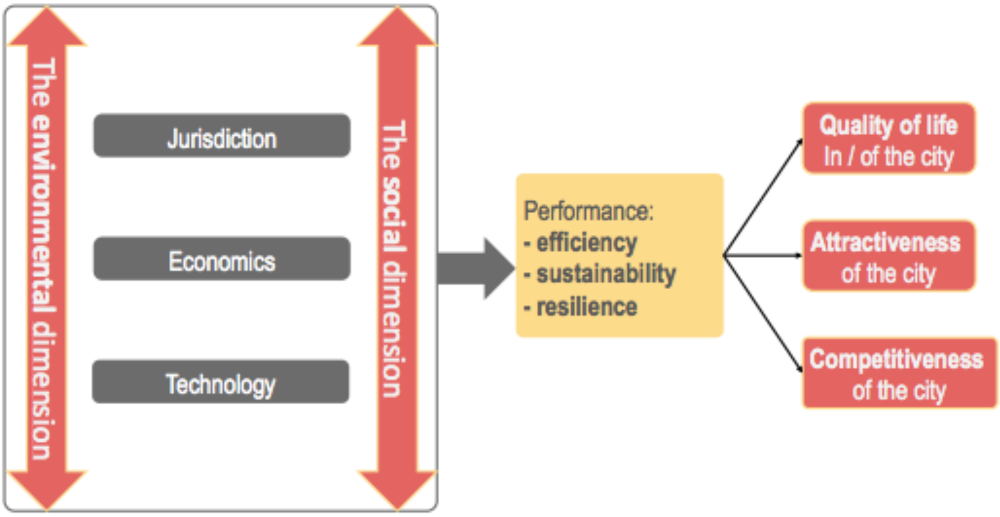


Figure 3: Urban infrastructure characteristics and their implications.

**Main analytical perspectives on urban infrastructure systems**

All the challenges of managing urban infrastructure systems (such as the challenges to make them efficient, sustainable, and resilient, as previously discussed) can be approached from two distinctive intellectual perspectives, each being coherent in its own right. These are the public policy perspective, on the one hand, and the public economy perspective, on the other.

From the *public policy* perspective, the overall objective is to provide the best public services possible to the inhabitants of a city, guided by the principles of accessibility, quality, affordability, and equity. In other words, infrastructure services come before all public services. Of course, there are some financial constraints, but the services and their affordability are more important overall than the money available. Making a profit is not the main objective in this case. Also, in this perspective, the preferred mode of providing services falls to companies that are owned directly by the municipality. If the company providing the services is or cannot be owned by the municipality, the public authorities engage in a contract with a private or public-service provider.

Contrastingly, in the *public economy* perspective, the basic goal is to provide the service in a profitable manner (or at least in a way that the costs are covered by the revenues). In this perspective, infrastructure services come before all commercial services and markets (for infrastructure service) and are the preferred arrangement. Ideally, this arrangement also means that there should be competition among the different providers of infrastructure services (for example, among telecommunications operators and electricity services providers). If competition is imperfect, which it generally is in infrastructure markets, unbundling (of the competitive and the monopolistic infrastructure elements) and subsequent regulation, and not ownership, are seen as the preferred tools for guaranteeing service delivery. Recourse to financial support from the local authorities in the form of subsidies is acceptable only as a last resort and only in case of market failure.

**Illustrative case: Mexico City**

Mexico City stands out as a prominent global example of the challenges urban infrastructure system managers have to confront. The Mexico City metropolitan area is the largest agglomeration in the Western Hemisphere. The city is home for over 20 million people today. The Aztecs established the city around 1325, and it quickly became the dominant state-city in the region. This leading role continued during the Spanish occupation up to 1821, and the city became the country's capital soon after.

The city infrastructures developed by the end of that century, and the city experienced an explosive growth that has continued up to the present, but which came at a burdensome price. By the 1970s, basic services were hardly met, and the situation deeply worsened during the 1980s after the oil crisis. Pollution and smog produced serious health problems that extended well into the 1990s, when a crime wave hit the city, putting it on the ropes. Cuauhtémoc Cárdenas then became the first elected mayor of Mexico City in 1997, signaling the start of a much-needed transformation of the city management.

