THE ACCESSIBLE CITY

TNO innovation for life

HYPERMOBILITY – THE SYSTEM IS SLOWING DOWN

An accessible urban environment is crucial for a healthy, dynamic and economically vibrant city. It will not come as a surprise to anyone to learn that accessibility is a growing problem for many cities. In recent decades, the number of inhabitants has risen considerably, while economic activity has also increased. It is only logical that the number of travel journeys has therefore also grown strongly. In many places, this has been to the detriment of the living environment, with congestion forming a major risk to economic vitality. It is notable that although this growth has exposed the limits of the existing mobility system, it has not yet structurally changed it. Solutions for improving accessibility often emanate from the prevailing notion that additional infrastructure is the answer. For many years this has worked, but it is time for a new approach. Urban accessibility requires reasoning from the perspective of mobility rather than modalities. This involves having the end-user as key.

We live in the age of hypermobility[1]. This term is being used more and more often as a means of demonstrating that there are limits to the need for interconnectivity. Because of the ever-greater levels of urbanization, space for infrastructure is becoming more and more scarce (especially in inner-city areas), while at the same time it is that very urbanization that makes the need for more space for infrastructure even greater. The viability of the living environment and economic vitality are coming under increasing strain. The greatest problems are occurring in relation to congestion, safety, parking, air quality, and energy consumption[2]. Many cities are starting to acknowledge the need for a sustainable, dense, and efficient mobility and transport system. The problems are urgent, but it is also in the cities where the solution lies. Given that many people there benefit from the resolution of bottlenecks, there are significant societal advantages to be had[3]. But what form will such a future system take? Urban mobility policy has traditionally been strongly based on party political lines. By lifting the 'car versus public transport' discussion out of its box, and by taking a more integrated view, more can be achieved than is currently the case.

1. *Hajer, M., Hoen, A., & H. Huitzing (2012). Shifting Gear: Beyond Classical Mobility Policies and Urban Planning (Chapter 7, pp. 151–178) in Van Wee, B. (Eds.) Keep Moving, Towards Sustainable Mobility. The Hague: RIi, EEAC & Eleven International Publishing.*
2. *Ministry of Infrastructure and the Environment (2015). Around the world in eighty days. The Hague: Ministry of Infrastructure and the Environment.*
3. *Verrips, A.S. & A. Hoen (2016). Kansrijk Mobiliteitsbeleid. The Hague: The Netherlands Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency.*

We are on the brink of far-reaching changes to the mobility system itself. During the next few decades, urbanization will continue, both in and outside the Netherlands, so there is a great need to keep cities accessible. Moreover, there are ever-more technical solutions available – and in the pipeline – that can bring about changes in attitudes and which will alter how the mobility system is managed. This will be supported by turning societal and organizational innovations into sustainable mobility solutions by means of integrated system considerations (and integrated monetarization, for example). This is current largely organized top-down from each separate system. It means that the decentralized systems and related parties often do not operate beyond their own boundaries. Self-organization is needed if a connection is to be made with end-users and if a certain degree of customization is to be possible. Each part of the system should be linked to and communicate with a physical internet. Users want to be able to board at their place of departure and alight at their place of arrival, with the help of a smoothly organized service (mobility as a service). For them, it is less relevant who actually organizes the mobility. The same thing applies to the logistics. It does not really matter to consumers what form the logistical processes take, as long as the goods are transported in an efficient and sustainable manner and arrive on time.

A physical internet also needs instruments and knowledge in order to take integrated system decisions. A balance between centralized control, decentralized implementation, and self-organization of the system. A balance between modality, mobility, accessibility and – increasingly importantly – perception[4], and preferably, customization.

How can we keep the city of the future accessible? How can we best serve the end-user with the opportunities that the mobility system offers? What are the choices we need to make here? In this position paper, we present our view of the accessible city of the future.

We predict an important paradigm change to the urban mobility system and reflect on the consequences and challenges.

The accessible city – a detailed definition of 'accessibility'

Accessibility is about the quality of a connection, how easily or otherwise it can be reached. About an exchange between different locations. It does not matter what is exchanged. This could be anything – people and goods on physical roads, but also virtual flows like ideas and e-mails over the phone and the internet (the latter falls outside the scope of this position paper, but does increasingly form the basis for physical exchange).

Accessibility is about the whys and wherefores behind these flows – why do exchanges take place between these specific locations exactly, and how are these connections organized? The terms in which accessibility is expressed, and how the accessibility of a location – quality of the connection – is experienced depends very strongly on personal preferences. This will play a more and more important role in the future.

