Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

In Zusammenarbeit mit der KTI

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Map of Swiss potential for transformation of mobility

Catalogue of technology options for transformation and practical report of recommendations for supporting the system transformation

SCCER Mobility Deliverable D1-B2.4

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1 Introduction

Mobility is a requirement and an engine for the society and the economy. Despite of increasing prices for energy and mobility, the traffic volumes are growing. At the same time the negative consequences of transportation need to be reduced. Transport accounts for a share of 31% of Swiss greenhouse gas emissions in 2013, a bigger amount than any other sector (industry and services 30%, households 18%, agriculture 12%, waste management 7%; data from Federal Office for the Environment FOEN 2015). This means that especially the transport sector is highly relevant for cutting the emission of greenhouse gasses such as CO_2. This goal cannot be achieved just by making combustion engines more efficient but only with fundamental changes in the transport system.

Thus, especially in the context of climate change a need for transformation of the transportation system becomes obvious, Innovative technologies are expected to solve these problems and help adapting to the changing circumstances, but also new mobility concepts or mobility behaviour change have potential to support the transformation process.

In order to support the transformation process of the transport system the SCCER research program is focused on reducing energy consumption and greenhouse gas emissions (especially CO_2). The goal of the research presented here is to analyse the current state and situation in Switzerland in terms of transformation potential and to provide a conceptual transformation framework. However, we will not only address climate change but also health issues regarding pollution and traffic safety and, more general, the socio-economic and environmental implications of energy consumption as a focus of SCCER.

1.1 Research questions

Related to the goals described above the Swiss potential for transformation is analysed based on the following main research questions and derived sub-questions.

Which main trends characterise determine the current and might determine future mobility in Switzerland?

How can Swiss mobility system be transformed in order to reach an energy transition? This question needs to be seen from a supply and a demand perspective, which both play an essential role. The supply side offers mobility options and sets the legal and infrastructural framework. The demand side (i.e. the people) is requesting mobility as a basic need and makes use of the options provided. The interrelations and interactions between supply and demand are of great importance as they create the system's dynamics.

These general dynamics imply some sub-questions concerning the understanding change processes: Which general mechanisms underlie systemic change processes? How can change processes be pushed in a sustainable direction as defined in SCCER and where are starting points for such interventions? How can individual travel behaviour be changed? What is the role of decision makers on the supply side in the transformation of the mobility system?

1.2 Approach and Methodology

Mobility[1] is a basic human need. It provides the connections between locations where basic needs such as living/residing, working, supply/shopping, recreation, education and

[1] In this context "mobility" means spatial mobility in the sense of a temporary location change.

communication/social life are fulfilled[2]. By this, every person creates their own mobility patterns. A first idea to make Swiss mobility more sustainable is therefore to address these individual mobility behaviours. However, individual behaviour is embedded in a larger environment that is beyond the control of the single individual. The availability of different transportation modes and the access to infrastructure, economic resources and many more aspects influence and determine options for different behaviours. Those frame conditions are superordinate and therefore need to be assessed too. But also this systemic and integrated view on a bigger scale is not yet enough to fully understand *how* and *why* change occurs. The reason is that the 'mobility system' is not a self-sufficient and closed system but is closely interrelated with what happens in economy, technology, etc. (Figure 1-1). Climate change provides an example for this interrelatedness. It is substantially carried by greenhouse gas emissions from the transportation sector. This is the reason that due to more and more visible impacts of rising global temperatures, the transportation sector is increasingly under pressure to reduce these emissions.

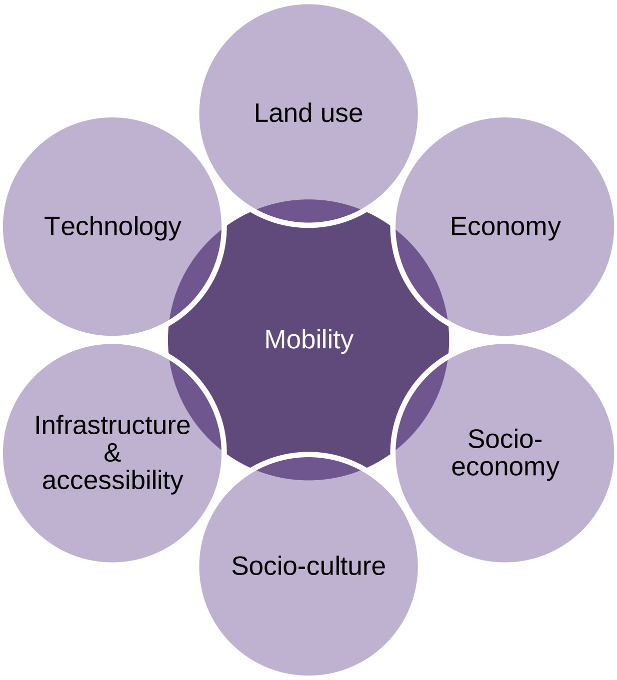

Figure 1-1 An integrated view on the mobility system

The phenomena on the different scales and their interrelatedness are key issues that are to be targeted in transformation research. To support sustainability of the whole system, Swiss mobility needs to be analysed in a comprehensive way. To do this systematically, the differentiation of spatial as well as organisational levels is needed. In our approach three levels have been defined (Figure 1-2).

[2] This list is based on the so-called "Grunddaseinsfunktionen", a concept of social geography that points out basic human needs from a spatial perspective.

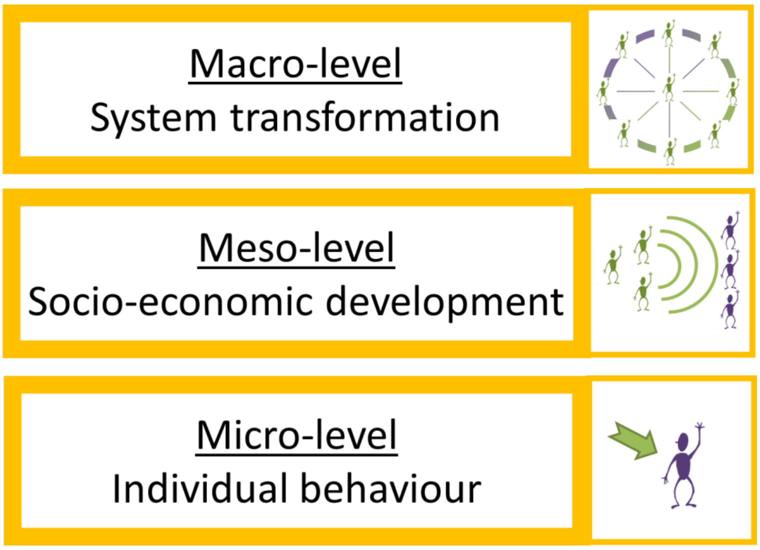

Figure 1-2 Transformation on different scales/levels

1. *The Individual: Micro-level*

Individual conscious and subconscious decisions and behaviours lead to individual mobility or travelling patterns. Those patterns can be analysed and they can also be addressed in interventions to induce change.

2. *The Organisation: Meso-level*

The meso-level provides a more generalised view on mobility. Here we focus on mobility trends, organisations and decision making. General trends[3] in mobility and mobility behaviour can be described and analysed. This helps to identify needs as well as options for interventions: concerning which aspects is it necessary to influence the development to reach the goals of the Energy Strategy 2050 and which starting points are most promising to take action? This also means that a better understanding of change on an organisational level and of decision making processes is important. Therefore, stakeholders of different kinds are important actors here. So after all, the meso-level comprises mobility on behaviour, decisions and trends, that will be relevant and influence the future development.

3. *The System: Macro-level*

The system level sees the whole mobility system of Switzerland as one entity, that is interrelated with other systems (Figure 1-1). It inherits all demands and structures that shape the mobility-“landscape”. Also large-scale dynamic developments affecting the system via different paths (e.g. society, economy, transport), so called ‘megatrends’, are included in the macro-level.

The different levels are interlinked and therefore it is necessary to combine them in a general conceptual model depicting change processes. Such a framework helps to define the research objects and their interrelations further. A well-established approach to explain systemic changes is the ‘multi-level perspective’ (MLP; Geels 2002). It focusses on a systemic level of change but provides the option of integrating developments on bigger scales as well. The MLP

[3] Future developments which are expected due what happened in the past and what is happening in the present.

approach (more details in 3.1), is used as a guiding line for parts of this report and adapted to our needs[4]. The MLP describes and analyses change as interaction processes of three organisational levels. The core is a *'sociotechnical regime'*, i.e. the socio-economic and cultural practice associated with a certain dominant technology[5], which was aligned to the organisational meso-level. Yet, frame conditions for regimes are not static but changing, which is represented through a so-called *'landscape level'* in MLP. It exerts pressures that challenge the current configurations of the regime and are beyond the control of the actors. Megatrends can be considered as 'landscape pressures'. If such challenges cannot be dealt with by the regime itself, there are solutions coming out of *'technological niches'* that can step in and help changing the regimes or replace them based on a new technological solution. This is also part of the organisational meso-level, yet on a smaller scale. The micro-level of the individual is regarded to be a more fine-grained analysis of both regimes and niches, which is conceptually not included in the MLP at the moment. Yet we consider it essential to understand change processes that occur on the micro level.

The short description points to complicated or even complex interrelations and mutual influences of the different objects of investigation. Accordingly, this implies the application of many different methodologies like e.g. statistical analysis, trend analysis, literature reviews, living labs or foresight methods. The report is structured as follows:

In chapter 2 ecological, technological, economic, social and sociodemographic trends are identified that are regarded as relevant for mobility. Based on the quantitative and qualitative analysis of these trends, key findings are summarized (section 0). The theoretical approach for systemic change based on the above-described MLP is depicted in chapter 3. First, a focus on technological transformation is presented by the evaluation of the abovementioned "multi-level perspective" approach (3.1). But not only is a technological perspective important. Also the individual behavioural change is a key aspect to system transformation. Because of this, a literature study on behavioural change theories and their application in the field of mobility is conducted and the results summarised (section 3.5).

The combination of analysis of general trends (chapter 2), theoretical perspective on system change (chapter 3) and practical application provides a general view on the chances and limits of the Swiss mobility system (chapter 4). Based on this comprehensive overview on potentials, specific conclusions and recommendations on action fields are derived as (section 5) and assigned to the different scales defined in the beginning (Figure 1-2). Additionally, case studies from Southern Switzerland that exemplify an approach to combine both the technological and the behavioural perspective conclude this section are presented in chapter 6.

[4] The following lines are based on section 3.1 and therefore do not include references at this point.

[5] In the case of the mobility system, the sociotechnical regime is based on the individually used internal combustion engine (ICE) vehicle.

2 Map of Swiss potential for transformation of the mobility system

Transformation of the Swiss mobility system supporting “Energiewende” needs fundamental change. Speaking about the future system one has to consider ongoing changes and fields related to mobility influencing supply and demand. Thus, a trend analysis was undertaken in order to identify developments supporting or hindering energy transitions.

2.1 Trends in mobility (ZHAW)

Changes in mobility patterns of the Swiss population are extensively monitored by the Microcensus on Mobility and Transport conducted by the Federal Statistical Office (FSO; German: BFS). This is a federal survey held every five years since 1974, and it is the most comprehensive source of statistical data regarding passenger transport and mobility behaviour in Switzerland. The latest version compiles data from 2010 (FSO, ARE 2012), whereas data of the 2015 survey is expected to be available not earlier than mid of 2017.

2.1.1 Mobility demand

Looking at the data to characterize mobility behaviour in Switzerland (Figure 2 1) some trends can be identified. Throughout the last years[6], the share of people undertaking journeys (= not staying at home) remained constant while the average number of daily trips per person went down from 3.6 in 2000 to 3.4 in 2010[7]. However, mobility demand increased in terms of time and distance. The average daily travel time increased by 7.6% from 77.5 to 83.4min between 1994 and 2010, although from 2005 to 2010 a reduction of 5min is reported. During 1994-2010, the covered daily distance grew by 17.3% from 31.3 to 36.7km. The continuous strong growth of distance going along with a less strong increase of travel time indicates a higher efficiency of transport throughout Switzerland. It also reflects that increasing efficiency due to capacity growth did enable travel over longer distances, which is an indicator of rebound effects. Regarding the intermodality involved in the aforementioned trips, the number of trip legs (mono-modal steps of the modal chain) per journey has increased from 4.5 to 5.0, while average daily number of trips remains the same; both can be explained by people combining more legs in one journey. To summarize, the aforementioned data reveal a general trend of growth in travel distances and intermodality for the future, while the share of mobile people remains the same and their number of trips slightly increased. Thus, a trend for more flexible mobility and long-distance travel can be stated.

Longer,
faster,
more flexible.

Whereas the values stated above illustrate individual behaviour, also the development of the whole system need to be considered. It can be characterised according to the mobility demand. The total amount of passenger kilometres per year in Switzerland is on the one hand depending on the average distance covered by person. On the other hand, it is also largely depending on the number of people living in Switzerland and covering these distances. With the predicted population growth (see 2.6.1), the total travel distances are likely to increase. The same can be predicted for the total amount of trips in Switzerland. Therefore, the Swiss Federal Office for Spatial Development has created scenarios[8] that quantitatively capture these projections. They show growth of about ¼ in the

+25% of total trips expected for 2040

[6] These chapters focus on the surveys from 1994, 2000, 2005 and 2010.

[7] No data available for 1994.

[8] The Transportation Outlook 2040 develops a **reference scenario** and three scenarios that illustrate the implications of different directions of spatial development options. For these special Scenarios please refer to ARE (2016), in this report primarily the reference scenario is considered. The reference scenario is based on the

reference scenario concerning total person-km travelled in 2040 compared to 2010 and a corresponding increase in terms of total trips that are travelled in Switzerland (Figure 2-2; note the variability due to changing population and economic development input values in a high and in a low version of the scenario).

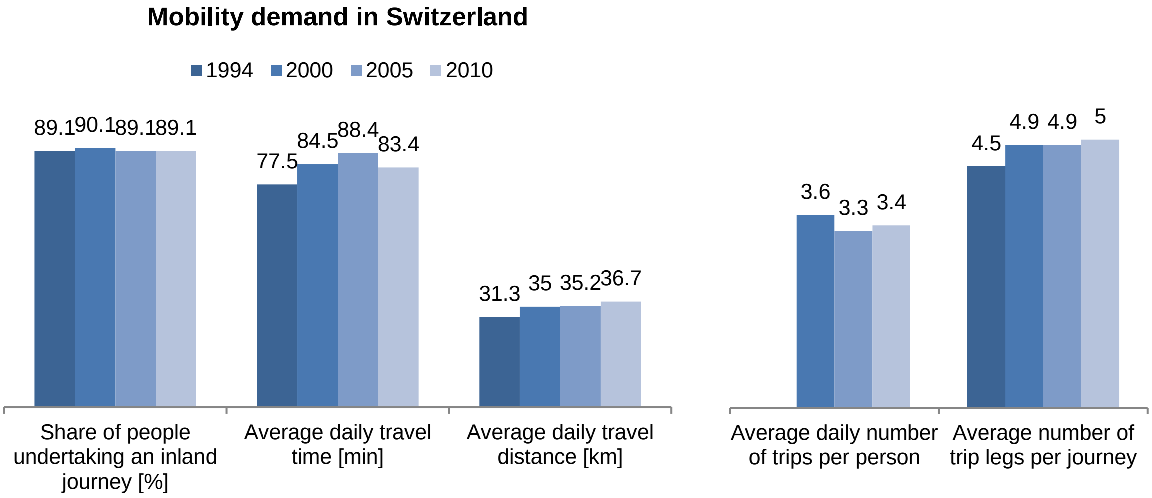

Figure 2-1 Evolution of average personal inland mobility patterns in Switzerland 1994-2010

Data source: FSO, ARE 2012, 2007, 2002

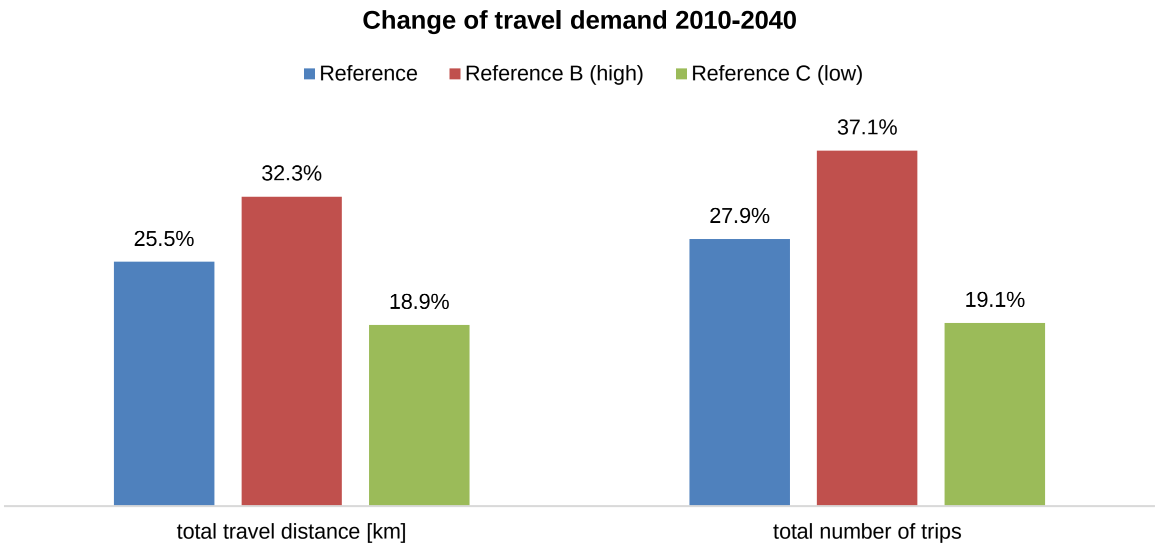

Figure 2-2 Travel demand in Switzerland 2010-2040

Data source: Federal Office for Spatial Development ARE 2016

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extrapolation of past developments enriched by latest trends and projections. It is complemented by two variations that differ concerning population growth and economic growth: **Scenario B** with a higher growth and **Scenario C** with a lower growth in both aspects compared to the middle reference scenario. (Federal Office for Spatial Development ARE 2016, p. 51ff).

2.1.2 Modal choice and modal share

As certain modes of transport vary in their impact on sustainability, this modal share greatly influences the sustainability of the whole transport system. The usage of different transport modes is determined by the modal choice of the travelling person between the car, public transport, bike, walking, etc. The total growth in daily distances (2.1.1) is covered by these modes to different extents. Whereas the average daily travel distance per person increased for most means of transport since the 1990s (Figure 2-3), their share has undergone differentiated developments (Figure 2-4). Concerning distance covered, the car is still by far the most important means of transport. But its relative lead has declined while the share of trains as well as their distance covered features increasing growth. This means that the absolute increase in the average daily travel distance per person is mainly covered by more and/or longer trips by rail.

Car of remaining importance, long train trips

For short distances, the absolute values of cycling remain almost constant while share of daily travel distance decreased. The distance covered by walking has slightly increased, interestingly also the share of average daily travel distance.

Active modes stable share

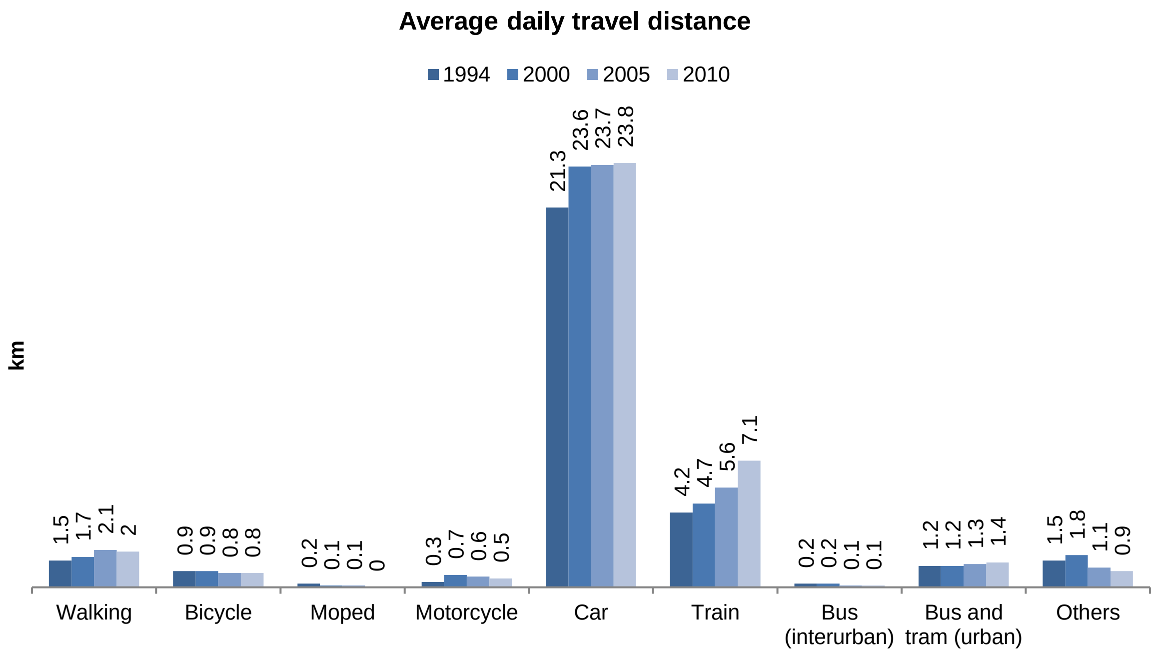


Figure 2-3 Daily travel distance per Swiss person by means of transport 1994-2010

Data source: FSO, ARE 2012

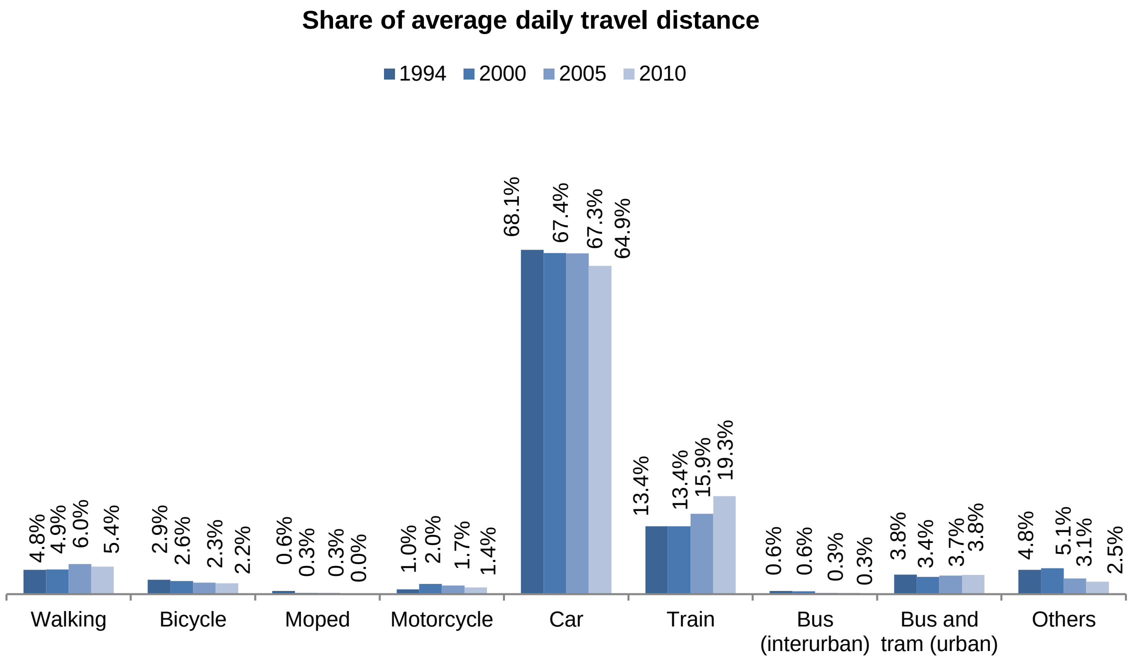


Figure 2-4 Share of daily travel distance per Swiss person by means of transport 1994- 2010

Data source: FSO, ARE 2012

Rail enables long distances

Comparing the modal share of Switzerland with its neighbouring countries and the European Union, some remarkable differences can be noted (Figure 2-5). The share of car passenger-km in Switzerland in 2012 was lower than in the other countries, except Austria. Moreover, the share of car passenger-km has decreased in Switzerland from 81.1% in 2000 to 77.7% in 2014 (-3.4 percentage points), while in the EU-28 this share slightly increased (1.0 percentage point) in the same period. In Germany, this share increased 0.5 percentage points, but in Italy, France and Austria a reduction was reported as well (-2.5, -1.0 and -2.4 percentage points respectively). The reduction of car passenger-km in Switzerland between 2000 and 2012 was mainly due to the rapidly increasing role of train transport. Compared to other European countries as well as to the EU average, Switzerland shows a relatively high share of train trips (distances) that also increased much faster than in other countries (from 13.7% to 17.3% = by 3.6 percentage points). The rail share increased 2.4 percentage points in Austria and 1.0 percentage point in Germany[9], while in Italy the road-based public transport share increased by 2.0 percentage points but the rail share only 0.5 percentage points. The bus share remained almost constant in Switzerland between 2000 and 2014.

[9] Note that this does not yet reflect the increasing long distance coach market in Germany to a full extend

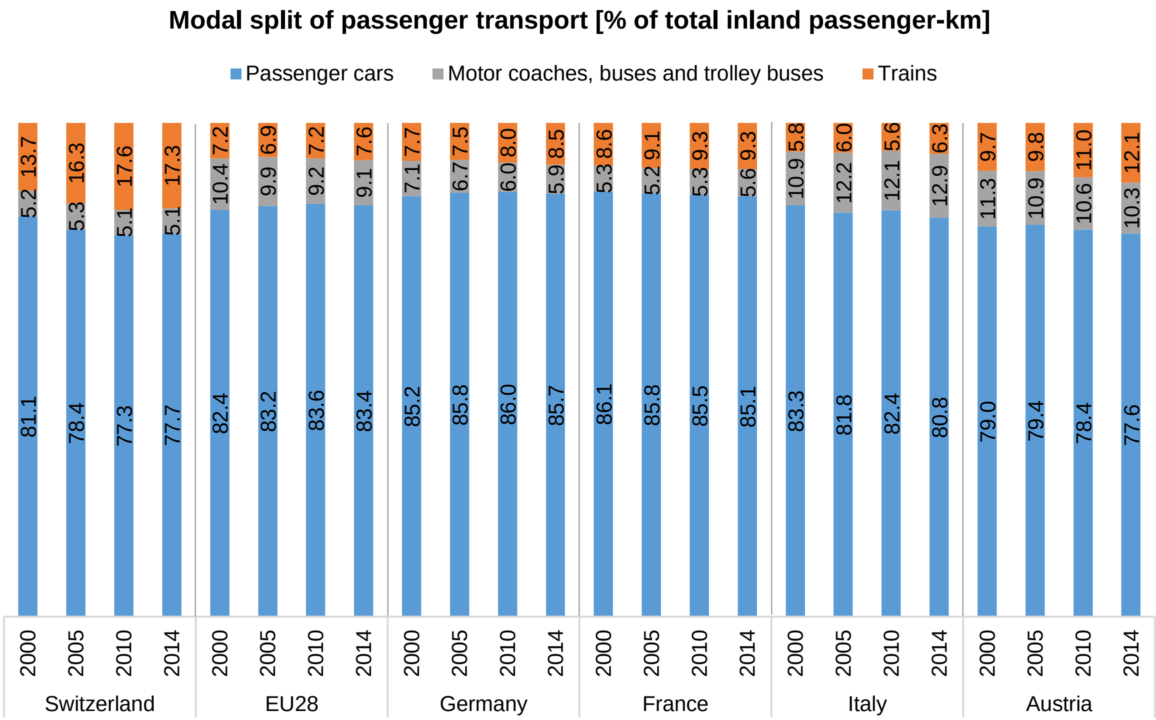


Figure 2-5 Modal share of passenger transport concerning travel distance

Data source: Eurostat 2016

The described trends are supposed to continue (Figure 2-6) according to the Federal Office for Spatial Development ARE (2016) which prognoses that motorized individual traffic will decrease until 2040 by about 4.3 percentage points of the modal share measured in person-km compared to the level of 2010. In contrast, the share of person-km of public transport will increase up to 4 percentage points. Concerning absolute development of mobility demand all modes are expected to increase in pkm travelled (Figure 2-7). So according to Federal Office for Spatial Development ARE (2016), the current trends in modal choice and therefore modal share will continue.

ARE: Increasing demand for all modes

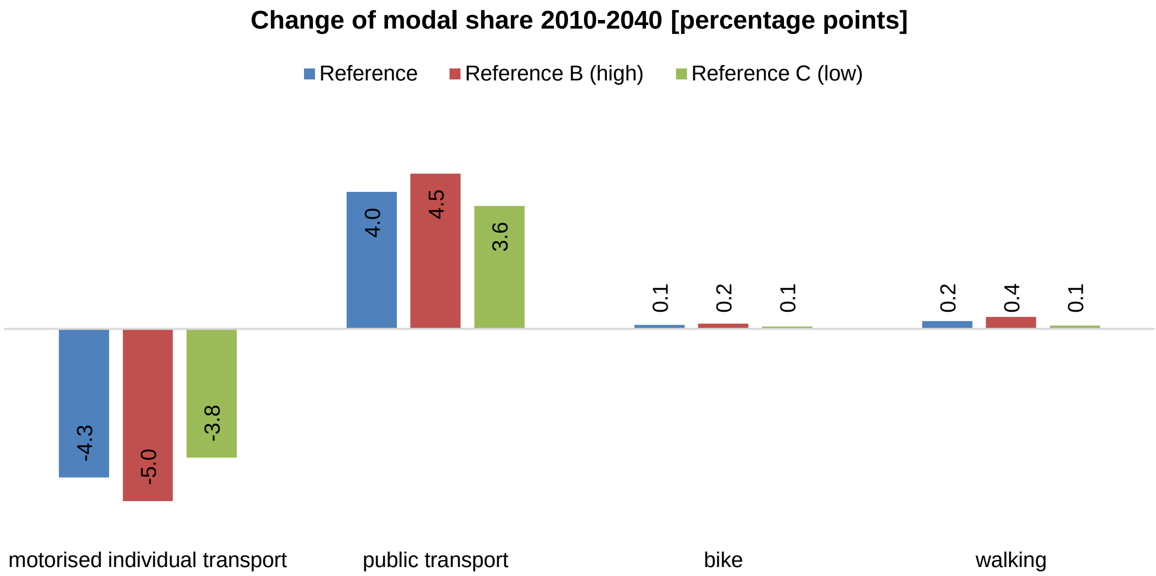
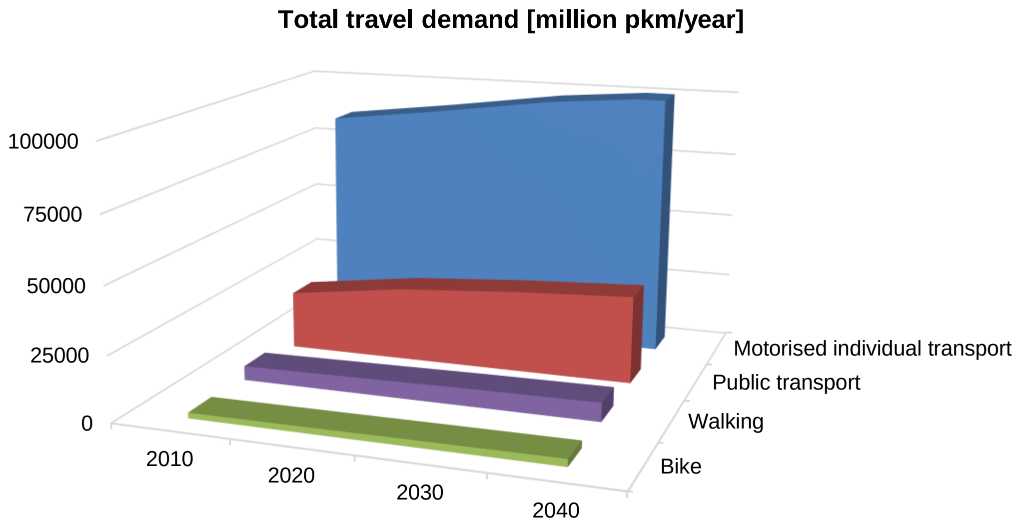


Figure 2-6 Projection of modal share changes in Switzerland 2010-2040

Data source: Federal Office for Spatial Development ARE 2016



	2010	2020	2030	2040
Bike	2116	2342	2621	2822
Walking	5466	6094	6760	7190
Public transport	22163	28053	31266	33568
Motorised individual transport	85442	90981	97172	100930

Figure 2-7 Projection of absolute mobility demand growth by mode 2010-2014

Data source: Federal Office for Spatial Development ARE 2016

2.1.3 Travel purpose

Mobility demand is also depending on the purposes of trips (Figure 2-8, Figure 2-9). The mobility purpose accounting for highest amounts of both time and distance in Switzerland with declining trends in distances however is leisure activities. Travelling to work or educational facilities follows on the second place and accounts for an increase both in travel times and in distances.

Longer commuting, shorter (still long) leisure trips

Commuting distances became longer for work and education in the last two decades, while the average commuting time shows no significant trend – again reflecting that increasing transport efficiency does not lead to significantly shorter travel time but savings are invested to extend the radius for workplaces suitable for commuting.

This is important especially in the context of the future labour market (2.5.2) as an increasing absolute number of employees accelerates this growth in respect to the total mobility demand and the energy needed for this. In contrast to trends in commuting, the time spent in trips for professional activities e.g. a meeting or a visit to a customer reduced to less than half of its initial value between 1994 and 2010; the daily kilometres, instead, decreased less intensely. Especially the economic development of Switzerland (0) will have notable impact on the amount of absolute growth of the transport demand as it influences both the employment situation as well as the (financial and time-wise) potential for leisure activities.

Economic & employment growth drive mobility demand

Besides work and education leisure is still the main purpose accounting for the highest share in both travel distance and time; contradictory to this traffic peaks caused by commuting are still driving forces for the expansion of transport infrastructure, transport capacities and services.

Different indications for/from leisure & work related mobility

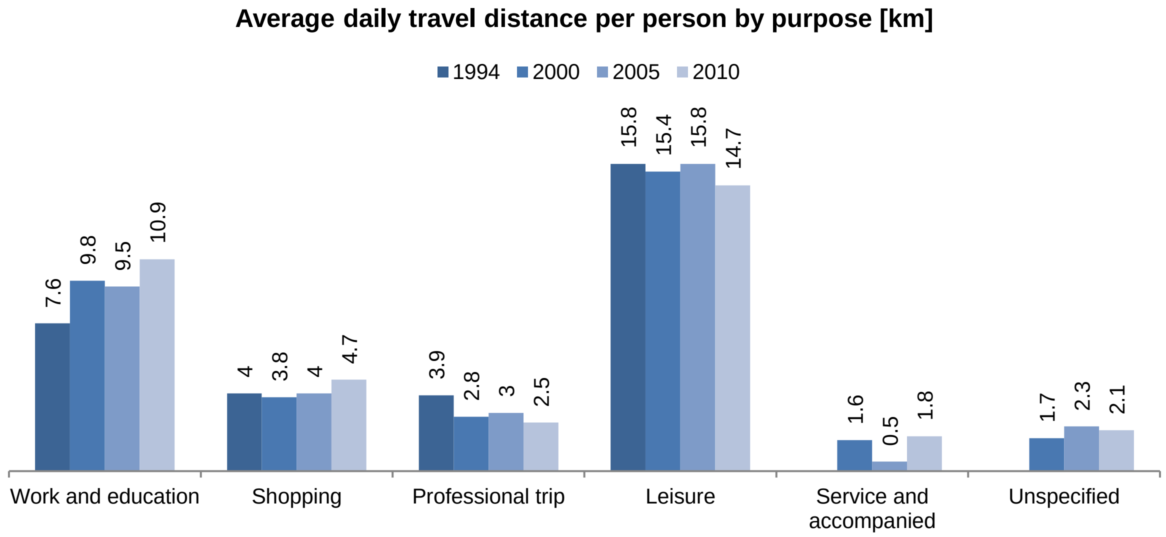


Figure 2-8 Daily travel distance according to purpose in Switzerland 1994-2010

Data source: FSO, ARE 2012

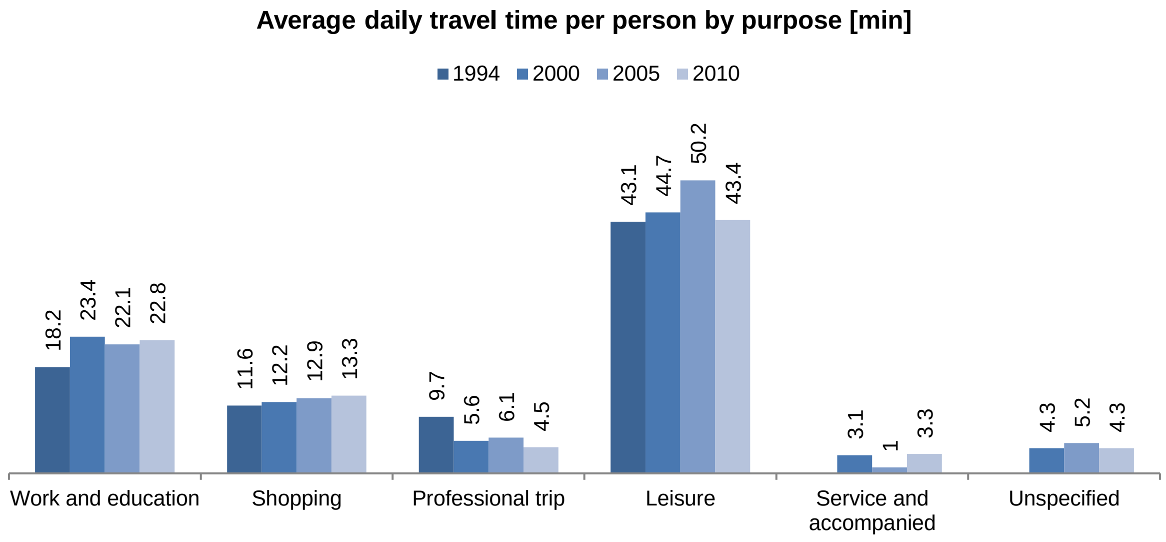


Figure 2-9 Daily travel time according to purpose in Switzerland 1994-2010

Data source: FSO, ARE 2012

Economic growth & migration

The projection of the future development of the travel demand analysed separately for the different purposes (Figure 2-10) indicates growth in all fields. Obviously, the amount of this absolute growth in mobility demand depends on the amount of population growth. This can be shown by the example of work-trips. A big share of immigration to Switzerland is work-related and therefore the growth of travel demand for work-related trips is highly depending on the population development. The differences between the scenarios show this: reference scenario B with a large growth of the population projects an increase in work-related travel distances that is almost 15 percentage points higher than in reference scenario C (small population growth).

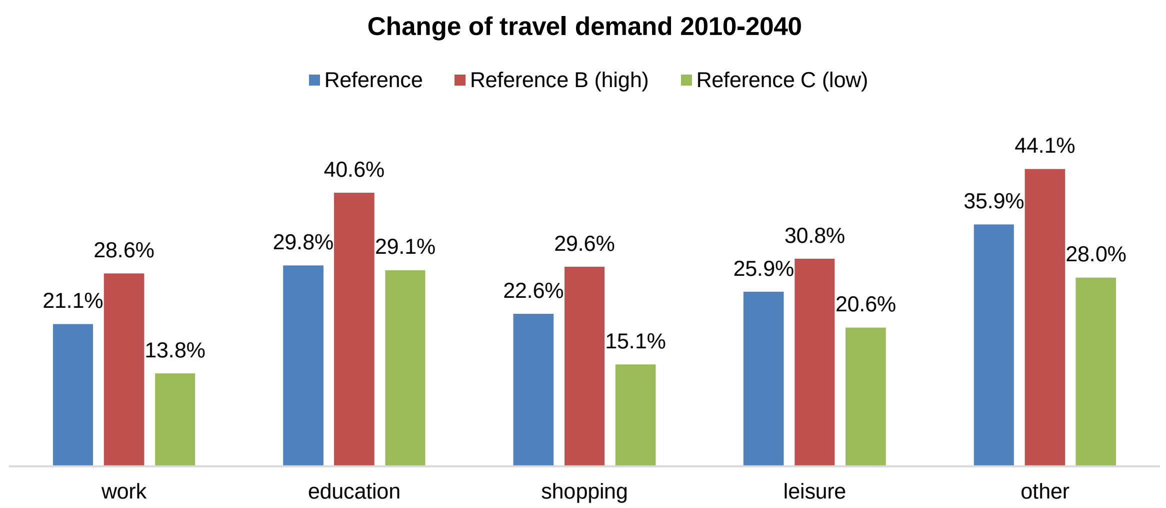


Figure 2-10 Percentaged change of travel demand in pkm by trip purpose 2010-2040

Data source: Federal Office for Spatial Development ARE 2016

2.2 Trends in accessibility and transport infrastructure (SUPSI)

Availability of transport infrastructures drives mobility modal choice: improvements in accessibility by means of transport other than the car tend to favour a reduction in car use, while additional developments of road-based transport infrastructures reinforce tendency towards car use. In this section, we analyse past trends in the evolution of transport infrastructures (road and railway network) and present their effects on traffic congestion and accessibility levels.

2.2.1 Length and capacity of the road and railway network

A first general indication on transport infrastructures in Switzerland comes from the length of the road and railway network. At present the system accounts for 5'124 kilometres of railway lines and 71'550 kilometres of roads. The evolution over time of those variables is shown in Figure 2-11.

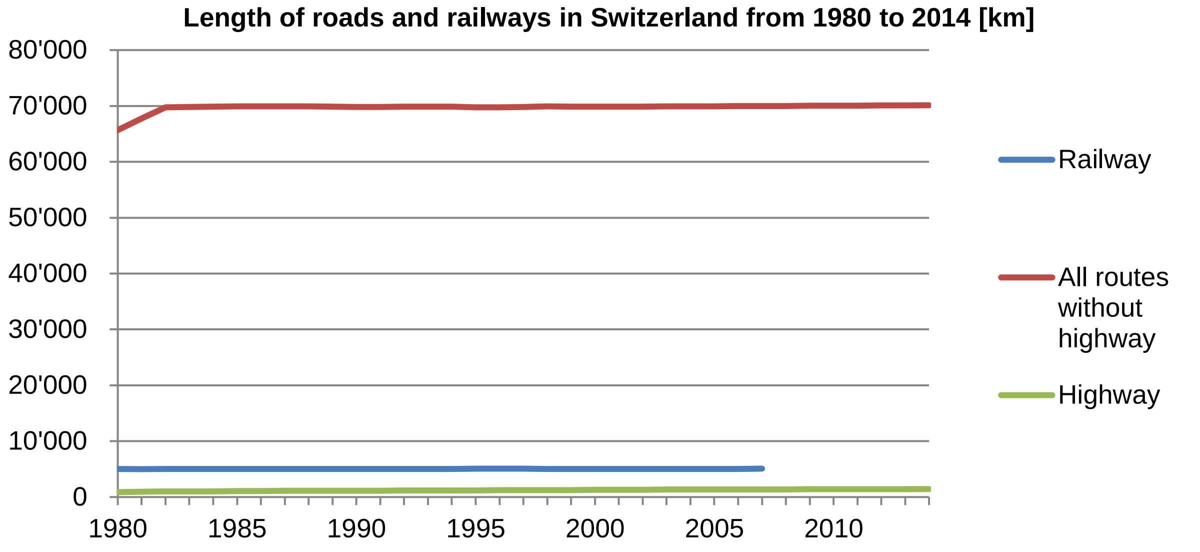


Figure 2-11 Development of the length of the road and railway network in Switzerland 1980-2015

Data source: Federal Office for Roads (ASTRA) - Federal Office for Statistics (BFS) Indicator T.11.3.1.1

At the level of zoom shown in Figure 2-11, no significant increase in the length of the roads and railways seems to have happened from 1982 to 2014. However, considering the percentage variations in the kilometres of transport networks between 1980 and 2014 shown in Table 2-1, a general increasing trend can be noticed. In particular, length of roads increased definitely more than railways and highways show the highest increase rate, equal to 63%. Such an increasing trend is in particular presented in Figure 2-12: data show that from the end of the 1980s its speed has slowed down.

Length of roads increased more than railways

Data regarding the evolution in the length of cantonal roads also show that municipal roads increased of around 11% in the last 34 years. Part of such an increase needs to be attributed to a change in competences between Cantonal and Municipal authorities. If we consider the total of national, cantonal and municipal roads, we get an overall increase of 7.5% from 1980 to 2014 (Figure 2-13). This is correlated with the urban sprawl phenomenon indicated in section 2.4. Most important, following a period of stabilisation from 1998 to 2007, after 2007 a marked increasing trend can again be noticed. Such data confirm a deeply rooted dependency on car use.