Today, Mexico City is still battling its own problems. In this section, the Mexico City case will help illustrate the demographic, socioeconomic, technical, environmental, and jurisdictional challenges modern urban infrastructure systems encounter around the globe.

***The demographic challenge***

Population growth in the Mexico City metropolitan area has followed a steep curve that has strained the city's capabilities to provide basic services. Acting as a magnet for rural populations in search of higher living standards, the city grew steadily throughout the past century, with a dramatic increase between the 1960s and 1990s when the population exploded from 5 million to more than 15 million (see Figure 4).

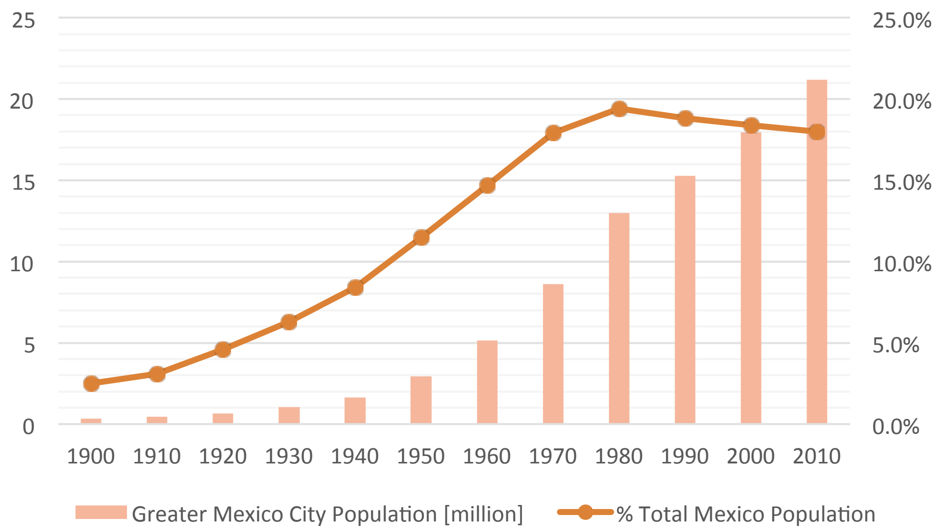


Figure 4. Demographic population in Mexico City Metropolitan Area 1900–2010. Author's elaboration with data from Connolly 2003; INEGI 2011.

Currently, the population of the Mexico City metropolitan area is over 21 million people, with a growth rate that has fallen below 2 percent but is expected to reach 23 million by 2020 (World Population Review 2015). Despite the drop of the population growth rate, the deep imprint of uncontrolled expansion remains starkly visible across the agglomeration, with poor housing and urban infrastructure marginalization erupting abundantly all over the region.

The social structure is under transformation in Mexico City. The demographic and economic changes in the agglomeration are driving the change. A drastic reduction in fertility caused by family planning policies introduced in the 1970s and the increase in life expectancy have changed living styles, particularly among women. As a consequence, the population growth has decelerated (although not the city expansion); the population is aging rapidly; and women are taking a more active economic role (Connolly 2003).

Additionally, the traditional immigration of rural Mexicans into the country's capital has greatly weakened. Rural inhabitants are now even more attracted to crossing the border and moving to other large and medium-sized cities (Connolly 2003). Indeed, there are more people leaving the metropolitan area of Mexico City than arriving (INEGI 2009). This generates a shift from an uneducated, rural population massively coming into the city to the departure of the best-prepared inhabitants with profound implications both in the demographic and socioeconomic characteristics of the agglomeration.

All these trends are dynamically defining the new demographics of the city, whose infrastructures should be adapted to fit the new needs of a differently defined population. The effects of this demographic challenge heavily impact the urban infrastructure systems in the city.

