D.T1.3.3 REPORT ON BENEFITS OF BEHAVIOURAL CHANGE

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1. Introduction

Almost a quarter of Europe's greenhouse gas emissions and the main cause of air pollution in European cities is caused by transportation (EUROSTAT, 2017). Due to rising sustainability challenges in the past few years the need to adopt an environmentally friendly mobility culture by using new technologies and services emerges more and more (Bekiaris et al., 2017). However, the worldwide demand for cars is still growing and expected to rise from approximately 1 billion in 2015 to 2.4 billion in 2050 (OECD/ITF, 2017). If negative impacts from transportation are to be reduced, changes in people's transport behaviour are unavoidable (Schwanen et al., 2012). This could lead to advantages for the environment, society and individuals.

This report has been designed to point out the benefits of a behavioural change towards sustainable mobility. It provides information about the environmental, social and economic advantages of different transportation modes. Breaking the norm of using cars and switching from private vehicles to alternative sustainable means of transportation is challenging. Thus this report investigates transportation behaviour basics and examines factors affecting travel mode choice.

The structure of the report is the following:

Section 2 Behavioural change
Outlines basic information about behavioural change theory and its implications for sustainable transportation.

Section 3 Benefits of the increasing use of sustainable mobility
Illustrates the benefits of the increasing usage of sustainable mobility offers.

Section 4 Benefits of mobility concepts
Describes how new mobility concepts can be an option to allow people to change their habits. Beforehand, their additional environmental and social value are outlined.

Section 5 Drivers for behavioural change
Provides an overview over potential drivers and influencing factors which foster adoption of sustainable mobility concepts.

2. Behavioural Change

The action that people take and the choices they make have a direct or indirect impact on the environment (Jackson, 2005). Almost all environmental problems underlie human behaviour (Manning, 2009). It is well established that the challenges of mitigating climate change and finding a path towards a more sustainable future require different ways of living and consuming. This can only be reached if people change their behaviour (House of Lords, 2011).

The first section of this report attempts to give a definition of behavioural change and its implication referring to sustainable mobility.

The term behavioural change comprises all theories and techniques to modify and change human behaviour (van der Pol, 2017). There is no single scientific discipline about human behaviour. Behavioural sciences cover the systematic analysis of the processes underlying human behaviour. They combine knowledge and research methods from the field of psychology, economics, sociology and neuroscience among other sciences (Lourenco et al., 2016). Regarding the theoretical base for behaviour change, the theory can be divided in 2 sections ((Darnton, 2008), (Hunecke, 2015)): models of behaviour and theories of behavioural change.

1. Models of behaviour

Models explain why people make decision and display certain behaviours. Factors that influence behaviour are identified and focus on describing existing behaviour, e.g. how intentions, attitudes, values and other factors shape behaviour.

2. Theories of behavioural change

Theories deal with the question how a current behaviour can be changed into a more desirable behaviour. A set of theories and techniques tries to explain how behaviour can be changed.

Both bodies are complementary. It is necessary to understand behaviours by identifying the underlying factors as well as the techniques of how behaviours can be changed in order to develop effective approaches to behaviour change.

2.1. Implications for transport

Theories of behavioural change can assist in understanding social and psychological influences of the travel mode decision making process (Hunecke, 2015). An individual's choice of transportation mode is influenced by a number of factors. Social norms, habitual and automatic behavior and public transport infrastructure have been identified as particularly important (Midden et al., 2007). Understanding what motivates people to change their behavior is a key element of successful persuasion (Forbes et al., 2012).

Important theories in the transportation context are the "theory of planned behaviour" (Ajzen, 1991) and the "norm activation model" (Schwartz, 1977). Those theories, besides many others, help to identify and understand key behavioural determinants (Michie et al., 2005). These determinants are then targeted by behavior-changing techniques and interventions (Forbes et al., 2012). Such Behaviour changing interventions aim to change specified behaviour patterns.