Table 2-1 Variation of the length of road and railway network in Switzerland 1980- 2014

	1980 [km]	2014 [km]	Variation [%]
Railway lines	5'000	5'124	+ 2.5
Highways	869	1'429	+ 63.1
Other roads (total)	66'545	71'553	+ 7.5
• National roads	1'171	1'823	+ 55.7
• Cantonal roads	18'667	17'933	- 3.9
• Municipal roads	46'707	51'797	+ 10.9

Data source: OFS - Compte d'infrastructure routière (STR), OFROU - Route et traffic Indicator T.11.3.1.1

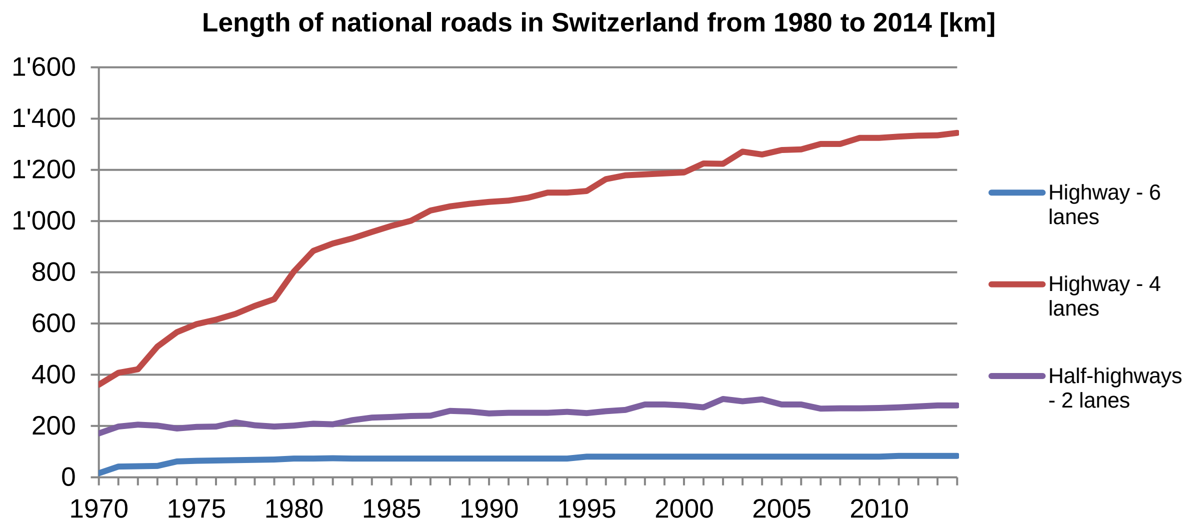


Figure 2-12 Development of the length of the national road network in Switzerland 1970- 2014

Data source: Federal Office for Roads (ASTRA) - Federal Office for Statistics (BFS) Indicator 11.1.3.5

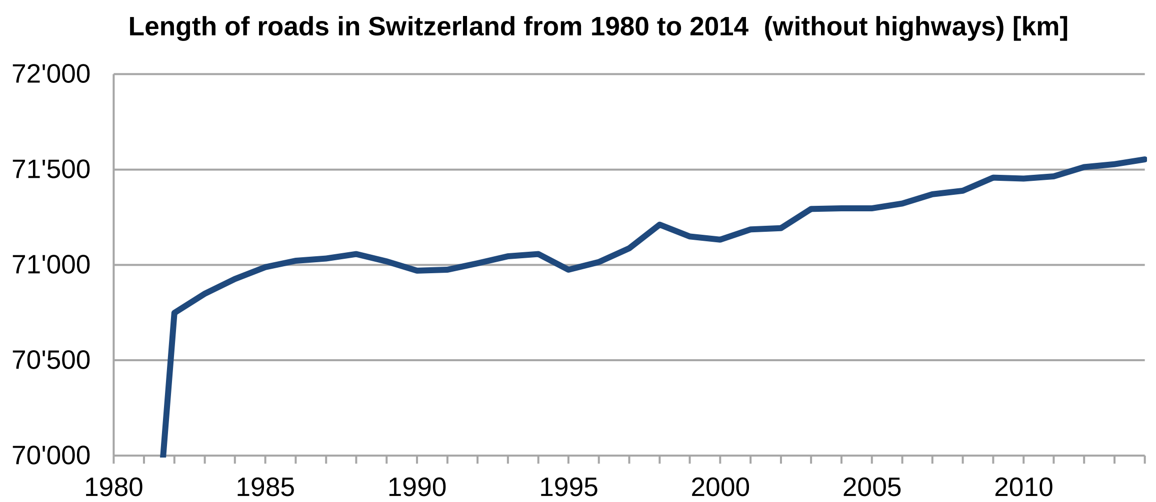


Figure 2-13 Development of the length of the road network in Switzerland 1980- 2014

Data source: Federal Office for Roads (ASTRA) - Federal Office for Statistics (BFS) Indicator T.11.3.1.1

In order to fully understand the evolution of transport infrastructures, it is also important to consider capacity of the road network. This might be indirectly expressed by an indicator accounting for the areas occupied by the transportation network and the related services. In particular, evolution in the extension of parking areas is a very effective indicator to understand trends in the level of dependency on car use.

To this purpose we can refer to land use statistics, gathered by interpretation of aerial photographs. Three standardized land use surveys were developed in Switzerland: data were gathered in the periods 1979–1985, 1992–1997 and 2004–2009, with a periodicity of 12 years (BFS, 2013a). According to the last survey, roads and parking areas cover 90% of the total transportation area, while railways cover the remaining 10% transportation area.

Areas occupied by parking lots and highways show a relevant increase

Between 1985 and 2009, all types of transport infrastructure gained extra space, as shown in Figure 2-14. Considering the evolution between 1985 and 2009, parking areas and highways show very relevant increases, respectively equal to 55% and 49%. On average, during such a period all the road areas grew by 15%, while railway areas only increased by 3%.

Parking areas grew with the same pace as passenger cars

It is interesting to compare such numbers with the evolution in the number of passenger cars: from 1985 to 2009, their number grew by 53%. Those data show that parking areas grew with the same pace as the number of passenger cars; instead, growth in the total extension of roads (both in terms of area covered and length), was less intense than growth in the number of passenger cars. Even though traffic flows depend on the amount of kilometres driven by each passenger car, such a discrepancy between growth in the road network and in the number of passenger cars implicates an increase in the level of traffic congestion.

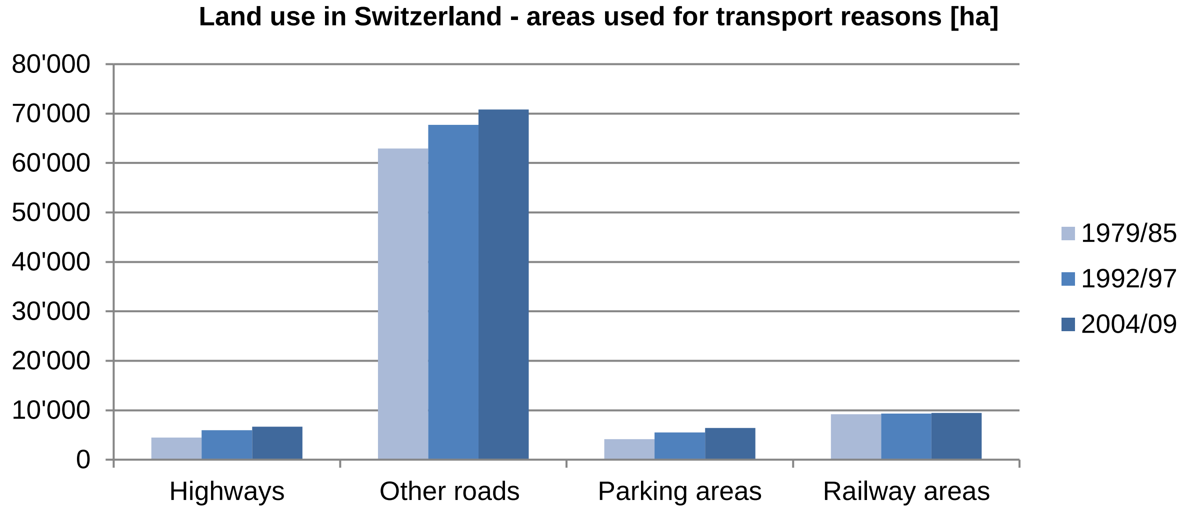


Figure 2-14 Evolution of hectares of land used for transport purposes in Switzerland 1979/85- 2004/09

Data source: BFS, Arealstatistik 2004/09, 1992/97, 1979/85 - 2013

2.2.2 Traffic congestion and levels of accessibility

Data gathered by the Federal office for roads confirm a significant increase in traffic congestion levels on national roads. As shown in Figure 2-15, the number of congestion hours registered every year on national roads grew from around 3'000 in 1995 to around 21'000 in 2014; and in both cases the majority of them is due to network overload.

Traffic congestion due to network overload conditions

Such elements are confirmed by Figure 2-16, which shows the average daily traffic registered all over the national road network in Switzerland in 2005 (a) and in 2014 (b): traffic flows increased in nearly all the routes across Switzerland, both along the North-south and the East-West corridors.

Congestion on the national road network in Switzerland [Thousand of hours/year]

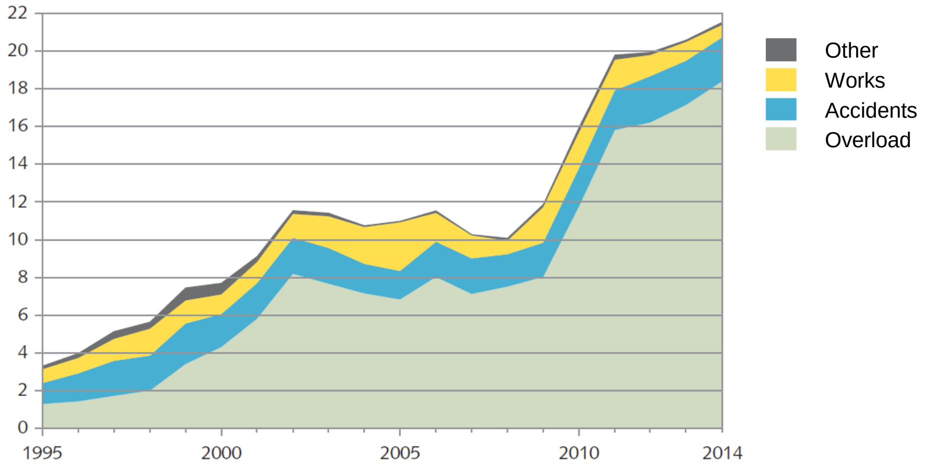
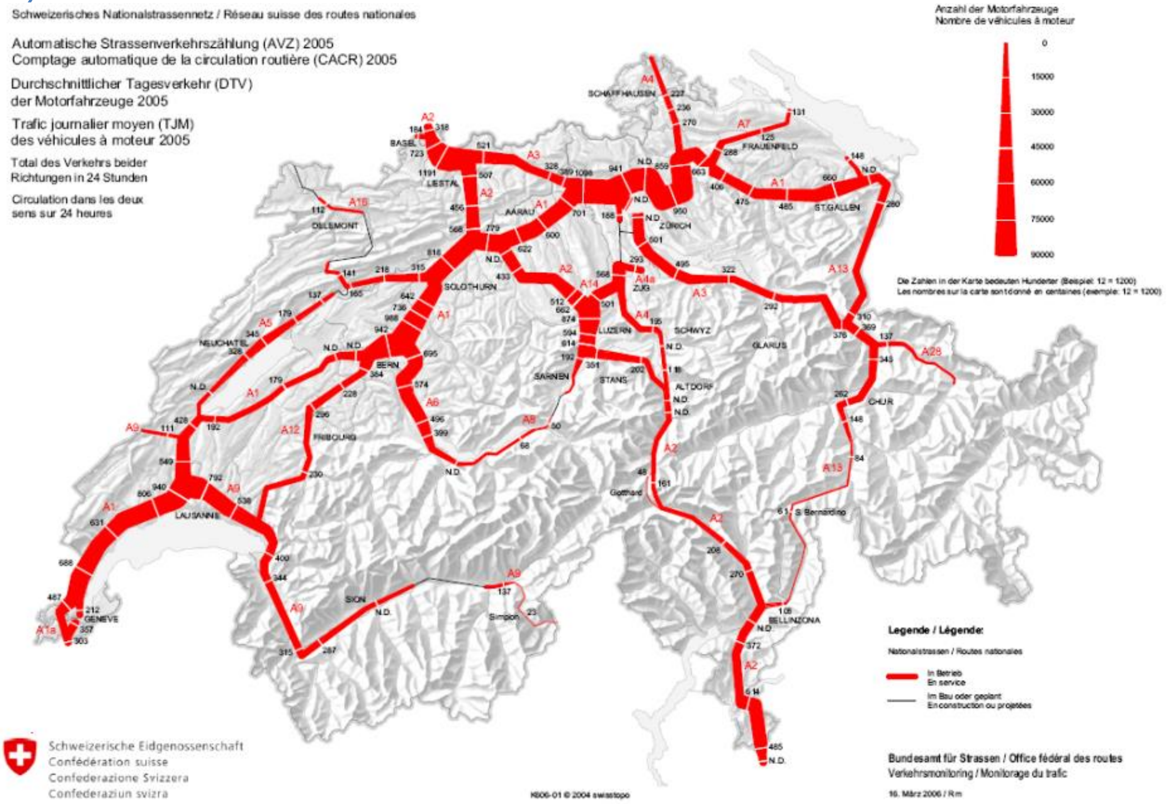


Figure 2-15 Evolution of congestion levels on the national road network in Switzerland 1995- 2014

Source: Federal Office for Roads (ASTRA) - Federal Office for Statistics (BFS) 2015

a) Year 2005



b) Year 2014

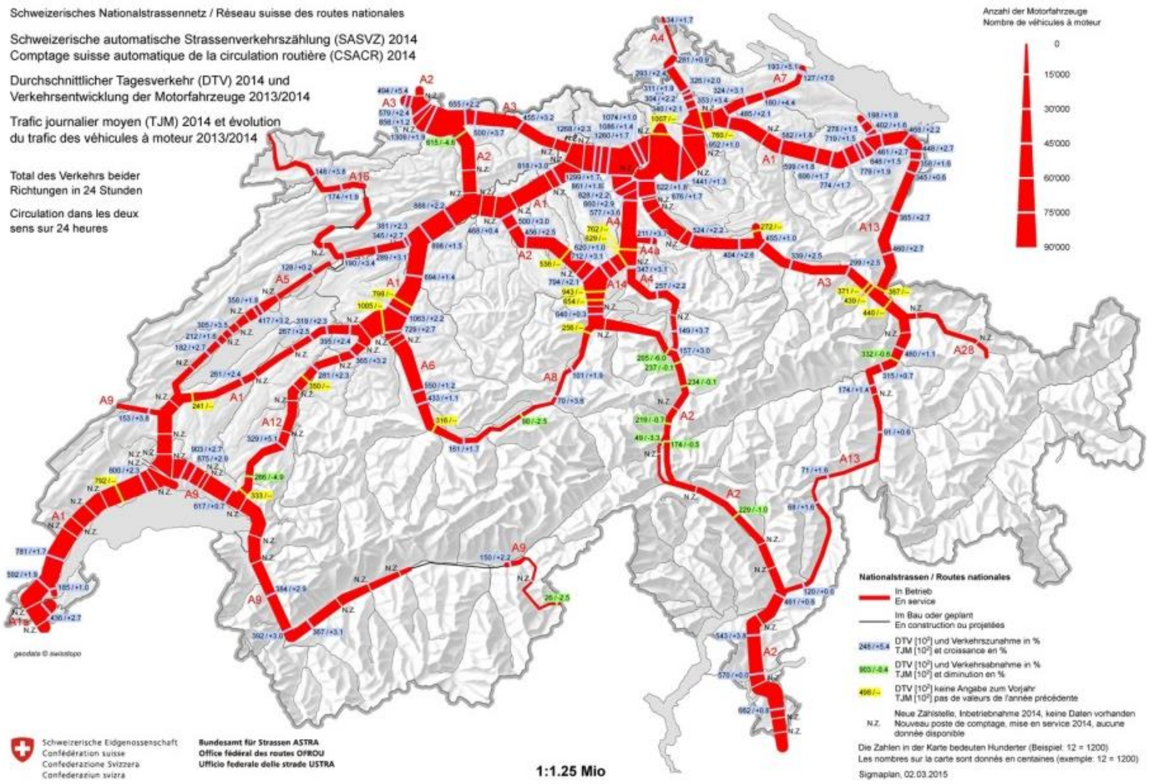
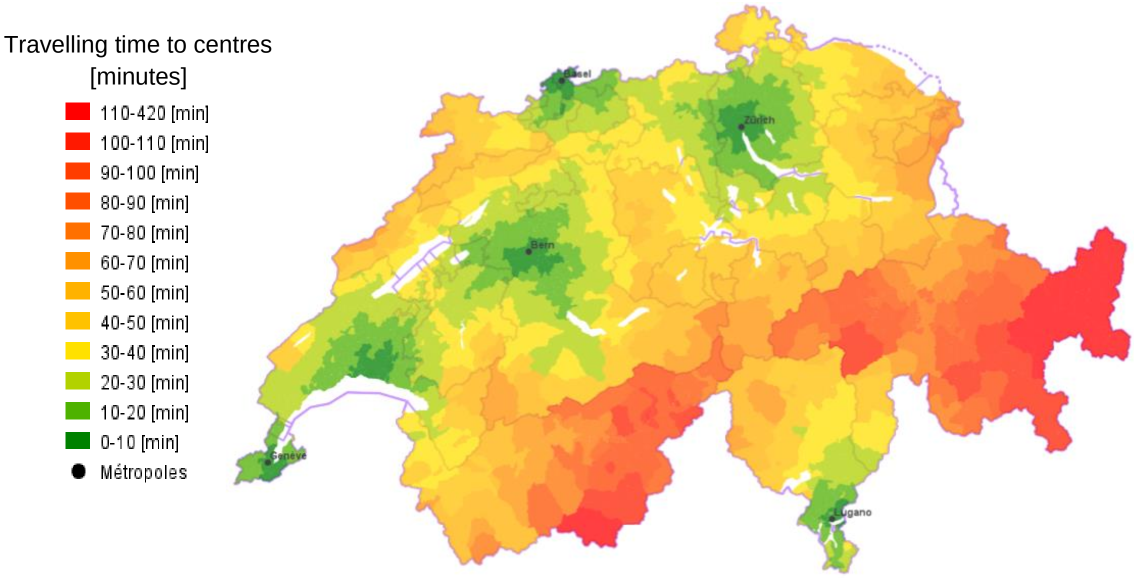


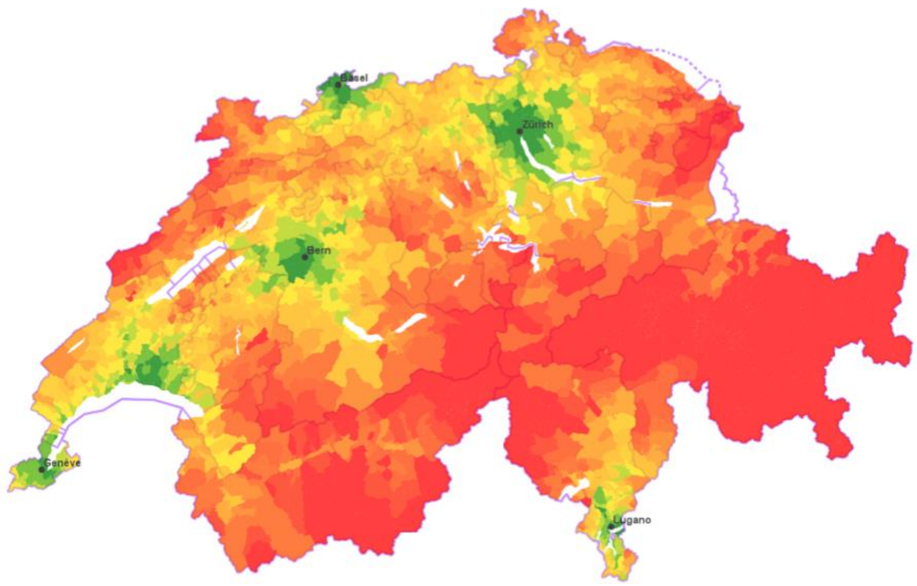
Figure 2-16 Average daily traffic registered on the national road network in Switzerland

Source: Federal Office for Roads (ASTRA) 2006 and 2015

Under such conditions it is also interesting to assess the overall level of accessibility to city centres offered by the Swiss transport infrastructure network. Recent research by the Federal office for spatial development (ARE, 2013b) allows to assess the overall travelling time needed to reach the closest centre, starting by any point in Switzerland.



a) Private Motorized Transport (PMT)



b) Public Transport (PT)

Figure 2-17 Travelling time towards the closest city centre in 2011
a) by private motorized transport (PMT); b) by public transport (PT)
Source: Federal Office for Spatial Development ARE 2013b

Results of the analyses are referred to the year 2011 and are shown in Figure 2-17, which considers both private motorized transport PMT (cars and motorbikes) (a) and public transport PT (b). The cartographic indicator measures accessibility as the travelling time needed to reach either (i) the closest isolated city or (ii) the closest centre of urban agglomeration or (iii) one of the following city centres: Basel, Bern, Genève, Lausanne, Lugano and Zürich. The maps show that travelling time towards the cities in the plateau region does not differ very much between PMT and PT. Instead, differences in travelling time become more significant in the Italian and French speaking part of Switzerland, and they always increase in rural areas, along with the distance from the centres themselves.

Travelling times by PT and PMT are equivalent in the plateau region

A strictly connected cartographic analysis also developed by the Federal office for spatial development (ARE, 2011) shows the general level of effectiveness of public transport. Effectiveness is classified in four levels, identified taking into account the timetables of the public transport companies (Figure 2-18). Such an indicator confirms that accessibility level by public transport decreases with the distance from city centres and, in general, that public transport is more effective in the large cities of the plateau regions.

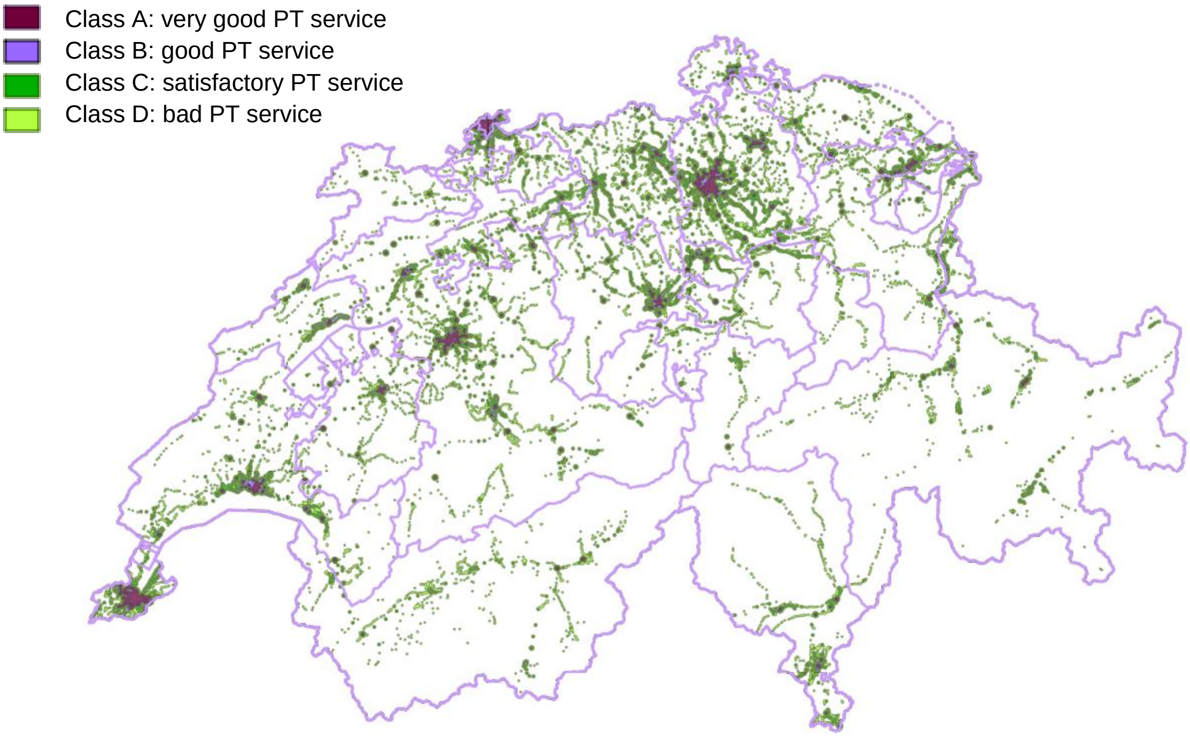


Figure 2-18 Quality of public transport (PT) service in 2011 based on the timetable of the public transport companies
Source: Federal Office for Spatial Development ARE 2011

2.3 Technological trends (SUPSI)

A transition to low carbon and low energy mobility sector is necessarily driven by technological development. This chapter provides an overview of innovative technologies already made available by the automotive industry and of their expected development in the very next future and summarizes the level of diffusion they had so far.

2.3.1 Market penetration of fuels and powertrains

To understand how technological trends affect transport demand, we focus on road passenger cars. The most important evolution refers to the dominant vehicle powertrain and to the strictly related choice of fuel.

Data gathered by the Federal Office for Roads (ASTRA) show that in the last twenty-five years the share of petrol-fed passenger cars decreased over time, being replaced by diesel-fed vehicles (see Figure 2-19). Without a doubt, internal combustion engine vehicles (ICEV) remained the dominant powertrain. Share of battery electric vehicles (BEV) was in fact negligible, being equal to 0.1% in 2014. If we consider trends over time, however, data regarding the number and share of electric vehicles show that, after a long stable period from 1990 to 2010, after 2010 a fast speed increasing trend took place: from 2010 to 2014, in fact, the number of electric passenger cars increased by 567% (see Figure 2-20).

Share of circulating electric vehicles is negligible (0.1%). Though, sales are fast increasing

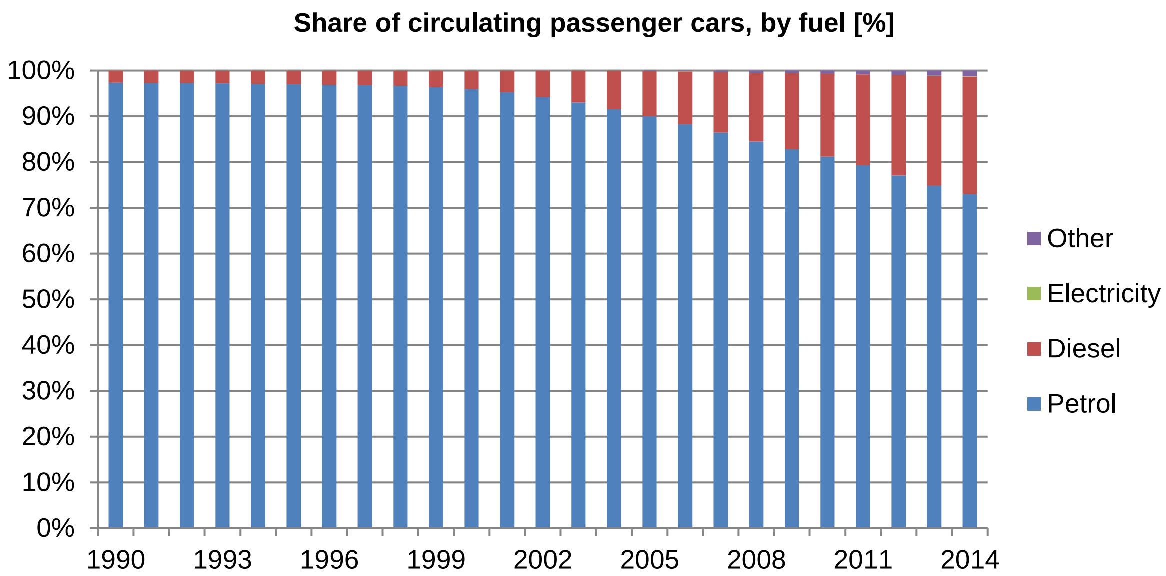


Figure 2-19 Development of the share of passenger cars in Switzerland, by fuel type 1990-2014

Data source: ASTRA – Motorfahrzeug- und Motorfahrzeughalterdatenbank (MOFIS), 2014

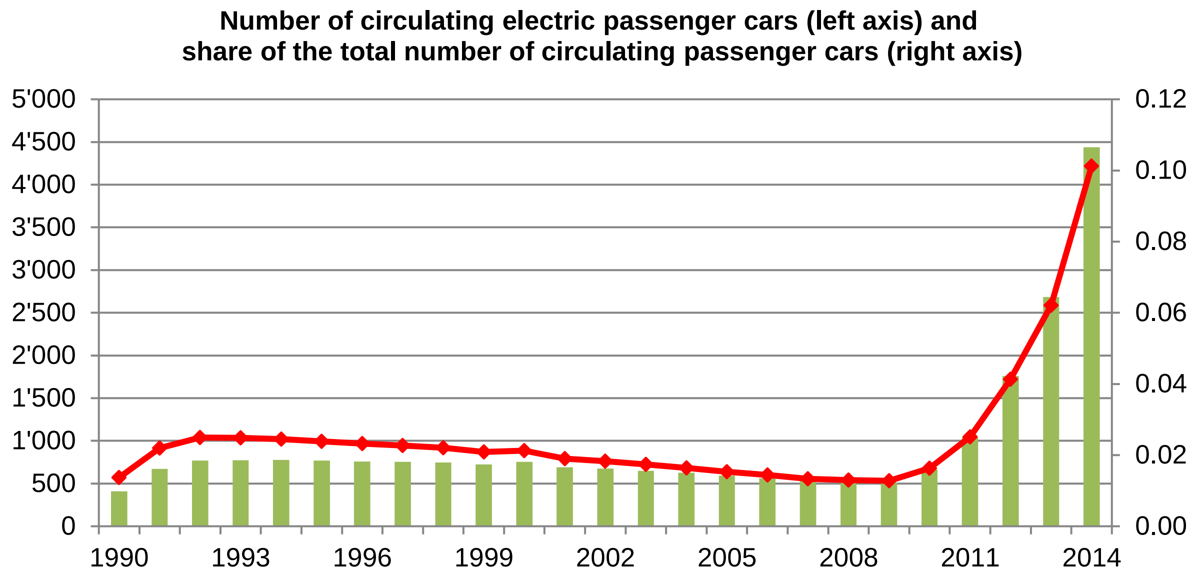


Figure 2-20 Development of the number of circulating electric passenger cars in Switzerland 1990-2014 and share of the total number of passenger cars

Data source: ASTRA – Motorfahrzeug- und Motorfahrzeughalterdatenbank (MOFIS), 2014

Such a trend can also be reckoned by analysing the share of electric vehicles among new passenger cars registered every year. Detailed statistics at the Swiss level are available since 2005 and are shown in Figure 2-21 and Figure 2-22. In particular, data highlight the increasing role played by hybrid petrol-electricity vehicles (HEV). Notwithstanding increasing trends, absolute values keep remaining very low: in 2014 HEVs accounted for only 2 % of the new passenger cars (while purely electric vehicles represented 0.6% of the new passenger cars).

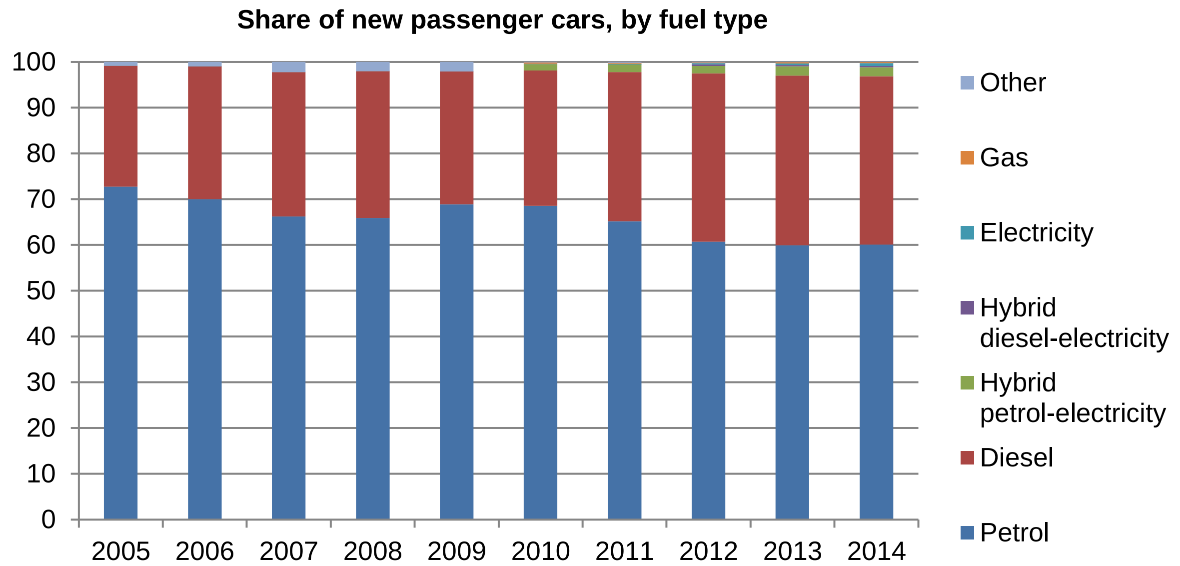


Figure 2-21 Development of the share of new passenger cars in Switzerland, by fuel type 2005-2014.

Data source: ASTRA – Motorfahrzeug- und Motorfahrzeughalterdatenbank (MOFIS), 2014

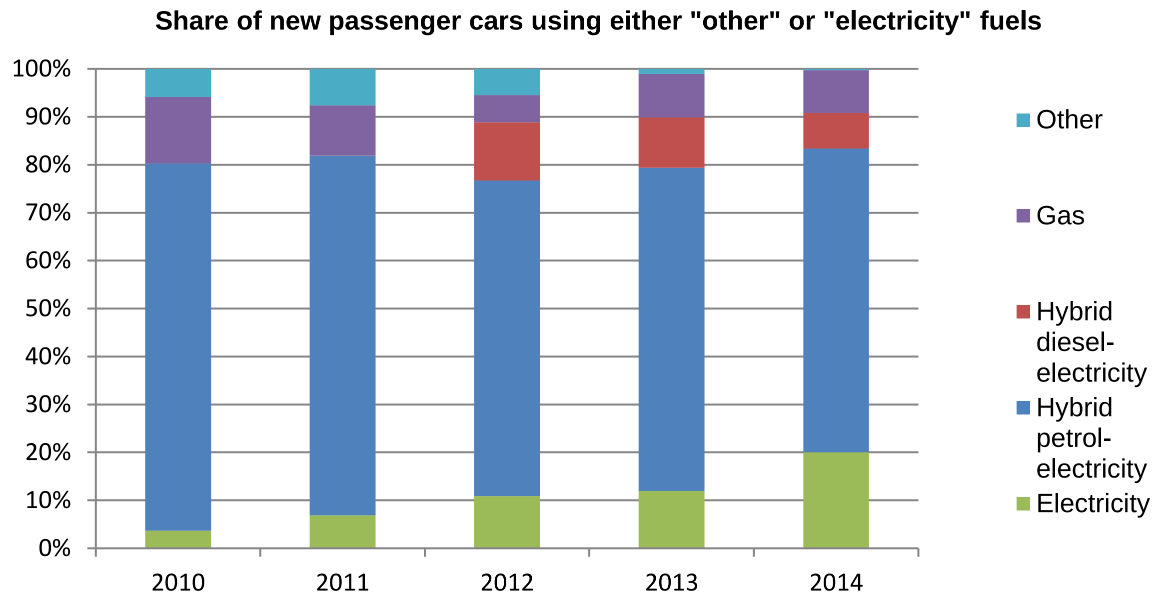


Figure 2-22 Development of the share of new passenger cars in Switzerland 2010-2014 for fuel types other than "other" and "electricity"

Data source: ASTRA – Motorfahrzeug- und Motorfahrzeughalterdatenbank (MOFIS), 2014

For Switzerland, scenarios regarding the evolution of the share in powertrain and fuel usage of circulating vehicles were elaborated at the Federal level within the 2050 Energy strategy. Using the same terminology introduced in Table 2-5 (High, Medium and Low energy scenarios), Table 2-2 and Figure 2-23 show the prospected evolution of internal combustion engine vehicles, petrol and diesel-fed, and possible paths for their substitution by other powertrains or fuels.

The 2050 Energy strategy scenarios envision increasing shares for (hybrid) electric vehicles

In the Low energy scenario, in 2050 share of petrol and diesel vehicles in the overall number of circulating vehicles would fall to 56%, from the present 99% share. In such a scenario, both battery electric vehicles and hybrid electric vehicles would have an important role. Interestingly, according to such a scenario, in 2050 fuel cell hydrogen-fed vehicles are attributed a 4% share. Presence of internal combustion engine vehicles fed by natural gas is supposed to increase respect to 2014, however without getting a key role. In the other two scenarios, which do not differ for hypotheses regarding powertrains and fuels for circulating vehicles, the overall share of internal combustion vehicles would only decrease to 67%. Also in those scenarios, however, battery and hybrid electric vehicles would case be the most important alternative to the dominant petrol and diesel-fed internal combustion engines.

Table 2-2 Share of circulating vehicles in 2035 and 2050, according to the 2050 Energy strategy scenarios

	Today	High scenario		Medium scenario		Low scenario	
	2014	**2035**	**2050**	**2035**	**2050**	**2035**	**2050**
Battery Electric Vehicles	0.1	5.0	15.7	5.0	15.7	8.0	21.9
Hybrid electric Vehicles	1.2	8.1	10.8	8.1	10.8	11.9	15.3
Natural gas vehicles	0.0	1.9	2.7	1.9	2.7	1.4	2.1
Hydrogen/fuel cells vehicles	0.0	0.0	3.5	0.0	3.5	0.0	4.4
Petrol/diesel vehicles	98.7	85.0	67.3	85.0	67.3	78.7	56.3

Data source: Energyscope Calculator - EPFL, based on (Prognos, 2012)

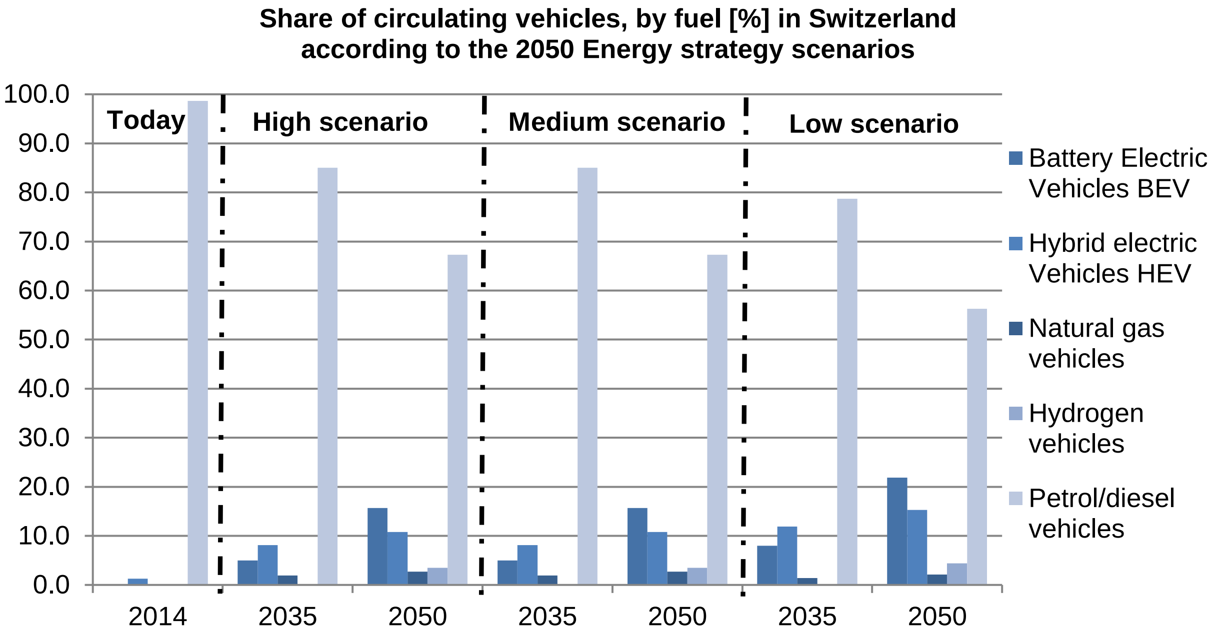


Figure 2-23 Development of the share of circulating passenger cars in Switzerland according to the three 2050 Energy strategy scenarios

Data source: ASTRA – Motorfahrzeug- und Motorfahrzeughalterdatenbank (MOFIS), 2014 and Energyscope Calculator - EPFL, based on (Prognos, 2012)

Evolution in the share of vehicle powertrain and fuel is strictly connected to developments in the recharging and fuel distribution networks. Scenarios elaborated within the 2050 Energy strategy are coherent and conservative respect to the present diffusion of recharging points, shown in Figure 2-24: compared to a total of 3'480 petrol and diesel service stations, in 2014 in Switzerland only 140 gas service stations were available. Instead, around 1'000 electric charging stations were already available, including 70 fast charging stations. Compared to other countries in the world, Switzerland is among the countries with the highest concentration of electric charging points.

Fast electricity charging stations are becoming widely available

a) 

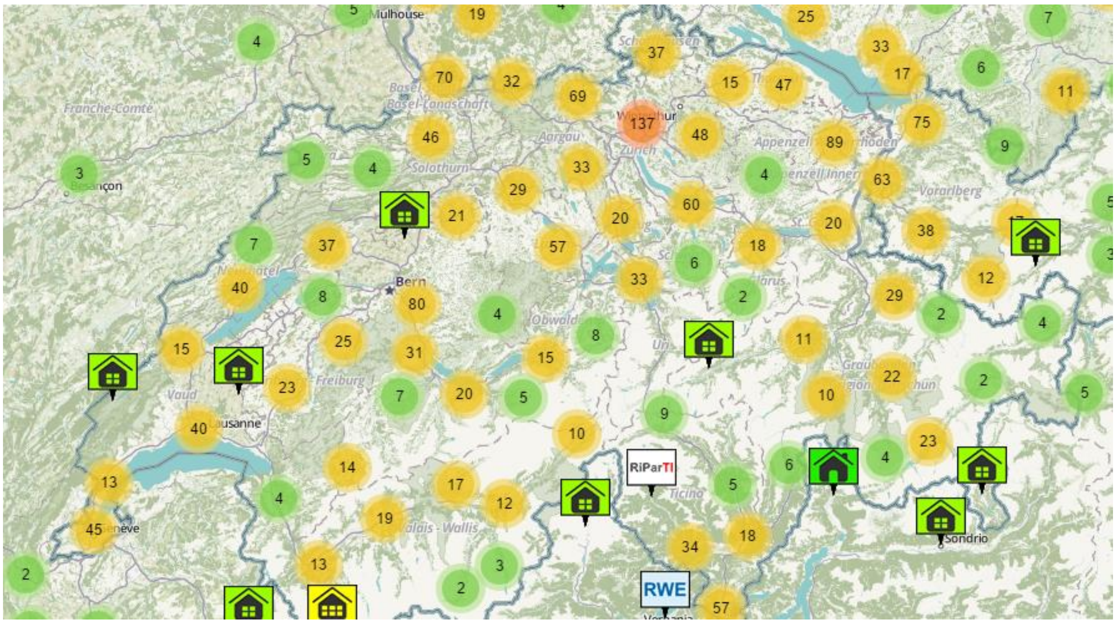
b) 

Figure 2-24 a) Gas service stations and b) Electric recharging stations in Switzerland in 2016

Source: a) Erdgas, 2016; b) LEMnet 2016.

2.3.2 Disruptive technologies for private motorized transport: autonomous driving

The 2050 Energy strategy scenarios assume the present transportation system will basically look the same in 2050, only with different powertrain and fuels. However, a disruptive technology might come into play and produce completely different scenarios: according to the companies who are developing them, fully autonomous self-driving vehicles might be available on the market within a decade, by 2025 (Mitchell Walldrop, 2015). Technological progress in this field was in fact very fast: in less than ten years, it was possible to move from the early driverless car concept

Technological progress in autonomous driving is very fast and ideas to production and prototype testing. In June 2015, Google, world-leader of driverless cars since 2010, declared that their fleet of driverless cars reached the first milestone of a total of one million of miles (equivalent to 1’600’000 kilometres) safely driven in California; in the same period, they also obtained authorizations to test a driverless car fleet on public roads in Zurich.

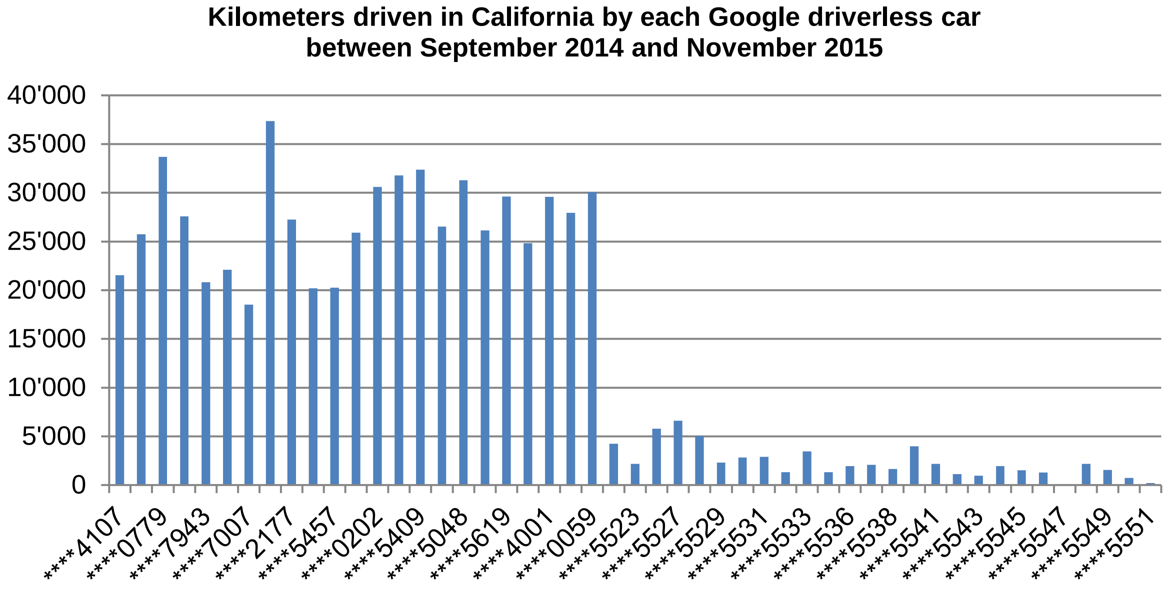


Figure 2-25 Kilometres driven by each Google driverless car on public roads in California

Codes on the horizontal axis are plates identifying each driverless vehicle of the fleet.

Data source: Google, 2015

Future autonomous vehicles will be equipped with sensors and radio technology allowing direct communication both between vehicles (vehicle to vehicle, V2V technology) and between vehicles and the infrastructure (vehicle to infrastructure, V2I technology), such as for example smart traffic lights: vehicles and infrastructure will share safety messages regarding their position, speed and position of travel, with the aim of optimizing the overall system performances. As optimization of the system supports traffic flow more individual motorized mobility might be induced as a rebound effect, if delay due to traffic jams is reduced.

Future automated vehicles will drive at lower speed but keep traffic flowing

Fully automated vehicles will move at lower speed, however a general coordination among them will be guaranteed, so that traffic will keep flowing and good commercial speeds will be obtained. This will result in preventing accidents and in greatly reducing stop-and-go traffic congestion, therefore reducing energy consumptions and CO_2 emissions. Since safety will increase, all the heavy materials of the shell, nowadays necessary to increase safety in the cabin, will no longer be needed. Therefore, driverless cars will be lighter, with further benefits regarding CO_2 emissions and energy consumptions. Moreover, the general reduction in car speeds and the significant decrease in car accidents might indirectly favour cycling, thus stimulating an additional reduction in energy consumptions and CO_2 emissions. Finally, driverless cars might also adopt electric powertrains, further reducing consumptions and emissions (Seba, 2014).

