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Capstone final report

>2020/2021

5G controversies in European cities

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(Master Governing Ecological Transition in European Cities)

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The “Cities and Digital Technology” Chair of Sciences Po’s Urban School has been launched in March 2017 to better grasp the impact of digital technologies on urban governance. Funded by three sponsoring firms (La Poste, RTE, Caisse des Dépôts), the Chair aims to create new research fields exploring the interaction between digital technology and cities in an empirical and comparative perspective.

Summary

5G has begun to be deployed intensively in European countries in 2020, with some delays due to the Covid-19 pandemic. The rollout of this technology was not straightforward in all cities. Indeed, 5G has been at the core of tensions and controversies between actors in several European cities. While 5G is presented as an element to improve economic dynamism and competitiveness by some actors, such as telecommunication industries and certain policymakers, others urban actors are opposed to it, invoking potential social and environmental risks.

Our research focuses on five case studies of different European cities: Geneva, Barcelona, London, Grenoble, Helsinki & Stockholm. In those cities, we studied the rollout of 5G, its origins and its impacts on the existing urban ecosystem. As the environmental impact of 5G has already been studied and debated in other research, our work focuses on the urban governance dynamics of 5G. Each city has its own specific urban context including specific actors, legal possibilities, political culture but also economic environment. We then studied how 5G inserts into those existing urban contexts, and how it provokes controversies and challenges in urban governance processes.

Keywords: 5G, Urban governance, Digital technologies, Smart city, Geneva, London,

Helsinki, Stockholm, Barcelona, Grenoble

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Introduction

This research project is the product of a collaboration between Sciences Po Urban School students and the Centre for European Studies and Comparative Politics, through the Cities and Digital Technology chair. It is a teamwork carried out by Sciences Po Urban School students in the context of their first year of master's degree. The focus is made on the controversies surrounding the development of 5G networks in urban contexts. The rolling out of this technology is indeed at the core of the tensions between actors in cities. Whereas this technology is presented as an element to foster economic dynamism and competitiveness by various actors, including telecommunication industries and some policymakers, some others are opposed to it by invoking potential social and environmental risks induced.

From October 2020 to June 2021, our group is working on this report conducting an analysis of five fields of enquiry, in different national contexts, in collaboration with the Urban School Administration, Antoine Courmont, scientific director of the Chair, and Gauthier Roussilhe, researcher specialised on digital technologies. Besides a mapping of the different actors involved and a framing of the debates and the arguments mobilised, cross-national and interrelated dynamics are being assessed to develop a comprehensive study that would lead to a better understanding of the issues at stake on this emerging, yet global, technology.

To grasp the complexity of this debate, it is worth having in mind what 5G is and why it is different from previous 2G, 3G and 4G technologies.

The functioning systems of 2G, 3G and 4G are based on the same idea. Antennas, often above buildings roofs, deliver a powerful signal to cover a specific area. Depending on the antenna's power, obstacles such as buildings and weather conditions, it will cover a defined surface. The coverage is guaranteed by using waves with specific frequencies (900 MHz and 1900-2100 MHz for 4G systems for instance). The signal spreads in every space’s direction, creating a coverage that can be represented as a dome. Moreover, the power delivered by the antenna, and therefore the quality of the signal delivered, is constant. Thus, the more users there are, the poorer the quality of the signal will be since the power delivered is divided by the number of users. In crowded areas such as city-centers, lots of powerful antennas are often deployed. This system raises questions about energy efficiency.

5G networks function differently. Contrary to 4G antennas, the 5G ones are designed to work punctually, only when there is a demand: they send waves to a specific device willing to connect to the internet, hence limiting useless emissions. Nevertheless, they are more expensive, both in money and natural resources. Also, frequencies used are different (3.4 GHz to 3.8 GHz) for the first antennas rolled-out in France and in Europe between 2019 and 2021. For these specific frequencies and according to Alain Sibille[1], there will be no major

[1] Alain Sibille, French specialist on 5G questions, professor and researcher at Telecom Paris.

difference from the performance delivered by 4G coverage. The next step with 5G is to roll-out antennas which will deliver millimeter waves with a 26 GHz frequency. These antennas will be much more efficient and will deliver better performances than 4G emitters.
Nevertheless, millimeters have poor capacities to spread and pass through obstacles and they have a short range. Hence, more 5G antennas are needed to have the same coverage in a specific area than the coverage guaranteed by 4G antennas. In France, specialists of this question are talking about doubling the number of new antennas to reach a satisfying coverage (Ciblat, 2021). In terms of efficiency, 5G developers argue that since devices are targeted, it will limit the consumption of antennas. Nevertheless, this idea does not take into account the rebound effect. If it turns out that people use more of their connected devices, there will be no economies of scale in energy consumption. 5G promoters argue that it will be the opposite, saying that the internet consumption will be quite constant and therefore, expecting such economies is realistic.

The debate around the 5G rollout is global and refers to broader issues shaping urban governance for a few decades.
Cellular antennas are hardware infrastructures fostering the creation and the flow of massive amounts of numeric information. Since the end of the 2000's, these "big data" became, in a matter of years, a central influencer that made a difference on how urban socio-economic environments are organised. Whereas individual human agents are being empowered by smartphones which concentrate different uses, collective organisations such as companies, associations but also public authorities changed their habits and increased their reliance over numeric tools to organise and monitor their activity. To accelerate this trend and accompany these new uses, the successive development and installation of cellular antenna technologies, from 1G to 4G+, accelerated the numeric coverage of the city and allowed a fluider connectivity. Whereas 5G antennas are the last born in this series of connective equipment, 6G ones are already programmed for the end of the decade.
Digital development does not seem to be an option for most of the cities. Due to the heavy reliance they create, those infrastructures became central components for competitiveness and attractiveness policies in a context of a globalised competition between cities. The access to a performing numeric network is perceived to be crucial to attract businesses and foster economic development. This narrative is in fact embedded in a global discourse related to techno-scientific liberalism putting forward those new numeric networks as intrinsic features of a global, dynamic and connected city. 5G antennas are the newfangled infrastructures of this kind. Besides being the "logic" further step towards a bright numeric future, it is at the core of economic strategies widely discussed, from Industry 4.0 to Virtual Reality technologies by passing through remote surgical operations.
After a decade of conquest, it now seems that 2020 opens a decade in which digital actors, devices and uses become dominant in citizen's and worker's daily lives. The Covid-19 breakdown and the lockdowns implemented worldwide accelerated this move and forced a majority of urbanites to become dependent on digital infrastructures. The sharp rise of teleconferencing applications is, in that respect, symbolic of the breaching of those new actors in both professional and private spheres.

Concomitantly to that technological development, new ways to govern the cities emerged. Tech companies such as IBM, Cisco, Huawei or Dassault Systems are promoting, for more than a decade, new digital tools to monitor the city. Technical solutions are presented as ultimate solutions to solve complex urban issues: whereas energy flows were supposed to be optimised, traffic congestion and crimes should have been problems of the past thanks to real time control and intervention.

The high level of complexity induced by those technological fixes enabled new private actors to get into urban governance. Whereas public authorities are fixing the broad direction on how those technologies should be developed within territories, private actors are in charge of the effective implementation of those technical equipment and solutions. This is the case for the rollout of cellular antennas. Even if public authorities are validating what private actors would be able to operate within the urban fabric, the latter seem rather independent on how the antennas are finally deployed in the environment.

Whatever the situation, the rolling out of this technology induces power balances among operators and constructors, but also between those companies and public authorities. One of the most significant examples of this could be found in Singapore where the government of the city-State arbitrated for a balanced repartition between Nokia and Huawei 5G antennas.

The deployment of 5G happens at a time of strong international competition for innovations in digital technologies and artificial intelligence on which Europe intends to play a central role.

The race for data collection and analysis is now viewed by states as a major means of power. Countries, but also companies, see it as a key economic and security factor that will condition their future prosperity. The opportunity for Europe lies in industrial data or services such as health and education. In that respect, 5G is key for European countries with strong strategic ambitions.

Nonetheless, European countries move forward in dispersed order. In Great Britain, the debate was very politicized: at first, the government authorized a limited access to Huawei, as Vodafone uses it for many of its European networks. However it underwent a change of policy in summer 2020, following rules set by the “5 eyes” and will no longer use Huawei devices by 2027. In Germany, there were divisions in Merkel's coalition about the topic of Huawei. Even if socio-democrats are in favor of banning Huawei, Merkel seeks to maintain good relations with Beijing for trade. On the eastern side, Poland, Latvia and Lithuania want NATO and the EU to find a common ground. Hungary, Slovakia, Spain and Portugal don't want to change their decision of allowing Huawei because they don’t want to be falling behind in the 5G race as their government has identified 5G as a strategic priority. In France, the government has issued a limited authorization to operators using the Chinese technology for 3 to 8 years maximum. But it is excluded from the "cœurs de réseaux" (central networks) and from the Paris area. What’s more, the government made an explicit move by asking companies not to choose Huawei.

Besides, the EU has been hesitant to fully support the two European 5G companies : Ericsson (Sweden) and Nokia (Finland). Ericsson is the world n° 2 of the 5G market behind Huawei, with 27% global market share. It took advantage of the ongoing oppositions around Huawei to gain market shares in Germany, Great Britain and Canada. Nokia is world n° 3 with around

19% of the global market. However, even combined together, the two companies invest less in R&D than Huawei.

A tool for the ecological transition or a technology carrying high environmental costs?

Environmentally speaking, 5G also raises challenges. One of the critics it faced so far is the lack of knowledge about its consequences on health and therefore on ecosystems. In a 2019 intermediary report on 5G, the ANSES asserted that there was a lack of data concerning potential biological and sanitary effects (Anses, 2019). Many associations have demonstrated their anger towards such a project, ongoing even with the uncertainty of its aftermath. Researchers are still wondering if microwaves have long-term impacts on health, since it seems not to be the case for short-term analysis. Moreover, the sanitary issue is linked to the ecological one. If associations have complained about 5G microwaves leading to an overexposure of local inhabitants to sanitary risks, the ecosystems surrounding the antennas would not be left out. For now, no test has brought precise results regarding the impacts of this new network on fauna or flora.

Concerning the effects of 5G at the global scale, there are still uncertainties but some actors fear that the massive deployment of the new technology will have negative impacts on the environment. Today, the digital sector represents almost 4% of global greenhouse gases emissions, and grows rapidly (The Shift Project, 2021). Even if individual antennas consume less energy than 4G, the deployment of 5G will probably lead to a "rebound effect": the considerable increase of the demand for data could counterbalance the energy efficiency of the technology itself. The modification of the users' behaviour will annulate the energy gains realised. According to The Shift Project, in France, the energy consumption of network operators will be multiplied by 2.5 or 3 within the next 5 years because of 5G, which represents a 2% increase of the electricity consumption of the whole country (Damgé, 2020). Even the president of the French network operator Bouygues Telecom, Olivier Roussat, has admitted in 2020 to the Senate that after the first year of 5G deployment, the energy consumption of all operators will considerably increase (Damgé, 2020).

On top, the deployment of 5G will necessitate the construction of new consuming data centres to manage the increase of data linked to new usages. Moreover, the deployment of 5G also requires new materials. The quasi totality of currently used mobile devices are indeed not compatible with 5G. If the user wants to benefit from the network, they will need to buy a new smartphone, hence raising questions on technological waste management and on the environmental cost of producing all these new smartphones and new 5G antennas. According to the Ademe, the fabrication of the technological equipment for the consumers is indeed at the origin of 47% of GHG emissions generated by the digital sector[2].

[2] *La face cachée du Numérique, réduire les impacts du numérique sur L'environnement*, Janvier 2021, p.4 https://www.ademe.fr/sites/default/files/assets/documents/guide-pratique-face-cachee-numerique.pdf

Analysing a controversial digital innovation in urban contexts

The 5G technology is a technological innovation raising challenges in different domains. Through this report, we will then wonder how those controversies are embodied in urban ecosystems. To what extent the rollout of 5G networks is a digital innovation that generates, by its nature, both specific and cross-context controversies within urban socio-ecological contexts? Whereas it is worth reflecting on why this innovation crystallises tensions between urban actors, some endorsing it and some rejecting it, it is also relevant to understand the particular agencies that lead to those controversies, as well as their structuring patterns regardless of cities and countries.
The controversies around the development of 5G in European cities will be studied from a social science perspective. Beside academic literature reviews, media monitoring and official document analysis, campaigns of interviews were carried out in each field. Borrowing literature and methods coming from sociology, political science but also from geographical science, our team aims to have a holistic understanding of the controversies at stake within the fields we have chosen to focus on. An analysis of six European cities will be developed within five chapters. A sixth chapter will act as a conclusion that will compare fields and distinguish the structural trends we captured by analysing 5G antenna developments in the urban governance processes examined.

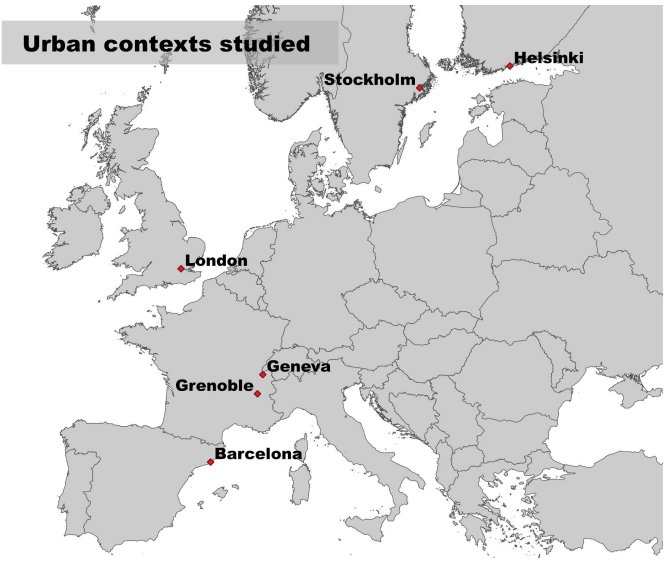
All research fields have been chosen due to their local context that would enable us, added together, to have a comprehensive understanding of the challenges raised by this new technology. Whereas some already have a substantive network of 5G antennas, some others don't have any. Also, 5G debates are locally framed differently.
The situation in Switzerland and more peculiarly in Geneva is ambivalent. 5G has been deployed around the country and covers all the Swiss territory. Nevertheless, a moratory has been voted in Geneva, to stop the implementation of new antennas across the city. The three major operators are pushing the government to allow them to implement new antennas.
Barcelona is an interesting territory for the deployment of 5G due to its technological capabilities, available infrastructure, research and innovation capacity. The governance of this digital technology is complex and to some extent ubiquitous. On that matter, the 5G Barcelona alliance, a network created by private companies with support of the public authorities coordinate and align all the 5G related actors in various fields. On the other hand, and transpiring from a different project, the neighborhood of Poblenou is also leading the way as a 5G test-bed to validate new technology and services, alongside its urban transformation projects. It is evident that the objectives of both projects are not in conflict, but instead they are acting independently.
London is an innovation driven city deploying 5G in a context of economic changes. The city wants to boost its digital and creative industries, so the deployment of 5G was taken into consideration quite early by the Greater London Authority. The study of Transport for London's role in the deployment of this plan shows how 5G accelerates the reinforcement of

London's competencies and decisional autonomy, but also the development of public-private partnerships.

Stockholm and Helsinki are technological innovation clusters in which dialogue and collaboration between the stakeholders is very strong. Swedish and Finnish cultures are also rather favorable to technological innovation. Thus, the diverse actors in both capitals have rapidly and efficiently agreed on working together to implement 5G, in link with their ambition of becoming smart cities.

Grenoble is one of the main French technology clusters, with strong links between science, industry and local governments. One could thus suppose that Grenoble would be at the forefront of 5G development and implementation in France, but actually the Green municipality is strongly opposed to 5G and has raised sanitary, environmental, and democratic concerns.

Figure 1: Urban contexts studied



Reflecting on 5G controversies in several urban contexts leads to reflect on structuring elements observable in all contexts, but with specific patterns for each.

The access to a 5G connexion is enabled by antennas that are spread differently. On the one hand, the rollout in itself admits strong differences from one country to another. Whereas this technology covers most of some national territoires, some others are only sparsely equipped. On the other hand, those antennas are material infrastructures installed in cities. They are inserted within the public space, into more or less densely urbanised areas. Those new and visible urban objects may be invasive and could raise some fears from people living nearby.

The deployment of those antennas may also be understood as components of wider strategies developed by governments. 5G rollout strategy may indeed be intertwined with other components of public action at the urban level. Whereas this could be understood as a tool to foster economic development and competitiveness, 5G could also be a technical solution to enhance or create policy instruments. By permitting fast connections between human agents and machines, 5G technology may raise the interest of local actors aiming to connect

infrastructures in thematic action plans on a variety of topics, from smart transportation systems to smart grids or smart urban furniture. This reasoning may be applied both on a national and on a local scale.
On the contrary, the rollout of 5G technology could be a source of tension between actors of urban governance. The location of those antennas, first, could be questioned by urbanites who take a dim view on those infrastructures installed near their residence or their workplace. Even if most of the actors appreciate the possibility to access a fluider connexion, few of them have the same enthusiasm when this leads to a 5G antenna installation nearby. Besides the visual impact and the spatial bulkiness induced, many fears, more or less rational, arise from those new emitors. This logic of NIMBYism is indeed coupled with a distrust of citizens towards authorities and companies who are organising 5G rollouts. Only sparse and smoky information seems available to the wider public on the actual environmental, economic but also sanitary impact of 5G emitors. Indeed, the few reports and articles do not provide similar figures and draw conclusions that differ, or contradict, from one another.

By unpacking the six urban contexts and after a first comparison, we have identified recurrent elements regarding policies, actors and power balances. First, it seems fundamental to have in mind the actors involved in the process regarding the rollout of the network. It includes the authority in charge of allowing the development of networks, the kind of antenna which would be installed and the operators in charge of managing the network but also all the actors concerned by the subject in one way or another. Then, an analysis of the policy strategies is crucial to understand how these technological features are embedded in material and institutional infrastructures within the city. It includes both the pre-existing strategies initiated by public and private actors in which the 5G network is an additional component, as well as action plans launched by 5G.

All along this study, several questions guided our reasoning. What differs from one actor to another? What starting assumptions and positions are making those actors differ? In which institutional and political context each case is embedded in? The five following chapters will try to answer these questions by finding a balance between a comparison between the fields, and a more tailored narrative to demonstrate the specificities of each city.

Geneva

MAIN FINDINGS:

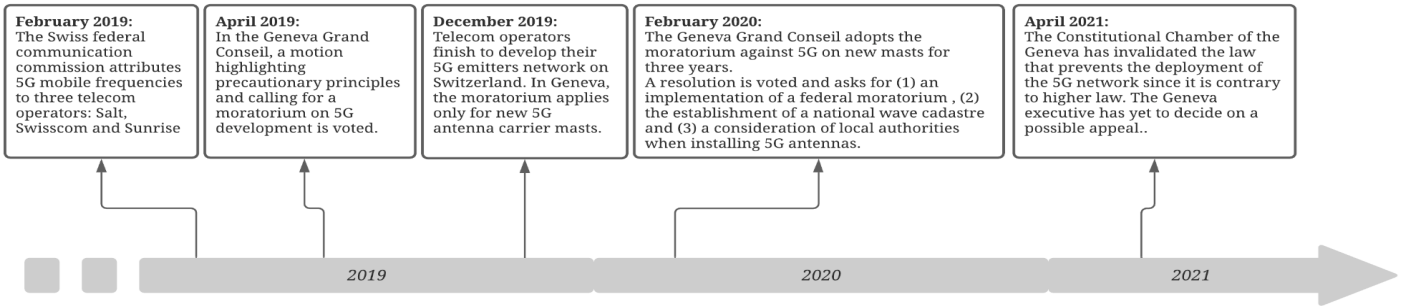
- ➔ Even though Switzerland is the European country with the most extensive 5G coverage, this rollout raised controversies in Geneva. The moratorium voted in 2019 is doomed to fail because of institutional deadlocks in favor of the federal State
- ➔ The analysis of 5G emitters already installed countrywide showed that 5G antennas are urban phenomenon items and are developed around economic centres
- ➔ By comparing antennas and their embeddedness among other economic infrastructures, we demonstrated that antennas tend to be developed following two logics affiliated to different kinds of urban areas:
  - ◆ in dense urban areas: a granular network of short-range antennas
  - ◆ in suburban areas with industrial and mixed activities

Switzerland has been one of the European early birds in the deployment of 5G antennas on its territory. The telecom operator Swisscom indeed prides itself that more than 90% of Swiss households already have access to 5G. Analysing the way 5G has been deployed on the whole country and narrowing down the analysis on an urban context in which controversies are raised, seems particularly interesting to reflect on the challenges associated with 5G. Swisscom, Sunrise and Salt are the three operators that have been allowed to exploit Swiss frequencies for this last generation of cellular connection devices: financing 5G infrastructures, adapting 4G antennas and installing new ones. 5G concessions were bought for 380 million of CHF to the Swiss government, giving them the right to implement and exploit 5G infrastructures. For now, only 3,2 GHz antennas have been deployed, and the 28 GHz antennas are supposed to be installed as well in a few years.

Swisswide, 5G deployment has been slightly different from one city to another. Whereas 5G roll-out generally did not foster opposition from the citizens, strong oppositions appeared in the Geneva canton. 5G antenna roll-out led to a reaction of a group of citizens that formed a moratorium committee. This has been followed by a majority of elected representatives in the Grand Genève council, who voted for a high-profile moratorium at the end of 2019. The parliament took this decision putting forward the constitutional precautionary principle to stop the antennas rollout. Arguing that microwaves could have an impact on citizens' health and protesting the lack of democratic process, actors of this mobilisation and elected representatives of the Canton are requesting an independent enquiry from the World Health Organisation to examine whether 5G antennas could be a threat for shoreline landowners. The procedure that started in 2019 had some limited effect; the construction of 5G antennas has been forbidden for 3 years even if operators could update masts with 4G antennas by installing new 5G emitters. However, recently, the cantonal Court of Justice, which ruled in favour of the Swiss Federal State, challenged this decision considering that the canton was not competent to establish such a restriction. With this decision, the court reminded the canton of the pre-eminence of the federal state in the

execution of certain public policies relating to the development of new telecom technologies. Now, it seems that 5G opponents do not have grounds to impede the development of 5G infrastructures.

Figure 2: Main stages of the 5G controversy in Geneva



This chapter aims at analysing how this debate has been framed in Geneva, and in Switzerland. Besides a qualitative analysis to understand the way the debate took place in Geneva, the national context is examined to assess the current state of play of 5G rollout in Switzerland to understand the driving forces behind the location of 5G antennas.

A local controversy around 5G rollout in a 5G frontrunner country

The controversy raised by 5G in Geneva is symptomatic of the tensions and differences in appreciation that the actors affected by the development of this new technology may have. Both sides mobilise semantic elements, prospective arguments but also action tools to assert their position.

The voting of the moratorium, unlikely to succeed from the beginning, could be understood in several manners. Some see it as a form of institutional amateurism and a desire to act quickly without measuring the limits of such a political stance. For others, this initiative can, in a more positive way, be seen as a first stone laid for an opposition destined to structure itself on these issues, based on the precautionary principle.

Emmanuel Deonna, member of the Grand Conseil Parliament: "*We cannot accept everything, we do not know what the consequences are on health [...], as a precaution we should first conduct studies on the impact of 5G on health [...]], we knew that the motion would be defeated but this is only the beginning, we are preparing another file which will come later.*"

For 5G opponents, until no official report from an institution independent from the federal state (e.g. the WHO), fears won't be relieved[3] regarding the impacts of this technology on people's health. Ecological questions are also raised by 5G opponents, although more subsequently.

> Emmanuel Deonna: "*We do not need such a technology, it does not respond at all to the ecological emergency, not to mention the problem it creates around the exploitation of rare earths*."

For actors involved in the roll-out of a 5G network in Geneva, this technology is supposed to be the next technological driver of Geneva's industrial revolution. As in many contexts, the arguments mobilised are largely based on the notion of competitiveness. Both for industry and for initiating the transition towards the digitalisation of services to people (connected vehicles, IoT, etc.). 5G is then presented as an evident step to avoid lagging behind competing territories. For instance, Swisscom gives many examples of 5G usage:

> Swisscom website: "*Increased speed, huge bandwidth, short reaction time, energy efficiency and capacity make 5G the key technology in many application areas. It makes things possible that we don't even think about today."*[4] *"In the future, we will play online games, listen to music or watch TV streaming everywhere, without the need for an ultra-powerful PC. Other applications are expected in augmented/virtual reality. It will then be possible to see a piece of furniture in a store's showroom directly from one's living room or to virtually visit one's house under construction on a piece of land.*."[5]

This controversy could be understood in a twofold manner. On the horizontal axis, the analysis of the interplay between local actors is quite telling. The series of debates challenges this "logical" direction of technological progress, even if the mobilisation of citizens must be relativised. During the review we carried out on Geneva, no source indicated a massive mobilisation of citizens against the rollout of 5G besides the group of coordination in favour of the moratorium. On the vertical axis, the conflict between the canton of Geneva and the federal state raises fundamental institutional and democratic questions. The rejection of the decision taken by local representatives of the canton of Geneva reminds that such strategic issues are often governed at the national level, with marginal room for manoeuvre for local authorities.

