EXECUTIVE SUMMARY

Introduction

The mobility of persons and goods leads to important benefits for the Flemish inhabitants and the economy in Flanders. Passenger transport makes it possible for people to go to work to earn an income, to undertake leisure activities and activities for their personal development, and to have a network of social contacts. With efficient goods transport firms can organise their production process efficiently and easily reach their customers. However, transport also leads to a range of persistent, interrelated problems that are classified as external costs. These include among others the damage caused by the emissions of greenhouse gases and air pollutants, the loss in quality of life, congestion, noise pollution, traffic accidents and inefficient land use.

The level of ambition for reaching a more sustainable mobility is high and there is a large need for solutions in the transport sector. Smaller solutions will not suffice, and more fundamental changes will have to underpin the realisation of the sustainability aims. In other words, there is a need for a sustainability transition in the mobility system.

Aim and scope of the study

This study contributes to the Environmental Outlook 2018 of the Environmental Reporting Department (MIRA) of the Flanders Environment Agency (VMM). Its purpose is to give an overview of the innovations / solutions that may contribute to the transition to the environmental sustainability of the mobility system, of their potential and of the levers that may help to realise that potential, and of the barriers that may be lowered by them.

Parallel with this study two other studies have been carried out for the Environmental Outlook 2018, covering the energy and the food system. The link with the transitions in those two systems is highlighted as much as possible in this report. However, for elements that are specific to those systems, reference is made to the two other studies. There is also an important interaction between the evolutions in the mobility system and land use changes. That interaction is covered in more detail in the Environmental Outlook for land use.

The strong link between the Flemish mobility system and other social systems

An important characteristic of the Flemish mobility system is that it is not an isolated system, but strongly connected with other social systems both within Belgium and abroad. On the one hand the many links that exist make it more complex to make the mobility system more sustainable. One the other hand they can also offer opportunities for tackling the challenges for the mobility system through the other social systems. For example, better spatial planning may reduce the need for transport or it may make it more attractive for public transport to meet the transport needs.

An additional observation is that many new initiatives, products and services which may be relevant for the mobility system are popping up. Some have already found enthusiastic users (e.g. electric bicycles), others have success with a small but motivated group of users (e.g. car sharing), while others are still in an early stage (e.g. hydrogen cars). In many cases they can be considered to still operate in ‘niches’. These are still under development but may potentially play a role, and in some cases a large role, in the transition towards sustainable mobility, if the necessary conditions are fulfilled. The way in which such niches may lead to system changes is an important topic within transition thinking. That field of research analyses how to accelerate system changes and to support them through transition governance. The final aim is to change the (mobility) system by (gradually) replacing the dominant but unsustainable regimes by other, more sustainable, alternatives. This study aims to explore/shed light on some of those niches and to analyse their potential for a more sustainable mobility system.

Innovations and solutions for the mobility system: from longlist to shortlist

The public debate on making the mobility system in Flanders and also globally more sustainable puts forward many different solutions and innovations. As a first step the study drafted a longlist of possible innovations and solutions. They were classified according to the three broad solution approaches of the European Environment Agency:

- ‘Avoid’: this refers to solutions and innovations that make the mobility system more sustainable by reducing the number of trips and by reducing the average trip length (e.g. e-working).
- ‘Shift’: this refers to solutions and innovations that encourage the use of other, more environmentally friendly, transport modes (e.g. replacing the car for a number of trips by an electric bicycle).
- ‘Improve’: this refers to solutions and innovations that improve the environmental performance of transport means, e.g. by technology improvements, by increasing the occupancy or loading rate, etc. (e.g. replacing a internal combustion vehicle running on fossil fuels by an electric vehicle).

In addition, the link was made with five overarching categories of innovations and solutions that were identified as potential game changers in a recent transition paper for the Flemish Government entitled ‘Towards a smooth and safe mobility system’:

- Connected mobility and (partly) autonomous transport means
- Combined mobility
- Shared mobility
- Personalised mobility services (or Mobility as a Service)
- Green mobility

The longlist was drafted on the basis of a literature review and insights obtained from a number of experts in the field. From this longlist was then distilled a shortlist that covers ten groups of solutions. The selection of those ten groups was based on a first estimate of the environmental potential and the extent to which the innovations imply a transition, as indicated by the experts and the literature review. Moreover, the selection aimed to include examples for the three broad solution approaches that are put forward by the European Environment Agency (Avoid, Shift, Improve).

The next table summarises the shortlist with the ten groups. Some groups only apply to passenger transport (Groups 1, 2, 6). Group 3 focuses on freight transport. The other groups of solutions may be relevant for both passenger and freight transport.