From the user perspective, driverless cars would allow people to recapture the time and the psychic energy they lose every day when struggling in traffic (KPMG and CAR, 2012): always digitally connected, people could use commuting time to work, read, watch movies or simply sleep. Together with the technological revolution, driverless cars will probably also foster a behavioural revolution: they will foster a progressive abandon in car ownership, further favouring the diffusion of ride-sharing services triggered by the digital revolution (see Section 2.7.2). Whenever one will need to make a journey, she will simply use an app to book her transport service and a car would quickly appear. Driverless ride services might be offered by fleet operators, offering different levels of service: from the basic economy car to luxury sedan car. Under such a system, driverless cars would keep moving from one user to another, simply programmed by digital applications, thus limiting very much the time they spend in parking areas. Therefore, this would allow to attribute to other uses many parts of the urban settlements that at present are allocated to parking lots, leaving room for new urban activities.

Driverless cars might favour transition to ride-sharing services

Notwithstanding the speed of the technological evolution and the important benefits both at the collective and individual levels, widespread diffusion of driverless cars soon after 2025 cannot be taken for granted. It will at least be influenced by the following elements (Nature, 2015):

- trust and acceptability by the population: it will probably require many years before the early majority of users will accept riding in a driverless car;
- cost: driverless cars will be more expensive than today's cars, due to the high technology they need to be equipped with;
- legal issues and responsibility in case of accidents: even though dramatically reduced, in fact, accidents will still take place. In the absence of a human driver, who will bear the responsibility of the accident? Either the car producer, the company elaborating the driving algorithms or even the company producing the maps guiding the car?

Therefore, even though the technology will certainly develop very fast in the next years, it is still unknown by when it will be widespread.

Most important, its consequences on the overall transport demand and energy consumptions and CO_2 emissions are still unclear. In fact, with no drivers to pay and significant fuel economies, the cost of driving might collapse. This might induce a rebound effect, leading to a general increase in transport demand (Plumer, 2013; Brunn and Givoni, 2015). Moreover, if driverless cars can offer quick, efficient transportation, then more people will move to urban suburbs, thus intensifying urban sprawl phenomena and, again, increasing transport demand. And finally, more people will be allowed to use a car on their own (people under 18 years old, elderly, disabled people), instead of relying on public transportation.

Availability of driverless cars might produce an increase in mobility demand

2.3.3 ICT technologies

A key factor affecting mobility demand as a whole could come from the *digital revolution* and progress in *information and communication technologies* (ICT field). ICT technologies might in fact favour both a reduction in the overall mobility demand (transport volume and person-kilometers travelled) and a shift towards public transport and slow mobility. Daily activities and/or working can nowadays theoretically be performed online from any place and at any time of the day or the night. It is still unclear, however, how effective ICTs will be in reducing demand – depending on how life style (in terms of leisure activities and social life) and the working world will change. A recent publication by the Federal Office for Statistics (BFS, 2016) indicates for example that in 2015 21% of the active population (931'000 persons) at least occasionally exploited teleworking opportunities. However, only 2.7% of the active population (120'0000 persons) were involved in systematic teleworking schemes. Such numbers are four times higher than corresponding numbers registered in 2001; however, they are still very limited.

Besides this, rebound effects might happen, since time saved from everyday mobility duties might be filled up with additional free time activities, frequently performed by individual motorized transport: depending on individual situations, the balance between saved and additional mobility demand might therefore be negative.

Diffusion of ICT technologies might also favour a shift towards multi-modal use of the means of transport, and a general reduction in car use. This is favoured by the wide diffusion of smartphones, estimated in 2012 for Switzerland in 43% of the population above 16 years old (Google-ISPSO, 2012). In fact, exploiting ICT technologies and real-time traffic information provided by means of smartphones, public transportation might become more flexible, attractive and competitive: already now, individual mobility services which combine traditional public transport offer (backbone of the mobility system) with ride-sharing services and slow mobility opportunities are being made available. For example, in the Italian speaking part of Switzerland a pilot project testing the Social Car app (www.socialcar-project.eu) is planned for 2017, while a test of the MobAlt app has been developed in late 2015 (see Section 6.4 for a description of the experiment). Diffusion of such systems might be supported and amplified by a closely related socio-economic trend, which has gained momentum in parallel, and thanks to, the digital revolution. We refer to the *sharing economy*, which is explicitly discussed in Section 2.7.1. Possibilities to take advantage of advanced and personalized information systems, combined with shared vehicles and offer of mobility services, might profoundly influence modal split respect to the present situation. Quantitative effects on the modal split due to the diffusion of ICTs and sharing economy are however difficult to predict and require availability of specific datasets.

2.4 Spatial structures (ZHAW)

Spatial structures also play an important role in the development of mobility systems. For instance, urban municipalities usually have a better connection to the regional and national public transport networks and also provide municipal public transport whereas some rural communities largely depend on private motorised transport. In addition, there are reciprocal effects between spatial development of housing/industrial areas, which on one side follow transport infrastructure but due to increasing mobility demand also enforce investments in road or public transportation.

Growth focus around centres

The development of the shares of inhabitants and jobs in the different types of municipalities illustrates ongoing trends of spatial development (Figure 2-26). From the ARE-survey in 1979/85 to the survey in 2004/09 the share of population and employments has decreased in large and middle centres, while both shares increased in their surroundings. This sub- and periurbanisation trends reflect urban sprawl (Federal Office for Spatial Development ARE 2014). A scenario of an ARE forecast suggests a continuation of this trend until 2030 (Figure 2-27). According to that, the surrounding areas of both large and middle centres will account for the highest employment increase until 2030, while the surroundings of middle centres will report the highest population increase.

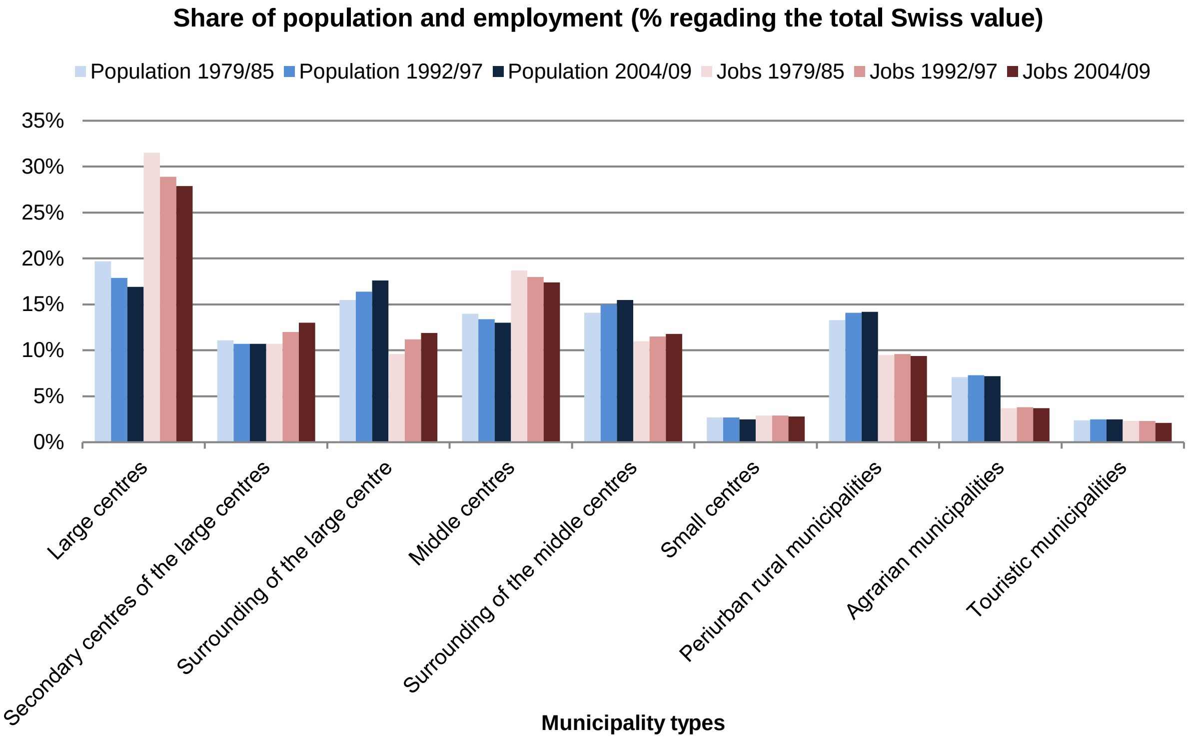


Figure 2-26 Development of population and employment according to municipality type 1979-2009

Data source: Federal Office for Spatial Development ARE 2014

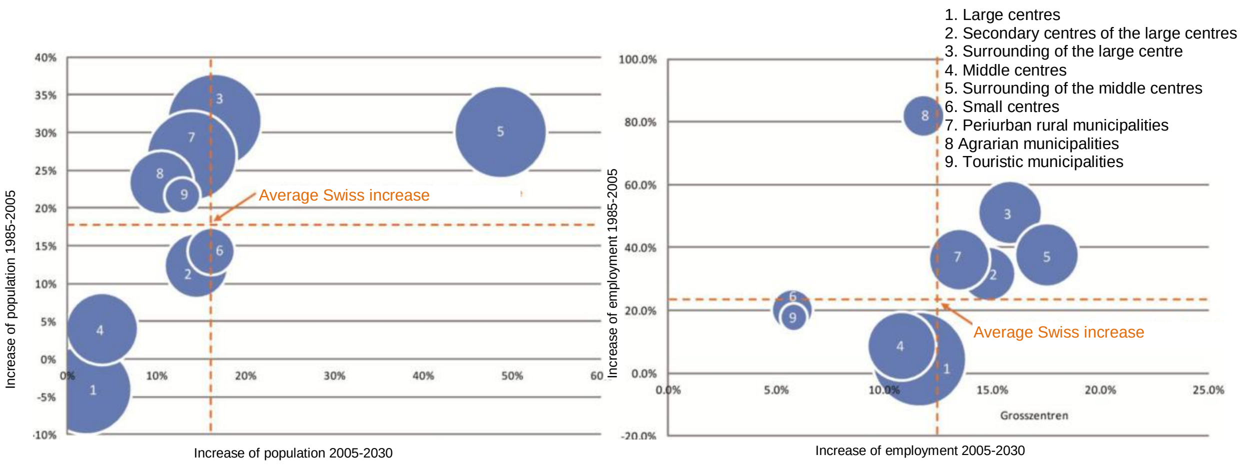


Figure 2-27 Development of population and employment according to municipality type 2005-2030

Source: Federal Office for Spatial Development ARE 2013 (edited)

Lower but growing mobility demand in centres

Growth next to the centres also changes the spatial structure of mobility demand and patterns. The Microcensus on Mobility and Transport (FSO, ARE 2012) confirms this assumption since it shows that people living in central municipalities cover less kilometres compared to those who live in the surroundings (Table 2-3). However, the travel distances in centre municipalities are growing (just as in rural areas) whereas they are decreasing in the surroundings of the cities. Furthermore, the number of trips that an urban individual undertakes is also growing, which after all shows increasing urban mobility demand.

Taking into account the modal share of different municipality types (Figure 2-28), rising population and employment numbers taking place outside centres would not only result in growing mobility demand but also in an increasing use of private motorised transport. Therefore, transformation strategies that specifically target sub- and periurban growth areas need to be developed for the future. Push factors for urban spreading like decreasing quality of life and increasing real estate prices in centres need to be considered in this context.

Table 2-3 Main passenger mobility indicators according to spatial structures 2000-2010

		Centre municipalities	Other agglomeration municipalities	Rural municipalities
Daily travel distances [km]	2000	29.9	37.3	38.9
	2005	31.3	35.5	39.4
	2010	32.1	36.4	41.2
Daily travel time [min]	2000	82	87	86
	2005	88	87	91
	2010	84	83	83
Daily number of trips	2000	5.1	5.0	4.7
	2005	5.4	4.9	4.5
	2010	5.6	5.0	4.6

Data source: Federal Statistical Office FSO 2015b

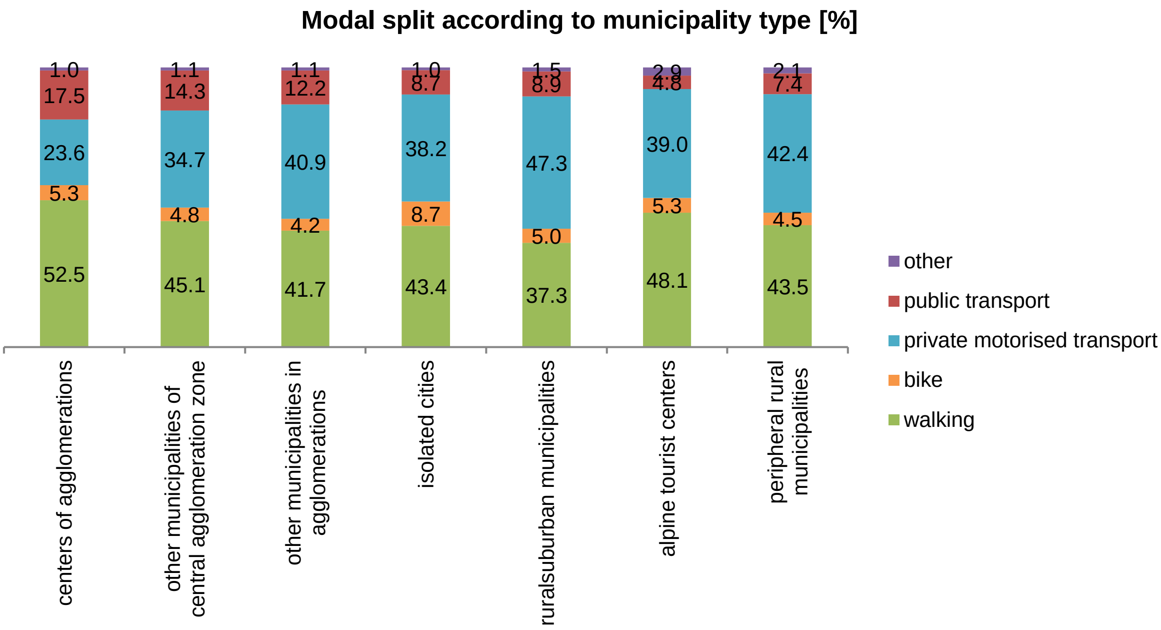


Figure 2-28 Modal share according to number of trip legs by municipality type 2010

Data source: FSO, ARE 2012

2.5 Economic trends (ZHAW)

Economic developments on international, national, regional, local and individual scale influence mobility behaviour and demand, as three examples show: the choice of transport mode is related to the income of a person; economic growth fosters increased transportation of goods; shifts in the labour market induce changes in commuting patterns. These are just few of the many ways in which economic development influences mobility, which will be analysed for Switzerland for the main economic aspects related to mobility demand.

2.5.1 GDP

The development of the Swiss Gross Domestic Product (GDP) index has mostly increased in the last decades (Figure 2-29). For the future, long-term (e.g. State Secreteriat for Economic Affairs SECO 2005) as well as short-term prognoses (e.g. State Secreteriat for Economic Affairs SECO 2015) suggest ongoing expansion. However, long term prognoses that suggest continuous GDP growth (e.g. Surchat 2011) need to be handled with caution because economic crisis can unexpectedly arise changing the forecasted data[10]. Aspects of uncertainty are e.g. development of the CHF exchange rate, related industrial exports and the performance of Swiss financial industry – to name only a few. So far, economic growth has always induced an increasing mobility demand (e.g. Graham & Glaister 2004).

GDP growth = more mobility demand

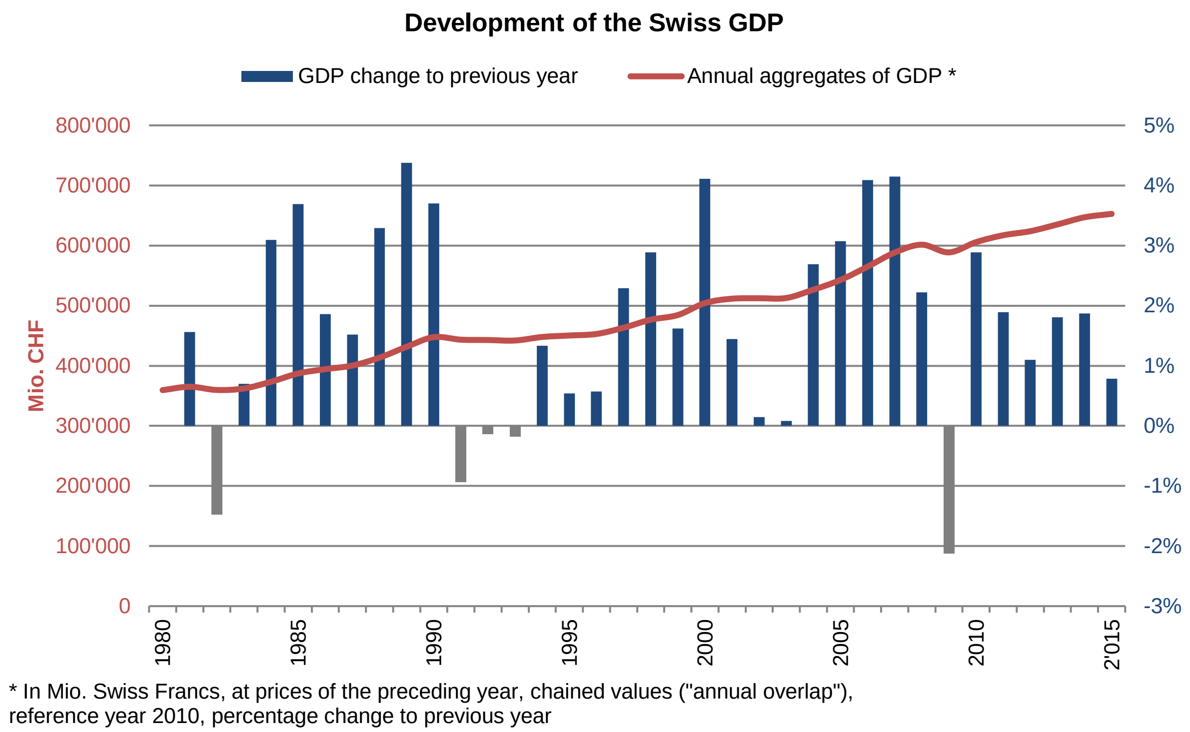


Figure 2-29 Development of the Swiss GDP 1980-2015

Data source: State Secreteriat for Economic Affairs SECO 2016

The general economic growth is also reflected by the regional GDP data, where most of the cantons share the same trends with differences in the absolute values of GDP (Figure 2-30).

[10] See e.g. the financial and economic crisis that resulted in shrinking GDP in 2009 (Figure 2-29, Zürcher 2010).

The GDP per capita is also growing in many cantons but the trend is not that clear in every case and there are also notable differences between the cantons concerning the absolute values (Figure 2-31). This of course has implications on further variables of e.g. incomes, available public money (through taxes) for investments, labour market etc. and therefore also influences regional differences in regional developments (see also chapter 0). Especially increase of lower and medium level incomes are related to increasing mobility demand (e.g. in leisure mobility); thus economic and income development in lower and medium income cantons has the potential to affect mobility demand.

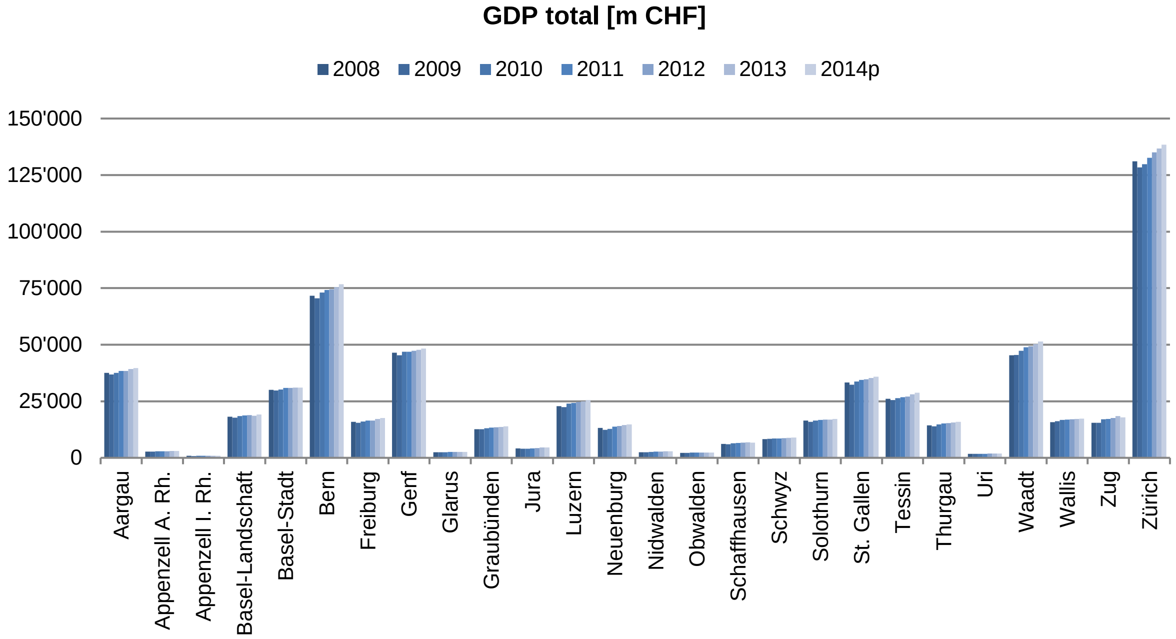


Figure 2-30 GDP in Swiss cantons 2008-2014

Data Source: Federal Statistical Office FSO 2016

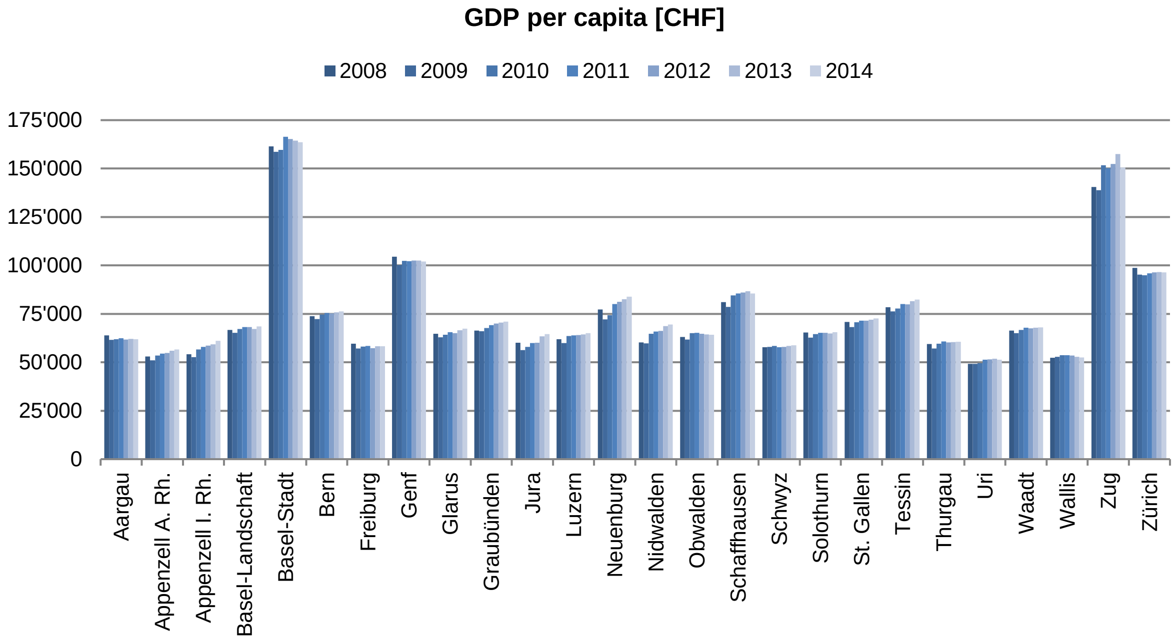


Figure 2-31 GDP per capita in Swiss cantons 2008-2014

Data source: Federal Statistical Office FSO 2016

2.5.2 Labour market

Commuting to work generates traffic, accounting for 24.3% of the total pkm travelled in Switzerland (2010; Federal Office for Spatial Development ARE 2016). Mobility demand is depending on certain aspects such as distance, available means of transport, income (see 2.5.3) or personal preferences. With a growing working population, more mobility demand is induced based on commuting plus leisure activities of the growing population. Furthermore, commuting distances have increased in the last years (see 2.1.3)

Switzerland has experienced a growth of the working population in the last decades and this development is likely to continue in the upcoming years (Figure 2-32). This growth of the number of working people is mainly due to an expected positive migration balance (see 2.6.1), while according to the outlook the labour-force participation rate will decline (Figure 2-32) due to demographic change with increasing numbers of >65 years old persons (see 2.6.2). The forecasted expansion of the total workforce will have respective implications on the mobility system.

Increasing working population raises mobility demand

In the reference scenario[11], an increase of 500'000 full-time workers until 2045 (with a beginning decline afterwards) is projected. Nevertheless, it has to be taken into account that this number is largely depending on the population development, especially on changes in labour migration.

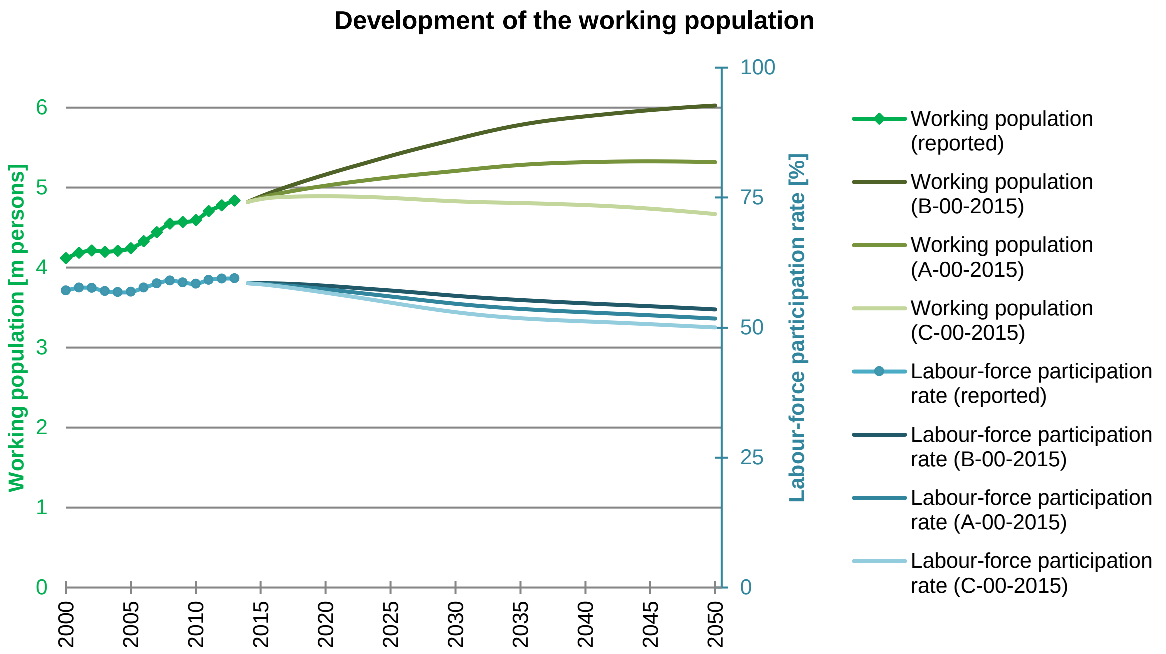


Figure 2-32 Working population and labour-force participation rate 2000-2050

Data Source: Federal Statistical Office FSO 2016

[11] For a brief explanation of the different scenarios, please refer to chapter 0 and to Federal Statistical Office FSO 2015c

2.5.3 Income

Another economic aspect is the income of employees and households. The amount of available money influences the modal choice as e.g. more money provides the freedom to choose the fastest/most suitable/most comfortable/etc. means of transport.

The salaries, determining the household income, differ on regional/cantonal level but has generally grown in the last years (Figure 2-33). According to the prevailing economic trends illustrated in 2.5.1 it can be expected to further increase. However, the changes of income are only a relevant parameter, if they are changes of the actual wages[12]. The actual wages in Switzerland grew by 10.3% between 2000 and 2014 (data for calculation: Federal Statistical Office FSO 2016), which means that Swiss employees on average actually have more money available.

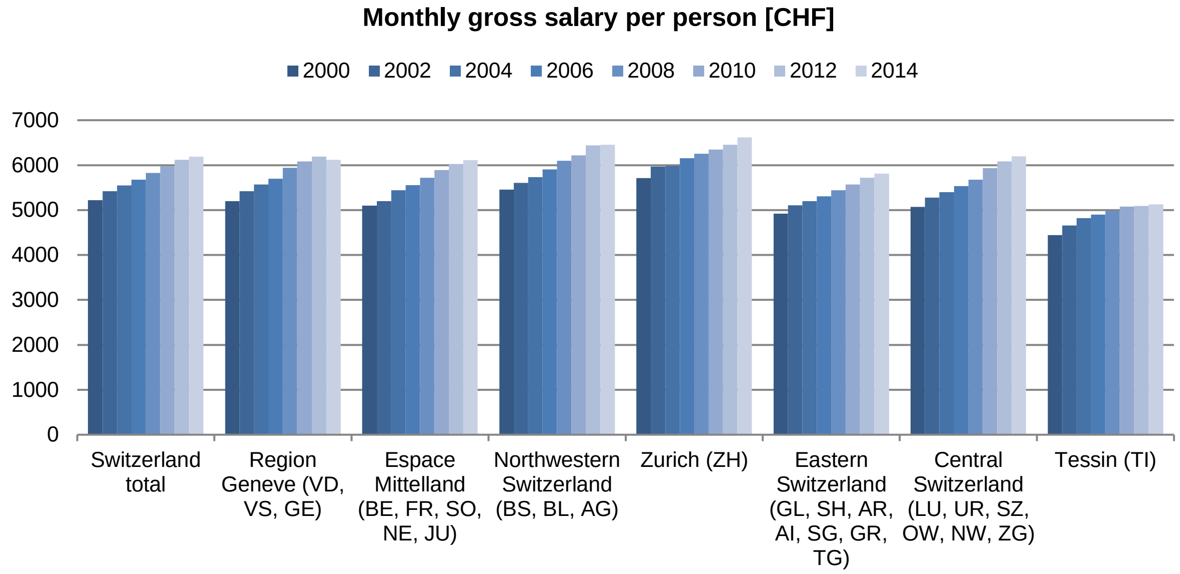


Figure 2-33 Monthly gross salary 2000-2014 (median)

Data source: Federal Statistical Office FSO 2016

A household's income influences mobility behaviour of its members concerning travel time and distance as well as number of trips (Figure 2-34). In general, a higher household income is related to higher mobility demand of the household members. This is especially significant concerning travel distances, where the highest income group (>14.000 CHF) travels 162% more than the lowest (≤2000 CHF) (own calculations based on FSO, ARE 2012). Daily travel times and number of legs per trip are still about ½ higher (54%/48%), whereas the influence of income on whether a person travels at all is much lower (19%) (own calculations based on FSO, ARE 2012). Increasing income allows for more mobility due to money available, which can be used for leisure activities or for travel to work. On the other side, a high salary might come with the need to commute longer to a specific and well-paid job. However, there is no clear tendency on how the mobility behaviour changed over time (data between 2000 and 2010) within income groups.

Increasing incomes produce mobility demand growth through commuting

[12] percentage of increase/decrease of nominal wages minus percentage of increase/decrease of consumer prices

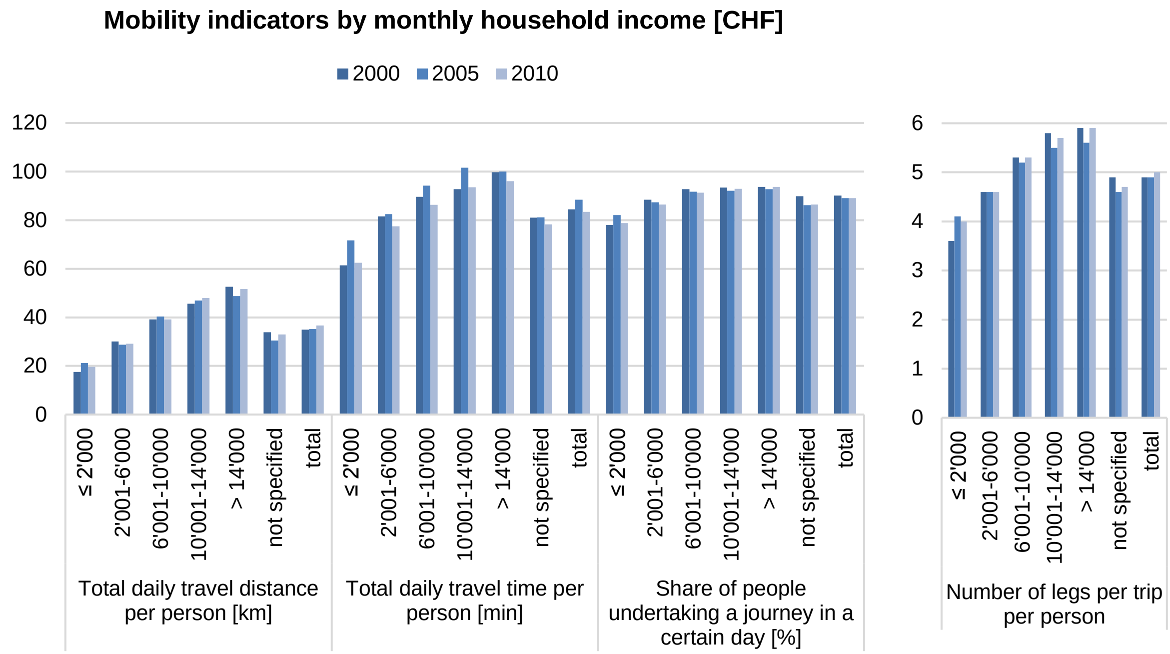


Figure 2-34 Mobility indicators according to income 2000-2010

Data source: FSO, ARE 2012

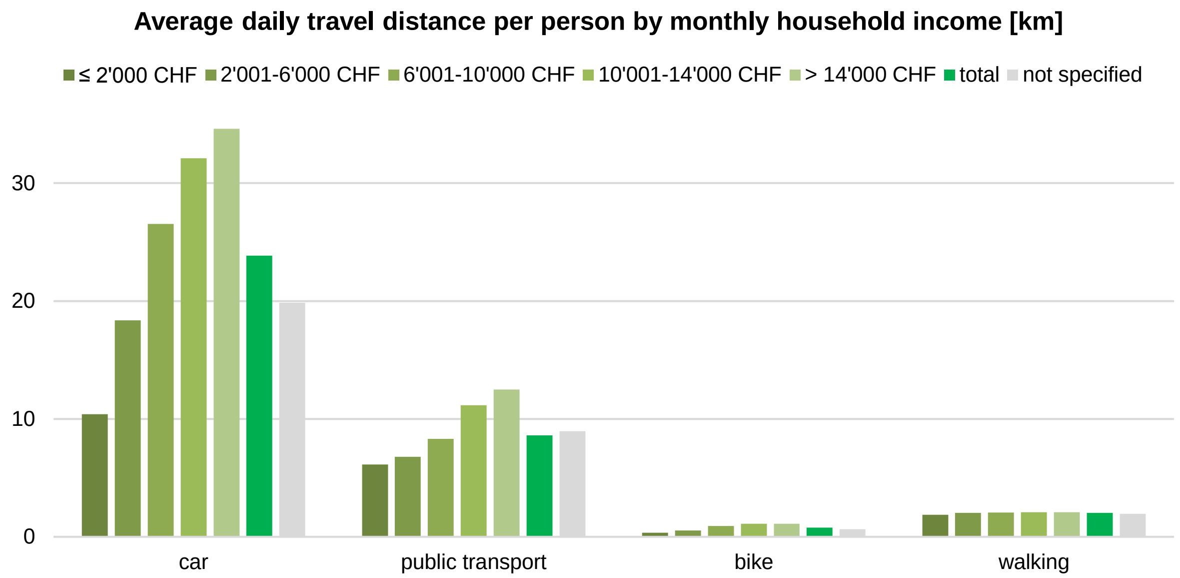


Figure 2-35 Travel distance according to transport mode and income 2010

Data source: FSO, ARE 2012

As travel distance is the indicator, which is determined most by income differences, and it is the main variable characterising demand for physical mobility, it needs to be analysed in more detail concerning the effects on different modes (Figure 2-35, Table 2-4). Whereas the biggest growth in travel-distances by car occurs between the lower income classes, growth is increasing with higher income classes in public transportation[13]. The biggest relative differences for cycling and walking occur between the lower income groups; however, the changes of absolute values are only marginal. After all, especially an increase in income for the lower income classes can be expected to increase the total mobility demand, especially concerning car use.

Table 2-4 Difference of travel distance between income groups according to transport mode (2010)

Income group	Difference of average daily travel distance compared to the next lowest income group							
	Car		Public transport		Bike		Walking	
	km	%	km	%	km	%	km	%
≤ 2'000 CHF	-	-	-	-	-	-	-	-
2'001-6'000 CHF	+8.0	+43.4	+0.6	+9.5	+0.2	+37.1	+0.2	+7.7
6'001-10'000 CHF	+8.2	+30.8	+1.5	+18.4	+0.4	+40.5	+0.0	+1.0
10'001-14'000 CHF	+5.6	+17.4	+2.8	+25.4	+0.2	+17.8	+0.0	+1.2
>14'000 CHF	+2.5	+7.2	+1.3	+10.6	+0.0	+0.1	-0.0	-0.2

Data source: FSO, ARE 2012 (own calculations)

The general trend of higher travel demand associated with higher income can be differentiated by travel purposes (Figure 2-36). The difference between the lowest and the highest income group however are significantly different for different purposes. The travel distances for of shopping do not increase as much with income as e.g. work (commuting; see 2.5.2) or leisure trips. Another difference between the income groups can be identified concerning the ratio of commuting distances and leisure trip distances. Whereas for persons from a household with an income >14’000 CHF the ratio is 1:1.1 in 2010 (i.e. on an average day, they travel the same distances for commuting and for leisure), the same ratio is 1:2.5 for persons from a household with an income ≤2’000 CHF. So even if the total travel distances are much lower for persons that have less money available, their mobility demand for leisure purposes is higher if related to work purposes. However, the general decrease in leisure mobility demand in the last years (see 2.1.3) is shown to occur across all income groups; in contrast, work related mobility seems to be less flexible, as it remains quite stable between 2000, 2005 and 2010.

[13] Note that the growth declines again between the two highest income groups. This might be due to saturation effects.

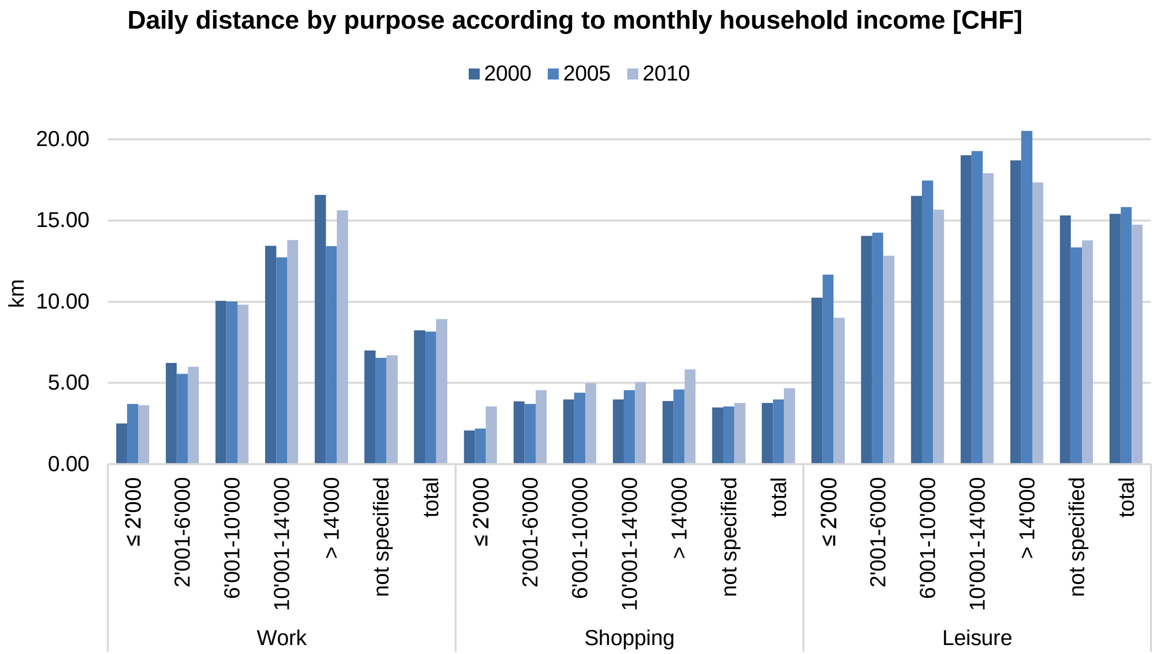


Figure 2-36 Daily travel distances by purpose according to household income 2000-2010

Data source: Federal Statistical Office FSO 2016

To summarize, a higher household income goes along with higher mobility demand in Switzerland.

2.5.4 Fuel price

Another aspect that can influence mobility behaviour – which is interrelated with the economic development – is the fuel price as it has some effect on the usage of motorised individual transport (Graham & Glaister 2004; see also 5.2.2). While increasing fuel prices can induce a reduction of fuel consumption (e.g. through less driving), higher fuel efficiency of engines can partly compensate these effects (Barla et al. 2009, Frondel & Vance 2009). Therefore, it is difficult to actually estimate the implications for Switzerland, especially as other factors (culture, attitudes, etc.) might also influence decisions.

Empirical data from Switzerland (Figure 2-37) show big fluctuations in fuel prices and more or less a stagnation of the consumer price index (CPI[14]). As mobility demand continuously grew, no direct link to the fuel prices can be identified for the last years. Depending on a generally high income-level in Switzerland, the fluctuations of the last years did not show major effects on mobility demand. After all, a more detailed assessment of the implications of fuel prices on mobility behaviour is necessary for the Swiss case, to make distinct statements.

Increasing fuel prices did not affect mobility behaviour

[14] "The CPI measures the change in prices of goods and services which are representative of the private households' consumption in Switzerland. It indicates how much consumers have to increase or to decrease their expenditure to maintain the same volume of consumption, despite the variations in prices." (Federal Statistical Office FSO 2016)

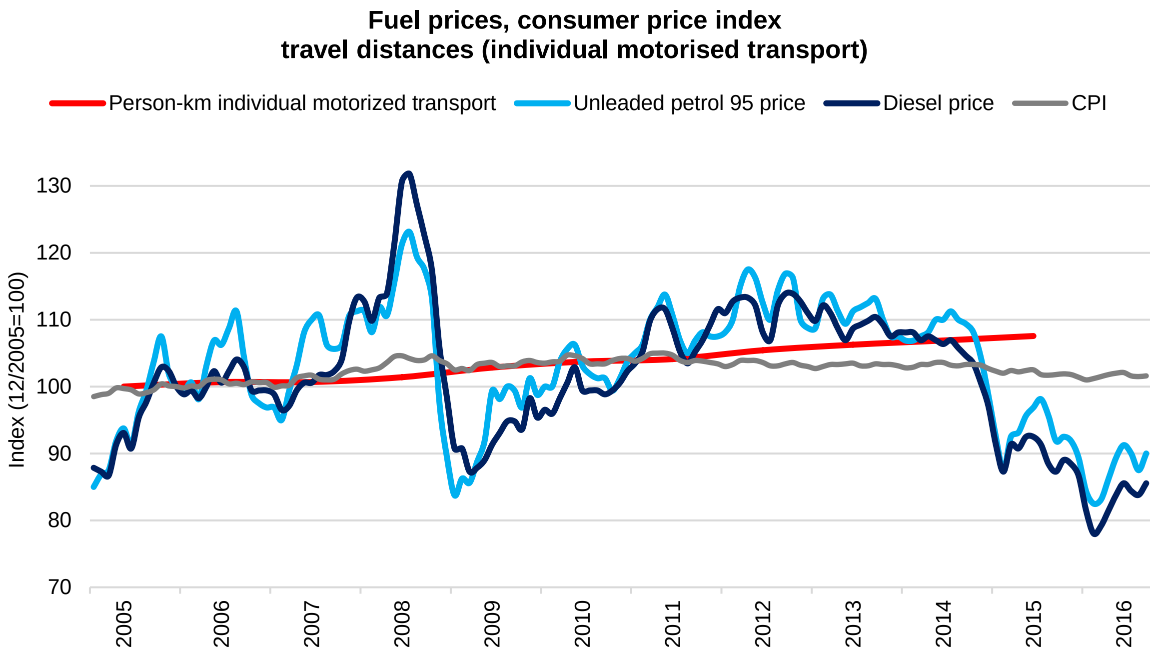


Figure 2-37 Development of fuel prices and Harmonised Consumer Price Index in Switzerland 2005-2014[15]

Data source: Federal Statistical Office FSO 2016; partly own calculations based on Federal Statistical Office FSO 2016

[15] The distances are calculated as distances per person i.e. the graph respects the ongoing population growth in Switzerland. The graph for the total distances covered would therefore show an even bigger increase.

2.6 Demographic trends (ZHAW)

Population growth as well as demographic changes have substantially affected mobility demand in Switzerland in the last years. Between 2000 and 2015 the Swiss population grew by about 1 million people from 7.2 to 8.2 million inhabitants (Federal Statistical Office FSO 2016). Between 1994 and 2010[16] the average daily travel distance of a Swiss person increased by 5.4 km and the average commuting distance increased by 43% (FSO, ARE 2012). Combining these two developments, especially in the context of population numbers that are expected to continue growing, it becomes apparent, that the future population numbers play a very important role in the anticipation of developments of transport systems.

The Swiss Federal Statistical Office developed several scenarios for the future demographic development of Switzerland from 2015 onwards. This report refers to the three basic scenarios, which are a "reference scenario" (A-00-2015) that assumes a continuation of the recent development, a "high scenario" (B-00-2015) that combines hypothesis that facilitate population growth and a "low scenario" (C-00-2015) that inherits hypothesis that constrain population growth (Federal Statistical Office FSO 2015c).

2.6.1 Population development

The natural balance of population depends on the number of births and the number of deaths. Figure 2-38 shows the recent developments and the likely development of these variables. The number of births per year is supposed to reach a more or less constant level whereas the number of deaths per year will strongly rise due to the ageing population (see section 2.6.2). Except for the high scenario the number of deaths will exceed the number of births by the 2030ies or 40ies onwards resulting in a negative natural population balance.