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[3] Unknown Author (2020). "Projet de loi modifiant la loi sur les constructions et les installations diverses (LCI) (L 5 05) (Pour la mise en application immédiate du moratoire sur la 5G)" République et canton de Genève, 04/02/2020. Retrieved from https://ge.ch/grandconseil/data/texte/PL12644.pdf on May 17, 2021

[4] Jungen Matthias (2020). "En plein milieu plutôt que juste au bord de la piste", Swisscom, 07/02/2019. Retrieved from https://www.swisscom.ch/fr/magazine/nouvelles-technologies/5g-streaming-realite-augmentee-editorial/ on May 27, 2021

[5] Unknown Author, "Que m'apporte la 5G ?", Swisscom, Retrieved from https://www.swisscom.ch/fr/about/reseau/5g.html on May 27, 2021

Today, nothing seems to prevent the development of a 5G network covering the whole of Switzerland and Geneva except a strong statement of health authorities to alert on the dangers induced by 5G on people's health. This contribution reminds us that stepping back from this heated debate and reflecting on the uses of this technology could be useful, especially since 5G is already here.

The framing qualitative analysis we specifically carried out in Geneva is telling us to take a step back and get a more comprehensive understanding on the logics behind the controversies that 5G raised locally. Behind the political discourse expressing concern or enthusiasm for 5G deployment and institutional frictions, we wanted to objectively assess the trends expressed by the locations and functions of 5G antennas in a country that is particularly advanced in terms of 5G rollout.

5G antennas, what are we talking about?

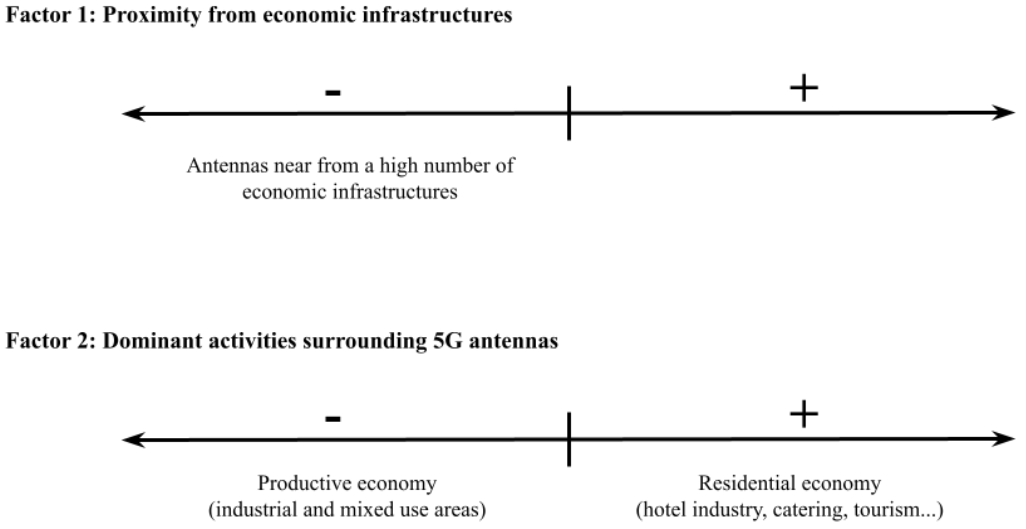
For this chapter, we carried out a quantitative analysis based on geospatial and statistical data. The research design could be summed up in figure 3. On the one hand, dimension reduction techniques were applied to synthesize the observations and capture trends behind the location of 5G antennas on the whole Swiss territory (Step 1) and in Swiss urban areas (Step 2). On the other hand, those factors were confronted to a series of statistical data captured every year at the urban level with a Multiple Regression Technique (Step 3): this analysis enabled an identification of some specific statistical variables that could explain the cities' factor profile differences by identifying regression coefficients for each. On a top-down manner, from the whole country to the urban region of Geneva, this overview turned out to be useful to understand the emitters installation driving forces.

Figure 3: Quantitative analysis research design

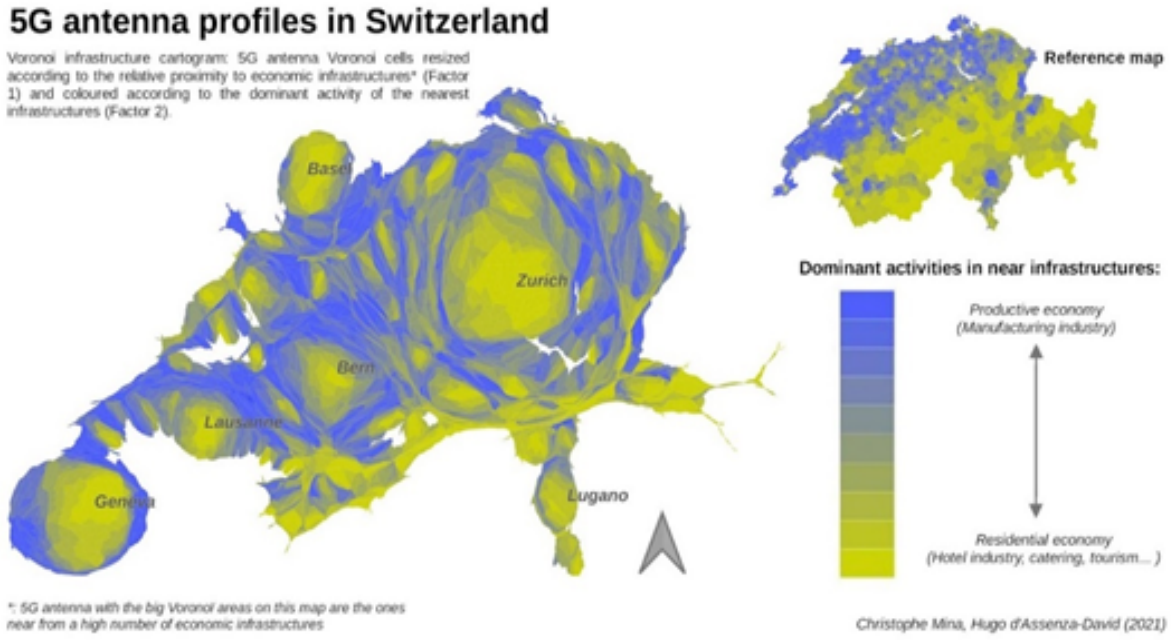
Results

At the Swiss level, the Exploratory Factor Analysis (EFA) puts forward two factors: F1 and F2. On the one hand, factor 1 highlights the degree of urbanity of the 5G antenna: if F1 is low for a given antenna, it would be located far away from urban infrastructures. On the other hand, Factor 2 is highly correlated to three variables. It is negatively correlated to temporal stay accommodation (-0.55), but positively correlated to industries (0.46) and industrial or commercial units (0.34)[6]. We could then assume that F2 shows the dominant kind of economic activities. If F2 is high for a given antenna, it would be near industrial areas but far from temporal stay accommodations. We could then assume that F2 depicts the functional affectation of land in the Swiss territory, with the industrial areas being separated from residential ones. Cities tend, without any surprise, to be mostly affiliated to the residential economy. It is also worth noting that spaces between cities in the North of Switzerland and near the main communication axis, tend to be more related to a productive economy. Having this in mind, it now seems relevant to have a look at the phenomena occurring at the urban level.

Figure 4: 5G antenna profiles in Switzerland



[6] Appendix 2



At the urban level, the exploratory factorial analysis enabled a more precise profiling of 5G antennas within cities. Two new factors are put forward: F1' and F2'. On the one hand, F1' is positively correlated to a wide range of urban infrastructures, except industrial areas, industrial or commercial units, but also discontinuous urban fabric. This highlights 5G antennas located in urban centres with a high level of accessibility to services. Antennas with a low F1' tend to be embedded in this kind of area. On the other hand, factor 2' underlines mixed business and industrial areas on the urban outskirts. A 5G antenna with a low F2' score then tends to be located within such an area.

Those two factors are useful to compare the different effective power radiation, which measures the combination of the effective power by the transmitter and the ability of the antenna to direct that power in each direction. 5G antennas' ERP has been grouped in four categories:

- Large ERP: more than 1kW
- Medium ERP: 100 to 1000W
- Small ERP: 10 to 100W
- Very small ERP: less than 10W

Comparing the urban embeddedness between antennas with different ERP powers is quite telling. Antennas with a small or a very small ERP tend to be mainly located in areas with a higher level of urban embeddedness: F1' median value for both small and very small ERP are below the first quartile for large ERP. Hence, urban centres tend to be mainly covered by small-range antennas. On the other hand, the comparison of antennas with factor 2' does not show clear patterns: antennas with large and small ERP powers tend to have the same level of embeddedness in industrial and mixed-use areas, even if more powerful antennas are more

heterogeneous. In other words, industrial and mixed-use suburban areas are composed of both small and large ERP 5G antennas.

Figure 5: Factor 1' and Factor 2'

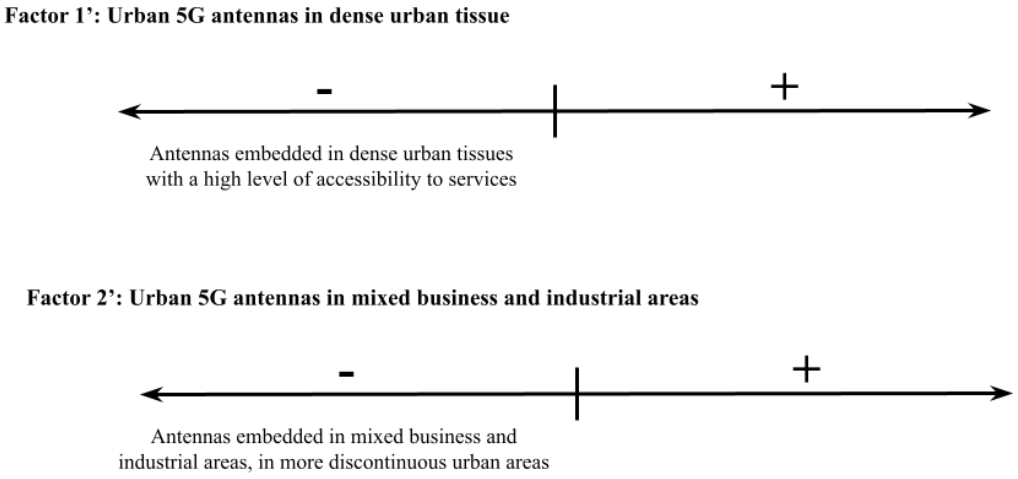
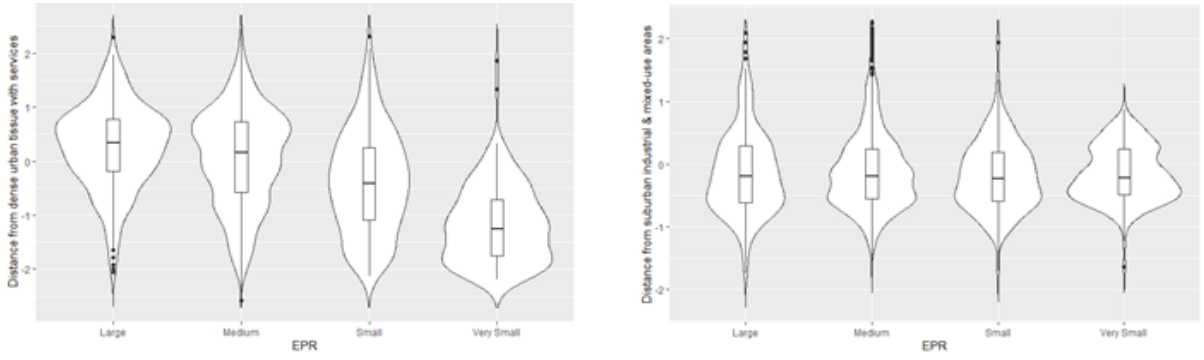


Figure 6: 5G antenna EPR factor 1' (on the left) and factor 2' (on the right) profiles



Finally, a hierarchical clustering technique separated antennas into four clusters. Whereas the ones belonging to cluster 1 are near urban centres with a high level of accessibility to services but far from mixed business and industrial areas, antennas from cluster 3 and even more cluster 4 are showing the reverse trend in more discontinuous areas. Antennas from cluster 2 are in between.

All those elements were useful to map the results, as displayed in figure 7 and 8. A city per city analysis is first quite telling to capture regularities in several urban contexts. A comparison of maps demonstrates that similar antenna patterns structure Swiss cities with more or less obvious concentric circles: whereas most of them have a significant number of antennas developed in urban centres with a high level of services, some of them are deployed far from the centre, near mixed business and industrial areas. Most of the time, we could also note a belt in between: an area in which those two components are intertwined.

As demonstrated in figure 8 linking those findings with a map enables a better understanding of how the 5G network has been rolled-out in Geneva. This spatial analysis delivers clear, although logical, observations on how 5G were rolled-out in the Geneva urban fabric. On the one hand, the dense city centre of the city is covered by a granular network of 5G antennas with a rather low ERP, surrounded by more service-like businesses. Due to the urban fabric, antennas have a lesser range of action and tend to be less powered. As opposed, the ones in urban outskirts tend to develop more sparsely, although with a higher EPR level: the absence of buildings enables emitters to have a longer range. Those antennas also tend to be located near industrial and mixed-use areas.

Figure 7: Swiss main cities factor profiles

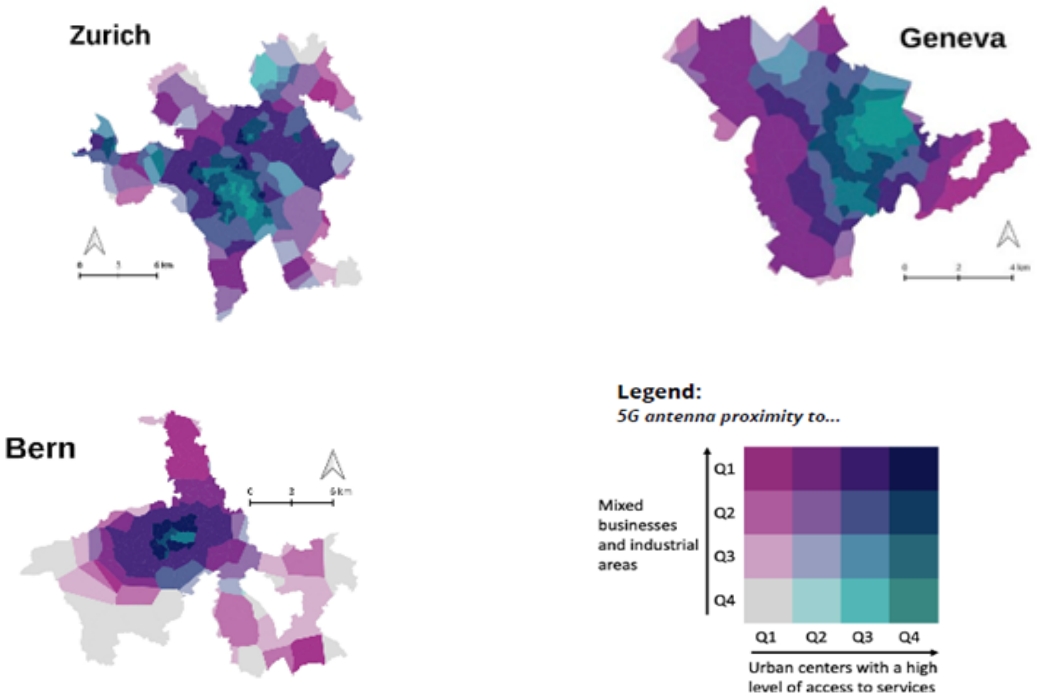
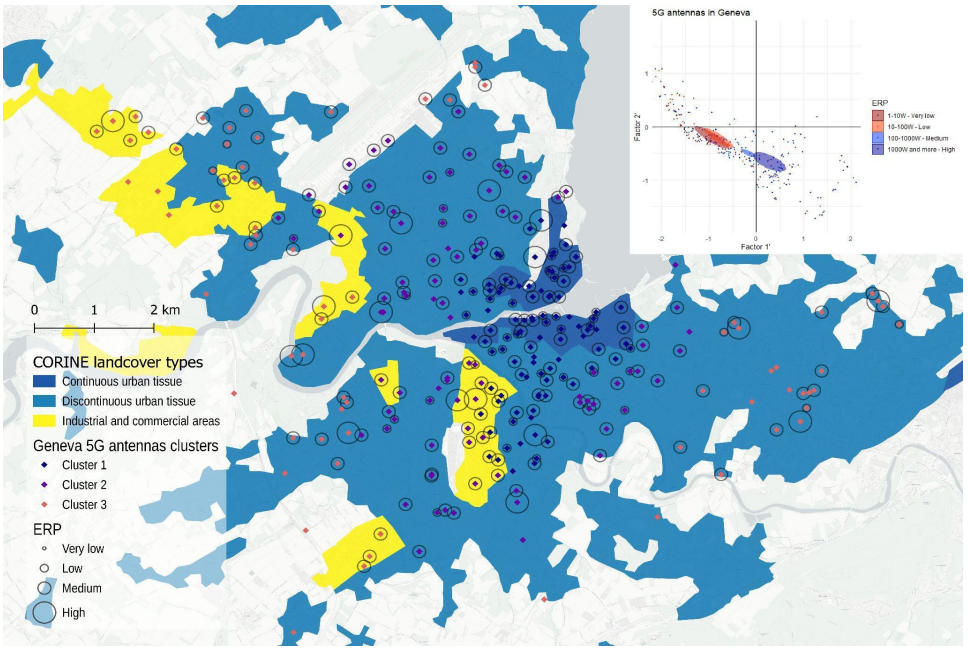


Figure 8: 5G antennas in Geneva: cluster and emission radiated power



Following this geospatial analysis, applying a multilinear regression method using F1' and F2' as dependent variables was useful to complete the picture. The one carried out for F1' shows that statistical variables captured only partially explain the variance of F1': besides the fact that R^2 is around 0.4[7], all variables but one have an insignificant impact on F1'. Nonetheless, this particular variable displays a striking correlation with F1: **it is clear that cities with a higher occupation density tend, quite logically, to get more 5G antennas with a high number of service-based activities nearby.**

The second regression demonstrates more telling elements, with an overall model that explains better the variance of F2' (R^2 a little bit higher than 0.66), although with correlations less striking that the one showed before. Cities with more 5G antennas embedded in industrial and mixed-use infrastructures tend to be composed of a younger population, whose occupational structure tends to be more blue-collar like, notably employed in the primary sector. It is worth noting that a higher number of such 5G antennas is also associated with a lesser level of unemployment.

Conclusion

In Geneva, the controversy around the development of the 5G technology was particularly strong and emerged at the end of 2019 thanks to the involvement of elected representatives. Even if the mobilization from the bottom must be relativized, it is worth

[7] Pearson's linear coefficient of determination, denoted R2 or r2 and comprised between 0 and 1, is a measure of the quality of the prediction of a linear regression.

noting that this is the first time that such mobilization emerged against the development of a telecommunication network. As opposed to the previous developments of 2G, 3G and 4G antennas, the precautionary principle argument is put forward by Grand Genève council representatives to oppose a decision coming from the federal state. Even if the moratory impeached the installation of new telecom infrastructures in the Geneva urban layout, the network has nevertheless developed. In addition, the canton faces an institutional deadlock and the moratory should be understood more as a posture of resistance than as a truly effective act to stop the roll-out. This highlights a clear tension between local and federal authorities. Even if the Geneva representatives are against the development of such a network, the competence remains at the federal level.

Through this chapter, we tried to take a step back from this heating controversy by developing comprehensive tools to understand how 5G antennas have been rolled-out on the Swiss territories. Since this country is one of the first to have been covered by 5G, the way antennas flourished on the territory is quite telling on the logic behind such a development.

Emitters developed in urban contexts are not all comparable and do not respond to the same needs. The ones installed in city centres and in the rural South of the country tend to be in areas composed of a denser network of residential service activities. In urban centres, the network is more granular and, even though antennas are the same, their ERP is much lower: since their range of emission is hindered by a dense urban fabric, it seems not adequate to get more powerful ones. On the other hand, 5G emitters installed in urban outskirts tend to be composed by more industrial sector establishments, but also with an occupational structure composed by more blue-collar workers and by less unemployment.

It is interesting to compare discourses around 5G and the materiality of antenna deployment. Whereas it is put forward as a game changer in some strategic industrial sectors, the Swiss case tends to demonstrate that just a part of them is developed around industrial facilities, others being installed in denser urban areas. Further research may be worth reflecting on precise case studies to investigate differences and similarities between initial objectives put forward and concrete antenna development. Also, while we have seen that 5G antennas can be distinguished from each other according to their insertion in urban fabrics, and that it is possible to establish tools to analyse them, it would be interesting to go further in this comprehensive approach to reconcile the needs of economic actors and limit the socio-environmental impact of 5G, by ensuring parsimonious development.

Barcelona

MAIN FINDINGS:

- ➔ A 5G governance marked by a myriad of pilot projects showcasing the ICT expertise of local economic actors. They act as the transmission belt of European objectives and leave a consequent room for manoeuvre to private actors
- ➔ A deployment of 5G on pre-existing economic ecosystems by public-private partnerships: there is a lack of clear direction given by the city to transform this innovation into an improvement for the city
- ➔ In the Poblenou district, 5G is a servicial component in a wider urban development project which aim relates to business attractivity

Introduction

The deployment of 5G technology in Spain has been underway since the end of 2015, but it was not until the approval of the 5G 2018-2020 National Plan, published by the Ministry of Energy, Tourism and Digital Agenda that 5G took shape in Barcelona. This National Plan aims to place Spain amongst the most advanced countries in developing this new technology so that, by the time 5G reaches its technological and commercial maturity point, Spain may be ready to harness all the opportunities arising from this network generation. The 5G 2018-2020 National Plan was approved as part of the European Commission project Horizon 2020, which supports and funds the research and innovation of 5G. Catalonia was identified as an ideal territory to lead the rollout of this new technology because of the available telecommunication infrastructures, its attractiveness for investors and the fact that the Mobile World Congress is held every year in Barcelona. The Mobile World Congress, organized by the Global System for Mobile Communications, attracts over 800 international operators and it's an opportunity to get first-hand knowledge of the present and future trends of the mobile market. Recent years have shown how Catalonia managed to capitalize on this asset and now it aims to multiply and maximize its effectiveness with the deployment of 5G. This part seeks to identify what drives Barcelona to try and position itself as a major European actor in 5G industrial and economic development. It will show the variety of actors involved in this process, identify the purposes they follow, and analyse the way they coordinate.

In 2018 and 2019, Barcelona was recognized by the Financial Times dDi Magazine as “the best Southern European region for foreign investment”, one of the most prestigious recognitions by multinational companies to study future investments opportunities. As one of the most important industrial spheres, the ICT in Catalonia benefits from a group of highly competitive software developers supported by the magnitude to produce innovative solutions adapted to the real world and the vertical industries or services required by the region. Moreover, according to the ‘Digital Startup Ecosystem Overview’ published by Mobile

World Capital Barcelona Foundation, 453 million euros have been invested in Barcelona as part of the entrepreneurial and startup setting, and this number accounts for 58% of all the investment made in Spain as a whole (Government of Catalonia, 2019). This investment volume in Barcelona demonstrates the capacity of the city to greatly prosper in the mobile technology sector. The technological capacities of Barcelona in regard to 5G exist at the local level with the infrastructure and mobile network extension, at the regional level, proving that it is the best area for investment in southern Europe, and at the international level, with the Mobile World Capital and 5G Barcelona initiative which further accentuate the impact and international image of Barcelona. The 5G ecosystem, derived from the capabilities of ICT and by the synergies between research institutions, public authorities and private companies is what makes possible the current deployment of 5G in Barcelona. This distinct cooperation makes possible the development of various pilot projects around Barcelona. 5G is governed in an institutional framework in which different levels of governance and various actors cooperate at the same time to make a project happen. This distinct type of governance brings attention to the impacts it has in the city and opens up questions about the concrete improvements and advantages of implementing 5G in Barcelona.

The case of Barcelona brings to light issues of governance, competence and the collaborative relationship between local, national, and European entities in the deployment of 5G. By taking this into account, this chapter focuses on analyzing the governance processes surrounding the deployment of 5G in Barcelona. This will be done by analyzing the way the European-scale projects concerning 5G are developed and integrated at the local and urban level. Additionally, the governance processes of 5G will also be analyzed by understanding Barcelona from an experimental urban laboratory perspective by focusing on the way various pilot projects are developed and coordinated by the competent actors. The study will illustrate specific trends that are probably not exclusive to Barcelona but can also be applied to other European cities. It will be further discussed that the deployment of 5G is not aligned with a comprehensive plan to assist the interests of the public, for the reason that 5G seems to be serving the already existing economic and business circumstances.

