ECONOMIC EFFECTS OF INFRASTRUCTURE INVESTMENT AND ITS FINANCING

# The Infrastructure Nexus: From the Future of Infrastructures to the Infrastructures of the Future


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## Abstract

The *Infrastructure Nexus* policy-brief is a response to the call to *re-couple* economic growth and social progress, at the dawn of a global infrastructure tsunami. It highlights the lack of a definitive model of urban/metropolitan sustainability and researches on its impacts for global infrastructure and multilevel governance needs. It emphasizes that while infrastructures are forming a growingly boundless system, piecemeal approaches to developing urban sustainable agendas and projects are still prevailing, overlooking the systemic impacts of urbanisation on biodiversity and ecosystem services, which are also boundless. The first paper of a series that is to be continued, it complements the TF4 policy brief *Building Resilient Infrastructure Systems*, it advocates for a new generation of science-to-society and knowledge-to-policy connectivity to reposition infrastructure investments and value chains. In an era of rising resources limitations and urban growth, the paper outlines the underestimated role of research infrastructures in infrastructure for development policies and it proposes new priorities for a more comprehensive urban agenda within the G20, including biodiversity, with a specific focus on critical regions such as the Amazon and the Arctic.

## Challenge

### 1. What infrastructures for a world of 1,000 metropolis?

In the past twenty years, the role of infrastructures to promote and sustain economic growth has been acknowledged (Calderon and Seven, 2004). After the 2008 financial crisis, infrastructure investments have been pushed as drivers for economic recovery and growth (Yifu, 2012). Sustainability has made its way in the debates between post Keynesian ecological economics and neo classics (Holt, 2010). The need for green, green [1] infrastructures has been emphasized, such as climate friendly railways and waterways, clean and renewable energy projects etc. (ADBI & ADB, 2008, Bielenberg et al., 2016, OECD, 2018).

Along with climate change, urbanization is the other contemporary transformative mega-trend (WBGU, 2016). It goes with metropolisation, a less studied feature of global policy-making (Katz, 2013, Ahrendt et al., 2015, Gomez et al., 2017). Contrary to the vision of a prosperous post Cold-War world of global cities (Sassen, 2001) our world is of more than 4.000 cities of +100.000 inhabitants and 1.000 metro areas of +500.000 inhabitants across the globe (UNDESA, 2016). This complex and conflicting intertwining of local and global scales is both an issue of macro- and micro economics. Many metro-regions surpass countries GDP. And yet, there is no corresponding multi-level governance (Snower, 2019).

With over 70 million more people living in urban areas annually (World Bank, 2018), investment gaps are widening, inequalities are rising (OECD, 2018), territorial and social cohesion is at risk (Fleurbaey et al., 2018). Moreover, land-use policies are massively ailing (Seto et al., 2012; Angel, Galarza et al., 2016) and the ecological footprint of human activities is rising faster than ever before (Boulding, 1966; Meadows et al., 1972; Wackernagel, 1996; Rockström, 2009;

[1] *Green Infrastructures* refer to interventions to preserve the functionality of existing green landscapes (including parks, forests, wetlands, or green belts), and to transform the built environment through phytoremediation and water management techniques and by introducing productive landscapes (IPCC 2014b). This can be termed blue infrastructure if aquatic ecosystems are concerned (European Environment Agency 2017). Source: *Global Research and Action Agenda on Cities and Climate Change Science, 2018*

Sachs, 2015). This is the new normal for infrastructure investments, only that solid evidence about future cities -and corresponding infrastructure systems - is still to be built up.

In the absence of a clear pathway regarding optimal cityshape ensuring equality, sustainability and growth (Salat et al., 2012; Ahfeldt, 2017), communication about off-grid local experiments or the investments in designated smart urban mega projects tends to be overemphasized. In developed countries, the management costs of existing infrastructures are soaring, citizens' reluctance or resistance to new projects is growing. In low and middle income countries, the lack of infrastructures and infrastructure finance threatens long-term growth (Floater et al., 2017).

Following over a decade of loosely coordinated action and policy-making at combined micro, metro and macro-scales (Buchoud, 2019), we have reached a turning point. As illustrated by the Nationally Determined Contributions (NDCs) to reach the Paris agreement and the Voluntary National Reviews of the Sustainable Development Goals, the call for cross-sectoral approach to urbanization and infrastructure development is getting higher on local, regional and global agendas (IISD, 2017, AFD, et al., 2018). It still is to be transformed into applicable policies.