Shortlist with ten groups of solutions

Group	Overarching category transition paper Flemish Government	Passenger/freight transport	Avoid/Shift/Improve
1: Working, learning, meeting from a distance	Other	Passenger transport	Avoid
2: Ridesharing passenger transport	Shared mobility	Passenger transport	Improve
3: Logistic improvements	Personalised mobility services Combined mobility	Freight transport	Avoid/Shift/Improve
4: (Electric) bicycle and new light electric vehicles	Green mobility	Passenger and freight transport	Shift
5: Vehicle sharing	Shared mobility	Passenger and freight transport	Avoid/Shift/Improve
6: High-performing mobility services or Mobility as a Service	Personalised mobility services Combined mobility Shared mobility	Passenger transport	Shift
7: Autonomous vehicles	Connected mobility and autonomous vehicles	Passenger and freight transport	Shift
8: Battery electric vehicles	Green mobility	Passenger and freight transport	Improve
9: Electric vehicles with hydrogen fuel cell	Green mobility	Passenger and freight transport	Improve
10: Advanced biofuels	Green mobility	Passenger and freight transport	Improve

The environmental potential of the ten groups of solutions in the shortlist

The next table summarises the general findings about the environmental potential of the solutions and innovations in the shortlist. A distinction can be made between three categories.

First, one distinguishes a number of innovations and solutions that have a beneficial environmental effect within a specific segment of the mobility system. That is the case for the first six groups in the shortlist. The way in which these positive effects arise differs between the six groups, and is summarised in each case in the table. An important condition is that extra transport policy is introduced in order to mitigate as much as possible any unwanted reboundeffects. Ideally, the extra policies confront the transport users as much as possible with the social costs of their transport choices. In the absence of this, the positive effects will be smaller and in some cases substantially so or even almost non-existent (as for example in the case of e-working).

The second category consists of innovations and solutions that may have a much larger environmental potential because they apply to a much larger part of the mobility system. That is the case for the alternative propulsion technologies and possibly also for advanced biofuels. However, also in this case there is an important precondition, namely that the generation of energy and the production of biofuels is done in a sustainable way, which is currently not (yet) or insufficiently the case. The possibilities for realising this in the Flemish energy system are discussed in more detail in the parallel report about the energy system.

The third category consists of autonomous vehicles. The developments in that domain may have a potentially very large impact on the mobility system. However, at this stage it is difficult to gauge the effect on mobility demand and its related environmental impacts. Also in this case it can be pointed out that there is a need for a good policy framework in order to realise a positive environmental impact and to keep under control any reboundeffects that may arise, but it is even more uncertain whether policy makers will be able to anticipate quickly enough on the new context that will be created by these developments.

Overview of the environmental potential of the groups of solutions in the shortlist

Scope	Positive environmental effects	Negative environmental effects	Level of uncertainty	Reboundeffects without extra policy?
Working, learning and meeting from a distance				
Passenger transport - Commuting - Home-school - Business Relatively small segment of mobility system (about 16.2 % of passenger km)	- By replacing motorised transport - Highest potential if it replaces trips by cars with an internal combustion engine running on fossil fuels, or air trips - Positive effect decreases as the vehicle stock gets cleaner		Relatively low	Probably strong reduction of direct impact through: - Energy consumption at home (this falls as residential energy efficiency improves) - Income effect: money saved is spent on other consumption, including trips - Location effect: live further from job/school such that total travel time is unchanged - Latent demand: people scared off by high congestion travel again by car if congestion is reduced - More and longer business trips by easier virtual/digital contacts
Ridesharing				
Passenger transport Car trips for all purposes In this report: commuting traffic by car	Highest potential if solo car drivers with internal combustion engine car running on fossil fuel switch to carpooling		Relatively low	Via - Income effect: money saved is spent on other consumption, including trips - Latent demand: people scared off by high congestion travel again by car if congestion is reduced (if strong breakthrough at times and locations with congestion)

Scope	Positive environmental effects	Negative environmental effects	Level of uncertainty	Reboundeffects without extra policy?
Logistic improvements				
Freight transport Last stage in decisions about transport and logistics choices (many determining factors such as location are fixed at this stage)	- Via modal shift, but difficult to realise - Via higher efficiency: lower growth road transport, but no reduction in tonkm - Physical internet (for urban distribution) that optimises loading rates and number of trips, but still under development		Relatively low for existing solutions High for solutions in early stage	Lower freight transport cost by higher efficiency → higher freight transport demand
(Electric) bicycles and light electric vehicles				
Passenger transport Relatively short distance trips (up to 15 km) (79 % of trips, but only 24 % of distance travelled) Longer trips if combined with public transport	- Higher energy efficiency than car - Potential highest if switch from car with internal combustion engine running on fossil fuel - Positive impact on noise - Environmental benefit highest with sustainable production of electricity ** note: the social health benefits are very high, higher than the environmental benefits	Environmental benefit lower with unsustainable production of electricity	Relatively low for bicycle High for LEV because still in early stage	- Latent demand: people scared off by high congestion travel again by car if congestion is reduced (if strong breakthrough at times and locations with congestion) - Income effect: money saved is spent on other consumption, including trips