To conduct this research, we mobilised qualitative methods, including semi-structured interviews, field observations and a review of academic and governmental resources. The first step was to conduct an in-depth study of Catalonia as a digital region to understand the main idea behind the deployment of 5G, the process and the objectives. This investigation led the research to make sense of the technological capabilities of the region and Barcelona's trajectory towards a supposed leading 5G hub for Southern Europe. But, as the research unfolded, it became clear that the interconnectedness of actors and institutions is more complex and not as straightforward as it seemed. This is because, initially, there was a subtle supposition of how 5G was developing with a clear governance and hierarchical structure, but this was not the case. For this reason, we decided to have a dual analysis to observe the deployment of 5G in Barcelona as a whole, followed by an analysis at the district level with Poblenou. The latter shows how the neighborhood appears as a showcase for 5G. Since the development of 5G in Barcelona is achieved as a joint effort between the private and the public sector, the role of public authorities was a significant element to grasp. For this

section, the analysis of governmental resources was of essence as it provided the basic framework for this standpoint. Even though these resources provided a fundamental, but ubiquitous sense of the 5G ecosystem, they nevertheless helped frame the main questions regarding Barcelona.

Finally, and in order to consolidate and incorporate the knowledge of the overall research into a logical argument, this research also obtained primary data from semi-structured interviews in Barcelona with experts. These were an essential part of the research as the knowledge provided by the actors thoroughly explained the dynamics of 5G. The knowledge obtained from these primary resources revealed the interests, observations, issues at stake. It also helped us understand the relationship among actors and with the 5G infrastructure and services. Even though, ultimately, some actors and objectives are fused in both analyses, there was still some inquiry on how these dynamic relationships between actors worked. These questions will be further discussed in the following sections.

5G actors - horizontal structure

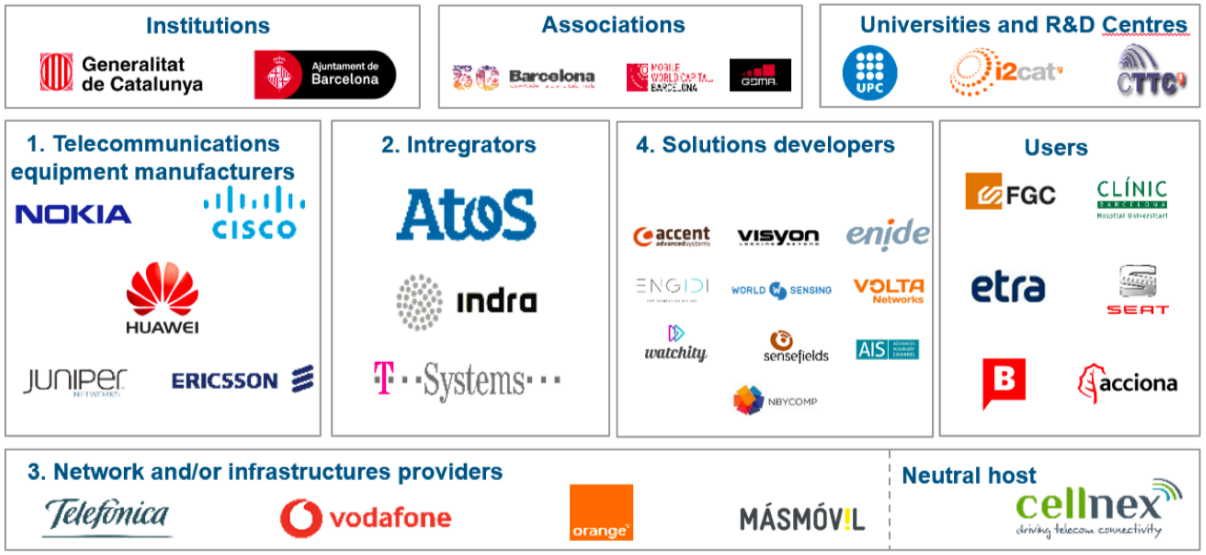
For the actors involved in pilot projects, 5G is expected to radically transform public, private and industrial sectors. This technology entails a redesign in the value chain of the traditional communications sectors and an increase in participation of new actors. In the case of Barcelona, the additional actors under the new telecommunication ecosystem of 5G prove to have an undeniable and essential role in the development of 5G.

The 5G project at the national and European level have materialized by the formation of the 5G Barcelona Alliance. This public-private initiative operates to position Barcelona as an innovative and open environment for the validation and adoption of 5G technologies. It creates synergies within the 5G ecosystem and offers an experimental infrastructure to test, prototype and implement new digital solutions, thus transforming Barcelona into a neutral laboratory, in which any stakeholder may design, develop and test services and applications put into action by 5G technology (Government of Catalonia, 2019: p.20). The neutrality aspect is an essential part of the development as it indicates that the initiative is not exclusively linked to any institutions or private companies. Being a ‘neutral operator’ provides the stakeholder with easy access, therefore increasing participation from different sectors of society, and at the same time demonopolizing the deployment of 5G, which also reduces costs.

By bringing together different players and fields of knowledge to this initiative, 5G Barcelona can offer services in different areas, ranging from encouraging the adoption and validation of 5G technologies and the transfer of knowledge of 5G to create new business opportunities. In the case of Barcelona, “city governments cooperate with non-state actors, encouraging and facilitating voluntary action undertaken by businesses and citizens" (Kern and Alber, 2009). The role of the private sector is to manage the 5G ecosystem in a

cooperative fashion and public authorities on the other hand, tend to have more of a secondary role by enabling these actions. Governing by enabling refers to the idea that instead of the public authorities supplying and executing policies, rights, services, its role is to ensure that the conditions, resources and opportunities are available for the citizens, organizations or private companies (Zaban, 2012). This model of governance provides the state with a robust private sector which it can rely on. The public authorities enable the deployment process of 5G, thus increasing flexibility, efficiency and the scope of governance between different sectors in society.

Figure 9: Companies and stakeholders of the 5G ecosystem in Catalonia.



Source: Smart Catalonia (2018).

Pilot projects

In 5G's initial development, some priorities have been identified. According to Sergi Figuerola, the 5G Barcelona's objective regarding the pilot projects is to mobilize an applied investigation in regards to technology, or more specifically the internet, which can have an impact on society and in the information and communication technology sector. 5G Barcelona participates mainly in investigative programs at the European level in which they can distinguish the required technological needs, and in the implementation of the digital public policies alongside the Government of Catalonia to deploy the 'SmartCatalonia' strategy. The pilot projects are born from this strategy, which established various zones of 5G ecosystems around Catalonia, in which pilot projects can be developed in a joint effort with operators and the community in each zone.

These innovative projects are aimed at producing technological solutions in real life and then to be validated, through analysis of industrial, technical and market aspects. 5G Barcelona focuses on 8 different vertical industries: automotive, financial services, industry, rural, transport, health and healthcare, media and entertainment, and security and defense.

Some of the pilot projects that are already underway:

- 5G Railway Lab: this project deploys one of the world's first railway facilities with coverage between stations. It will explore industrial solutions, railway mobility and logistics and the management and control of passengers and freight movements. It will also test disruptive solutions, as well as improve user experience on a functional and entertainment level. The user will benefit from real-time information systems, personalization of multimedia entertainment and increase capacity for remote assistance. During the beginning of this year, the 5G Railway was successfully deployed in an operational environment.

- 5G Rural: a nectarine farm in Albatarrec has been the first field connected with 5G and this initiative is an example of how this technology can contribute to improving agricultural productivity in rural areas. The project consists of a communication system through which an advisory technician can train and guide in real time through a solution that allows the analysis of the particularities of each productive zone and transfer of the best strategies. This allows a single agricultural engineer to supervise a large number of operators in real time, achieving optimization of the processes, thus increasing productivity.

- 5G Emotional Robot: Misty II is a small personal robot capable of moving and interacting with the user, equipped with a camera, microphone, sensors and an Android operating system. This robot aims to provide emotional support, supervision and care to the elderly by interacting with them. Additionally, because the robot takes advantage of cloud computing, medical services, emergency services or maintenance services can be managed in any territory.

According to the 5G Barcelona website, the projects mentioned above are already finished. All these pilot projects are aimed at enhancing the quality of life of citizens, by increasing efficiency in health, rural industry, transportation among other things. All the projects are made possible due to the collaboration and coordination between the institutions in charge of the investigation within the 5G ecosystems and the institutions in charge of the technical aspect of their development.

Poblenou

In Catalan, Poblenou translates to "new town" and the neighborhood emerged during the industrial revolution as a new space dedicated to the new technologies of production of the time, especially for the textile industry (Gdaniec, 2000). During the beginning of the 20th century, Poblenou was nicknamed the "Catalan Manchester" because of its significant industrialization and politically active population. However, when deindustrialization struck the area, Poblenou lost more than a thousand factories in less than 30 years, and as the

industries started to leave the district, the buildings fell into neglect (Adorjan, 2016). The structural change from industrial to tertiary economy was a significant blow for Poblenou.

In July 2000, all political parties unanimously approved the 22@Barcelona Plan, which has as one of its main objectives “to reinterpret the function and the spirit of the old industrial Poblenou and create a new model of urban spaces” (Adorjan, 2016). The 22@ Plan included subsidized housing, the creation of green areas and redevelopment of streets, facilities for public life, such as schools and community centers but also for the economic actors. The Barcelona City Council played an important role in putting everything in motion by encouraging public companies and universities to move into the district to support the different centers.

Within the city of Barcelona but forming part of a project stemming from the European Union’s Horizon 2020 program, the district of Poblenou has become a 5G-IoT testing ground as part of the European FLAME (Facility for Large-Scale Adaptive Media Experimentation) and 5GCity projects. Collaborating with the project, the Barcelona City Council wants to prioritize the practical, direct and positive impact of 5G technology on the city’s residents and their standard of living by transforming the neighborhood into Barcelona's technological and creative heartland. To understand why Poblenou is or not of interest for the 5G strategy, it is essential to take a look at its history, current projects and the extent to which 5G plays a role at the neighborhood level. As it will be explained in the next few paragraphs, we have come across the fact that there is no link between these urban projects and the current deployment of 5G in Poblenou. By examining the neighbourhood of Poblenou, we can determine that the objectives of the deployment of 5G and the urban plans, depart from each other, even though both operate under the Barcelona City Council.

Today, Poblenou is home to more than 1,500 companies related to audiovisual, information technology, energy, design and scientific research. The physical proximity between firms, research centers and universities can increase the potential for innovation as a result of the high density of formal and informal channels of collaboration and communication between them. Due to its historical role in the innovation sector and the potentiality surrounding the 22@ plan, Poblenou serves as the ideal territory for the deployment of 5G technologies. Thus, in 2018, the trendy neighbourhood of Poblenou in Barcelona became one of the fields for a 5G roll-out full-scale test. The entire Poblenou superblock, as well as its surrounding streets, will provide the testing ground for the 5G project. But how does this relate to the previous cases of 5G Barcelona, pilot projects or the overall management of 5G?

5G deployment in Poblenou

This European project, operating as well in other cities in Europe, creates an experimental, open environment which acts as an urban, citizen and technology laboratory to validate 5G technologies and services. This environment is based on the collaboration

between various stakeholders, both public and private, and a stimulus for the existing innovation in Poblenou, helping to attract foreign investments, boost technology start-ups and start an industry around 5G.

- FLAME (Facility for Large-Scale Adaptive Media Experimentation): This platform allows testing audiovisual applications on wireless communications infrastructures and WSN servers (Wireless sensor node). Their aim is to deploy a network/service infrastructure to validate such as placing the future technology at the service of Barcelona and its citizens. The idea is to democratize the access to the mobile networks infrastructures that today are limited to mobile network operators, facilitating and maximizing the "neutral operator" figure. Through the platform's fast and dynamic service request routing capability, media service providers will have a fine-grained control over load and therefore costs across the network. This offers the potential to significantly reduce the overall costs while ensuring fast availability of services towards end users.

- 5GCityprojects (neutral operator in development of 5G): 5GCity will design, develop, deploy and demonstrate, in operational conditions, a distributed cloud and radio platform for municipalities and infrastructure owners acting as 5G neutral hosts. The project will essentially turn a city into distributed, third-party, multi-tenant edge infrastructure, extending the cloud model all the way to the edge while enabling dynamic, fast, and interoperable provisioning of 5G-based services. 5GCity will start with the infrastructure built by FLAME, to improve the infrastructure until the possibility of deploying to Barcelona a low-cost mobile communication technology driven by independent software, thus creating the concept of "Neutral Operator". The idea is to democratize access to the network infrastructure (which is currently limited by Mobile Operator). If the cost of the mobile network is reduced, the Public Administration will be able to act like an Infrastructure Operator, getting a strong position in front of traditional mobile operators.

As explained, Poblenou is currently undergoing an innovative urban transformation as part of the initial projects of the century. One of the most important urban projects underway is the Superblocks. Poblenou Superblock, which was developed in 2016, is the first of the current set of streets 'interventions' towards a more pedestrian-first environment. Superblocks are new urban units, larger than a block, but smaller than a neighborhood. The implementation of superblocks is part of the Urban Mobility Plan, aimed at reducing private traffic by 21% and increasing the use of bicycles, public transport and walking. Additionally, the 22@ Barcelona project is still being executed with the corresponding adaptive and innovative changes to respond to the needs of the city. This area was developed to increase the city's economic growth and this part of Barcelona is known as the technological district, so needless to say, Poblenou becomes an experimental test-bed for the deployment of 5G. Beside the main focus on large technology companies, it also includes residential areas, green zones, and many services and amenities for the people that live there. During the field visit in Barcelona, we were able to perceive the results of said projects. We noticed a stark difference

between the neighborhoods in the city, especially in relation to transportation, signaling and street level activities. Poblenou displays a much more organized, less crowded and less tense atmosphere compared to other parts of the city.

Furthermore, the field visit also gave the opportunity to observe the 5G antennas currently located in the Superblocks. The display of the antennas were discrete and it did not disrupt the overall atmosphere of Poblenou. The front of the antennas were branded with the names of the current partners, some were 5GCity, others FLAME, some CroCow and naturally, Barcelona City Council. The deployment of 5G and the development of urban projects meet in the same neighborhood, even though both projects are not linked together. Both operate under the Barcelona City Council, but the objectives and design are not coordinated. During the interview with Neda Kostandinovic, who is in charge of International Relations Projects at the Office of the Chief Architect of Barcelona, she indicated the lack of insight on the deployment of 5G in Poblenou. Surprisingly enough, there is a lack of awareness among urban planners in Poblenou and 5G technology. This opens up an opportunity to link both projects. Kostandinovic asserted that the use of technology is growing as a tool for better management of the city, but 5G has not been assessed yet. By taking the 'right to the city' concept, the City Council could thus profit from the use of 5G technology as a tool for citizen participation and collaborative decision-making by incorporating citizens' necessities and difficulties in the overall planning process.

Results and discussion

5G technology is serving as a transformation stimulus that private companies are using to position Barcelona as a leader in innovation, digitalization and technological development at the entertainment and the industrial level. However, and with the research done in Poblenou, there is not an evident connection nor relationship between the urban project and the deployment of 5G, specifically in Poblenou. As both projects operate with different actors, but both under Barcelona City Council, it is clear that private companies take the lead for innovation. This is clear with the pilot projects, which operate as a result of the private companies desire to innovate locally and internationally. To some extent, we can think about 5G in an almost neoliberal context where private companies invest and develop 5G as a way to attract businesses with innovative technology, and not primarily to improve the urban environment and the overall well-being of Barcelona's citizens.The deployment of 5G does not follow a plan based on serving public interests or looking for long-term benefits. It is mostly driven by economic opportunities based on the already existing economic ecosystem of the city. The role of public authorities is mostly that of *governing through enabling* (Alber & Kern, 2009) in a neoliberalist context: local authorities coordinate and facilitate partnerships between local actors resorting mostly to persuasion and incentives.[8]

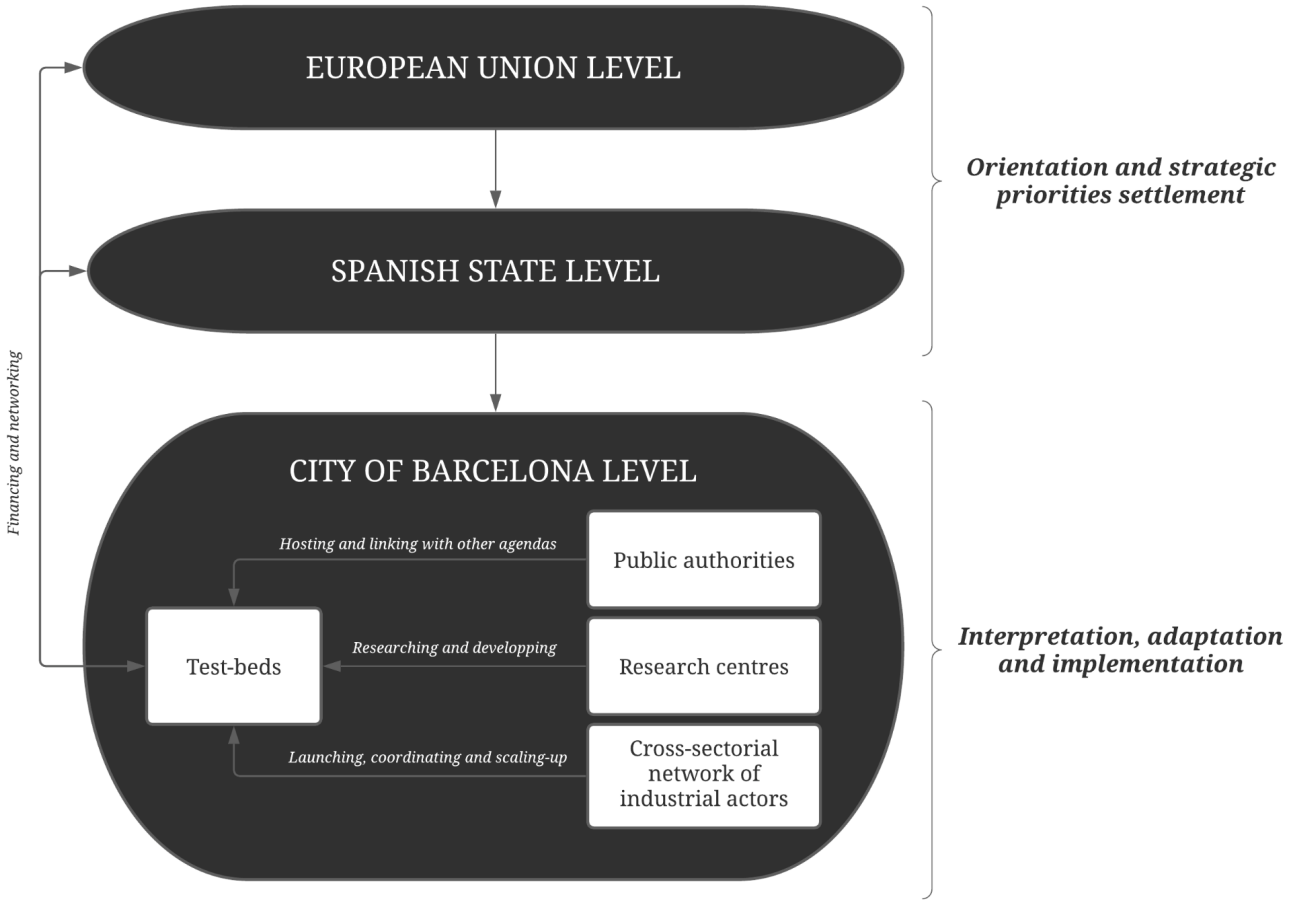
[8] Alber, G., Kern, K. (2009). "Governing Climate Change in Cities: Modes of Urban Climate Governance in Multi-Level Systems".

Barcelona is an interesting focus because of the complexity behind the management of 5G. It is clear that the rationale behind both the 5G Barcelona Alliance and the 5G deployment in Poblenou, although not in conflict, are diverging from each other. There is a clear connection between and among the actors, but there is no governance or regulation per se, that could and would alienate both into the same strategy. On the one hand, there is the 5G Barcelona public-private initiative, in charge of the pilot projects, which basically dominates the horizontal administration of 5G. On the other hand, there is a public initiative, implemented by the City Council with the aim of prioritizing the practical, direct and positive impact of 5G technology on the residents of Poblenou and their standard of living. Both initiatives do not seem to be in the same context even though they work with similar actors but have different deployment strategies and even different objectives.

The neighborhood of Poblenou is experiencing lasting transformation in their infrastructure apart from the introduction of new 5G technologies. However, these two projects do not overlap with each other even though the results of a joint initiative could fulfill both objectives in a much more certain and valuable way. The actors involved in both projects are definitely different, since for the urban projects it is composed of public authorities and for the 5G deployment it is a public-private initiative. As there is no wider and comprehensive project focused on the improvement of the city, which can take into account 5G technologies, it seems like the objectives for Poblenou are shortsighted. If we take into context the results from the previous paragraphs, it seems like innovating for the sake of innovating in coordination with private companies can be a more valuable process to achieve urban improvements in the district, but the proper synchronization and implementation have not taken place yet.

As for the pilot projects and active 5G laboratories, the private companies are taking the lead without much regulation or governance from behalf of the public authorities. As mentioned above, governing by enabling gives the public authorities a secondary role in the context of 5G Barcelona. However, interestingly, each year, the president of 5G Barcelona changes from the Barcelona City Council to the Government of Catalonia, which substantiates the role of public authorities in 5G Barcelona, but it is not clear how this position in the leadership actually serves as a form of authority in relation to the private actors. 5G Barcelona is a network initiated by private actors with the idea of consolidating and coordinating all the efforts of all 5G related actors in Barcelona. Consequently, Eduard Martin from Mobile World Capital explains that there is not an intricate manner by which the association divides the “work” regarding the deployment of 5G. Instead, as companies gathered and cooperated, they were able to work on the needs of Barcelona in order to come up with significant and useful projects that will place Barcelona as an innovation hub. With this said it is clear that even without clear governance in the region and projects stemming from the European Union, the Spanish government or the Government of Catalonia, the private actors and their initiatives have managed to lead the way for innovation in Barcelona. The city of Barcelona enables these actors and acts as a field of experiment or testbed to attract businesses and for which the improvements are yet uncertain.

Figure 10: Multilevel governance interplay in Barcelona



Conclusion

Through this focus on Barcelona, we have seen how central digital innovation is in the strategy of Barcelona economic actors. The different pilot projects and initiatives we assessed along the focus provided key insights on the logics behind this quest for innovation in niche sectors which, when added together, allows Barcelona to be a pioneer in the development of digital urban laboratories. This development is only possible as a result of increased competitiveness of the private companies involved, but to what extent is innovating for the sake of innovating worth it? Even so, Catalonia's technological capacities proved to be essential for the 5G roll out, it might be worth reflecting on the actual needs of the city, as well as the direct impacts these new technologies have in the short and long term. Needless to say, Catalonia does benefit from the available infrastructures, the 5G research and innovation capacity, driven by the private sector and its information and communications technology

sector to manage a disruptive technology such as 5G, but does it mean that it must be deployed without the appropriate impact analysis?