In the transition towards the decoupling of economic growth from carbon emissions (Snower, 2018), a new approach to infrastructure projects is emerging, connecting *hard* and *soft* infrastructures, infrastructure finance and users' behaviors, civil and financial engineering, changing industry processes (WEF, 2017; Kelly, 2019) and the development of inclusive infrastructures (Mc Kinsey, 2016; IDB, 2018). Yet, two problems are not being addressed.

The first one is a confusion between *urbanization* and *urban infrastructures*. Cities and metros need infrastructures, be it about energy, mobility etc. But infrastructures serving interconnected urban areas are metropolitan, national, regional, continental, or even global. They go far beyond city limits yet with no corresponding *urban* governance at those combined scales. Hence, the quest for autonomous off-grid settlements on the one hand (Lemoine, 2014), and the development of new *geopolitical infrastructures* on the other hand, such as the One Belt One Road initiative led by China, with little left in-between.

The second problem is a chronicle deficit of knowledge about what *a global future of cities and metros* means to citizens, public and private investors, governments. It took thirty years for IPCC to build evidence, knowledge and *science-to-society* interface about climate change. At the same pace, we would have to wait until 2050 to deploy to renew *science-to-policy* partnerships in the field of urbanization, with a priority on informality, urban planning and design, green and blue infrastructures (Parnell et al., 2018). As we are touching upon limitations of natural resources and the regeneration of eco-systems is questioned (Silvain et al., 2018, Nofal et al., 2019), 2050 is way too far a horizon.

## 2. Rethinking the governance of infrastructures and urbanization

The shift towards a predominantly urban world has been formally assessed around 2005/7 (Peirce et al., 2006-8, Buchoud, 2008) but it took over a decade to start building multilateral regulatory frameworks.[2] Meanwhile, local and regional governments, a wide range of stakeholders and interest groups from the civil society and the private sector have grasped change much more firmly than national governments. Urban growth has stirred unprecedented market-driven development opportunities in sectors such as smart cities, real estate development, creative industries which, up to a point, has blurred the lines between the general interest and the promotion of embodied interests (Peck, Tickell, 2002; Larner, Laurie 2010; McCann et al., 2013; Raco, 2013).[3] The

[2] The adoption of the United Nations Agenda 2030, including the Sustainable Development Goals (SDGs) and SDG11 on "sustainable, safe and resilient cities and communities" took place in the fall of 2015. The Paris 21st Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) setting up new goals to mitigate climate change and curb CO2 emissions also took place in the fall of 2015. The Habitat III Summit which issued the New Urban Agenda took place in Quito a year later in 2016. The rise of a global agenda on biodiversity is only happening now, with the 15thmeeting of the Conference of the Parties to the Convention on Biological Diversity (COP15) to be hosted by China in 2020.

[3] Real estate markets should account for more than US$ 4,3 trillion by 2025 (Grand View Research Inc, 2018) and yet the affordability gap is ceaselessly growing, estimated at more than US$ 650 billion per year (UN Habitat, 2018). Depending on sources, the global smart cities markets should account for more than US$ 2 trillion per year (Frost & Sullivan, 2018) to US$ 3,5 trillion per year (Research and Markets, 2017) by 2025. Yet, there is little evidence that internet 3.0, IoT, industry 4.0... are self-help drivers for inclusive territorial development (Eubanks, 2018, Temin, 2017). While in cities and regions across the globe,

formation of new knowledge out of interdisciplinary strategies has been comparatively very slow (Revi et al., 2018) and weak.

Since the turn of the millennium, many cities have engaged in long-term visioning exercises, with infrastructure planning as a key. From New-York to Tokyo, Sydney to London, Moscow to Shanghai, Singapore to Paris, the UAE or recently Saudi Arabia, such *grand* plans have led to the adoption of significant investment packages. A number of cities in India, South-East Asia or Central Asia are now following the way. Despite the lack of reliable and internationally comparable data and the routine presence of lagging indicators (Leff, Petersen, 2015), the *Greater Paris* or *Greater Moscow*, the *New-York* or *London Plan*, etc… nurtured an overall impression of progress and a new literature about *Mayors Ruling the World* (Barber, 2013).