2.1.1. Changing travel behaviour

Mobility Management is one example of how behavioural change is used in the transport sector. The aim hereby is the reduction of car usage by modification of travel behaviour. Therefore, communicative measures, also called soft measures or psychological and behavioural strategies, are being used (Fujii and Taniguchi 2005). Instead of policy rules and regulation the developed interventions try to change perceptions, beliefs and attitudes (Forbes et al., 2012) (Graham-Rowe et al., 2011). For example, travel feedback programs are being used to change travel behaviour from the usage of automobiles towards alternative travel modes such as public transportation or sharing modes (Fujii and Taniguchi 2005). The participants in these programs receive information based on their personal travel patterns in order to increase their awareness and knowledge (Fujii and Taniguchi 2005).

A main barrier for inter- and multimodality is the lack of information about different travel options (Behrendt et al., 2017). Behaviour change programs advance the knowledge of shared modes by using intervention tools. Interventions using media campaigns show positive effects on mode shift. Such measures are useful in increasing awareness and knowledge (Scheepers et al., 2014).

The situational combination of different transport modes is an important key to ensuring sustainable mobility (Klinger, 2017). Due to behavioural patterns it is challenging to lead people towards multimodality. The question of how to understand and intervene in habitual carbon intensive travel practices has become crucially important.

For a transition towards the combined usage of sustainable modes, behavioural aspects and user preferences need to be known for a successful development of policies and programs (Böcker and Meelen, 2017; Habib et al., 2012). Those interventions should be non-regulatory in character thus there is increasing recognition that interventions to change behaviour in the long term should draw on models of behaviour and theories of behavioural change. (Michie, 2008)

2.1.2. Advantages for interventions and measures

Changing transport behaviour is a complex process. There is a wide range of theories each with its own techniques (Forbes et al., 2012). However, there are good reasons to be found why those are an important base to reach behavioural change.

If carbon emissions from transportation are to be reduced, certain level of behavioural change is unavoidable (Schwanen et al., 2012). For this purpose, psychological strategies and soft measures are less costly and may be more publicly acceptable than structural interventions (Graham-Rowe, et al., 2011). Additionally, those approaches are efficient. A meta-analysis on Travel Feedback programs in Japan (Taniguchi et al., 2007) found a mean reduction in car usage of 19 %. Möser and Bamberg (Möser and Bamberg, 2008) predicted an increasing use of non-automotive transport modes up to 7 % through combined measures in Mobility Programs. Brög et al. reported achieved behaviour changes of 5 to 15 % in reducing car trips through voluntary travel behavioural changes initiatives (Brög et al., 2009).

Interventions to reduce car use could lower CO_2 emissions from road transport more quickly than technological measures (Graham-Rowe, et al., 2011). However, it is challenging to implement them in practical settings. Behaviour change theory-based interventions and applications facilitate an understanding about different motivations for people to use public transport or shared modes. They provide a helpful basis to design change but are just one component to move people towards a more sustainable mobility behaviour. Further important factors are shown in section 5.

3. Benefits of the increasing use of sustainable mobility

The second passage of this report introduced the theoretical background of behavioural change. The following section shows the benefits of an increasing usage of sustainable mobility offers and argue thereby why changing transport behaviour towards these modes result in environmental, social and economic benefits.

3.1. Ecological benefits

Emissions, air and noise pollution

Transportation causes almost a quarter of Europe's greenhouse gas emissions and is the main cause of air pollution in cities (EUROSTAT, 2017). The European long-term objective regarding transportation is the reduction of greenhouse gas emission by at least 60 % until 2050 compared to 1990 levels (European Commission, 2011).

This cannot be realized without sustainable transportation. The electrification of transportation plays a key role in solving cities' most urgent environmental problems. In contrast to cars with a combustion engine, electric vehicles do not emit harmful emissions and greenhouse gases during their direct use. Therefore, the air quality can be improved (Soret et al., 2014) and the amount of greenhouse gas emissions during the usage is being minimized (Ajanovic and Haas, 2016).