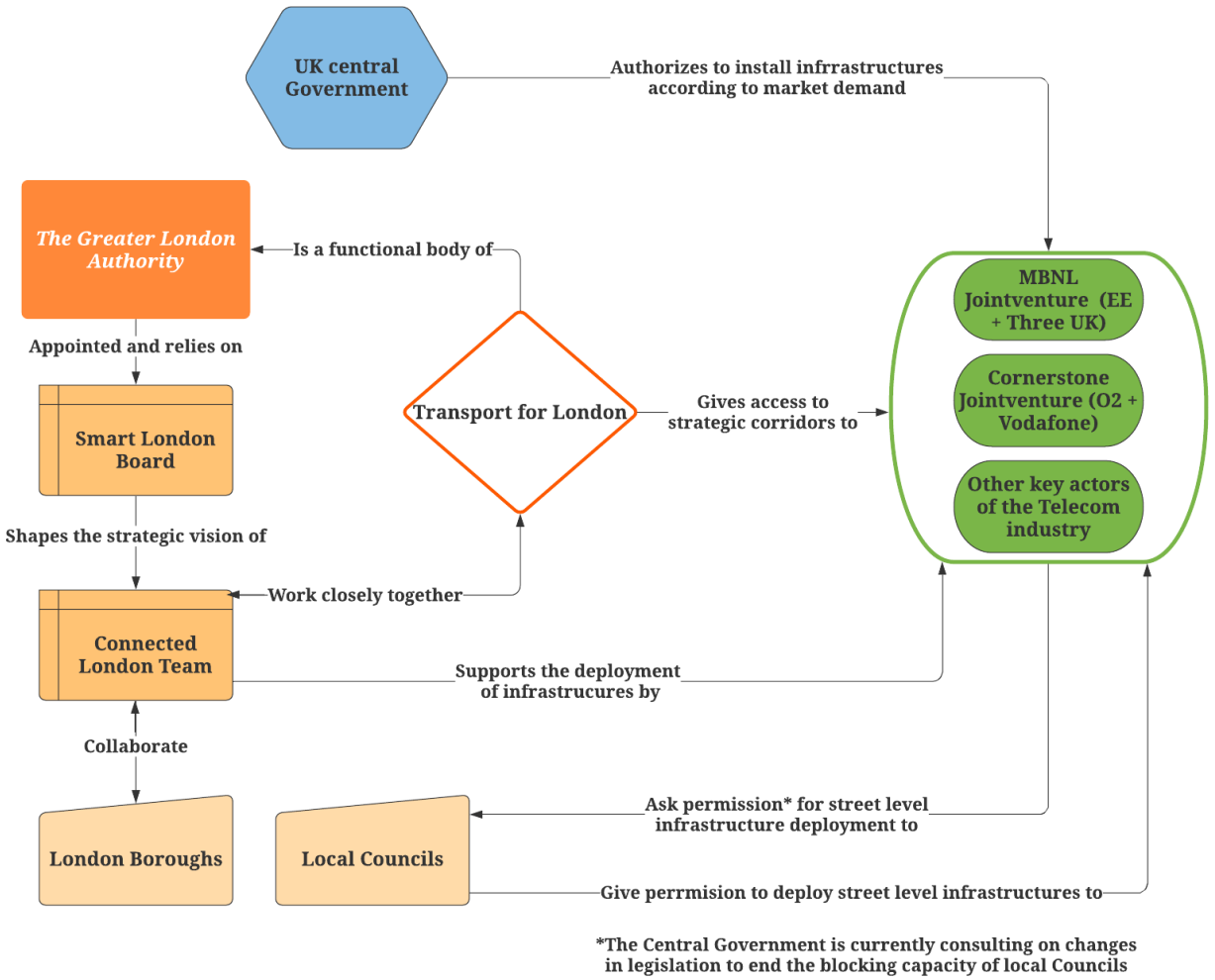
In this chapter we have analyzed the governance process surrounding the deployment of 5G in Barcelona. Even though the Barcelona City Council and the Government of Catalonia are present in the deployment of 5G, it is clear that their role is secondary, in comparison to the private sector. As mentioned earlier, the public authorities govern the 5G deployment by enabling the use of the city, almost like a tool, to attract businesses. The deployment of 5G is dominated by a private innovation ecosystem that operates in synergy with public authorities, research and technology centers, service and public suppliers and operators. Although the regulation and governance per se is lacking and there is a lot of freedom to operate by coordinating with key actors, the circumstances indicate that this arbitrary coordination will have to change for the future. In that respect, it would be interesting to assess in the future the trajectory of the interplay between this innovation ecosystem and the way this is coordinated with an overall improvement for the city. The showcase of Poblenou and the European 5GCity initiative, demonstrates that Barcelona is moving towards an advantageous position within the European entrepreneurial collaborative work of pilot projects at the international level. As we have seen in this chapter, the lack of a clear link between pilot projects and government urban projects generates difficulties in determining the effects 5G can have in the public sphere and for the public good. The deployment of 5G is still a process and before it completely launches, all the actors and stakeholders must synchronize their interests, strategies and objectives.

London

MAIN FINDINGS:

- ➔ 5G is part of a digitalization strategy pursued by the Greater London Authority in the context of diverse public-private partnerships
- ➔ Focus on the role of 5G in transportation systems: 5G uses are not yet focused on infrastructures management but more on the passenger's experience (access to 5G for the consumers during the travel)
- ➔ 5G as a window of opportunity for London's position and autonomy vis-à-vis the State. Gaining technical competences (i.e., cybersecurity) and economic attractivity tend to strengthen London's political power.

Figure 11: Map of the actors involved in the deployment of 5G in London



Introduction

As an innovation-driven city, London is currently a leading actor in Europe on 5G implementation and uses. The deployment of this technology has been a priority for the metropolis. Its dynamic economic sector requires solid infrastructures that can attract business, and this strategy will only grow in importance after the UK's exit from the European Union. Facing the risk of financial companies leaving the city, the UK government and the Greater London Authority (GLA) have developed a strategy to remain competitive by making London a center for financial and innovation activities. This partly explains why London is investing heavily in developing state of the art telecommunication systems. This chapter will try to analyze how this process is taking place with 5G deployment by focusing on transportation, a sector in which 5G could be a game changer for both operators and users.

At the national scale, London is in a situation where the British government wants to speed up the roll out of gigabit-capable broadband in rural areas and wants the UK to be a world leader in 5G. According to official reports, the majority of the population must be covered by a 5G signal by 2027[9]. Switching to the urban scale, the question that can be already asked is about the precise objectives that the city of London pursues with the deployment of 5G. London seems more advanced than most other European cities regarding its ambitions with this new network generation, but it is still unclear what uses of 5G will be made and how the stakeholders of 5G deployment will coordinate.

Why approach 5G in London through the case of transportation?

This chapter studies the governance of 5G in London. As we know it, London is a big and complex city, with major actors of the digital world and various layers of public authorities. The main actors of 5G development include first the UK central Government. The entity in charge is the Department for Digital, Culture, Media and Sports (DCMS), which has an explicit objective of encouraging growth and promoting Great Britain abroad[10]. DCMS provides funds to local authorities like Boroughs, and it also funds initiatives that favor innovations in the form of quasi public companies such as Connected places Catapult.

Connected Places: Catapult is a public funded company specialized in urban development challenges, specifically urban digital uses. 45% of its funds are provided by the central government, and the rest is provided by the benefits of the services it sells to various

[9] https://www.gov.uk/government/publications/telecommunications-security-bill-factsheets/factsheet-6-5g
[10] https://www.gov.uk/government/organisations/department-for-digital-culture-media-sport

clients. The public funding is conditional on achieving certain profit targets. It collaborates with SMEs, startups, and public authorities.

In London's urban governance, the most important actor in terms of 5G development remains the GLA. Led by the Mayor of London and the London Assembly, the authority is in charge of the strategic administration of both the city of London and the county of Greater London. GLA has responsibilities in various fields which it delegates to various bodies such as Transport for London (TfL), the Mayor's Office for Policing and Crime, the London Fire Commissioner and the London Legacy Development Corporation. Besides these statutory bodies, London hosts a large ecosystem of private startups and SMEs that specialize in the digital sector.

A proper analysis of the governance of 5G in the British capital would require deeper investigations. Instead, focusing on one aspect is relevant, provided that it is representative of phenomena happening city-wide. Being a major actor that is directly related to GLA, TfL appeared as a good way of approaching the subject, in particular because it plays a key role in the city's logistics and therefore is an interesting case for 5G uses.

London's 5G development: an explicit strategy by the mayor

The question that can be already asked is about the precise objectives that the city of London pursues with the deployment of 5G. A first answer can be found in a document published in 2018 entitled "Smarter London Together" (SLT). This report made by the GLA sets up the strategy for making London the "smartest city in the world". It shows the city's ambitions to become competent regarding various goals such as cyber-security, innovation, education or inclusion. Connectivity is presented as a way to make the city more attractive. A first opposition therefore stems from this report on who will benefit from the heavy investments made in that regard: is it London's local population or London's economic agents?

The report mentions various institutions created to carry out this mission:

- A "Chief Digital Officer" position was created by the Mayor of London. His role is to lead the city's strategy for digital transformation, to support the innovative approaches of economic and digital actors in the city, and to develop Public-Private Partnerships (PPP).
- The "Smart London Board" is a major institution of the SLT, having the broad task of supporting the implementation of the SLT plan through shaping the agenda and the investment plan of the project. The board includes academics and entrepreneurs of the tech sector.

- The “City Data Analytics Programme”, previously named the “London Office of Data Analytics”, aims to equip and increase the capabilities of London’s public organizations in terms of data science. The program provides various resources, including data science expertise from data scientists working for GLA and partners involved in the project, and also a data platform, the London DataStore.
- The London Office of Technical innovation (LOTI) aims to foster collaboration of a coalition of London boroughs in order to deploy digital methods for public engagement, to provide recommendations and guides, and displays the will to tackle social issues resorting to technology. It is likely that behind the displayed goal of social inclusion, it should mostly be conceived as a tool to implement technologies at the borough scale, especially to overcome resistances to the implementation of technical innovations. In other words, the LOTI is a tool to enable GLA objectives to percolate at the neighbourhood level.

This overview suggests two other stakes in the deployment of new technologies. Firstly, it shows the extensive resort to public-private partnerships between GLA and smart city companies such as Bloomberg Associates. Secondly, the deployment of AI related technologies appears as a catalyst for London’s extension of its field of competency. “Smart technologies” bring to the fore areas such as cybersecurity (SLT mentions developing a “city-wide cybersecurity strategy”), social inclusion and education that are more traditionally associated with the national scale. The multiplication of parapublic organisations mentioned above introduces a new way of governance. GLA maintains itself as a major actor for its area, but its power is not centralized. Instead, the challenges of digitization, with the expertise and investments it requires, led GLA to resort to multiple sub-institutions whose role is to attain the city’s objective through compromise, partnerships and alliances with local technical actors, be they public or private.

On the private side, the mobile operators in London are EE, O2, Three UK and Vodafone. Each deploy their own infrastructure but do also share infrastructure where possible through joint ventures. EE and Three have created a joint venture called MBNL. Similarly, O2 and Vodafone have created a joint venture called Cornerstone. There are also other businesses which install mobile infrastructure across London and open these up for operators to use. The GLA does not govern where operators install mobile infrastructure as they are given rights under the Electronic Communications Code set out by the Central Government, which allows them to install infrastructure where the market requires. This is also in combination with planning regulations which operators must abide by. When operators install infrastructure at street level, such deployment currently requires permission from the local council where the asset will sit. The application also requires no objections from local residents and businesses who can block the infrastructure being deployed near them. But the British Government is currently consulting on changes to legislation around permitted development, which if approved in the current state will allow operators to install

15m monopoles without seeking planning permission. so as to increase 5G roll out across London and the rest of the UK[11].

5G in London's Underground system

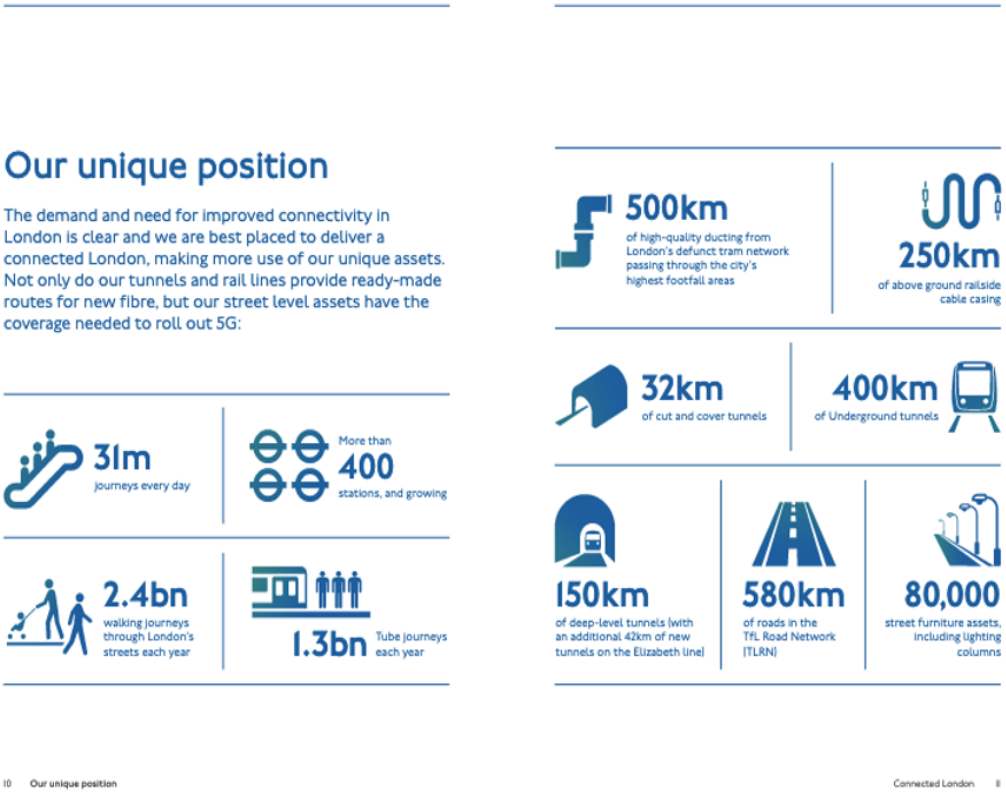
TfL: a powerful actor

TfL is a major statutory corporation that has a budget of over £10 billion and employs 28,000 people. It manages various modes of transportation across the city, including the Underground, train systems, bus networks, taxis, cycle paths, river mobility, and some major routes. Its huge size makes it both a powerful and versatile actor. It gathers operational and strategic capacities, consulting services, urban planning units but also digital innovation functions. In the context of 5G networks development, it plays a key role in deploying optic fiber cables. Indeed, the Connected London program, which coordinates connectivity projects and 5G projects for GLA, collaborates with TfL on 5G development, relying on its capacity to invest in optic fiber and, more importantly, on its access to strategic underground corridors. As a consequence, TfL is reinforcing its central position in the governance of London's digital networks. The complexity of 5G is pushing public bodies to develop partnerships with the private sector. Instead of acquiring an expertise in the domain of digital technologies, TfL reinforces its authority in terms of making key decisions regarding London's networks and infrastructures thanks to its "logistical power" (Mutter, 2020)

The reference document for London transportation systems' strategy was until recently the Mayor's Transport Strategy (MTS) published in 2018. It set ambitions for a more efficient and greener transport system. Following the recent Covid-19 pandemic and the decrease in public transportation use, TfL faces the need to change its business model. As a result, projects such as a paying belt around London are currently under study. Secondly, the objective is to encourage a change in mobility to favor cycling and walking through the London Street Space Plan. Thirdly, the current strategy seeks to encourage the use of buses, which are more flexible and less costly from an infrastructural and operational point of view than the train or the subway. The 5G ambition, however, remains unchanged at large according to both interviewees.

Figure 12: TfL's assets for telecommunication network deployment

[11] https://www.gov.uk/government/consultations/proposed-reforms-to-permitted-development-rights-to-support-the-deployment-of-5g-and-extend-mobile-coverage



Although TfL has the assets for housing fiber optics and various kinds of digital infrastructures in their tunnels, actually installing any form of communications technology on the Underground network itself has been a long struggle that is still ongoing today. On a first level, this is due to the geology, with the fact that radio communications tend to be hindered deep below ground. On a second level, this limitation is related to a political and economic issue about the lack of available finance and political will to significantly upgrade these systems.

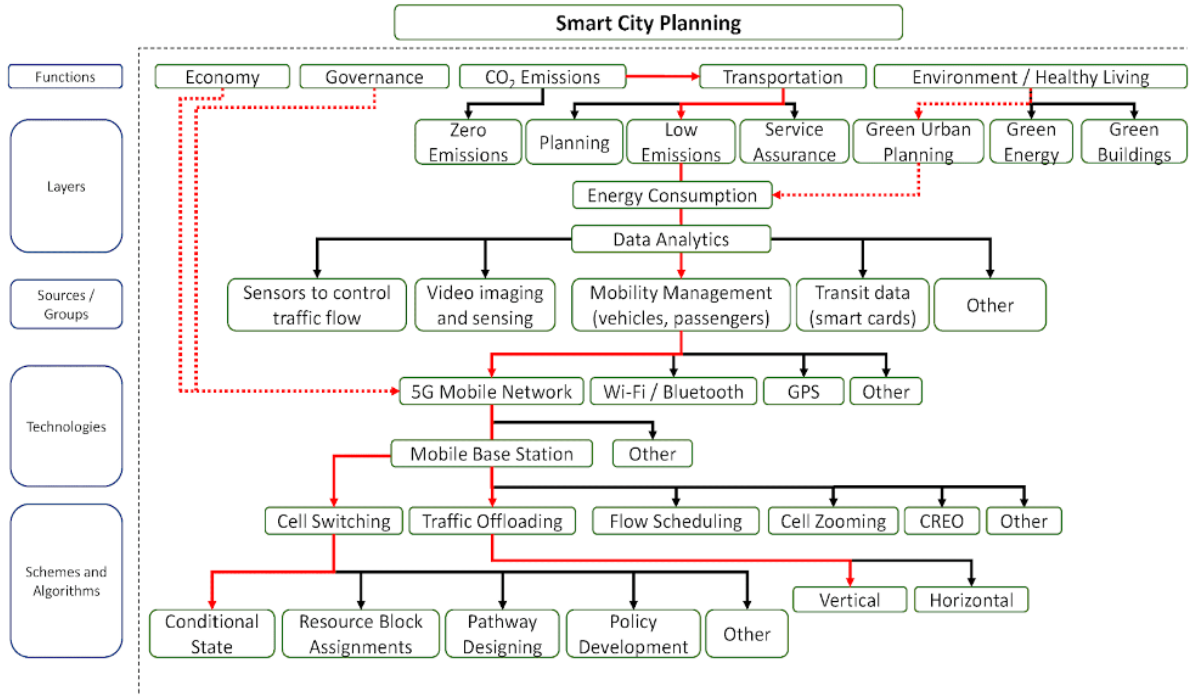
5G: An opportunity for environmental performance in London transportation systems?

When mentioning the "London Connected" program and its coordination of 5G deployment in relation to TfL, the Smarter London Together report emphasizes objectives such as "support[ing] a new generation of smart infrastructures through major combined procurements" or "promot[ing] standards with smart tech to maximize benefit". Such goals set efficiency objectives in transportation systems management. Various research[12] has tried to assess how 5G could potentially lead to energy efficiency. They mostly rely on 5G's operational capacities to collect passenger data in real time to optimize the transport logistics. Such a research perspective seems consistent with the assets of 5G: it suggests taking

[12] See : https://ieeexplore.ieee.org/abstract/document/8671464/authors#authors; https://www.mdpi.com/2624-6120/1/2/10/htm; or https://www.mdpi.com/1424-8220/20/9/2629

advantage of 5G's greater bandwidth and lower latency to enable the monitoring and control of complex networks. As a consequence, it is believed that 5G would enhance environmental performance through energy savings. The question of how to concretely use this new network technology is still open, and research mostly makes suggestions and hypotheses that still require actual experimentation. In parallel, the possibility of such a technical advancement calls for frameworks of governance models. For example, ARUP, a major company in engineering, design and consulting services for urban projects that collaborates with TfL, offers their customers governance models and business models for 5G development[13]. Figure 10 provides an example of a governance model suggested by our interviewee Syed Asad on the potential uses of 5G for environmental performance in London transportation systems.

Figure 13: 5G in a smart city planning structure



Source: Asad et al. (2020)

London Transport logistics are actually far from being operated by 5G networks

Despite the multiple works on how to integrate 5G into transportation networks, the current technology is not 5G based. The main infrastructure management systems used for the London underground are sold by the French company Thales. On the webpage "Growth Signals"[14], the electronic system company details the modernization plan designed in 2016 of four metro lines in London, following the agreement on a £760 million contract. The technology used to manage the coordination of trains movements is the "SelTrac "system,

[13] https://www.arup.com/expertise/services/digital/5g-networking
[14] https://www.thalesgroup.com/en/worldwide/magazine/growth-signals

which is sold as allowing efficiency gains relative to the previous generation, by enabling more intensive movements thanks to a better signaling technology. SelTrac can, for instance, automatically calculate the safety gap between two subway trains. According to what was put forward by Thales in 2018: “The next stage of this digital modernization journey [in London] is about developing more integrated solutions, bringing signaling and communications systems together with trains, depots and maintenance, and information about passenger flows.”[15] For the latest generation of train management systems, Thales sells a “Future ready” solution based on “evolutionary hardware platforms, ready for 5G & autonomy”[16]. The concrete use of 5G is thus still far ahead.

Even for lighter hardware products, 5G is not yet of any use in transport infrastructure management, according to Program Director for TfL services at Thales Peter Gaylor. When asked about the need for a refresh of the communication network of London Underground, which is based on the company’s TETRA system, he states: “The technology that we’re talking about now, the basic technology hasn’t changed, it’s still TETRA and what was installed is the latest hardware or software to support that. So, for our customers, it’s less about the bells and whistles that you see with the 4G and 5G.”

So is 5G absent from London's underground system? Reading carefully the reports by TfL and the Mayor of London, there are 2 reasons why TfL is so engaged in deploying 5G networks and, generally speaking, improving connectivity. Whereas TfL’s specific position enables it a unique access to strategic corridors, the purpose of 4G and 5G networks for the company is to enhance the WIFI access for its customer. As the Mayor puts it: “Internet connectivity is now a key public utility”[17]. The goal, in coordination with the Smarter London Together plan, is to resolve the problem of “not spots”[18]. As a result, Thales’s TETRA system and, only very recently, WiFi, are as high-tech as the London Underground gets.

5G and digitization in London

In the transport arena, we showed there is a contrast between the functional use of 5G applied to complex network management, which is not implemented in London, and general connectivity, which is the main axis of development. What about the broader urban governance context?

The question of 5G poses the general question of urban service digitalization. In particular, the digitization process can be analyzed in terms of the priorities that local authorities follow. GLA is aware of the necessity to communicate to London boroughs on the importance of digitizing public services, focusing on urban planning, urban management and

[15] https://www.thalesgroup.com/en/united-kingdom/news/digital-journey-modernising-londons-tube
[16] https://www.thalesgroup.com/en/markets/transport/urban-mobility/seltractm-g8
[17] http://content.tfl.gov.uk/connected-london.pdf
[18] https://www.london.gov.uk/sites/default/files/smarter_london_together_v1.65_-_published.pdf

local community engagement. One of the stakes is to facilitate the coordination between urban development (various projects including mobility, housing…) and urban regulation (the set of rules that establish what is possible and what is not according to law and regulations). In that respect, the major obstacle for these smaller subdivisions is the "non-attractive format", to quote Sebastian Herman, in which citizen data is recorded. Concretely, most data is registered through paper or pdf files by local councils, which makes it difficult to access and even harder to analyze. One major digital governance question in London is: how to manage local actors to move from unstructured data to more structured ones? The efforts to operate such a transition are the responsibility of the London Office for Technical Innovations (LOTI). GLA thus created a data planning platform that seeks to mutualize the relevant information for urban planning questions. This broad challenge is confronted to the inequality of resources among local communities. Many depend heavily on funds provided by the central government, but inequalities are also present in the capacity of a given local community to show their capacity to invest the funds provided by the state, which even creates greater inequalities.

Sebastien Herman (Digital Urbanist, Connected Places Catapult): "*Utility of 5G for the public domain is ten steps ahead. There is still no direct use for local authorities and municipal governments. That is not to say that 5G won't help; it's just not going to be the first thing to occur because there's a huge gap between local authorities in their capacity to adopt 5G.*"

In that respect, a huge contrast appears with the will to develop 5G in the city. This network technology appears as a big jump, one that is actually too big for some boroughs which lag far behind in terms of incorporating basic digital tools to their competencies. A quick and intensive development of 5G here appears as a priority for the private sector first and foremost, given the commercial perspectives it opens, and less for the public. The process of digitization of public institution's tools happens in the UK with the extensive collaboration of private enterprises, mainly SMEs and startups specialised in developing digital tools and data analytics. This sharing of competencies between the public and the private sector, which involves sharing public data, can be attributed to the discrepancy between real digital needs and the priority given to the development of 5G. Digitalizing, but even more 5G deployment, is indeed costly in the short term and the longer term, as it necessitates recruiting specialized employees and creating specific units among public bodies for digital transformation. Public-Private partnerships are thus growing and reinforcing in London for the urban development sector, but it is also generally the case in other areas such as health or education.

A window of opportunity for London's position and autonomy

While concrete use of 5G over complex systems is still far ahead, there are consequences in terms of autonomy and strength of London's local authorities. TfL is undoubtedly gaining expertise in network management and authority in enabling access to its strategic corridors for optic fiber to be deployed. Furthermore, London is fostering a true digital ecosystem of digital companies. This ecosystem can be mobilized to achieve digitalization goals set by the local authorities or the central government. This in its turn threatens public authorities to lose competencies in digital matters and also to give away citizen data that it collects. We can thus say that the digitization process in London accentuates liberal trends. For example, TfL doesn't have its own public transit app. Instead, it provides its Application Programming Interface (API) to more than 8,000 developers. Its data is currently used in more than 500 apps.

However, the close collaboration between GLA's functional bodies truly reinforces the position of the urban scale in front of other actors, in particular the central government. In addition to operational experience, the Greater London public Authority acquires more responsibilities in terms of strategic deployment and management of network communications. In that respect the State is increasingly losing the monopoly of regalian competencies, in the form of a competency acquisition in sectors like cyber defense by local actors. Indeed, the security parameters and protocols of 5G are of a different kind, and their extensive use and management in a city such as London will probably reinforce the capacities of the city.

Conclusion

The various public sources coming from public authorities emphasise the need for 5G in relation to the productivity gains that good connectivity enables and, on the other hand, the detrimental effect of bad connection for London's wealth production[19]. The deep ties between 5G development and economic profitability is also reflected in the main uses of 5G that are currently being developed in London. Widening the scope from the field of public transportation to the broader question of 5G uses at city scale, the main developments associated with this technology are found in various testbeds. There, the kind of tests conducted concern innovations for the creative industry and IoT[20].