Yet, the promotion of innovation and the development of new large scale mobility systems have not prevented a global systemic decline in housing affordability (UN Habitat, 2018, Schumann, 2019). The governance of complex metro areas is generally weak (Lanfranchi et al., 2017) and the adverse effects of infrastructure development on spatial inequalities underestimated (Combes and Lafourcade, 2011, Fingleton and Szumilo, 2019). The connectivity between investments in large scale infrastructure projects and the building of social capital has been neglected by neo-classics and post-Keynesian economics.[4]

There is a failure in the promotion of compact urban development models.[5] Apart from questionable success stories such as the densification of Vancouver downtown, contemporary urban growth consumes three times more land per

citizens are struggling with congested mobility systems, social networks, design, television and cinema, literature, including cartoons and mangas, are boiling with anticipation and science fiction, all about cities and their future virtual and physical infrastructures. Creative industries as a whole shape global (urban) imaginaries worldwide with a market of more than US$ 2 trillion per year (PWC, 2015, WCCE, 2018).

[4] A recent survey in 347 districts of England and Wales shows that while multi-billion pound investments in high-speed rail increased averages wages by 2% in the region, its impacts on districts was quite heterogeneous and sometimes negative (Fingleton and Szumilo, 2019).

[5] Despite the invention of Transit Oriented Development (Calthrope, 1993), the number of motorized vehicles and especially private cars in the world is expected to reach 1,5 billion in 2020, out of 675 million in 1990 (Sperling and Gordon, TRB, 2009, UNECE, 2015).

capita than in the 1990's (Angel, Galarza et al., 2016), which is true in all parts of the world.[6]

Unregulated urban growth is the cradle of urban financial success stories bringing hope but also confusion. According to McKinsey, $110 billion has been invested in mobility startups between 2010 and 2016 with most of it going to startups in the sharing and autonomous vehicle spaces and the bulk of the investment coming out of Silicon Valley.[7] The global venture capitalist community has been looking for the next big opportunity and believed it to be mobility (not infrastructures), causing systemic disruptions in urban governance, infrastructure finance and planning models.[8] The stock-exchange value of ride-hailing companies now often exceeds some of the largest infrastructure investment packages across the globe.[9]

Subsidized public transit has long been a preferred way to move large flows of people at low levels of pollution and congestion per capita. Many promising

[6] There is a high probability (> 75 %) that large areas of the European continent totaling approximately 77.500 km2, that is the equivalent of the total surface of Belgium and the Netherlands together, will be or have been converted to urban areas between 2000 and 2030 (Seto et al., 2012).[6]

[7] Investments are also coming from China and South-East Asia now.

[8] Uber has raised a total of $24 billion in over 22 rounds and hopes to go public in summer 2019 at a valuation of $120 billion. But the company has challenges. It is burning through cash (in the second quarter of 2018, it lost $891 million) and has increasing competition due to low barriers to entry. Cities are also starting to question their offer of "let us fix your urban mobility problems". New York was the first major city to limit the number of vehicle licenses after a study reported that Uber was contributing to traffic. In Germany, Uber was briefly banned in 2014, and currently only operates in Berlin, Munich, Düsseldorf and Frankfurt. Uber's vision is to be the world's first private multi-modal operator moving commuters by bike, car, air taxi and autonomous vehicle in the future. Whether this is a vision shared by the public and cities alike, only time will tell.

[9] As of 2018, the total market value of the world's largest global ride-hailing companies was about US$ 100 billion, a calculation is based upon the market value of the companies Lyft, Grab, GoJek and Uber as of December 2018. Uber stock-exchange market value alone was worth US$ 71 billion in 2018, which is more than the combined total investment costs for the London Crossrail project (circa US$ 20,1 billion, source GLA 2018) and the Grand Paris Express metro network serving the Greater Paris metro area by 2030 (circa € 38 billion or US$ 43 billion, source Société du Grand Paris, 2018), two of the world's largest metropolitan transportation infrastructure projects. Not only are large scale infrastructure projects costly to finance.

mobility models now reflect an individualization of travel (Schwanen, 2016) with *apps* and *fleets* of cheap light electric vehicles and devices to move people as effectively at much lower costs.[10] In the United-States, public transit ridership figures are already declining. Should cities forego massive infrastructure spending and repurpose roads and parking bays for new free-floating fleets? To what extent new technologies can replace complex transport infrastructures is unknown as no city has been able to reduce car ownership significantly enough to test the hypothesis.[11]

Many changes in infrastructure development and management are under way, from integrated multimodal infrastructures (Ambrosino et al., 2003) to multirole infrastructures combining mobility and energy systems (Hautière et al., 2013; Cirimele et al., 2016, Crozet and Koning, 2019). Intelligent Transport Systems (ITS) are promising ways to review infrastructure pricing and favor clean transport (Harris et al., 2015; Cramton et al., 2018; Schuitema and Steg, 2018; Koning et al., 2019).[12] Yet, the upscaling of such sets of solutions require multi-level urban governance systems which are missing. As of today, divided urban systems are commonplace, in lieu of harmoniously networked urban mangroves (Mangin, Girodo, 2016).