Shared modes, especially car sharing, lower CO_2 emissions (Baptista et al., 2014) reduce vehicle ownership and car travelled kilometres (Nijland/ van Meerkerk, 2017). However, the strength of these effects depend on the shared mode other determinants.

Shared automobile usage reduces the negative impacts of private vehicle ownership (Shaheen and Coheen 2012). Ridesharing in its various types can help to mitigate travel congestion and lower pollution by a more effective degree of capacity utilisation. (Furuhata et al., 2013) Furthermore, shared travel modes affect the mobility behaviour of its user. After the registration for a car sharing program, customer used public transport more often, drove their own car less and walked and cycled short distances more often (Katzev, 2003) (Nijland and van Meerkerk, 2017).

Saving resources

The current way in which we are satisfying our mobility needs is resource intense. Energy is needed for the use of a car but as well for raw material processing, car manufacturing and recycling. 9-12 % of the total manufacturing costs are energy related costs. (Fysikopoulos et al., 2012). Table 1 gives an overview on the energy consumption during vehicle assembly.

Table 1 Energy per Vehicle produced

Car manufacturer	Total energy consumption per vehicle (MWh / vehicle)
BMW (2016)	2,17
Nissan (2017)	1,8
General Motors (2016)	2,19
Volkswagen (2017)	2,01

Differences in the spectrum of energy intensity per vehicle depend on factors such as calculation type and underlying system boundaries.

Raw material and water consumption, waste and emissions are the main environmental impacts besides energy consumption in the automotive assembly. Mobility concepts which lower motorized individual traffic can help to save scarce resources needed for the automotive production (Böcker and Meelen, 2017). The potential of car sharing for the reduction of passenger vehicles on the road has been examined frequently. Table **2** shows the findings of the car replacement rate through car sharing vehicles.

Table 2 Replacement Rate of Car sharing

Reference	Replacement rate 1 CS vehicle replace x private cars
Martin et al., 2010	1:9 - 1:13
Shaheen and Cohen 2012	1:7 - 1:10
Carplus , 2016	1:10,5
Schreier et al., 2015	1:2- 1:3,6

It has to be considered that the calculation of those replacement rates are highly complex. Findings vary on study design, car sharing system (station based, free-floating), location and further components.

Other modes of the shared mobility such as scooter sharing, bike sharing and peer to peer car sharing eliminate the need for a private vehicle to complete trips. In combination with public transport, people have the ability to fulfil mobility needs without owning a vehicle. Having a car in urban areas makes no sense, if people use these offers (Belk, 2014).

A behavioural change towards non-motorized and public transportation has numerous benefits. Active transportation like walking and cycling do not have any negative impacts such as congestion, noise and air pollution (Rabl and Nazelle, 2012).

The use of public means of transport and decreasing use of private vehicle results in less energy consumption and a lower demand for parking space (Baptista et al., 2014). Public transport reduces automobile travel (Litman, 2000). Fewer vehicles means a lower requirement for new roads and can help to reduce land consumption (Firnkorn and Müller, 2011). Scarce resources, otherwise needed for automotive production and construction for infrastructure, can be saved (Böcker and Meelen, 2017).

3.2. Social benefits

Transportation affects the health of people, especially in urban areas. Air and noise pollution has the biggest environmental impact on health in Europe (World Health Organization, 2011). Changing transport behaviour towards sustainable mobility contributes to a healthier lifestyle for the following reasons:

- Sustainable means of transportation do not harm the public health due to the fact, that they cause less or no emissions compared to car traffic
- Public transport, carpooling and car sharing lead to more walking and cycling
- Physical activity brings large health benefits. (Rabl and Nazelle, 2012)

Another social advantage is the access to mobility and the possibility to fulfil mobility needs. Shared means of transportation provide access to mobility without the requirement of owning a vehicle. People have the possibility of making trips they could otherwise not have made. (Sikorska and Grizelj, 2015)

Additionally, customers have the benefit of transferring the responsibility for the vehicle or the mobility service to the service supplier (Hirschl et al., 2003). Sharing instead of ownership or active and public transport provide easier mobility solutions. Users do not have to worry about fuel, insurance, parking fees or maintenance. (Belk, 2014) Life quality can be enhanced by offering easier and more comfortable mobility solutions.