It is therefore clearer that what really drives the development of 5G in London is neither public interest nor environmental performance. Local communities are not digitizing at a sufficient pace to draw any benefit for it, while infrastructure management resorting to 5G is still out of sight in London. What seems to drive the city in this process is rather a broader economic strategy designed to serve London's competitiveness in some sectors. As the multiple testbeds supported by both the central government and local authorities show, the

19 https://www.london.gov.uk/what-we-do/business-and-economy/supporting-londons-sectors/connectivity/digital

20 For instance the Millbrook 5G testbed, one of the most important ones in the UK, is specialized in experimenting with autonomous vehicles.

goal is to foster a digital and creative industry to offer new digital services and products that can be then exported abroad. And London appears as an ideal laboratory for such purposes, given the density of infrastructures it possesses as well as the digital ecosystem it hosts.

As a consequence, two correlative trends are observed at the level of London. The focus on the management of London's Underground system showed the role of 5G in reinforcing TfL's grasp over the city's telecommunication networks. Its unique access and control over strategic corridors reinforces its authority as access provider and regulator of the city's network. TfL thus extended logistical power and decisional sphere, and such a reasoning can be extended to GLA. 5G reinforces GLA's autonomy, both on an operational and decision level. It indeed places in its hands a technology that implies heavy economic stakes, strategic orientations, security matters and data access. That is not to say that London is on its way to becoming a state within a state, but rather that it is reinforcing its status and reducing the vertical relationship with the central government, increasingly becoming a partner more than an inferior tier. The authority of GLA is implemented by institutions that depend on it and were created for the purpose of governing the digitization process. The mode of governance is not that of a public authority taking a decision imposed upon the rest of the actors, citizens, companies or boroughs. It is true that the main municipal authority sets out a general plan. But it has set up parapublic satellite authorities, where public action is not characterized by a top-down relationship, but by a governance through dialogue, compromise and partnership. Such action is certainly not as centralized as in other forms of governance, but it can still give the city a certain power over the processes related to digitization and technology innovations. In parallel to the reinforcement of GLA, this case study shows a development of Public-Private Partnerships in London. They are stimulated by the lack of heavy investment capacities and the high technicity of 5G networks and digital technology. Indeed, the reinforcement of GLA's position is the product of alliances between local economic actors and local public actors, leading it to a distinctive path compared to the central State.

Helsinki and Stockholm

MAIN FINDINGS:

- ➔ Similar political, economic and cultural environments favorising trust in public institutions, powerful innovation clusters driven by two major telecommunication groups Nokia and Ericsson, and symbiosis between the different public and private urban actors
- ➔ Key role of the municipality as facilitator and coordinator of the 5G rollout
- ➔ 5G as a tool for the development of the smart city and integrated to pre-existing public policies
  - ◆ a focus on open data and citizen service in Helsinki
  - ◆ an integration to environmental objectives in Stockholm

Introduction

Helsinki and Stockholm are respectively the capitals of Finland and Sweden, two countries known for their historical relation to technology and innovation, and especially in telecommunication services. Both capitals have strong innovation clusters driven by two major telecommunication groups, Nokia (Helsinki) and Ericsson (Stockholm). With such a favourable environment, the logical next step for local political and economic ecosystems was therefore to launch the 5G in both capital cities. Following a meeting between Nordic prime ministers, many manufacturers and telecom groups from the region signed a Letter of Intent to lend their support to the rollout, stating that the region should be the "first and most integrated 5G region in the world". This agreement occurred one year after their adoption of the Nordic-Baltic ministerial declaration called the Digital North, indicating that the region will tackle large challenges such as the ecological transition through the development of advanced digital technologies.

Being able to impede Huawei in Europe, it is the best interest of Finland and Sweden to develop 5G as quickly as possible. Whether for economic or ecological reasons, 5G is perceived as a factor in improving the quality of life in cities and everything is done to ensure that it is distributed throughout Europe thanks to the local telecommunication champions Ericsson and Nokia. Since 2018, partnerships have been established between private companies, universities and public actors in order to use Helsinki and Stockholm as urban laboratories for 5G. The new technology is seen as an important step towards the "smart city" and many actors think that its potential will grow more and more in the future, which is why it should be developed as soon as possible in the two capitals.

In this chapter, we decided to jointly study 5G deployment and strategies in both Helsinki and Stockholm because the two capitals share many similarities, be it in terms of size, culture, politics, technical progress or even actors. It is thus particularly interesting to see what the common trends concerning 5G development are, but also where the two cities differ. Thus, this chapter aims to describe the dynamics of urban governance at work, but also

to understand the links between Research and Development, between public and private sectors. We will also analyze the discourses of progress that support the close collaboration taking place between all pro-5G actors (universities, private companies, the municipality) as well as the massive investments in AI.

How does 5G technology constitute a relevant vehicle to illustrate a symbiotic interplay between urban actors in both Stockholm and Helsinki? A few hypotheses guided this study. First, private companies and the telecommunication groups work together since they all agree on the importance of 5G and the benefits they can draw from its implementation. Second, both municipalities participate to build a frame fostering the collaboration between the aforementioned actors. Finally, Swedish and Finnish citizens are used to a culture marked by an important part of technological innovations and also participate in it. Therefore, the absence of controversies among the main players of urban governance makes the situation all the more suitable to a 5G rollout and makes the implementation easier for all stakeholders.

To carry out such a project, we conducted an extensive literature review to better understand the trajectory of the two cities regarding technological development, the concept of smart city, and then 5G rollout. This literature review also helped us to compare the two cities, and to understand the reasons why 5G is a crucial stake for both capitals, to highlight the political choices made in terms of urban governance. Secondly, we conducted five interviews with relevant actors to better understand the deployment of 5G in the cities and the arguments mobilised by the political and economic ecosystems.

Helsinki and Stockholm: two similar Nordic cities

An economic environment favorable to collaboration between stakeholders

What we can see in Helsinki and Stockholm is a close relationship between industries and research labs (with telecommunication giants Nokia and Ericsson at the forefront), universities, and urban authorities. Some of our interviewees themselves described the situation in both cities as perfectly representative of the Triple Helix Model (Etzkowitz & Leydesdorff, 1995), emphasizing the collaboration between academia, public powers and industries. This fruitful collaboration in both cities illustrates the particular economic environment we can find more generally in Finland and Sweden, the result of decades of public policies which encourage dialogue, collaboration, and Research and Development activities.

Finnish state policies, whose goals were to increase national R&D activities, started in the 1960s and 1970s. According to Oinas (2005), the Finnish Innovation System was a key policy which put emphasis on research activities via technical faculties and firms, and helped

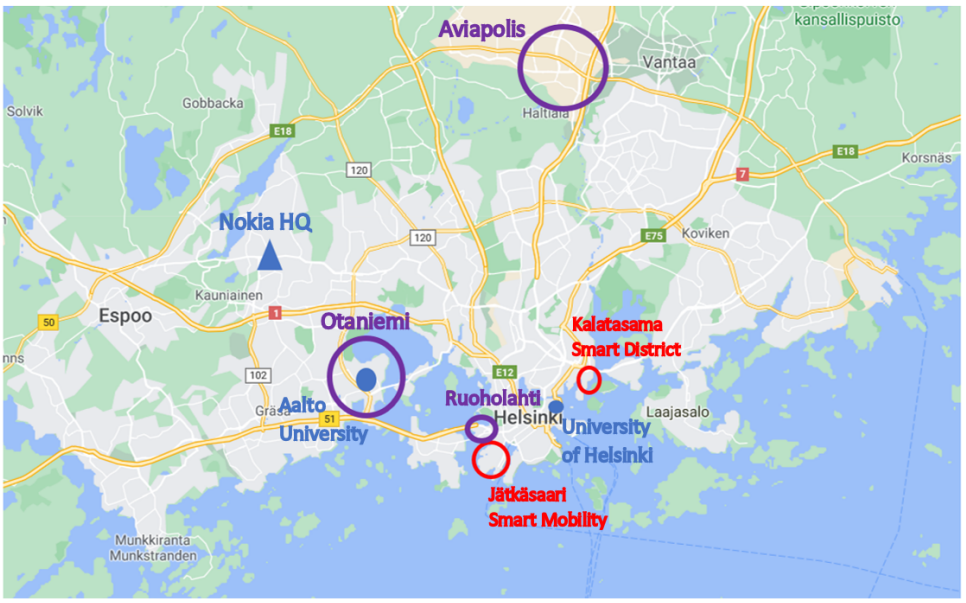
national companies to develop R&D in Finland despite the internationalisation of R&D in the recent decades. Thus, the Finnish Innovation System has "evolved as a result of the interaction of government actors committed to a consistent policy line supporting the interactions between private firms and universities and research institutes in R&D activities" (Oinas, 2005). Froehlicher (2008) describes the Helsinki region as a business ecosystem dedicated to innovation, due to the different actors' common vision of the future: the "shared innovation project". The role of universities is especially important: Aalto University is dedicated to innovation, while the Helsinki School of Economics hosts the Centre for Knowledge and Information Research (CKIR), a think tank that plays an important role in fostering R&D. This ecosystem is characterized both by collaboration and open competition between stakeholders, notably concerning the development of the smart city. Living Labs are for instance used by the public actors as a policy instrument to stimulate innovation and competitiveness, and foster dialogue between all the local actors (Hielkema et al., 2013).

Comparatively to Finland, Sweden has a weaker entrepreneurial culture, but there is also a strong focus on innovation and open collaboration between public and private actors. At the beginning of the 21st century, Sweden has given a so-called "third task" to its universities, thus asking them to transfer the results of university research into private business, which is one characteristic of a strong innovation system (Dahlstrand, 2007). In 2004, the Swedish government's first "Innovation Strategy" emphasised the importance of increasing the commercialization of research results, and thus the collaboration between public and private actors. Today, Stockholm is characterized by its knowledge-intensive industries, especially in Information and Communication Technology and represents a "major enabler for research collaboration and knowledge transfer" (Paschou et al., 2013), with major universities such as the Royal Institute of Technology (KTH). Stockholm has been successfully branded as the "Capital of Scandinavia", an important city for both tourism and business, with 45% of Swedish companies of more than 250 employees based in the Stockholm region.

Two cities with powerful innovation clusters

To better understand the economic environment in Helsinki and Stockholm, and especially the innovation clusters grouping public and private actors, we tried to map those clusters and some of the key actors in both cities.

Figure 14: Innovation clusters and main universities in Helsinki



In the Helsinki metropolitan area, the main economic clusters are the districts of Aviapolis (in Vantaa, near the airport), Otaniemi (at the border between Helsinki and Espoo) and Ruoholahti (in Helsinki). Otaniemi is especially important for R&D activities in the high technology and scientific sectors, and benefits from the presence of Aalto University. Jätkäsaari and Kalatasama are two districts that constitute urban laboratories respectively for smart mobility and smart district. In those neighbourhoods, innovations are tested, in collaboration with the inhabitants, the Forum Virium, the municipality and diverse start-ups.

Figure 15: Kista Science City, the major innovation cluster in Stockholm

In Stockholm, Kista Science City is the most important cluster for ICT (Information and Communication Technologies) in Europe (second largest in the world after Silicon Valley). Today there are 972 companies and 32,500 jobs in the district, including 18,108 in ICT. The most important companies in terms of jobs are Ericsson, IBM and Tele2 Sverige.

The presence of the KTH, a renowned university working closely with private companies to develop research activities, is very important for the vitality of the cluster. Kista also hosts the Urban ICT Arena, a testbed where 5G and IoT technologies are created and improved in collaboration between the different actors.

A political and cultural environment favouring trust in technology and in political institutions

Another common point in Helsinki and Stockholm regards their cultural and political environment, both conducive to trust in any upper authority. In this context, 5G is therefore easily accepted by citizens, Swedish and Finnish alike.

Indeed, as much research shows, the cultural and social traditions of these two Nordic countries show a strong acceptance of technology, and of any decision taken by a higher authority more generally. For instance, the notion of "flexible society" is used to characterize Finnish culture (Oinas, 2005). This is the idea that Finnish society is relatively cohesive and seldom questioning the government's decisions, in order to build a stronger nation. This collaboration between citizens is also made possible by the fact that the population is quite low in these two countries.

In such a climate of trust, citizens are unlikely to question technology, much less if the actors who put it in place are in collusion with the State. Indeed, the Swedes and the Finns generally display trust towards the elected officials, thinking that the latter are best placed to manage their country and thus, have the impression of not having a say. More generally, in Scandinavia, technology and democracy do not even seem to be perceived as necessarily in opposition (Asdal & Gradmann, 2014). On the contrary, the first is presented as a tool to achieve the second. It is also through the strategy of "smart city" that technology is presented. By promoting a 'citizen city', the authorities suggest that the whole purpose of technology is in fact to take them better into account, and to invite them to the transformation

> Kalle Toivonen (City of Helsinki): *"Finland as a nation, we are quite digital friendly so citizens are not afraid of those technologies*."

More specifically, our exchanges with 5G players in Finland and Sweden confirmed to us this reigning digital culture which allows a rapid development of 5G, or at least which does not have to face any controversy. As governments have always been used to being transparent about even the smallest spending, citizens do not think they have to fear anything from their representatives. In addition, technology has only brought prosperity to these countries to this day. Nokia, for example, has enabled Finland to rise to the international stage in terms of digital competition (Gufflet & Kremp, 2021).

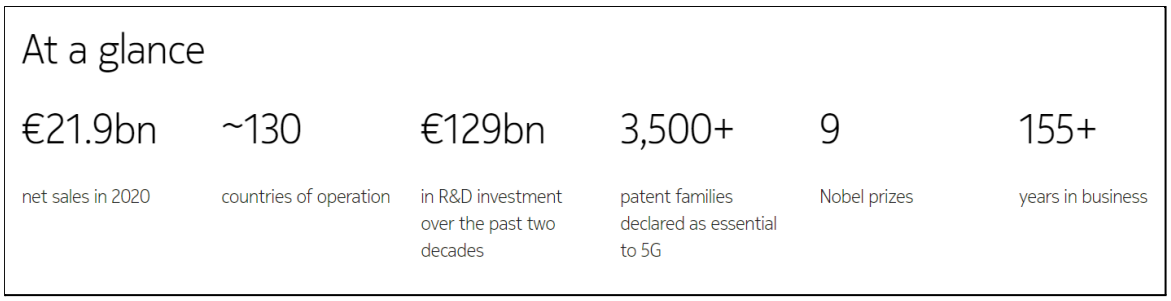
The organization of the 5G rollout in Stockholm and Helsinki

The importance of two major economic drivers: Nokia and Ericsson

In this chapter, evoking the cultural and political context of these countries is not enough to understand the challenge of 5G. It is indeed advisable to recall the last common point specific to these two cities which caught our attention in the choice of this chapter. In addition to having successfully created an environment conducive to technological innovation, the capitals of these two Nordic countries have seen the development of two key players: the multinational telecommunications Ericsson and Nokia, respectively established in the suburbs of Stockholm and Helsinki.

Nokia

Nokia is a world technological leader in the field of communications, which made its transition to telecommunications in the 1990s. In 1998, the company became the best-selling mobile phone brand in the world. In 2003 they released the first camera phone and in 2011 they partnered with Microsoft. And in 2014, Nokia sold its mobile and devices division to Microsoft. It was when Nokia Networks was established that Nokia became primarily a supplier of network hardware and software. Its customer base was also expanded following the acquisition of Alcatel in 2015.
Nokia, headquartered in Finland, near the capital, works in around 130 countries. 6000 employees make up the Nokia community around the world, representing 68 nationalities. In Finland, the company's premises are divided into 3 headquarters: in Espoo, Oulu and Tampere.

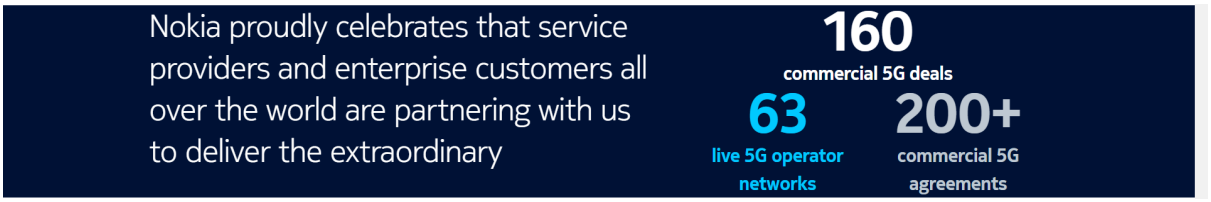


Source: Nokia website.

Nationally, Finland has also seen the birth of the Nokia Bell Labs, whose experience in terms of innovation has already led the company to win 9 Nobel Prizes. In addition, the Espoo, Oulu and Tampere sites are in the top 3 sites for all Nokia patents filed worldwide in 2019.

In 2020, Nokia signed a 5G contract with 66 telecommunications operators around the world, including 3 of the 4 major US operators. This is the same year that Pekka Lundmark took office as the new CEO of Nokia. In Finland, the company has contracts with Elisa, SYV and Telia, and in Sweden, with Tele2, Telenor and Telia. In France, Orange and Free have chosen Nokia to be one of their 5G antenna providers. Its equipment is currently present in 32 active 5G networks around the world.

Figure 16: Nokia at the forefront of 5G development



Source: Nokia website.

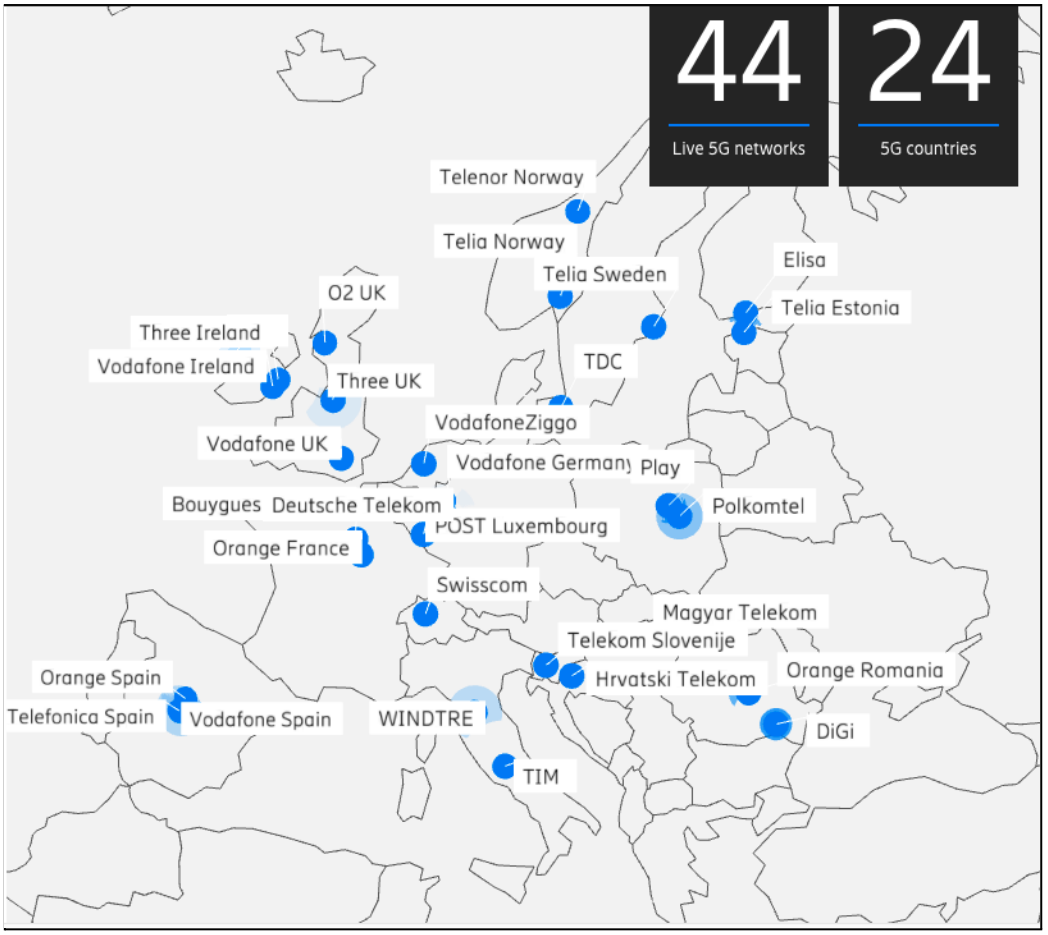
Ericsson

Börje Ekholm (President and CEO of Ericsson) : *"Our purpose is to empower an intelligent, sustainable and connected world. For more than a century, we have been putting smart tools in the hands of people in every sector of our society, creating intelligent technologies that drive positive change. We remain committed to this effort, leaving no one behind."*

Ericsson was established in 1878, by Lars Magnus Ericsson. By the year after, it was already Scandinavia's largest supplier of telephones. In 1900, shortly thereafter, Ericsson had 1,000 employees and had 50,000 telephones produced on its meter. 2 years later, the first American points of sale were launched. It was in 1950 that the company became a pioneer in terms of international telephone exchanges.
Worldwide, Ericsson employs more than 100,000 persons, including 13,300 in Sweden. They have 21 European R&D centers and spend €3 billion investment in R&D per year. With 57,000 patents, Ericsson is the first mobile telecommunications provider in Europe.

Ericsson is the first telecommunications company to launch 5G commercial networks live on 4 continents. Today, among the world's leading 4G network service providers, 70% use Ericsson's radios and base bands for 5G. A third of the world's population is now a customer of Ericsson's rope solutions, from 2G to 5G. In terms of operators, Ericsson has more than 100 customers around the world, which allows it to accumulate 26% market share in 5G equipment. Ericsson's commercial contracts with operators currently amount to 139. In France, for example, Orange has chosen to source 60% of its network from Ericsson.

Figure 17: Ericsson's live 5G networks in Europe.



Source: Ericsson website.

During our interviews with representatives of Nokia and Ericsson, we found that 5G was a real competitive issue between the two companies. An employee of the municipality of Helsinki phrased it well.

> Tapani Nevanpää (City of Helsinki): "*Of course they* [Ericsson] *got their 5G licenses quite late, compared to us. It must have been quite research-oriented, I think.*"

Rather than comparing the competition between the two companies, we will instead look at the relationships they have with the other players there. Indeed, although they are essential in the development of 5G in Stockholm and Helsinki, Ericsson and Nokia are helped by other actors who work on their project.

A strong collaboration between the urban stakeholders

A key characteristic of 5G deployment in both Helsinki and Stockholm is that it was made in collaboration between different city actors, especially the industries, the telecommunication operators, and the municipality.

Kalle Toivonen (City of Helsinki): "*The good thing about Finland and Helsinki is that the collaboration and dialogue between the different actors is quite open here."*

"Open on-going dialogue" and "collaboration" were two expressions that came up a lot during the interviews with the city of Helsinki and the city of Stockholm. All actors seemed to have the same opinion about the development of 5G. For Helsinki, the discussions about 5G started around four years ago, with the different stakeholders involved in the matter. The municipality of Helsinki had a role of organizator and facilitator of the rollout, although the actual deployment was carried out by the operators. The city tried to orient the development of 5G so that it would be the most beneficial to all.

Kalle Toivonen (City of Helsinki): *"We really tried to figure out jointly the way forward and the solutions that would be the most valuable for us as a city."*

The municipality in Helsinki thus supervised the deployment, and facilitated the dialogue and transfer of knowledge, notably the results of the research projects for the application uses of 5G, between actors. This is also the case for the city of Stockholm. The municipality has regular discussions (once every three months) with the mobile operators concerning their needs and the future development of the network. This close collaboration with operators has its roots in the previous rollout of 3G and 4G. The city of Stockholm is also in dialogue with Ericsson to understand "how they would like to develop the 5G network", as the interviewees from the municipality explained to us. Finally, the city discusses weekly with universities such as KTH to share knowledge and promote research activities in the 5G domain. As in Helsinki, the municipality of Stockholm thus has a role of facilitator and coordinator in 5G rollout, in collaboration with other public institutions (the county, universities) and private businesses (Ericsson, operators, and other companies).

Per-Olof Gustafsson (Stokab / City of Stockholm): *"We try to find win-win-win solutions."*

The interviews with Viktor Arvidsson (Ericsson) and Juha Salmelin (Nokia) have highlighted this public-private collaboration. It is especially important for future 5G developments regarding application uses for the city, since the rollout in both cities is almost completed today. For instance, the LuxTurrim5G Project, a Nokia driven innovation ecosystem which aims at developing fast 5G network based on smart poles, is an example of fruitful collaboration between public actors (municipalities of Espoo and Helsinki, Aalto University, University of Helsinki, Tampere University) and private actors (Nokia, Spinverse, Vaisala, Teleste…): 26 partners in total. The tests are carried out in the Kera district of Espoo (Nokia headquarters) and the objective is to *"create a digital backbone for smart cities"* (Juha Salmelin). The city of Espoo is largely invested in the project, while the municipality of Helsinki is also interested in the commercial applications of the research.

A favorable context of competitivity and innovation

Besides a close collaboration between all urban actors, 5G development in Helsinki and Stockholm has been facilitated by a global context of competitiveness and innovation. Both Finland and Sweden (although in Sweden the licences were attributed later than in Finland) have rapidly deployed 5G in the major urban centres, and today Helsinki and Stockholm are almost completely covered by 5G network. According to the municipalities, open competition between operators is the reason why this high connectivity has been achieved quickly.

The need to be competitive also played a role in this fast development. Both cities host major telecommunications actors Nokia and Ericsson, which have international ambitions for 5G and need the support of their innovation clusters. Equipping some key areas of the cities in priority with the 5G network was important for the competitiveness of start-ups and research labs. In this, the municipalities had a role in facilitating the dialogue between the operators and the industries, to figure out where it would make the most sense to start the rollout at the beginning of 5G development.

