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Transforming the Swiss Mobility System towards sustainability

Mapping Options, Barriers and Action Fields

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The current effects of the Swiss transport sector on greenhouse gas emissions and energy consumption require a transformation towards a more sustainable mobility system. Identifying options and barriers of the current system for such a transformation allows deriving different action fields, which will provide the starting points for developing specific strategies.

1 Mapping potential options and barriers for transformation

The transport sector is responsible for about 1/3 of the Swiss CO_2 emissions (BAFU, 2017, p. 17) and 1/3 of the Swiss final energy consumption (BFE, 2016, p. 3). Despite the anticipation of emission reductions in other sectors such as households or industry, no decline is expected in the transport sector in the next years (Betschart et al., 2016). It is a goal, also regarding the Swiss Energy Strategy 2050, to reduce the energy consumption and the CO_2 emissions of the transport sector, which requires a broad transformation of the mobility system.

'Transforming the Swiss Mobility System', includes the core idea that the development of the complex socio-technical mobility system can be actively influenced, i.e. the system can and has to be transformed towards sustainability. In this context we assume the mobility system to include everything related to transportation and (spatial) mobility, both from a physical and a social perspective (see 1.1). This system is not static but dynamic; its properties and interactions change constantly. From the sustainability perspective, a certain direction of development is envisioned: from an ecological and climate-change viewpoint, especially a reduction of greenhouse-gas emissions and energy consumption are desirable (Raubal et al., 2017). When trying to influence the direction of a complex system development, it must be considered that the lack of linear causalities in complex systems does not allow for suggesting simple measures, which steer the development in a desired direction. This is why we do not suggest direct measures but action fields; after identifying transformation needs and potentials. The action fields are meant to serve as general principles that must be taken into account when designing measures as well as specific economic, social, technological, cultural and political areas that can be targeted to transform the Swiss transportation system. Also the action fields must be seen as interrelated, when designing measures or interventions to transform the mobility system.

As a precondition for action, there is a need to know about the transformation potential of Swiss mobility. To assess this systematically, it is necessary to identify options that facilitate change and barriers that limit or might prevent change. These options and barriers include both internal characteristics of the system as well as external landscape factors influencing the system. A well-established approach to combine the internal and external perspective, as well as positive/favourable and negative/unfavourable influence, is the SWOT analysis (strengths-weaknesses-opportunities-threats). We used it as a basis to analyse the transformation potential of the Swiss mobility system and identify action fields for supporting transformation from that.

1.1 SWOT analysis

The method of SWOT analysis originates from business studies and is applied in a variety of fields and contexts. By separating an internal and an external perspective on the subject (here: the Swiss mobility system) and identifying positive and negative influences, a four-field-matrix results: strengths, weaknesses, opportunities and threats (Table 1-1). Each field has its own implications on how the associated items should be handled in strategy development. **Strengths** are aspects which are already developed or developing in a way that is considered positive. Therefore, they should be facilitated and maintained. **Weaknesses** on the other hand need to be fought and limited as they restrain favourable developments. **Opportunities** are positive external developments that can and should be employed to support improvements. **Threats** need to be considered as potential limiting external factors that can hinder or slow down progress, which means that approaches to deal with them must be developed.

Table 1-1 Scheme of a SWOT Analysis

		Influence	
		Positive/favourable Helpful influence related to the goal	**Negative/unfavourable** Harmful influence related to the goal
Perspective	**Internal** Properties of the subject that can be actively influenced	**Strengths** Maintain them and develop them further	**Weaknesses** Reduce them in quantity and quality
	External Landscape factors beyond the subject's control	**Opportunities** Develop strategies to incorporate and increase their benefits	**Threats** Prepare for coping with them to decrease their potential impact
		⇨ **Options**	⇨ **Barriers**
		for system transformation	

The subject of the SWOT analysis is the current Swiss mobility system in terms of its potential for transformation towards sustainability. A definition of 'the Swiss mobility system' depends on the assessment perspective, methods and research goals[1]; we stick to a rather generic way of addressing it. The way of delineating the system is inspired by the analytical framework of the multi-level perspective (MLP; Geels, 2012a, 2002). The core of the MLP is the 'socio-technical regime' – "a coherent, highly interrelated and stable structure … characterized by established products and technologies, stocks of knowledge, user practices, expectations, norms, regulations, etc." (Markard and Truffer, 2008, p. 603). Correspondingly our SWOT-

[1] Future work: In the second phase of the SCCER Mobility research framework, it is one of the main goals to develop a more detailed description of 'the mobility system'.

subject comprises actors' behaviour[2], thinking and interaction as well as technology and (infra)structures. We consider the dominant regime with its technology (internal combustion engine and individual motorised mobility), but we also include subaltern regimes (e.g. public transportation, cycling, walking) as part of the system[3]. These regimes are what needs to be transformed towards sustainability (Berkhout et al., 2004), for instance concerning their shares (more public transport and cycling and less car traffic) and their internal development (e.g. more sustainable propulsion technologies). Besides regimes, the MLP considers the 'socio-technical landscape' ("a set of factors that influence innovation or transition processes but are hardly (or only in the long run) affected by themselves"; Markard and Truffer, 2008, p. 603) and 'socio-technical niches' ("protective space for path-breaking innovations"; Smith and Raven, 2012, p. 1025). Those two are considered the external influence on our subject of the SWOT analysis[4].