3.3. Economic Benefits

A negative side effect of transportation in general are the external costs for society. When people take their decision on transportation, they do not take external costs into account. Those are e.g. time costs of delays due to congestion, health costs caused by air and noise pollution or environmental costs caused by all environmental damages (European commission (ed.) 2014). Behavioural change towards sustainable mobility is a cost-effective way to dramatically reduce environmental and socioeconomical impacts and the resulting costs derived from the car-based transportation model. When considering full transport costs, including vehicles, fuel, operational expenses and losses due to congestion, sustainable mobility can deliver savings of 70 trillion US-Dollar by 2050 (World Bank, 2017).

Lower internal costs for individuals are incentive to change transportation behaviour. Vehicle owners have to pay high fix costs, irrespective of the degree of use. Shared mobility offers a “pay as you go” alternative which enables a short term vehicle use without the full cost of ownership (Shaheen and Cohen, 2012).On average, a car costs 6.500 € per year to own and run compared to average car expense of 50 € per month for Carsharing members (Baptista et al., 2014) (BEUC, 2016). Ridesharing and Carpooling reduce travel costs as they will be split between all participants (Furuhata et al., 2013). The decrease on fixed costs associated to vehicle ownership is one of the main advantages of shared mobility.

Promoting pedestrian and bicycle mobility is a cost-effective way to dramatically reduce environmental impacts derived from the car-based transportation model (Orellana et al., 2016).

4. Benefits of mobility concepts

The average car in North America and Western Europe is being used only 8 % of its lifetime (Belk, 2014). Over half of all car journeys are less than 6 km in length (European Environment Agency, 2017). Changing behaviour and breaking the norm of using cars will be a key challenge for sustainable transportation in the future. Alternative mobility concepts support these processes as they are environmental beneficious and influence people's mobility behaviour.

4.1.1. Collaborative- and shared mobility

Over the past few years collaborative and sharing economy have shown the potential to change travel patterns and the way people use cars (Prieto et al., 2017). Collaborative platforms are internet based tools that enable transaction between people providing and using a service (European Union, 2016). Such internet-based information tools facilitate easy swapping, sharing and borrowing of goods between customer to customer (Botsman/ Rogers, 2011). Because of the convenient and cheap access to transport vehicles, it is not necessary for users to own them. Collaborative consumption can enhance sustainability and change mobility behaviour as described in the following points (Schor, Fitzmaurice, 2015):

- All services are pay per use based which gives an incentive to drive less and use other transportation modes. The economic advantage for users lowers the consumption of physical resources (Litman, 2000)
- Private vehicles are older than those offered in car sharing fleets. Hence, the latter have better environmental characteristics (Martin et al., 2010)
- Shared services help to stabilize a car-less lifestyle caused by the interaction of behavioural change techniques (Baptista et al., 2014)
- The collaborative use of transportation vehicles leads to longer and a more intense use (European Union, 2016)

Besides shared mobility, other mobility concepts provide sustainable benefits. These concepts can be an option to allow people to change their habits enhancing the implementation of intermodal systems in an urban context (Mugion et al., 2018).

4.1.2. Demand responsive Transport (DRT)

Demand responsive transportation services are flexible public transportation services in which the routing and the schedule of vehicles operating are defined in response of the demand (Rahimi et al., 2018). Passengers ride together on a minibus or medium sized vehicle but do not necessarily share origins nor destinations (Ronald et al., 2016). The vehicles are usually restricted to a defined service area.

Flexible transport services meet social needs and are environmentally friendly. In areas where people have no access to mobility, DRT has the potential to combat social exclusion (Ryley et al., 2014). On rural sites the density for fixed route public transport is often too low. The only remaining transportation option is motorized individual traffic. Dial a ride and other DRT services can lower the car dependency in those areas (Ronald et al., 2016).