Innovation activities are quite important in the two capitals, driven by Nokia and Ericsson, and their partner universities. For instance, in Stockholm, the KTH is at the forefront of research on continued development of 5G and as such a first version of 5G has been installed on site in 2018 by Ericsson and Telia. The KTH, and Digital Futures Strategic Research Programme, are very active in developing solutions for smart cities, including 5G-related devices and services, and there is an on-going partnership between the city, the industries, and the university to share knowledge and figure out solutions for the future. 6G is also already on the minds of the local and national stakeholders. The Hexa-X project, a joint European initiative to research and develop 6G, is piloted by Nokia and Ericsson with other partners in the industry and academic, under EU funding, with the objective of building an European leadership on 6G for the EU to be competitive vis-à-vis the rest of the world (Vetter & Frodigh, 2021).

Finally, the favorable context of competitiveness and innovation in Helsinki is particularly well-illustrated by a specific actor: the Forum Virium. This company is fully owned by the city of Helsinki, which subsidizes it, and focuses on building a portfolio of different innovation projects. Basically, the Forum Virium enables the start-up and companies to test their innovations in real conditions in certain neighbourhoods, with thus the possibility to have citizen feedback. Their two main projects at the moment are mobility and smart city (in which 5G would play a huge role). The Forum Virium works in constant dialogue with the Economic Development Department and the solutions found are shared with the local ecosystem.

Kalle Toivonen (City of Helsinki): *"What is important is that the innovation projects they build are always in line with the strategies of the city and the goals of the city. So they* [Forum Virium] *are, in a way, an 'innovation hand' to us."*

Strategies of 5G deployment: a tool for future smart cities

For both Helsinki and Stockholm, 5G is one of the tools believed to be essential in achieving smart city agendas. In 2020, Helsinki ranked second, and Stockholm ranked 16th (they respectively gained 6 and 9 places compared to the previous year) in the Smart City Index of the IMD. But for now, both capitals could be qualified as "learning cities" (Gufflet & Kremp, 2021): not proper smart cities yet, because a lot of future developments and innovations are still coming, but they are following this path. What is interesting is the reasons why Helsinki and Stockholm are today very motivated to develop 5G network and 5G services, because this is where the two cities, very similar in other respects, slightly differ.

Helsinki: an emphasis on open data and citizen service

For the municipality of Helsinki, 5G application uses will be completely integrated in the already existing strategy of the city to put data at the service of the citizen.

Tapani Nevanpää (City of Helsinki): *"We have a strong belief that 5G is a fundamental part of a smart city technology and it enables things that we don't know yet but that can be done for citizens and companies being here."*

5G in Helsinki is seen as a technology bringing new improvements for citizen service in the future, even if all the uses that could be made of the technology are still unknown (more innovations are yet to come). 5G development is a key part of the future Helsinki smart city, being both an asset for the city's projects and a benefit for local companies. For the municipality, 5G is particularly interesting because the technology is expected to help increasing knowledge about the city and to influence better, more efficient public policies. The benefits for the citizens of Helsinki are highlighted.

Kalle Toivonen (City of Helsinki): *"We as a city want to use the data in a way that we can provide more predictable information for our citizens (...). We want to make sure that our managing and decision-making is based on real data and most up-to-date or real-time data. In doing that, we need to make sure that the connectivity is there and, in that, the 5G actually brings huge value for us."*

5G is integrated in already existing policies about open data, transparency and sharing knowledge about the city. Helsinki is indeed a frontrunner in promoting the possibilities of open data and open data sharing: the city promotes the use of public data and offers it freely to the companies in order to enable innovations which would benefit the local inhabitants. The website “Helsinki Region Infoshare” is the interface enabling anyone to freely access datasets gathered by the public sector. This open data policy is made in all transparency: citizens have the possibility to better understand what kind of data is collected and can give or take consent away via the platform “My Data Operator”. Helsinki is also the first city along with Amsterdam to have developed a transparency tool concerning IA, by creating an IA register, which is a platform listing all the uses of AI in public policies.

For Juha Salmelin (LuxTurrim5G project), 5G will be the key to building a “digital backbone” for the city and bringing efficient services for the citizens. For instance, the smart poles that are currently under test in Espoo will be an important part of the future smart city, as they will be full of sensors which will bring information to the city’s decision makers. A particular example of service which is being developed is an autonomous bus functioning via 5G and smart poles’ sensors, with the driver in an office controlling multiple buses at the same time. This new service is still in development and would not appear in the city before the next decade at the least. Eventually, it would enable a more flexible service, reduce costs, and ameliorate the efficiency of the network (with the possibility for the customer to order the bus). 5G is thus seen as an enabler to create new services which will benefit the inhabitants of the Helsinki region in the future.

Stockholm: a development integrated to environmental objectives

In Sweden, and more specifically in Stockholm, 5G is not deployed just to serve citizens. Indeed, the city’s approach is also in line with the country's desire to achieve carbon neutrality by 2040. In this perspective, 5G is seen as a very useful tool to meet this objective.

The municipality of Stockholm has already won numerous awards in the environmental domain, such as that of “European Green Capital” in 2010, which could be an explanatory factor for the city’s desire to use 5G for ecological purposes. The city has been mainly relying on technological developments to respond to environmental issues and become a model of “green-sustainable city” (Paschou et al., 2013). Furthermore, showing that technology can go hand in hand with ecology helps to maintain an attractive image of the city, as a modern, healthy environment in which it is good to live and which is enviable for all locals as for foreigners. What strengthens the municipality's argument for deploying 5G is the 2040 vision envisaged by the country and also desired by the city. To this end, all public policies put in place by Stockholm are intended to contribute to this objective and 5G is one of them.

Indeed, the organization of the city-archipelago shows to what extent it is a living environment in harmony with nature, justifying a real interest in developing technologies

allowing to link all potential data on nature conservation. Regarding the issue of water quality, 5G would improve it so that the inhabitants of the city can make the most of the basins offered by the archipelago. To this end, sensors have been placed everywhere in order to know in real time the quality of the water, which avoids compulsory and regular withdrawals. Although the idea was not kept in the end, because it was not effective enough (the sensors still needed to be regularly withdrawn from the water), the municipality had nevertheless considered this use of technology in the service of nature and the inhabitants (Gufflet & Kremp, 2021).

Thus, 5G is not seen per se as *beneficial* for the environment, but rather as an *enabler* that facilitates data collection with the aim of improving municipal services.

> Anders Broberg (City of Stockholm): *"5G will not directly save the planet. But we need more data to make better decisions."*

On the contrary, when they are questioned about the possible negative environmental impacts of 5G, the actors answer that according to them, this technology can only go in the good sense of ecology. Viktor Ardvisson, France Director of Ericsson, even lists other areas in which 5G is virtuous. For example, he mentions the issue of streaming, which is often criticized but which, according to him, can have a real impact on the consumption of citizens. In this, cities would have a role to play in the development of 5G to reduce the energy consumption of their inhabitants.

Conclusion

In this chapter we studied the characteristics of 5G development in Helsinki and Stockholm, two similar cities on the political, economic, and cultural levels. Both capitals share a favorable context for innovation. The Triple Helix model can be applied to Helsinki and Stockholm, as there are very strong links between the academia, the municipality and the industries. Other characteristics of this favorable context for innovation are the transparency and trust between the citizens and national and local governments, and also the presence of two major telecommunication companies, Nokia and Ericsson, as drivers.

5G deployment in both cities has been supported by all main urban actors and there were apparently no controversies regarding the technology deployment. The municipalities had a role of facilitator and coordinator of the rollout, ensuring the dialogue and a fruitful collaboration between the different local stakeholders. But what does it mean exactly to have a "dialogue" if all the actors participating in this dialogue share the same opinion? And does a dialogue without contradictory opinions always lead to the best decision concerning the common good? In both Helsinki and Stockholm, all the actors emphasised the expected benefits of 5G, seemingly minimizing the potential bad negative impacts, or not considering them altogether. 5G has been developed rapidly and effectively, but there are still many unknowns, including what exactly are the uses that are going to be made of this technology.

In fact, 5G is fully integrated in the existing public policies of the cities, and is seen as a tool for the future Helsinki and Stockholm smart cities. Although the urban authorities tend to emphasize different aspects of the technology (open data and citizen participation in Helsinki, integration to environmental targets in Stockholm), in both cases 5G is seen as a catalyst that will bring value to the cities. Helsinki and Stockholm's public authorities are developing 5G because they expect this new technology to enable a better knowledge of the urban environment, thus helping the cities to make better decisions. 5G thus inserts itself into narratives about the "smart city" that emphasize the need for more data for better decision-making. Finally, local actors have hopes that 5G will allow both cities to become more competitive, and overall lead to future benefits for the citizens, even if the shape of the new services enabled by 5G is yet uncertain.

Grenoble

MAIN FINDINGS:

- ➔ A city divided between its technological ambitions and its environmental ambitions
  - ◆ Grenoble is one of France's major innovation clusters and there is historically a close cooperation between local actors
  - ◆ The city is led by a Green municipality since 2014 which tries to implement ambitious climate plans and today opposes 5G deployment on environmental and ideological grounds
- ➔ 5G as a political symbol of the opposition between those two ambitions: an object that crystallizes the tensions
- ➔ The local controversies echo the tensions at the national level, and illustrate a deeper debate on the role of cities and State

Introduction

Grenoble is one of France's major technological clusters and a highly competitive and innovative city due to its history and particularly the close relationships between science, industry and the academia in the city. In this context, one could expect Grenoble to be at the forefront of 5G deployment: however, there are strong controversies surrounding the rollout of the new technology in the city. The Green mayor, Eric Piolle, has repeatedly spoken against the deployment of 5G in its municipality, emphasising the possible sanitary risks, the environmental impacts, the lack of democratic debate prior to implementation, and the risk of aggravating the digital fracture between French territories.

Grenoble's case is particularly interesting because it appears that 5G has become a symbol of the internal contradictions of the city. Grenoble is a technological and innovative metropolis, but its municipal authorities implemented an ambitious ecological agenda since the election of the Green municipality in 2014. Those two ambitions are clashing together today on the topic of 5G, which for the operators and industries is a necessity, but for the municipality represents an environmental threat. Grenoble is one of the French cities where the controversies are the strongest, because of this internal contradiction and the actions the mayor took at the local and national levels to protest against 5G deployment. However, despite its opposition to 5G, the municipality has actually no legal power to stop the rollout, as this is a State's competence, which caused tensions in the city.

In this chapter, we are wondering how the case of Grenoble reflects competing views and interests among urban governance's actors. We aim at understanding the 5G-related controversies with particular emphasis on the arguments mobilised by both pro- and anti-5G actors and the pre-existing tensions that crystallised around this new technology. To sum up, we are attempting to show how this situation of high tension and seemingly impossible debate has arisen in Grenoble.

Our research was guided by a few hypotheses. First, the urban authorities are constrained juridically in their opposition to 5G, but they dispose of other resources to impede the deployment of the technology in Grenoble (such as media presence or indirect legal tools). Second, the local scientifico-industrial nexus is in conflict with the municipality and puts forward the imperatives of competitiveness and progress to justify the need to develop 5G. Third, being a "green" city is an argument for Grenoble's authorities to reject the 5G on environmental grounds. Finally, the controversies in Grenoble are embedded in a context of tension around the rise in power of cities and the relative weakening of the State, which nonetheless still imposes its decisions in a top-down way.

The first step of our focus on Grenoble has been to conduct a preliminary research to be able to better contextualize the current controversies. We started by retracing the history of the city to highlight the particular relationship between science, industry, the academia and urban authorities. We then conducted a press review to better handle the current situation in the metropolis and in France. We finally realised a mapping of the different actors involved in the controversies in Grenoble. The next step was to realise interviews with some key actors in Grenoble to better understand the controversies surrounding 5G deployment and the pro- and con- arguments.

France: a context of high tensions regarding 5G deployment

5G controversies in Grenoble must be understood as part of a more global context of tensions and questions surrounding the development of this new technology. France seems to be a European country in which 5G controversies have been particularly strong. Those tensions around the 5G technology appear to reveal deeper debates, notably about the role of State and the competences of municipalities.

A context of national, strong political controversies

France seems to catalyze a lot of controversies regarding 5G rollout. Indeed, there have been examples of citizens' mobilization in different cities, the public opinion seems to be particularly divided on the topic of 5G, and political actors are involved in a national (non)debate about 5G. Some left-wing and green municipalities, such as Lyon and Bordeaux, as well as grassroots organizations, are opposing the State and national operators (Orange, SFR…) to try to stop the deployment of 5G. Politically, they pointed out the necessity to organize a democratic dialogue around the deployment of new technologies.

As in other European countries, there has been a wave of attacks on antennas in France since early 2020, driven partly by the influence of conspiracy theories linking 5G to the Covid-19 pandemic (O'Brien, 2020). Several cell phone towers have been lit on fire during the first lockdown, in different parts of the country, as in Jura or in the Toulouse

region (Abéla, 2020). There were also several arsons and diverse sabotage actions in and near Grenoble, and anticapitalist groups have claimed responsibility for some of them on the Internet while calling for revolt (Abéla, 2020).

French public opinion seems quite polarized on the 5G question. Some polls made in September 2020 have made the understanding of how deep opposition to 5G runs in France very confusing because of contradictory results. While one poll conducted on behalf of an anti-5G lawyers' association found that 65% of French adults support a moratorium on 5G, another poll made by IFOP claimed that 62% of the respondents wanted the authorities to facilitate 5G development (O'Brien, 2020). However, IFOP also found that 48% of the respondents wanted to suspend 5G deployment until mid-2021 and that 50% were worried about the impacts of electromagnetic waves on health (O'Brien, 2020).

In September 2020, nearly 70 left-wing and ecologist politicians called for the government to impose a moratorium on 5G deployment in the Journal du Dimanche. This moratorium was also demanded by the members of the Convention Citoyenne pour le Climat in their report (CCC, 2020). Some of the signatories of the call for the moratorium are mayors of major French cities such as Lyon, Bordeaux, Marseille and, of course, Grenoble. The signatories asked the government to suspend 5G deployment until summer 2021 and requested a "decentralized democratic debate on 5G and on digital usages" (JDD, 2020). They advanced five main arguments for asking for the moratorium, based on arguments made by the Convention Citoyenne pour le Climat and the Shift project[21].

- there is no public debate on whether or not 5G should be implemented in France;
- there will be environmental impacts due to 5G deployment and they should be questioned[22];
- there is a lack of information on the potential effects of 5G on human and non-human health, and the authorities should apply the precautionary principle and wait for further studies before implementing the technology;
- the deployment of 5G risks worsening the digital fractures that already exist in France, particularly between urban and rural areas;
- with the development of the Internet of Things (IoT) and the multiplication of connected networks, there is a risk for the privacy of personal data.

However, the government has not been receptive to the idea of debating 5G implementation. On September 14th 2020, the French President Emmanuel Macron stirred up a controversy when defending 5G and refusing any moratorium on the rollout. He notably declared: "I hear a lot of voices saying that the complexity of contemporary problems should be addressed by returning to the oil lamp! I don't think that the Amish model can solve the challenges of contemporary ecology." (Damiani, 2020). This comparison to the Amish community has been heavily criticized by the opponents to 5G, who saw there a provocation from the President. For instance, politicians like Manon Aubry (European Parliament

[21] The Shift Project is a French think tank focused on carbon transition.
[22] We mentioned those impacts in the general introduction of the report (risk of "rebound effect", increased waste and acceleration of the exploitation of natural resources).

lawmaker) or Pierre Hurmic (EELV mayor of Bordeaux) complained that the President was imposing 5G without any consultation and blocking the debate (Damiani, 2020; Sportouch, 2020). Grenoble's mayor, Eric Piolle, also denounced Macron's "Jupiterian policy" and qualified his comparison of "outrageous discourse". He also deplored that the President does not take into account the difficulties experienced by French territories outside Paris : "He needs to get out of his bunker in Paris for a bit. His 'start-up nation', a lot of people do not relate to it, today, when they have no access to the digital." (France Info, 2020).

A debate on the role of the State and local authorities

The case of Grenoble also illustrates a particular debate on the role and the powers of the State, opposed to those of local authorities. Indeed, despite their opposition to 5G deployment, Grenoble's municipal authorities cannot actually do much to stop the implementation of this new cellular network in the city by telecommunication operators.

In 2011, the Conseil d'Etat decided that only State authorities designed by the law are competent to regulate the implantation of cell towers. Juridically speaking, neither the mayor of Grenoble, nor the MPs opposed to 5G deployment, can impose a moratorium on 5G. Moreover, local authorities cannot use the precautionary principle to stop the implementation of 5G in their territory. The Conseil d'Etat, indeed, does not estimate that this is a competence that belongs to the local authorities. The Conseil notably declared that "even in the hypothesis where the limit values of exposition of the public to electromagnetic fields fixed by decree are not sufficiently taking into account the exigencies of the precautionary principle, mayors are still not habilitated to adopt a reglementation concerning the implementation of cell phone towers." (Damgé, 2020). Local authorities would need to give some proof of the dangerosity of those antennas for the precautionary principle to apply, given that at the moment, no risk for health has been identified or proved in relation to the presence of cell phone towers (Damgé, 2020). To date, no such risk has been proved by the studies released by the Agence Nationale des Fréquences (ANFR, 2019) or the Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses, 2019), which are still undergoing.

However, if municipalities have little to none legal power to directly oppose 5G deployment, they can still slow down the process via indirect methods. According to David Deharbe, a lawyer specialised in public law and environmental law, urban authorities can make sure that the antenna is not being built on a site protected by the urbanism code. They can also use the local urbanism plan ("PLU") to reject the antenna if its implementation does not respect the plan (concerning the height of the installation or the nature of certain areas, i.e. natural or agricultural zones). If not, the city can then ask an administrative judge to make a decision, after making a judiciary expertise (Damgé, 2020). But nothing guarantees that the judge will designate experts to evaluate the claim, or ultimately validate the request of urban authorities. Moreover, the current rollout of 5G is not made via new antennas, but mostly by

the transformation of existing 4G cell towers, which limits the possibilities for urban authorities to oppose the process.

One of the big tensions that structures the controversies is the opposition that is being made between economic growth imperatives on the one hand, and common good ideals (environmental concerns, democratic process) on the other hand. Pro-5G actors, such as the industries, network operators, and the government, all put forward the argument of economic competitiveness and network efficiency as reasons to develop 5G rapidly and vastly in the major French cities. They argue that if time is "lost" at debating whether 5G should or not be deployed, economic concurrents of France will take advantage of the French delay. This is for instance what explains the Finance Minister Bruno Le Maire when he said about delaying 5G development: "It would be a step backwards for France, and I prefer France to go forward, as a conqueror who is economically successful, rather than the fossilised France that doesn't move" (Damiani, 2020). This is also why 5G rollout started before reports on the impacts of the new technology were released.

Grenoble: "tech" city or "green" city?

Grenoble is an interesting city because it contains a double, but potentially contradictory, ambition. On the one hand, Grenoble is an innovative, high-tech city, whose industries and labs need 5G to stay competitive. On the other hand, Grenoble's Green municipality wants the city to play a frontrunner role in the ecological transition and sees 5G as a symbol of the negative impact of the digital in our lives.

Grenoble, an innovative city with an old industrial and technological tradition

If Grenoble is today one of the French main technological clusters, it is because this tradition of industrial and technological innovation is deeply rooted in the history of the city. Since the end of the 19th century, an urban innovation system has developed in Grenoble, already industrialized and engaged in hydroelectricity. After the government implemented new reforms which created universities from the existing faculties, local governments heavily subsidised and developed technical institutes, creating thus an scientifico-industrial system around electricity (Grossetti, 2001).

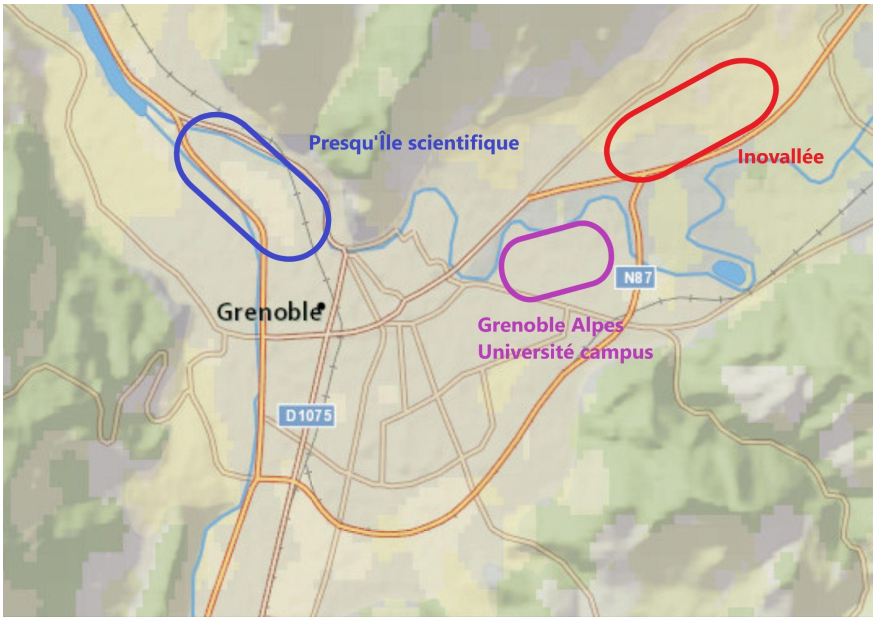
After 1945, Grenoble saw a precoce development of electronics and informatics, with the creation of companies which developed R&D activities to take advantage of the local scientific potential. These trends were reinforced by the decentralization policies pursued by the State in the 1960s, with the implantation of schools and laboratories in Grenoble (for instance the Centre d'Etudes Nucléaires). Personalities like the future physics Nobel prize winner Louis Néel, helped to structure Grenoble's innovation ecosystem, with the idea of creating powerful research clusters organised in a quasi-industrial way (Ambrosino et al., 2016).

What we can observe in Grenoble is the convergence of different actors to ensure the city's competitive development, in particular in the industrial-technological domain. For Spivak L'Hoste and Vinck (2011), Grenoble is a perfect example of such a "convergence", defined as a process engaging science, technology, industry and territorial organization, and aiming at improving research, tertiary education, and enriching industrial competitiveness. The key idea is that Grenoble's actors have a common objective and orientation, which is linked to the specificities of a type of production and associated knowledge (nanotechnologies, electronics…), and which arises from the close cooperation between different entities. Similarly, Vinck et al. (2014) have used the Triple Helix Model to describe Grenoble, highlighting the fact that the city is marked by very close interactions between the academia, the industries, and local governments. The key actors in Grenoble's convergence are public actors (Ville de Grenoble, Conseil Général du Département, Région, and, more recently, "La Métro"), industrial companies (such as STMicroelectronics, NXP, Freescale, IBM), public institutions and tertiary education providers (Commissariat à l'énergie atomique et aux énergies alternatives, Institut National Polytechnique, Université Grenoble Alpes), and finally clusters such as Minatec and Nanobio (Spivak L'Hoste & Vinck, 2011).

Today, Grenoble's nanotechnology cluster is the second largest in France after the Parisian one and has been recognized as a "world-class competitiveness cluster" by the DATAR in 2005 (Ambrosino et al., 2016). In 2013, Forbes ranked Grenoble at the fifth place of its list of the world's most innovative cities, while in 2014 Grenoble was one of the finalists contending for the first European Capital of Innovation award. Grenoble is clearly labeled as an innovative city at the national, european and international levels.

The emphasis put on the "convergence", shared vision of the city, and development of the knowledge economy, acts as a strategy for economic growth and is a reality on the job market. Indeed, in 2011, 21,378 jobs in Grenoble were directly linked to R&D activities, which represents 7% of local jobs, twice as much as the French average (Ambrosino et al., 2016). Minalogic, one of the six "pôles de compétitivité d'envergure mondiale", groups 46 institutions and 11,000 employees. The Minatec innovation campus today counts 3,000 researchers, 1,200 students and 600 business and technology transfer experts, and represents an international hub for micro and nanotechnology research (Minatec, 2021). The LETI, part of this campus, has been one of the pioneer labs involved in the development of the 5G technology, notably for the Olympic Games of Pyeongchang.

Figure 18: Main innovation clusters in Grenoble



Grenoble, a pioneer city for ecological development

But Grenoble also has another ambition, which sometimes is in contradiction with its technological side. The municipality of Grenoble is run by a green majority led by Eric Piolle since 2014. Even before the arrival of the Greens, it was in Grenoble that the first French "écoquartier" was built (ZAC de Bonne, in 2003). Grenoble is also the first city in France to have adopted a Climate Plan, in 2005. The city has reduced its GHG emissions by 25% between 2005 and 2016 and is working towards a 50% decrease by 2030 (European Commission). In 2019, a Metropolitan Local Climate Air and Energy Plan has been implemented, which aims at reducing energy use by 50% by 2050 (European Commission). In 2020, Grenoble has been designated as European Green Capital 2022, an award that recognizes the efforts made by the metropolis and encourages further environmental policies.