The SWOT analysis is guided by fields that were identified to be relevant for the performance and future development of the Swiss mobility system (Table 1-2). Their identification – as well as the following assessment (1.2) – is based on an extensive analysis of trends and developments that have impacts on the mobility system. The targeted trends were in the following thematic areas: mobility behaviour, accessibility and transport infrastructure, technology, spatial structure, economy, demography socio-culture, environment (Hoppe et al., 2017). The fields cover both the internal and the external perspective and they are interrelated. For instance, politics (taxes, regulations) can strongly influence markets, existing infrastructure limits or supports certain behaviours, etc.

Table 1-2 Relevant fields for the SWOT analysis of the Swiss mobility system

Field	Internal element of the Swiss mobility system	External influence on the Swiss mobility system
Existing infrastructure	X	
Planned infrastructure	X	
Technology investments	X	
Focus of research (funding, patents, publications)	X	
Mobility behaviour of users	X	
Attitudes of key players	X	
System resilience	X	
Openness to innovation (new ideas and technologies)	X	
Energy prices and availability	X	X
Policy and legal framework	X	X
Norms and values		X
Demographic development		X
Structures of society		X
Development of the economy		X
Spatial structures		X

[2] For the SWOT-Analysis of the Swiss mobility system, we primarily look at the transportation of people and do not consider the transportation of goods. Still it is important to notice that both are interconnected through mutual influence on different levels, e.g. by using the same infrastructure. However, the two have different mechanisms so they have to be analysed separately.
[3] Note the difference between subaltern regimes (Geels 2012) and niches. Whereas niches are characterized by technological innovations, that do not have a (fully developed) market or technology scheme, subaltern regimes are completely market-ready and established, yet do not have the authority of a dominant regime.
[4] We abstain from a more detailed explanation of the MLP framework and refer the reader to the corresponding literature.

The development goal, in relation to which the influence of certain aspects is considered either positive or negative, comes from the goal of sustainable development as described for SCCER Mobility. "The Swiss Competence Center for Energy Research - Efficient Technologies and Systems for Mobility aims at developing the knowledge and technologies essential for the transition of the current fossil fuel based transportation system to a sustainable one, featuring minimal CO_2 output and Primary Energy Demand as well as virtually zero-pollutant emissions" (SCCER Mobility, 2017). Thus, the SWOT is used to assess the transformation potential of the Swiss mobility system towards sustainability – in the framework of sociotechnical transitions as well as related approaches – with the steps shown in Figure 1-1. As the idea of sustainability includes the three dimensions of ecological, economic and social sustainability, all of them need to be considered, which is reflected by the investigation fields (Table 1-2).

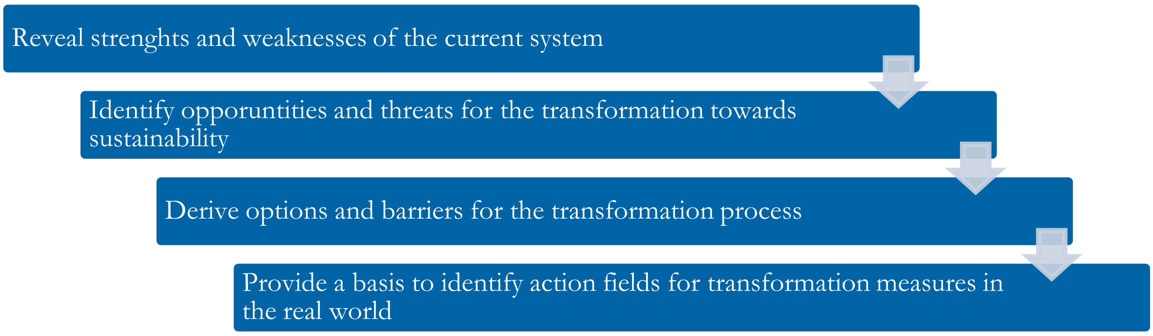

Figure 1-1 Application of the SWOT analysis for system transformation

1.2 Options and barriers for the mobility system transformation towards sustainability – application of the SWOT-analysis

A SWOT analysis on the Swiss transportation system helps to get an overview about the system's state concerning its transformation potential. The presented SWOT matrix (Table 1-3) reflects an assessment of the different interrelated fields of the Swiss mobility system (see Table 1-2), in relation to sustainable development. Threats and opportunities which might arise from external developments (outside the mobility system, such as social, political, economical trends or megatrends and other influential factors) are identified. Together with the internal strengths and weaknesses of the system, this allows to identify options and barriers for a transformation towards sustainability. Therefore, it can be used as a first step of transformation potential analysis, by figuring out which options could likely be realized and which barriers need to be overcome when designing strategies and measures to be implemented in practice. In the next steps in our SCCER Mobility work packages, we will use these findings to concretise potential development trajectories and their likeliness to occur. In addition, a more detailed development of action plans towards sustainability is pursued.

