

THE SUSTAINABLE CITY



TNO innovation
for life

URBAN DYNAMICS - OPPORTUNITIES FOR SUSTAINABILITY

Cities and urban agglomerations have shown strong growth in recent decades. Not just worldwide, but also in the Netherlands. Some 44 percent of the country's population now lives in cities, even though urban areas cover just 13 percent of its territory. According to forecasts by Statistics Netherlands and PBL Netherlands Environmental Assessment Agency, the population growth in the Netherlands is set to continue to be concentrated mostly in the larger cities.¹

As a result of this concentration, cities and urban areas are becoming increasingly complex. People, businesses, and organizations are all in very close proximity

to each other and there is a great deal of interaction between them. There are many functions to be fulfilled and there are few open spaces. If there is no change to policy or if it is not sufficiently effective, urban sustainability will come under ever-greater pressure. This could affect such matters as health, the viability of the living environment, and the energy neutrality of cities. In turn, this could impact on their competitiveness. At the same time, these high concentrations and close interrelationships also offer many opportunities for dealing with the challenges relating to sustainability. However, responding effectively to this dynamic can be to cities' advantage. Also, each urban region has its own internal cohesion and dynamic, creating a unique profile in each region.²

Our focus in this paper is on the sustainable city. The starting point is that cities seek to retain and enhance their competitive strength, aim to be a favourable location for companies to be based, and wish to create a liveable, healthy, and energy neutral environment for their residents. Having a liveable environment also includes maintaining buildings, infrastructures, and mobility. This means that cities need to coordinate their sustainability policies in accordance with the close interaction and relationships between people, organizations, functions, and levels of scale. The sustainability challenges here are not just short term in nature, but also require a longer term vision. Cities cannot afford to put off the challenges of the here and now.

1 PBL Netherlands Environmental Assessment Agency and Statistics Netherlands (2016). PBL Netherlands Environmental Assessment Agency/Statistics Netherlands Regionale bevolkings- en huishoudensprognose 2016-2040: sterke regionale verschillen. The Hague.

2 Ruimtelijk-economische Ontwikkelstrategie (REOS) Noordelijke Randstad, Zuidelijke Randstad en Brainport Eindhoven. Bestuurlijke intentieverklaring: visie, ambities, opgaven en aanpak (2016), p.11. The Hague.

In order for cities to develop sustainably, we have to view the challenges as a whole. The focus here lies on improving quality – that is, finding a balance between growth and sustainability by dealing with the urban dynamic in a smart manner. Large-scale demolition and new-build properties are making way for selectivity, adaptivity, reuse, and small-scale projects. It is not new buildings, but transformation that is the driving force behind development³.

DYNAMICS IN THE CITY

Sustainability is a complex concept, which can be made more concrete by analysing a large number of frameworks. This analysis shows that sustainable development affects numerous fields, both tangible (building stock, population, infrastructure, land, water, air quality) and intangible (education, health, empowerment). In many cases, these fields interact with and influence one another. The fields all involve various actors, each with their own roles, interests, action priorities, and scope for action. In addition, sustainability is always linked to different levels of geographic scale – what may be sustainable for a city may be anything but for districts or blocks.

If we link the substantive complexity of sustainability to the complexity and dynamics of cities, the city is a complex adaptive system that is developing in a particular direction. To put this vision in more concrete terms for the purpose of urban development, we rely in part on Munasinghe's capital and resource model⁴, and regard urban sustainability as the most important capital of a city. This capital is made up of a large number of resources that correspond to the aforementioned fields, spread over four types of capital – economic, social, environmental, and institutional – with underlying actors. It is not just the resources (and their actors) that interact with each other in a continuous process, but there is also a constant synergy in the relationship between a city and its surrounding areas. This interaction means that cities are characterized by a lively dynamic of flows of people, materials, money, knowledge, innovations, and opinions, for example. This is described as urban metabolism or the urban ecosystem (see Figure 1).

These flows can affect both the quality and the quality of resources, positively and negatively.