In Japan as well as in many other areas of the globe, the need for *quality infrastructures* (Runde, 2017, 2019; Nakamura et al., 2019) to respond to climate change mitigation and adaptation and meet with societies needs is

[10] The demand for public transport in America continues to decrease as Americans prefer to spend time in their car alone than use mass transport. Transit ridership fell in 31 of 35 major metropolitan areas in the US in 2017 (Washington Post).

[11] Paris, which has low car use, has 150 000 parking bays at street level that could potentially be repurposed into lanes for new mobility (Héran and Ravalet, 2008; Gössling et al., 2016).

[12] Alternatively, integrated infrastructures may support the implementation of « quantity based regulation ». Assume that each citizen or economic agent is endowed with a given amount of "mobility permits", defined consistently with the maximal volume of transport-related negative externalities to be emitted (e.g. GHG or local pollutants quotas), but also with social considerations (e.g. people living in depraved areas, far away from the city center, receive more permits). An integrated and ICT-based interface between the users and the transport infrastructures could be an efficient way to implement and to monitor the system (your permits' account will be debited differently if you're using subways, bikes or cars; for 1 or for 10 kms), as well as to organize a market where economic agents who have an excess volume of permits could sell them to those who need to travel (and to pollute) more.

much asserted. Yet, the obstacles on the way to sustainability have silently piled up: multilateral frameworks about climate, cities, development and growth, came up as deep transformations of the economy, the society, and the environment were already well on their way.[13] This calls for a revised approach of infrastructure development.

## 3. Reviewing *research infrastructures* as a cornerstone of infrastructures for development

A global infrastructure Tsunami (Laurance, 2018) is bound to expand around the world as urbanization continues, with more than 25 million km of new roads by 2050. As of today, the Earth's surface is split in more than half a million patches. With investments in development and new infrastructures squeezing biodiversity (Ibisch; IUCN et al., 2016), we are way behind the targets set up by at the Aichi 2010 world conference on biodiversity (Watson, IPBES, 2018, Silvain et al., 2018). [14]

Only a small number of studies have really quantified the relationships between biodiversity and various ecosystem services over time (Laurance et al., 2017, Choi et al., 2018).[15] The private sector shows a growing interest in biodiversity

[13] Proposals such as the *Planetary Boundaries* (2009) or the reinforcement of the *Anthropocene Theories* (2009, 2016) offer new horizons for a more holistic approach to current global transformations but they have remained mostly conceptual.

[14] An unprecedented spate of road building is happening, with around 25 million km of new paved roads expected by 2050, according to a global comprehensive survey disclosed in 2016 and led by Pierre Ibisch at Eberswalde University for Sustainable Development, Germany. He attempted to map all of the roads and remaining ecosystems across Earth's entire land surface. Its headline conclusion is that roads have already sliced and diced Earth's ecosystems into some 600,000 pieces. More than half of these are less than 1 square km in size. Only 7% of the fragments are more than 100 square km. A quick look at OpenStreetmap also shows that cities are far better mapped than hinterlands. For instance, in the Brazilian Amazon, P.Ibisch colleagues recently found 3km of illegal, unmapped roads for every 1km of legal, mapped road. Source: *The Global Road Building is Shattering Nature*. The Conversation, Dec. 2016.

[15] According to a global survey of the latest research literature on biodiversity in 2018/2018 (Silvain, 2018), few studies have explored the spread of invasive species in relationship to transportation network. Our understanding of alien species distribution at large spatial scale in combination with spatial modelling procedures is weak. There are also key research gaps

offset policies but the process remains complex (Levrel et al., 2012, Global Inventory of Biodiversity Offset Policies, 2019).

Strategic features of environmental impact assessments (EIAs) such landscape fragmentation mitigation remain weak. *Strategic environmental assessments* (SEAs) and *strategic land-use planning* bring some advantages over EIAs but they are far from being the new normal (Laurance, Burgués Arrea, 2017).

We know little about the design of cities, roads and other infrastructures to minimize their ecological footprint. Finding the best development patterns to limit the adverse impacts of urbanization on ecological connectivity is crucial. Harmonized regional and global scale analysis to measure the *co-benefits* between biodiversity and the sustainable design and management of infrastructures is missing (Soubelet et al., 2019).

Large scale and long term big data analysis and modelling is the only way to anticipate the impacts of ecosystems degradation and biodiversity losses, to build urban environment plans at local and global levels, including biodiversity tradeoffs, to limit the risks of infrastructure failures.