Table 1-3 SWOT-analysis of the Swiss transport system

Strengths	Weaknesses
• Energy efficiency of the transport system • Investments in existing rail network • High level quality public transportation network • Swiss emissions legislations • Swiss 'Energiewende' • Support for 2000 Watt society by communes and BFE/Energieschweiz • Potential for hybrid vehicles • Potential for shared mobility • Use of Biofuels	• Dominant paradigm of motorised individual mobility in policy, and individual behaviour • Low occupancy rates of cars • High travelling speed • Fragmented political and administrational structures • High expectations about the level of transport connectivity • Urban sprawl due to settlement patterns and economic structure
Opportunities	**Threats**
• Economic growth enabling innovation • Sharing economy supporting shared mobility • Digital revolution enabling multimodal public transport • Political strategies related to global climate change and rising ecological awareness • Land use legislation supporting reduced land consumption • Potential behaviour changes of younger generations: decreasing use and ownership of cars • Niche: E-Mobility • Niche: Hydrogen-Mobility • Niche: Automated driving with shared vehicles	• Economic growth increasing mobility demand • Rising personal income going along with additional mobility demand • Growing real estate prices enforcing suburbanisation • Increasing mobility demand related to immigration • Economic structural change with increasing regional specialisation of the economy leading to longer commuting distances • Active lifestyles of growing older population increasing mobility demand • Niche: Automated driving with individual vehicles pushing motorised individual transport

Based on the identified internal strengths and weaknesses of the Swiss mobility system and together with the opportunities and threats arising from external factors options and barriers for the transformation towards a sustainable mobility system can be derived:

I. **Options** arise from the high level of mobility quality related to the Swiss public transport system. Public transport allows for mass transportation in an efficient way – although due to the high frequency of service and accessibility today's Swiss public transport system lacks resource efficiency. Increasing the resource efficiency provides a powerful leverage of energy savings and reduction of CO_2 emissions. Another option, coming from the political decision for the 'Energiewende' as well as from initiatives based on grassroots democracy like '2000 Watt society', can be linked to this. The awareness and willingness of huge parts of the Swiss society to limit waste of resources provides the legitimacy for measures to optimize the given public transport system towards sustainable mobility. Another option is related to economic growth, which can support this development as money for investments and for R&D in innovative technologies should be available.

New mobility concepts and technologies are being developed and have a twofold impact: they provide new solutions to optimize the current mobility system and they challenge today's mobility providers by increasing competition at the same time. The best, resource efficient solution might occur, if frame conditions like pricing of resources (e.g. internalized external cost) are aligned to the goals of system transformation towards sustainable mobility.

Another option comes with socio-economic trends like the potential change of mobility behaviour in young age cohorts, the upcoming trend of sharing instead of owning or the ongoing digital revolution. These developments will change how we live and work in the next few decades. Whether this will lead to a more sustainable economy and society will depend on appropriate supply of mobility solutions. Today we are in a crucial period concerning this, as the directions for the new trends are set within this phase of upcoming innovation and re-direction of the system development. Decisions within this crucial phase of re-orientation and uncertainty will set the paths of future developments and fix them to a certain extent, which can then become barriers for future transformation.

II. **Barriers** are rooted in the high quality of the mobility system with its path dependency. In Switzerland, not only the paradigm of auto-mobility is dominant, but also the one of high accessibility for both, individual motorized mobility and public transport. Components of this paradigm are the high level of: 1) connectivity within the transport system, 2) high speed in transport and 3) comfort in mobility. Those determine user expectations, transport provider standards and politicians' mindsets. This high quality system enabled a settlement structure to be developed, linking Swiss regions and cities with low time spending to travel between. Structures of urban sprawl and long-distance relations (e.g. between place of work and place of living) developed and determine todays transport demand. These structures with their dependencies build a barrier for change; a new system would most likely lead to different structures. Within a phase of systemic change, mobility demand driven by the old structure would still need to be served while in parallel new structures would already lead to different patterns of demand.

Another barrier comes from growth in fields such as economy, available income or population. In the past, growth in all these different, although related, fields lead to increasing mobility demand; these dynamics are likely to continue in the future. In this context, also lifestyle of high and growing activity has to be mentioned leading to further increasing mobility demand, especially related to leisure activities.

'Options and barriers' related to internal aspects of the system and external conditions can either support or constrain a development towards more sustainability. Thus, they can be used to identify action fields, in which activities are necessary to achieve the development goals of the transformation towards a sustainable mobility system and on how to make use of identified options and to overcome barriers in this process.

2 Action fields

2.1 Technological innovation, energy and system efficiency

Related to mobility demand, even the most optimistic scenario of the Energy Strategy 2050 projects only small reductions in traffic volumes or changes in modal split (Kirchner et al., 2012). On a European scale, no substantial change is envisioned either (Eißel and Chu, 2014). For making the mobility system more sustainable, two aspects will play a big role: energy efficiency and sustainability of energy sources; although measures in this field cannot substitute the need to reduce mobility demand. They provide additional potential to reach the energy strategy goals and run in parallel to aspiration for demand reduction.

2.1.1 Increasing energy-efficiency

Vehicles require energy for the engines themselves as well as beforehand for the production processes of vehicles plus fuels (petrol, diesel, natural gas, electricity, hydrogen…). A first goal is to reduce the amount of input energy for all components needed per passenger kilometre, independently from the type of energy that is used. Efficiency increases for the currently dominant internal combustion engine (ICE) technology are possible either by technical improvements for increased fuel-efficiency or by the amendment of niches (e.g. hybrid drivetrains). These changes do not affect already existing vehicles but on the long run they result in less energy consumption throughout renewal of the fleet. So over time, the energy efficiency of the whole system increases with a decrease of total energy consumption only if rebound effects can be avoided.