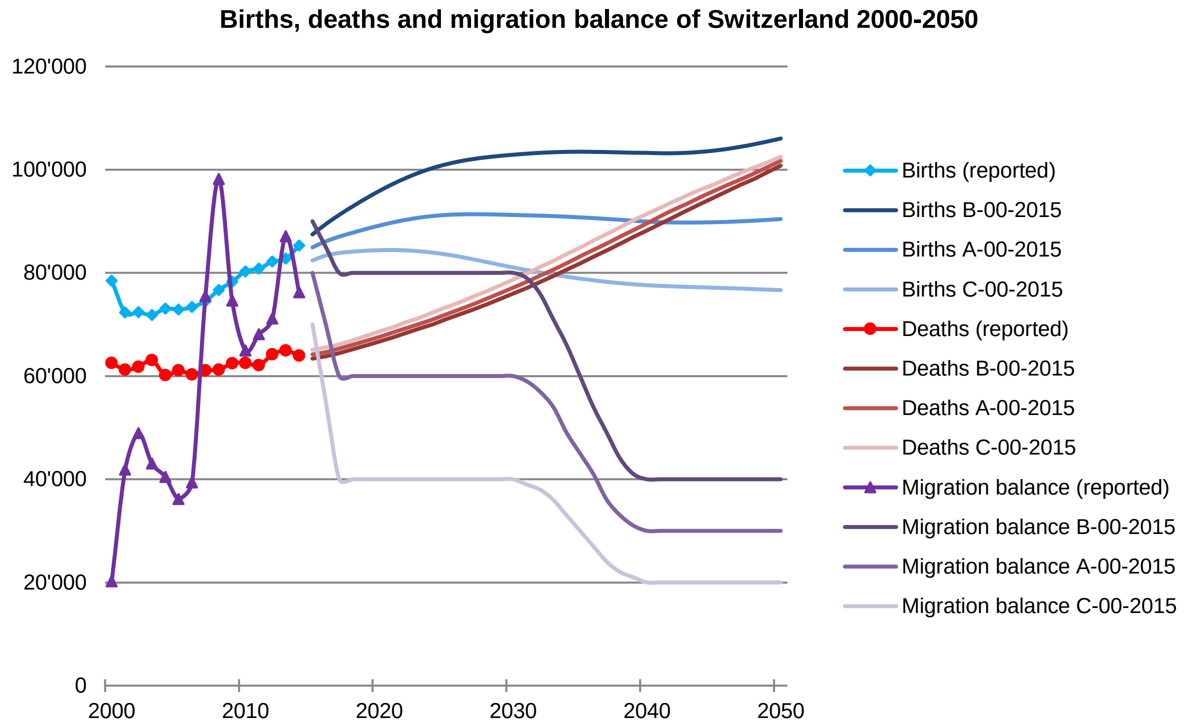


Figure 2-38 Natural population development and migration balance 2000-2050

Data source: Federal Statistical Office FSO 2016

[16] Data from 2010 is the latest available.

Population does not only depend on the natural balance but also on the migration balance (Figure 2-38). Since 1960 migration in Switzerland has reported several up and down phases, but after 1980 it has been mainly positive (Federal Statistical Office FSO 2015c, Federal Statistical Office FSO 2010). This means that almost every year the number of immigrants coming to Switzerland has been higher than the number of emigrants leaving the country. This migration balance is projected to decline[17] but to still remain positive in the future. This means that even in the low population scenario the negative natural balance will be compensated due to migration.

Population 10 Mio. in 2050

So after all, the Swiss population is expected to continue the recent development of continuous growth or at least enter a phase of stability (Figure 2-39). From a starting point of 8.2 million in 2014 a total population between 9.3 (+13%) and 11.3 million (+37%) (reference scenario: 10.3 million, +25%) is likely to be reached in 2050 (Federal Statistical Office FSO 2015c). Even in the low scenario, the population will continue growing until 2040 and only then slowly decline. Considering current mobility patterns, continuing population growth will also increase the mobility demand.

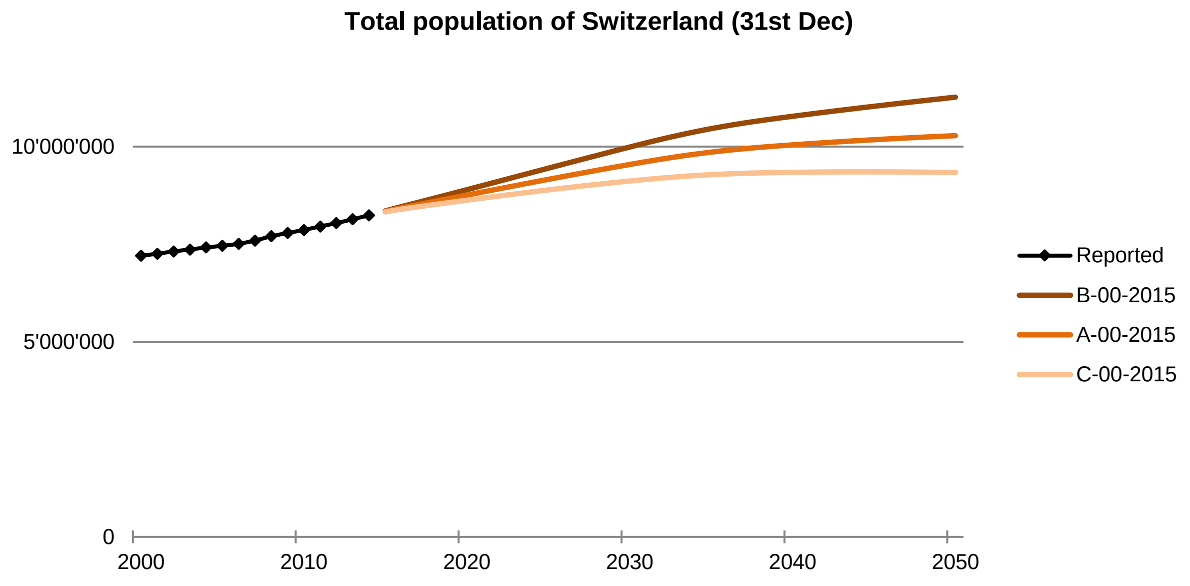


Figure 2-39 Population development in Switzerland 2000-2050

Data source: Federal Statistical Office FSO 2016

[17] Federal Statistical Office FSO 2015c (p. 13) expects a decline in immigration due to a positive economic development in many European countries.

2.6.2 Age structure

Besides population development in general, the demographic structure (age) as well as socio-economic factors, such as e.g. education or labour-force, are relevant for trends in mobility demand.

To give a general trend on the age structure of the population, three main age groups are specifically evaluated: young people under 15 years (children), people between 15 and 64 years (working age population) and people with an age of 65 or older (retired).

Growing group of elderly

Within all three scenarios, demographic ageing of the Swiss population is an obvious trend that has already begun (Figure 2-40). The share of the age group 65 and older is expected to rise by about 10 percentage points until 2050, which in fact means that the absolute number of people who are over 64 years will more than doubled compared to the current situation (see also Figure 2-41).

The decline of the share of under 15 year olds is still a significant trend but has decelerated. This means that especially the share of people between 15 and 64 years will decline (by about 8% until 2050) although if economic and labour market trends will go on as expected (see section 0), this group will still grow in total numbers. This age structure will strongly depend on economic development as well as number and age structure of migrants. Besides this, there is no doubt about the growing population of elderly, which has a higher income and more active lifestyle compared to previous generations. In addition, there will be more very old persons ("Hochbetagte") requiring special assistance for their mobility needs. Thus, a special mobility demand can be expected here.

Old people need more and different mobility

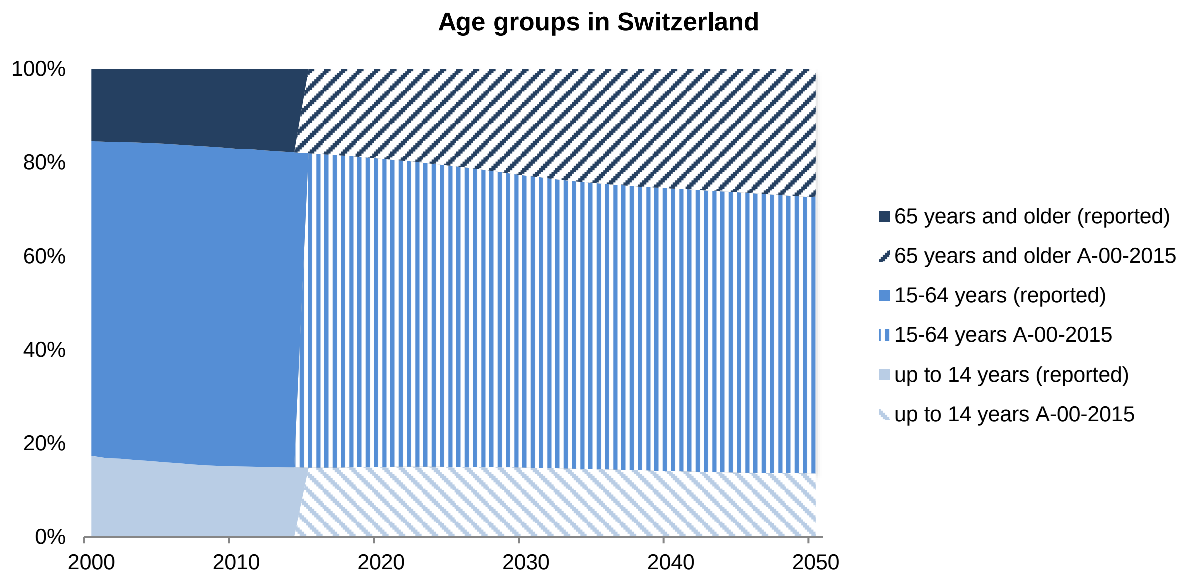


Figure 2-40 Development of age groups in Switzerland 2000-2015

Data source: Federal Statistical Office FSO 2016

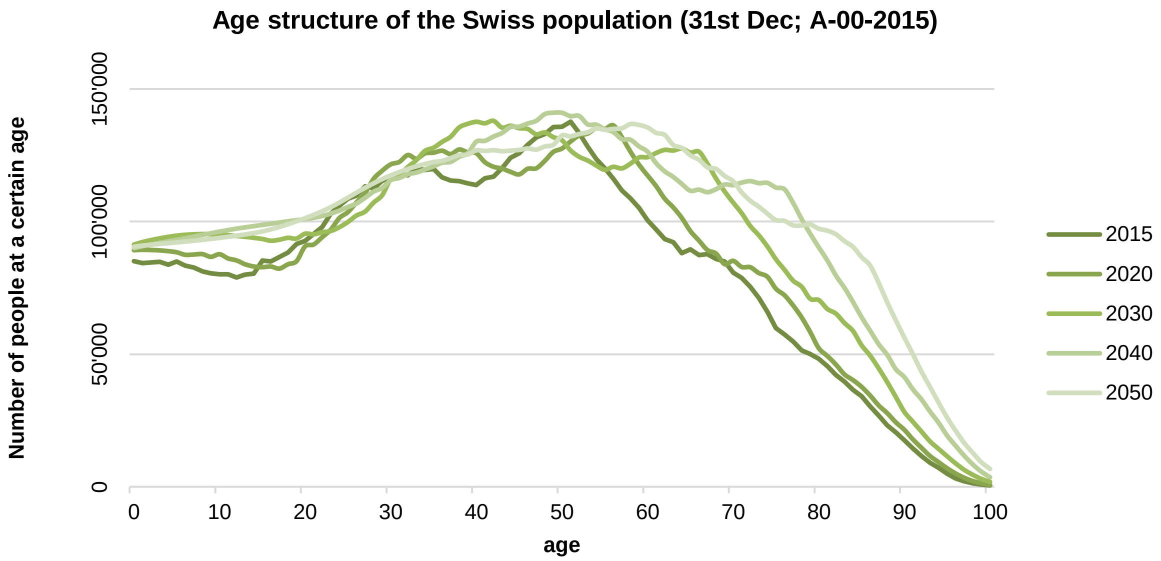


Figure 2-41 Development of the population numbers by age

Data source: Federal Statistical Office FSO 2016

Mobility behaviour is age sensitive and varies between different age groups respectively generations. To exemplify this, the indicators 'driving licence ownership', 'GA travelcard ownership' and 'daily travel distance' are analysed (see Figure 2-42 for the following).

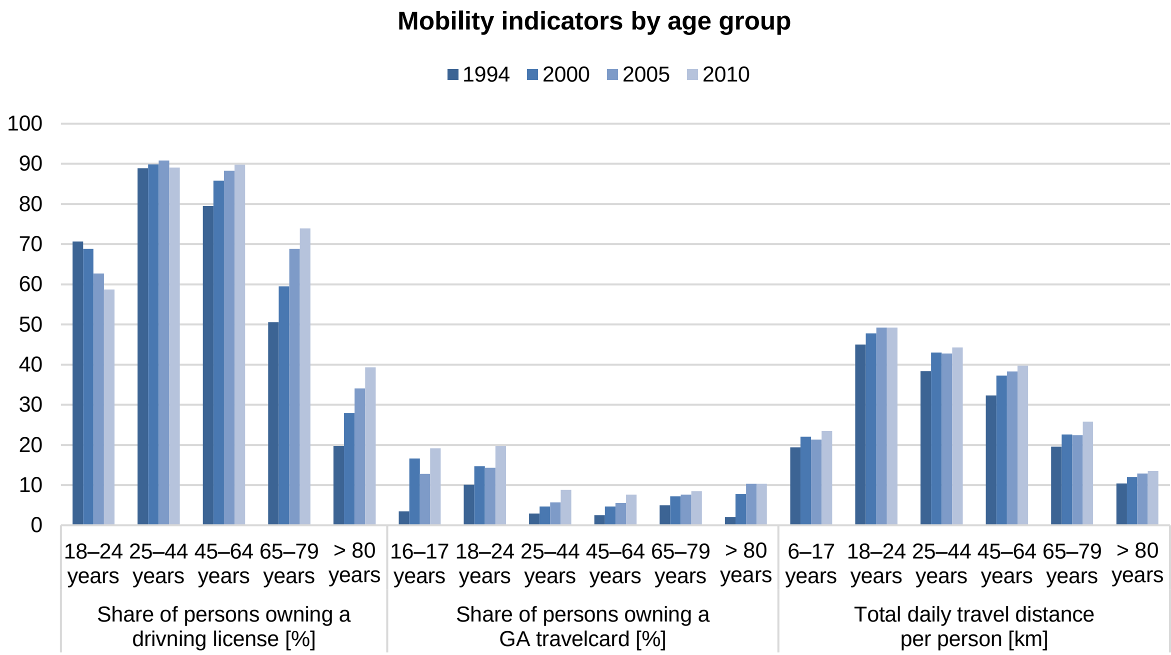


Figure 2-42 Age-depending variables determining mobility patterns 1994-2010

Data source: FSO, ARE 2012

Concerning **driving licence ownership**, two trends can be identified. The first one is an increase in the share of people older than 65 having a driving licence from 50 to 74% (for the 65-79-year olds) between 1994 and 2010. This is due to the fact that a generation is getting older, in which many more people acquired a driving licence than in the generations before. The high level is also increased in the following generation with around 90% of the 25-64-year-olds owning a driving licence. Secondly, however, especially amongst the 18-24-year olds, the share has been constantly dropping, and a decline for the 25-44-year olds between 2005 and 2010. After all, this means that the share of older people owning a driving licence will still increase in the upcoming years. New data of the Microcencus 2015 which will be available in 2017 will be able to either confirm this trend or tell that people only acquire their driving licences at later ages and the trend this is not significant (see also Zimmerli 2013).

More old and less young people with driving licences

Since the 1990s, the share of people **owning a GA travel card** has increased in all age groups[18]. The shares are especially high amongst younger persons, which might be because the prices are significantly lower for them. These high shares (every fifth between 16 and 25 owned a GA travelcard in 2010). Concerning the GA travelcard, the future development is more difficult to anticipate as the pricing is age-dependent, so not necessarily all young persons will continue buying it, as they grow older.

More GA owners

Travel distances increased in all age groups. However, they depend on a person's working life and leisure mobility demand: people between 18 and 64 have longer daily travel distances compared to older or younger age groups. A reduction of the share of this age group also implies a relative decline of their share on the volume of traffic. However, the total population is growing and this does not necessarily mean a reduction of the total volume of traffic, especially as the labour-force participation rate is projected to remain constant (Federal Statistical Office FSO 2015c p. 11). Especially the lowest age group here, the 18-24-year-olds have the highest total mobility demand of all age groups.

Young people travel longer distances

Compared to the other age groups, the population over 64 years will play an increasing role in the mobility of the future (Figure 2-41). As this age group, their mobility and their travel distances were already growing 1994 to 2010, in the future persons 65+ can be expected to account for a rising mobility demand. Furthermore, people accustomed to using cars as primary means of transport (see FSO, ARE 2012 p. 73) are steadily moving into that age group (shown e.g. by the increasing share of driving licence owners in this age group; see Figure 2-42). Thus, the specific requirements of this ageing population and a probably increasing amount of car drivers will shape mobility demand the next years.

Demographically ageing society essential for future mobility

[18] Please note that the variability is much bigger for the age groups 16-17 and 18-24. This however might also be due to the sample sizes that are significantly smaller than for the other age groups.

2.7 Socio-cultural trends (SUPSI)

The availability of new digital technologies and the rise of the new paradigm of the sharing economy, as a reaction to the consumer society, are affecting mobility behaviour in two ways:

- favouring tendencies to use transport services instead of owning cars;
- reducing the number of young people interested in driving cars and in obtaining driving licenses.

Such tendencies are especially acknowledged in the Millennials generation (or Generation Y), that is people born in the last two decades of the 20th century.

2.7.1 Mobility as a service: from owning to using

According to some lifestyle observers (Pyper, 2012; Tuttle, 2012; Godfrey, 2016), attitudes towards cars in industrialized countries would be changing: from a status symbol and key elements around which all the present settlements are built, some of them notice since the last years cars have started being seen from a purely functional point of view, as tools needed to satisfy specific needs to move from point A to point B. Cars would be acknowledged as important because of the service they offer, not as objects per se.

Such new attitudes would be the result of a variety of factors; the most frequently cited in literature are the following ones (Goodwin, 2012; Kuhnimhof, and Zumkeller, 2013; Goodwin and Van Vender, 2013; van Wee, 2015; Circella et al., 2016; Circella, 2017):

- digital technologies allow easy information on the availability of transport service alternative to the private car, offering immediate booking and pay-per-use functionalities, at any time of the day;
- the rising concept of the sharing economy is affecting all economic activities and is giving birth to new collaborative services, in every economic field;
- young adults seem to prefer living in cities, where owning a car is less necessary, since the majority of destinations are accessible by walking, cycling or using the public transportation system;
- the level of environmental awareness of the population is increasing.

Availability of new collaborative mobility services

The combination of those factors would have created a fertile substrate for the development of new mobility services, with totally different players respect to the traditional car producer companies and public transport suppliers: new public-private institutions are in fact offering car-based transport services, either purchasing and managing fleets of vehicles (car-sharing or ride-sharing services such as Mobility, ZipCar or Uber) or also exploiting peer to peer private vehicles owned by common citizens (Sharoo, Uber Pop). Within such a new system, the citizen would be free to pass smoothly from public transport to ride-sharing services, exploiting all the "collaborative mobility" or "co-mobility" (Miller, 2013; Beckmann, 2015) opportunities offered by the transport network. In such a context, peak-car would be taking place and a future where cars will be replaced by "cards" would be approaching (Newmann and Kenworthy, 2015).

Is such a phenomenon already taking place also in Switzerland? Data available at the Swiss level are not able to confirm a trend in the decrease in car ownership. Comparing data of the last four Mobility and Transport Microcensus surveys (OFS and ARE, 2012), covering years between 1994 and 2010, no clear decreasing trends can be seen in the number of households owning no cars (Figure 2-43). However, one must consider that the most updated data available refer to 2010, when the "sharing economy" concepts, ideas and tools had not started yet their rapid growth. To get an insight on the rise of such new cultural trends in Switzerland, one should wait for the next Mobility and Transport Microcensus, which was held in 2015 and whose results will be available in 2017.

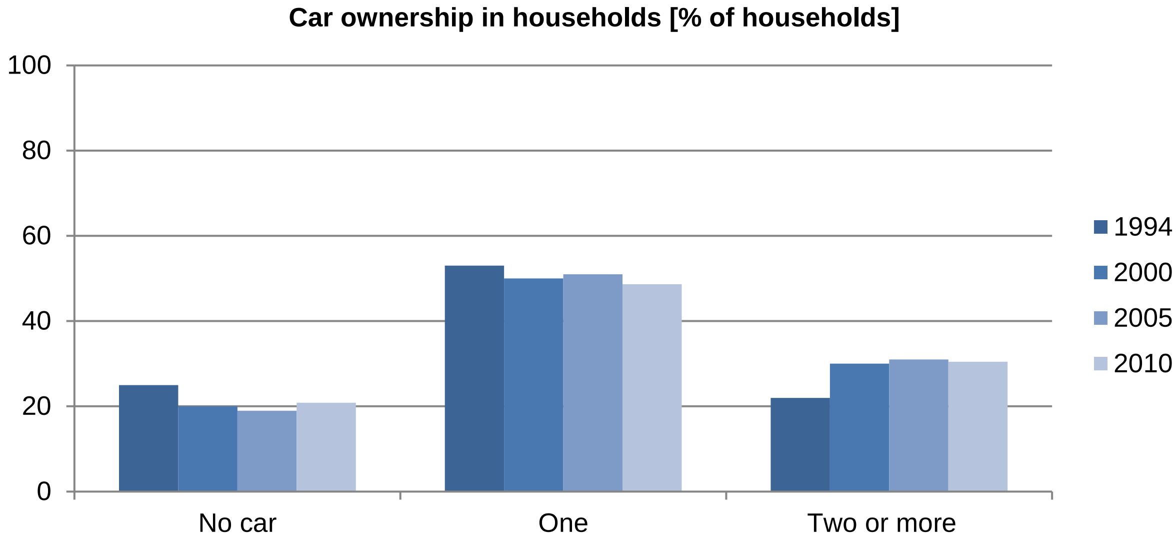


Figure 2-43 Car ownership in Switzerland 19942010

Data source: FSO, ARE 2012

Splitting past trend by linguistic regions highlights that, though starting from very different initial absolute values, the percentage of no car households is following the same general trend throughout Switzerland: between 1994 and 2000 the percentage of no car households decreased in the three linguistic regions, to start increasing again 2005 and 2010.

No clear trend on increasing "no car households"

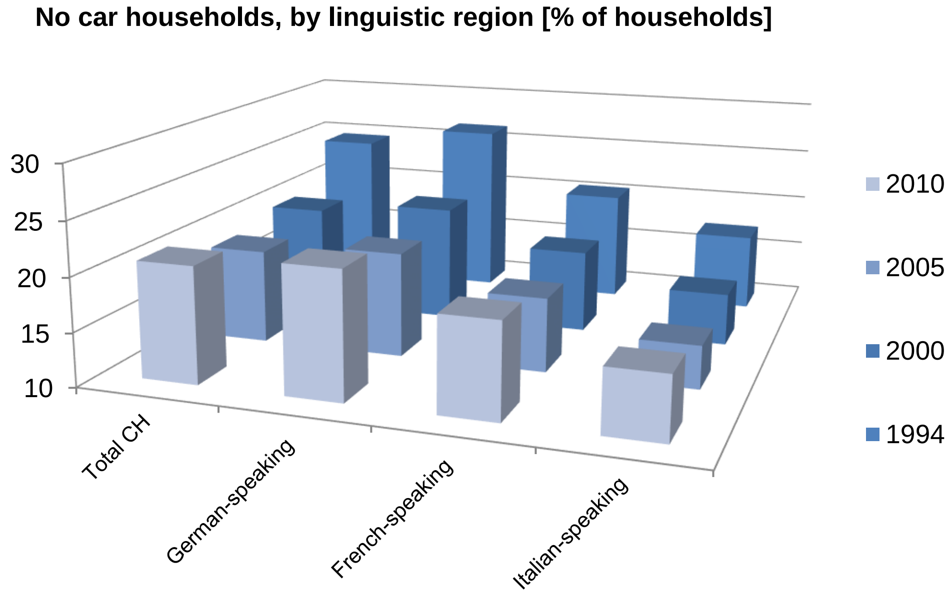


Figure 2-44 No car households in Switzerland in 2010, by language region.

Data source: FSO, ARE 2012

Considering absolute values, the Swiss German-speaking region shows higher values of no car households (and, at the same time, higher numbers of households owning at least one bicycle, as shown in Figure 2-45), which can be related to higher availability of cycling infrastructures and more effective accessibility to public transport services registered in the German-speaking region (section 2.2.2), together with possible cultural differences between such regions.

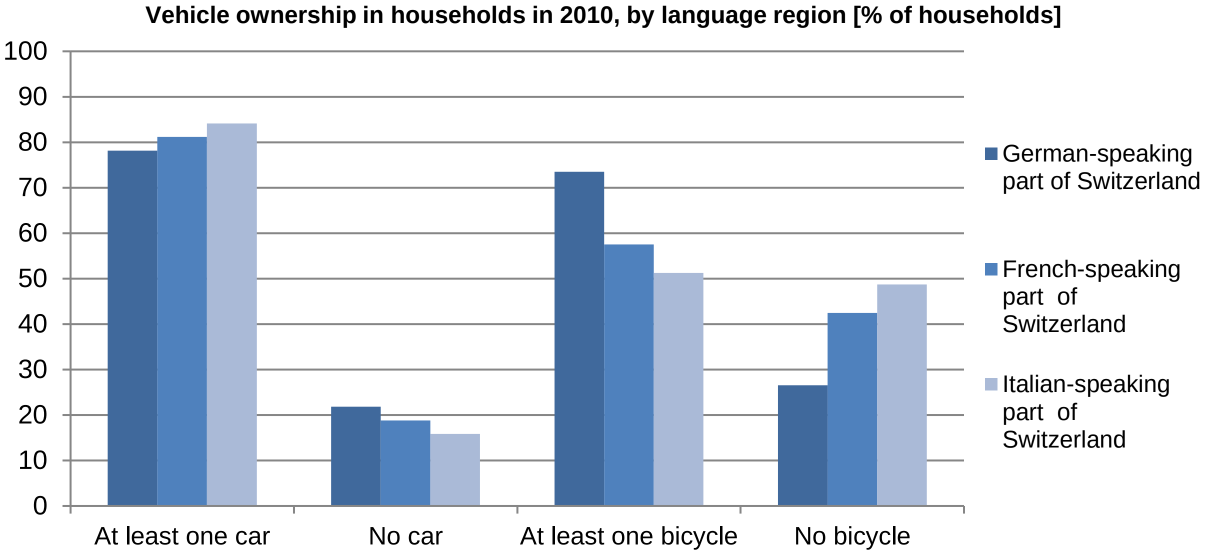


Figure 2-45 Vehicle ownership in Switzerland in 2010, by language region.

Data source: FSO, ARE 2012

Regular increase in the diffusion of "car-sharing services"

Data regarding the evolution in the number of clients of the Mobility car-sharing service (https://www.mobility.ch/), together with the number of Mobility vehicles available for car-sharing (Figure 2-46), show a firm increasing trend. Between 2006 and 2014, the number of Mobility clients has on average increased by 7.1% per year, while the number of vehicles of the Mobility fleet increased by 4.9% per year. Besides the traditional car–sharing system, also an innovative free-floating car-sharing is being experimented in Switzerland, for instance with the "Catch a car" company (https://www.catch-a-car.ch/) in the Basel area. Also, electric versions of car-sharing systems were being tested in a few spots in Switzerland, thus combining technological and societal innovation (Mobility, 2011).

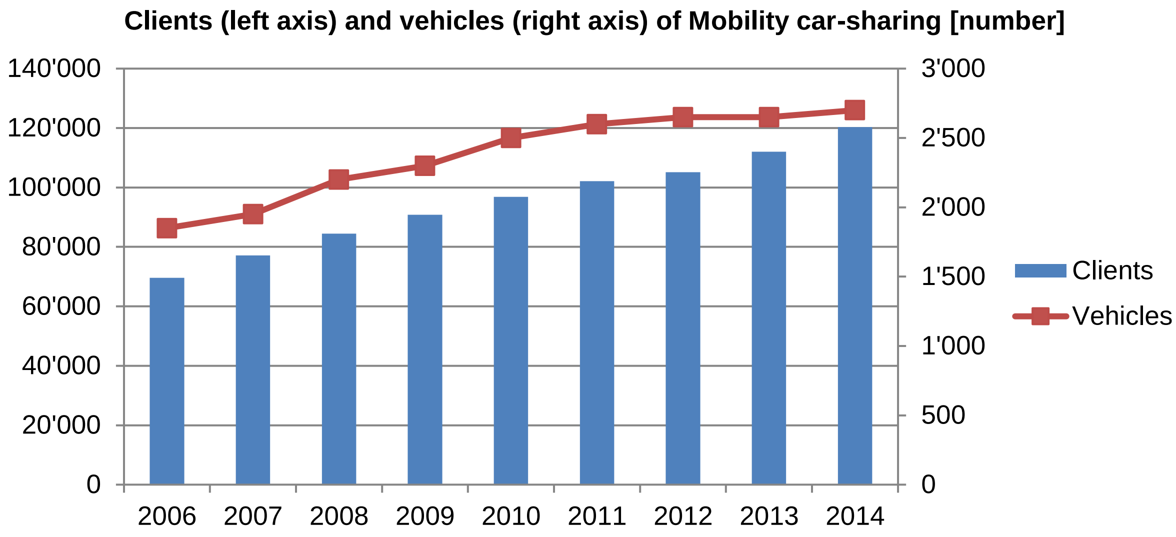


Figure 2-46 Evolution of the number of clients and vehicles of the Mobility car-sharing service

Data source: Mobility car-sharing, 2007- 2015.

Effects on mobility demand produced by the diffusion of car-sharing services were investigated by a survey commissioned by Mobility itself in 2011 (Interface, 2011). The survey stated that

- 70% of the pool of the 1’148 respondents (Mobility private customers) did not own either a car or a motorbike,
- and that but before subscribing to Mobility, only 54% of them was not owning cars or motorbikes.

Also, car-sharing subscribers were using public transport for around 50% of their mobility daily needs (in terms of kilometres), opting for private motorized transport for 40% and for slow mobility for the remaining 10%.

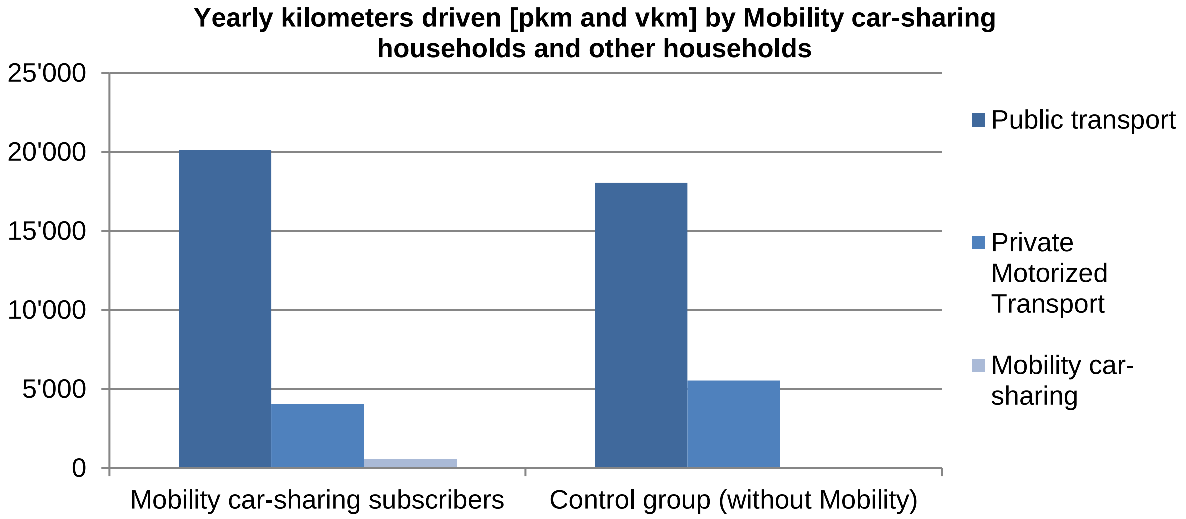


Figure 2-47 Comparison between Mobility car-sharing users and non-Mobility users

(control group based on the 2010 Mobility and Transport Microcensus data). For public transport, data show passenger kilometres (pkm); for private motorized transport and car-sharing, data show vehicle kilometres (vkm)

Data source: Interface, 2011

The general conclusion of the study, based on comparison with the 2010 Mobility and Transport Microcensus data, was that availability of a car-sharing scheme reduces use of the car, especially in favour of public transport. Also, leading to renounce to a private car, car-sharing contributes to free parking areas, which can in turn be re-dedicated to new uses and functions.

Besides the “fleet-based” car-sharing scheme, in the past years novel collaborative options for car-sharing services were also launched, such as for example the peer-to-peer car-sharing system “Sharoo” (https://sharoo.com/), that offers private people the possibility to make their own car available to other people for short period rents.

New ride-sharing and car-pooling services were launched

For the time being, systematic surveys such as the Swiss Mobility and Transport survey do not include figures about the size and diffusion of ride-sharing systems in Switzerland: thorough quantitative surveys are therefore not available for Switzerland; however, they are gaining momentum as well throughout Switzerland, as shown for example by Ciari, et al. (2012) and Ciari and Axhausen (2013). In the recent years, in fact, many car-pooling services were born, both for mobility management in companies and commuting to work and for ride-sharing trips during free time.

The last example of collaborative mobility option available in Switzerland was launched in Zurich at the end of 2014 by the Californian Uber company, with the “Uber Pop” service (https://www.uber.com/it/cities/zurich): common people can turn themselves (and their own car) into drivers, offering riding services under a fee. Even though the Uber Pop service was strongly contested by taxi drivers, up to the point that in some countries it was banned from the market due to incompatibility with the present legislation, in Zurich it is still allowed to operate on the market and it is gaining increasing popularity.

2.7.2 Interest in cars

According to some studies developed in the U.S., younger generations are said to show lower interest in driving cars and in obtaining driving licenses, with respect to the previous generations (Policy Frontier Group and U.S. PIRG Education Fund, 2012; McDonald, 2015). According to such studies, they are in fact said to value digital technology above all, which allows them to re-consider travelling time as a productive time they can use to work, study or have leisure. Smartphones, allowing them immediate access to information, family and friends, would give them the same feeling of freedom that their parents used to get from cars (Thompson & Weissmann, 2012; Rosenthal, 2013; Sakaria & Stehfest, 2013; Lyons, 2015).

In many cases, virtual meetings and social network are said to substitute meetings in person, both for free time and for job reasons, thus reducing the need for a car. And when physically being in a place is not necessary, teleworking and offices for co-working closer at home seem an effective opportunity to reduce travelling distances, often favouring the bicycle. Use of the bicycle in urban areas, in fact, is emerging as a trendy phenomenon, following the bicycle “critical mass” events and spontaneous, bottom-up movements of young citizens (Whitelegg, 1997; Blickstein and Hanson, 2001; Mapes, 2009; Furness, 2010). In such a framework, if longer distances are needed, or for those who do not like cycling, public transport is said to be emerging as a favourite means of transport – at least until driverless cars will not be available: it is appreciated since, thanks to the digital revolution and availability of information and communication technologies (ICTs),one can work in the train while commuting, or simply get relaxed by watching a movie, thus earning at least one hour per day (Weichbrodt et al., 2013). Such a modal shift towards public transport would definitely be advantaged than in the past, since a variety of smartphone applications are able to suggest real time public transport alternatives or to allow to identify, book and pick-up the closest bicycle of the bike-sharing network. Finally, the Millennials generation is said to reduce car use because people prefer to live in central urban areas, where all the commodities are easily reachable at walking distance. Also this is in contrast with the previous generations, who preferred to live in suburban single family homes, where they necessarily needed cars.

> *Younger people own less driving licences, more public transport travelcards*

Data collected by the 2010 Transport and Mobility Microcensus confirm such a tendency also for Switzerland: as already mentioned in Section 2.6.2, even though the total percentage of the population owning a driving license remained constant over time (rather, showing a small increase in the female population, Figure 2-45), the share of younger people (18-24 age range) owning a driving license considerably decreased between 1994 and 2010, moving from 71% to 59% (17% decrease, Figure 2-42). This is however compensated by increases in the older population ranges (age range superior to 45 years old).

Consistently, in the 18-24 years old slice of the population, the 2010 Transport and Mobility Microcensus registers an increase in the use of public transport season tickets and travelcards compared to the previous censuses, in particular as far as the AG season ticket is concerned with (Figure 2-42 and Figure 2-49).

Considering the period between 1994 and 2010, an increase in the percentage of population owning at least one public transport travelcard is registered for all age ranges, except for the one between 65 and 79 years (reflecting higher quality of life for the elderly population and more capability to keep driving a car than in the past) (Figure 2-50). In particular, age ranges regarding the new generations show the largest variations: for the 16-44 age range, a 28% increase is registered. Even though such data do not imply abandon of the car, they show that modes of transport alternative to car are increasingly being taken into consideration among the new generations, reinforcing the hypothesis that new socio-cultural trends are emerging also in Switzerland.

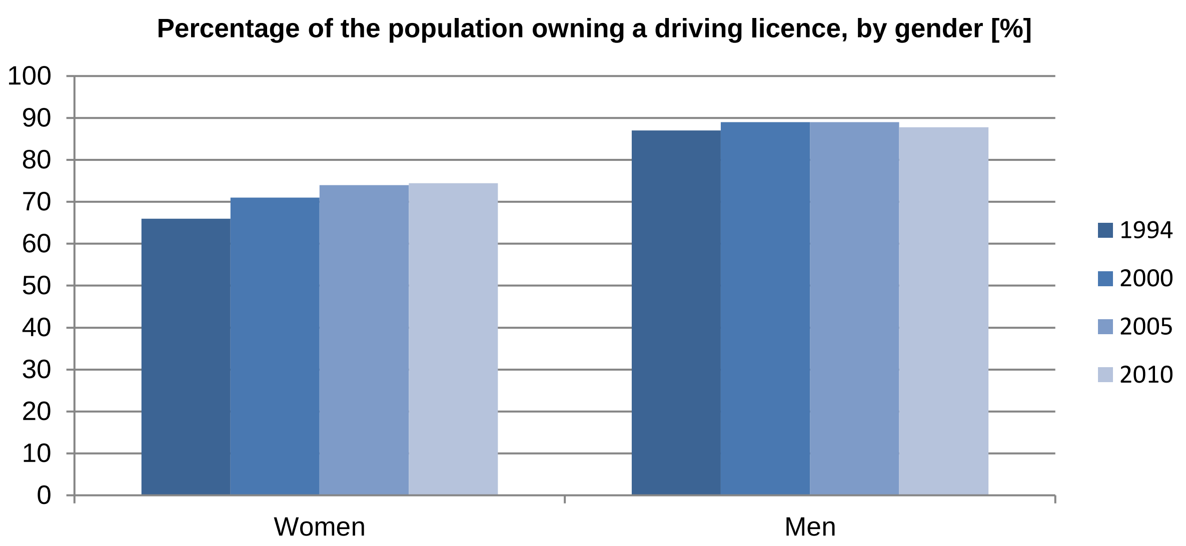
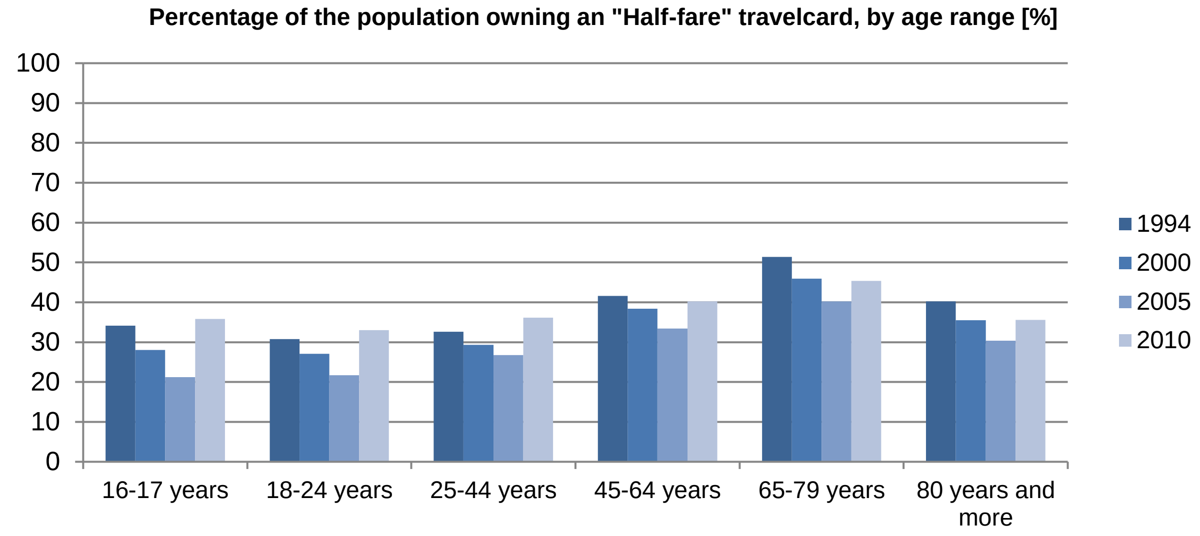


Figure 2-48 Ownership of a driving licence by gender in Switzerland 1994-2010

Source: FSO, ARE 2012

Differences among linguistic regions are however marked: data for 2010 show that public transport season tickets are more used in the German-speaking part of Switzerland, as shown in Figure 2-51. Again, this reflects the better level of accessibility by public transport indicated in Section 2.2.2.

Whether such tendencies will be confirmed when the new generations will get older and will get married and have children, we still do not know: it might in fact be that they are simply delaying car ownership and use (Klein and Smart, 2017). The 2015 Mobility and Transport Microcensus will provide us with key data to get a better understanding of such trends.



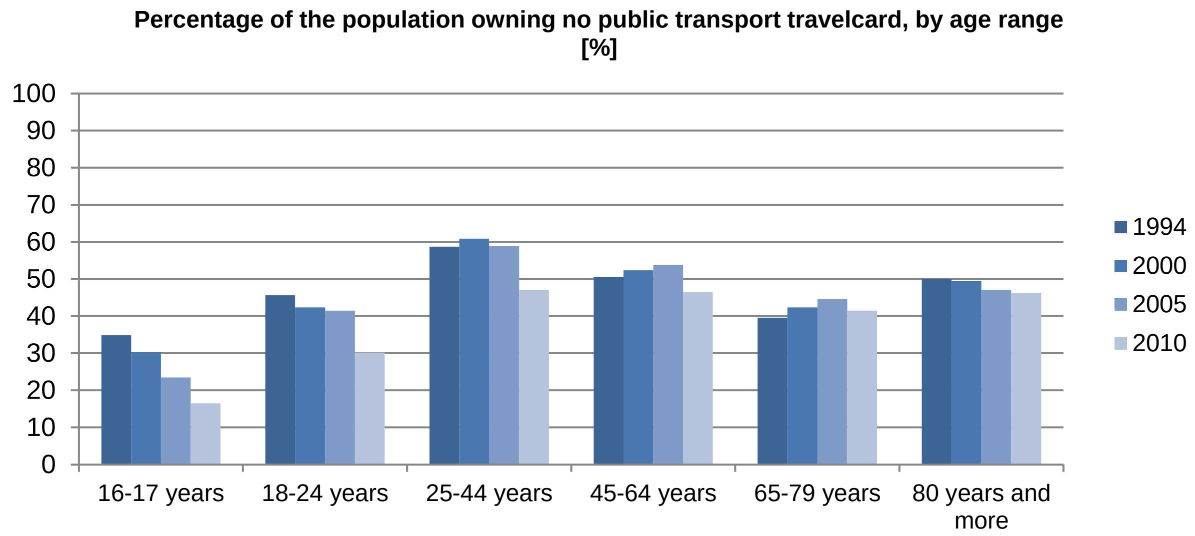


Figure 2-49 Ownership of transport season tickets by age range, in Switzerland 1994-2010

Data source: FSO, ARE 2012

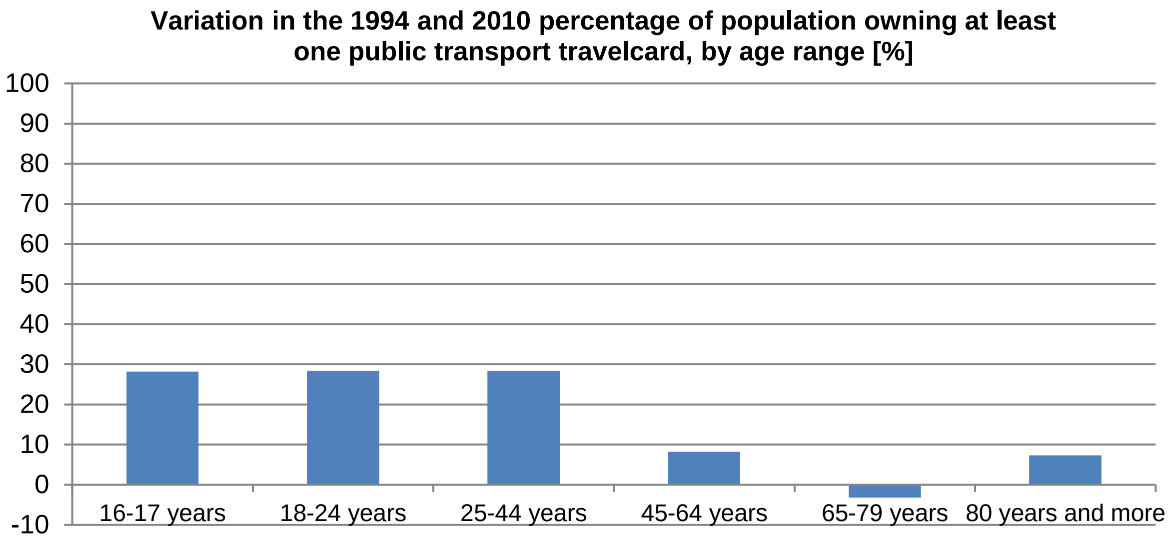


Figure 2-50 Variation in the 1994 and 2010 percentage of population owning at least one public transport travelcard, by age range

Source: FSO, ARE 2012

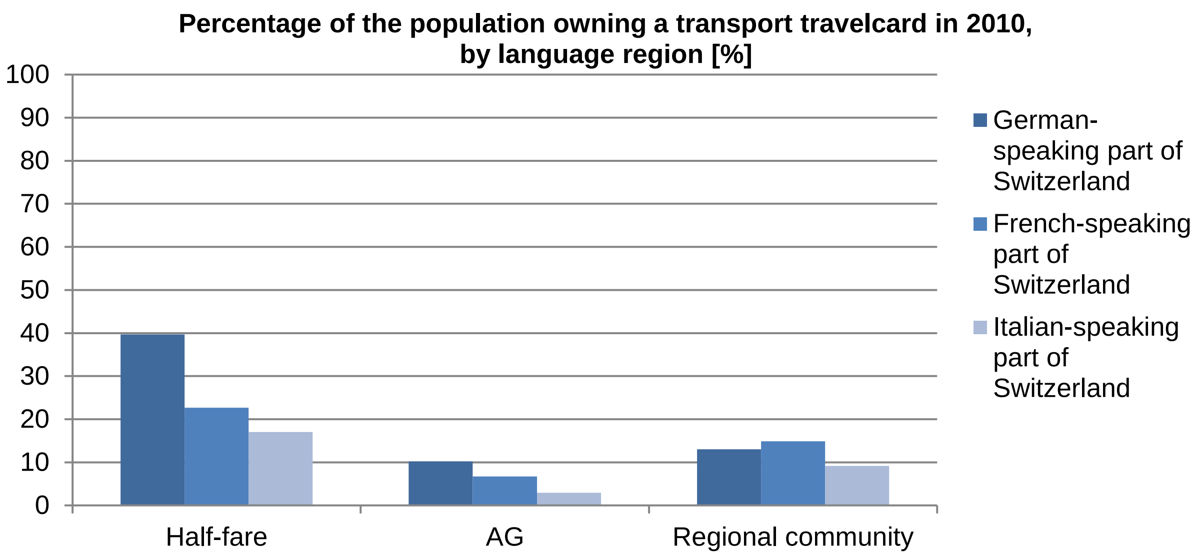


Figure 2-51 Ownership of transport travelcards by language region in Switzerland in 2010

Source: FSO, ARE 2012

2.8 Environmental trends (SUPSI)

Environmental impacts are a consequence of mobility demand and transport activities. However, they influence mobility demand, since they drive the introduction of regulations and incentives. The most relevant impacts produced by transport activities are the following:

- air pollution, produced by fossil fuel powered vehicles in road transport;
- noise, produced by road, railway and aviation transport;
- CO_2 emissions, mainly produced by fossil fuel powered vehicles in road transport.