Between 1990 and 2008, the number of cars on the Mexico City streets doubled from 2 million to more than 4 million, and energy consumption surged from 443 PJ to 545 PJ per year (equivalent to 90 million barrels of oil per year) (Cadavid 2010). These increments required the electricity infrastructure, as well as the transportation system, to adjust for dealing with the growing needs of the city (that is, expanding the distribution network, building of new streets, and scaling up of current infrastructures). Without any adaptation of the infrastructure to such an important demographic growth, roads, for example, suffer from saturation caused by the ownership of more cars by the growing population, which has, as you might guess, obvious environmental and economic impacts on the city as a system.

### *The socioeconomic challenge*

In spite of the changing demographic trends, the urban area seems to stubbornly continue expanding as a unique feature of the Mexican capital: population density has remained stable over 500 years, around 120 people per hectare (Connolly 2003). The city expands horizontally during recessions, since land is cheap, and increases density during economic prosperity. This need for expansion, which originated in the demographic challenge just discussed, has created the problem of poor housing accumulation in the outskirts of Mexico City, which forms characteristic "colonias populares" by irregularly occupying the steep slopes surrounding the long-dried lakes in which the city lies (Connolly 2003). Bringing basic services such as drinking water, wastewater collection, electricity, and public transport to these irregularly formed areas is not an easy task. The extension of the infrastructure networks is hampered by the lack of long-term planning and proper conditions for its development (that is, poor quality of the soil for hosting the water pipes).

Currently, Mexico City's irregular settlements constitute roughly half of the urbanized area, giving shelter to around 60 percent of its population and covering a wide social spectrum, not limited to the poorest residents, as well as varied housing quality (Connolly 2003). Uncoordinated policies between the Federal District (DF) and the metropolitan areas (that is, the ban on the development of housing estates in the 1950s in the DF) have contributed to worsening the problem by increasing the pressure on lower-income families to move to the hinterlands (incurring expensive, time-consuming commutes to workplaces) or to concentrate in growingly dense (and expensive) dwellings in the central neighborhoods of the city (Cities Programme 2006). Different public housing initiatives have helped relieve the situation (through the Housing Institute projects), although a complete solution still seems far off.

The resulting segregation problems in Mexico City pose great difficulties to overcome with inequalities in access to infrastructure. Additionally, the concentration of lower-income residents in the outskirts of the city puts additional pressure on the public transportation system, as well as on the traffic system itself, to ensure commuters reach their workplaces every morning. When added to the demographic challenge, unparalleled demands for the transport infrastructure emerge, clearly shown by the explosion in private cars traveling the urban area: from 2 million in 1990 to more than 4 million by 2008 (Cadavid 2010).

To try to minimize further traffic congestion, the urban infrastructure managers need to ensure low environmental impact and sufficient complementary public transit. They need to think about how to incentivize the shift from personal car use to public transportation, by developing, for example, mechanisms to penalize the use of private cars and subsidizing public transit to make it really competitive to private car use for middle-class urban dwellers.

For many lower-class urban dwellers in Mexico, public transit costs represent half of their daily income, which does not seem sustainable. Social pricing mechanisms, for those who cannot afford public transit, have to be developed to tackle the socioeconomic challenge.

Despite consistently generating between 30 percent to 40 percent of the country's GDP, as much as half of the agglomeration economy is attributed to the informal sector (Cities Programme 2006). After the deindustrialization of the 1960s, up to three out of four workers employed in the services sector were suffering an important drop in their real income with the economic crisis of the 1980s and the opening-up to global competition (Cities Programme 2006). These factors have greatly favored the growth of the black market, with the number of street vendors booming in the city center during the early 2000s, which particularly affects high social-exclusion risk groups such as women, seniors, and undereducated youngsters (Cities Programme 2006). For the urban infrastructure manager, this situation translates into a shortage of resources from taxes and from charging fees to the services users, given that to ensure affordability of the service, the fees need to remain proportionate to the income level of most users.