INTERNET OF THINGS MAKING FLEXIBILITY THE NEW STANDARD

We stand on the threshold of a number of innovation breakthroughs and the large-scale application of proven technologies that are going to change the urban mobility landscape. This concerns primarily the extensive use of large quantities of data that are available about transport flows of people and goods, and the preferences and wishes of stakeholders. Thanks to ICT and sensor systems, it is becoming increasingly possible to continuously monitor the journeys of the smallest unit (packages and persons) and to influence the route they take. In addition, both infrastructure and vehicles are becoming ever-smarter and more flexible. ICT in the form of future Intelligent Transport Systems is one of the strongest forces that will change the system of mobility movements. It will change not just our mobility wishes, but also how efficiently we can meet these wishes in a sustainable manner[5]. The potential effects of ICT on urban mobility are summarized in Figure 1[6]. The diagram shows that these effects can be expected via various paths. To identify these effects, a broad-based analysis of ICT on the whole urban system is needed.

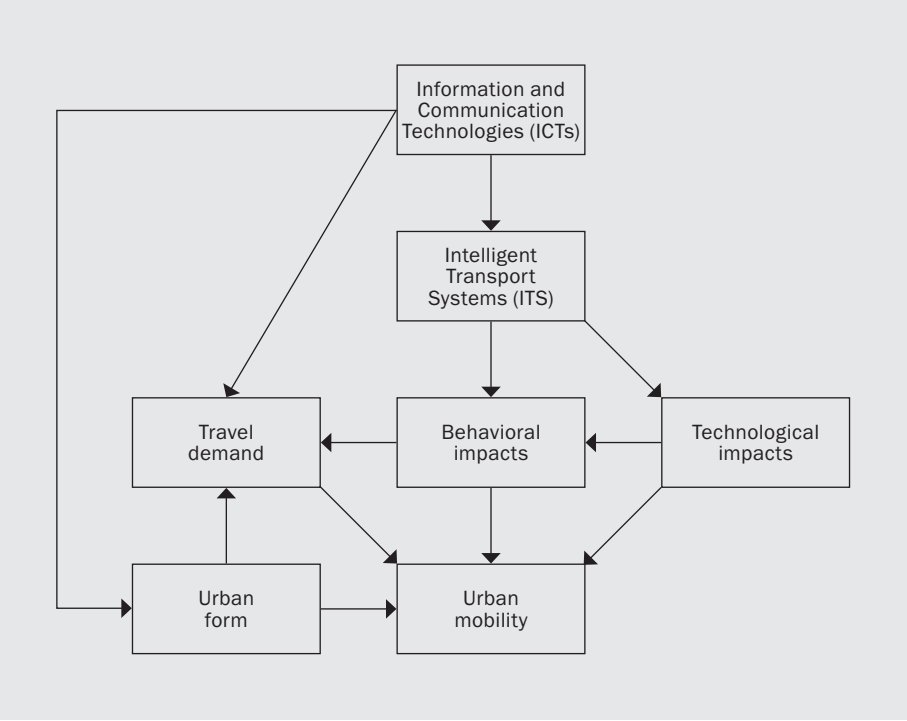


Figure 1 – The potential effects of ICT on urban mobility.

4. *Ruimtevolk (2016). Perspectief op mobiliteit van de toekomst.*
5. *Sweatman, P. (2012). Information and Communications Technology (ICT) Unleashed (Chapter 4, pp. 85-107) in Van Wee, B. (Eds.) Keep Moving, Towards Sustainable Mobility. The Hague: Rli, EEAC & Eleven International Publishing.*
6. *Cohen-Blankshtain, G. & Rotem-Mindali, O. (2016). Key research themes on ICT and sustainable urban mobility. International Journal of Sustainable Transportation, 10:1, 9–17.*

It should be mentioned that a broad consensus exists regarding the expectation that developments in ICT will change not so much the number of urban mobility movements, but rather patterns of mobility and how efficiently traffic is managed. This may not be same for parts of the system, however. For example, the efficient coordination of inner city logistics can indeed have major consequences on the number of mobility movements.

THE CITY AS A LIVING NETWORK

Cities work like a magnet and have a natural network function. Innovations in automation and ICT considerably stimulate the network opportunities that characterize cities. Knowledge of virtual networks enables us to strengthen the natural growth of cities and their network functions. The internet, with its speed and its capacity to bring together people separated by great distances, also provides inspiration for taking physical networks to that high level. In such cases, a city behaves like a physical internet.

The ICT systems that monitor and direct the various infrastructure modalities and the transport movements ‘talk’ to each other and together form an urban operating system, as it were. A system of this kind can have different forms. For example, it could be in the form of a top-down managed system coordinated from control towers. However, it could also be more self-organized (based on block-chain technology, for instance) on the basis of self-learning ICT and networks. Because the various systems have to be able to work together, a large self-regulating urban infrastructure is created that continuously optimizes itself at whole-city level according to different conditions and control parameters. Not a single cross-roads or ring road. This is relevant to the increasingly important demand for a sustainable mobility system. Distributed intelligence in the system is created by equipping the smallest components of the infrastructure, persons, and packages with smart ICT and sensors.