2.8.1 Air pollution

Air pollution is caused by fossil powered vehicles: cars, buses, trucks, motorbikes. Although air pollution mainly characterises urban areas and might be particularly critical in specific places and periods of the year, especially when long drought periods happen, data at the Swiss level allow us to perform a general trend analysis.

At present main air pollutants due to the transport sector are particulate matters PM10, nitrogen oxides NO_x and Volatile organic compounds VOC (see Figure 2-52). According to the emissions data for 2000, in the past transportation was highly responsible also for emissions of sulphur dioxide SO_2 and ammonia NH_3. Technological progress and regulations for air pollution control (in particular emanated at the European level, starting from Euro 1 in 1993 to Euro 6 in 2014) allowed to limit those emissions, which nowadays are no longer critical. Finally, transport is still responsible for more than 50% of carbon monoxide CO emissions and for around 25% of the emissions of lead Pb, which is monitored as a component of particulate matters. However, overall values of their concentration in the atmosphere are well below the legal thresholds imposed by the Federal Ordinance on air Pollution Control (OAPC): technological progress and wide diffusion of unleaded gasoline made them not critical emissions any longer.

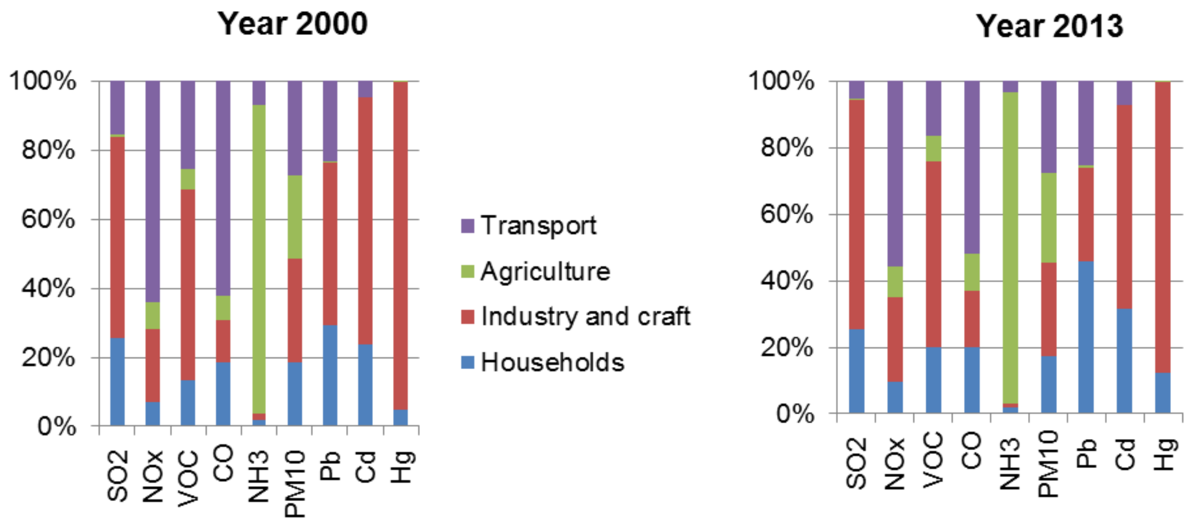


Figure 2-52 Share of air polluting emissions, by economic sector in Switzerland: comparison between year 2000 and year 2013.

Data source: Federal Statistical Office FSO 2015a, indicator T.2.3.3.1

Particulate matters PM10 are among the most critical parameters for air pollution due to the transport sector. In fact, notwithstanding the clearly decreasing trend shown in Figure 2-53, the average yearly PM10 concentrations due to traffic in urban areas were below the legal threshold values only in 2014. To the contrary, however, transport related PM10 emissions show an increase over time (Figure 2-53). This is due to the increase in mobility demand and, especially, to the increase in the number of diesel vehicles (see Figure 2-19 and Figure 2-21). Opposing trends regarding PM10 emissions and PM10 concentrations can be explained with the effect of meteorological conditions: wind, in particular, is very effective in favouring dispersion of PM10 emissions, thus controlling the levels of PM10 concentrations.

PM10 emissions due to transport are increasing

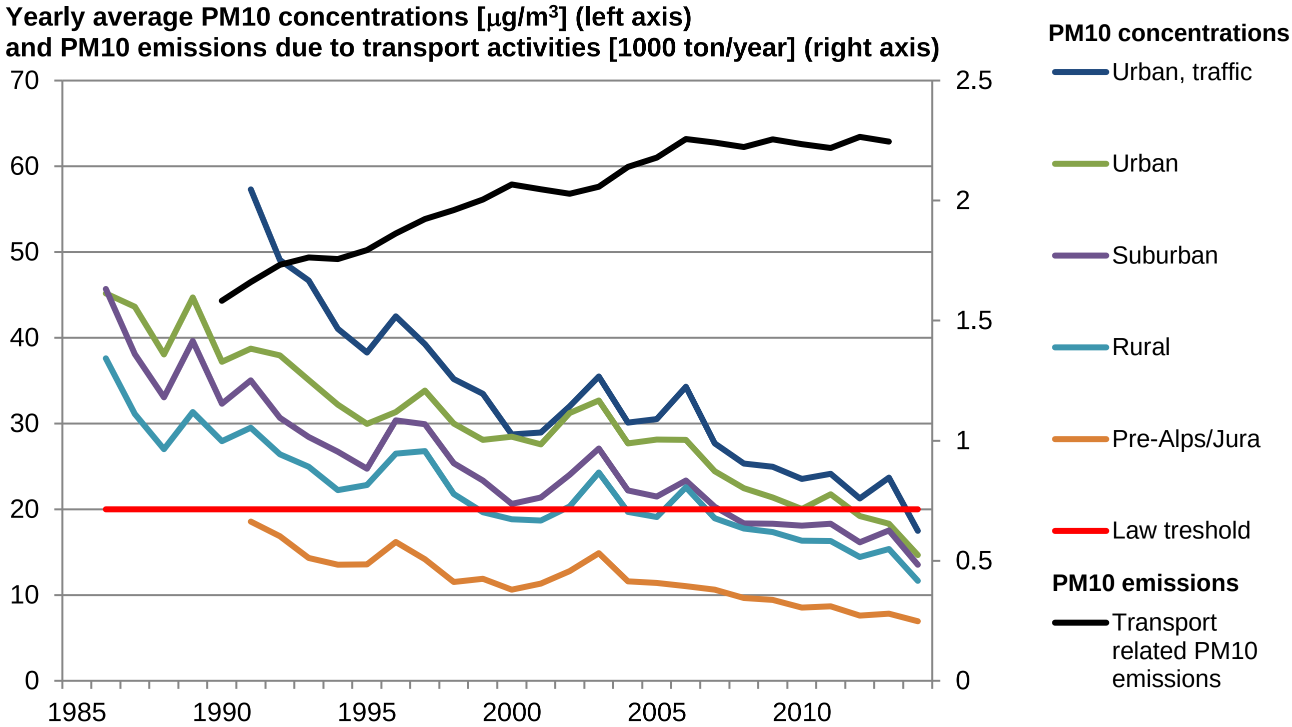


Figure 2-53 Development of yearly average concentration of particulate matters PM10 in the atmosphere for different types of settlement in Switzerland 1986-2014 (left axis) compared to development of transport related yearly emissions of particulate matters PM10 in atmosphere 1990-2013 (right axis).

Data source: Federal Statistical Office FSO 2015a, indicators T 2.3.3.5 and T 2.4.7

Nitrogen dioxide NO_2 is as critical as PM10 as far as the average yearly values of concentration in the atmosphere due to the transport sector. As Figure 2-54 shows, in fact, those values are highly above the legal threshold values allowed. However, historical series concentration data show a general decreasing trend.

NOx urban concentrations attributed to traffic are decreasing, though well above the law threshold

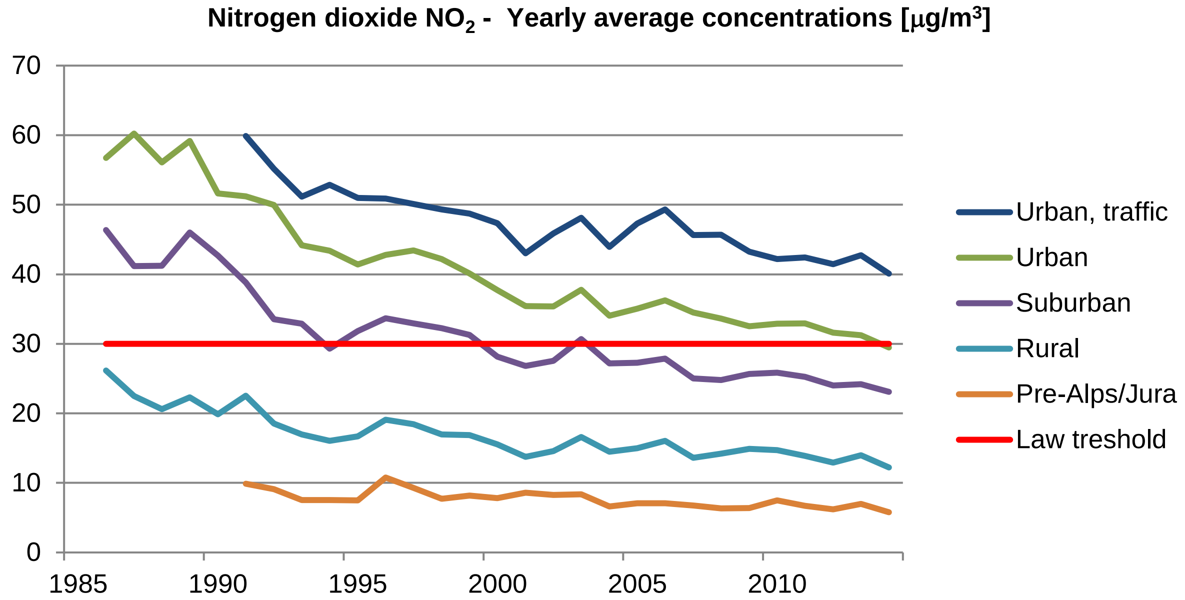


Figure 2-54 Development of yearly average concentration of nitrogen dioxide NO_2 in the atmosphere, for different types of settlement in Switzerland 1986-2014.

Data source: Federal Statistical Office FSO 2015a, indicators T 2.3.3.5

Coherently with concentration data, NOx emissions due to transport activities show a decreasing trend over the years (Figure 2-55). NOx emissions are often associated to Volatile Organic compounds VOC emissions, since, together, they contribute to the creation of high concentrations of tropospheric ozone O3: they are ozone precursor pollutants, which, reacting with solar light, produce ozone. As well as NOx emissions, also VOC emissions showed an impressing decreasing trend in the last 25 years (Figure 2-55).

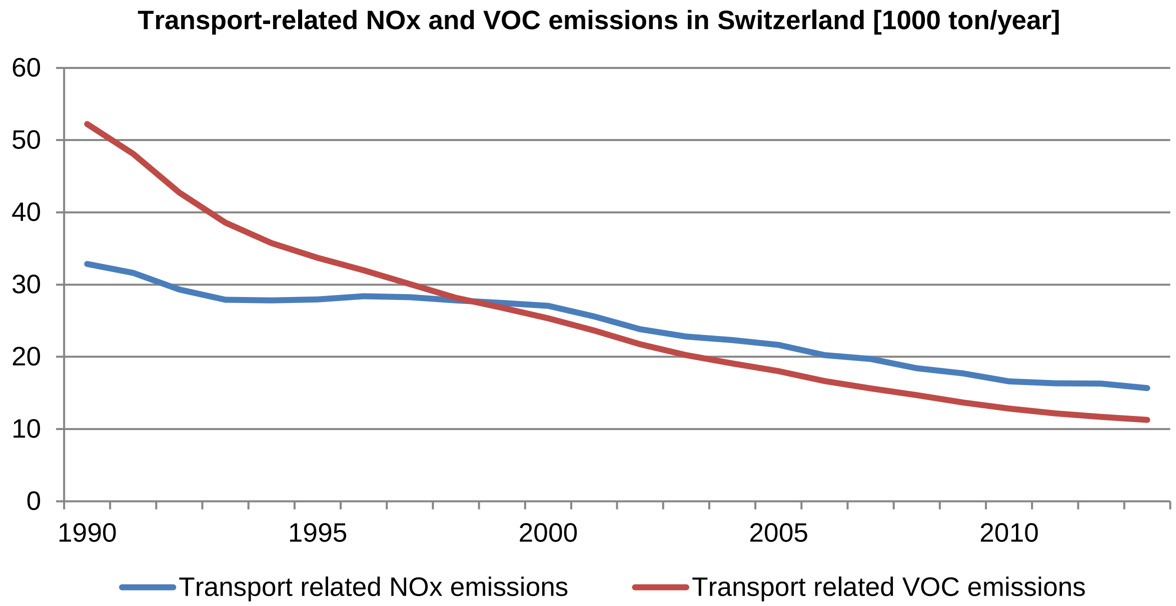


Figure 2-55 Development of transport related yearly emissions of nitrogen oxides NO_x and volatile organic compounds VOC in atmosphere 1990-2013.

Data source: Federal Statistical Office FSO 2015a, indicators T 2.4.7

However, in some specific geographic areas this is not enough to prevent high values for O3 concentrations. Diffusion of ozone and its concentration in the troposphere are strongly affected by meteorological, morphological and urban settlement conditions, and therefore they widely differ across Switzerland. Figure 2-56 shows for example that the Lugano conurbation is much more affected by acute episodes of ozone concentration, well above the legal allowed threshold, than the other urban conurbations in Switzerland. Even though also in Lugano a slight decrease between the late 1980s and today can be seen, acute episodes of ozone concentration are more difficult to be removed. Beyond technology, in fact, they are strongly dependent on the exogenous factors mentioned above.

Site specific acute episodes of high O_3 concentrations still place

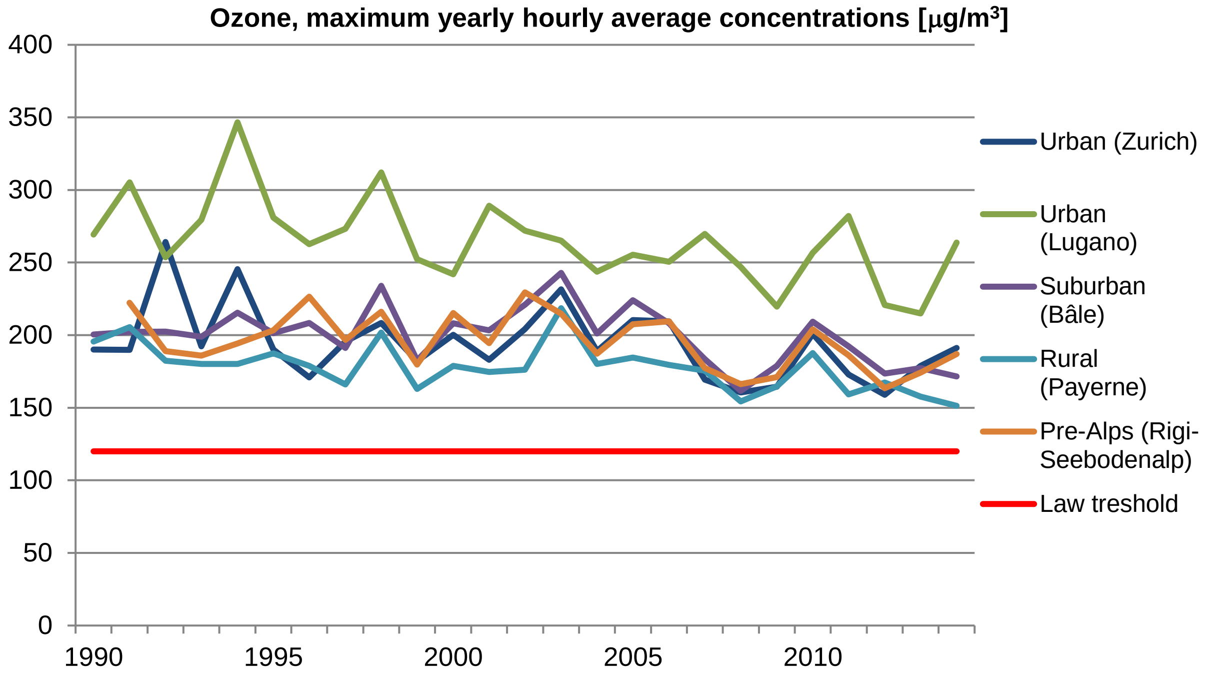


Figure 2-56 Development of the maximum hourly average ozone concentration in the atmosphere registered every year, for different types of settlement in Switzerland 1990-2014.

Data source: Federal Statistical Office FSO 2015a, indicators T 2.3.3.5

Other dangerous air polluting substances related to fossil fuels combustion, such as sulphur dioxides SO_2, are instead less dependent on traffic reasons. As shown in Figure 2-57, in fact, since the early 1990s SO_2 concentrations remained well below the legal threshold values allowed. In particular, traffic-related concentrations in urban areas were around half of the concentrations in urban areas, due to due to other factors (combustion of fossil fuels for residential services, industries, commerce and services). Correspondingly, sulphur dioxide emissions due to the transport sector show a significant decrease (Figure 2-57).

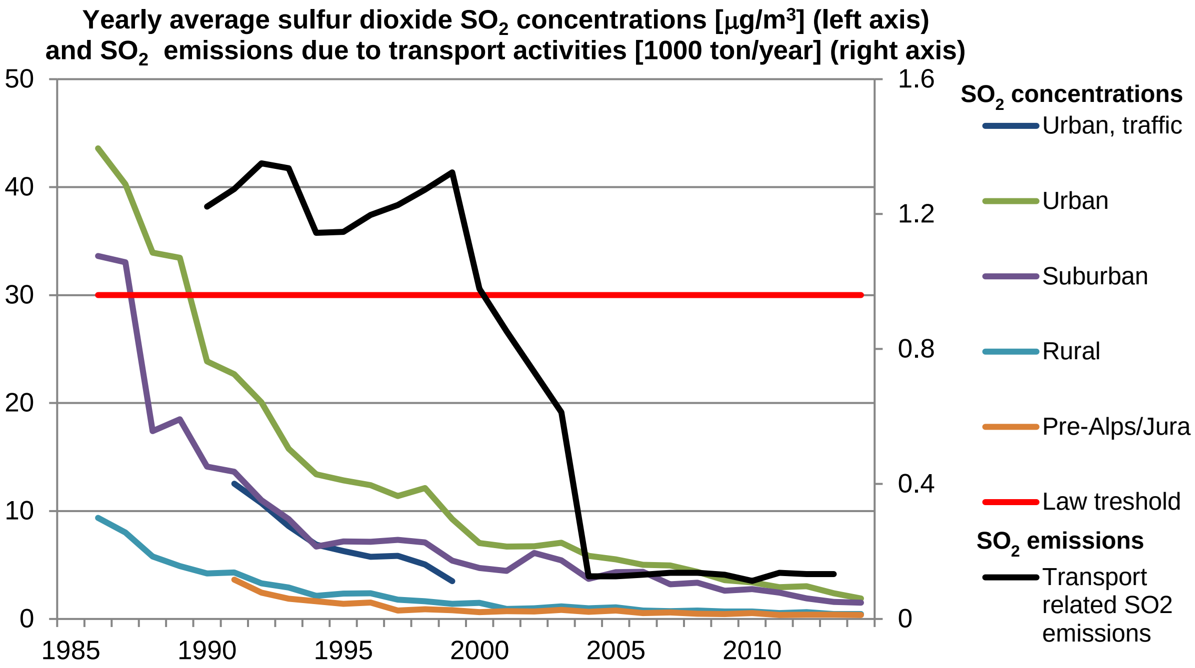


Figure 2-57 Development of yearly average concentration of sulphur dioxide SO_2 in the atmosphere, for different types of settlement in Switzerland (left axis) and transport related SO_2 yearly emissions 1986-2014.

Data source: Federal Statistical Office FSO 2015a, indicators T 2.3.3.5 and T 2.4.7

Finally, as already reported, also transport-related carbon monoxide CO emissions are not critical any longer. Concentration in the atmosphere is well below the legal threshold, up to the point that this pollutant is no longer monitored by the official pollution monitoring network stations in Switzerland.

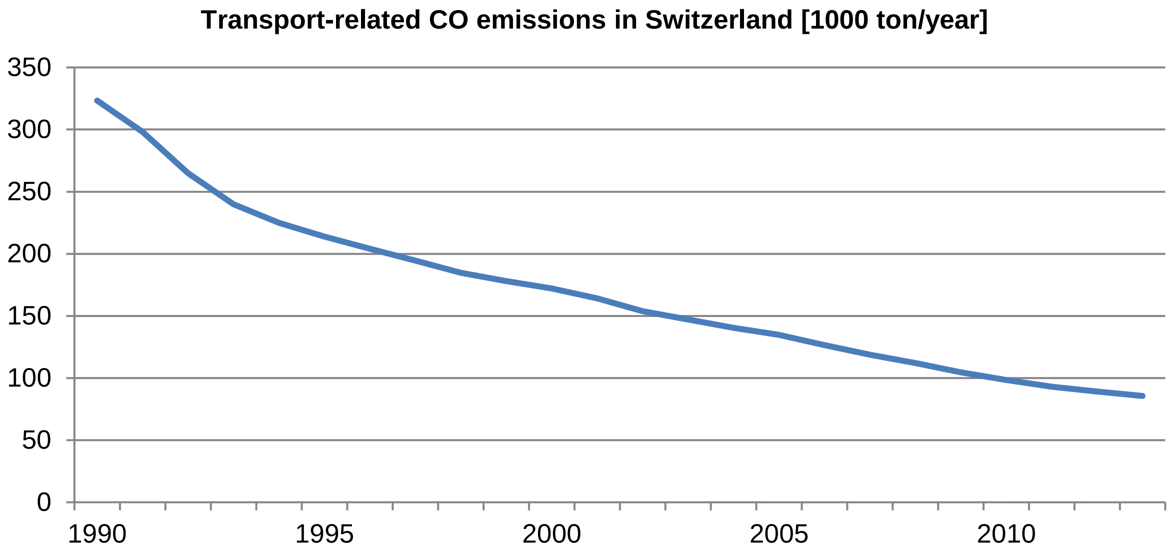


Figure 2-58 Development of transport related yearly emissions of carbon monoxide CO in atmosphere 1990-2013.

Data source: Federal Statistical Office FSO 2015a, indicators T 2.4.7

2.8.2 Noise

Besides air pollution, transport produces noise. According to the SGB 2012 survey on health performed by the Federal office for statistics (BFS, 2013b), in 2012, 26% of the population perceived being affected by transport noise at home. A comparison with historical data collected during previous surveys shows however a decreasing trend: in 2002 and 2007, 32% of the population perceived disturbance by transport noise (Figure 2-59).

Population affected by transport noise is decreasing

Percentage of the Swiss population affected by transport noise at home (road, air and rail traffic) [%]

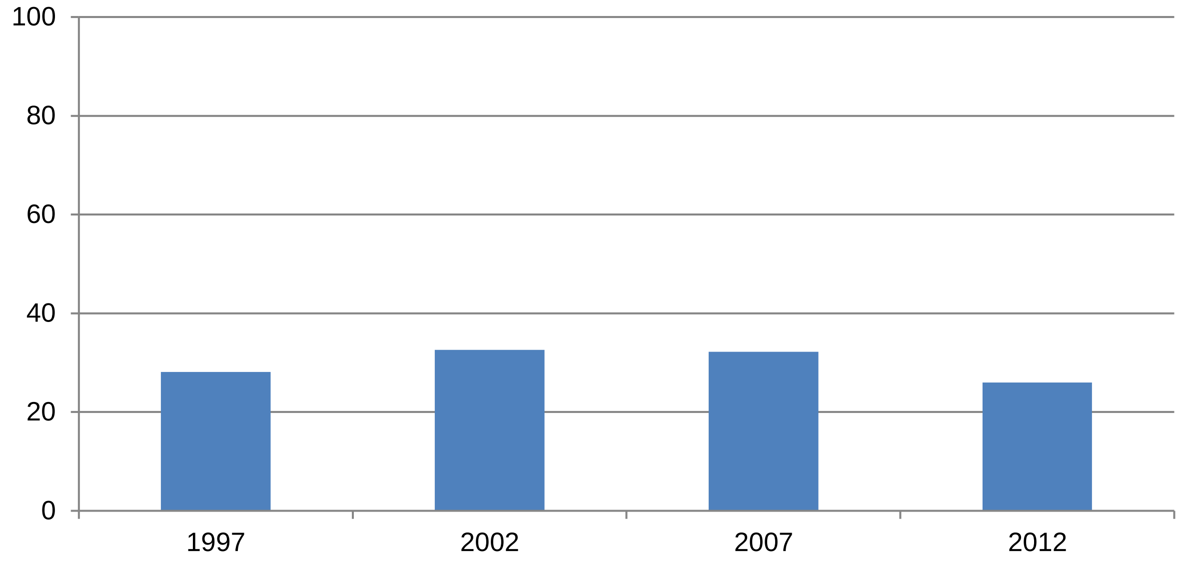


Figure 2-59 Development over time of the percentage of the Swiss population regularly affected by transport noise at home.

Data source: BFS 2014, Swiss survey on health SGB 2012 – Sustainable development indicators MONET

As shown in Figure 2-60 and Figure 2-61, such a disturbance is mainly due to road transport. The phenomenon is, however, decreasing over time. Railway and air traffic are in fact site-specific sources of noise and affect a definitely smaller percentage of the Swiss population.

Data shown in the two figures differ, however not significantly, in the estimate of the percentages of population affected by rail and air traffic noise. This can be explained considering that they are obtained using different estimation models and reflect a different perspective. Figure 2-60 in fact represents data gathered by a survey on the perceptions of the population, while Figure 2-61 is based on noise level data actually tracked by the Swiss national noise monitoring network, with further modelling regarding the identification of the population exposed to harmful or nuisance noise levels, according to the procedures defined in the Swiss noise abatement ordinance (NAO). Comparing the figures, disturb by air and railway transport seems to over-estimate, while estimates of road noise seem basically the same in the two approaches.

Interestingly, according to the most recent noise monitoring campaigns performed at the Swiss level (years 2006 and 2010), road traffic noise does not differ very much between day and night. Finally, as one might expect, transport noise mainly affects population living in urban areas (Figure 2-62).

Noise abatement effects for road transport can be obtained by both technological and demand management measures. The first refer to the diffusion of low-noise road surfaces and quieter tyres, the latter to optimising traffic flows, reducing speed limits and favouring a general reduction in the demand for private motorized transport.

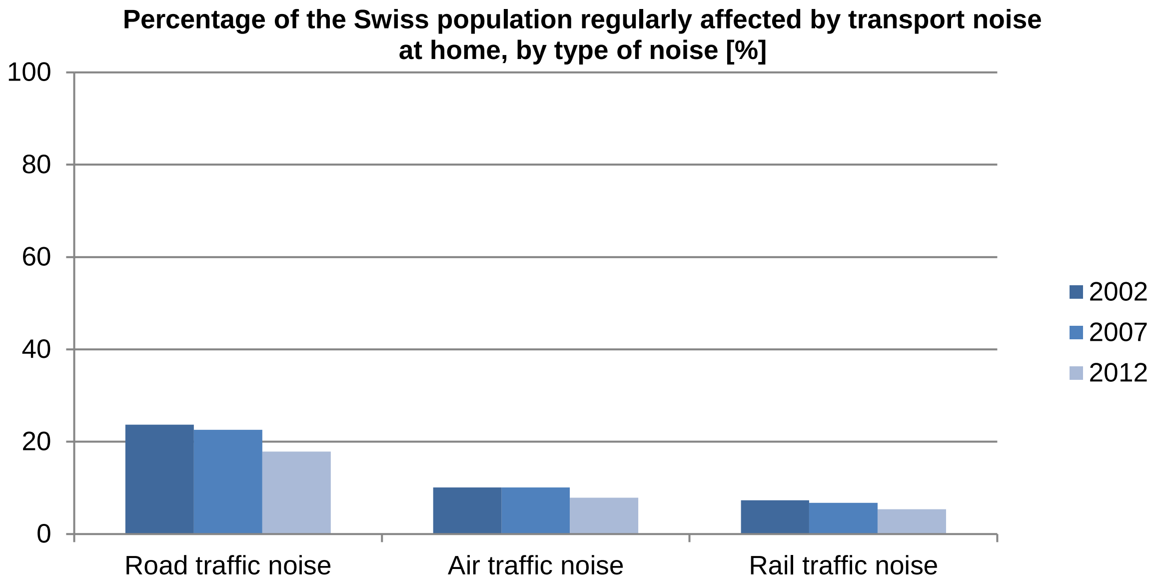


Figure 2-60 Evolution over time of the percentage of the Swiss population regularly affected by transport noise, by type of noise.

Data source: BFS 2014, Swiss survey on health ESS 2014 indicator SUMWE01

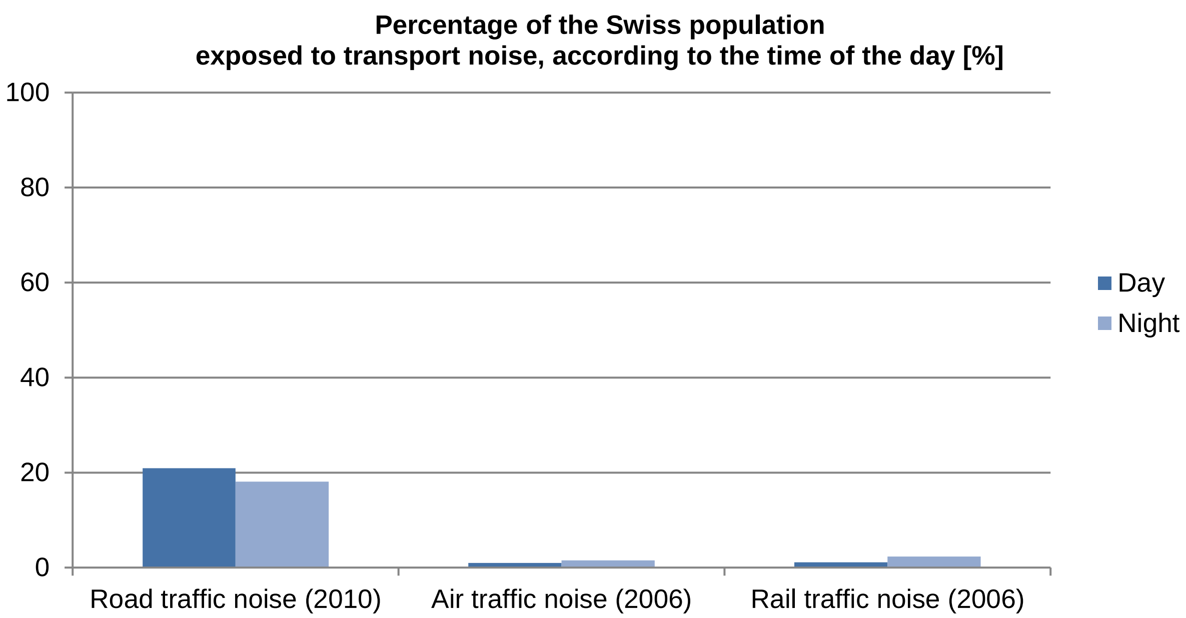


Figure 2-61 Exposition of the population to noise produced by transport activities in Switzerland.

Data source: Federal Office for the Environment FOEN 2015, sonBASE

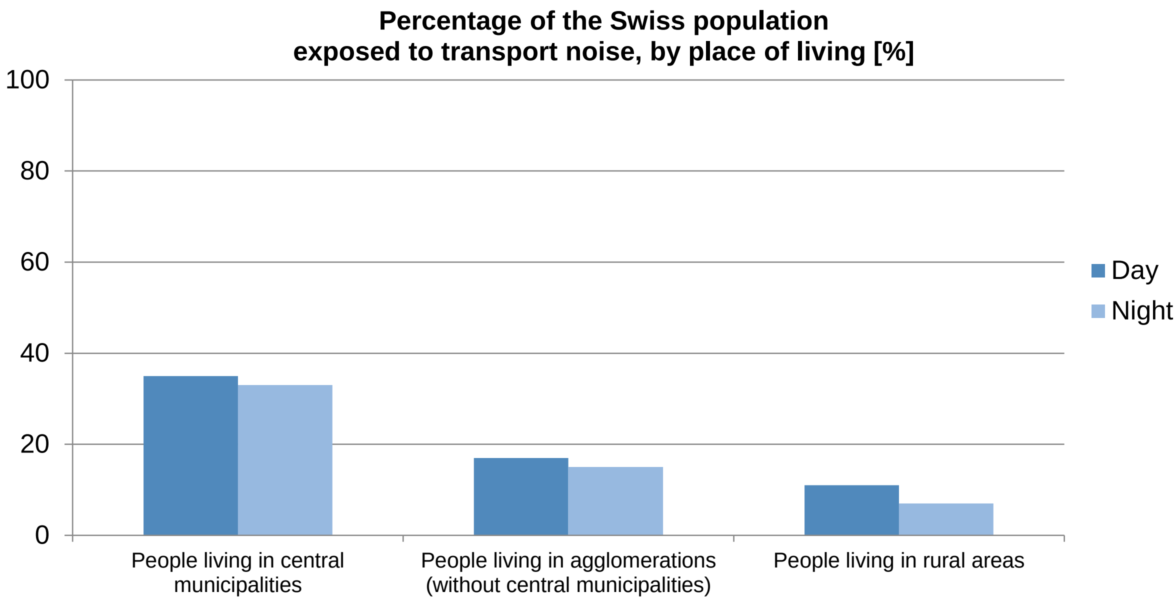


Figure 2-62 Exposition of the population to noise produced by transport activities in Switzerland, according to the place of living (central municipalities, urban agglomerations, rural areas).

Data source: Federal Office for the Environment FOEN 2015, sonBASE

2.8.3 CO_2 and greenhouse gases emissions

Estimates of CO_2 emissions shown in this section are performed according to the Kyoto Protocol emissions inventory and the Swiss CO_2 law; they do not consider CO_2 emissions produced by international aviation and navigation. They are obtained by multiplying the estimates of energy consumptions (as monitored by the Federal office for energy) with the corresponding CO_2 emission factors. As shown in Figure 2-63, in Switzerland transport activities account for around 30% of the CO_2 equivalent emissions, a value that keeps quite stable over time. However, considering the absolute values of transport-related CO_2 equivalent emissions, an increasing trend over time.

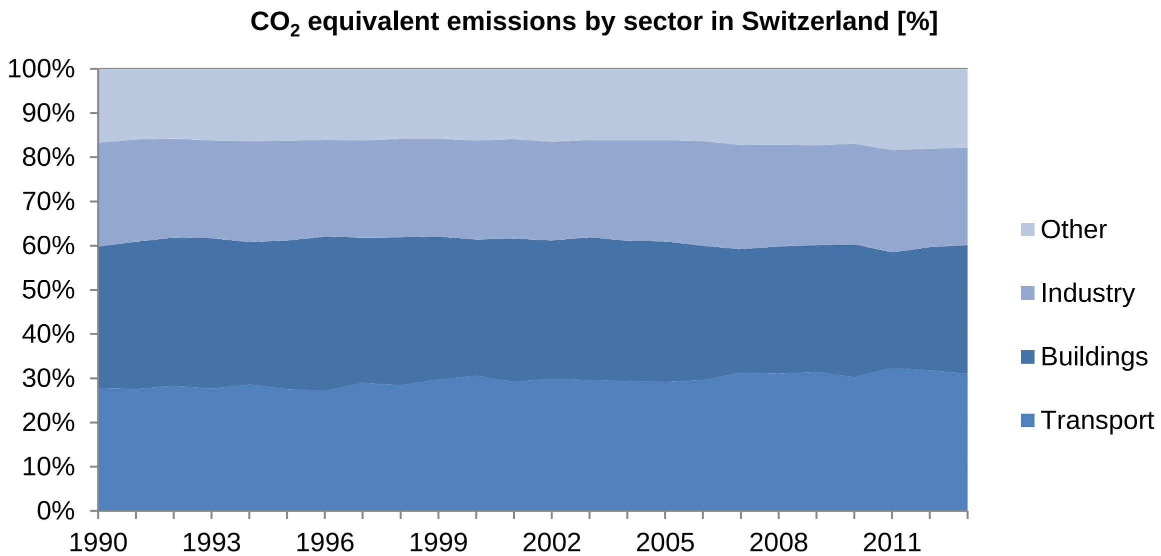


Figure 2-63 Development of the share of CO_2 emissions by final consumption sector in Switzerland 1990-2014.

Data source: Federal Office for the Environment FOEN Greenhouse gas inventory 2015

The same trend emerges considering only transport-related CO_2 emissions, as Figure 2-64 shows: from 1990 to 2014, a global 10% increasing trend is registered. An inversion in such a trend can however be noticed by considering only the period 2008-2014: in the last six years in fact an overall 3.3% decrease is registered in transport-related CO_2 emissions.

Transport related CO_2 emissions started declining in 2008

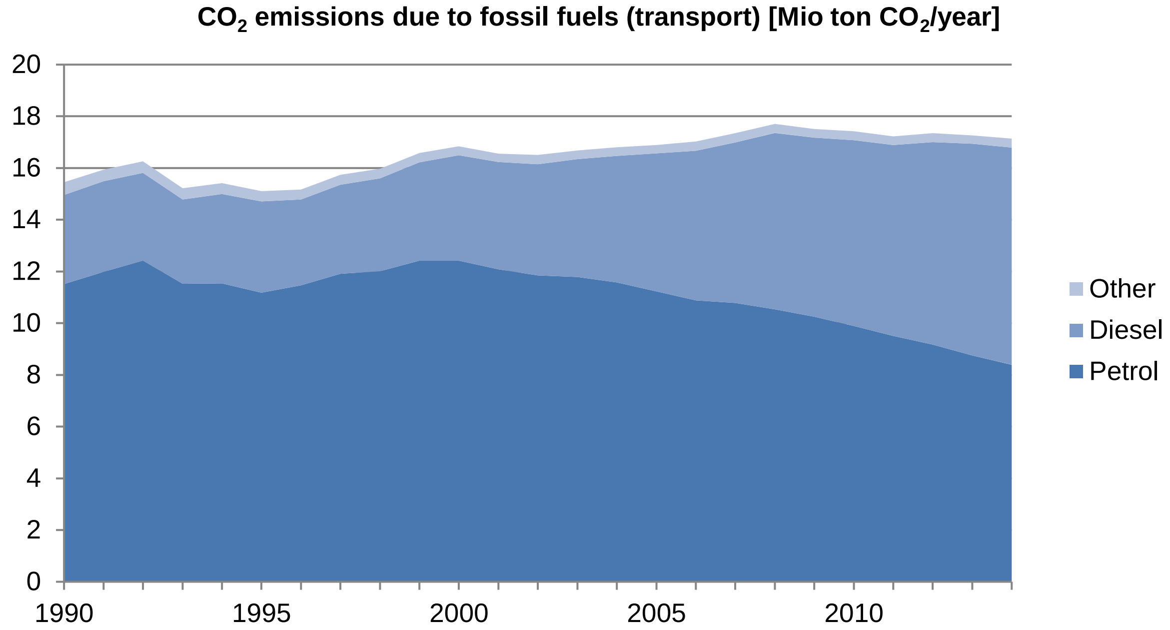


Figure 2-64 Development of greenhouse gases emissions due to transport activity in Switzerland 1990-2014 , divided by fuel.

Data source: Swiss Federal Office for Environment FOEN - Greenhouse gas inventory 2015

Detailed data are available to analyse how much consumptions of each fuels contributed to transport-related CO_2 emissions: as shown in Figure 2-64, petrol emissions show a significant decrease from 1990 to 2014, equal to 37%; instead, diesel emissions show a very critical increasing trend: from 1990 to 2014, their value increased by 59%.

The overall increasing trend in transport-related CO_2 emissions is quite critical, since it is happening notwithstanding the present regulations governing the maximum levels of CO_2 emissions allowed per km travelled for new passenger cars: following regulations introduced at the European level, the Swiss CO_2 act in fact imposes thresholds on CO_2 emissions of newly registered vehicles. For 2015 the threshold is set to 130 g CO_2/km; it is set to 95 g CO_2/km by 2020. At the time of writing the present report, no data are available for 2015; even though we cannot assess the achievement of the 2015 target, the general trend registered between 1996 and 2014, shown in Figure 2-65, seems to indicate it will be met. Fuel consumptions and thus average CO_2 emissions per kilometre of new vehicles have in fact been constantly dropping since 1996, with an overall 34% reduction between 1996 and 2014. Starting from 217 g CO_2/km in 1996, they arrived to 142 g CO_2/km in 2014. In particular, from 2007 to 2014 an average 3.4% reduction per year is registered. However, as shown in the previous figures, such a technological progress is not enough to guarantee a global decrease in CO_2 emission due to transport activities: the positive effect of the falling CO_2 emissions of newly registered vehicles is largely offset by the

Regulations on new imported cars impose decreasing CO_2 emissions thresholds growth in the number of registered vehicles and in the amounts of kilometres driven by each vehicle.

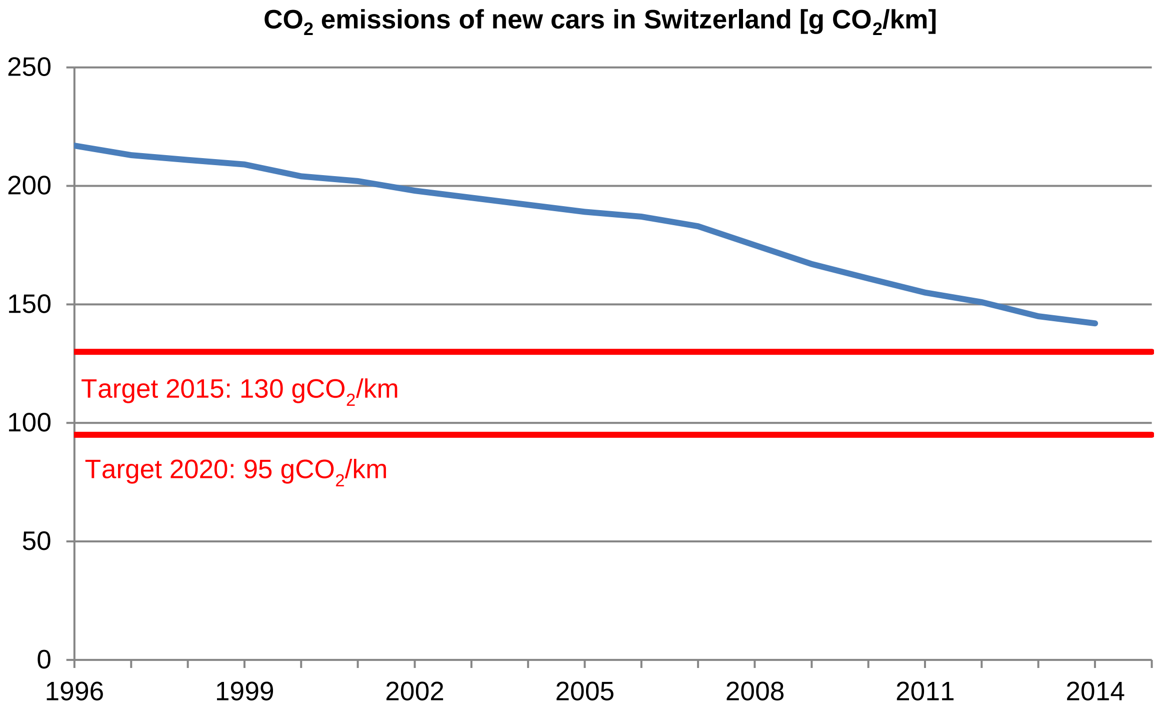


Figure 2-65 Evolution of average CO_2 emissions per kilometre of newly registered passenger cars in Switzerland 1996-2014

Data source: Swiss Federal Office for Energy OFEN 2015 Greenhouse gas inventory

So far, besides the regulations on maximum CO_2 emissions per kilometre allowed, no measures able to counteract such a rebound effect have been implemented in Switzerland. In particular, no taxation on transport-related fossil fuels consumption is foreseen for the future: even though taxation on CO_2 emissions was introduced for fossil fuels used for heating or industrial purposes, proposals to tax the use of fossil fuels for transport purposes were rejected by the Swiss parliament.