On the other hand, highly specialized global services firms (such as finance and IT) are increasingly present in the region. However, they employ a limited share of the workforce and appear functionally and territorially disconnected from the surrounding city. They seem to be unable to drive up the productivity and competitiveness of the urban area that remains among the lowest of its international peers (Parilla et al. 2015; Cities Programme 2006). Associated with the change of land use after industries moved out of town, this trend has helped create a fragmented city with disparate growth rates, unutilized industrial areas, and insular suburban service-oriented nodes (Cities Programme 2006). This trend strongly affects the urban infrastructure systems by requiring their adaptation to the new situation, and dealing with fragmented demands from users could pose a threat for the whole network stability (such as the electricity grid).

These broad strokes on the socioeconomic challenges in Mexico City shape a worrying bigger picture: the city is dangerously exposed to economic cycles and external shocks (in other words, is vulnerable to economic crisis and the ups and downs of commodity prices). Its urban infrastructure systems show low resilience to shocks and need much improvement.

### *The technological challenge*

Technological change in networked infrastructures is uneven. Long asset lifetime and high capital costs tend to entrench the problem, making public authorities reluctant to confront it. Old transportation infrastructure with obsolete public transit vehicles, or the need to spread the reach of communication technologies networks concentrated in spared economic hubs (see the socioeconomic challenge), are just some of the technical challenges Mexico City faces. However, drinking water supply is undoubtedly the most worrisome issue, with officials openly calling for an extensive technological update in Mexico City.

Ironically, despite sitting in an ancient lake basin, Mexico City desperately needs to bring water from water sources in the metropolitan area periphery, while suffering important flooding risks, with up to 6 million people living in high-risk areas (Connolly 2003; Chelleri et al. 2015). Demand is estimated at 173 percent for the locally available freshwater sources, and around half the water needed must be brought into the city. For this purpose, 910 km of primary supply and 11,900 km of distribution pipelines are employed (Spring & Cohen 2011). Only 60 percent of the piped water is suitable for human consumption due to poor pipeline conditions and conditions of the groundwater sources, favoring the overexploitation of available resources (Spring & Cohen 2011).

Deteriorated infrastructures built sixty 60 years ago with rapidly declining performances are a main cause of this problem, deepening the lack of resilience of the city (i.e.leaving it vulnerable to exposure to cClimate cChange effects) (Martinez et al. 2015). It is estimated that the water infrastructure of Mexico City experiences in an average of 40% percent of leakages. These leakages could come from poor connections between water networks, in-compatibility of subsystems, or poor maintenance of the water adduction pipe, for example. Technology is the answer to these leakages, which assess the existence ofare a true technical challenge. Because of the rising demographics, more and more people will need water at home, which will put more pressure on the network, and, if nothing is done, will increase the leakages in the network. Technical and demographic challenges are completely linked.

Additional problems such as abundant illegal connections (coming from the socioeconomic challenge) to the water supply or governance issues (such as jurisdictional discoordination, misaligned policies, and low funding) push the urban infrastructure water system high on the list of concerns in Mexico City (Martinez & Bandala 2015). The demographic challenge experienced in the city simply adds pressure to the water infrastructure problem by magnifying its scale.

### *The environmental challenge*

Mexico City, as any major city, has a large impact on the ecosystem in which it is located. The impact needs to be contained and managed by coordinating efforts through policies, infrastructure management, and users. In 2007, the municipality of Mexico City published the Green Plan framework, a 15-year strategy addressing environmental issues until 2021 (Danish Architecture Center 2010). The environmental issues are structured in seven columns that reflect the main environmental challenges faced by the city, including, among others, waste handling, land use, mobility (that is, pollution), and sanitation (such as keeping water sources clean) (Danish Architecture Center 2010).

The biggest environmental concern for the city was related to the health of its population: air pollution. The geographic and climatic location of Mexico City, allied with the demographic boom it experienced, together created deathly high pollution levels in the urban area. First warnings were delivered in the 1970s, although little mitigation was made during the 1980s, so air pollution became a public health emergency in the following decade (Garza 1996).