Regarding interventions, emission regulations have proved to be beneficial to improve fuel efficiency. However, as the ICE regime is locked-in[5], market mechanisms or classical / traditional policies are not likely to induce substantial change if following the rules of the given regime. "Charges to use the car may increase substantially, but political pressures are always present to moderate any substantial rises in price, so that motoring remains relatively cheap" (Banister, 2008, p. 76). Therefore, system-external (landscape) pressures identified as options (see Table 1-3), especially due to climate change, need to be translated into political action. In Switzerland, some import rules for cars concerning CO_2-emissions are already implemented. Due to the fact that the Swiss economy is not as much depending on car manufacturing compared to other countries like Germany[6], it might be easier to enforce strict emission legislation. The way of implementation through a penalty tax shows a general challenge: a (market-) liberal way of thinking makes it harder to limit the individuals' 'rights' to use transportation in the way they wish (Banister, 2008). In Switzerland, also the generally high income-level makes taxes less efficient, unless they are remarkably high. It is politically challenging to enforce more effective yet more radical prohibitions instead of setting incentives (see also 2.2.2). However, incentives (e.g. monetary or psychological) are beneficial and – together with constraints – are an essential part of policy mixes (Attias and Mira-Bonnardel, 2017).

2.1.2 Use of sustainable energy

ICEs are likely to remain an essential technology for quite some time. Even if the efficiency of ICEs is improved and hybrid concepts are widespread, the issue of sustainability of the input energy prevails[7] and energy needs to be produced as sustainably as possible. A shift from petrol and diesel[8] to biofuels could be a solution – but only if negative side effects can be avoided. The sustainability of biofuels (gas, ethanol, and diesel) is still being debated and a comprehensive study by the United Nations Environment Programme (Bringezu et al., 2009) shows that no clear general statement can be made yet how sustainable they are; it largely depends on the type of fuel and the raw material. At least some approaches have potential to contribute to a more sustainable development, especially advanced biofuels (second generation biofuels). Those are not produced directly from (food) crops like the first-generation fuels based on vegetable oils, sugar or starch, but through the processing of diverse organic waste. This is important because biofuel production and consumption have to be seen in a global context (Eißel and Chu, 2014) also when looking at the Swiss transportation system. Only truly sustainable biofuels can improve the system. This means that they must fulfil the following criteria: they must not be produced in competition with food, no ecosystems can be

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[5] For instance the MLP regards dominant technologies and their associated regimes as 'locked-in' (Geels and Schot, 2007) as conceptualised by path dependency theory (David, 1985).

[6] According to a study by the ETHZ, the Swiss car related industry (component suppliers) accounts for 24.000 jobs (0.5% of all jobs) and a gross value added of 19 billion CHF (3% of the GDP) in 2013 (Müller, 2013).

[7] In the case of plug-in-hybrids, also the sustainability of the electricity needs to be ensured by use of renewable energy sources, sustainable battery production and recycling.

[8] Natural gas is also seen as a possible option. Yet, it is a non-renewable resource and therefore does not fulfil sustainability criteria. However, it can be seen as a transitory technology in a switch to biogas, especially as it emits fewer pollutants than petrol or diesel.

destroyed (such as primeval forests), no fossil energy or other non-renewable resources are used in the supply chain and adequate salaries and working conditions are ensured in the related industries.

Another essential form of energy is electricity, which is already used in public transportation and will have an increasing importance for future transport systems. New technologies such as battery electric vehicles (or fuel-cell vehicles) require large quantities of electric energy (or Hydrogen produced with electricity). The primary energy source for this electricity must be sustainable, i.e. renewable energy (solar, wind, water and geothermal power).

2.1.3 New technologies

In addition to improving existing technologies, also niche technologies like hybrid vehicles (as a bridge technology), battery-electric vehicles or fuel cell vehicles can be implemented and supported within the current regime leading to an evolutionary system transformation. Also there might be more innovations upcoming, that we are just not aware of at the moment. Such wild cards (Hauptman et al., 2015) have potential to improve the regime through fundamental changes of technologies. New technologies in this sense do not necessarily have to be new propulsion technologies. Also information and communication technology (ICT) can increase the efficiency of a system (and contribute to its change). Examples are rides-haring-applications that help increasing the occupancy rates of cars and therefore reduce emissions per capita. Other examples are 'Mobility as a Service' solutions targeting behaviour change via ICT means such as apps (Weiser et al., 2015). ICT can generally account for positive as well as negative effects. "Although there is a large substitution potential [for mobility or transport], the relationships between transport and ICT seem to be symbiotic with a greater opportunity for flexibility in travel patterns, as some activities are substituted, whilst others are generated, and some replaced by fewer longer distance journeys" (Banister, 2008, p. 75). This makes it crucial to address rebound-effects parallel to any improvements of efficiency and optimization of the given system (2.2.3).

Technological niches can play an essential role in making transport systems more energy efficient. They potentially reduce the ecological impact of transportation if smart technologies are used in a smart way. Therefore, not only from an innovation research (multi-level) perspective describing the transformation of a regime through new technologies, but also from a pragmatic point of view, it makes sense to support the development of technological niches. The approach of strategic niche management provides a systematic approach to achieve this by a sequence of "creation, development, and breakdown of protected spaces for promising technologies" (Kemp et al., 2001, p. 270). Through such a target-oriented support of favourable socio-technical niches, a systemic sustainability transformation can achieved (Geels and Kemp, 2007). A general openness towards new ideas, innovation and change in society, economy and politics creates an atmosphere that is supportive for this kind of niche development.

2.1.4 Overall system optimization

Even though the Swiss mobility system provides a high quality of public transport services and high accessibility for motorized individual transportation, the system is not organized in an optimal way; infrastructure capacities are designed to handle traffic peaks of the morning and afternoon for both car and public transport. In public transport, high accessibility and flexibility of services all over the country and during the whole day are provided. This high quality leads to inefficiencies of the mobility system, as for certain times of the day infrastructure and services are underused, while during peak hours (3-4h per day) capacity is lacking in certain locations, such as the city centres and within some agglomerations. In the case of public transportation, this results in an average degree of capacity utilisation of 32% in long-distance and only 20% in regional transport for SBB trains (Müller-Jentsch, 2013). Therefore, new solutions to address these capacity issues are required, such as flexible pricing, shared mobility, new business models etc.