If policies are not changed and if no innovative solutions are forthcoming, the flows will result in a large number of resources – and therefore cities' capital – evolving in a non-sustainable direction to an increasing degree. This will manifest itself in greater traffic congestion, impoverishment, segregation, harm to health, crime, shortage of homes, and interruptions to energy supplies. Cities will then no longer be able to meet the ambitions of their residents and visitors; the only way of turning the tide would be to use innovative policies and innovative solutions aimed at sustainable urban development. Cities are therefore constantly facing the challenge of adapting their built-up areas to the changing requirements of our time. Moreover, users want more quality – for example, they want more space and luxury for their homes and leisure, better amenities and better access to them, more reliable and faster public transport; they are also making tougher demands of the energy performance of their property. A continuous process of transformation keeps a city vibrant and is a source of prosperity.⁶

The city as a complex system – how different functions affect each other

If the infrastructure of a city does not function well, this leads not only to economic harm in terms of traffic congestion, but also damage to health caused by fine particles and CO₂ emissions. Health is also negatively affected by poorly ventilated buildings and homes, for example. With the help of a TNO model for the urban system, we can consider which interventions would achieve the greatest sustainability benefits. It is therefore not just the relevant flows (such as how much traffic, what kind of traffic, where, and when) that have to be analysed, but also the quality of the relevant resources (such as air quality, health, and infrastructure). We need to bear in mind here that changes to flows in the short term are a factor, but that their effects only become visible in the long term.

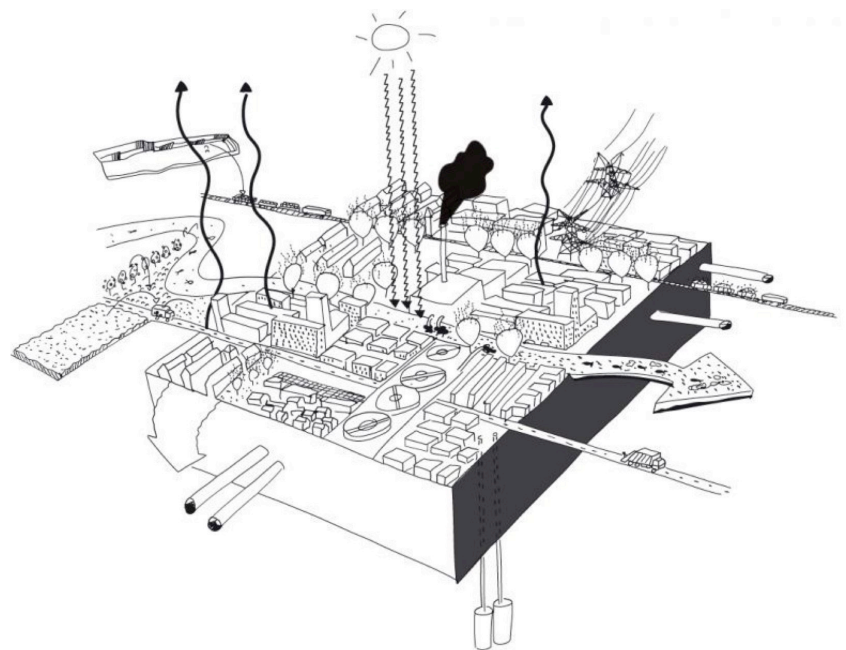


Figure 1: Urban ecosystem⁵

3 Council for the Environment and Infrastructure (2014). *De toekomst van de stad. De kracht van nieuwe verbindingen*. p.20. The Hague

4 Munasinghe, M. (1993), *Environmental economics and sustainable development*, World bank environment paper Vol. 3 (1), 1

5 See also: <http://www.bna.nl/onderzoeks-project/de-stad-als-ecosysteem-ontwerpen-met-stromen/>

6 Council for the Environment and Infrastructure (2014). *De toekomst van de stad. De kracht van nieuwe verbindingen*. The Hague.

AIMING FOR SUSTAINABILITY

A city is a complex system that is always moving, and which needs movement. In order to manage this process, we need an insight into urban complexities and dynamics: what are the essential functions, who are the relevant actors, what are their skills and wills, how are functions evolving and how can we deal with things more sustainably? In other words, analysing, (measuring, monitoring), planning (creating visions and designing) and responding to the



continuous interplay of technological, social, and policy renewal by means of co-creation form essential pillars for sustainable urban development.

If public-sector bodies, the business sector, and local-level initiators have an insight into urban complexities and dynamics, they can manage their activities on the basis of sustainability. This applies not just to the operational level, but also to the tactical and strategic levels, such as urban design and the development of scenarios.