Scope	Positive environmental effects	Negative environmental effects	Level of uncertainty	Reboundeffects without extra policy?
Car sharing				
Passenger transport Potentially all car trips	- More direct confrontation with car costs + requires more efforts from car user → less car km - Right-sizing (less use of vehicles that are 'too large') → lower environmental impact per km - First and last mile transport for public transport (public transport more attractive) → lower environmental impact per km - Case for alternative fuel vehicles is improved - Younger and therefore cleaner vehicle stock - More efficient vehicles - Less need for parking spots	- Car becomes an option for people who otherwise would not be able to afford one - In some cases switch from cycling or public transport to car - Km driven to bring back vehicles to their depot	High Behavioural changes of frontrunners are possibly not represen-tative for the average transport user	- Latent demand: people scared off by high congestion travel again by car if congestion is reduced (if strong break-through at times and locations with congestion) - Income effect: money saved is spent on other consumption, including trips (car sharing leads to lower car costs)
High-performing mobility services or MaaS				
Passenger transport Potentially large scope but limited by available public transport capacity (currently less than 10 % of passenger km by public transport) In urban context: Demand Responsive Transport	- With bundling of transport flows in public transport: lower environmental impact per km - Largest with switch from conventional car - Larger with further improvement in environmental performance of public transport - Large in the case of Demand Responsive Transport in urban context See also shared mobility	- If switch from public transport to car sharing - See also shared mobility	High	More trips because of more attractive mobility services

Scope	Positive environmental effects	Negative environmental effects	Level of uncertainty	Reboundeffects without extra policy?
Autonomous vehicles				
Passenger transport Freight transport Potentially large scope (all vehicles and trips)	- Higher energy efficiency - Right-sizing – avoid the use of 'too large' vehicles → lower environ-mental impact per km (if shared vehicles) - Case for vehicles with alternative fuels/technologies improves - Less car km because of higher cost - Less parking spots in cities	- Km driven for picking up other passengers - Via location choice impact on land use and because of this more km - More parking spots outside of cities - Space for locations where passengers can be picked up	Very high Technical possibilities and costs uncertain	- If car trips become more comfortable and if lower time costs, parking costs, insurance costs → More car km - Via location choice (further distances because of lower time cost)
Battery electric vehicles and hydrogen fuel cell vehicles				
Passenger transport Freight transport Potentially large scope (nearly all vehicles and trips)	- Greenhouse gases: if electricity / hydrogen is produced sustainably - No local pollution (of exhaust emissions), but still exhaust emissions - Positive impact on noise - Stronger case for renewable electricity - Environmental benefit falls when conventional vehicles become cleaner	- If electricity / hydrogen is not produced sustainably - More energy intensive production of vehicles	High to very high Cost uncertainty Uncertainty about technological possibilities (especially for hydrogen fuel cell)	If higher cost per km → less km and vice versa Green paradox in case of sustainable electricity
Advanced biofuels				
Passenger transport Freight transport Potentially large scope (nearly all vehicles and trips)	- Depends on feedstock and production pathway - Effect on greenhouse gas emissions without land use changes would be positive for 2nd generation but negative for 3rd generation - Effect on greenhouse gas emissions taking into account land use changes is positive in some cases	- Effect on greenhouse gas emissions without land use changes would be negative for 3rd generation (current situation) - Effect on greenhouse gas emissions taking into account land use changes is negative in some cases	High to very high	- Via effect on cost per km - With lower demand for fossil fuels → lower price → increase in demand - Via 'green paradox'

Other effects

Most of the groups of solutions in the shortlist can be expected to also have an impact on the other external costs of transport, more particularly on congestion and traffic accidents. There will also be some other consequence for transport users, including among others the health benefits of the more active transport modes. In addition, a number of wider social impacts can be expected to come into play for several innovations and solutions. These include among others the impact on inclusion, privacy, the market power of suppliers and the broader economic and social consequences related to the upcoming of new technologies and the extraction of the raw materials that are used.

Barriers and levers for a selection of three groups of solutions

Out of the shortlist of ten groups of solutions, three groups of solutions were selected for an in-depth analysis of levers and barriers:

- (Electric) Bicycles and new light electric vehicles
- Shared mobility
- Battery electric vehicles (BEV)

Next to these three cases, the levers and barriers of the remaining seven groups of solutions are analyzed. This analysis is based on literature and interviews with experts.