2.2 Avoiding rebound effects

It is regarded as a general principle that people try to reduce their overall costs for travelling, namely monetary costs and time consumption (Banister, 2008). Additionally, it becomes increasingly important to reduce the environmental costs of travelling and ecological ways of thinking can actually influence mobility behaviour (Gardner and Abraham, 2008). For ecological as well as economic cost reduction, the idea of energy efficiency is addressed in 2.1. Another aspect of efficiency increases from a user's perspective concerns time: increased time-efficiency travel allows for longer distance. Time efficiency can for instance be achieved through building new roads or railway routes, increasing their capacity or introducing new services.

In the past, technological as well as organisational solutions helped for increasing efficiency in transportation. But such improvements in technology and infrastructure induce behavioural responses; the dilemma about efficiency is that it tends to create rebound effects, which interfere with the intended effects (Binswanger, 2001). Increasing efficiency often does not lead to reduced environmental impacts, but savings are invested elsewhere leading to a transfer of resource consumption, however not to a decrease in total but even an increase. In the following, we discuss the rebound effects that might be induced by increasing time efficiency (2.2.1), cost efficiency (2.2.2) and energy efficiency (2.2.3) (for specific policies that target these action fields see Font Vivanco et al., 2016).

2.2.1 Time-efficiency

Increasing time-efficiency of the transportation system means reducing the travel time related to distance. Shorter travel times have positive effects on the social and economic dimension of sustainability, as people gain more time and energy for work as well as recreation. Nevertheless, there is a twist to the positive effects. Based on empirical data, many studies propose the existence of a constant travel time budget. This daily travel time of about one hour[9] seems to apply quite independently from cultures and modes of transport; although it is not a universal constant for individual behaviour but an average aggregated value (Lyons and Urry, 2005). Taking this constant average travel-time budget as a basis, the average travelled distances automatically get longer when the average travel speed increases through time efficiency measures.

Through constant travel time budgets, the potentially positive effects on the social and economic dimension of sustainability do not come into effect any more. Additionally, increased travelling speed and longer distances require more energy, which also means that time-efficiency has counterproductive effects on ecological sustainability. Increasing travel time efficiency can even be responsible for changes in modal split. "Even though travel time may have remained constant as cities have spread, both distances and speeds have increased substantially. Local public transport, cycle and walking have become less attractive, and this in turn has resulted in the greater use of the car" (Banister, 2008, p. 73).

In Switzerland, time efficiency is realized mainly through infrastructure projects such as building new roads/railway/transit lines and increasing capacities of existing infrastructure. The daily travel distance of an average Swiss person showed an increase by 5.5 km from 31.3 to 36.8 km per capita during the last 21 years (BFS and ARE, 2017, p. 19). To reach more ecological sustainability, effective measures have to stop the circle of increasing travel speeds, distances and therefore energy consumption of the whole mobility system or even reduce them. The two most important travel purposes in Switzerland concerning distance are leisure (44% of the daily distance; additionally some parts of shopping (13%) can be seen as leisure as well) and workplace commuting (24%, year 2015; BFS and ARE, 2017, p. 38), They should be the primary target areas for implementing measures (see also 2.3.1 and 2.4.2).

[9] Travel times in Switzerland are generally higher than in other European countries and are about 1.5 hours per day and have not varied by more than 10% in the last 20 years (BFS and ARE, 2017, p. 20).

2.2.2 Cost-efficiency

In 2011 Swiss households spend on average 8.0% of their gross income or 768.34 CHF (2009: 7.7%, 716.98 CHF) on transportation (BFS, 2013, 2012). Thereof purchasing car fuel accounts for almost one fifth of the total expenditures. Data of the Swiss Microcensus confirm that mobility demand increases with rising income (BFS and ARE, 2017, p. 56; see also Graham and Glaister, 2004). A higher amount of disposable income is associated with longer travel distances and longer travel times. In a meta study on road traffic elasticity and income[10], Goodwin et al. (2004, p. 278 f.) stated that a 10% increase in real income results in 4% more cars and fuel consumption within one year and over 10% on a longer timescale, while the volume of traffic increases by 2% respectively 5%.

Table 2-1 shows the elasticities of road traffic variables related to fuel price increases. It becomes obvious, that an increase in fuel prices is related to reduced traffic and fuel consumption as well as less vehicles owned, while efficiency of fuel use is increasing. Thus, a possibility to achieve a higher degree of ecological sustainability in mobility therefore is an increase in prices, especially in the case of ICE cars as the ecologically most harmful means of transportation. In the past, expectations of market-driven increasing oil prices and reduced oil consumption have not been fulfilled. Instead of relying on 'normal' market mechanisms, political action is necessary here. This must consider a broader context because an optimisation of the whole system requires shifts in behaviour indifferent fields such as mode choice, location choices etc.