The contemporary global biodiversity crisis highlights the deficit of globally coordinated research infrastructures (Silvain, 2018, Barot et al., 2018), whereas the gradient of systemic complexity is exponentially rising from infrastructure development issues, to urbanization, to Earth system.

Change factors exist. Research can help understand how infrastructures can be beneficial for biodiversity in an Earth system perspective. Research on urban

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regarding the impact of infrastructures related to tourism and recreation. This is particularly true in southern most biodiverse countries where new infrastructures accelerate deforestation and forest degradation (Laurance et al., 2017) contributing to global changes. On coastal areas, artificial coastal infrastructures are developed in response to land reclamation and sea level increase while their impact on wetlands and aquatic ecosystems is poorly understood (Choi et al., 2018). Speaking of concepts such as "biodiversity-friendly designs" or “urban green infrastructure” or “Working with nature” (PIANC), research must be continued to set up solid bio-indicators of ecological status and accountable metrics to indicate fragmentation, connectivity, and isolation of populations at different scales. In this matter, bio-indicators at the scale of community or ecosystem are generally more accurate than focusing on selected populations of rare or endangered species.

metabolism and circular economy (Fernandez, 2013, Van Timmeren, 2015) is changing infrastructures impact assessments. Within G20, several countries are implementing new comprehensive national research strategies focusing on Earth System (Cornell et al., 2012, Biermann, 2014, Latour, 2017). Yet, the collaboration among national systems remains prone to chronical instability due to short project-finance cycles and to the lack of cross-sectoral research on biodiversity and urbanization.[16]

The reinforcement of a global agenda on biodiversity could be durable game changer in research with numerous impacts in the economy (Soubelet et al., 2019).

## Proposal

Regional and cross-continental integrated and smart infrastructures systems are emerging such as with power grids built on long-term forecasts by 2040 (ENTSO-E, 2018) 2050 or beyond. This provides an interesting model for the development of a new generation of scientific and research infrastructures, as centralized and distributed networks working at micro and macro scales on combined physical installations and virtual connections.

The focus of the international community on large scale research infrastructures is nothing new (OECD, 1992 to 2010, Belmont challenge, 2009, 2011) but it has to be broadened. In the 18th century, major endeavors such as the Great Northern Expedition mobilized hundreds of scientists from different countries along existing mapping and infrastructures. They nurtured the creation of new routes and new knowledge and contributed to the formation of modern science.

To address the pressing knowledge gaps of the 21st century highlighted in the present paper, we propose to include in T20 priorities a focus on large scale

[16] An overlook of the 95 mega projects selected under the current H 2020 program by the European Union shows that none of them, though, has targeted urban related issues as a designated focus area.

research infrastructures [17] and to foster a fast-track approach connecting infrastructure development, urbanization governance and Earth System theories and research programs.

We recommend to enrich and deepen the T20 infrastructure agenda by:

- connecting with the emerging IPCCcities and with the U20 engagement group of G20
- building a dialogue between long term research strategies across G20 members
- reflecting on key proposals such as the creation of a global fund for biodiversity, complementing climate finance

The *One Planet Summits*, the project of a *Global Pact for the Environment*, the SDSN, the preparation of 2020 *IUCN Congress* and *COP15 Biodiversity* in Kunming could serve as catalysts.[18]

In that context, we view the transformation and development of the Amazon as well as of the Arctic and circumpolar regions as issues for T20 infrastructure agenda, in a vary rapidly changing context.[19] If the combination of a natural and geo-science focus with an infrastructure and urban focus is not managed properly, the risk is that such critically changing regions become areas of ruthless competition only, in lieu of places to cooperate for the long-term

[17] Tomorrow, the focus on large scale research infrastructures could also include space.

[18] Recent literature on sustainable finance, impact finance, responsible finance, finance and the SDGs, climate finance and infrastructures, etc. account for massive estimates, that is of global investment needs to achieve the Agenda 2030 of US$ 5 to 7 trillion per year with a gap of about US$ 2,5 trillion per year, and over one-third of it for Africa alone.

[19] So far, a very limited number of institutions have managed to launch and to sustain advanced research programs connecting urban and regional development to environment and climate change through actual evidence and data collection based upon physical research facilities and large scale research infrastructures. The example of the transformative role of the Trans Siberian Scientific Way developed by the national research Tomsk State University could serve as a benchmark for such initiatives. It connects a mega-profile ranging from Central Asia to the Arctic Circle and a circumpolar network of research bases.

management of our urbanizing planet.

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