Not only is more data becoming available, it is also becoming easier to carry out measurements, and data is being linked up more and more. Analysing (measuring and monitoring) this data provides new insights and makes it possible to focus on the underlying processes. We can then optimize these processes, steering them towards the desired sustainability results, such as better road traffic flows and improved air quality in residential districts. These sustainability results and underlying processes are then monitored so that any fresh policy interventions can be made, if necessary.

However, there is more to steering a city in a sustainable direction than optimizing processes. It also requires working on the future of the city. Using smart designs, we can not only take account of future developments such as climate change and the transition to stable and clean energy supply, but actually influence them. Designers can bring about a spatial transition by devising scenarios that illustrate which challenges can be met, and by what measures. Such scenarios, which should be devised participatively – that is, with the relevant stakeholders – also highlight the uncertainties of future developments and what no-regret measures are available.

DEVELOPMENT TOWARDS SERVICES

In cities we are seeing a development, from a sustainability perspective, towards services with which parties use the opportunities offered by an urban environment. The development of services is a concept through which parties directly and indirectly contribute to the sustainability of a city. Ruimtevolk described this phenomenon in its blog, *Het einde van het industriële tijdperk maakt de stad tot platform*,⁷ as follows: ‘A significant proportion of current production will shift to the cities – close to the users. Production will take place in shops where the last components can be printed to order, for example, where you

From measuring and monitoring to managing the environment

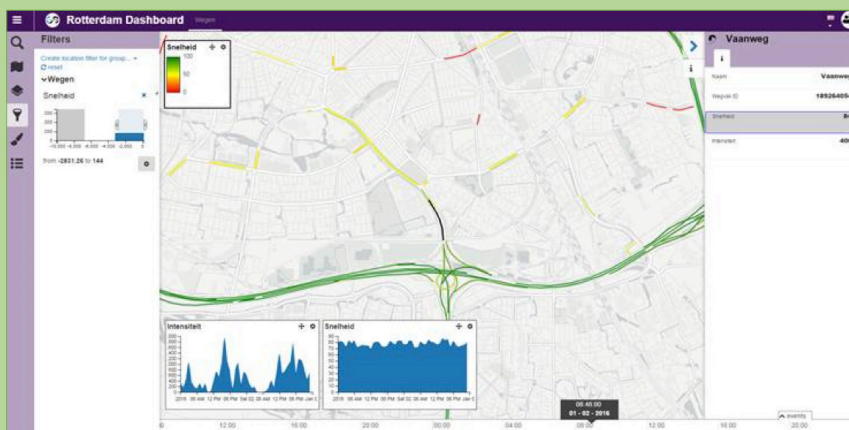
Within the foreseeable future, the Netherlands will have a dense measuring network for establishing continuously how many and which harmful substances are emitted where, and what the source is. ICT and sensor technology make it possible to collect specific and local environmental data in real-time and to respond to it much more quickly than now. TNO is developing systems that offer real-time decision support for industry, the authorities, and citizens.

Environmental sensing is evolving rapidly from measuring and monitoring to managing the environment. Take Rotterdam, for example. This bustling city has a port, a growing industrial sector, and attractive leisure locations. For this city, these elements have to go hand in hand. Environmental sensing helps identify the spaces that form part of the environment by linking sensors to models. TNO is developing sensors capable of measuring more and increasingly accurately, while the models place the data in its overall context.

The aforementioned elements are brought together in the *Stadsdashboard Rotterdam*, (see the diagram below). There are dozens of cameras measuring

traffic flows in the city, and where they are moving. The information is classified into passenger vehicles, delivery vehicles, and freight vehicles. At the same time, we can see which commercial traffic is active in which areas. And how all of this affects air quality. The ‘stadsdashboard’, or city dashboard, provides insights for administrators into how to make the city clean and liveable.

Together with the Rotterdam City Council, TNO is working on applying the city dashboard in everyday practice. Cities often have an insufficient understanding of the logistical flows in and around their cities, and that makes it difficult to take appropriate measures. In a web environment, the city dashboard shows relevant data in real-time, concerning mobility, logistics, and air quality. It is crucial that the information in the city dashboard is translated into air quality. After all, it is all about having a clean and liveable city. Because there are so many types of data that feature on the city dashboard, it is an excellent instrument for assessing the consequences of environmental measures on traffic, noise, and emissions. For example, the Rotterdam City Council can use the dashboard to monitor and evaluate interventions, such as large-scale renovation projects.