Table 2-1: Effects of a 10% increase in fuel prices on mobility behaviour and fuel consumption

	Short term change (one year)	Long term change (about 5 years)
Volume of traffic	- 1%	- 3%
Volume of fuel consumed	- 2.5%	- 6%
Efficiency of fuel use	+ 1.5%	+ 4%
Total number of vehicles owned	- 1%	- 2.5%

(Data: Goodwin et al., 2004, p. 278)

However, there are additional ways of steering developments through pricing (summarized in Table 2-2). Most of the measures mainly consider only ecological sustainability while price increases always have to be evaluated in the respect of social and economic sustainability, too. Whereas a 'green economy' approach can help in mediating effects on the latter, the social perspective is more problematic. With increasing prices, households with lower incomes can afford less mobility, which might reinforce social disparities. In order to balance the social, environmental and ecological dimension of sustainability a reasonable access to mobility needs to be granted for everyone, without disproportionate privileges for those who can afford spending more money on transportation.

[10] The studies used were "confined to those carried out in the UK or other countries broadly comparable with the UK" (Goodwin et al., 2004, p. 276).

Table 2-2: Impacts of different type of pricing

Type of impact	Vehicle Fees	Fuel Price	Fixed Toll	Congestion Pricing	Parking Fee	Transit Fares
Vehicle ownership. Consumers change the number of vehicles they own.	✔				✔	✔
Vehicle type. Motorist chooses different vehicle (more fuel efficient, alternative fuel, etc.)	✔	✔				
Route Change. Traveler shifts travel route.			✔	✔	✔	
Time Change. Peak to off-peak shifts.				✔	✔	
Mode Shift. Traveler shifts to another mode.		✔	✔	✔	✔	✔
Destination Change. Motorist shifts trip to alternative destination.		✔	✔	✔	✔	✔
Trip Generation. People take fewer total trips (including consolidating trips).		✔	✔	✔	✔	
Land use changes. Changes in location decisions, such as where to live and work			✔		✔	✔

(Litman, 2017, p. 16)

2.2.3 Energy-efficiency

Energy efficiency is closely related to cost-efficiency. The more expensive fuels are, the more motivation consumers have to use fuel- respectively energy-efficient transportation (Table 2-1). On the other hand, Brännlund et al. (2007) simulate that increasing efficiency of propulsion technologies in the end leads to increasing CO_2 emissions from car transportation. Such energy efficiency rebound effects (Linn, 2013; Stapleton et al., 2016) can be counteracted by interventions in pricing as shown in 2.2.2. In the case of public transportation, increasing energy-efficiency actually always accounts for a reduction in emissions.

Rebound effects of energy efficiency increase are not necessarily related to pricing. When it comes to individual mobility behaviour, a psychological aspect is considered relevant: the more fuel-efficient ICE-vehicles are, the better people might feel about using them, because they use less fuel and therefore harm the environment less than before, e.g. in the case of hybrid vehicles[11]. In fact, also electric vehicles, which 'outsource' emissions to the generation of electricity, face a similar problem, as long as not all electricity originates from renewable sources. In the end, allegedly clean(er) technologies might even be responsible for increasing energy consumption. This can only be targeted by combining efficiency measures with addressing behavioural change and a restructuration of the whole mobility system (de Haan et al., 2013).

[11] For a more general review on rebound effects of energy efficiency in household consumption see e.g. Binswanger (2002).

Looking at the current trends in energy efficiency from a technological perspective, fuel efficiency of ICEs is increasing. Yet it does not play out the full effect because efficiency increases in propulsion technology are (at least partly) counteracted by an increasing energy demand of vehicles due to higher vehicle weight, additional features (ICT, extra equipment) and a demand for more powerful engines (Kammerlander et al., 2015). This issue is already targeted by emission laws, which state maximum amounts of emissions for new vehicles imported to Switzerland by a company which still allows for heavy and high consuming cars. Regulation could be improved by not using the emission values for the average fleet, but for each single vehicle. Also it is worth discussing whether penalty taxes or subsidies could be replaced by establishing fixed emission limits. This issue is especially important also concerning social sustainability, as penalty payments affect people with less money stronger than more affluent people and due to the fact that the general high income in Switzerland makes users sell sensitive for financial instruments.

2.3 A paradigm shift for the mobility system

Mode choice is based on the availability of different transportation modes as well as on travel time and comfort related to them, whereas environmental aspects play a minor role (BFS and ARE, 2017). For many people the car is the most convenient option, as it provides flexible, comfortable and cheap door-to-door transportation. The more sustainable modes of public transportation often require a higher number of trip legs i.e. transfers between vehicles and/or modes.

A shift from car to public transportation has the potential to increase sustainability, as energy efficiency is higher in trains or busses with high occupancy rates compared to cars. Therefore, the attractiveness of intermodal mobility – with a focus on public transportation and cycling/walking – needs to be increased relative to car mobility.

An initiative for supporting intermodal mobility needs to be driven by policy and planning while companies need to develop new business models. Successful implementation requires "two key elements to the personal (rather than the social) dimension. The first is that there is an acceptance that the policy package being proposed will work and is efficient. The second is that it is fair, both to the individual travellers, and more generally to society as a whole." (Banister, 2008, p. 76) To ensure that and to manage this fundamental change, which requires a paradigm shift, mobility strategies on the national, regional and local scale need to reflect the benefits of intermodal mobility compared to mode-based travel.

On the individual level, a change of attitudes and behaviour is necessary for the shift from mode-based to intermodal mobility. Two general strategies to support behavioural change can be distinguished: setting incentives to motivate voluntary change and imposing rules, restrictions or barriers. Besides providing incentives, which is seen as a promising approach in market societies, new technologies should support the systemic change. "In general, people prefer technological solutions to behaviour changes, because the latter is perceived as more strongly reducing the freedom to move" (Steg and Gifford, 2005, p. 60). This means that mainly two issues need to be worked on; the usability and the convenience of multi-modal trips and the motivation for and support of behaviour change. One idea is the integrated concept of 'mobility as a service' (MaaS; e.g. Datson, 2016). Here, not the single means of transport need to be compared by the user but algorithms take over planning, informing and paying. In the end, users of such solutions, mostly smartphone applications, are offered a mobility solution from one source with increased usability.