THE USER DECIDES

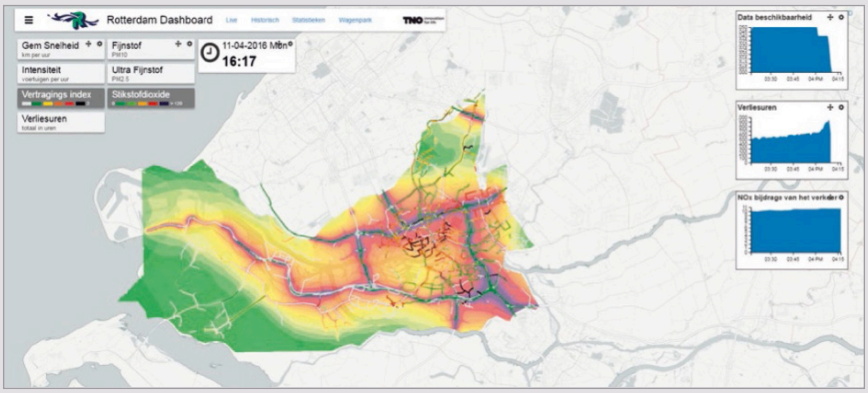
Experts are clear in their prediction that customers or users of the mobility system will get a much stronger voice. This is an explicit break with the here and now, in which mobility flows are often fixed and are imposed top-down. An example that comes to mind is that of public transport timetables. Another is that of logistical chains that often operate according to a schedule previously set by shippers or carriers. In the future, the mobility system will be controlled from the other end, from the bottom. This concept is sometimes referred to as ‘mobility as a service’. The user is key and determines the conditions under which he is transported from A to B. The provider of the mobility service makes a suitable offer accordingly. Inner city and other goods flows could also use other modalities and infrastructure as a result of this development. There will be a level of administration at the smallest entity. Two major challenges exist here. The first concerns the question of how the system can be set up in such a way that the mobility service can make suitable provision for the overall group of mobility users. The second challenge is of an administrative nature. Who will guarantee that the outcome of the system is actually in the public interest? In other words, sufficient interventions and adjustment options should be incorporated that enable the concession provider or city authorities to guarantee that sustainable and societal yields can be optimized.

In recent years, consumer wish lists have become longer and longer. These range from next-day deliveries in the logistics sector to various optimization options for routes in navigation systems (eco, tourist, fast, short, etc.). The information about air and noise pollution that is available makes it possible for users to factor in these aspects when deciding on a suitable route. A long wish list is not necessarily an impediment to an efficient mobility system. However, it is important that users are not forced into making a particular choice. Online orders could be delivered a few days later more efficiently (here, too, economizing offers opportunities at this level). In some cases, there is absolutely no need for orders to be delivered the following day. With regard to logistics, it is the case that packages themselves become part of the logistical system (by means of distributed intelligence) with their 'wishes' and 'conditions'.

Experts expect that sustainability will become an increasingly important feature of user wish lists. Developing the right indicators for this and making information public will enable users to gain a picture of how their logistical and mobility demands are being dealt with in a sustainable manner.

Example: Dashboard Rotterdam

When a local authority has identified the causes of air pollution in real time, it is able to take measures straight away in response. The city dashboard is part of an instrument that TNO has been developing to a high level in recent years: Urban Strategy. We have incorporated all our models on mobility, transport, air quality, and noise into the instrument. This allows us to quickly calculate not only future scenarios, but also measures that need to be taken immediately. Cities often have an insufficient understanding of the logistical flows in and around their cities – and of their consequences – and that makes it difficult to take appropriate measures. The dashboard shows all relevant mobility, logistics, and air quality data in real time.



The experiences are now being expanded with the development of an open platform and simulation tool for Smart Mobility, known as SimSmartMobility, together with the Delft University of Technology and the Connecting Mobility programme (Ministry of Infrastructure and the Environment). This will make it possible to gain an insight into the impact of Smart Mobility services, for example, on accessibility or road safety in a particular city or region. Smart Mobility is the deployment of information and communication technology for innovative mobility solutions, for the purpose of improving accessibility, safety, and the viability of the living environment. Smart Mobility is about automated cars, shared cars, new public transport solutions, and the computerization of cars, among other things. The gathering, processing, and exchanging of information makes vehicles and roadside systems (traffic lights, traffic information systems) 'smarter'. This information also serves as the basis for developing mobility services that users can call upon with the help of their cars or smartphones. The SimSmartMobility simulation tool should give a clear picture of the potential of Smart Mobility services at an early stage of its development.