It is no surprise then that the environmental impact of 5G is concerning the municipality of Grenoble. The mayor interrogated the necessity of developing 5G, arguing that it is not useful to connect more and more objects for our daily life and that it will most likely create further inequalities between urban and rural areas (Sportouch, 2020). 5G has become a symbol for the municipality, a symbol to put into question the idea of progress and reconsider the link between technology and well-being.

Some of Grenoble's grassroot organizations, such as the association Handmade Pieces ("Pièces et main d'oeuvre"), have also protested against 5G deployment on ecological and ideological grounds. This is not the first time that Handmade Pieces has protested against technological innovation in the city, as the association was particularly vocal in its opposition to the creation of the Minatec campus in 2004-2006.

5G deployment: a battlefield for the confrontation between the two ambitions of Grenoble

A chaotic development

In this dual urban context, the development of 5G could not be done smoothly. Confrontations between the players for and against the deployment of this technology have necessarily taken place, each wanting to defend its position. In our meeting with these actors, we realized that this was a game of ping-pong that could only lead to a stalemate.

The government has decided which frequencies are allocated to operators in September 2020. This has taken place without anyone having carried out a health or environmental investigation or even asking residents or their elected officials for advice (JDD, 2020). The municipality has not been the only one to complain about this lack of debate and dialogue. Didier Chaminade, regional delegate for Orange also told us.

> Didier Chaminade (Orange): *"Today we are faced with a difficulty which is really local, which is the absence of dialogue."*

Indeed, Orange has opened several sites, including ten in the city center and a few in surrounding towns. Their purely commercial strategy is to only support 5G if they are sure to cover at least 80% of the population of the metropolitan area with 3.5GHz. According to his words, Didier Chaminade explains that Orange has tried to do everything possible pedagogically and is now trying to keep a low profile "so as not to attract lightning", which illustrates the tense context that reigns.

He then explains to us that all work in the city requires a "Prior Statement" ("Déclaration Préalable", or DP), an urban planning document that must be validated by the town hall. According to Didier Chaminade, the municipality of Grenoble uses this tool to refuse any installation of 5G antennas. A DP has in the past already been refused to SFR. For the moment, Orange has been able to turn on its sites without DP but is now stuck in the progress of the 5G project. The company is aware of the need to renew dialogue with local elected officials.

> Didier Chaminade (Orange): *"We know that if we ask for DP we are going to get them retorted. So for now we are completing our coverage, we are locating our next stages of ignition in the Alps. But of course, we will have to go back."*

On the other hand, an elected representative of the metropolis, Florent Cholat, also mayor of Champagnier, tells us that following the DP refusal to SFR, the operator took the town hall to justice and that the antennas did indeed end up being installed. In addition, the

metropolis is in fairly regular contact with Free, SFR, Orange and Bouygues, which shows that the problem is more complex than a simple lack of dialogue.

Following the one demanded by the city of Grenoble, the metropolis has also voted for a moratorium. Florent Cholat explains that it's not just to prevent the 5G installation work.

> Florent Cholat (Grenoble metropolis): *"The wish of the metropolis of Grenoble is close to the city of Grenoble: to warn about the potential drifts of 5G, to challenge questions rather than asking for it to be stopped outright."*

Not having many tools to counter the deployment of 5G, the metropolitan elected officials opposing this technology can however assert the Local Inter-municipal Urbanism Plan (Plan Local d'Urbanisme Intercommunal) that they have available. Indeed, the town hall does not communicate the files on this subject to the metropolis, according to Florent Cholat. *"The metropolis is incompetent in terms of town planning but has a strict Local Inter-municipal Urbanism Plan on the siting of pylons, for example"*. This PLUI has negative aftermaths on the work of the operators since it limits the height of the pylons to 20 meters and therefore prevents them from obtaining sufficient coverage. The latter regularly negotiate with the metropolis to raise the threshold accepted by the PLUI, but elected officials refuse to do so.

Although the city can act on the height of the pylons, it has no opinion to give on the rest of the work. Thus, the only mission in which the metropolis is committed remains that of education. *"It is not in our competences directly but we do a work of accompaniment of the municipalities, of acculturation of the mayors, in the small towns. Because the operators have organized a great vagueness around 5G. We set goals, give back information, acculturate them on the issues that this poses. This is part of the wish voted by the metropolis."* (Florent Cholat)

Thus, the project seems to have reached a deadlock, all the actors wishing to defend their position with the citizens. On the one hand, operators like Orange want to reassure residents about 5G because they complain about the lack of debate on this technology, which is already considered harmful; on the other hand, city and metropolitan elected officials are trying their best to slow down the work in order to take the time to question the usefulness of 5G. However, despite this slowdown, operators are managing to deploy 5G antennas, local elected officials being the only ones to oppose it, and not being supported by other actors at regional or national level.
In this context where everyone thinks that a debate would be beneficial but where no one accepts dialogue, 5G should be analyzed as an ideological and political symbol rather than as the central subject of this battle between operators and local elected officials. .

5G: an ideological and political symbol

In our interviews, we realized that the battle against 5G was joining other battles, and that another technology could have been at the center of this local debate. This is the first criticism that Didier Chaminade tackles when we meet him.

Didier Chaminade (Orange): *"5G is more of a symbol than a real subject."*

Three points should be mentioned: the headlong rush of our society, the ecological issue and finally the matter of surveillance and privacy. For opponents, these three arguments are used.

Eric Piolle, mayor of Grenoble, refers to two of them when he reacts to President Macron's remarks, calling opponents of 5G "Amish". "*We think of three things when we listen to the President of the Republic say that. First, there is this caricature of a neoliberal model which, ultimately, is no longer in tune with the aspirations of society and becomes extremely violent [...] The second is that there is a real question about greenhouse gases. The weight of digital in these emissions is growing, so we need to think about where we are told that the greenhouse gases linked to digital will be doubled.*" (France Info, 2020)

Among all the arguments to oppose 5G, many are present in the speech of the elected of the metropolis Florent Cholat. At the ecological level, the main issue, according to him, is the rebound effect that 5G would necessarily have. Although it is presented as optimizing energy consumption, it would generate overconsumption of data which would in fact cancel out this first beneficial effect. In addition, it tells us that the operators do not take into account the accumulation of all frequencies. *"You don't turn off the antennas of the old generation, you stack the layers. This makes additional energy consumption. In our wish, we indicated that we wanted to eliminate the ADSL and 2G networks"*.
Then, local elected officials also highlight the fact that the government, by hastily selling these 5G bands, would invest in this technology to the detriment of the construction of other infrastructures, such as fiber, necessary under the "France numérique" plan, to link French households. He denounces this poor competition between technologies, in favor of that which would be the least urgent to install.

But the Orange regional delegate sees it as a much larger problem - proving that the issue is not just in 5G -, that of reluctance to technology in general.

Didier Chaminade (Orange): *"The reaction to digital technology, in France anyway, reveals something else: the reaction of civil society to technology. It turns out that digital is the technology that is exploding at the moment and growing the most. It is a bit like the*

octopus is everywhere, so we focus on digital, but overall it's a reaction to technology. In the 1960s, technology was equal to progress while today technology is questioned."

On each of the points mentioned above, Didier Chaminade has his analysis. Regarding the society of always more, he does not understand why elected officials are beating down on operators. *"Operators carry the data, but the data is generated and fabricated, by others. The general public doesn't miss out on making cat videos or filming their weekend barbecue. It's the GAFAM that hook you to your screen to sell time. This is the current digital business model. According to the regional delegate, the problem therefore lies elsewhere, and more particularly in the regulation of consumer behavior. The question goes far beyond the subject of 5G."* Same argument for the question of surveillance. According to him, 5G is only a means of transport, the stakes are elsewhere and taking 5G as a battle will not change anything.

If on these first two subjects, Didier Chaminade is certain that the local elected officials are leading the wrong fight, he believes on the other hand that the environmental problem is real and fully understands the critics. But he wishes to recall certain figures. *"Digital represents 4% of greenhouse gases in human activity, compared to 35% for agriculture, for example. Certainly, there is significant growth and in 10 years this share will perhaps have reached 10% and we must take care of it. But our challenge is therefore to reduce our environmental footprint, while dealing with data volumes that increase by 40% each year. You understand the paradox we face."* Thus, if energy consumption continues to grow, the switch from 4G to 5G could have an advantage, that of dividing by 20 the environmental footprint of mobile networks. As for the use of terminals, the problem is, once again, not so much 5G but rather demand from French consumers, who already change phones every 24 months on average.

Therefore, he believes that all of the criticism about 5G is in fact indicative of a relentlessness against the technology in general.

Didier Chaminade (Orange) : "*Since it's a symbol* [5G] *and we have it on hand, it's practical. Eric Piolle does not hide it, he is against the ever-growing consumer society.*"

This question of 5G as an ideological and political symbol makes all the more sense as it takes place in a very particular French political context. Indeed, one year before the national elections, Eric Piolle does not hide his presidential ambitions. Therefore, it is legitimate to wonder if 5G in Grenoble, presented as a local battle, is not in reality the playground of politicians, that will divide at the national level.

Conclusion

In this chapter we have studied the controversies and tensions surrounding the rollout of 5G in Grenoble. On paper, Grenoble is a city where 5G development could have been seen as the logical next step in the history of the city. Grenoble is one of France's main innovation clusters and the city hosts many research labs and industries developing 5G or willing to benefit from the new technology in order to stay competitive on the European scale. For more than a century, Grenoble has been an example of the Triple Helix model, with a very strong collaboration between the academia, the industries, and the municipality. However, 5G deployment has led to controversies in the city. This is because Grenoble is not only a "tech city", but also a metropolis with environmental ambitions. Since 2014, the Green municipality has transformed the city and tried to set up ambitious targets for the ecological transition. Moreover, 5G has revealed and exacerbated broader tensions regarding technological progress and its role in societal improvement.

Today, we can see in the controversies surrounding 5G the confrontation between those two ambitions of Grenoble. 5G has become in the city, and in France in general a political symbol. Anti-5G actors see in the 5G technology a symbol of the consumer society and of the negative impacts that technology has on the environment. To make a larger political claim, the municipality of Grenoble has attempted to stop 5G deployment in the city, and by doing so, has taken up competences that it does not possess (as the deployment of mobile networks is a State's competence). We can thus see in Grenoble an example of conflicted urban governance: a local authority which refuses the 5G but cannot effectively oppose the deployment. 5G also revealed the fragilities in the Triple Helix model of the city, with the municipality going against the wishes of the academia and the industries. But ultimately, we could say that this attempt to oppose 5G did create a deadlock for the operators, which have slowed down the rollout in Grenoble, but all actors in the city are aware that this is only a temporary situation. In the end, 5G will be developed in Grenoble, it is only a matter of time.

Conclusion

5G, a singular technology driving change

The place of 5G in the urban space environment

Before digging into the complexity of 5G networks and their mode of governance, one can already draw conclusions on its specificities as a material object. These aspects are indeed relevant to mention as they have consequences on the governance of this technology in cities.

5G antennas are part of the urban environment, and their visibility makes them components of the public space. Despite the generic name “5G antenna”, there are several types of it, depending on their wavelength, their location and the way they are inserted into the urban environment. Overall, 5G programs are deployed in specific contexts this research tried to analyze. As the geo-functional study on 5G antennas in Switzerland showed, antennas serve different purposes depending on their location. We observed that they are more concentrated in city centers, where they serve individual uses, while there are fewer antennas serving a productive economy. Another example is the way antennas were deployed in Barcelona’s pilot project: in the case of the 5GCity program, they have been first located in Poblenou, a district recently transformed and developed as Barcelona's showcase for businesses and capitals. In this context, 5G antennas are integrated in an environment of technical innovations, alongside modern buildings, digital companies and attractive pedestrianized zones.

Thus, the materiality of 5G also calls our attention to the fact that 5G devices pose an unconventional problem in terms of spatial impact on the city. Antennas are not infrastructures that consume a large part of urban land. They don’t add pressure on the scarcity of available space, as buildings, transport installations or other facilities may do. The social tensions they crystallize are a matter of mistrust of populations towards political and economic institutions. One of the important characteristics of 5G antennas that make them subject to such conflicts and tensions is that as infrastructures, they are part of the city. They are visible and tangible. But their effects on the local environment (be it economic or sanitary) are still unknown.

The object itself has become a symbol that epitomizes social conflicts, fears, but also fantasies: one could have in mind the various conspiracy theories that emerged around 5G in 2019 and in 2020. 5G antennas were subject to degradation in many European cities in protest. The introduction of 5G, whose impacts are still uncertain, also puts forward risks of deteriorating the quality of life. The logic is not about classical NIMBYism since the technology is not refused for nuisances like noise, space occupation, functional disturbance etc. It is refused for the fears it embodies, in terms of potential health consequences or various effects. Such a fear can be attributed in great part to the doubt casted by the lack of

transparency in the technical debate that 5G represents. We could then assume that such gaps provide a fertile breeding ground for the rise of conspiracy theories.

On another level, the 5G antenna symbolizes an important aspect of smart city strategies. It is part of most projects and plans designed by municipalities or companies to develop digital networks and data driven policies. This is particularly visible in the cases of Helsinki and Stockholm, where digital technologies are expected to improve the quality of life. In London and Barcelona, 5G antennas are implemented in contexts where it is presented as a factor of acceleration of future policies based on technology. This idea can be criticized in the sense that urban authorities hope to get more data on their city, have better knowledge about it, and make better decisions. But it has yet to be confirmed that 5G can actually improve the governance of cities.

What is certain, however, is that this generation of cellular networks opens the door to a transformed urban environment including remote-controlled vehicles (automated cars, buses…), smart poles with sensors providing all kinds of information (weather, pollution…), IoT devices etc. Such innovations indicate other material consequences yet to come after the deployment of 5G in cities. But it is too uncertain to assert whether or not it will have a significant impact on urban mobility, residential issues or even ecological transition.

This latter theme is of utmost importance. As most antennas are located in urban areas, 5G makes cities even more crucial actors to ensure that this technology develops in a harmless way for socio-environmental ecosystems. The potential environmental impacts of 5G technologies are huge in terms of CO2 emissions, notably in case of rebound effect. Hence, even though the deployment of these networks is limited to some local areas, the impact it has on the environment is global. Drawing some conclusions for future urban governance, we can say that cities are both a place where CO2 emissions are generated, but thus also a place where public policies regarding climate change are even more relevant. What matters is the use of 5G that is going to be made, and cities have a great role to play in this. In that sense, this report does not have the ambition to study the environmental impacts of 5G. Instead, it provides tools that enable us to understand the way 5G is actually implemented, thus foreshadowing the kinds of energy consumption and energy benefits related to 5G. Specialized reports on the environmental impacts of 5G can therefore be considered complementary to this work.

The stakes of 5G in urban policy

For urban policy-makers, 5G represents two major stakes: firstly, it holds an ambivalent relation with technique, and secondly, the new technology crystallizes several uncertainties on different aspects of the urban environment.

The 5G technology is a good example of an innovation which divides urban actors because of its ambivalent relation with technique, which makes some actors question whether 5G is wishable for the city, while others praise it for the progress it would bring. On the one hand, pro-5G actors have huge hopes that 5G would be key to reinforce the competitiveness of cities. Those actors have very high faith in 5G and in the benefits of technological

progress. For instance, in Helsinki and Stockholm, the development of 5G has been supported by all public and private actors, because both the municipalities, the two telecommunication leaders Nokia and Ericsson, and the local ecosystem of universities, research labs and start-ups, saw in 5G the future of the local business. 5G is anticipated to be beneficial for the city's economy and for its international position. Moreover, the faith in progress means that any potential problem with 5G could be overcome in the future when new innovations will appear.

On the other hand, 5G is a technology which still has many unknowns, hence some urban actors are reluctant to develop it. There is notably a lack of precise knowledge about the sanitary impacts of 5G, on both human and non-human health. Facing this lack of certainty, some actors invoked the precautionary principle to oppose 5G deployment. For instance, in Grenoble, the urban authorities try to stop, or slow down, the rollout of 5G, partly because the different researches on the impacts of 5G (conducted at the national level by the Anses, the ANFR, and the Ademe) are not completed yet, and the rollout started before the first conclusions of the findings were made public.

As a consequence, 5G gathers many uncertainties concerning policy development. The question can be raised of its compatibility with an already complex urban environment, which admits a myriad of factors. Firstly, there is an economic uncertainty regarding 5G. For now, no one can tell if 5G will be a flop, the biggest innovation of the decade, or a moderate asset since we are still in the early stages of the rollout in most cities, and commercial use is still limited. For instance, in Helsinki and Stockholm, urban actors were very keen to develop 5G as soon as possible, even if the municipalities do not know yet what will be the uses for the technology. More innovations are expected in the future, but nothing is certain regarding the benefit or the feasibility of those innovations; nonetheless, the authorities have decided to launch 5G first, and see what can be done more concretely with it later. Moreover, it is difficult to tell at this stage the consequences of being "late" at developing 5G in the city: it is only in the long-term that we could see if a late deployment had a negative impact on the local economy or no impact at all.

5G also represents a democratic uncertainty. In all our case studies, 5G has been implemented without prior consultation of the citizens or democratic debate, whether at the local or national levels. In most cities, this did not result in particular controversies regarding the rollout, while in others, there have been huge tensions arising in part from this lack of democratic process (e.g., Grenoble). The absence of controversies in certain cities seem to be due to the particular culture of the country, notably the relationship between citizens and public authorities. For instance, in Helsinki and Stockholm, the citizens usually trust their governments, which in return have strict transparency policies, thus minimizing tensions.

Finally, there is a lot of uncertainty concerning the environmental impacts of 5G. The reports that have been made on the question are often contradictory depending on the authors, or the scopes taken into account in the analysis. Operators insist that producers and consumers are mostly responsible for the volume of data consumed and that they are just providing a service. They also highlight the fact that 5G is more energy efficient than 4G. But the real environmental impact of 5G is still unknown. There are risks that 5G will provoke a rebound effect and that many waste will be generated because the terminals will need to be

replaced. Besides, even if 5G leads to energy gains, one should keep in mind that 4G and the other generations will not disappear in the near future, 5G will just be added to the existing network, thus increasing the energy bill of cellular networks.

A matter for urban governances

In the course of this investigation, we have seen how this technical innovation raises its own issues. Similarly, the characteristics of 5G make its deployment a challenge for urban governance. While the debate around 5G transmitters network is transversal and fragmented between levels of governance, the economic, socio-ecological, technical and democratic challenges it poses highlight the need to revisit the way in which 5G, and numeric technology in general, is being deployed.

A fragmented governance

Throughout this study, we realized to what extent 5G was developed in a fragmented governance between different levels of public action.

At the European scale, the European Union is a level of action at which the strategic priorities around this new technology are established. It is within these instances that main holistic priorities related to the development of digital technologies are set, at least in a discursive way. Indeed, in addition to the strategic action plan, Europe is funding, through research programs, pilot projects aimed at demonstrating the effectiveness and applicability of 5G technology in urban contexts. As we have seen with the steps initiated in the context of 5G Barcelona, these initiatives cover a wide range of applications and give rise to decentralized cooperation programs between European urban authorities.

Despite this, it is important to bear in mind that 5G network development in urban areas is taking place in distinct national contexts. Whether or not they are member states, this level of governance is central to the development of a digital strategy. Even if we can observe real recurrences from one national space to another, such as the presence of an oligopolistic market of operators deploying 5G or the prospective arguments put forward by the authorities to justify the deployment, we can note clear divergences. Undoubtedly to a greater extent than at the supranational level, it is at the state level that priorities and modalities of 5G network deployment are established. Let us note that these modalities are embedded in national normative contexts more or less restrictive. These elements explain disparities that can be observed from one national space to another in terms of cellular network deployment status, choice of transmitters and relations with local authorities. In addition, these differences can lead to duplication in the delivery of strategic programmes. As we have seen with the pilot projects developed in the chapter on Barcelona, some initiatives aimed at demonstrating the benefits of 5G, although framed by the European Union's research programmes, admit of duplication from one national context to another.

Finally, the local level is the closest level of governance for the implementation of a 5G network in territories. Therefore, cities are at the forefront of the concrete difficulties in the implementation of this technical network. This is indeed where debates around 5G get out of the technical sphere and where emitters are incorporated in substantial urban layouts with their social, environmental and infrastructural complexity. Hence, the antenna rollout in urban contexts mobilises a greater community of stakeholders whose stakes on 5G can be quite divergent. Sometimes, views of the main governance actors are aligned and the development of 5G is the fruit of urban coalitions for projects on territories, like we have observed in the Barcelona, Stockholm, and Helsinki cases. In other contexts, such an alignment is absent and diverging views on 5G antennas may be at the core of controversies between actors.

In our enquiry, we have seen that 5G also needs to be understood through interactions between levels of governance. Most of the time, the deployment of 5G is embedded in pre-existing settings. Whereas this could be a matter of institutional conflicts between the different levels, between the city and the State as we have seen in both Grenoble and Geneva, the technology could also be understood as a way to establish the urban area as a frontrunner compared to the heavy, slow and heterogeneous national level. By doing so, local authorities establish the importance of their territories in the national context.

5G related controversies hence successively percolated in a top-down manner from national and international levels to the more local one, in cities. At this stage, the debate on 5G takes a different shape and intrinsically moves out of the technical sphere to be confronted by other actors and institutions within the city. It is quite paradoxical since most of the decisions were already taken beforehand, hence creating institutional, economic and technical deadlocks difficult to question right before the deployment.

Beyond the vertical interplay between layers of the multilevel governance, 5G controversies may also be understood on a horizontal axis independently from the scale of action. From the analysis of the contexts studied as well as the literature review, horizontal dynamics at play are relatively similar regardless of levels of actions.

The development of 5G technology has to be understood in a context of global competition between companies, but also between territories and supralocal entities. At the international level, controversies largely covered by the literature raised between nation states, companies and other international actors: one may have in mind the controversies raised by the Huawei ban in several countries, and more generally the competition between industrial champions making 5G emitters are structuring horizontal relations.

At a local scale, horizontal interactions could be structuring for urban governance around those issues. On the one hand, some urban contexts encompass a real symbiosis between main actors of the governance around digital matters. It is worth noting that the circle of actors involved on numeric issues are rather closed. Whereas some urban actors tend to be excluded from those considerations, in the forefront of which are the citizens, others engaged in such a policy development tend to be on the same page regarding their perception on the assets it would bring to the territory, but also to their own agenda. Such a convergence has been observed in Helsinki and in Stockholm, in which actors are developing 5G to

achieve specific agendas on open data and environment.
On the other hand, governance processes can also be theatres of conflicts and oppositions. This induces both divergences between actors on the way 5G networks should be developed, but also on the 5G technology in itself. As opposed to the global trend putting forward 5G as an absolute necessity to foster the economic competitiveness of the territory, they tend to question the absolute need of this technology. Whereas the ones in favour of an unconditional rollout tend to link technological innovations with a global improvement in various fields, the more sceptical tend to have a more balanced view on this. Even if we can find the corollary of 5G beatism within the community of 5G sceptical actors, whose views are categorical on the dangers provoked by this new technology, some others tend not to question 5G, but the way it is being rolled out.

When analysing horizontal interactions between actors, we have identified a recurring trend towards a weakening of the public sector in the governance of 5G in most of the urban contexts. The rollout of the network seems dictated by agendas pursuing territorial competitiveness: 5G is, for most of the actors we analysed, an essential tool, a service, to attract new businesses. The logic applied is the fear to lag behind other territories: not developing 5G may indeed be a risk taken if other competing territories would do so. Developing 5G is then an imperative to respond to the (potential) needs of the existing (and potential) economic ecosystem rather than a concerted and planned strategy in the long term. Whatever the territory is, the same supposed technical enhancements are put forward to justify this innovation: besides the economic argument, 5G is an angular stone for the smart city and the development of IoT, autonomous vehicles and other innovations supposed to change how the city is organised.

In the course of our study, we observed that controversies and debates around the 5G technology, but also the absence of debates in some contexts, could be understood by taking a step back and having in mind the actors' perception regarding technique and technologies.

On the one hand, unconditional supporters of the 5G technology have a strong belief that such a digital technology would be a major game changer for issues at stake in urban contexts. Grounded in many policy but also business discourses, this technological optimism put forward the intrinsic link between innovation and improvement. Technique, which includes 5G, is an unquestionable imperative for human development. On the other hand, opposition against 5G is embedded in a wider opposition towards technique, perceived as a destructive item for socio-ecological environments. This is both at the local and at the global level: besides the potential impact of 5G waves, emitters and 5G-compatible devices manufacturing and use induce a higher consumption. Relying on both solid and more fictitious arguments, this technical skepticism on 5G may find part of its source in the way the debate is framed in the contexts studied, which tend to be both technical and restricted to a limited circle of actors operating in the city.

By comparing different fields, we observed a trend towards a dichotomisation of the positions in 5G related debates. Actors involved tend to take strong stances on one side or on the other, hence leaving narrow room for a balanced position. In that respect, this may be a

potential area for improvement in the role of public authorities which could act by seeking compromises and ensure a parsimonious rollout of 5G. Such a position induces, by extension, a renewed way to govern the implementation of digital technology within territories.

Challenges for the governance of cities

5G is here, so what?