To contribute to a more sustainable transport system, multi-modal mobility should result in a reduction of individual transportation in favour of shared and collective mobility. A barrier for a sustainable development is the deeply rooted paradigm of individual motorised mobility[12], which developed especially in the second

[12] "Our work- and leisure-travel behaviour have been designed on the principle of individual motorised mobility" (Kammerlander et al. 2015, p. 7).

half of the 20th century and is part of the socio-technical ICE-car regime (Geels, 2012b). A shift towards a sustainable mobility paradigm would need to give up the primacy of individual motorised mobility and at least partly replace it with shared/collective mobility. Today, there is a tendency visible towards less car use especially for younger age groups (BFS and ARE, 2017) showing a window of opportunity for the reduction of car ownership and usage.

2.3.1 Changes in the economy, the working world and related mobility

Workplace commuting accounts for 1/3 of the average daily distance travelled by a Swiss person during weekdays (BFS and ARE, 2017, p. 42). Work-related mobility plays an important role, as it is a main reason for traffic peaks and the resulting too low overall (energy) efficiency of public transport. Sustainability in this field can be increased through a reduction of commuting ways in both frequency and length. Also providing travel alternatives to individual motorised mobility and increasing efficiency with the least rebound effects possible (2, 2.2) should be the goal.

2.3.2 Flexibility in work place and time

Flexibility of working places allows a reduction of commuting trips, if people work from home or in flexible offices located close to their home. Flexible working times provide the opportunity to reduce peak pressures on the transportation system, as not all employees have to commute at the same time. For both aspects, there are three preconditions which are supported by recent trends[13].

(1) *Change of the working world*
Traditional jobs, especially in the industrial production of goods or in basic services, require fixed working places. However, there is an increasing number of jobs, primarily in the field of knowledge-based services[14], which do not require employees being at a specific location during all (or at least during some) of their working time. Besides the general deindustrialisation and this transition towards a knowledge-based service economy, a rising share of digital native freelancers can account for a reduction in traditional office workplaces. As many job activities also do not require fixed working times, the commuting time flexibility increases.

(2) *Technological change*
Digitalisation of society is the basis for new ways of working. Due to the technological advancements of internet and mobile working devices, the barriers for working in (multiple) different places are decreasing. Cheap and easy to use telecommunication innovations such as video conferencing also reduce the need for physical mobility.

(3) *Cultural change*
The technological and organisational opportunities can only have effects, when innovations are implemented and used. It is primarily the task of employers to provide the technical and organisational possibilities and to support the related change of working culture. Employers need to provide infrastructure with mobile working devices, communication interfaces, remote access to data etc. They also need to allow and encourage their employees to have flexible working hours and the possibility to work in other places than at their office desks, which requires mutual trust on both sides. Due to digitalization, changes of the working world will happen anyway and therefore flexible working places and schedules can be offered, not only supporting sustainable mobility, but providing attractive options for a better work-life-balance.

[13] Mobility trends and other related (landscape or niche) trends were assessed during the SCCER Mobility research.
[14] Sometimes also called quaternary economic sector.

Despite the fact that especially aspects (1) and (2) are already existing since several years[15], the total amount of commuting distances did not decrease. For the future, especially public service providers can be attributed a key role because politics can influence them more easily than the private sector. They can set trends in the job market by providing options as well as incentives to reduce commuting.

2.3.3 Distances between workplace and home

The reduction of the travel distances between workplace and home can happen either through less frequent travelling (see above) or through a reduction of the physical distance. Within a strongly diversified and specialised job market, living closer to the workplace might only be possible in sectors with well-distributed jobs. Moving to a new home might be difficult due to social aspects (friends, family) and cost (rent, relocation costs, residential property). In Switzerland, the relocation rate is rather low and even dropping (homegate.ch, 2014) and 66% of the Swiss employees do not consider relocating due to a new job (Aeschlimann, 2016). This might partly be a result of the well-developed Swiss transportation system that allows commuting over long distances within a reasonable time; especially with public transportation. This points out the interrelatedness of (high) accessibility, urban and agglomeration development as well as mobility demand. All mentioned factors influence each other by positive feedback; high accessibility of many locations outside of and even far from economic centres with high job density pushes new settlements leading to increasing mobility demand, again requiring increasing transport capacities and so on (see also 2.4).

New and innovative options are therefore necessary. A project worth mentioning is 'Villageoffice' (VillageOffice Genossenschaft, 2017), whose vision is to provide a nationwide network of co-working spaces, which are easily accessible with public transportation or bike. They provide an amendment or alternative to home offices and traditional office space in the company and therefore allow more flexibility for employees, employers and freelancers.

2.4 Integrated spatial and transport planning

Transportation is linking locations for living, work, education, supplies, leisure and social life. The closer these locations are the less distance has to be covered to access them. In theory, providing mixed functions (e.g. through areas of mixed zoning) should lead to less transport demand; thus, spatial planning is required to provide everyone with all necessary facilities at the least distance possible. According to Banister (2008, p. 75) "it is one area of public policy where intervention can take place". He mentions several aspects to address: increasing densities and concentration, mixed use development, housing location, the design of buildings, space and route layouts, public transport oriented and car-free development, among others. However, a solution is not only to be found in providing mixed functions and increasing density of housing in areas with a good service infrastructure. Especially the quality of life needs to be increased, as too high density can affect quality of life with noise, emissions or a lack of recreation space. This can support either suburbanisation with resulting increased demand for commuting mobility or high leisure mobility demand for 'escaping' the city (see also 2.4.2).