Source: City Dashboard brochure (TNO)

TRENDS IN MORE DETAIL

FUTURE DEMAND FOR TRANSPORT

How many mobility flows will be needed in the future and what exactly will be transported? The WLO ('prosperity and living environment') scenarios recently published by the Bureau for Economic Policy Analysis and the PBL Netherlands Environmental Assessment Agency show for example that, for passenger transport, both the number of transport movements and journey duration will be at about the same level in 2050 as they are now. However, it is expected that the number of kilometres covered will grow considerably[7]. The Bureau for Economic Policy Analysis and the PBL Netherlands Environmental Assessment Agency have calculated that the number of kilometres covered in 2050 will be between 15 and 30 percent higher than in 2010. In the case of domestic goods transport – a greatly significant factor as far as urban accessibility is concerned – there is a great margin of uncertainty. In the low-end scenario, the number of goods journeys will stay the same, while the number in the high-end scenario will increase by 25 percent by the year 2050[8].

But where are the major uncertainties and possible game changers that could drastically alter demand for transport?

7. *The Bureau for Economic Policy Analysis and the PBL Netherlands Environmental Assessment Agency (2015). Toekomstverkenning Welvaart en Leefomgeving. Achtergronddocument Binnenlandse Personenmobiliteit. The Hague: The Netherlands Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency.*
8. *The Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency (2015). Toekomstverkenning Welvaart en Leefomgeving. Achtergronddocument Goederenvervoer en zeehavens. The Hague: The Netherlands Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency.*

3D printing is often presented as disruptive technology. Does the same thing apply to its influence on mobility patterns as well? That is not easy to predict. The effect is more likely to be in the form of a shift to more transport of low-value flows, and less of semi-manufactured goods or products.[9] However, it could also mean that there will be more transport to order. This will make the challenge of combining logistic movements more difficult. An additional uncertainty is that we currently do not know for which products 3D printing really does offer an answer. This makes it impossible to state exactly which conventional production processes and goods flows will actually change.

E-commerce has really taken off in recent years. The trend has resulted in additional transport journeys in urban areas (last-mile transport) and also has an enormous potential for sustainable urban logistics. Cleaner electric vehicles are ideally suited to cover these quick and short distances.

The automated car could, in due course, markedly change how city streets look. Imagine a future in which every taxi and every bus operates without a driver. The space in the city currently reserved for parking will be reduced drastically. And although new areas will be created where people can be dropped off or picked up, the automated car will, on balance, give a positive boost to the liveability of public spaces in cities and also make more space available for cyclists and pedestrians. How quickly automated cars will feature on a large scale cannot be predicted accurately. The results of a recent scenario study show that automated cars will quickly come to dominate the market if they are able to compete commercially with conventional cars. It is expected that they will appear on the market at a competitive price somewhere between 2025 and 2045[10].

In the past few years, *car-sharing* has become popular, especially in larger cities. Even though the phenomenon is still a modest one, it could be developed to the full in urban areas. Research by PBL Netherlands Environmental Assessment Agency in the Netherlands has shown that car-sharing leads to a reduction in car ownership and use. It also leads to less pressure on parking spaces in cities[11]. The OECD[12] has concluded that a complete changeover to shared automated cars in a city (the city in the model was Lisbon) results in 95 percent fewer parking spaces, a 3 percent fall in the number of cars, and a decline in the number of vehicle kilometres of 37 percent. This would allow the price of commuting to fall by 50 percent. Because of the more intensive use of vehicles and short depreciation periods, it is possible to factor in new CO_2 reducing technologies more quickly.

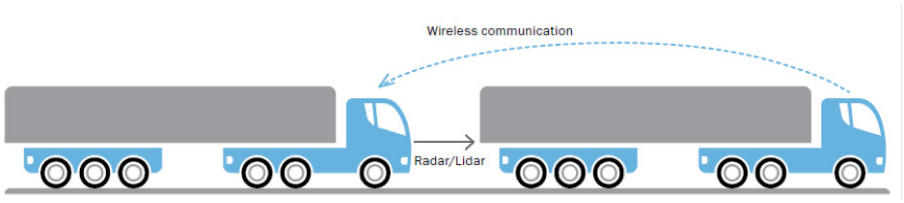


Figure 2 – Truck platooning (TNO White Paper, 2016)

Battery-related developments. The developments in relation to batteries for electric vehicles are difficult to predict. It is not impossible that a battery will become available in the short term that will largely eliminate the objections to electric vehicles. Many of the emissions-related arguments for banning cars and logistics vehicles from cities will then no longer stand up. Congestion and safety will then be the most important arguments for a sustainable urban mobility policy.

To an efficient choice of modality

The overall mobility system consists of various modalities, such as bicycles, public transport, cars, inland shipping, and maritime shipping. The transport of goods and people is currently relatively statically distributed across these different modalities. Bringing about major changes to this distribution is a complex task – a modal shift. Reducing car use, in particular, in favour of low-carbon transport cannot be achieved without substantial restrictions, price increases, and lower maximum speed limits[13].