In order to support climate policy decision-making, the Swiss Federal office for environment developed scenarios for the evolution of CO_2 emissions in the transport sector until 2050. Those scenarios are based on the 2050 Energy strategy scenarios developed at the federal level, therefore they share the same hypotheses on organizations, regulations and measures for the energy system. They are called High, Medium and Low scenario, according to the resulting level of energy consumptions and CO_2 emissions in 2050, and their main characteristics are reported in Table 2-5. Hypotheses directly related to the transport sector are highlighted in bold.

Table 2-5 Main hypotheses characterising the 2050 Energy strategy scenarios

High scenario	Medium scenario	Low scenario
Evolution according to the present energy policy	Evolution according to the “political measures” identified by the Council of State	“New” energy policy
Electricity production by combined cycle gas turbine covers the electricity gap due to the elimination of atomic power plants	Electricity production by combined cycle gas turbine and renewable energies cover the electricity gap due to the elimination of atomic power plants	Electricity production by renewable energies and importation
Taxation on CO_2 emissions for fossil fuels equal to 76 CHF/ton in 2016 (it does not apply on fuels used for transport]	Taxation on CO_2 emissions for fossil fuels equal to 76 CHF/ton in 2016 (and 96 CHF/ton in 2018) (it does not apply on fuels used for transport]	Priority to measures aiming at achieving by 2050 the 2000 Watt/1 ton CO_2 vision (CO_2 emissions equal to 1 ton CO_2 per inhabitant). No specific measures towards this are however identified
Promotion of energy efficiency in the economic sectors, continuation of the Energy Swiss programme and of incentivization of renewable energies (electricity)	Promotion of energy efficiency in the economic sectors, continuation of the Energy Swiss programme and of incentivization of renewable energies (electricity)	Systematic activation of high efficiency technologies in all the economic sectors
Incentives for energy refurbishment of existing buildings (200 millions per year from 2015) and regulations for energy prescriptions in the building sector (Minergie® label for all new buildings by 2015)	Incentives for energy refurbishment of existing buildings (600 millions per year from 2015) and regulations for energy prescriptions in the building sector (zero net energy buildings by 2020)	Significant increase in the rate of energy refurbishment of existing buildings, rigid regulations for new buildings, promotion of heat pumps and solar thermal energy
Climate cent: for every liter of fossil fuel used in the transport sector, 1.5 cents CHF are withdrawn for climate activities	**---**	**Promotion of electric mobility, both for passenger cars and for freight transport**
Regulations on the CO_2 emissions/km of new passenger cars: 130 g CO_2/km by 2015, 95 g CO_2/km by 2030	**Regulations on the CO_2 emissions/km of new passenger cars: 130 g CO_2/km by 2015, 95 g CO_2/km by 2020, 35 g CO_2/km for the future**	**Promotion of biofuels both for passengers and freight transport**

Data source: Swiss Federal Office for Environment FOEN 2015 “Treibhausgasemissionen der Schweiz, Emissionsperspektiven bis 2050”, based on (Prognos, 2012)

Hypotheses concerning demography and economic development are the same in the three scenarios. Also, two scenarios share hypotheses on the evolution of transport demand over time: the High and Medium scenarios make the same “business as usual” hypotheses on transport demand, while the Low scenario hypothesizes an overall reduction of transport demand over time and a decrease in road transport demand, in favour of rail transport.

Table 2-6 Estimates for the evolution over time of population and transport demand according to the federal 2050 Energy strategy scenarios

		2000	2010	2020	2030	2040	2050
Population [Million inhabitants]		7.18	7.82	8.38	8.73	8.90	8.98
Passenger transport [Billion person-km]	High and Medium scenarios	100	114	131	141	149	151
	Low scenario			127	135	138	140
Ratio of passengers transport route/rail [%]	High and Medium scenarios	85/15	82/18	80/20	79/21	78/22	77/23
	Low scenario			77/23	73/27	70/30	69/31

Data source: Swiss Federal Office for Environment FOEN 2015 "Treibhausgasemissionen der Schweiz, Emissionsperspektiven bis 2050", based on (Prognos, 2012)

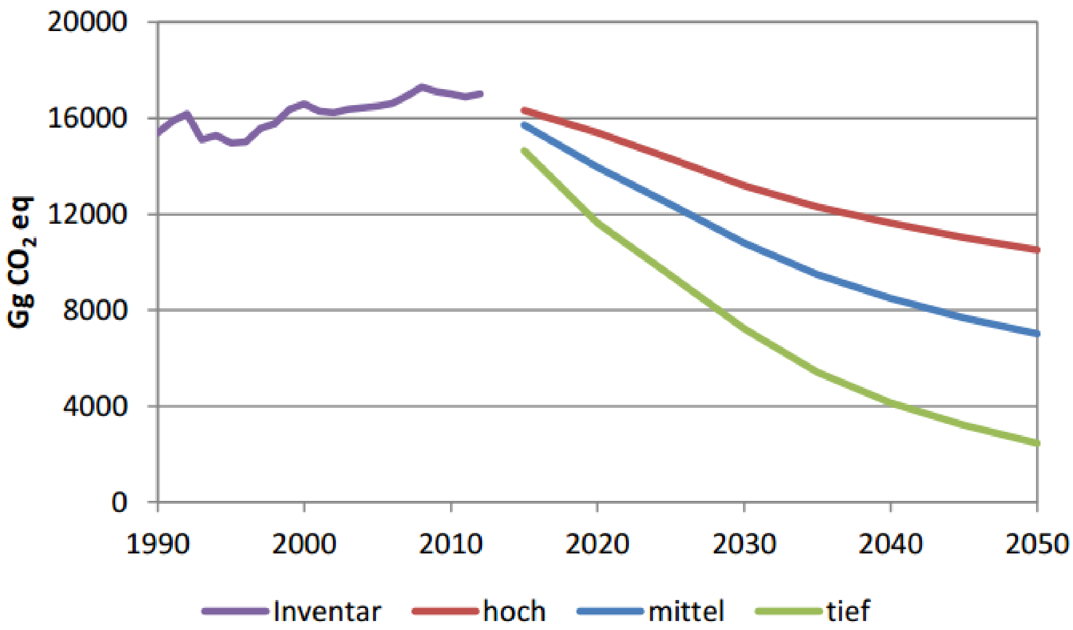


Figure 2-66 Reported (until 2013) and forecasted (from 2015 to 2050) CO_2 eq. emissions due to transport activities in Switzerland 1990-2050

according to the three scenarios High (*Hoch*), Medium (*Mittel*) and Low (*Tief*)

Source: Swiss Federal Office for Environment FOEN 2015 "Treibhausgasemissionen der Schweiz, Emissionsperspektiven bis 2050", based on (Prognos, 2012)

Estimates of the effects of the three scenarios in terms of CO_2 emissions produced by the transport sector are shown in Figure 2-66. They all produce a decreasing trend in CO_2 emissions. Which scenario will actually take place, mainly depends on political choices made at the federal level regarding the 2050 Energy strategy.

2.8.4 Energy consumptions

Energy consumptions in the transport sector have been constantly increasing since the Fifties, as shown in Figure 2-67. Only in the last years a tendency to stabilisation seems to appear. They are nearly entirely covered by fossil fuels: electricity contributes for less than 4%, while gas (both natural gas and biogenic gas) only covers around 0.75% (Figure 2-67).

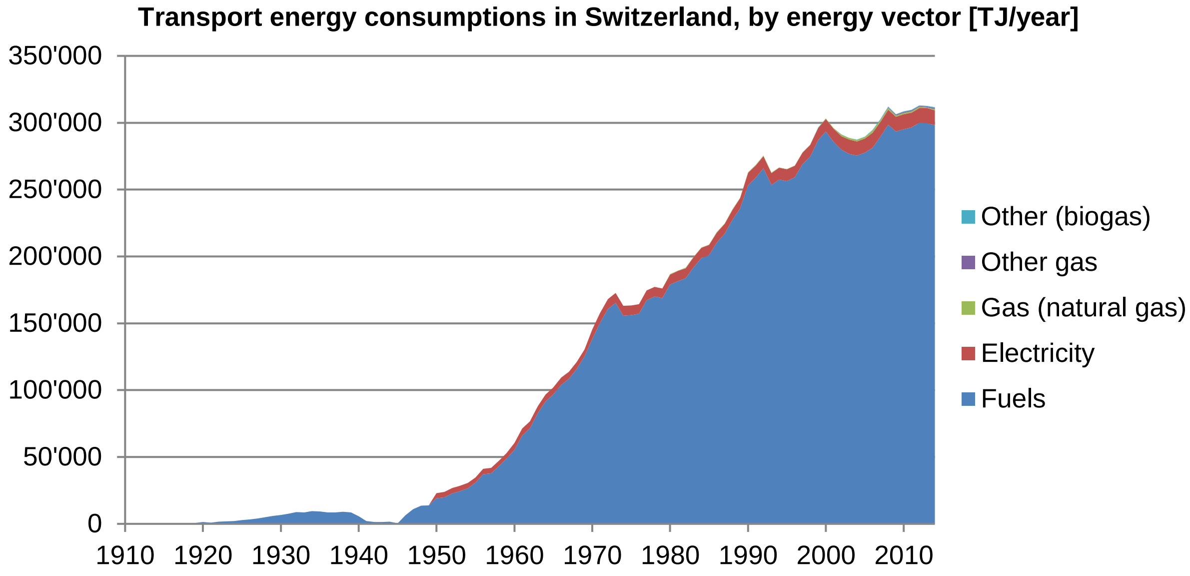


Figure 2-67 Development of energy consumptions in the transport sector in Switzerland 1910- 2014 by energy vector. "Gas" refers to natural gas distributed via network
Data source: Swiss Federal Office for Energy SFOE 2015 Gesamtenergiestatistik 2014, Table 17C

Average energy consumptions of new passenger cars are descreasing

Nonetheless, very significant technological progress is being made in passenger cars. Following regulations on CO_2 emissions, in particular, average energy consumptions of new passenger cars have been constantly declining since 1996, as shown in Figure 2-68. Also, the average number of kilometres driven every year by passenger cars remained quite constant since the 1990s (Figure 2-69). Increase in the overall energy consumptions can therefore be attributed to increase in the number of vehicles. Regarding passenger cars, with an average 1.67% yearly increase between 1990 and 2014, this variable has in fact never stopped increasing.

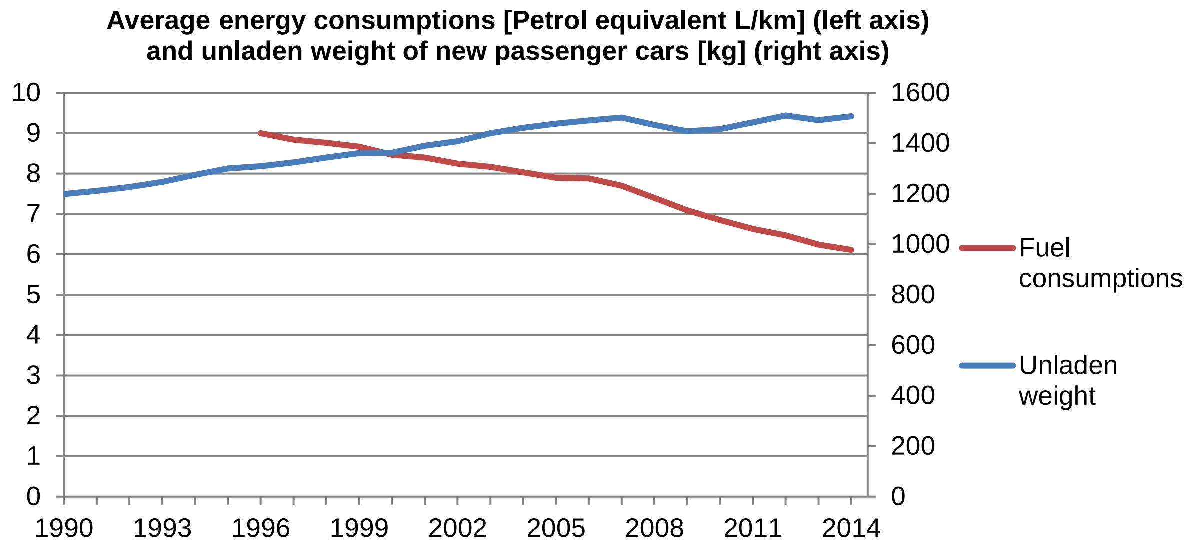


Figure 2-68 Development of average fuel consumptions of new passenger cars in Switzerland 1990-2014 compared to the development of unladen weight of passenger cars.

Data source: Swiss Federal Office for Energy SFOE 2015 Gesamtenergiestatistik 2014, Table 17C

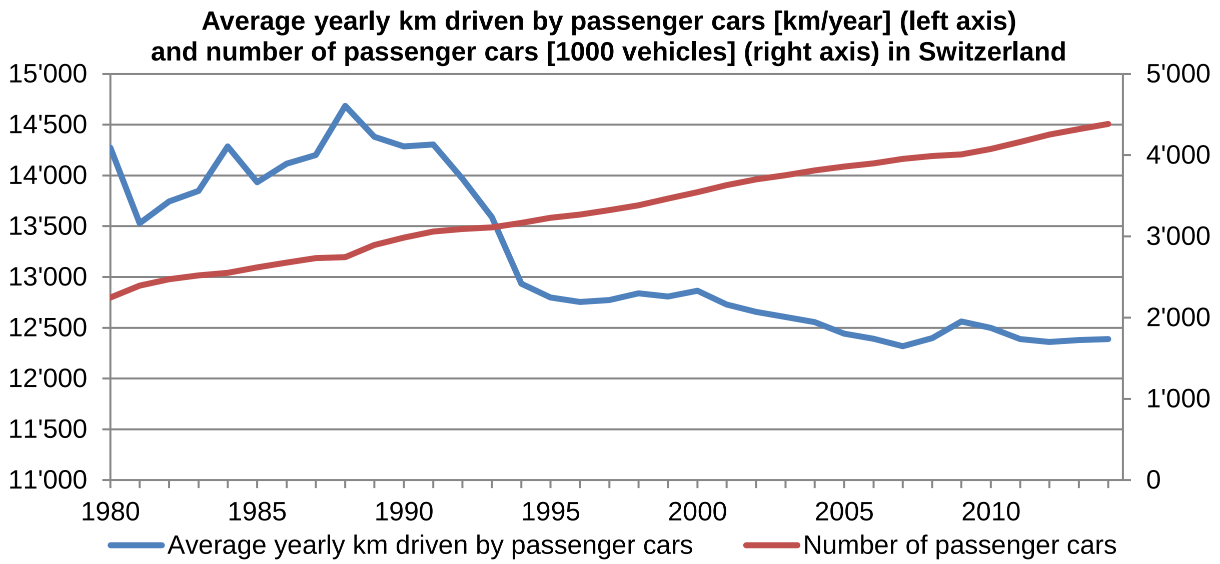


Figure 2-69 Development of the average number of kilometres travelled every year in Switzerland by passenger cars 1980-2014

Data source: SUPSI elaborations, based on Swiss Federal Office for Statistics 2015 Indicators T 11.4.1.1 (People transport: millions of vehicles/km for passenger cars) T 11.3.2.7 (Number of passenger cars for people transport) and T 11.3.2.7 (number of passenger cars)

Projections for future energy consumptions in Switzerland were elaborated within the definition of the 2050 Energy strategy. All the three scenarios already indicated for CO_2 emissions (see Table 2-5) are expected to reduce the overall energy demand of the transport sector: in 2050 the most optimistic "Low" scenario is expected to attain a 42% reduction respect to the 2011 reference consumption values, while the most pessimistic "High" scenario should attain a 24% reduction (Figure 2-35). Fossil fuels consumptions are expected to reach even more significant reductions, since high substitution rates between internal combustion engine vehicles and electric and hybrid electric vehicles are expected.

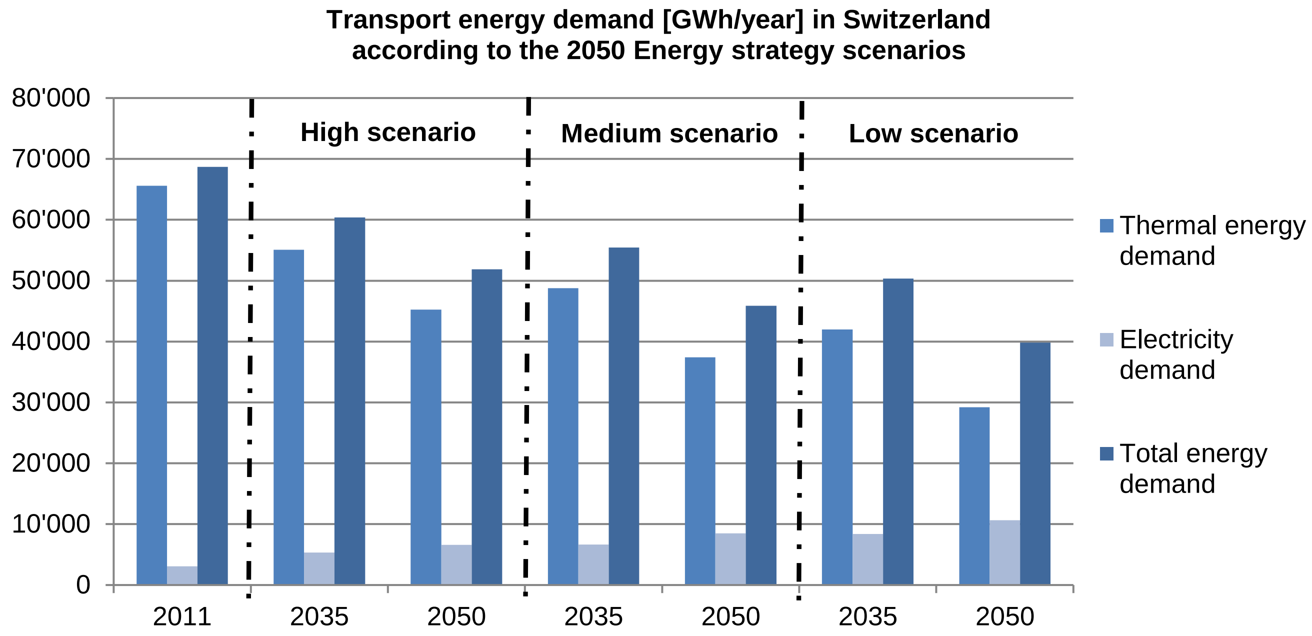


Figure 2-70 Development of energy consumptions, according to the Swiss 2050 Energy strategy scenarios

Data source: Federal office for energy 2015, Energyscope calculator (http://calculator.energyscope.ch/)

2.9 Map of Swiss potential for transformation

The analysis of recent trends and future prospects allows a synopsis of developments relevant for systemic change, the discussed transformation of the mobility system. Identified trends differ in their expected dynamic as well as concerning their expected change on mobility. The table below summarizes both aspects for the identified trends, with the column in the middle describing the explanations and assumptions of how the identified trends (first column) would lead to the expected impact on mobility (last column).

As developments of considerable strength especially demographic ageing, regulations on greenhouse gas emissions and energy consumption, the appearance and distribution of disruptive technologies as well as different aspects of the digital revolution can be expected. On the side of push factors for mobility demand demographic ageing will most probably lead to increasing mobility demand due to active lifestyle and leisure mobility of the elderly; also disruptive technologies have the potential to increase mobility demand as they provide additional mobility options, which has led to increasing mobility in the past.

Other fundamental changes provide the potential of stabilizing or even decreasing mobility demand, e.g. regulations aiming for this respective goal, but also developments related to the digital revolutions allow for replacing physical mobility. Aspects related to economic growth such as increasing GDP, working population and income are expected to only slightly increase in the near future, but would lead to increase of mobility demand and/or car use; the same can be assumed for the extension of the road infrastructure.

Some trends with expected moderate increase are include and are related to population growth: urban sprawl, extension of the rail network - leading to increasing mobility demand. Fuel prices, technological development (powertrains) and sharing economy are expected to moderately increase supporting decrease of mobility demand and/or supporting more sustainable mobility modes.

In general, factors related to the specific Swiss situation of a strong and still growing economy with effects of population remain as drivers for mobility demand - while general, global technological and social trends as well as political regulations stand against the continuous growing mobility. Thus, decoupling economic and population growth/development from mobility demand is key aspect to reach the goals of the intended energy transformation.

	Expected development in future	Relevance for mobility	Expected change on mobility
GDP	Slight increase - with uncertainty	Economic growth and activity lead to commuting	Slight increase of mobility demand
Working population	Slight increase but slowing down (in a medium scenario)	Potential commuters	Slight increase of mobility demand
Fuel price	Moderate increase with volatile dynamic	Mode shift depending on the price elasticity	Reduced / stabilized car use
Population	Moderate increase (in a medium scenario)	Mobility demand of new inhabitants: work & leisure	Moderate increase of mobility demand
Age group over 65 years old	Considerable increase	Special mobility needs of the aging population beyond commuting	Moderate increase of leisure mobility
Age group under 24 years old	Lower/constant share of population	Lower share of driving licenses	Slight decrease of car use
Incomes	Slight increase depending on GDP / competitiveness	Increase travel distance and time	Increase of (leisure) mobility
Land use	Urban sprawl	Regionally differing impact on travel demand and modal choice	Longer travel distances; increasing use of car or PT depending on infrastructure accessibility
Regulations on CO_2 emissions and energy consumption	Considerable increase in strictness of the regulations	Evolution of powertrain and fuels, but system remains car-based	Single cars more efficient; effects depending on mobility demand (→ rebound effects)

Length and capacity of the road network	Slight increase	New roads areas increase attractiveness of car use	Slight increase of car use
Length and capacity of the rail network	Moderate increase	New and faster connections increase attractiveness of public transport enabling long distance commuting	Moderate increase of public transport use & commuting distances
Evolution of powertrain and fuel	Evolution towards alternative technologies	Innovation will occur, but the system is still based on individual vehicles (cars)	Constant mobility demand with shift between vehicle categories
Sharing economy	Moderate increase on supply and demand side	Diffusion of the "mobility as a service" paradigm	Shift towards multi-modal mobility with reduction of private car
Digital revolution	Increase in ICT-based mobility options (e.g. MaaS)	Change of individual mobility patterns	Reduction of individual car use and increase in intermodality / PT use
	Further development in teleworking options	Potential increase in remote work	Reduction of car use and mobility demand in general
	ICT based organisation of road transport	Efficiency increase of roads with partly automated driving	Increase of car use
Disruptive technologies - driverless cars	Expected market entrance in a decade	Change of mobility culture on the level of individuals and society	Increase of individualized moblity and of individual vehicles use

3 Transformation of the mobility system

The SCCER programme is set in the context of the Swiss Energy Strategy 2050, whose goal is to guarantee the quality of energy supply and reduce the environmental impacts of energy production and usage in Switzerland, a goal that requires a transformation[19] of the energy system and related fields. Within this context "The Swiss Competence Center for Energy Research - Efficient Technologies and Systems for Mobility (SCCER 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" (http://www.sccer-mobility.ch/). The changes needed to achieve these goals affect the whole mobility system. "It is widely recognised that transport's decarbonisation is a massive challenge that can only be achieved by combining measures targeting multiple elements within transport systems – means of transport, their users, fuels, prices, regulations, infrastructures, the separation of origins and destinations – simultaneously" (Schwanen et al. 2011).

The research presented here aims to provide an analytical framework for such systemic change towards a sustainable mobility system. This framework will serve as a basis to derive recommendations for policy and planning with a special focus on technological and socio-economic developments to address the systems complexity, as it is not only the goal of SCCER to provide theoretical insights but also show opportunities how change processes can be actively supported.

The analytical framework provides deeper knowledge on system transformation for different aspects and system levels. Therefor it is organized in different modules, to be used accordingly to the level of analysis, which is intended:

I. Superordinate system level: To find out how transformation can be initiated a comprehensive understanding of change processes is necessary. Doing this in a structured way requires a theoretical framework. As such a framework, the 'multi-level perspective' (MLP) by Geels (2002, 2012) can be used (chapter 3.1). The MLP is a broad approach trying to incorporate the totality of systemic change as an integral process. It is therefore useful for understanding systemic change on a superordinate level and to identify general starting points, mechanisms and dynamics of transformation.

Besides the global picture, an applied perspective on systemic change requires a specific understanding of real world processes. Thus, additional approaches that allow for a deeper understanding of parts included in the MLP model or that incorporation a specific *transformation* perspective are used to complete the framework:

II. The role of governance in transformation: transformation is carried by norms, values and behaviour of actors. All these characteristics are manifested in social, economic, political and cultural practices, which need to change in a transformation process as well. To better understand the change processes in these practices and to also identify potential starting points for intervention, perspectives focusing on a facilitation of intentional change are needed. General principles with best practice

[19] The terms 'transformation' and 'transition' and are not used consistently throughout academic and popular publications and discussions. Due to our applied perspective with a focus on actively initiating a system change and shaping a sustainable system, we use the term 'transformation' instead of 'transition'. At certain points however, expressions established in a certain research context or community are used such as 'transition management' in 3.3, which goes more in the direction of transformation.

on governance and transition management towards sustainability are identified as well as potential starting points and transformation pathways for niche technologies in this context (chapter 3.2).

III. Stakeholder in transformation: Related to governance stakeholder are key persons in a transformation process with the power to shape, intensify or interfere with it. Thus, a framework for transformation needs to systematically analyse stakeholders and provide a basis on how to involve them in the change process (chapter 3.3).

IV. Transformation Design: In the broad field of design research, transformation design is an idea of introducing a normative sustainability notion. It discusses how designers can contribute to change processes. As an example for the need for interdisciplinary and the benefits from new input in research on socio-technical transitions we also discuss these methodological approaches (chapter 3.4).

V. Transformation as behaviour change: mobility and mobility related behaviour of individuals lead to demand in transport, which is shaping the transport system at the end. Therefore, a bottom-up perspective complements the top-down systemic view of MLP with a special focus on behavioural change as powerful driver in the transformation process. This level is considered in a meta-model on behaviour change that integrates findings from different streams of research, mainly within the field of psychology (chapter 3.5). The model shows individual behaviour change as a process with different stages, in which appropriate interventions for each step can support most effectively. Such interventions are the starting points for transformation related to the micro-level of MLP (see 1.2).

3.1 Understanding systemic change: The multi-level perspective as analysis framework

SCCER Mobility is a technology-focused research program which is complemented by socio-economical aspects. Thus, the theoretical framework needs to integrate the role of technological innovations for the process of systemic change. From such a technological perspective on systemic changes, Markard & Truffer (2008) identify two main streams of research. The first perspective analyses how new technologies gain importance and diffuse and therefore can transform the system. The second perspective looks at systems as such and how they change as a whole due to the rise and fall of different technological paradigms leading to 'socio-technical transitions' (e.g. Geels 2011). This "transition perspective" (Markard & Truffer 2008) is theoretically framed as "multi-level perspective" (MLP; e.g. Geels 2002, 2012). The MLP model is represents our general view on socio-technical systemic change and is used as a framework for analysing how change happens and where there are potential starting points for interventions. The MLP is chosen, because it integrates both a technological innovation perspective and a socio-economic perspective.

The MLP (Figure 3-1) shows that technologies might have a primacy; and how that can change over time. Geels (2002) illustrates this with the historical example of merchant ship fleets: within only few decades, the technology of sailing ships. which has been dominant in shipping for centuries was completely replaced by steamships. The reason for this was on the one hand the invention of the new technology, but also, and more important for the breakthrough, changing frame conditions. This example already illustrates that there are different levels or entities that need to be analysed concerning their interrelations to understand socio-technical transitions. MLP integrates three levels:

- *The socio-technical regime* (3.1.1) is the meso level analytical construct to assess a currently dominant technology within a certain field and its associated social, economic, political and cultural practices.

- *Niches* (3.1.2) refers to the micro level where radical innovations take place. They are new technologies or techniques with potential to gain importance in the future.

- *Socio-technical landscape* (3.1.3) depicts the external framework. On a macro level, it describes changing frame conditions for the socio-technical regime.

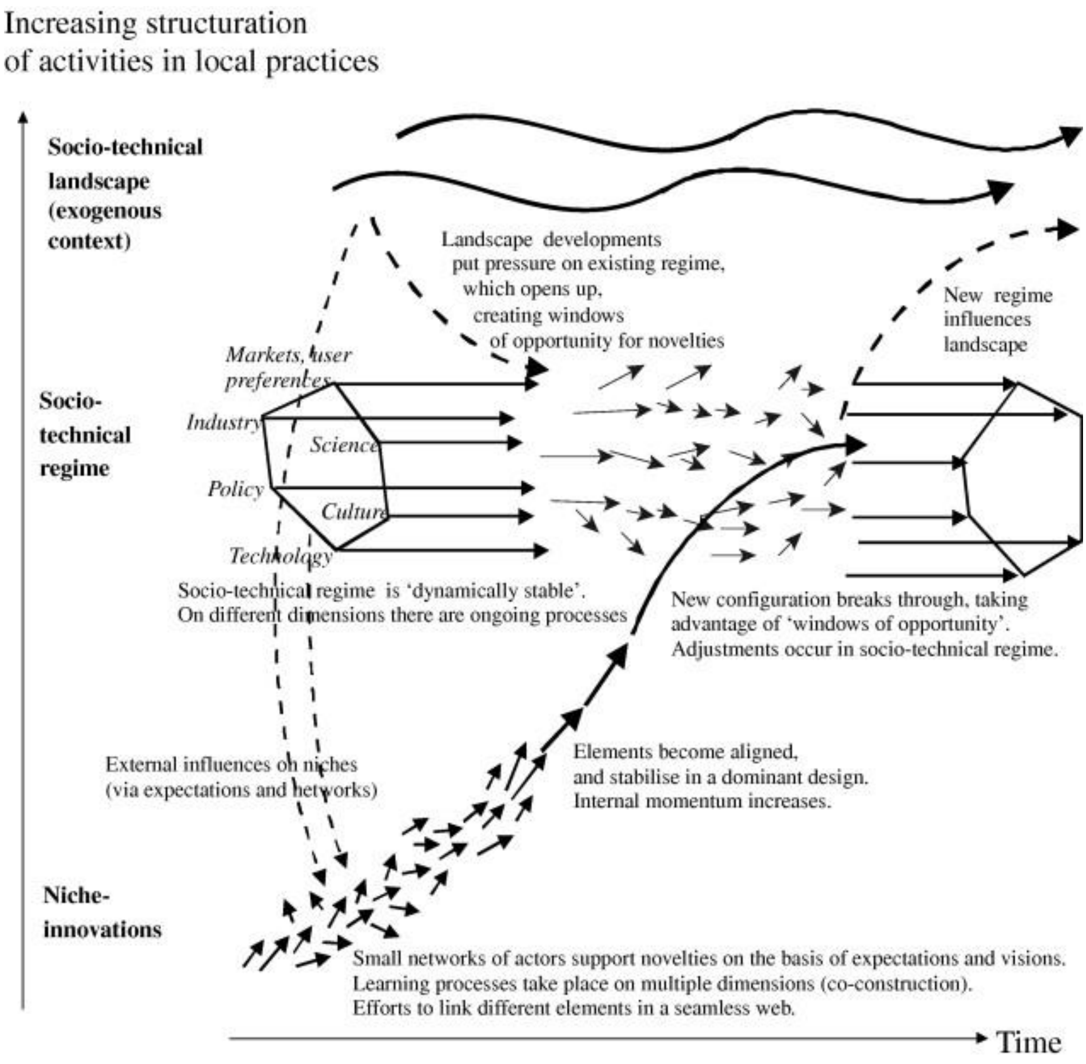


Figure 3-1 The multi-level perspective on transitions

Source: Geels 2012, p. 472

3.1.1 Socio-technical regimes

According to Geels (2012), socio-technical regimes are defined by a common thinking and way of action expressed in “shared beliefs, norms, standardised ways of doing things, heuristics and rules of thumb” (Geels 2012, p. 473). Socio-technical regimes are “an interpretive analytical concept, which invites the analyst to investigate the ‘deep structure’ behind activities” (Geels 2012, p. 473). They are the central part of the MLP, with the landscape influencing them (3.1.3) and the niches where potential amendments or competitors might come from (3.1.2).

Markard & Truffer (2008, p. 605) state that the term (socio-) technical regimes is not always used coherently within academia, sometimes not even by the same authors. In general, the label 'regime' is used for a set of "rules: in particular, the rules and grammar that are implied in sociotechnical configurations" (Kemp et al. 2001, p. 272). While Kemp et al. (2001) used the phrase 'technical regime' Geels (2002) adds the prefix 'socio-' to stress the social components. The background of what is considered a socio-technical regime has also changed over time. In the beginning, it still included physical aspects such as infrastructure (Geels 2002, p. 1263) but later most publications have primarily focused on the social interaction aspect and leave out an explicit reference to physical structures. This is shown by the different aspects that are regarded to be part of the regime (Figure 3-1): Technology, policy, industry, markets & user preferences, science and culture. However, what is consistent throughout literature (according to Markard & Truffer 2008) are the main characteristics of regimes, which are described in the following paragraphs.

One key to understanding the mechanisms of regimes is the concept of path dependency and the regime's nature "as an emergent, collective outcome that cannot be changed at will" (Markard & Truffer 2008, p. 604). Regimes "stabilize certain technological trajectories" (Markard & Truffer 2008, p. 607), which means that a development path is difficult to reverse or substantially change it. Path dependency can be explained by three interrelated aspects: technology, economies of scale and almost irreversible investments (Berkhout et al. 2003; David 1985). Established technologies with the economies of scale developed over time in a mature economic system and pay-off of former investments stabilize the given system. These aspects are closely linked to social, institutional, political and economic structures that co-develop and constitute the regime. This process of the alignment of technology and socio-economic practices is already described in the first introduction of path dependency to economic science by David (1985). Path dependency is not planned but occurs through a certain set of preconditions and developments (that often become obvious only in retrospect), which lead to the lock-in of a technological setting. In his original case study on the QWERTY-keyboard-layout David also states the temporal component of this process: "This, then, was a situation in which the precise details of timing in the developmental sequence had made it privately profitable in the short run to adapt machines to the habits … rather than the other way around. And things have been that way ever since" (David, 1985, p. 336).

A regime's path dependency and its lock-in on certain technological trajectories account for both its prosperity and for its potential downfall at some point. Path dependency grants stable development through standardised behaviour, networks and interrelations in the regime leading to stability and predictability of developments. However, it also means that a regime is not necessarily flexible in reacting to changing external conditions or forces that challenge its structures.

The socio-technical regime approach is suitable for systemic transformation research in SCCER because it explains how technology becomes relevant through user practices. However, it is not enough to identify a regime but it also needs to be analysed. For empirical studies, it is essential to define the regime related to the specific research question. The extent of "socio-technical regimes may be defined at the sectoral or sub-sectoral level or at the level of particular technologies" (Markard & Truffer 2008, p. 606), as "regimes exist on different scales" (Smith et al. 2005, p. 1493) [20].

[20] Smith et al. (2005, p. 1493) speak of 'nested subordinate' and 'spanning' regimes.

Concerning transport, one dominant regime developed since the beginning of the 20th century[21]: the auto-mobility regime. Transportation based on internal combustion engine vehicles became dominant for both individual mobility and economy related mobility in many industrial and western countries. In parallel to this dominant regime[22], some other regimes developed in the long term, such as the public transport or the bicycle regime. However, they are less important in terms of mode share (measured by person kilometres, distance or time) and therefore can be considered as 'subaltern regimes' (Geels 2012). This also applies to Switzerland. Despite the growing mode share of railways (Figure 2-3) the Swiss transport system is still dominated by the car.

3.1.2 Niches

Niches are 'spaces'[23] where innovations can originate. Niches can for example originate from and be based in R&D facilities, start-up companies or research institutions. These spaces are not yet exposed to normal market conditions and requirements and therefore "are commonly referred to as protected spaces or incubation rooms in which new technologies or socio-technical practices emerge and develop" (Markard & Truffer 2008, p. 605). Markard & Truffer (2008) distinguish two different types of niches: technological niches and market niches. In technological niches, new technologies are developed and explored concerning their potential benefits. Market niches are more or less test markets. Here, the willingness of customers (early adopters) to pay a higher price with the reward of using alternative technologies is tested. Market niches can also incorporate established technologies if they are applied in a new context. E-Mobility can serve as an example here: electricity-powered vehicles have been on the market for many years already. However, they only served niche markets. With increasing investments, subsidies and governmental support, the technological niche might get a boost and develop certain components further (e.g. batteries). This shows that the same technology can be assigned to both a market niche and a technological niche.

When comparing niches and regimes, they show similarities in their general properties (Markard & Truffer 2008) such as being constituted by actor relations, ways of thinking and behaviours. However, niches do not inherit the continuity and stability of a regime as they lack a critical size.

3.1.3 Socio-technical landscape

The term 'socio-technical landscape' refers to all contexts that influence regimes (and niches). On the one hand, it describes the actual (physical) landscape or spatial structures and on the other hand general conditions, trends and developments e.g. in economics, society, norms and values, politics, media etc. It can be described a set of "background variables" or "residual[24] factors that have an impact on innovation and production processes without being influenced by the outcome of innovation processes on a short to mid-term basis" (Markard & Truffer 2008, p. 606).

The socio-technical landscape therefore is not directly capable of being influenced by developments occurring in socio-technical regimes but rather responds to or reflects them.

[21] This primarily applies to industrialised countries.

[22] This dominance can be identified by analysing different indicators, e.g. modal share (person-km covered), share of (infrastructure) investments.

[23] 'Space' is meant both in an abstract as well as in a literal sense.

[24] Footnote by Markard & Truffer 2008, p. 606: "With 'residual' we mean factors that influence innovation and production processes but cannot be reasonably allocated to the nice or regime level."

More importantly, it can impose pressures on them. Landscape changes (trends or megatrends) can challenge regimes concerning different aspects and with varying intensities. The changes occur on different temporal as well as spatial scales. Examples for long-lasting and slowly developing landscape megatrends are climate change, the growing demand for oil[25] in emerging market economies, the increasing importance of information and communication technologies, demographic ageing or the individualisation of lifestyles. The landscape factors are not necessarily determining developments but can be rather fundamental conditions "that make some actions easier than others" (Geels & Schot 2007, p. 430).

Landscape pressures can be specified according to their duration and intensity, which can induce different kinds of transition pathways (Geels & Schot 2007; 3.1.4). While climate change and related emission legislation have long-term and profound influence on the auto-mobility regime, short-term fluctuations in oil prices do not significantly challenge it. Changing general norms and values of the society, such as rising environmental awareness or a paradigm shift from an individualistic towards a more holistic way of thinking, are long-term processes, which can have profound impacts. The following section shows different ways of adapting or replacing an existing regime depending on landscape pressures and regime resilience.

3.1.4 Types of transformation itineraries

To analyse changes, Geels & Schot (2007) specifically distinguish between 1) mere technological advancements or 2) the replacement of one technology by another and actual regime/system change. Considering path dependency and resulting lock-ins, regimes tend to "focus on system optimisation rather than system innovation, because [of] habits, existing competencies, past investment, regulation, prevailing norms, worldviews" (Köhler et al. 2009, p. 2985), which prevent from changes. Regime change always means a shift of paradigms in manifold ways: "technologies and technical artefacts as well as in user practices, policies, markets, industrial structures and supporting infrastructures" (Markard & Truffer 2008, p. 603f). This is the kind of transformation, which can be analysed using the MLP.

According to the MLP model, the precondition for change is the occurrence of landscape pressure(s) on the socio-technical regime (3.1.3). Even if changes on the landscape level are constantly occurring, they only become landscape pressures, "if they are perceived and acted upon by regime actors" (Geels & Schot 2007, p. 406). Only developments that are also relevant for the course of action within regimes are considered to be pressures. Such pressures can open a "window of opportunity" (Geels 2002, p. 1262), i.e. chances for change from the locked-in path[26]. Such windows provide the chances for niche innovations to be amended and introduced to the existing regimes or even replace the latter; "key events in the transition to a sustainable low carbon economy may occur through technological changes, forming of institutions, revisions to business strategies or changes in user practices, and how these changes interact with changes in natural ecosystems" (Foxon 2011, p. 2263).

Historical case studies show that transitions do not follow linear trajectories and that they are not well-structured intentional developments (Foxon et al. 2013). They always include uncertainties and struggles before specific paradigms prevail. The success of these processes and the ability to use a window of opportunity largely depends on comprehensively developed

[25] To a certain degree, this growing demand is also caused by the regime itself. This shows that both levels can mutually influence each other.

[26] The mechanisms behind this will be described in the following paragraphs.

niche innovations, as well as on the intensity of landscape pressures. Depending on a niche's status, on the magnitude and type of landscape pressure as well as on the resilience of the current dominant regime, Geels & Schot (2007) developed five typologies of sociotechnical transition pathways[27].

0) Reproduction process

Reproduction of current regimes is actually no transition but the continuation of locked-in 'business as usual' (=preservation). It occurs when "there is no external landscape pressure […], then the regime remains dynamically stable and will reproduce itself". This stability means that niche innovations cannot come into effect because the capacity of the regime to deal with (moderate) landscape pressures, i.e. its resilience, is sufficient. Innovation is still likely to happen but only within the system. Therefore, the development trajectories remain predictable and locked-in.

1) Transformation path

A transformation path occurs when larger gradual landscape pressures are exerted on a regime but no niche-innovations are developed enough to replace it at the beginning of the window of opportunity. Nevertheless, there is a need for adaption of the regime, possibly articulated by external (niche) actors. They call for regime change and also provide alternative technologies. The actors of the current regime can adapt these technologies, if they do not require fundamental changes. However, due to the already outlined development trajectories (probably even lock-ins) this adaption only takes place gradually. In the end, the transformation path results in the preservation of a regime and its adaption to new landscape conditions with the help of symbiotic external niche innovations. These "*add to* the regime and do not disrupt the basic architecture".

2) De-alignment and re-alignment

When landscape pressures occur with strong intensity and in a short period of time, this leads to many internal troubles in the regime so that it possibly even "erodes and de-aligns" in the end. If this vacuum-like window of opportunity cannot be capitalised by a niche-innovation because none is readily developed, multiple possible innovation paths co-exist. In this phase of uncertainty, different "embryonic niche-innovations" compete for resources until one new and dominant regime gains momentum and replaces the discontinued one (re-alignment).

3) Technological substitution

The starting point for the technological substitution way of transformation are niche-innovations "that have stabilised and gathered internal momentum". However, as long as the dominant regime can still follow its trajectory due to no relevant landscape pressures, this does not come into effect. But after a (sudden and strong) landscape change, such as indicated in 2), the niche sociotechnical innovation can directly step in and replace the 'old' regime.

4) Reconfiguration pathway

The initial development of the reconfiguration pathway is a transformation pathway (see 1): Symbiotic niche-innovations are amended to the regime and improve it in a certain (mostly economic) ways. The difference however is that the introduced innovations can induce further

[27] All direct citations in the following texts are taken from Geels & Schot 2007.

changes in the regime, due to the exploration of synergetic effects. Under landscape pressure, this may even lead to regime shifts that would not have been possible without the amendment of the niche innovations. So the regime is reconfigured from an internal momentum, which was made possible by the previous implementation of niches. The key factor is not "*one* technology, but […] sequences of *multiple* component-innovations".

5) Sequence of transformation pathways

The aforementioned pathways (or parts of them) are likely to occur as a sequence, especially when landscape pressure is articulated as "disruptive change"[28]. With moderate landscape pressure in the beginning, regime actors try to make use of niche-innovations in the context of the transformation path. If the pressure continues and intensifies so that adapting new niches is not enough to stabilise the system, reconfiguration is likely to be required. However, if the 'problems' of the regime that show up due to landscape changes are so big, that the resilience of the regime is overstretched, either technological substitution or de- and re-alignment follow. Seeing this as a sequence of 'events' can also motivate niche actors to invest in innovations to get them ready for the market in case the current regime fails (see also 3.2.1). "Climate change may in future decades become such a disruptive landscape change, triggering such a sequence of transition paths in transport and energy regimes" (Geels & Schot 2007, p. 413).

3.2 Managing systemic change: Governance, transition management and niche management

Are there ways of utilising the transition mechanisms (3.1) for managing change in a sense of transformation towards a sustainable mobility system?

Managing transformations is not only a question of *how* but also a question of *who*. The idea of 'governance', which goes beyond a top-down government approach, is essential here. The notion of governance does not only focus on formal relations of actors governing a system but also includes informal relations between actors that are not necessarily always stable (Kemp et al. 2005, p. 17). "Governance for prosperity must engage actively with citizens both in establishing the mandate and delivering the change." (Jackson 2009, p. 168). Governance approaches provide systematic insights into the feedback-processes and control mechanisms of transformations.

Two concepts of supporting transformation 'transition management' (3.2.1) and 'niche management' (3.2.2) appear to provide solutions in this context.

3.2.1 Transition management

A variety of different measures can be thought of to improve the sustainability of the Swiss transportation system. However, as pointed out earlier, the system is highly complex and just introducing different actions in different fields is not enough to achieve systemic change with long-term effects. Efforts need to be aligned to achieve a system innovation. Rotmans et al. (2001) developed the approach of "transition management" and sees the following characteristics as key aspects in transition management:

- "Long-term thinking (at least 25 years) as a framework for shaping short-term policy
- Thinking in terms of more than one domain (multi-domain) and different actors (multi-actor) at different scale levels (multi-level)

[28] „*Disruptive change* corresponds to changes that occur infrequently, develop gradually, but have a high-intensity effect in one dimension" (Geels & Schot 2007, p. 404).

- A focus on learning and a special learning philosophy (learning-by-doing and doing-by-learning)
- Trying to bring about system innovation alongside system improvement
- Keeping a large number of options" (Rotmans et al. 2001, p. 22).

Transition management is designed as a process that gradually produces systemic change through building on the system's capacities and stimulating the development in a certain direction[29]. Government plays an important role in this process, especially in the preparation phase of a transition, where they should ensure a huge variety of development options (niches; see also 3.2.2), and in the take-off-phase, where an activation and alignment of all kinds of actors is necessary (Rotmans et al. 2001). From a transformation governance view, Kemp et al. (2007, p. 81f) identify five challenges related to actors that need to be dealt with:

1. *Dissent:* not all actors have the same perspective on challenges and possible solutions. However, at least key parameters of the transformation goals can be agreed on in formulating a vision (3.3.2). Additionally, a constant, transparent and objective discourse is helpful.
2. *Distributed control:* actors do not only have diverging views but also power is distributed amongst them. This requires long-term network management and cooperation strategies to achieve the commonly developed goals and visions.
3. *Determination of short-term steps:* it is not yet clear how short-term steps can be strategically aligned to achieve long-term goals. This requires the involvement of scenarios for forward-looking reasoning (forecasting; 3.3.2) as well as backward reasoning (backcasting; 3.3.3).
4. *Danger of lock-in:* If a certain technology for achieving the goals (i.e. development trajectory) is already selected in the beginning, this bears the risk of the exclusion of other, possibly even better options that were just not enough developed at that point of time. A lock-in on a sub-optimal solution can happen. The suggested solution is "the development and use of a portfolio of options" (Kemp et al. 2007, p. 81; 3.2.2).
5. *Political myopia:* General consensus amongst political actors is needed to overcome short-term political changes as managing transitions is a long-term project. Mechanisms and approaches have to be developed so that the transition agenda will not become subject to short-term political interests.