Vehicles were to be blamed for up to three quarters of the pollution, and thus the efforts were focused on reducing their impact by renovating old diesel public transport services and introducing electric alternatives (such as trolley buses) (Garza 1996). The effectiveness of such measures was modest since they did not address the main source: private mobility inside the city. A battery of regulatory measures transforming the transportation system in the city was then put in place during the late 1980s and the 1990s, such as tightening emission standards requirements, the planned-to-be-temporary "A Day Without Car" program prohibiting the circulation of each automobile one day per week, incentivizing unleaded fuels, or inspecting industrial facilities to control emissions (Garza 1996). Several policies were developed to implement public transportation systems (Metrobus project, ecobici) to push citizens to choose collective public transportation rather than use personal cars, which had a positive impact on the city's green-house gases (GHG) emissions.

The combined effects of multiple actions aligned into a unique direction—toward reducing air pollution—has proven effective in the long run. In the last 25 years, pollution has dropped dramatically with some components such as sulfur dioxide reduced to one third its levels in the 1990s (Ireland 2014), despite the continued expansion of the city and its population. However, the challenge remains. Current pollution levels are still the highest in the country, with some substances at dangerously high levels (that is, ozone concentration is 2.5 times the safety levels recommended by the World Health Organization) (Ireland 2014). Hence, additional initiatives should be put in place by the urban infrastructure systems managers to reinforce the downward trend (such as an eco-bike program across the urban area or expansion of metro lines) (Ireland 2014).

### *The financial challenge*

All prior challenges have in common the need for financial resources to address the pressing issues combined. However, they have to ferociously compete against each other, as well as against other infrastructure services in the city, for scarce, limited funds. The troubled evolution of public investment in the city—where the collapse of federal investments in the metropolitan region in the 1990s greatly undermined its aspirations to compete with European or Asiatic cities (Cities Programme 2006)—proves Mexico City is familiar with the struggle to fight over limited funds. Hence, urban infrastructure managers in Mexico City have to work out a delicate balance to allocate resources, or to try to find new ones.

Fragmented jurisdictions in the metropolitan area make coordination of financial efforts difficult. Joint developments will result in reducing coordination costs, making available more funds for the projects (or other purposes) (Cities Programme 2006). International organizations such as the World Bank can and often have become partners of the local infrastructure managers to finance particular projects under favorable lending conditions. However, a key source of funding that remains underexploited is the private sector.

Drawing from the bigger picture, from the $1.2 to $1.5 billion per year needed in infrastructure investment in developing countries worldwide (European Investment Bank 2010), less than 25 percent is provided by the private sector, which leaves room for great improvement (Francke et al. 2012). Mexico City can thus benefit from the expansion of public-private partnerships to raise investment in services of metropolitan interests while guaranteeing the public interest (Cities Programme 2006). As an example, synergies can be found in critical fields for environmental and socioeconomic challenges such as transportation as studied for the Metrobus development (Francke et al. 2012). Financial challenges are obvious in the case of water network improvement. For the moment, in some municipalities of Mexico, it is cheaper to continue to pump (that is to say over-pump) the underground water, even with 40 percent leakage, than repair the network in order to have fewer leaks (in other words, more efficiency is gained and fewer water resources are consumed).

In urban infrastructures, demographic challenge creates socioeconomic challenges, which are visible through technical challenges with environmental impacts, and where jurisdictional and financial challenge can act as a lever to solve the overall problem. All these challenges are interrelated, which underlines the necessity to adopt a systemic view to tackle these challenges.

We have seen among the different challenges faced by Mexico City how complex and entrenched some urban infrastructure system problems can be, as well as its paramount relevance. However, it is the intimate interrelationship among all the five dimensions that makes an integrative approach to the task indispensable. Stemming from the demographic challenges experienced by the city, the rest of the challenges add pressure to the strained urban infrastructures. The intertwined technical and social aspects require the sociotechnical perspective employed in this course, to fully understand how demographic, socioeconomic, environmental, technical, and financial challenges condition the management of urban infrastructures.

Upcoming sessions will look deeper into how to tackle these challenges by introducing the main tasks of urban infrastructure managers, the stakeholders involved in urban infrastructure systems, the main characteristics of the systems, and the principal schools of thought, with an eye toward discussing energy and transportation systems later.

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