As far as this cohesive system of modalities is concerned, there are three important future developments.

First of all, we face the challenge of optimizing the individual modalities and making them more efficient. The improvement to the 'separate' capillaries of the system will open up the system as a whole more effectively.

An interesting example of such optimization is the recent development regarding truck platooning. This concept is shown in Figure 2.

Truck platooning works on the basis of vehicle-2-vehicle communication (WiFi) where freight vehicles are driven close to each other in a train. The vehicle at the front determines the speed. Platooning results in less congestion, better use of the road network, fewer CO2 emissions and improved safety. Full automation (level 5) is of even greater interest to the professional transport sector because of the significant cost reductions that could be as much as 50 percent of the operational costs. Any such cost reduction could result in an extensive modal shift.

A second strategy for optimizing the overall mobility system concerns structurally influencing the choice of modality. In that context, it is urban policy efforts in particular that are important for discouraging the use of cars and encouraging the use of bicycles and public transport. More and more cities are either discouraging or banning cars from their inner city areas. Examples are attractive alternatives such as light railways, underground systems, and good bus connections[14]. The most important reason for choosing alternative modalities is the reliability of journey times.

9. *See note 5.*
10. *Milakis, D., Snelder, M., van Arem, B., van Wee, B., Correia, G., (2015). Development of automated vehicles in the Netherlands: scenarios for 2030 and 2050. Delft: Delft University of Technology.*
11. *Nijland H., A. Hoen, D. Snellen & B. Zondag (2012). Elektrisch rijden in 2050, gevolgen voor de leefomgeving. The Hague: PBL Netherlands Environmental Assessment Agency.*
12. *OECD (2016). Shared mobility. Innovation for liveable cities. Corporate Partnership Board Report.*
13. *Bleijenberg, A. (2012). Wishful thinking in Transport Policy (Chapter 6, pp. 135-150) in Van Wee, B. (Eds.) Keep Moving, Towards Sustainable Mobility. The Hague: Rli, EEAC & Eleven International Publishing.*
14. *Ministry of Infrastructure and the Environment (2015). Around the world in eighty days, The Hague: Ministry of Infrastructure and the Environment.*

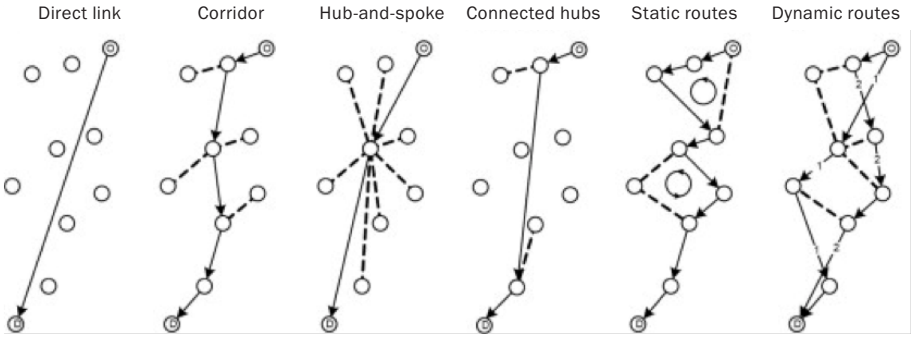


Figure 3 – Mobility systems and routes

The latest developments can be best described as 'synchromodality'. Synchromodality involves not opting for any particular modality, and not excluding any either, for a given transport movement. The concept is currently being tested in the logistics sector especially, but could also be valuable in relation to passenger transport. Depending on the wishes and the specific circumstances, the user chooses in real time the train, the car, the freight vehicle, etc. During the journey, the modality or route can be changed, if the prevailing circumstances give rise to this. Figure 3 shows the development and design of the mobility system[15].

For any such concept to succeed, it is crucial that the mobility system functions as a whole and that real-time information is available for all the various modalities and bottlenecks. System integration and coordination is carried out from control towers which have an overview of the transport flows, transport wishes, and infrastructural availability.

FLEXIBLE INFRASTRUCTURE

As well as the future mobility patterns and ICT developments, the infrastructure of urban areas is essential for accessibility. Infrastructure – roads, cycle paths, bus and tram lanes, railways – take up a lot of space in cities. Moreover, this line infrastructure often passes through cities, so that they unintentionally become split up into multiple socially isolated sections. Future infrastructure will be more multi-functional. Both usage and maintenance are currently insufficiently flexible. There is a big innovative challenge here.