Moreover, demand responsive transport could be used as a feeder for bus, tram and rail services in urban areas (Mageean and Nelson, 2003). The international transport forum of the OECD estimates that demand responsive transportation in combination with public transport could reduce traffic emission by on third. The car fleet in cities could be minimized and less space would be required. (OECD and ITF, 2016)

4.1.3. Low carbon transport – electrification of transport

Over the past years, sales for electric vehicle (EV) increased rapidly. Despite the strong growth, electric vehicles have had a total market share of 0.81 % in Europe in 2017 (European Alternative Fuels Observatory, 2018). This makes 1.4 % of cars sold in Europe in 2017 that were electric (European Automobile Manufacturers Association, 2018).

The European Union has set the goal to reduce the usage of conventionally fuelled cars in urban transportation by half until 2030 and to achieve emission free urban passenger transport by 2050 (European Commission, 2011). To reach this goal, it is essential to enlarge the share of electric Mobility. Besides the reduction of direct emissions and energy consumption, the electrification of transport is affecting people's travel behaviour.

Electric cars are often purchased as a second car but end up as the main vehicle for daily transportation (Figenbaum/ Kolbenstvedt, 2013). The limited range of EVs force drivers to plan their travel. Type and range of the travelled distances are getting evaluated and trips become more effective. Due to the constricted use of electric cars for long distances the intermodal combination of electric cars and other modes within one distance is suitable (Ajanovic and Haas, 2016).

Changes in travel behaviour have also been proven for the use of electrically assisted bikes. People with access to e-bikes used their car less and replaced former car trips with pedelecs (Winslott-Hiselius and Svenssond, 2014). Owning or using e-bikes via bike sharing has impacts on other modes of transportation, especially car driving. Users of bike sharing programs became potentially interested in buying pedelecs and use their car less (Eddeger et al., 2012). E-cycling presents a low cost / high impact way of encouraging more sustainable travelling (Cairns et al., 2017). Electrically assisted bikes are effective to reduce car miles travelled and promote inter and multi modal transport by affecting user mobility behaviour (Cairns et al., 2017).

4.1.4. Automated Transport

Autonomous vehicles are expected to fundamentally change passenger transportation. The environmental aspects of a broad implementation are not predictable yet. However, there is an ongoing debate about potential sustainable benefits of autonomous vehicles.

Self-driving vehicles use less gas and energy when driving, compared to a vehicle driven by a human. Due to more efficient road use, optimized vehicle operation and reduced traffic congestion through smart connected vehicles, road transportation is getting more effective and efficient (Greenblatt and Shaheen, 2015). Autonomous vehicle could reduce direct and indirect emissions, as it changes the current mobility model from the common practice of owning private cars to a shared use of mobility services (Iglinski and Babiak, 2017). Those switching to shared autonomous cars could provide first and last mile connectivity to public transport and fill service gaps in future transportation networks (Greenblatt and Shaheen 2015). Combining automated vehicles and on demand mobility increase the benefits of demand responsive transportation, especially for rural areas.

Whether automated transportation reduces or enlarges environmental impacts depends not only on technical but also on behavioural aspects. Self-driving buses and cars could reduce motorized individual travel. In worst case commuting radius, travel miles and travel speed increase and public transportation gets substituted. (Miller and Heard, 2016) That is why the range for automated vehicles in future scenarios varies from a 60 % reduction in energy consumption up to a 200 % increase (Gawron et al., 2018). It is too

early to determine environmental impacts of automated vehicles, but it can be said, that behavioural aspect will play a key role.

5. Drivers for behavioural change

This report illustrated the benefits of behavioural change towards sustainable mobility. Behavioural change theory and alternative mobility concepts are important tools for transition.

However, the choice of travel mode is determined by various factors and therefore, practical changes are difficult to reach. Research literature has identified factors which influence mobility patterns. This can be interventions by local authorities or motivating and driving factors for individuals. Mobility management and transportation planning categorise measures to change behaviour in two categories. On the one hand soft measures or soft policy on the other "hard" or system-based measures or regulations. Following this approach, interventions, drivers and motivators are categorized in "hard" and "soft" factors in table 3 and 4.