As we observed in the fields, the 5G roll-out has already been decided and negotiated with telecom operators in most European countries in a context of a race to benefit from this digital enabler supposed to foster economic development. Besides the pilot projects carried out since 2014 and the H2020 programme, 5G antennas are currently being installed in European urban contexts following the greenlight of national authorities. Such top-down decision making created conditions for institutional, economic and technical locks hence dodging any possibility for public debate and contestation at other levels. Nonetheless, this way to develop numeric infrastructures is not without difficulties and tends to be confronted with the urban materiality but also the socio-economic fabric. Where to install those antennas? How to involve impacted local actors, including citizens, in the process of equipping cities with a 5G network?
Besides, one needs to have in mind the environmental consequences of an uncontrolled development and usage of this technology that still relies on fossil fuels, in a sector with an increasingly large carbon footprint. This indeed raises the question of parsimoniousness. How can 5G fulfil promises regarding environmental constraints? How to think and implement policies to control and account the usages of the 5G technology?

These elements imply taking into account a whole range of certainties and uncertainties. Whereas some implications of 5G are already known regarding the environmental but also economic impacts of the 5G, some others are yet uncertain and have to be carefully accounted to enable 5G to keep its promises but also to ensure a clever use of this innovation, putting it at the service of economic but also socio-environmental progress. In that respect, it seems imperative for public authorities, both at the local and at the national level, to enable informational empowerment of all actors, but also letting room for manoeuvre for action.

Towards a paradigmatic shift?

For urban governance, the deployment of 5G technology in the urban fabric points out real shortcomings regarding decision-making on topics related to digital technologies. Indeed, the criticisms addressed to smart cities find a particular resonance in the study of 5G rollout and controversies in urban contexts. Whereas the decisions regarding frequency band attributions, emitter suppliers and network management tend to be taken in a technocratic manner inside rather exclusive circles of actors, the techno-solutionist approach prevents any questioning of potential technical deadlocks. In addition, and maybe as a consequence, such a policy agenda escapes public open debate and prevents itself from contradiction.
5G may well be strategic for the attractiveness of the territory... But in whose eyes? At what

price? The controversies we focused on demonstrate that adhesion to such technologies is not a given. Actors' engagement is key. Those elements underline the need for a renewed paradigm in the way urban governance around the development of numeric technologies must be settled. Besides enabling an increase of vertical and horizontal cooperation with all actors impacted by such a rollout, it seems relevant to question the notion of improvement related to technological innovation. What improvement are we seeking? What are their side-effects? In that regard, imposing top-down decisions in the name of a strategic agenda or acting accordingly to the actor's market interests seems to be inefficient.

Opening the black box of 5G and fostering a strategic vision

5G deployment fosters challenges for vertical interactions between levels of public action. Whereas national actors tend to have the technical, institutional but also financial tools to decide how to develop 5G networks in the city, local actors are the ones who are the most concerned by the actual implementation of such objects. In this research, the mismatch between decision-making and 5G network installation in urban territories has demonstrated its weaknesses. In that respect, it may well be that implementing more flexibility and subsidiarity in the way decision making is carried out for both digital networks strategic thinking and installation would turn out to be useful for a balanced deployment of the technology considering local specificities and socio-environmental constraints. This would involve opening the 5G black box and allocating 5G policy components to different levels: whereas broad strategic decision may well be taken at the European level (or at the national one), some concrete parameters related to antenna location, exchanges with 5G users and public informational empowerment could be designed in more local contexts.

Moreover, we have seen how horizontal dynamics are unbalanced in favour of a market-centred vision consisting in developing 5G at any cost to foster territorial competitiveness, attract new businesses and respond to an assumed customer demand. By doing so and by paving the way for subsequent, yet potential, technical digital innovations, 5G rollout is justified. However, is that what improvement means? This is obviously an axiological question to be answered. To do so, governance at the national level, but maybe more at the local level, has an important challenge ahead: how to define collectively what improvement is? Whereas the economic vision tends to prevail until now, the rise of technical skepticism and the actors who invite themselves into the debate are like incentives to go beyond this approach. On that point, the role of public authorities could evolve: instead of being economic enablers fostering innovation at any cost, they could be engines for a translation from a technical innovation to substantive improvements. In other words, politics induce a strategic vision and implies bridging the gap between what 5G is as an innovation, and what 5G should be as an improvement. Moreover, public authorities could also be seen as guardians of the common good. Consequently, they could be facilitators of a democratic debate to get all actors engaged, to foster parsimonious uses of digital networks and finally to facilitate the building of a desirable direction in such technological juncture.

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Appendices:

Appendix 1: Interviews carried out

Focus	**Actor interrogated:**	**Date:**
Geneva	Diego Alan ESTEBAN - *Geneva Grand Conseil vice-president*	14/05/2021
Geneva	Emmanuel DEONNA - *Geneva Grand Conseil member*	17/05/2021
Barcelona	Neda KOSTANDINOVIC - *International Relations Projects at the Office of the Chief Architect of Barcelona*	04/03/2021
Barcelona	Eduard MARTIN – *Director of the 5G program at Mobile World Capital Barcelona*	25/05/2021
Barcelona	Federico RUIZ - *5G National Observatory Spain*	25/05/2021
Barcelona	Sergi FIGUEROLA - *Founder and CTO of the 5G Barcelona Alliance*	28/05/2021
London	Syed ASAD - *PhD in Electronics and Electrical Engineering, University of Glasgow*	03/03/2021
London	Pepe MONROY - *Urban Planner for TfL*	08/03/2021
London	Sebastien HERMAN - *Digital Urbanist, Connected Places Catapult*	27/04/2021
London	Becki CLARCK - *Senior Consultant, Perform Green*	04/05/2021
London	*Connected London team*	09/06/2021
London	Samuel MUTTER, *Birkbeck, University of London*	13/06/2021
Grenoble	Didier CHAMINADE - *Delegate at Orange (major French telecom group) for the Alps area and President of Inovallée, an innovation cluster located in the Métropole*	06/05/2021
Grenoble	Florent CHOLAT - *Mayor of Champagnier and advisor at the Métropole de Grenoble for digital development, digital innovation and public*	11/05/2021

	management of data	
Helsinki & Stockholm	Juha SALMELIN - *Nokia Ecosystem Leader for the LuxTurrim5G Project in Espoo (a joint research initiative aiming to develop smart poles with sensors functioning through 5G technology)*	10/05/2021
Helsinki & Stockholm	Benoît GUFFLET - *co-author of the report* Across the Blocks*, which analysed different smart cities across the world including Helsinki and Stockholm*	10/05/2021
Helsinki & Stockholm	Viktor ARVIDSSON - *Europe director for Ericsson*	11/05/2021
Helsinki & Stockholm	Kalle TOIVONEN and Tapani NEVANPÄÄ - *City of Helsinki, Economic Development Division (Innovation and New Experiments Unit)*	12/05/2021
Helsinki & Stockholm	Anders BROBERG - *Senior Advisor Smart City at the City of Stockholm* Per-Olof GUSTAFSSON - *Senior Advisor at Stokab (City of Stockholm's IT Infrastructure Company)*	25/05/2021

Appendix 2: Quantitative analysis methodology for Geneva

The following operations enabled an understanding of the 5G rollout in the Swiss territory. In all the steps, the location of 5G antennas is the independent variable that will be confronted to the location of various kinds of economic infrastructures, types of urban land occupation as well as socio-economic data drawn from census.

After an analysis of the whole Swiss territory, we zoomed our attention on the main Swiss municipalities (the ones that publish, every year, socio-economic statistics) by computing another EFA using the data gathered for antennas in which Voronoi cells intersect municipal boundaries. To have a better understanding of the phenomenon at stake within cities and to make a classification of antennas, we used the maximum-likelihood method by imposing an orthogonal rotation. Factors drawn are then not correlated from one another and the phenomena studied are clearer to analyse.

Once factor scores were established, we identified the factor profiles of some cities and we carried out multiple linear regression analysis (MLR). It enabled a more fine-grained understanding of the driving forces influencing 5G antenna location within cities. For MLR, whereas factor scores have been used as dependent variables, the census data were the independent variables.

Appendix 2.1 - Geospatial analysis

To carry out the geospatial analysis, two databases have been mobilised: the Corine Land Cover (CLC) European dataset, that maps all European land occupation, and the Open Street Map (OSM) database, a crowdsourced initiative mapping the entire world thanks to citizen's contributions. Whereas three kinds of land occupations have been kept from CLC for the analysis, eleven kinds of economic infrastructures have been downloaded from the OSM dataset. Once geodata points downloaded and cleansed, we carried out dimension reduction techniques to identify dimensions and factors to put forward the trends structuring the development of 5G antennas in Switzerland first (PCA) and in the main Swiss cities (EFA).

Appendix 2.1.1 - List of OSM variables used

Code	n	k	Description
osm_accomodation	5058	12	Hotels, hostels, Apartments, Motels, Guest houses, Houseboats, Bungalows, Caravans, Cabins, Chalets, Caravan sites, Alpine huts, Dormitories
osm_catering	24174	56	Sustenance - like bar, bbq, biergarten, cafe, drinking water, fast food, food court, ice cream, pub, restaurant
osm_culture	5860	14	Entertainment, art and culture: Cinema, theatre, club, casino, planetarium...
osm_education	9025	21	College, kindergarten, library, archive, public bookcase, school, music school, language school, university, research institute
osm_industry	3347	8	Predominantly industrial land uses such as workshops, factories or warehouses
osm_offices	3063	7	A place of business where administrative or professional work is carried out
osm_publicservice	1865	4	Courthouse, Fire stations, Hospitals, Police Stations
osm_shops	32704	75	Place of business that has stocked goods for sale
osm_sports	19140	44	Facilities for sport activities, and piste related facilities
osm_tourism	1211	3	Places and things of specific interest to tourists
osm_transports	32202	74	Bus stop, train stop, tram stop, trolley stop, airport, ferry

For the OSM data, we measured the mean of the distance to the k nearest infrastructures, k being calculated according to the number of infrastructures per antenna, and the number of infrastructure in each category. To reduce skewness and kurtosis, to have as normal as possible data, we transformed all those variables by using a cubic root function.

$$k_x = n_x\left(\frac{n_{infra}/n_{antennas}}{n_{infra}/N_{infra}}\right)$$

- ➔ ***k_x*** is the number of nearest infrastructure “x" to calculate around each 5G antenna;
- ➔ ***n_x*** is the overall number of infrastructure “x”;
- ➔ ***n_infra*** is the overall number of infrastructures (137649);
- ➔ ***n_antennas*** is the number of 5G antennas (4765);
- ➔ ***N_infra*** is the number of different kind of infrastructures.

Appendix 2.1.2 - List of CLC variables used

Code	Description
clc_continuousurban	Most of the land is covered by structures and the transport network. Building, roads and artificially surfaced areas cover more than 80% of the total surface. Non-linear areas of vegetation and bare soil are exceptional.
clc_discontinuousurban	Most of the land is covered by structures. Building, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces.
clc_industrial&commercial	Artificially surfaced areas (with concrete, asphalt, tarmacadam, or stabilised, e.g. beaten earth) without vegetation occupy most of the area, which also contains buildings and/or vegetation.

For the CLC data, areas have been gridded in 4km² hexagons: the distance from the nearest ones has been used as a variable.

Appendix 2.2.1.3 - Swiss 5G antennas factor profile Factor 1 and Factor 2 composition

Factor	Positive loadings (>0.3)	Negative loadings (<-0.3)

1	**osm_education (0.97)** **osm_shops (0.95)** **osm_sports (0.93)** **osm_catering (0.93)** **osm_transports (0.93)** **osm_offices (0.92)** **osm_culture (0.90)** **osm_publicservices (0.88)** **clc_continuousurban (0.81)** **osm_industry (0.72)** **clc_industrial&commercial (0.70)** osm_tourism (0.69) osm_accomodation (0.65) clc_discontinuousurban (0.52)	
2	osm_industry (0.46) clc_ industrial&commercial (0.34)	osm_accomodation (-0.55)

Appendix 2.2.1.4 - Swiss 5G antennas factor profile Factor 1 and Factor 2 composition

Code	Inhabitants	Name
261	409241	Zürich
6621	200548	Genève
2701	171513	Basel
5586	138905	Lausanne
351	133798	Bern
230	110912	Winterthur
1061	81401	Luzern
3203	75522	St. Gallen

5192	63494	Lugano
371	54640	Biel/Bienne
942	43743	Thun
5002	43181	Bellinzona
355	41507	Köniz
6421	38625	La Chaux-de-Fonds
2196	38521	Fribourg
2939	36332	Schaffhausen
6643	35132	Vernier
3901	35038	Chur
6266	34599	Sion
198	34516	Uster
6458	33578	Neuchâtel
6628	31942	Lancy
1024	30682	Emmen
1711	30205	Zug
5938	30143	Yverdon-les-Bains
191	28141	Dübendorf
243	27079	Dietikon
1059	26997	Kriens
3340	26989	Rapperswil-Jona
5886	26574	Montreux
4566	25442	Frauenfeld
293	24536	Wädenswil
121	24513	Wetzikon (ZH)
1701	24322	Baar
6630	24144	Meyrin
3427	23768	Wil (SG)

2125	22709	Bulle
295	22514	Horgen
6608	22336	Carouge (GE)
4671	21801	Kreuzlingen
4001	21268	Aarau
2703	21244	Riehen
5591	21036	Renens (VD)
2762	20913	Allschwil
4045	20721	Wettingen
5724	20533	Nyon
66	19978	Opfikon
53	19888	Bülach
5890	19827	Vevey
62	19408	Kloten
4021	19175	Baden
2773	19144	Reinach (BL)
6631	18977	Onex
131	18803	Adliswil
247	18760	Schlieren
199	18693	Volketswil
2581	18389	Olten
96	18317	Regensdorf
1630	18247	Glarus Nord
6136	18174	Martigny
3443	18171	Gossau (SG)
5590	18160	Pully
141	17857	Thalwil
2770	17805	Muttenz

6153	17563	Monthey
363	17546	Ostermundigen
2546	17140	Grenchen
296	16975	Illnau-Effretikon
6248	16860	Sierre
2601	16703	Solothurn
1702	16571	Cham
2831	16388	Pratteln
404	16280	Burgdorf
1322	16269	Freienbach
4082	16078	Wohlen (AG)
5113	16012	Locarno
69	15939	Wallisellen
5642	15838	Morges
939	15816	Steffisburg
3001	15780	Herisau
329	15639	Langenthal
2765	15580	Binningen
1301	15550	Einsiedeln
1372	15000	Schwyz
5254	14914	Mendrisio
306	14887	Lyss
4401	14537	Arbon
158	14435	Stäfa
154	14307	Küsnacht (ZH)
2829	14269	Liestal
6640	14091	Thônex
156	13999	Meilen

1058	13915	Horw
4280	13606	Oftringen
1054	13531	Ebikon
4461	13462	Amriswil
138	13454	Richterswil
4258	13337	Rheinfelden
6644	13329	Versoix
6002	13109	Brig-Glis
5721	13078	Gland
356	13058	Muri bei Bern
161	12983	Zollikon
3408	12849	Uzwil
768	12707	Spiez
6711	12625	Delémont
3271	12612	Buchs (SG)
616	12533	Münsingen
1632	12521	Glarus
5635	12488	Ecublens (VD)
2769	12203	Münchenstein
118	12157	Rüti (ZH)
2	12146	Affoltern am Albis
6623	12131	Le Grand-Saconnex
2228	12114	Villars-sur-Glâne
5589	12110	Prilly
1362	11877	Arth
177	11864	Pfäffikon
6612	11862	Chêne-Bougeries
4040	11788	Spreitenbach

5889	11752	La Tour-de-Peilz
52	11655	Bassersdorf
4289	11561	Zofingen
3251	11549	Altstätten
861	11439	Belp
627	11394	Worb*
4946	11388	Weinfelden
362	11335	Ittigen
2771	11221	Oberwil (BL)
117	11199	Hinwil
4095	11129	Brugg
4254	11004	Möhlin
4436	10969	Romanshorn
155	10957	Männedorf
3851	10937	Davos
6633	10697	Plan-les-Ouates
3402	10551	Flawil
1707	10515	Risch
2937	10454	Neuhausen am Rheinfall
2766	10410	Birsfelden
6436	10389	Le Locle
361	10314	Zollikofen
2761	10237	Aesch (BL)
1407	10236	Sarnen
4201	10173	Lenzburg
4012	10154	Suhr
5401	10131	Aigle
546	10079	Münchenbuchsee

1103	9900	Sursee
1708	9875	Steinhausen
250	9783	Urdorf
5822	9699	Payerne
3215	9418	Rorschach
1201	9273	Altdorf (UR)
2763	9202	Arlesheim
2534	8875	Zuchwil*
5624	8645	Bussigny
1509	8411	Stans
2275	8222	Murten*
5250	8182	Chiasso
5583	8037	Crissier
6297	7891	Visp
700	7477	Moutier*
6800	6809	Porrentruy*
6412	5825	Peseux*
3101	5809	Appenzell*
6300	5643	Zermatt
581	5592	Interlaken
3787	4994	St. Moritz
723	3698	La Neuveville*
3921	3185	Arosa*

Appendix 2.2.5 - Swiss urban 5G antennas factor profile - Factor 1' and Factor 2' composition

Factor	Definition	Positive loadings (>0.3)	Negative loadings (<-0.3)

1’	5G antennas which are located with urban centres with a high level of accessibility to services (Variance explained = 0.45)	**osm_catering (0.96)** **osm_shops (0.89)** **osm_accomodation (0.87)** **osm_culture (0.78)** **osm_transports (0.71)** **osm_office (0.71)** osm_publicservices (0.69) osm_education (0.66) osm_tourism (0.64) clc_continuousurban (0.64) osm_sports (0.61)	
2’	5G antennas in mixed business and industrial areas on the urban outskirts (Variance explained = 0.23)	**osm_industry (0.71)** osm_education (0.68) osm_sports (0.66) osm_transports (0.57) clc_ industrial&commercial (0.54) osm_offices (0.50) osm_publicservices (0.48) osm_culture (0.44) clc_discontinuousurban (0.44) clc_continuousurban (0.38) osm_shops (0.35)	

Appendix 2.2 - Multiple regression analysis

Multiple linear regressions identified trends observable in Swiss cities. For the dimensions 1' and 2', computed successively as dependent variables, we confronted a range of socio-economic data available for all the main Swiss cities. F1' and F2' were determined by the mean of 5G antennas F1' and F2' values in each city, weighted by the share of the corresponding Voronoï cell in the municipal territory.

For some of the independent variables, we mobilised a dimension reduction technique (PCA) to get a more synthesized analysis. For the dimension related to age groups, cities with high values tend to get a more aged population. For jobs, component 1 puts forward the trends in the occupational structure, opposing blue collar workers with white collar workers, and component 2 is understandable as the presence of the primary sector, or not. Components related to establishments are showcasing the establishment composition, opposing small-sized to medium sized establishments on the one hand (dimension 1), but also the presence of big sized companies on the other hand (dimension 2).

Appendix 2.2.1 - Variable transformations

Appendix 2.2.1.1 - Proportions

Many variables were informed as absolute values. To allow comparison, we transformed them into proportional values by applying the following operation:

Where:

- ➔ is the absolute number of x observations in the commune
- ➔ y is the proportion of x observations among all observations in the commune
- ➔ T is the total number of observations

Appendix 2.2.1.2 - Variable reduction

Components for economic establishments

Component 1: Establishment structure

- Negative: Principally composed by small-sized (less than workers) establishments
- Positive: Principally composed by medium-sized and big sized establishments

Component 2: Presence of big-sized companies

- Negative: absence of big-sized companies
- Positive: presence of big-sized establishment employing more than 250 people

Var	Loadings - etab_d1	Loadings - etab_d2
etab_1_9_p	-0,981	-0,054

etab_10_49_p	0,921	0,169
etab_50_249_p	0,906	-0,291
etab_250p_p	0,617	0,783

Components for occupation repartition

Component 1: Occupational structure

- Negative: Dominantly composed by tertiary sector workers
- Positive: Dominantly composed by secondary sector workers, and primary sector workers

Component 2: Presence of primary sector workers

- Negative: absence of primary sector workers
- Positive: presence of primary sector workers

Var	**Loadings - emp_d1**	**Loadings - emp_d2**
emp_s1_p	0,526	0,850
emp_s2_p	0,956	-0,292
emp_s3_p	-0,985	0,170

Components for age structure

Component 1: Age structure

- Negative: more young generations and families
- Positive: more old generations

Var	**Loadings - cage_d1**
cage_m20_p	-0,326
cage_20_39_p	-0,917
cage_40_59_p	0,565
cage_60p_p	0,869

Appendix 2.2.2 - Variables used for the multiple linear regression

Source	Use	Code	Label
T 1.3	Final	acc_nat_1000	Accroissement naturel - pour 1000 habitants
Authors	Final	cage_d1	Classes d'âge - Component 1
T 3.2	Final	chom_p	Taux au chômage (%)
T 5.3	Final	den_occ_z	Densité d'occupation par pièce
T 1.1	Final	dens_pop_18	Densité de la population 2018
T 1.5b	Final	etr_p	Proportion d'étrangers
T 1.3	Final	mig_1000	Solde migratoire - pour 1000 habitants
T 6.1	Final	nui_1000	Nuitée pour 1000 habitants
T 8.1	Final	tx_soc_2018	Proportion des bénéficiaires parmi la population résidante, en % - 31.12.2018
Authors	Final	emp_d1	Emplois - Component 1
Authors	Final	emp_d2	Emplois - Component 2
Authors	Final	etab_d1	Etablissements - Component 1
Authors	Final	etab_d2	Etablissements - Component 2
T 3.1	Reduced	etab_1_9_p	Établissements - taille des établissements en emplois: 1-9
T 3.1	Reduced	etab_10_49_p	Établissements - taille des établissements en emplois: 10-49
T 3.1	Reduced	etab_50_249_p	Établissements - taille des établissements en emplois: 50-249
T 3.1	Reduced	etab_250p_p	Établissements - taille des établissements en emplois: 250 et plus
T 3.1	Reduced	emp_s1_p	Emplois - secteur primaire
T 3.1	Reduced	emp_s2_p	Emplois - secteur secondaire
T 3.1	Reduced	emp_s3_p	Emplois - secteur tertiaire
T 1.2b	Reduced	cage_m20_p	Classes d'âge – 0-19
T 1.2b	Reduced	cage_20_39_p	Classes d'âge – 20 - 39
T 1.2b	Reduced	cage_40_59_p	Classes d'âge – 40 – 59

T 1.2b	Reduced	cage_60p_p	Classes d'âge – 60+

Appendix 2.2.3: Swiss cities 5G profiles – Multiple linear regression results

Operation for F1' as dependent variable:

lm(formula = Weighted_F1 ~ etr_p + chom_p + den_occ_z + nui_1000 + tx_soc_2018 + dens_pop_18 + acc_nat_1000 + mig_1000 + cage_d1 + emp_d1 + emp_d2 + etab_d1 + etab_d2, data = dt)

Residuals (F1')				
Min	1Q	Median	3Q	Max
-1.6922	-0.2784	-0.0115	0.2132	3.5211

Operation for F2' as dependent variable:

lm(formula = Weighted_F2 ~ etr_p + chom_p + den_occ_z + nui_1000 + tx_soc_2018 + dens_pop_18 + acc_nat_1000 + mig_1000 + cage_d1 + emp_d1 + emp_d2 + etab_d1 + etab_d2, data = dt)

Residuals (F2')				
Min	1Q	Median	3Q	Max
-2.1322	-0.3447	-0.0338	0.2295	1.7340

Swiss cities 5G profiles – Multiple linear regression results

Coefficients	Factor 1'			Factor 2'		
	Estimate	Std. Error	T value	Estimate	Std. Error	T value
(Intercept)	-0,63	0,58	-1,09	0,18	0,68	0,27
Foreigners (%)	-0,01	0,01	-1,04	0,01	0,01	1,02
Unemployment (%)	0,03	0,07	0,47	**-0,11**	0,08	-1,29
Occupancy density - per room	**2,31**	1,10	2,11	0,07	1,29	0,06
Overnight stay - per 1000 inhabitants	0,00	0,00	-3,24	0,00	0,00	11,21

Social minima beneficiaries - 2018 (%)	0,04	0,03	1,57	0,00	0,03	0,00
Population density - 2018	-0,02	0,00	-6,70	-0,01	0,00	-2,50
Natural increase - per 1000 inhabitants	0,01	0,02	0,45	-0,02	0,03	-0,88
Net migration - for 1000 inhabitants	0,00	0,00	0,22	0,00	0,00	-0,52
Age groups - Component 1	0,05	0,05	1,06	**-0,11**	0,06	-1,88
Jobs - Component 1	0,06	0,03	1,85	**0,12**	0,04	3,15
Jobs - Component 2	0,03	0,05	0,54	**0,21**	0,06	3,69
Establishments - Component 1	-0,06	0,03	-2,15	-0,08	0,04	-2,19
Establishments - Component 2	-0,01	0,05	-0,26	-0,05	0,06	-0,86
	Multiple R-squared: 0.4165			*Multiple R-squared: 0.6653*		
	Adjusted R-squared: 0.3676			*Adjusted R-squared: 0.6372*		