We have already noted that lanes can be used dynamically on certain stretches – the rush-hour lanes and tidal flow lanes. The emergence of the automated car, advanced vehicle-2-vehicle and vehicle-2-infrastructure communication make it possible for the infrastructure to be used dynamically throughout. Use the surface area as flexibly as possible. The function of controlled crossroads and line markings will change in the future, or even disappear altogether. Available space will be allocated in real time to the means of transport that need to use it at the time. From this perspective, it is very much the question of what the future of tram infrastructure is. Tram lanes are an example of highly inefficient and non-flexible dedicated lanes. It should be pointed out that prioritizing such infrastructural flexibility for certain users, such as the emergency services, is a significant challenge. For that, genuine real-time fine tuning of the system is needed.[16] Another related challenge is of an organizational nature. It is not inconceivable that the future system will introduce price mechanisms that regulate right of way and speed at individual traffic flow level.

Infrastructure will be multifunctional. This is related not just to flexible usage by multiple modalities. The limited space in cities makes it necessary that infrastructure be designed in multiple ways. Multiple in the sense that the space should not just accommodate mobility movements, but also be a pleasant environment that includes 'avenue and boulevard concepts'. The terms 'positional value' and 'interchange value' have an important role to play on this cutting edge of mobility and urbanization. A location has a value as a position that is, and a value in the mobility system as a multimodal interchange. In many cases, positional value is at the expense of interchange value, and vice versa. We note that positional value and interchange value are becoming increasingly complementary.

International ambitions for encouraging public transport

The UITP, the international federation of public transport companies, set the ambitious goal of doubling its transport share by 2025. This target must be attained through a series of some 350 new climate initiatives among 110 public transport companies across the globe. In addition, 23 major cities signed the C40 "Clean Bus Declaration". This declaration aims to be a catalyst for cleaner bus traffic. The target: increasing the number of clean buses in the bus fleet by one quarter by 2020.

In many countries, the use of bicycles fell sharply as prosperity grew. Now that cities are making an effort to remain accessible, reduce air pollution and contribute to combating climate change, the bicycle is making a comeback. The World Cycling Alliance (WCA) and the European Cyclists' Federation (ECF) have committed to promoting bicycle transport, through their organizations, in as many cities as possible, and to doubling the number of bicycle movements in Europe by 2020. This requires a great deal of effort. European cities such as Paris, Barcelona and Berlin have introduced popular rental bike systems, and even New York has built separate bicycle lanes for cyclists. Such investments in bicycle infrastructure have laid the foundation for achieving the intended share of bicycles particularly in urban movements. This does not just involve passenger transport, but also, for example, messenger services and bicycle taxis.

Source: Ministry of Infrastructure and the Environment (2015). Around the world in eighty days. The Hague: Ministry of Infrastructure and the Environment.

14. *Ministry of Infrastructure and the Environment (2015). Around the world in eighty days, The Hague: Ministry of Infrastructure and the Environment.*
15. *SteadieSeifi, M., Dellaert, N. P., Nuijten, W., Van Woensel, T., & Raoufi, R. (2014). Multimodal freight transportation planning: A literature review. European journal of operational research, 233(1), 1–15.*
16. *Goodwin, P. (2012). Keep Moving Towards Sustainable Mobility – What Does It Mean? (Chapter 1, pp. 11–22) in Van Wee, B. (Eds.) Keep Moving, Towards Sustainable Mobility. The Hague: Rli, EEAC & Eleven International Publishing.*

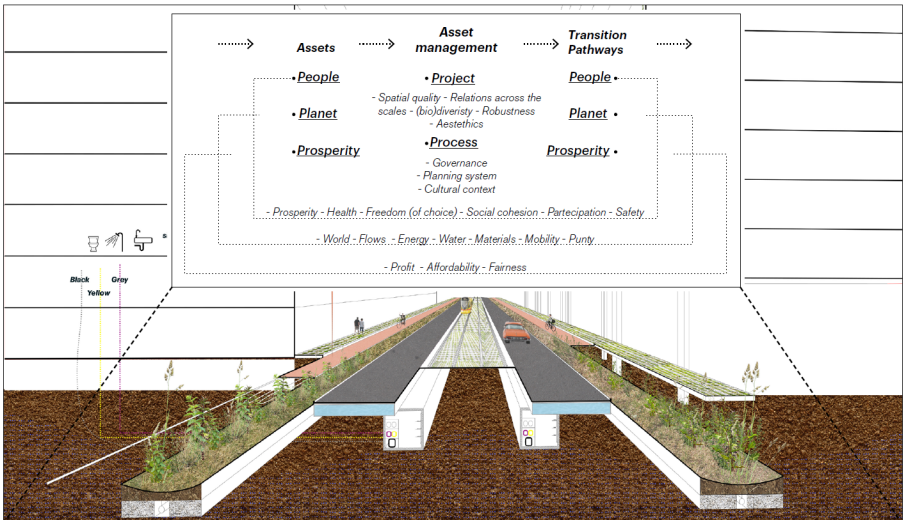


Figure 4 – Horizontal and vertical infrastructure approach (Delft University of Technology: Hooimeijer, Bacchin, Lafeleur, 2016).