Table 3 Hard factors driving behavioural change

Hard factors driving behavioural change		
Interventions	▪ National or urban tax credit ▪ Registration fees ▪ Priority parking for Car Sharing and electric vehicle ▪ Parking limitation ▪ Priority lanes for clean vehicle ▪ Bus priority lanes	▪ Providing funds to help car sharing programs become established ▪ Governmental support: through tax incentives and starting investments, marketing ▪ Emission zones ▪ Road pricing ▪ Road closures ▪ Expansion of public transport

Drivers & Motivators	▪ Prices, speed comfort ▪ Attractive pricing policy for public transport ▪ Rise of the car ownership cost (taxes, dues…) ▪ Financial incentives for reduction of car usage ▪ Municipalities strategies and plans for sustainable mobility ▪ Availability and closeness to transportation infrastructure ▪ Allowing self-organization of different types of partnerships	▪ Favourable taxes for “greener vehicles” ▪ Low electricity prices for overnight charging of e-mobility ▪ Reduction of transaction costs ▪ Attitudes and commitment of policy makers ▪ Cooperation between companies and mobility provider (car sharing and public transport companies) ▪ Information technology ▪ Free or reduced parking for car sharing, ridesharing and electric mobility ▪ Usability of mobile applications

Table 4 Soft factors driving behavioural change

Soft factors driving behavioural change		
Intervention	▪ Mobility management ▪ Education	▪ Travel Feedback Programs ▪ Raise awareness among general public ▪ Promotion of eco driving campaigns
Driver & Motivator	▪ Local mobility culture (city has clear impact of becoming multimodal) ▪ Service quality and access to public transport ▪ Societal cultural change ▪ Changed living conditions support behavioural changes ▪ Major life events (children, divorce, new job, moving to a new city)	▪ Changing value perceptions in society: sharing instead of ownership ▪ Partnership of new mobility concepts with existing public transport ▪ Environmental motivation ▪ Social motivation: ▪ Cultural aspects ▪ Social norms habitual and automatic behaviour ▪ Social features

6. Discussion and conclusion

This report reviewed the benefits of a behavioural change towards sustainable mobility. The current automobile-focussed transportation system causes environmental problems and does not pay enough attention to multi-modality, public transport or active modes. (Vagnoni and Moradi, 2018). People need to change their behaviour for a transition towards an environmentally friendly mobility culture. The increasing combination of different transportation modes and the reduction of car usage at the same time are therefore primary goals for passenger transportation (Klinger, 2017).

Theories of behavioural change can assist in understanding social and psychological influences of the travel mode decision making process (Hunecke, 2015). This is fundamental for designing personal interventions. Such soft measures can be less costly, more publicly acceptable, faster and more effective as structural interventions (Hunecke, 2015) (Forbes et al., 2012).

The increasing use of sustainable mobility services lead to environmental, social and economic benefits. Hence, among others, resources can be saved (Martin et al., 2010), emissions, air- and noise pollution can be minimized (Soret et al., 2014; Ajanovic and Haas, 2016; Shaheen and Cohen, 2012).

Furthermore, sustainable means of transportation contribute to a healthier lifestyle. (Rabl and Nazelle, 2012; Sikorska/ Grizeji, 2015). Additionally, financial advantages arise for society as well as for individuals. Alternative mobility concepts maintain and contribute to the process of changing towards a more sustainable mobility culture.

However, reaching changes in mode choice is complex. First of all, mobility behaviour is based on attitudes, values, knowledge, socio demographic profile, economic aspects and cultural context. Even if interventions are based on behaviour change theories, it is impossible to address all users with the same techniques and strategies (Hirschl et al. 2003). However, the world of transportation is changing rapidly, and its future path is uncertain. Wheter or not new technologies might solve or rather increase current problems depends on the way we are going to use them.

Therefore, modelling people’s behaviour towards a sustainable mobility consumption is important to guarantee equitable, safe, efficient and climate responsive mobility in the future.

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