Working interactively on sustainable urban development

An increasing number of aspects have to be involved in the sustainable urban development design process; this should be across the full width of the quality of everyday surroundings, such as the environment and the health of residents and others living nearby. As a result of various societal processes, such as increasing sustainability and the tightening of environmental requirements, the process of developing urban areas has become more complex. Nowadays, it is often about the transformation of existing surroundings – looking for new designations for buildings, renovating, and taking action against buildings being left vacant. This involves more and more stakeholders; not just public-sector bodies, property developers and financiers, but also businesses and local initiators.

These changing circumstances require a strategy that is appropriate to the complicated interplay of all the factors. At the basis of this complex approach is knowledge about how urban areas are structured and the societal and financial consequences of this. TNO has this knowledge – in the form of Urban Strategy, for example – a model that provides information during the planning phase about the effects that measures have. Another example is that of PICO, the *Project Innovatieve Communicatie- en Ontwerptool* (project innovative communication and design tool), which demonstrates the possibilities for making a district energy neutral. These tools support the interactive design and policy process, thereby contributing towards sustainable urban development.

can see where the product comes from, where you can contribute ideas towards the design, where you can meet the designer or producer himself, and where raw materials are collected. Products will only be made if they are actually requested, in a particular size and shape. The factory employees of the past will no longer exist; instead, they will increasingly be local entrepreneurs (or partners of same) who sell, repair, and recycle products, who provide do-it-yourself courses and teach, and provide services.' Because of these new types of services, the interaction and dynamic in the city will only increase. Below, we set out two types of service in relation to the sustainable city: 'environment as a service' and 'material as a service'.

ENVIRONMENT AS A SERVICE

In the sustainable city, we measure its performance using parameters that make the city attractive. We evaluate it interactively by modelling and analysing, and extrapolate this into the future with the help of a design, and we continue monitoring. That provides us with indicators that put the sustainability in a new perspective, namely, the effect of our activities. Sustainability has a market value – businesses will seek to make a positive impact. Administrators can respond to this by always having a framework for action to offer that makes sustainable behaviour the attractive alternative.

Environmental sensing is focused on measuring sustainability. Measuring is becoming less costly as more, and more affordable, sensors are available for various parameters. Using an extensive sensor system, making the living environments measurable, and making calculations based on a city's flows and resources, creates a platform from which parties can start to develop services. They can subsequently charge for the services, thereby providing an incentive for investment. The residents and businesses who are attracted will be helping to promote the sustainability of the city, both directly and indirectly.

CITYkeys: indicators for sustainable cities

In the CITYkeys European research project, two sets of indicators have been developed that are connected to each other. One of the sets is intended to check in a harmonized and transparent manner how effective smart city projects in European cities are. These project indicators show what difference the project has made by comparing the situation if the project had not been carried out with the situation after the project. The second set is intended to show what contributions the smart city projects have made at city level.

Both sets contain indicators relating to sustainability.

CITYkeys Sustainability Framework

To develop the CITYkeys framework, account has been taken of the wishes of the cities and citizens for projects and indicators, with inclusion of the themes of people, planet, prosperity, governance, and development. The structure is based on an inventory of the 43 existing indicator frameworks for sustainable cities and projects. Most of the indicators selected in CITYkeys have been derived from these existing indicator frameworks. New indicators have been proposed in order to fill any gaps in the existing

frameworks, primarily with a view to specific features of smart-city projects.

CITYkeys sustainability indicators

For each of the themes of the framework (such as health, energy and mitigation, equality and community involvement), indicators have been identified that clarify the impact of smart-city projects. A unique feature of CITYkeys is that it includes indicators that make the projects reproducible and scalable, make it possible to repeat and upscale innovations, and accelerate the transition to smarter, more sustainable cities.

A total of 94 project indicators and 76 urban indicators have been selected. Not every indicator is equally suitable for evaluating every type of smart-city project. Although there are a considerable number of common indicators, a relevant subset may be used for specific sector-based projects; a sub-selection of indicators may be used for projects in the fields of mobility, construction, and IT.