Moreover, the infrastructure is playing an ever greater role in the energy and climate fields. Roads are used for generating energy, for example by integrating solar collectors or through the reclamation of heat from their surfaces. This requires a 'vertical' line infrastructure approach which should emphatically also include the subsurface in the design. Water storage – a crucial element in urban planning, because of climate change – will in future feature more and more under the surface of the infrastructure.

Not just design, but management and maintenance are also areas where there is scope for innovation. In the short and medium term, the Netherlands faces an extensive challenge in replacing ageing infrastructure. This provides opportunities for implementing new technologies, in relation to renewable energy, for example. Dense sensory networks in the infrastructure also make it possible to carry out preventive maintenance at exactly the right time, so that major maintenance work can be postponed or even prevented entirely. As a result, cities are more accessible because the number of traffic jams caused by maintenance and road closures is reduced. Also, these sensor systems help create a safe infrastructure, which is also very durable. Thanks to real-time asset management, it remains usable to optimum effect. From the point of view of the circular economy, extension of the lifespan is to be preferred to replacement.

THE INFLUENCE OF URBANIZATION POLICY

Technological developments are going to change the mobility system and in the future will undoubtedly affect the accessibility of urban regions. However, it is not just this progress that will determine how accessible our cities will be. A crucial component is how cities are laid out. How do we situate spatial functions liking housing, work, and leisure in relation to each other? What mobility flows are created as a result? Urban accessibility depends in part on this spatial planning policy. This concerns concepts like clustering, development of interchanges, transit-oriented development, functional blending, and urban design[17]. Even though no robust scientific consensus exists regarding the exact consequences of 'urban form', as the trade jargon has it, on mobility movements[18], there is an important challenge in terms of examining in greater depth and using the value of the 'spatial planning' instrument for sustainable urban accessibility[19]. This is chiefly about interventions such as urban transformation and concentration, multiple uses of space, car-free zones, and innovatively designed streets for public transport, cyclists, and pedestrians. To what extent do they enhance a city's accessibility? There are opportunities for developing user-friendly methods for analysing and illustrating for policymakers the relationship between spatial planning, mobility movements, and accessibility. This enables them to experiment with new options for taking action.

The scope for action among users and interests with regard to accessibility will start to play a greater role in spatial planning policy. It is quite conceivable that a clear division will arise, of transport and mobility flows between urban regions on the one hand, and local traffic and urban logistics on the other. Such a system will relieve urban areas by reducing noise and air pollution. It will make it possible to

Figure 5 – ICT developments in mobility and logistics.

17. *Verrips, A.S. & A. Hoen (2016). Kansrijk Mobiliteitsbeleid. The Hague: The Netherlands Bureau for Economic Policy Analysis and PBL Netherlands Environmental Assessment Agency.*
18. *Stead, D. (2016). Identifying key research themes for sustainable urban mobility. International Journal of Sustainable Transportation, 10:1, 1–8.*
19. *Van Wee, B. & Handy, S. (2016). Key research themes on urban space, scale, and sustainable urban mobility. International Journal of Sustainable Transportation, 10:1,18–24.*

Examples of cross-sectoral integration

Electric vehicles that charge up while being driven on the road
There is a greater need for an integrated urban approach regarding mobility, energy, and spatial planning. These three policy fields are overlapping with increasing frequency, especially as a result of the sustainable energy transition and the related decentralization of the energy system.

The electrification of different modalities also requires extra capacity and places conditions on the urban energy infrastructure. This concerns not only integration within the chain (vertical integration) but primarily the cross-sectoral integration of fields (horizontal integration). Integration of projects, plans, and procedures is a requirement for being able to give a political and organizational answer to socio-technical issues.

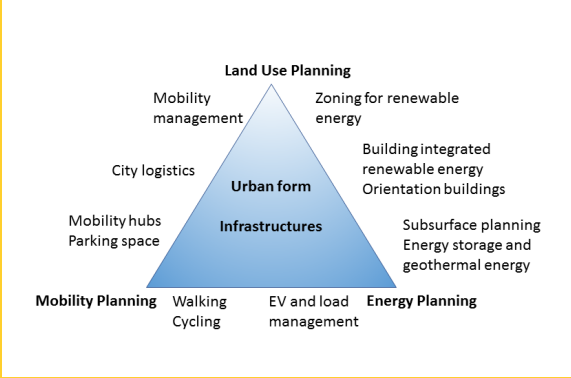


Figure 6 – Connections between spatial planning and energy and mobility planning (TNO, 2016).

provide a dense and sustainable urban distribution network that uses small and environmentally-friendly vehicles. A network that is managed and coordinated from one or several points so that congestion can be prevented as much as possible. Any such division will require storage and transshipment points and multimodal interchanges on the edges of cities. It is the task of urban planners and designers to look for locations of this kind, and to design them and embed them into the urban fabric.