A solution is integrating spatial and transport planning. Urban spaces can be designed or re-designed to support certain transport modes and means of transport by focussing on high quality of life. For this, a change in the way of thinking and a hierarchy of priorities for different transport modes is necessary; Banister (2008) suggests to replace conventional paradigms in transportation planning with an alternative approach of sustainable mobility (Table 2-3). One example is a broadened understanding of public street space

[15] About 1/3 of Swiss employees make use of home office options. About 1.4 million people work at home for an average of 8.1 hours per week. Home office accounts for 8% of all hours worked in Switzerland. The share of people making use of home office is especially high amongst self-employed persons (90%), whereas only 1.2% of 'regular' employees use home office as their primary workplace. In total, there are about 40 million home office days per year in Switzerland, which means correspondingly less commuting. (Weichbrodt, 2014)

where its purpose is not only transportation segregated by modes but being an integrated mobility and living space, while providing multiple options for activities and social interaction (Appleyard et al., 1981). In general, more holistic and integrative concepts and paradigms are necessary to address systemic transformation towards sustainability. Especially in a planning context, it is also important to be aware of consequences for the future development that arise from building physical structures.

Table 2-3: Contrasting approaches to address transport planning

Conventional approach of transport planning and engineering	Alternative sustainable mobility approach
Physical dimensions	Social dimensions
Mobility	Accessibility
Traffic focus, particularly on the car	People focus, either in (or on) a vehicle or on foot
Large in scale	Local in scale
Street as a road	Street as a space
Motorised transport	All modes of transport often in a hierarchy with pedestrian and cyclist at the top and car users at the bottom
Forecasting traffic	Visioning on cities
Modelling approaches	Scenario development and modelling
Economic evaluation	Multicriteria analysis to take account of environmental and social concerns
Travel as a derived demand	Travel as a values activity as well as a derived demand
Demand based	Management based
Speeding up traffic	Slowing movement down
Travel time minimisation	Reasonable travel times and travel time reliability
Segregation of people and traffic	Integration of people and traffic

(Banister, 2008, p. 75; adapted)

2.4.1 Sufficiency principles for planning and decision making

Even if mixed functions and short distances are realized through spatial planning, this does not necessarily mean that mobility demand would decrease, as not everybody might stay within this ‘compact city’. The principle of ‘sufficiency’, which generally means a limitation to the necessary – mobility, infrastructure, services etc. – can provide solutions. As it is up to debate, what should be considered as necessary, there is a need for a social discourse on the quality (e.g. comfort, flexibility and price for public transport; high way capacities) and quantity (e.g. frequency and location of public transport; size of street infrastructure and network) of the mobility system we would like to have and we are willing to pay for. Sufficiency principles should be taken into account by policy and planning, when reorganising existing or planning new spatial structures.

2.4.2 Quality of life and mobility for leisure activities

A specific field where sufficiency is beneficial is mobility for leisure activities. Leisure is by far the most important and a still increasing purpose for traveling. During an average day in 2015, 39% of the trips, 44% of the distance and 50% of the time travelled by a Swiss person were dedicated to leisure purposes (BFS and ARE, 2017, p. 46).

Many different factors are influencing leisure travel behaviour, and one of them is the quality of life (OECD, 2000). In densely populated areas, one purpose of leisure is compensating "for the deteriorated psychological and social quality of life" (OECD, 2000, p. 22). The built environment of housing areas determines the options that individuals have for realizing their leisure activity close to their homes. Therefore, increasing the quality of life can reduce the push-factors that trigger leisure mobility because needs can be satisfied without or with less travelling.

A first assessment for the quality of life can be done by evaluating the properties of the natural and built environment around the home. However, many different studies that try to measure quality of life have been conducted from different perspectives, not only focussing on this objectively measurable dimension (Steg and Gifford, 2005). As quality of life is different depending on individual needs and preferences it might be measured by subjective indicators. The subjective dimension is expressed through a person's satisfaction in the context of their environment and how it is perceived (Marans, 2003). Policies supporting an increase in the environmental quality of life around the homes and a decrease of travel distances can be mutually reinforcing. The subjective experience of quality of life has to be considered as well, when designing measures as it encompasses the fact that different people perceive the same environment differently.

3 Summary

This working paper gives an overview on transformation potentials for the Swiss Mobility system by pointing out different aspects that can either hinder or support sustainability developments. The main barriers for a sustainability transformation can be found in the continuing growth of mobility demand, lack of (political) regulation in some fields and the persistence of an individual (ICE) vehicle paradigm. Options are provided through many different technological innovations of vehicle technologies and ICT-solutions etc. Nevertheless, they do not have considerable effects when they are not accompanied by corresponding social and political change processes. Those need to be supported by political/societal actions for two reasons: 1) new socio-technical innovations compete with persistent regimes and sustainable solutions thus might start from a weak position 2) the risk of counterproductive rebound effects needs to be reduced.

Described action fields take up the options and barriers, which were identified. Measures to increase the sustainability of the Swiss mobility system should therefore include 1) the support of (socio-)technical innovations and systemic improvements while 2) tackling potential rebound effects, 3) reducing the mobility demand through spatial and organisational change and 4) integrate sufficiency principles in behaviour as well as in policy and planning.

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