MATERIAL AS A SERVICE

The primary reason for using products, materials, and raw materials for as long as possible is to reduce the CO₂ and material footprint and the production of waste. This helps towards achieving climate targets and the transition to renewable energy. It also means that the reliability of the supply of raw materials and materials for which no substitutes yet exist can be safeguarded. This mainly concerns the flows of materials and raw materials, especially the circular aspect. In fact, it is about the logistics before, during and after the economic production processes in relation to the elimination of negative external effects such as exhaustion, waste, emission, environmental harm, and health risks.

In order to increase circularity, concrete frameworks for action can be identified that are based on sufficient knowledge of local physical flows and material consumption. Databases and models are used to identify flows through the city. Circularity in a city capitalizes on the resources (raw materials and products) there. There are various ways of contributing to the circularity in a city and of adding value to it (see Figure 2).

You can add value at the waste stage by closing circular systems, such as in the construction industry. Similarly, you add value to the user stage if you are able to use materials for longer and extend the lifespan. This leads to jobs and value retention and has a favourable impact on the environment.

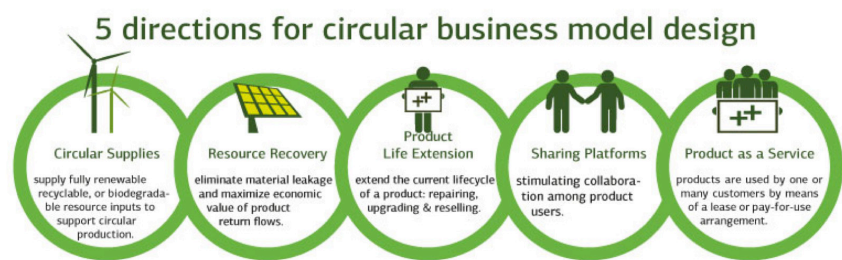


Figure 2: Five business models based on circularity ⁸

Sustainable infrastructure and extending its lifetime

Customers in the groundwork, road-building and the waterway construction sectors are committed to sustainable infrastructure (roads, rail, locks, bridges, and tunnels) that places only a small burden on the environment. That is why Rijkswaterstaat, ProRail, and various regional and local authorities give significant weighting to sustainability in their tenders. TNO is helping reduce the environmental burden with innovations in relation to design, construction, and maintenance, in collaboration with public and private sector organizations. TNO is strongly committed to three sustainability aspects:

- Reducing emissions. This can be achieved by using materials and energy more efficiently, by extending the lifespan of materials, by recycling

materials, and by opting for innovative materials, products, and processes. These measures often entail lower costs, as well as reducing the quantity of materials used and the emissions of harmful substances.

- Closing raw material chains. Asphalt and concrete are the most extensively used materials in our infrastructure. Thanks to new and improved recycling and production methods, more and more raw materials can be re-used. This leads to smaller waste flows and to fewer primary raw materials (such as bitumen, gravel, and cement) being needed.
- Less damage and inconvenience caused by noise and vibrations. New railway lines, more and faster trains, and homes close to railway lines make it necessary to reduce noise and vibrations. TNO is conducting research into how serious vibrations are.

At the same time, TNO is developing innovative monitoring systems and models that can predict lifespans. Given that replacing structures is an expensive matter, efforts at finding out how they can be used for a longer period of time are definitely worthwhile. It has often been found that more accurate examinations of structures reveal that they are easily fit for purpose. Replacement is then not necessary from a technical point of view, which saves on needlessly incurring costs. Innovation is targeted at monitoring and calculation techniques that are better at taking uncertain factors into consideration. TNO is also developing innovative techniques for renovating civil engineering works. This concerns maintenance that is based on condition rather than on a mark on the calendar.

8 Source: <https://simapro.com/2016/five-ways-to-circular-economy-and-lca-product-as-a-service>



Examples of co-creation that contribute towards sustainable cities

Air quality measuring campaign

In 2015, Friends of the Earth Netherlands organized a measuring campaign in which citizens collected data about the air quality at 58 locations in the country.

Schiphol

Residents who live in the vicinity of Schiphol measured excessive noise in order to compare this to Schiphol's own data.

Energy flows

Initiatives for producing renewable energy yourself, such as via solar energy or wind energy. With these initiatives, citizens take charge themselves in order to make their own energy supply sustainable.