HANDS ON THE WHEEL

A central element of this paper is that the urban infrastructure will become one large system (a physical internet) as a result of various developments in ICT and network technology, and that users of this system will occupy a more important position. This will all happen of its own accord. The organizational issue is at least as important as the technological developments. We see a number of challenges.

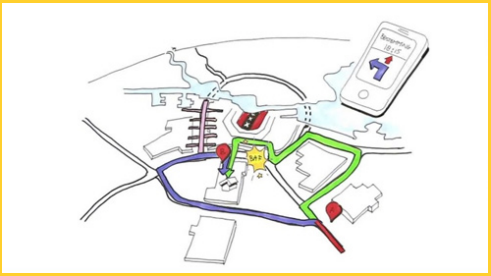
An urban operating system runs on a large quantity of open data. The availability of data is of enormous added value, compared to ten years ago. At the same time, we need to be careful. The quality and usability of this data varies and systems that analyse and process the data may be susceptible to unauthorized access. An urban infrastructure that depends on open and unprotected data is a major risk. The big challenge is to turn the large amount of open and unprotected data into information that really can be used, is reliable and secure, without it losing its real-time applicability. Cyber security is becoming an increasingly important issue.

An urban operating system depends on human control. The parties in any such system will always have to work together – sharing data, guaranteeing interoperability, and initiating multidisciplinary projects. Behavioural change is another important aspect. We know from research that part of this change can be achieved through price incentives. Some change will have to be imposed, though, through legislation and regulation. The ideal is a self-learning and self-organizing system based on distributed intelligence, in which the need for central coordination steadily decreases.

The accessible city of the future is more than a system issue. A form of direction is needed. For example, who decides on the architecture of such a system? Who guarantees that different systems are compatible and able to communicate with each other? Who takes responsibility for the risks of them not functioning? And who supervises the large-scale transition from one system to the other? *Anticipating governance* means that you start organizing without knowing in detail what is to come. This gives you the chance to manage and to prevent undesirable aspects in legislation and regulation.

Example: Praktijkproef Amsterdam

TNO and a large number of partners are involved with the Praktijkproef Amsterdam. This is a large-scale test using the latest innovations in cars and on the road. Nowhere else in the world is intelligent technology in the field of transport management being tested on such a large scale in everyday traffic. That is, with real cars and real road-users in the busy Amsterdam region. The aim of the practical experiment is to gradually work towards a future in which cars, traffic lights, and information signs are connected to each other digitally and work together completely. In this way, the experiment is helping improve traffic flows, reduce the amount of congestion, and make the city cleaner (www.praktijkproefamsterdam.nl).



Experiments like the Praktijkproef Amsterdam are steps towards a physical internet. Cars, infrastructure, and traffic systems that communicate with each other continuously.

System issues require heavy investment. In order to prevent divestment, it may be necessary that a government specifically opts for a technology so that other parties can target their investments entirely at that specific technology. If it concerns automated cars, the choice of in-car technology or technology where cars communicate with roadside units is crucial. Developing and using both systems side-by-side is unnecessarily costly. The choice of system should ideally be made on an international scale.

An important aspect for the next few years is the exponential acceleration of the innovation process. This means that relevant parties will forever have to anticipate possible game changers that cause a completely new dynamic.

IN SUMMARY – TNO AND THE ACCESSIBILITY OF CITIES

To keep cities accessible in the future, a large-scale transition is needed. Implementing new techniques in infrastructure and vehicles, behavioural change, innovative policy and design. The network is becoming larger and more complex. This exposes the area of tension between controlling and self-organization, and between optimization and parts of the whole system. Cooperation between actors in order to guarantee the exchange of information is crucial, as is cooperation and communication between different systems. This means that keeping cities accessible is primarily a governance challenge.

The field in which TNO operates is located between technical innovation, policy development, and logistics parties and mobility parties. We link parties together and guide them through the various stages of a joint process in order to achieve sustainable mobility and accessible cities. As an independent innovation partner, we have a good view of the steps that have to be taken in both the short and long term. Coordination between different projects and investments in particular is of crucial importance. With needs research, calculation of the effects of measures, and the development of logical parameters, we provide a well-founded choice for mobility policy that is likely to succeed.

WITH THANKS TO:
Lori Tavasszy
Jan Burgmeijer
Maaike Snelder
Mirjam van Iterson
Hans Quack
Marco Duijnisveld
Natascha Agricola
Ralph Klerx

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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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Version July 2017