Different levels of management have to be distinguished: the strategical level at which the visions and goals are set, the tactical level where networks are formed and agendas are negotiated, and the operational level at which the actual implementation of measures and experiments takes place (Kemp et al. 2007). As the assessment of the whole system is hard to handle due to its complexity, Kemp et al. (2007) see the role of transition management in making sub-systems more sustainable so that the sustainability of the whole system increases[30].

In general, transition management does not rely on market forces but influences the context in which market mechanisms take place (Kemp et al 2007). Arapostathis et al. (2013) state the special importance of 'branching points', when the directions of the further development of a regime are fixed. Those are points at which fundamental decisions about future pathways are

[29] Transition management therefore also incorporates the idea of 'transformation' as introduced in the beginning of this chapter.
[30]

made by actors, in the face of landscape pressures. The identification of such branching points for the Swiss mobility system helps to manage the transition, i.e. to make it a transformation.

In summary, the following conclusions can be drawn from the reviewed literature on governance and transition management towards sustainability:

- All political, economic, environmental, social, scientific and cultural actors create the transformation process through their action and interaction.
- The basis of system transformation through governance is a common vision of the future, from which specific goals can be derived. This includes having shared objectives (see also 3.3.2).
- System transformation always needs to be seen and enacted from a long-term (multi-generation) perspective.
- Several interlinked decision and impact levels have to be considered and coordinated, from a conceptual as well as from a practical perspective.
- Progress is made by changing current system properties, actors' behaviours and resource allocations as well as adapting new components.
- Technological and/or organisational lock-ins should be avoided.
- The occurrence of different views and opinions is seen positively as they can contribute diverse aspects to strategy development. However, a consensus on visions and goals is essential.
- The transformation needs to be organized in a reflexive way to deal with unexpected changes or trade-off effects. This also requires objective and measurable indicators to track change processes.
- Transformation requires institutional change and is not realisable solely through regular market functioning.

3.2.2 Niche management

According to the multi-level perspective, niche innovations are the key to transformation, as they provide the novelties that help relieving the landscape pressures for regimes or replace the latter. They are introduced and/or adapted via different transformation pathways (3.1.4). The potential for a niche's adaptation in an existing regime is depending on its compatibility with the regime (Markard & Truffer 2008). If a niche can possibly improve the regime's resilience towards landscape pressures, it is likely to be integrated. However, this also depends on the readiness for adaptation, i.e. the development status of a niche innovation. Geels & Schot (2007) point out four aspects, which show whether a niche is already in a stabilised state and therefore ready to be adapted or to potentially replace the regime: "(a) learning processes have stabilised in a dominant design, (b) powerful actors have joined the support network, (c) price/performance improvements have improved and there are strong expectations of further improvement (e.g. learning curves) and (d) the innovation is used in market niches, which cumulatively amount to more than 5% market share" (Geels & Schot 2007, p. 405). The question is how to support niche innovations in a way that they can grow to a state where they can be either quickly amended to the regime or replace it. The amendment of a niche requires the innovation to be less developed than for the replacement of the regime.

In contrast to niches technological developments can mostly be characterised as path dependent processes because certain inventions determine the range of the future steps that can be taken. But even if niches are still more open experimental fields compared to regimes and also several niches can exist at the same time, they are also not completely free, once a certain direction has been agreed upon. A strategic approach to specifically support technologies with potentially desirable development paths is useful, if the general development is meant to have a certain direction such as e.g. the regime(s) becoming more sustainable. Kemp et al. (2011) suggest the approach of strategic niche management (SNM) to implement this.

SNM creates a protected space, so that technology, goals, learning processes and networking can develop without having to cope with all market constraints from the very beginning. The initial idea and the development of the technology are followed by experiments to test and improve it. A key role is played by the early adopters of the technology: they should be both motivated to try and use something new as well as critical to give feedback to improve the technology. The early users' behaviour and feedback should be transferable to a large share of the total population to increase the results' significances. While setting up and later scaling up experiments, which is the next step in SNM, it is essential to keep development support and market pressure in a balance so that the technology is neither limited nor overprotected. The last step of SNM is the gradual phasing out of the protection, to let the technology deal with "real" market situations and to test its general applicability. (Kemp et al. 2001)

Within this development of niches supported by SNM three phases can be distinguished: visions or expectations, networks and learning processes (Geels 2011; Geels 2012)[31]. First the general visions and expectations need to be mapped and made public so that an initial flow of funding is directed towards the niche. After this, the (social) network requires expansion so that the niche is based on a broader set of resources for further development. Finally, an adaption to the market's requirements (e.g. concerning users, technical design, infrastructure, organisation, business models etc.) is necessary. Multiple iterations of these processes lead to more stability and therefore also to a higher adaptation potential of the niche (Geels 2011).

The SNM approach is not necessarily meant to be a government driven process (Schot & Geels 2008). It can also be steered by different economical or societal actors who want to create a 'proto-market' for a certain technology. SNM does not mean a top-down approach of enforcing new technologies but rather a steering process conducted and stimulated by a variety of different actors. Therefore a governance perspective instead of a government perspective is helpful (see 3.3). Empirical studies however show that the approach hasn't been completely implemented in practice and therefore its potential has not yet been fully used (Schot & Geels 2008). Instead of SNM, many actors or actor networks rather apply technology push approaches that focus mainly on the usability of a certain technology and less on the development of a whole niche in the sense of a 'micro-regime'. Key to success is not only the technical development and market-readiness of a technology but also behavioural change of the actors involved to stimulate the development and facilitate broad implementation.

Whether a niche-technology can successfully be developed, largely depends on the existence and functioning of innovation networks. This means that the quality of relations and interactions of actors is crucially important, as key processes in niches are networking, learning and convergence of expectations[32]. Caniëls & Romijn (2008) suggest using the tools of social network analysis (SNA; Borgatti et al. 2009) to quantitatively evaluate the actor-network structures within niches; they prove the added information value of applying SNA to SNM with the example of biofuel production in Tanzania.

[31] Please note the similarities to the participatory backcasting approach in the section about stakeholders (3.3.2).

[32] This relates to the section about stakeholder involvement (3.3).

In which way certain networks contribute to the development depends on their layout (Caniëls & Romijn 2008): Dense networks with intensive interaction of the actors can facilitate performance through quick and comprehensive information exchange. Loose networks with many connections to the 'outside world' limit the risk of a lock-in and open the network (and therefore the niche) for new ideas. There are networks with many lateral connections or with key actors, who connect all the others, which has certain implications: Assuming that a network with intensely interconnected actors has increased information flows, a network density indicator[33] can give first evidence of the communication potential and therefore of the development of the niche. E.g. if there is only one single key actor, its potential loss most probably means the end of the network. Supporting a set of key actors with new information or facilitating connections between them where there are deficits can be used to stimulate the network.

Looking at niche technologies and their development path dependency needs to be considered. "Intuition suggests that if choices were made in a forward-looking way, rather than myopically on the basis of comparisons among the currently prevailing costs of different systems, the final outcome could be influenced strongly by expectations. A particular system could triumph over rivals merely because the purchasers of the software (and/or the hardware) expected that it would do so." (David 1985, p. 335) All forward-looking decisions in favour or against certain technologies are based on expectations. Therefore, a careful evaluation of the regimes, the niches as well as the landscape needs to be done, as well as a realistic assessment of the technologies' potentials, before trying to actively influence niche development. The SNA can again deliver valuable insights here, as it shows the connections and interrelatedness of certain actors who might form specific interest groups.

In the field of transportation Geels (2012) identifies several "promising niche developments" (Table 3-1). Certain technologies face ups and downs in popularity and therefore also in development intensity. Geels (2012) illustrates this with the example of different technical approaches on 'green propulsion technologies' and the shifting public attention for them over time. Besides the time-aspect, popularity can also vary from a spatially (e.g. between different nations).

Table 3-1 Promising niche innovations in transport

Niche-innovations	Contribution to low-carbon transitions
1. Intermodal travel	New (integrated) modes of transport
2. Cultural and socio-spatial innovations	Reduced travel distance, new ownership styles
3. Demand management	Reduced car use, behavioural/organisational change
4. Public transport innovations	Modal shift
5. Information and communication technologies	
(a) Intelligent transportation systems (ITS)	Technical efficiency measures
(b) Tele-working, tele-shopping etc.	Reducing travel needs (substitution)
6. Green propulsion technologies	More efficient fulfilment of existing travel needs

Source: Geels 2012, p. 476

When it comes to translating niche support into policy and political action, decision makers and stakeholders face a dilemma (see Foxon 2011). On the one hand, niches need to receive

[33] E.g. "a scale ranging from 0 (no ties at all) to 1 (all actors are connected to all others)" (Caniëls & Roimijn 2008, p. 623).

enough support and options so that they can possibly benefit from learning effects and economies of scale. On the other hand, it is crucial to ensure a diversity of different niches so that no possible option is excluded.

3.3 Analysing and involving stakeholders in transformation

Approaches, such as strategic niche management or transition management include actors of change or stakeholders. Stakeholders can generally be defined, as "individuals or groups that are or perceive themselves as being affected by or interested in the decision-making on a certain issue" (van de Kerkhof 2001, p. 4). This definition is rather global and includes everyone somehow related to a topic. For empirical applications and from a governance perspective stakeholders are relevant for change if they have the ability to influence the process. This potential can only be effectively implemented if the power to influence the actions of other regime actors. The two criteria – agency and power (Smith et al. 2005) – are main aspects for evaluating who holds a stake and how relevant stakeholders are for transformation processes.

Stakeholders do not necessarily have aligned views about the direction, ways, means, goals and visions of change. Therefore, stakeholder analysis must include not only the stakeholders as actors *in* and agents *of* change[34] but also their interactions, their networks and, their relationship to the regime (Smith et al. 2005). This is especially true as no single stakeholder inherits enough agency, power and resources to substantially change the system on his own. Smith et al. propose the differentiation of "core (regime) members … non-core members and outsider actors" (Smith et al. 2005, p. 1504). These roles are determined by the degree of involvement of an actor in the regime concerning its reproduction. This thought is also used by van de Kerkhof & Wieczorek (2005, p. 737), who see a small core group of stakeholders as initiators and facilitators of participation processes for transformations. In general, stakeholders can be associated to five distinguishable, yet possibly overlapping societal groups: companies, research bodies, government and public interest groups as well as the public as such (Quist & Vergragt 2006).

The following section will give an overview on the roles of stakeholders in change processes. On the one hand, it is important to find out more about how stakeholders are involved in change. On the other hand, it is also essential to facilitate and/or increase this participation in different processes.

3.3.1 Stakeholder participation as a learning process

Van de Kerkhof & Wieczorek (2005) specifically focus on the role of stakeholders in the management of transitions, how learning processes amongst them take place and how those can be facilitated. Learning, from a transition management perspective, "can be understood as a collective process in which the policy makers, scientists and other stakeholders (i.e. subjects of learning) generate new insights into, and a better understanding of, the different perceptions, ideas, interests, and (normative) considerations that exist with regard to the nature of the transition theme, as well as with regard to the appropriate strategies to induce the transition (i.e., the objects of learning)" (van de Kerkhof & Wieczorek 2005, p. 736).

Learning processes are especially important in participatory approaches. To ensure effective learning in participatory stakeholder processes, the constitution and the evolution of the group' are important. The complexity of the system requires less top-down steering processes but rather a bottom-up facilitation of learning. When initiators of the participation process already

[34] This indicates that stakeholders can take both active and passive roles in transformations.

have fixed visions for the outcome, only anticipated or desired results might be produced. A neutral moderator is therefore considered useful. An important aspect of the composition of the group is finding a good balance between homogeneity and heterogeneity of stakeholders (van de Kerkhof & Wieczorek 2005). Heterogeneous actors ensure a diversity of viewpoints and an open discussion. Despite these advantages, there is also a need for homogeneity, as speaking 'the same language' and sharing fundamental ideas can ensure mutual understanding and a communication at eye level throughout the process[35]. Saritas et al. (2013) point out that non-scientific knowledge and social discourse have considerable influence on learning processes. Another balance needs to be found amongst visionaries and realists, so that future-oriented, yet realisable output can be produced. Four more requirements are crucial for a successful learning process: commitment, fairness, transparency and competence (van de Kerkhof & Wieczorek 2005).

After all, learning in participatory processes means not only the production and admission of new knowledge for the participants. It means also aligning views and developing joint strategies to achieve the desired goals. The idea of mutual learning for stakeholders is highly important for the success of transformations.

3.3.2 The role of stakeholders in Foresight

It is important to anticipate future developments of a system when trying to transform it, as this provides the possibility to not only design measures based on the current state but on how the system is expected to develop. This means that developments, which might harm the goals of transformation, can be attenuated and promising potentials can be utilized. Involving stakeholders in foresight studies and ensuring mutual understanding and learning by participants increases a studies' legitimacy (Saritas et al. 2013). The knowledge of people, institutions and organisations who are concerned with a certain issue in their daily thoughts and work, adds valuable insights to an academic perspective. Participatory aspects of future-oriented research focus mainly on the utilisation of expert knowledge, with methods like e.g. Delphi, scenarios, brainstorming or expert panels (Saritas et al. 2013; Table 3-2).

Table 3-2 Foresight methods according to time horizon

Timeframe	Methods
Short-term (< 5 years)	Trend analysis
Mid-term (< 15 years)	Delphi-Study
Long-term (> 15 years)	Scenario development

It is important, to include stakeholders from many different fields and backgrounds (related to the subject) to ensure a holistic view. They should fulfil certain criteria and Saritas et al. suggest three attributes (originating from stakeholder-theory, which is a business-oriented approach) they consider relevant for stakeholder identification: "1. A stakeholder's 'power' to influence decision making 2. The 'legitimacy' of the stakeholder with respect to the issue 3. The 'urgency' of the stakeholder's claim on the issue" (Saritas et al. 2013, p. 46). After all, stakeholder integration can help in getting an image of which development paths can be seen as possible and realistic under which conditions. Of course stakeholder involvement in foresight does not

[35] Note the similarities to strategic niche management, where also the heterogeneity and homogeneity of actors and technological approaches are relevant in niche development (3.2.2).

need to be limited to the gathering of knowledge but can also be used to trigger learning processes (3.3.1).

3.3.3 Participatory backcasting as strategic approach for stakeholder involvement

Not only foresight approaches can provide insights for potential transformation trajectories. Since the 1970s, an important contribution to the participatory involvement of stakeholders originates in the method of backcasting. The basis of backcasting is a desirable future state of a system (= a vision); going backwards from there, the steps and specific measures to achieve this state can be derived (Quist & Vergragt 2006). Backcasting therefore can complement forecasting methods. Not only trends and scenarios can be analysed and developed, but pathways towards desired futures can be created. Backcasting "is not based on the extrapolation of the present into the future – rather, it involves the extrapolation of desired or inevitable futures back into the present" (Vergragt & van der Wel 1998). Therefore, backcasting is especially appropriate when aiming for a desired future state based on normative goals, like sustainability. At this point, it becomes obvious that it is necessary to include stakeholders in the process to ensure the plausibility of the visions as well as the feasibility of the transformation pathways. Therefor the approach of 'participatory backcasting' was developed. Quist & Vergragt (2006) identify five steps for the participatory processes based on a literature review:

1. Strategic problem orientation
2. Construction of sustainable future visions and scenarios[36]
3. Backcasting
4. Elaboration, analysis and defining follow-up and (action) agenda
5. Embedding of results and generating follow-up and implementation

To target these steps, Quist & Vergragt (2006) identify four kinds of toolsets that should be applied:

- participatory tools and methods for involving stakeholders
- design tools and methods for system and process design (see also 3.4)
- analytical tools and methods for the evaluation of participants, plans, markets, etc.
- management, coordination and communication tools and methods for the maintenance of new stakeholder networks.

An essential part of the concept is the implementation of results, i.e. the development of action plans and their implementation in stakeholders' everyday activities are. Only a practical follow-up of backcasting can help to initiate a transformation. This follow-up contains three aspects: *(1) network formation* as an alignment of actors, activities and resources, *(2) the implementation of visions* as orientation and guidelines and *(3) the institutionalisation of the following process*. The fields in which these follow up processes occur are research, business, government and society (Quist et al. 2011). Nevertheless, not all participatory backcasting activities have the same mid- or long-term impacts, so Quist et al. (2011) derived some process-internal success factors; according to that especially high involvement and diversity of stakeholder and implementation orientation are beneficial (Table 3-3).

[36] Carlsson-Kanyama et al. (2006, p. 36) state that it is essential to develop more than only one scenario to be able to cover uncertainties.

Table 3-3 Internal factors influencing the extent of spin-off and follow-up after participatory backcasting

Enabling internal factors	Constraining internal factors
High degree of stakeholder involvement[37]	Low degree of stakeholder involvement
Diversity in types of stakeholder involvement	-
Single vision backcasting experiment	Multiple vision backcasting experiment
High degree of guidance and orientation of the future vision	Low degree of guidance and orientation by the future vision
Institutional protection	-
Presence of vision champions	-
Strong focus on follow-up and implementation	Strong focus on academic achievements
Joint an congruent learning	No learning and learning only at the individual level

Source: Quist et al. 2011, p. 893

Quist & Vergragt (2006) state that participatory backcasting can be applied also on socio-technical systems. Therefore, an application within the frame of a multi-level perspective seems realistic. However, the use of a transition perspective view on socio-technological regimes has not been elaborated on in detail (Quist & Vergragt 2006). Yet, Quist et al. state that "the agenda generated in the backcasting experiment [can] mobilise resources and turn this into actions and activities that ultimately result in 'spin-off and follow-up' that may evolve into a niche" (Quist et al. 2011, p. 887). The approach therefore can as well contribute to strategic niche management concepts (3.2.1; Quist et al. 2011).

3.3.4 Conclusions from a stakeholder perspective

Two conclusions can be drawn from what we have learned about the roles and functions of stakeholders. On the one hand, stakeholders can provide valuable information on both current and anticipated states of systems/regimes as well as possible transformation paths. "Through […] sharing, the interaction of stakeholders is expected to achieve some synergy whereby the outcome or result is greater than the sum of the individual elements being shared" (Currie-Alder 2003, p. 4). On the other hand, "new insights may lead to a change in actors' way of thinking and to joint actions that aim to contribute to inducing the specific transition" (van de Kerkhof & Wieczorek 2005, p. 376). Stakeholders are actors and facilitators of change and contribute actively to transformation processes. In this role, stakeholders can (from a multi-level perspective) fulfil two different functions: "An actor […] may simultaneously be intervening to articulate a selection pressure, while also making efforts to help coordinate the resources necessary for adaptation" (Smith et al. 2005, p. 1497).

3.4 Designing transformation

When actively influencing transitions, i.e. making them transformations, it is important to do this in a coordinated way. "In the context of their unsustainable metabolism, with its non-human nature, our societies will change in any case; the only question is whether by design or by disaster" (Sommer & Welzer 2016, p. 193). In the field of design research, the term 'transformation design' started appearing in the last 10 years. It suggests to use methods and ideas of designers to shape transformations. Sustainability is considered as a normative paradigm here. We discuss some facets of the idea of transformation design to show an

[37] Also supported by Saritas et al. (2013, p. 37): "The active involvement of the various stakeholders from initiation to implementation increases the likelihood of the implementation of the decisions taken".

example how research from a field that is not obviously related to SCCER Mobility can be potentially beneficial in interdisciplinary approaches.

In general, design provides the connection and interface between the user and the material world (artefacts). On the other hand, also social processes can be designed. Ward identifies a "de-material turn in design practice" (Ward 2016, p. 227), a shift from designing material artefacts to designing social an immaterial interaction processes, while conventional design approaches focus on setting material (infra)structure, i.e. physical artefacts that provide answers to any kind of questions that could arise (which therefore don't even need to be formulated any more). Transformation design however wants to ask questions, which might also be answered by not acting or not creating a physical product at all. "Transformation design aims for the least possible effort. This can also mean zero effort" (Sommer & Welzer 2016, p. 197). "The design of a sustainable, reductive modernity is, for the time being, not a design task aimed at designing or redesigning products, buildings, or cites. The development of transformation design is a social and cultural task and consists initially, in a higher level perspective, in democratically negotiating what is a good life and what it requires. And it consists in the task of drawing design conclusions from this definition" (Sommer & Welzer 2016, p. 198).

According to Jonas et al. (2016), transformation design's task is to shape the development paths of society and economy towards sustainable economic and societal configurations. In this context design can show options, lay out paths and construct opportunities. "The term *innovation* lies in the heart of the discipline, meaning that it is about change, about creating something new" (Joost & Unteidig 2016, p. 135). With the goal of sustainability in mind, transformation design is intentionally constructed on a normative basis (Jonas et al. 2016, p. 15). Some publications therefore normatively advocate an economic model without any material growth but actual reduction of resource usage and increased global fairness to be the basis of their design approaches (e.g. von Anshelm 2016, Melles 2016, Wood 2016).

Melles (2016) states that there are different approaches to assess this sustainability paradigm in general. On the one hand, there is the belief in human and technical superiority and its potential to make societies sustainable. On the other hand, there are post-growth theories, such as by Tim Jackson ("Prosperity without growth") or Dennis Meadows ("Limits to growth") that state the supremacy of nature's limits on (physical) growth. The field of design can already contribute a lot to the first perspective, e.g. by industrial design approaches that promote the use of less resources or more sustainable material components for products. The second perspective however is harder to implement, as it requires substantial and targeted systemic change in society, economy, policy, technology, education and research, culture, norms and values. Design can support here, as design is attributed "the process competence to conceive and organise change processes" (Jonas 2016, p. 115).

Generally, transformation design can be seen in the context of improving system resilience[38]. It "considers itself as resilience research and resilience generator – as means of restoring and maintaining resilience" (Sommer & Welzer 2016, p. 197). In accordance to the sustainability perspectives presented above, "transformation design will not only reduce the required quantities of material and energy, but it will also increase people's autonomy" (Sommer & Welzer 2016, p. 198) in the sense of an emancipation from relying on (critical) technical systems/infrastructures that greatly reduce the society's and also the individuals' resilience.

[38] Please note that the notion of 'system' has a much wider context than the one we talk about in 3.1.4.

Zerwas (2016) defines three general attributes for every process in transformation design: transdisciplinary, flexible and holistic. From a practical point of view, increased potential for change can be obtained by "social, economic, and ecological experiments […]. On a small scale, these experiments can be radical, fresh, totally different, and, in the broadest possible range, 'future-oriented'. The crucial point is not so much whether individual experiments are particularly successful; the mere fact that people experiment with new forms of social coexistence, of business, production, and human interaction, already engenders the necessary relaxation of the societal system" (von Anshelm 2016, p. 24). This view aligns with the approach of strategic niche management (3.2.1) and von Anshelm calls these niches "micro-utopias" (von Anshelm 2016, p. 25). This term already implies the future-directedness of the niches and the development of visions and dreams of 'how it could be'. Zerwas names the ability to develop utopias and envision the pathways leading to them "the competence of creative projection" (Zerwas 2016, p. 265). She also points out that both the free-minded ability to envision desirable futures and the more structured skills to perform deep analysis and integrated/networked thinking are essential for transformation design.

The process of designing utopias does not follow the standard design procedure (analysis – projection – synthesis) but sets the projection as first step. From this imagined future (vision), specific ways towards it can be developed[39]. Furthermore, drawing positive dreams as scenarios can cause strong desires so people aim at actually achieving them. "This imaginative process is very successful in creating acceptance for such new realities and realistic possibilities. By envisioning post-growth scenarios and designing fictional daily lives in the corresponding society, people begin to see worthwhile alternatives to today's unsustainable lifestyles. By focusing on positive aspects first, such future scenarios can become utopias with a strong pull effect" (von Anshelm 2016, p. 26). After all, also ways of effectively communicating these visions so that they unfold their motivating force are as important as the ideas and scenarios themselves. Yet, "so far, we have neither a theoretical model nor an empirical example of a modern society that realises the civilizational characteristics of freedom, democracy, the rule of law, social care, education, and healthcare under conditions of greatly reduced ecological impact compared with today" (Sommer & Welzer 2016, p. 195f).

Whilst transformation design requires a holistic approach (i.e. taking into account multiple perspectives) when discussing about utopias and visions, this does not mean that every aspect of change needs to be targeted at once. Designing transformation cannot have a controlled and intentional economic, social, political and cultural shift of the whole system as its goal. The reason is the complexity, non-linearity and emergence of unexpected outcomes in modern societies. Therefore, Sommer & Welzer (2016) suggest "to start from segmental transformations of different type and effect, which is also politically advisable". This aligns with a governance-perspective that envisions gradual systemic change through changing system components (3.3).

Wood (2016) attributes great importance to 'keystone innovations' as drivers for change. He sees keystones as tools to achieve the desired utopias through 'reverse-engineering' of technology/innovation design. This view can broadly be aligned with a MLP with existing paradigms as regimes and keystones as niche technologies. Keystone innovations can shape new paradigms, i.e. new socio-technical regimes when being developed and implemented at the right time[40].

[39] See also the approach of participatory backcasting in 3.3.3.

[40] 'Windows of opportunity' (3.1.4).

From a more stakeholder-oriented viewpoint, transformation can be supported as well by means of design. Employing a practical and pragmatic implementation perspective, Zerwas (2016) develops an idea how to facilitate creative approaches that lead to the desired motivating development of visions/utopias, e.g. in the form of workshops, which is summarised in Table 3-4.

Table 3-4 Method pool for involving actors in developing utopias/scenarios for sustainable transformation goals

Scenario Building	Scenario technique incl. storytelling elements (Ogilvy and Schwartz 2004)[41]
Design Fiction	Combination of storytelling with material crafting of objects. Bleecker (2009)[42]: 'Design fiction creates socialized objects that tell stories.'
Design Prototyping	Paper crafting, sketch notes, rapid prototyping
Performance	Bodystorming, improvisational theatre, lecture performance
Theory U, Future Workshop	Dialogue, discussion, prototyping
Creative Writing	Science fiction, short stories, personas
Cultural Hacking	Communication guerrilla, faked campaigns
Serious Gaming	Playful simulations, educational games

Source: Zerwas 2016, p. 273

The transformation-facilitating field of design, just as innovation in general, is no longer a top-down process run by experts ('designers') but rather a product of interacting actors. "A brilliant idea is not the only way to kick off a design process; on the contrary, a good network and a collection of resources might be just as vital and efficient" (Joost & Unteidig 2016, p. 138). The general individualisation of society and consumption opens up new chances for new products, business models, local interactions etc. (Joost & Unteidig 2016,). This can be seen as an increase of niche potential, not only for technologies but also for social practices. This is set in the context of global as well as local social networks and communities, whose aim is to implement their own vision of sustainability, e.g. with urban community gardening, sharing economy, that are in one way or another subject to design-issues (Joost & Unteidig 2016). Generally speaking, design is no longer attributed the business of realizing something new, but rather of abandoning things that are not needed any more, which "means, for example: no designing a bottle for a new mineral, but rather the signpost to the next tap" (Sommer & Welzer 2016, p. 199).

3.5 Change of mobility behaviour as a process (ZHAW)

Individual (mobility) behaviour and its change is a key issue within the transformation process towards as sustainable mobility system. To address problems of unsustainable mobility like too high energy consumption and pollution resulting in climate change and health issues (e.g. Hosking, Mudu & Dora 2011), in the few last decades, governments have implemented numerous push and pull measures to manage car transport demand and promote more environmental-friendly travel options respectively (Broaddus, Todd & Menon 2009). However, the success of such measures largely depends on public acceptability (Gärling & Schuitema 2007), which implies personal decision-making processes resulting in travel behaviour. Measures based on behavioural economics such as incentives or nudges (Thaler & Sunstein

[41] Ogilvy J., Schwartz P. 2004, Plotting Your Scenarios. Emeryville.

[42] Bleecker J. 2009, Design Fiction: Short Essay on Design, Science, Fact and Fiction. Los Angeles.

2009) have been suggested. Approaches focusing on awareness, motivation or decisions are also being discussed and have been tested in different projects. However, a systematic overview of factors influencing behaviour change in the context of mobility is yet unavailable. Behaviour change theories may play an important role in transport research by explaining this decision-making mechanism of travellers and the effect of measures that aim to influence it (Bamberg, Fujii, Friman & Gärling 2011).

Thus, a theory based model has been developed - as a basis for practical use and the design of systematic intervention aiming for systemic change at different levels of societal change, change in decision making as well as individual behaviour change. The model is based on a comprehensive literature review on the use of theory related to mobility behaviour change.

According to the recent compilation of Michie et al. (2014) there are 83 behaviour change theories. These theories define the determinants that influence actual behaviour and suggest causal models that explain the decision-making process. Behaviour change theories have been mainly created from a psychological, sociological, anthropologic and economic perspective, but they have been applied in different fields of study e.g. health, environment and transport (Michie et al. 2014). Existing transport literature reviews have focused on specific theories such as the Theory of Planned Behaviour and the Norm Activation Theory (Bamberg et al., 2011), while more extensive reviews are only available in other disciplines e.g. health communication (Angus et al. 2013). A comprehensive overview of the behaviour change theories that have been applied to explain travel behaviour in terms of sustainable mobility allow to identify most appropriate theories for sustainable mobility issues.

In the end, the knowledge of behaviour change should be used to design effective interventions. Interventions are measures that aim at changing behaviour and can comprise several techniques defined as “observable, replicable, and irreducible components of an intervention designed to alter or redirect causal processes that regulate behaviour” (Michie et al. 2013). It has been recommended to use behaviour change theories for interventions’ design to increase their effectiveness, to provide a better understanding of mechanisms influencing behaviour and to improve the suitability for predictive models (Michie et al. 2013). However, these theories concentrate on the definition of determinants that explain actual behaviour, and little information regarding the appropriate techniques required to apply the theories is available (Abraham & Michie 2008). Thus, the final goal within SCCER is to explore the type of interventions that have been applied based on concepts of behaviour change theories to change travel behaviour towards more sustainable mobility. The output may contribute to easing the selection of the most suitable intervention for the targeted behaviour change.

3.5.1 Interventions to change mobility behaviour

Interventions found in the reviewed empirical publications can be grouped in six categories: 1) providing information, 2) fostering self-experience of travel alternatives, 3) planning travel behaviour, 4) rewarding travel alternatives, 5) dissuading negative travel behaviour (mostly car use) and 6) improving conditions of travel alternatives like service, fee, infrastructure[43].

Information provision

Taniguchi et al. (2003) carried out the first attempt to explain the impact of the so-called Travel Feedback Programs in terms of a behaviour change theory. This intervention consisted of several phases. Firstly, participants received leaflets with explanations about the goal of the

[43] Publications can combine different categories of interventions. The following sections mainly focus thematically on one category; publications can contain several.

experiment, i.e. the reduction of CO_2 emissions through travelling in a more sustainable way. Secondly, the participants recorded their mobility patterns in a travel diary. Thirdly, they received suggestions from the project coordinator about how to change their travel behaviour. Finally, the participants kept a second diary and they received a final feedback comparing both diaries to show the change. The authors found positive effects of the Travel Feedback Program on travel behaviour and they were visible one year after the intervention. The study confirmed their initial hypothesis based on the Norm Activation Theory: awareness of consequences activates moral obligation, which influences behavioural intention. Therefore, not only "egoistic motivation", but also awareness of negative consequences of unsustainable mobility should be activated in order to change travel behaviour. Taniguchi & Fujii (2007) implemented a similar Travel Feedback Program but built a joint model with constructs from the Norm Activation Theory and the Theory of Planned Behaviour and considered the role of habits. By using this joint model, they demonstrated that habits blocked behavioural intentions and consequently behaviour change, whereas the altruistic factors from the Norm Activation Theory measure behaviour intentions better than the non-altruistic constructs of the Theory of Planned Behaviour. Furthermore, the Travel Feedback Program influenced intention through the information made available about new travel alternatives.

Beale & Bonsall (2007) explored the effect of persuasive messages by providing two different types of marketing material to reluctant bus users. The first one aimed to "correct" negative misperceptions about fare, waiting time or likelihood of seating, while the second one surprisingly admitted that the car might be a first option in some cases, but highlighting the convenience of bus use in other circumstances. The results showed that the first type of marketing material produced a negative effect on bus use, whereas the second type significantly increased it. The authors concluded that the message of the second marketing material, designed to take into account personal attitudes described in Theory of Planned Behaviour, was more persuasive because it was closer to participants' opinions. Bamberg (2013a) tested the joint model of Gärling et al. (2009) and Bamberg et al. (2011) by classifying the experiment participants by their stage of willingness to reduce car use (pre-decisional, pre-actional, actional and post-actional). The intervention consisted of phone calls providing specific suitable information for the corresponding stage. The experiment demonstrated that this personalised information reduced car use in a higher proportion than traditional standardised marketing material.

Tulusan et al. (2012) experimented with a mobile application to increase energy efficiency in the way of driving, also called eco-driving. The application provided in-car automatic feedback on acceleration, braking, speed, recommended gear and overall journey ecological score. The authors analysed the effect of this intervention on eco-driving through the lens of the Feedback Intervention Theory and they concluded that the feedback changed the locus of attention of participants from time to environmental concerns, reducing fuel consumption by 8%. Staubach et al. (2014) reduced fuel consumption by 18% with a similar device and they designed a questionnaire that measured the user acceptability of such equipment using three constructs of the Technology Acceptance Model: perceived ease of use, perceived usefulness and behavioural intention to use.

The organisation of public events can also contribute to increasing awareness for sustainable mobility alternatives. For instance, a "ride to work day" organized in Australia, including advice about cycling skills and distribution of information such as cycling maps, convinced participants to cycle. The Transtheoretical Model was applied to classify the survey participants according to their behaviour change stage (pre-contemplation, contemplation, preparation, action and maintenance) and to track their progress. Thus, 72% of new riders moved in one year to a more cycling engaged stage when their status before and after the event is compared (Rose & Marfurt 2007).

In summary, providing information and giving feedback can contribute to changing travel behaviour by activating altruistic motivations described by the Norm Activation Theory such as the awareness of negative environmental consequences of unsustainable mobility and by providing travel alternatives that increase the intention to change behaviour according to the Theory of Planned Behaviour. In order to maximize the effect of information material, it is recommended to classify the potential receptors by their stage of change, as Transtheoretical Model explains, and to provide persuasive content suitable for their attitudes as described by the Theory of Planned Behaviour. If the information is provided by means of an electronic device, its ease of use and its usefulness should be highlighted following the approach of the Technology Acceptance Model.

Fostering self-experience of travel alternatives

To stimulate first-hand experience of alternative travel choices, Abou-Zeid et al. (2012) forced workers in Switzerland to use public transport over a period of 2 or 3 days by providing free tickets. The rationale was that, as Prospect Theory states, travel choices are determined by gain or loss assessments regarding a reference point. Thus, the enforced first-hand experience with public transport may create a new and more consistent reference point for their assessment and for the comparison with car use. The study measured, by means of a questionnaire, four assessment-related variables before and after the free tickets: attitude, perception, expectation and satisfaction with public transport and car use. The result revealed that the satisfaction rate of participants increased, but none of them completely shifted from car to public transport. Unlike in Switzerland (Abou-Zeid et al. 2012), in Massachusetts (Abou-Zeid & Ben-Akiva 2012) 30% of workers participating in a very similar experiment stopped using cars (cancelling their parking permits and purchasing a public transport pass). However, “those who switched to public transportation were more predisposed to switching, were more cost-conscious, and had more favourable perceptions and attitudes towards public transportation”, while “those who did not switch became happier with their cars", which is a counterproductive outcome (Abou-Zeid & Ben-Akiva 2012). Hunecke et al. (2001) built a joint model mixing constructs from the Theory of Planned Behaviour and the Norm Activation Theory to analyse the impact of free tickets on subway use in Bochum, Germany. The model considered that personal ecological norm (measured by e.g. “responsibility for environment”) is influenced by four model constructs: feeling of ecological guilt (for using the car), awareness of consequences (e.g. pollution), subjective norm (expectations of a certain person) and perceived behaviour control (easiness and freedom to use subway). The research revealed that the intervention, i.e. the distribution of free tickets, had a positive effect on subway use, but it was similar to two other model constructs affecting subway use: personal ecological norms and subjective norms. Therefore, the research concludes that a mix approach “economical-plus-moral” is recommended to change travel behaviour.

Matthies (2003) and Matthies, Klöckner & Preißner (2006) also explored the effect of free tickets on public transport use in Germany, but built a model derived from the Norm Activation Theory. They assumed that mode choice depends on personal norms, social norms, perceived behavioural costs and habits. To change travel behaviour, the study participants received public transport tickets free of charge, a plea for commitment for public transport use or both. The study concluded small effects of the intervention compared to the control group and it argued that the effectivity of the interventions depends on framework conditions. Thus, a temporary change of behaviour caused by a defrosting intervention would only change behaviour in a long-term if new behaviour is considered as positive and more successful if personal norms and external determinants – like lower costs or better transport connections than expected - support the target behaviour (Matthies et al. 2006).

Bamberg, Rölle & Weber (2003) and Bamberg (2006) analysed the positive impact of providing a free one-day public transport ticket and an information kit to people planning to move to Stuttgart. To understand the reasons behind this modal shift, a model inspired by the Theory of Planned Behaviour was built and it found that the intervention changed behaviour model constructs such as attitude, subjective norm and perceived behavioural control indirectly (Bamberg et al. 2003). Bamberg, Rölle & Weber (2003) found that neither past behaviour nor current habit play an important role in predicting future behaviour. Bamberg (2006) confirmed this finding and concluded that objective increase of public transport quality and previous plans to change behaviour are more relevant in reducing car use. Thøgersen (2009) distributed one-month free public transport tickets among card drivers in Copenhagen. Additionally, some of them received a personalised travel plan. Applying a model with constructs from Theory of Planned Behaviour plus car habits and cost perception considerations, the study revealed that only the monthly ticket produced a significant increase in public transport use, mediated by intentions to use public transport. The effect of the intervention decreased in the course of time, but it was still appreciable after five months (Thøgersen 2009).

In short, forcing the experience with alternative ways of transport, e.g. by providing free public transport tickets, can cause a change in travel behaviour by defrosting habits. Both economic and moral incentives (described in the Norm Activation Theory) as well as previous plans based on attitudes (from the Theory of Planned Behaviour), are recommended to be addressed. However, to produce a durable change, the forced experience has to be positive e.g. public transport service has to be satisfactory. Otherwise, the intervention can become counteractive and dissuade from future use.

Planning travel behaviour

Eriksson, Garvill & Nordlund (2008b) asked study participants to keep a diary with the car trips they planned to make the following week. The authors assumed that car use habits can be mediated by personal norms, which is a relevant behaviour construct of Value Belief Norm Theory. The study measured both among the participants and confirmed that mode choice became "more deliberate" because the above-mentioned travel planning weakened the influence of car habits and strengthened the link between the targeted behaviour and personal norms (related to the motivation to reduce car use). Furthermore, participants with strong car habit and strong motivation to reduce personal car use became more willing to reduce car use after the intervention.

Therefore, the creation of a travel plan can increase awareness of actual mobility patterns and commitment for the targeted new behaviour. Personal (pro-environmental) norms described in the Value Belief Norm Theory can contribute to explaining the effect of this intervention.

Rewarding travel alternatives

Ben-Elia & Ettema (2011b) evaluated the effect of monetary rewards and credits for a smartphone handset in order to motivate commuters to avoid rush hours by changing their travel times, by using an alternative transport mode or by teleworking. They concluded that both kinds of rewards as effective tools to change commuting behaviour and they theorise assumptions and interpret results based on the relevance of attitudes according to the Theory of Planned Behaviour and of loss aversion according to the Prospect Theory (Ben-Elia &

Ettema 2011b). In another study, they found that sensitivity of travel behaviour as a result of monetary rewards decreases over time, while the possibility of winning a Smartphone motivated participants by means of fear of not winning something that they wish for (Ben-Elia & Ettema 2011a).

Hence, rewards can motivate individuals to change travel behaviour by means of the loss aversion described in the Prospect Theory. However, more than money, individuals seem to appreciate rewards associated with feelings or wishes. Thus, to maximize motivation, beyond economic remunerations, rewards have to connect with individuals' attitudes explained in the Theory of Planned Behaviour.

Dissuading negative travel behaviour
Schade & Schlag (2003) explored the acceptability of two strategies that combined different pricing measures such as fuel taxes, road pricing and parking fees in four European cities. Building a joint model with constructs from the Theory of Planned Behaviour and Norm Activation Theory, they found that especially social norm, personal outcome expectations and perceived effectiveness were positively related to the acceptability of pricing strategies.

Schuitema, Steg & Rothengatter (2010) focused on car toll charges and analysed user acceptance for two hypothetical road pricing policies: charging high congested areas and charging high mass/km vehicles. Supported by the Goal-Framing Theory they initially assumed that "both beliefs on individual and collective outcomes will predict the acceptability and personal outcome expectations of transport pricing policies". Their results revealed that acceptability of congestion dependent and mass dependent pricing increases when car users expect improvements in traffic congestions and environment. This implies that lacking acceptability of transport pricing might mainly be based on the fact that people are not convinced that these policies will reduce congestion and environmental problems.

Loukopoulos et al. (2005) presented three hypothetical alternatives for mobility measures to study participants, including two dissuading interventions with different levels of coerciveness and one informative action: 1) prohibiting car use in city centres, 2) road pricing and 3) individualized marketing. The study assumed, as the Theory of Planned Behaviour does, that beliefs determine attitudes, which play a relevant role in behaviour. Therefore, the experiment analysed the participants' beliefs regarding the impact of the three aforementioned measures on four issues: urban environment quality, car accessibility, non-auto accessibility and travel costs. Road pricing, followed by car use restrictions and individualised marketing, reported the strongest negative attitude score among the participants, while increasing non-auto accessibility lead to positive attitudes. Furthermore, overall attitude towards the measures was not found to be moderated by car ownership or household income, but by environmental concerns. Thus, the study concluded that measures affecting beliefs concerning travel costs and conditions of non-auto transport modes as well as increasing environmental awareness have higher acceptability.

In brief, interventions dissuading car use can have low acceptability. To increase this acceptability, it is recommended to appeal to moral reasoning and explain beneficial outcomes of travel behaviour changes as described by the Norm Activation Theory and Goal-Framing Theory.

Improving conditions of travel alternatives
The effect of the introduction of a semester ticket at the University of Giessen (Bamberg & Schmidt, 1998; Bamberg & Schmidt, 2001; Bamberg, Ajzen, & Schmidt 2003) was analysed

applying a model based on the Theory of Planned Behaviour. The semester ticket increased bus use and reduced car use in a similar proportion among students (Bamberg & Schmidt, 1998). The effect of the semester ticket was mainly "mediated by attitudes towards the behaviour (preferences) and by perceived restrictions" (Bamberg & Schmidt 1998). Unexpectedly, study participants more reluctant to restrict car use policies reported higher travel changes as a result of the semester ticket due to their higher elasticity to economic incentives (Bamberg & Schmidt 2001). Moreover, habits appeared to be relevant for current and future behaviours only if the framework conditions remain "relatively stable" (Bamberg et al. 2003). At the University of Columbia, a similar study analysed the impact of a universal bus pass by means of a model based on the Theory of Planned Behaviour plus additional constructs such as social norms, moral norms and environmental concerns. The universal bus ticket (called U-pass) produced an increase of public transport use by changing "attitudes and beliefs about transport modes" (Heath & Gifford 2002). Furthermore, the authors of the study concluded that "once participants begin to use the bus more often as a result of a U-pass program, they develop less biased, more realistic perceptions of public transportation, and that beliefs about the outcome of using public transportation become more positive" (Heath & Gifford 2002). Ceder et al. (2013) investigated how public transport passengers perceive the following five out-of-vehicle trip attributes with uncertainty: waiting time, transfer walking time, delay time, comfort of seating while waiting and personal security. The study modelled travel route choice according to the Prospect Theory and found that public transport users are more willing to undertake routes with lower out-of-vehicle times. Therefore, the authors recommend to increase "consistency in out-of-vehicle times" in order to increase attractiveness of transfers and public transport use.

The acceptability of improving conditions of travel alternatives has been compared with other types of interventions in Sweden. Thus, Eriksson, Garvill & Nordlund (2006) asked in a survey about three likely scenarios: awareness campaign with brochures containing information about the environmental impact of car use and more sustainable alternatives, increase of fuel taxes and improvement of public transport in terms of frequency and price. Survey respondents pointed to the improvement of public transport as the most effective measure for reducing car use, followed by fuel taxes and information campaign oriented measures. A model with constructs from the Value Belief Norm Theory revealed that the acceptability of fuel taxes measures is mainly affected by the level of moral considerations (feeling of responsibility regarding environmental problems due to car use) and perceived fairness of the measure, while the acceptability of improving public transport is especially dependent on the level of problem awareness and the perceived limitation of freedom in transport mode choice. Eriksson, Garvill & Nordlund (2008a) worked with a similar model, but considered the scenario of subsidising alternative fuels instead of the campaign scenario, and found that pull measures (public transport improvement and subsidies for alternative fuels) have better acceptability than push measures (increase of fossil fuel taxes). Moreover, the study revealed that problem awareness is the main determinant of the acceptability of pull measures and personal norms of acceptability of push measures. Furthermore, perceived fairness and effectiveness of the measures are particularly important for overall acceptability. Eriksson, Nordlund & Garvill (2010) evaluated these measures incorporating aspects of the Theory of Planned Behaviour into the Value-Belief-Norm Model. Considering the fuel tax, the public transport improvement and the combined scenario, it found that the last one is the most effective measure in reducing car use. In addition, it remarked that personal norms, intention and perceived impact of the measures are relevant factors that affect outcome.

In brief, the improvement of conditions of alternative transport modes has better acceptability among travellers than other intervention types, especially when positive effects and moral norms from the Value-Belief-Norm Theory are highlighted. For instance, public transport passengers especially welcome short waiting times in intermodal transfers under uncertainty conditions described by the Prospect Theory, and flat-rate ticket policies can improve attitudes and beliefs about public transport according to the Theory of Planned Behaviour.