The three case studies are analysed using a methodology that is inspired by the TIS-model, the Technological Innovation Systems model, of Suurs and Hekkert (2005). This model has a strong focus on the innovative possibilities of technologies as promising strategies for sustainability transitions. As the scope of our research includes both technological and non-technological innovations, the TIS-model is modified such that it can also be used for non-technological innovations. We named the modified model the TEMIS-model, the Technological And Societal Innovation Systems model ('EM' is Dutch for 'And Societal'). Next to technological factors, the TEMIS-model looks at societal factors such as behaviour, attitudes (including psychological factors), culture and policy.

The data collection of the study is based on an overview of the literature, fourteen interviews with experts and a workshop with experts. What follows are the most important results.

- Case 1: (Electric) Bicycles and new light electric vehicles

The (electric) bicycle has many assets and is a very sustainable means of transportation with considerable advantages concerning health and air quality. The awareness concerning these assets is rising such that (electric) cycling is on the rise in Flanders, and it also still has a large growth potential. The barriers include the current spatial planning which is very car-centered, the weather, and the importance of the car in the Flemish culture. The quantity and quality of biking infrastructure could still improve considerably, and there are insufficient public facilities to charge batteries and to safely park light electric vehicles. In many cases, rules and regulations still favour cars. The cultural shift away from the car is not made by many people yet.

– Case 2: Shared mobility (vehicle sharing)

The social and environmental potential of shared mobility is still under discussion. Vehicle sharing's potential primarily lies in urban areas and in transportation that cannot be done without a car. Shared mobility can have an added value as a component of a service offering mobility (Mobility as a Service). Levers include the financial advantages and the opportunities to move towards 'right sizing'. The barriers are 'the culture of owning a car' and the immediate access to a vehicle when it is needed.

– Case 3: Battery electric vehicles

Electric vehicles are, especially in an urban setting, a solution to some social issues, but they are not a universal mobility solution. The levers are that no big cultural changes are needed, and that local air quality and CO_2 emissions are improving considerably. The slow pace at which the energy system is transitioning towards 100 % renewable resources is an important barrier for the role of BEV in the transition to a sustainable mobility system. Other barriers include the high purchasing price, long charging times and the still limited range. Even when the technological barriers are overcome many experiments will remain necessary, because the psychological barriers (e.g. fear of running out of electricity) are harder to remove than the technological ones.

Even when the total cost of the ownership of a BEV would be lower than the price of a car with an internal combustion engine, the perception will probably remain that the BEV is more expensive. This can be explained by the salience of the higher purchase price and the lower visibility of the cheaper energy price per km driven.

General barriers and levers

A number of 'general' levers and barriers are relevant for many solutions and innovations.

First, it is clear that changes in the mobility system are being hindered by psychological and cultural barriers that have an influence on the behaviour and attitudes of citizens. The slow uptake of new technologies can be understood this way.

Second, we found high risks of rebound- and undesired side effects. These effects emerge when the direct gains on the one hand are offset by losses at the other hand. For example, the higher energy efficiency thanks to an optimization of engines can be used to increase the power or to add additional luxury. Or the possibility to work at home (telework) can motivate people to search for a job further away from their home.

Third, we conclude that the transition towards a sustainable mobility system (both the probability and the pace of the transition) will be determined to a great extent by policy interventions. Currently, the price of transportation (of people and goods) mostly does not reflect the external costs. Consequently, transport of people and goods is locked in in an unsustainable regime. It is important for governments to not only motivate, but also discourage certain behaviour. Public policy can discourage unsustainable transport by restricting access to cities, or by introducing a system of road charging. It is not a government's task to push a specific technology (be it electricity or other). The government should think about appropriate norms and strive for correct prices such that a level playing field can be created for the transition towards a sustainable mobility system.

Concluding remarks

The study shows that they are many solutions that can contribute to the transition to a more sustainable mobility. However, in many cases the future development of the solutions and/or their impacts are still uncertain. Moreover, reboundeffects or other indirect effects could reduce their impact, or the environmental potential depends on developments in other societal systems, such as the energy system. Many citizens and firms would also like to contribute to a more sustainable system, but often find it hard to change their habits.

Thé solution for a sustainable mobility system does not exist. Often a combination of solutions will be involved. For the actual realisation of their potential it is crucial that the government creates the appropriate framework, starting from a long term vision on sustainable mobility. It can use a range of policy instruments that can be implemented at various government levels.

- Supporting Research & Development – this can be done at Flemish level, but preferably also within a broader European framework.
- The further introduction of standards related to emissions and energy efficiency – here a European approach is crucial.
- To introduce local access regulations – such measures can be taken at a local level.
- To use an adequate pricing policy that confronts firms and passengers with the social consequences of their individual transport choices – this can be done at urban, regional or federal level, with Europe playing a role in some cases by setting general guidelines.

Such a policy framework creates opportunities for solutions and innovations and encourages citizens and firms to make sustainable mobility choices.