Sources: www.milieudefensie.nl; RLI, De toekomst van de stad, 2014

REALIZING AMBITIONS - GETTING DOWN TO WORK TOGETHER

A major characteristic of complex systems is that there is no predominant controlling figure. In practice, it means that parties have to look for solutions together. This is manifested in a changing role for the government, which is taking a more back-seat role in many areas, and in greater empowerment for citizens. This requires other ways of working and collaborating, other ways of delegating responsibilities or indeed taking them on, and other funding methods. This too, entails new participants joining the playing field, and others leaving it.

The substantive complexity is the result of the interplay between spatial, societal, and economic needs that physically come together in the city and therefore at project level – for example, the transformation of a building or a neighbourhood. All these aspects and developments are looked at and included in the considerations as a whole during any quest for sustainable solutions. This means that people and

organizations have to look beyond the bounds of their own disciplines and organizations. It is a challenge relating to the actual issues at hand; one that requires a willingness on the part of the relevant actors to take account of more than just their own interests. Such quests for sustainable solutions are complex from an administrative and process point of view, too, because they touch on the responsibilities of many different public-sector parties and levels. Moreover, parties and organizations in all different sections of society feel involved and are keen for their voices to be heard.⁹

Various studies emphasize that achieving urban ambitions should not only be politically, but also socially embedded.¹⁰ Cities are faced with an ever-greater need to organize relationships with higher echelons of government (regional and national) as well as with administrators at local and district level.¹¹ Cities are linked in complex vertical relationships with regions, central government and transnational institutes, and in horizontal relationships

9 Puts, H. & M. Rijnveld (2011). Ruimte voor kleine verhalen in planprocessen van de toekomst: kennismediation biedt perspectief. In: Bouma, G., Filius, F. & E. Vanempen et al (Eds.) *Planning van de toekomst: bijdragen aan de PlanDag 2011*. Delft: Stichting Planologische Discussiedagen.

10 Klijn, E. (2003). Leven met onzekerheid; Besluitvorming over duurzame stedelijke ontwikkeling. In: *Cahier Reeks Duurzame Stedelijke Vernieuwing (KEI/NIDO)* and Teisman, G. (2012). *Proceskunst, gebiedsontwikkeling nieuwe stijl*.

11 Healey, P. (1995). *Collaborative Planning: Shaping Places in Fragmented Societies*

Edelenbos, J. & G. Teisman (2013). Water governance capacity: the art of dealing with a multiplicity of levels, sectors and domains. *International Journal of Water Governance*, 1 (1-2), pp. 89-108.

with the private sector and organized local and societal interest groups.

The government will get the role of formulating sustainability ambitions and of changing how sustainability is regarded – that is, as a service. These ambitions will challenge parties to work together on finding solutions that make the city future-proof. The environment and sustainability will become the most important factors for determining where people and businesses will settle.

Co-creation helps towards the process of jointly finding sustainable urban solutions. We will then be able to use two features of a complex adaptive system – that is, emergence and self-organization, as a result of which all kinds of new structures and patterns will arise spontaneously (in other words, without being devised or controlled). This often means that innovative solutions are found for issues where the usual actors and routines fall short. In such cases, new and unexpected actors suddenly come to the fore. Co-creation is not just important for bringing about innovations for sustainable urban development and for implementing them, but also emphatically for obtaining and analysing data and for developing support models.

Working to create a sustainable city also requires a different type of city administration. What often happens is that measuring and monitoring activities are carried out and we then think we have enough information. Adaptive governance, however, supplements measuring and monitoring with reflection, experimentation, learning, and collaboration. This is about connectivity, not just in terms of infrastructure, but also in collaborative partnerships, between businesses, knowledge institutes, the public sector, citizens, and community organizations.¹² *The public sector, citizens, businesses and knowledge institutes are allies when it comes to developing sustainability, which is a continuous process. The composition of any such alliance, or network, changes all the time.*

¹² Council for the Environment and Infrastructure (2014). *De toekomst van de stad. De kracht van nieuwe verbindingen*, p.19, The Hague.

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LIVING ENVIRONMENT

As part of the Living Environment theme, we apply ourselves to devising innovations for vital urban regions. We work together with partners to create solutions for today and opportunities for tomorrow to enhance the viability, accessibility and competitiveness of these urban regions.

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