3.5.2 A model of behaviour change as a basis for intervention design

Behaviour change theories have been used in the context of changing mobility behaviour towards sustainability. Car use is the most frequently targeted behaviour, but recent mobility concepts such as electro-mobility, eco-driving, bike-sharing and intermodality have already started being investigated under the lens of behaviour change theories. The Theory of Planned Behaviour is by far the most applied behaviour change theory in this context. A possible reason for this is that it has been tested in numerous experiments beyond the field of transport (e.g. Armitage & Conner 2001; Hardeman et al. 2002), which might make researchers more confident to further apply it. Moreover, the cognitive approach of the Theory of Planned Behaviour might be especially suitable for the transport field because it assumes that experiment participants did not ask for help to change behaviour and their intention to change behaviour is not formed yet (Hardeman et al. 2002), which is normally the case in mobility related experiments. However, the dominance of this theory might have led to underestimated potential of other behaviour change theories. Besides the Theory of Planned Behaviour, nine other theories have been used to assess the impact of interventions. These theories can also play a relevant role in explaining additional issues of the decision-making process. In fact, several publications have combined approaches from different behaviour change theories to increase the accurateness of models. The most frequent combination includes the Theory of Planned Behaviour, which bases on rather individual aptitudes and perceptions to explain the intention to perform behaviour and the Norm Activation Theory, which is the second most applied theory and mainly focuses on the importance of more global aspects such as common problem awareness and sense of responsibility.

Regarding the interventions, it should be remarked that most of them comprised just one technique, e.g. the introduction of a public transport semester ticket. Travel Feedback Programs represent a partial exception. They comprise several techniques such as information about the negative impact of mobility, request of daily mobility reports of experiment participants and personalized feedback with suggestions on alternative mobility options to reduce car use (Taniguchi et al. 2003). Nevertheless, a comprehensive strategy including several techniques that cover all aspects determining the behaviour change process is still lacking in the literature.

Moreover, it has been found that pull measures, i.e. interventions that aim at dissuading from a negative travel behaviour, have lower acceptability than push measures, i.e. interventions that aim to convince about a new travel behaviour. However, most of the studies did not analyse the impact of implemented push measures, but just a subjective assessment of experiment participants regarding a hypothetical implementation. Their opinion might become more favourable after the implementation of the coercive measure and after the positive effects. In fact, it is recommended to combine both push and pull measures to increase the success of supporting individuals towards establishing new travel behaviour (Eriksson et al. 2008a).

Concerning the role of behaviour change theories, it is important to note that most did not actually use behaviour change theories to design interventions. Instead, the interventions were previously decided and the theories were just applied to model or interpret the impact of these interventions on mobility. Therefore, the potential of behaviour change theories to increase the effects of intervention towards a more sustainable mobility has not been completely exploited yet.

Based on these findings many options for supporting individual behaviour change towards sustainability appear; this reveals potential to support the new Swiss energy strategy, with transformation targeting a low-carbon and energy efficient energy and mobility system. A theory based model was developed to provide a basis for practical use and the design of systematic intervention aiming for systemic change at the level of individual behaviour change. Thus, the conceptual model presented here is meant to provide a theoretical basis with links to practical interventions that can be applied to address the key factors at the most promising starting points in order to change behaviour as derived from theories.

Instead of spreading measures based on a one-fits-all ideology, this approach should enable one to provide specific behaviour change support and thus to increase the success rate. In this context, the suggested model combines theories of behaviour change, which are structured along the process of behaviour change and are linked to certain interventions at different stages of this process. Based on this, a program of interventions can be developed, evaluated and used to further develop the approach. Related to the context of systemic transformation, the approach is covering a wide, more general claim of mobility behaviour change, which is based on the idea that certain aspects of behaviour change, e.g. like reducing the use of the car, are linked to general mobility behaviour, which are mainly due to two relevant points:

1. the individual need to replace behaviour/use of one mode (or modes) by another or other behaviours/modes, and

2. the growing focus on “mobility” instead of “trip, transport and travel” as classical research topics raises the awareness of and need for understanding travel as a holistic phenomenon which is reflected in the recent discussion of intermodal and multimodal services, shared mobility etc.

Thus, a model providing a broad basis for different behaviours to be analysed should help to address mobility behaviour change as a complex process, while at the same time doing both, allowing and requiring a specification for the application in practice, e.g. when building strategies and designing intervention programs.

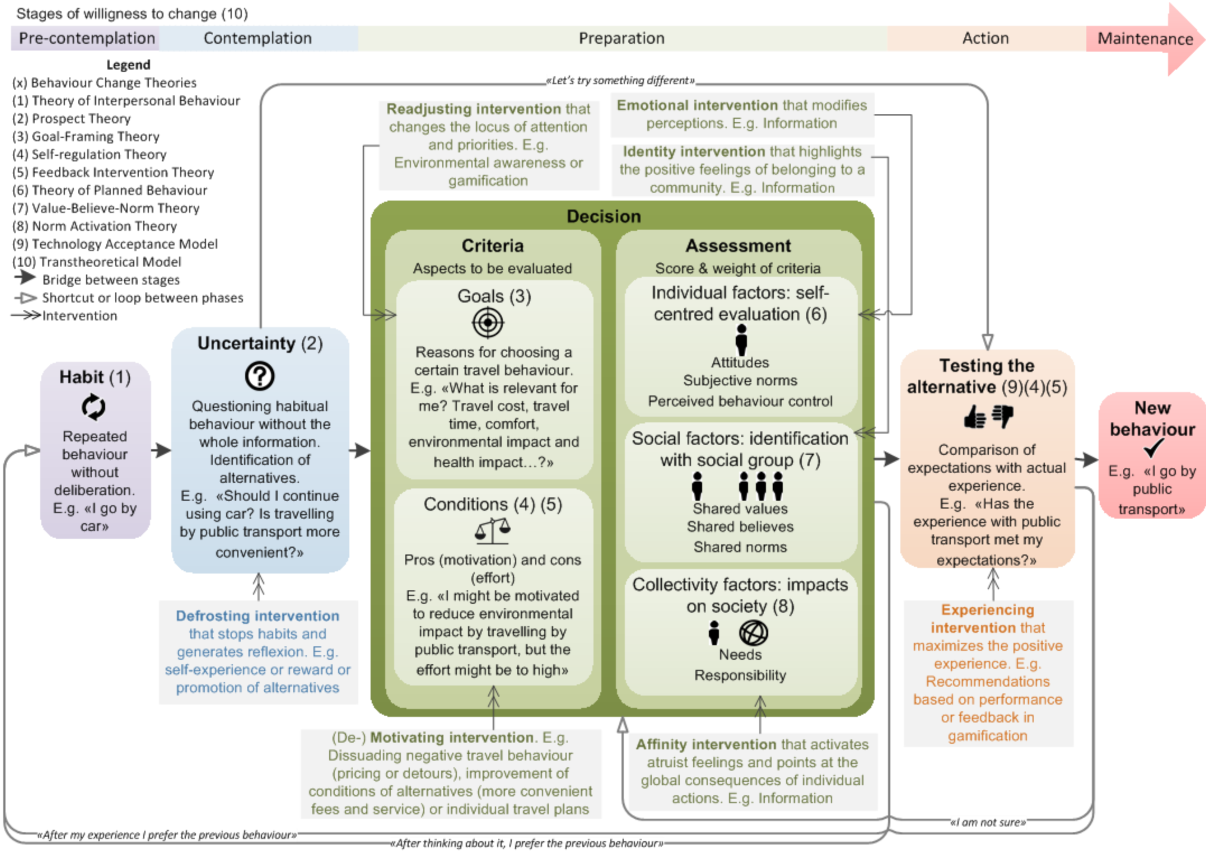


Figure 3-2 Process of changing travel behaviour including relevant theories and interventions

The customisation of interventions depending on the stage of behaviour change process of individuals appears to be crucial to increase their effectivity, as Bamberg et al. (2011; see also Gärling et al., 2009) stated in the context of effectiveness of soft transport policy measures and related to the self-regulation theory (Bamberg et al. 2011; Gärling et al. 2009), which suggests stages for the change process.

According to this, the suggested model covers five stages of behaviour change explained in the Transtheoretical Model of Behaviour Change for intentional change. The model is meant to guide decision makers and researchers in the design of the most suitable combination of measures for each target group that lead individuals' decisions through the different stages of change. By providing a package of interventions addressing specific stages in the change process they are expected to increase impact and extend permanency of the change.

Although behaviour change is described as a process of stages in a certain order stages might occur in parallel and also build loops of going back from one to a certain other stage instead of proceeding along the idealised process of the model.

In the **pre-contemplation** stage **habitual** behaviour is dominant; individuals do not think about changing it, e.g. travelling by public transport instead of using the car. The Theory of Interpersonal Behaviour can contribute to further explain this phase, since it shows the role of habits affecting intention, which is also different aspects of beliefs (attitudinal, personal and social normative) and facilitating conditions, according to the theory. Thus, designing conditions, addressing beliefs and breaking the habit should have an impact on the intention. Insights from the Norm Activation Theory addressing responsibility and supporting ability could help to find access to the normative representations of individuals and to design defrosting interventions for this crucial step.

The **contemplation** stage is one of first **uncertainty**, where individuals may start deliberating about the suitability of the habitual travel option. In this phase they do not yet have all of the information necessary for an assessment, but they question themselves whether they should change their behaviour. In order to stimulate this insight, a catalyst is helpful. Providing information about potential gain or loss, related to the Prospect Theory, linked to personal values and norms could help to stop habits in this phase of uncertainty. Defrosting interventions such as promotion of travel alternatives or induced experiences with rewards are recommended. Also forced experiences can produce a shortcut and push individuals directly to test alternatives (action stage) without a previous intentional decision process.

In the **preparation stage** individuals decide on the adoption of new travel options by **assessments** based on **evaluation-criteria**. Concerning criteria individuals may consider goals that make travel options eligible to them (e.g. comfort or low environmental impact). Interventions to increase environmental awareness or information related to individually relevant aspects such as health or fitness may change the focus of goals at this stage. The Goal-Framing Theory can point to the most appropriate goals (differentiated by normative, hedonic and gain perspective) to be activated with these interventions. Also **conditions** for the achievement of goals need to be taken into consideration, i.e. advantages and disadvantages (pros and cons) of the different travel options. Thus, interventions that aim to modify these considerations should increase the required efforts of unwanted, less-sustainable travel options (e.g. by pricing) and increase motivation of positive new travel options (e.g. by improving service). The Self-Regulation Theory and the Feedback Intervention Theory can contribute to the design of these interventions with aspects related to the perception of the individuals' environment and with the foresight of motivating and demotivating consequences of feedback when experiencing the new travel option.

The **assessment** of the identified criteria is influenced by individual, social and collective factors addressed in: Theory of Planned Behaviour referring to rather self-centred factors such as attitudes, subjective norms and perceived behavioural control, the Value-Belief-Norm Theory indicating the relevance of identification with social groups and the Norm Activation Theory focusing on more global factors like needs and a sense of responsibility. Using this knowledge, interventions aiming to influence criteria assessment should specifically change perceptions, stimulate identity feelings or activate altruistic actions. Thus, depending on the assessment level interventions would differ. While on the individual level emotional intervention, e.g. activating norms and perceived behavioural control by story-telling, on the level of social factors pro-environmental beliefs and norms might be linked to group experience on social events or within social networks.

In the final **action** stage individuals have already taken a decision based on their experience with a new travel option. At this moment, individuals may compare their expectations with the actual performance. If the balance is positive, they will repeat and adopt the new behaviour, but if the balance is negative, they will reject a new trial or will deliberate again about the convenience of the new behaviour. Thus, interventions during this critical stage on the way of establishing a new habit one should focus on motivating individuals for repeating the behaviour, e.g. with incentives or feedback based on gamification. The Self-Regulation Theory and the Feedback Intervention Theory may provide hints about the formulation of the motivating feedback. The Technology Acceptance Model may help to highlight the easiness and usefulness when becoming familiar with the use of new technologies, e.g. electronic devices or information apps, especially in the testing phase where difficulties to handle the technology might lead to a throwback to familiar habits.

The model suggested here provides a framework combining behaviour change theories with interventions on a general level to be applied in practice; it should serve as a basis for designing these intervention (programs) addressing specifically certain stages in the process of behaviour changes, which is expected to increase the success rate of change in the long-term.

An issue, which needs to be solved for the practical implementation of the model, is how to identify individuals' current stage within the change process and to classify them into different target groups. As interventions are part of projects, campaigns or programs supporting change in the first step of target group analysis, necessary data need to be collected, e.g. by using questionnaires, interviews or focus groups.

Results of previous research and successful campaigns provide evidence for certain stages of life linked with stages in the potential change process. For example, moving to another location most likely leads to uncertainty related to the phase of contemplation. Supporting behaviour change by defrosting interventions or as already successfully tested in practice through providing experience of alternatives is not only explained by the model, but beyond this, based on the model, we suggest to combining these kinds of policy, for example, with awareness campaigns addressing motivation or affinity interventions to give positive feedback and strengthen a sense of belonging.

In order to increase the efficacy and theoretical support of transport policy measures, more comprehensive strategies are required. Thus, interventions may comprise a set of techniques that specifically address the seven issues that determine travel behaviour change according to behaviour change theories. The set of techniques should ideally be customised depending on the actual (intentional) stage to change of the target group.

4 Map of potential options and barriers for transformation

For the assessment of the Swiss mobility system concerning its transformation potential, not only the system itself needs to be analysed but also its environment – following the theoretical framework with the multilevel perspective, which distinguishes the regime (= mobility system) from external factors of the landscape level with impact on the regime. To analyse the transformation potential systematically, it is necessary to identify options that facilitate change and barriers that limit or prevent change. These options and barriers can appear due to internal characteristics of the system as well as due to external factors of the landscape 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, which is employed in this chapter. To make practical use of the insights, the identified options and barriers are used as a basis to derive a set of action fields in a synthesis in chapter 5. This also includes 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.

4.1 SWOT analysis methodology

SWOT analysis originates from business studies and is applied in a variety of fields and contexts today. By separating an internal and an external perspective on the subject and identifying positive and negative influences, a four-field-matrix results: strengths, weaknesses, opportunities and threats (Table 4-1). Each field has its own implications, how the associated items should be handled. 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 cannot be directly influenced, however they can and should be employed to support improvements. Threats on the other and need to be considered as limiting factors that can hinder or slow down progress, which means that strategies to deal with them must be developed.

To make use of the full potential of SWOT analysis, two aspects have to be carefully considered: 1) what is the subject to be examined? A delineation of what is considered internal and what is considered external has to be made. 2) What is the development goal?

Table 4-1 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[44] 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**
		system transformation	

[44] See 4.1.1 for the definition of the subject in this study.

Related to the transformation of the mobility system towards sustainability opportunities can be identified by combining internal strength with upcoming externally driven opportunities, while barriers for transformation become visible when integrating internal weaknesses with external threats. Both aspects will allow for assessing how the identified transformation potential of the mobility system (chapter 2) can be realized.

4.1.1 Definition of the subject for the SWOT analysis

The subject of the SWOT analysis is the current Swiss mobility system in terms of its potential for transformation towards sustainability.

Based on the analytical framework (3.1) the subject/system with its internal characteristics corresponds to the "regime" of the multi-level perspective, while landscape and niches are treated as external inputs/influences in this SWOT. For the system, we consider the dominant regime with its technology, but we also include subaltern regimes as part of the system[45].

In these regimes we consider the actors' behaviour, thinking and interaction as well as physical structures. 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. Both are interconnected through mutual influence on different levels, such as for instance infrastructure when sharing roads or rails as well as behaviour (for example e-commerce creates new transportation needs); but the two have different mechanisms so they have to be analysed separately.

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 4-2). They cover both the internal and/or the external perspective and they are of course interrelated. For instance, politics (taxes, regulations) markets can strongly influence; existing infrastructure limits as well as supports certain behaviours; etc. Within the system outlined by these fields and based on the goal for the sustainable development of the system (4.1.2), we identify the different strengths, weaknesses, opportunities and threats for the future (4.2).

Table 4-2 Relevant fields for the SWOT analysis of the Swiss mobility system

Field	System-internal element	External influence
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

[45] Note the difference between subaltern regimes (Geels 2012; 3.1.1) and niches. Whereas niches are characterized by technological innovations, that do not have a (fully developed) market scheme, subaltern regimes are completely market-ready and established, yet do not have the authority of a dominant regime.

4.1.2 The goal of the SWOT analysis

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 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" (http://www.sccer-mobility.ch/). Thus, the SWOT is meant to assess the transformation potential of the Swiss mobility system as identified in chapter 2 towards sustainability – using the analytical framework developed in chapter 3 – with

- ⇨ revealing strength and weaknesses of the current system,
- ⇨ identifying opportunities and threats for the transformation towards sustainability,
- ⇨ deriving options and barriers for the transformation process,
- ⇨ providing a basis to identify action fields for transformation measures in the real world.

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 choice of fields for investigations (Table 4-2).

4.2 Options and barriers for the mobility system transformation towards sustainability

A SWOT analysis on an aggregated level such as the Swiss transportation system cannot give detailed insights into different aspects but it provides an integrating overview about the systems state concerning its transformation potential. The presented SWOT matrix (Table 4-3) reflects an assessment of properties of the different interrelated fields of the system[46] (see Table 4-2), in relation to sustainable development (4.1.2). Threats and opportunities which might arise from external developments (outside the mobility system, like the trends analysed in chapter 2) are identified. Together with the internal strengths and weaknesses of the system, this allows to identify options and barriers for the transformation towards sustainability. Therefore, it can be used as an assessment of the transformation potential, 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.

[46] SWOT items are meant to be a synthesis of the previous chapters. The strengths, weaknesses, opportunities and threats are integrating aspects of different fields.

Table 4-3 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 • Emissions legislations • “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 occupation rates of cars • High standard of travelling speed • Fragmented political and administrational structures • High expectations about the level of transport connectivity • Urban sprawl due to settlement patterns with their functional specialisation
Opportunities	**Threats**
• Economic growth enabling innovation • Sharing economy • Digital revolution • Political strategies related to global climate change and rising ecological awareness • Land use legislation supporting reduced land consumption • Potential behaviour changes of younger generations • 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 spatial specialisation of jobs 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 strength and weaknesses of the Swiss mobility system 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 especially 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 todays Swiss public transport system lacks of resource efficiency. Increasing the resource efficiency provides a powerful leverage of energy savings and reduction of CO2 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 on one side and on the other side challenge todays mobility providers by increasing competition. The best, resource efficient solution might result – 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 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, leading to new path dependencies (see 3.1); this is leading to the issue of barriers for the 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) speed in transport and 3) comfort in mobility, which determine user expectations, transport provider standards and politicians' mind-sets. 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.

5 Synthesis: action fields for the transformation of the Swiss mobility system

The SWOT analysis revealed options and barriers for the development of the Swiss mobility system towards more sustainability. ‘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.

5.1 Technological innovation, energy and system efficiency

Even the most optimistic scenario of the Energy Strategy 2050 projects only small reductions in traffic amounts and changes in modal split (Swiss Federal Office of Energy SFOE, prognos 2012). On a European scale, no substantial change is envisioned either (Eiβel & Chu 2014). For making the system more sustainable, two aspects will therefore play a big role: energy efficiency and sustainability of energy sources. Of course, measures in this field cannot substitute the need to reduce mobility demand. Yet, they show what is possible even within scenarios that are the basis for today’s policies.

5.1.1 Short-term measures to increase energy-efficiency

From a systemic perspective, vehicles require energy for both, the engines and for producing this energy (petrol, diesel, natural gas, electricity, hydrogen…). A first goal is to reduce the amount of input energy needed per passenger kilometre, independently from the type of energy needed. Efficiency increases for the currently dominant internal combustion engine (ICE) technology can happen either by technical improvements by increasing fuel-efficiency or by the amendment of niches, e.g. by hybrid drive. These changes do not affect already existing vehicles but they result in less energy consumption through renewal of the fleet. So over time, the energy efficiency of the whole system increases.

Emission regulations have proved to be beneficial to improve fuel efficiency. However, as the ICE regime is locked-in, market mechanisms or politics are not likely to induce substantial change just out of intrinsic motivation. Banister (2008, p. 76) e.g. states: “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.” Therefore, system-external (landscape) pressures, especially climate change, have to result in 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 as e.g. the German[47], it can be politically easier to enforce strict emission legislation. Yet, the way of implementation through a penalty tax shows another more 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.

[47] 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 (http://www.nzz.ch/wirtschaft/equity/einheimische-zulieferer-von-der-krise-gezeichnet-1.18189092).

5.1.2 Use of sustainable energy sources

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 the sustainability of the input energy prevails[48] and energy needs to be produced as sustainably as possible. A shift from petrol and diesel[49] to biofuels could be a solution – but only if their sustainability can be guaranteed. 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 second-generation biofuels. However, biofuel production and consumption have to be seen in a global context (Eiβel & 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 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 in the related industries.

5.1.3 Introduction of new technologies

In addition to improving existing technologies, also new ones like hybrid vehicles (as a bridge technology), electric vehicles and fuel cell vehicles (2.3.1) can be supported within the current regime leading to an evolutionary system transformation. Also there might be more new technologies that can improve the regime through change of technologies, that we are just not aware of at the moment (i.e. newly emerging niches). 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 regime (and contribute to its change). Examples are ridesharing-applications that help improving 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 (see also GoEco! in 6.5). Banister (2008) states that ICT in general can account for positive as well as negative effects. "Although there is a large substitution potential, 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 addressing rebound-effects in parallel with any improvements of efficiency and optimization of the given system.

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 a multi-level perspective describing the transformation of a regime through new technologies (3.1), but also from a pragmatic point of view, it makes sense to support the development of technological niches. Strategic niche management (3.2.2) is a systematic approach to achieve this. 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.

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[48] In the case of plug-in-hybrids, also the sustainability of the electricity needs to be ensured, which means that it can only come from renewable energy sources.

[49] 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.

5.1.4 Overall system optimization

Even though the Swiss mobility system provides high quality of public transport services and high accessibility for motorized individual transportation, the system is not organized in an optimal way. Infrastructure and 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 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 rush 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).

5.2 Avoiding rebound effects

It is regarded as a general principle that people try to reduce their overall costs for travelling, namely actual monetary costs and time consumption (Banister 2007). Additionally, it becomes increasingly important to reduce the ecological “costs” of travelling and environmental beliefs can actually influence mobility behaviour (Gardner & Abraham 2008). For both aspects, ecological and economic cost reduction, the idea of energy efficiency is addressed in 5.1. A third aspect of efficiency increases that are desirable from a user perspective concerns time: the more time-efficient travelling is, the less time is needed to cover a certain distance. Time efficiency can for example be achieved through building new roads or railway routes, increasing their capacity or introducing new services. After all, technological as well as organisational solutions help for increasing efficiency in transportation.

Such changes in technology and infrastructure however induce behavioural responses (Binswanger 2001, p. 120). The dilemma about efficiency is that it tends to create rebound effects, which interfere with the intended effects. Increasing efficiency often does not lead to reduced environmental impacts, but savings are invested elsewhere leading to a shift of resource consumption, but not to a decrease in total. In the following, we discuss the rebound effects that might be induced by increasing time efficiency (5.2.1), cost efficiency (5.2.2) and energy efficiency (5.2.3).

5.2.1 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 can use more time and energy for work as well as recreation. But 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[50] seems to apply quite independently from cultures and modes of transport, but is not a universal constant for individual behaviour but an average aggregated value (Lyons & 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, the increased travelling speed and the longer distances covered require more energy, which also means that time-efficiency has counterproductive effects on ecological sustainability.

[50] Travel times in Switzerland are generally higher than in other European countries and fluctuate between 1.25 und 1.5 hours per day (2.1.1).

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 2007, p. 73).

The described trends also apply to Switzerland, where 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 a Swiss person showed a constant increase during the last years (2.1.1). To reach more ecological sustainability, effective measures would actually have to reduce travel speeds, distances and therefore energy input for the whole mobility system. The two most important travel purposes in Switzerland concerning distance are leisure (40% of the daily distance) and workplace commuting (24%), they should be the primary target areas for implementing measures (see also 5.3.1 and 5.4.2). Of course, travel time is only one parameter to be addressed and it always has to be seen in combination with other factors.

5.2.2 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 (Federal Statistical Office FSO 2011, Federal Statistical Office FSO 2013c). Thereof purchasing car fuel accounts for almost one fifth of the total expenditures. In 2.5.3 (Figure 2-34, Figure 2-35) it was showed that mobility demand increases with rising income (see also Graham & Glaister 2004). A higher amount of disposable income is associated with longer travel distances and longer travel times. In a meta study[51] on road traffic elasticity and income, Goodwin et al. (2004, p. 278f) state 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 5-1 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.

Table 5-1: 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 source: Goodwin et al. 2004, p. 278

However, there are additional ways of steering developments through pricing which are summarized in Table 5-2. Most of the measures mainly consider ecological sustainability. Price increases always have to be evaluated in the respect of social and economic sustainability.

[51] 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).

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.

Table 5-2: Impacts of different type of pricing

Type of impacts	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			✔		✔	✔

Source: Litman 2013, p. 16

5.2.3 Energy-efficiency

Cost-efficiency is closely related to energy efficiency, when it comes to fuel costs. The more expensive fuels, the more motivation consumers have to use fuel-efficient transportation (Table 5-1). 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 can be counteracted by interventions in pricing as shown in 5.2.2.In the case of public transportation on the other hand, 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. In fact, also electric vehicles, which ‘outsource’ emissions to the generation of electricity, face a similar problem, as long as not all electricity is based on renewable energy. 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.

Looking at the current developments 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. However, regulation could be improved by not using the emission values for the average emissions of all vehicles imported by a company, as it is currently implemented, but to 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.

5.3 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 (FSO, ARE 2012, pp. 57, 59, 62, 64, 68). 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, which means 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 higher occupancy compared to cars. Therefore, the attractiveness of intermodal mobility - with a focus on public transportation and cycling/walking - would need 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 is 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 behaviours is necessary for the shift of mode-based to intermodal mobility. Two general strategies to support behavioural change can be distinguished here: 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 & Gifford 2007, p. 60). This means that mainly two issues need to be worked on: the usability and convenience of multi-modal trips and the motivation for behaviour change. One idea is the integrated concept of 'mobility as a service'. 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 product 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[52], which developed especially in the second half of the 20th century. 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 (2.7.2) showing a window of opportunity for the reduction of car ownership and usage.

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

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

Workplace commuting accounts for 1/4 of the average daily distance travelled by a Swiss person throughout the week (FSO, ARE 2012). During weekdays, about 40% of the average distance travelled is work-related (according to data from FSO, ARE 2012). Work related mobility plays an important role, as it is a main reason for traffic peaks and the resulting too low (energy) efficiency of public transport. Achieving sustainability in this field could be reached through a reduction of commuting ways in frequency and length. Also providing travel alternatives to individual motorised mobility and increasing efficiency with the least rebound effects possible (5.1, 5.2) should be the goal.

5.3.2 Flexibility in work place and time

Flexibility of working places allows a reduction of commuting trips, if people work from home or flexible offices, which are 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:

1. *Change of the working world*
   Traditional jobs, especially in the industrial production of goods or in basic services, require fixed working places. But there is an increasing number of jobs, primarily in the field of knowledge-based services[53], that do not require employees being at a specific location during all or at least 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 more and more. Cheap and easy to use telecommunication innovations such as video conferencing also reduce the need for physical mobility.
3. *Cultural change*
   The abovementioned opportunities can only have effects, when technologies are implemented and used. It is primarily the task of employers to provide the technical and organisational possibilities and to also support the related change of working culture. Employers need to provide the 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. One has to be aware that the need for sustainable mobility can be expected to drive these kind of change. Due to digitalization changes of the working world will happen anyway flexible working places and schedules can be offered, not only supporting sustainable mobility, but providing attractive options for a better work-life-balance.

Despite the fact that especially aspects 1. and 2. are already existing since several years[54], the total amount of commuting distances did not decrease. Especially public service providers

[53] Sometimes also called quaternary economic sector.

[54] 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

can be attributed a key role for the future, 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.

5.3.3 Distances between workplace and home

The reduction of the overall travel distances between workplace and home can happen either through less frequent travelling (see above) or through a reduction of the physical distance between workplace and home. 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 economic cost (rent, relocation costs, residential property). In Switzerland, the relocation rate is rather low and even dropping (Homegate 2016) and 66% of the Swiss employees do not consider relocating due to a new job (EY 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 which points out the interrelatedness of (high) accessibility, urban and agglomeration development as well as mobility demand. All these factors influence each other by positive feedback, if high accessibility pushed new settlements leading to increasing mobility demand, again requiring increasing accessibility and so on (see also 5.4).

New and innovative options are therefore necessary. A project worth mentioning is 'Villageoffice' (http://www.villageoffice.ch/home), 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.

5.4 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. In theory, providing mixed functions should lead to less transport demand; thus, spatial planning is required to provide everyone with all necessary facilities at the least distance possible. "It is one area of public policy where intervention can take place, through increasing densities and concentration, through mixed use development, through housing location, through the design of buildings, space and route layouts, through public transport oriented development and transport development areas, through car-free development, and through establishing size thresholds for the availability of services and facilities. The timescale over which sustainable mobility might be realised is similar to the turnover of the building stock (about 2% per annum), but decisions on the location of new housing will have a single dramatic effect on travel patterns and these effects will impact over the lifetime of this housing" (Banister 2008). But the solution is not only to be found in providing mixed functions and increasing density of housing in areas with a good service infrastructure. Especially quality of life needs to be increased, as too high building density affects quality of life with noise, emissions or a lack of recreation space, which pushes people out of the cities resulting in mobility demand for commuting.

A solution is integrated spatial and transport planning. Urban spaces can be designed or re-designed to support certain transport modes and means of transport. 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

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. (Data: Weichbrodt 2014) alternative approach of sustainable mobility (Table 5-3). One example is a broadened understanding of public street space 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. In general, more holistic and integrative concepts and paradigms are necessary to address systemic transformation. Especially in a planning context, it is also important to be aware of consequences for the dependent future development paths that arise from building physical structures.

Table 5-3: Contrasting approaches to address transport planning

Transport planning and engineering – the conventional approach	An alternative approach – sustainable mobility
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

Source: Banister 2008, p. 75

5.4.1 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 of resource consumption 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 are willing to pay for. Sufficiency principles should be taken into account by policy and planning, when reorganising existing or planning new spatial structures.

5.4.2 Quality of life in cities/agglomerations 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 quantitatively increasing purpose for traveling. During an average day in 2010, 37% of the trips, 40% of the distance and 47% of the time travelled by a Swiss person were dedicated to leisure purposes (FSO, ARE 2012).

Many different factors are influencing leisure travel behaviour, and one of them is the quality of life (Heinze 2000). In densely populated areas, one purpose of leisure is compensating “for the deteriorated psychological and social quality of life” (Heinze 2000). 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 & Gifford 2005). Quality of life can also 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 policies supporting a decrease of travel distances can have mutually reinforcing effects. The subjective experience of quality of life hast to be considered as well, when designing measures as it encompasses the fact that different people perceive the same environment differently.

6 Field experiments and future scenarios for Southern Switzerland (SUPSI)

Complementary to the theories discussed in the previous chapters, a bottom-up approach is effective in identifying actual barriers to change at the systemic level. In particular, it helps in recognising which elements of the mobility system favour or, to the contrary, prevent individual behaviour change. This provides policymakers with a powerful insight and decision support for the definition of future policies.

Bottom-up approaches are popular in social sciences to observe phaenomenon directly in their natural environments. Possible tools to perform such studies are direct interviews, collective discussions and focus groups, questionnaires and surveys or field observations.

We choose the living lab approach, an innovative research methodology that offers most of the positive elements of the above-mentioned tools.

6.1 The “living lab” methodological approach

The living lab approach is grounded in the theoretical framework of the Strategic Niche Management (SNM) approach, developed in the late 1990s at the European level and already successfully applied in the transportation sector in the past (Kemp et al., 1998; Schot et al., 1999; Kemp et al., 2000).

Acknowledging that technological and behavioural aspects are strictly interconnected, the SNM approach states that complex transitions can be obtained in terms of *regime shifts*, by artificially creating protected spaces for testing and developing new technologies. That is, new technologies are artificially made attractive and real life users are allowed to exploit them.

Offering the technology a protected space, in which it is defended by the full force of normal selection processes, the analysis of the users' behaviour allows to assess the effects of the technology itself, both in terms of technical and economic viability and in terms of social desirability. Information gathered during SNM processes thus allows to identify the most effective policies capable of favouring the diffusion of the technology on the market and able to expand the niche size, with a gradual implementation of the transition.

The niche is always composed of *a group* of persons: it allows to examine collective problems beyond a single-actor perspective, however giving each participant the same opportunities and importance. Provided that a significant number of participants is involved, the social dimension of the niche guarantees that diversity, openness and multidisciplinary aspects are considered (Pallot et al., 2010), thus favouring a later wider spread and adoption of the innovative technology.

Following a more recent definition, we indicate such bottom-up and user-centred inter-disciplinary processes as "living lab" processes. This definition is effective in highlighting the involvement of *real-life users* for the exploration of new technologies in their own, *real-world* settings (Higgins and Klein, 2011).

The term "living lab" was first introduced by W. Mitchell, K. Larson and A. Pentland in the MIT laboratories (Media Lab and School of Architecture and City Planning) (Eriksson et al., 2006), when they gave real-life end users the possibility to test smart and energy-efficient building performances, by living in those buildings for a certain period of time. They were in fact convinced of the need for explicitly taking into account the social aspects of technological innovation, as the only way to facilitate a large-scale diffusion of the innovation itself, and, in general, to determine a real transition in the society.

Living labs thus configure as test-beds for *in vivo* experimentation of new technologies or policies, as opposed to *in vitro* experimentation (Dutilleul at al., 2010). The possibility of testing, validating and refining innovation by monitoring real-life users in their real-life context has in fact proven to be far more effective than testing and validating it in simply *realistic* scenarios (Almirall et al., 2012) or than simulating users behaviour.

Even though still lacking a formal supporting theory (Schuurman et al., 2012), the concept of living labs gained momentum and started being used in a variety of processes (Dell'Era and Landoni, 2014), insomuch that it has become a mandatory activity in a variety of Horizon 2020 call for research projects within the European Union.

The SNM and Living lab methodologies are especially effective in systems offering environmental and social benefits which are undervalued on the market (Kemp et al., 2000), in particular by single individuals, as in the transportation sector. Successful experiences in this sector were for example gathered in Denmark since 2009, with the TryAnEV/Insero E-mobility project (Agerskov and Høj, 2013). For less recent experiences, one can for example refer to (Hoogma et al., 2002).

In this document we focus on the outcomes of two living lab projects run by SUPSI between 2012 and 2016:

- the *e-mobiliTI* living lab, aimed at investigating:
  - potentials and implications of the diffusion of electric mobility at the urban level;
  - potentials for a comprehensive transformation of urban individual mobility behaviour, in terms of modal change: decrease in the use of private cars, in favour of slow mobility, intermodal use of public transport and vehicle sharing;
- the *MobAl*t living lab, aimed at investigating opportunities and barriers to decrease use of private motorized means of transport when commuting to work.

A third living lab, the *GoEco!* living lab, was activated by SUPSI in 2016, with the aim of investigating if and how information feedback and social interactions, provided by means of a smartphone app, can be effective in fostering changes in personal mobility behaviour. Can we exploit mobility tracking apps, eco-feedback and peer pressure in order to favour walking, cycling and use of public transport? Field activities in *GoEco!* have currently still ongoing and results will be available by the second half of 2017. Here we can however provide insights on the characteristics of the participants to the project and their attitudes towards car use and analyse data gathered after one month of field monitoring: they already provide us with further insights on barriers to change.

An additional living lab, related to the *Social Car* H2020 project, will be activated in early 2017. It envisions testing the Social Car smartphone app, which allows its users to find real time multi-modal travel opportunities, exploiting both the public transport offer and ride-sharing offers by private cars. The next SCCER report will provide insights also from such a living lab activity.

Main common feature of the SUPSI living labs is that they focus on understanding possibilities for *modal change* only. Other, much more challenging mobility transitions, such as an overall decrease in mobility demand (both in terms of the number of trips and of the kilometres driven), are not analysed in those experiments. Also, an additional unifying elements is that they all exploit ICTs and smartphone apps, either to stimulate a change in mobility behaviour or to monitor its evolution over time under stimulation by external factors.

6.2 e-mobiliTI: potentials and implications for the diffusion of electric vehicles

The transition towards electric mobility (see Section 2.3.1) is increasingly acknowledged as one of the most beneficial strategies for the reduction of air pollution and noise in urban areas, for climate protection at the worldwide level and for direct integration with smart electric grids.

The cost of electric vehicles has worldwide sensibly decreased, up to the point that in a few years it is expected to become equivalent to conventional internal combustion engine (ICE) vehicles (see for example (World Bank – PRTM Management Consultants, 2011).

Apart for the main barrier still represented by the purchase cost, the adoption of electric vehicles is however still hindered by barriers such as the autonomy range, the availability and diffusion of recharge points and the overall perceived performance (see for example Everett et al., 2011; Turrentine et al., 2011; Deloitte, 2010; Cocron et al., 2011; Graham-Rowe et al., 2012; National Research Council NRC, 2013). Are these real barriers or are they just psychological, a priori barriers that can be removed by means of direct experience?

In Switzerland, according to the 2010 Swiss Transport and Mobility Microcensus (OFS-ARE, 2012), 84% of the trips are shorter than 10 kilometres and 73% of them are less than 5 kilometres long. According to these numbers, more than 80% of the demand for personal mobility could be covered by electric mobility. Moreover, a widespread network of public charging stations is nowadays available all over the urbanised areas. In Switzerland, thanks to the "EVite" initiative by the Swiss Association eMobility (www.evite.ch), up to 250 public fast-charge stations will be installed in the next years. Finally, the Tesla carmaker has just installed eight "super-chargers" stations all over Switzerland, as a special benefit for the owners of Tesla vehicles.

Despite these progresses, and even though the diffusion of electric vehicles is increasing from year to year, in Switzerland their number keeps in the order of 0.10% of the present car fleet (Astra, 2014). Therefore, understanding and, at a later stage, fostering the transition towards more sustainable mobility patterns, imposes to go beyond the traditional technological approach, to integrate psychology, sociology and cultural aspects and to explicitly address consumer perceptions and behaviours (Geels et al., 2011).

We investigated potentials and implications of the diffusion of electric vehicles in the e-mobiliTI living lab, a socio-technical process held in Southern Switzerland between 2012 and 2015. We involved eleven early adopters of electric vehicles (EAs, in the following, identified according to Rogers' theory of Diffusions of innovations (Rogers, 1962 and 2010) and sixteen mainstream consumers (MCs, in the following), all living in the Lugano area, the main urban conurbation of the Italian-speaking part of Switzerland. According to Rogers' categories, the latter are the "early majority" consumers. That is, they are intrigued by EVs but, for a number of reasons, they have not adopted this mobility option yet.

In spring 2013 a first three-months monitoring phase allowed us to identify their present mobility habits. In Spring 2014, during a second three-months monitoring phase, they experienced new mobility options (electric cars and bicycles, public transport season tickets and car and bike-sharing subscriptions) in their complex, real-world settings (see Figure 6-1).

Monitoring was performed by means of the e-mobiliTI smartphone application, developed on purpose. For a detailed description of the experiment and of the application, please refer to (Cellina et al. 2013; Rizzoli et al., 2014; Cellina et al., 2015 and Cellina et al, 2016).

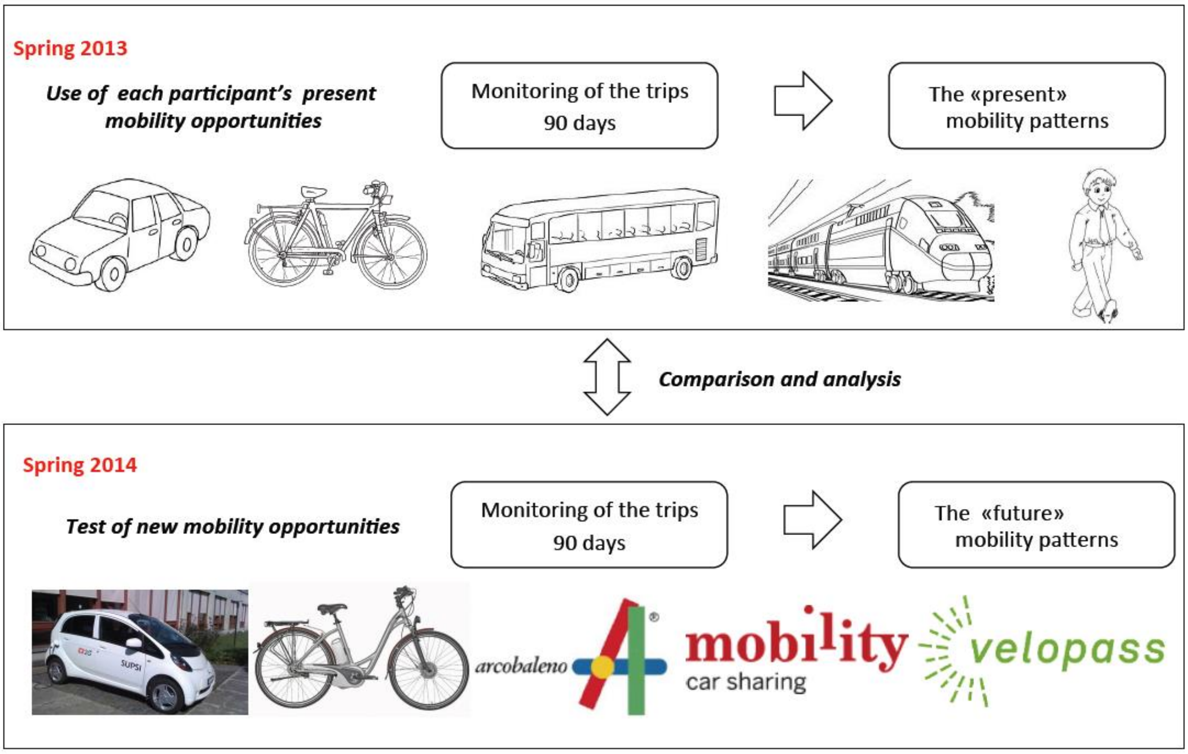


Figure 6-1 The design of the e-mobiliTI living lab experiment

Before presenting results of the e-mobiliTI living lab, we highlight the main critical points of the whole experiment, related to the size of the sample and the duration of the testing period.

Our results in fact have limited representativeness, since the sample is very small and is not built with representativeness purposes: participants are in fact the result of self-candidacy activities. Specific mobility needs of the users in our sample might therefore have tangibly influenced the global results. The results we gathered are also influenced by the duration of the testing period. A three months testing period is not long enough to overcome the initial "novelty effect", which causes a strong interest in the new mobility option (the electric car), consequently leading to use it as much as possible. A testing period of at least one year should have been definitely preferable, in order to detect effective changes in mobility patterns and to verify whether new, consolidated habits are created.

However, especially the qualitative elements arising from the whole experiment provide meaningful insights regarding potentials and barriers to the diffusion of electric vehicles.

Results we gathered by means of the smartphone-based automatic tracking show that in the mainstream consumers of the e-mobiliTI sample the potential for substitution between conventional and electric cars is high - however still significantly limited by the current barriers on range autonomy and investment cost. Substitution between ICE (internal combustion engine) and electric cars in fact took place both in terms of kilometres driven and in terms of number of trips: on average, the electric car replaced the conventional car for 63% of the daily kilometres travelled and it was used for a number of trips double than the ICE car. Individual interviews and focus groups held during the project in particular show that performances of electric cars are highly appreciated and they are regarded as valuable alternatives to ICE cars.

Even more interestingly, data even show that a "rebound effect" may occur, that is an increase of the daily kilometres and in the number of trips driven by car, either electric or ICE. Within the e-mobiliTI sample, an increase in the use of private motorized transport (PMT) is registered as a consequence of the availability of an electric car.

Insights gained during individual interviews show that this is mainly due to a "novelty effect", combined with the awareness that the electric car would remain available for a limited period of time. During that period the users were led to use it as much as possible, in order to get acquainted with all its functionalities. We believe that a longer period of testing would have definitely reduced such a rebound effect.

Notwithstanding those very promising results for the potential EVs (electric vehicles) diffusion, the large MCs majority declared that, should they replace their ICEV (internal combustion engine vehicles) today, they would not buy an EV as one and only family car:

- six families out of nine would buy an EV as second (or third!) family car;
- five families out of nine would not buy an EV, but a fuel-electricity hybrid vehicle (HEV);
- one family out of nine would instead buy an EV.

Reasons for this choice were investigated during focus groups and individual interviews and were classified in categories as shown in Figure 6-2. The really critical limitation perceived by e-mobiliTI MCs lies in the autonomy range: participants dislike the idea that for some occasional trips they will not be able to use their own car: “*Since one needs to pay a lot of money for an EV, one expects to use it in any occasion, also to go on holiday once a year*”.

Further critical elements refer to battery recharging activities. Weaknesses are registered for both recharging at the domestic level, for those living in flats without a direct connection to their own electricity counter (“*Recharging at home is impossible, since there’s only one plug, shared with the other tenants, which is even far from our parking”*), and when travelling. For the latter activity, weaknesses are indicated both regarding travels abroad (“*why not allowing to recharge via credit card, instead of limiting access to subscribers of regional recharging systems?*”) and regarding local travels (“*recharging stations are often busy in the central areas of Lugano, street indications to find them are lacking and occasionally there are maintenance problems and they are out of order*”).

Finally, the investment cost for electric vehicles is still considered too high for many e-mobiliTI MCs, if compared to conventional vehicles of the similar classes. Some of them would therefore be interested in buying second-hand cars, however so far there is hardly no market for second-hand electric cars.

Instead, the need to plan one’s own trips in advance and the corresponding lack of flexibility is not seen as a really critical limitation, though being acknowledged as a factor one needs to take into account when organizing one’s daily activities (“*It’s true: one needs to plan the trips for the following days. But all in all it is easier than planning trips by public transport*”; ”*In a few weeks you learn how to organize yourself: now I’m used to asking myself every night: where should I go tomorrow?*”). Rather than being perceived as a real barrier for change, this is presented as a matter of fact, without negative implications.

Remarkably, a few MCs identified among the key barriers for change also technology elements which are not specific for EVs, being instead usually available also for conventional ICEVs. Three of them in fact lamented "*I do not like the automatic gear, which decreases my pleasure of driving*". This is quite interesting, considering that driverless cars are among the most promising transport option for the future.

From a totally different point of view, other MCs highlighted that EVs and conventional ICEVs share critical impacts from the environmental and traffic point of view: "An electric car is always a car, therefore it produces traffic congestion and soil sealing for roads and car parks". Further, depending on how electricity is produced, electric cars might be responsible for air pollution and CO_2 emissions: "I did not pollute at home, but somewhere else the electricity power station polluted. From a global energy perspective, I don't see EVs as something really convenient". Finally, some MCs expressed concerns for the whole production and disposal process of the electric car, especially regarding consumption of rare raw materials for battery production.

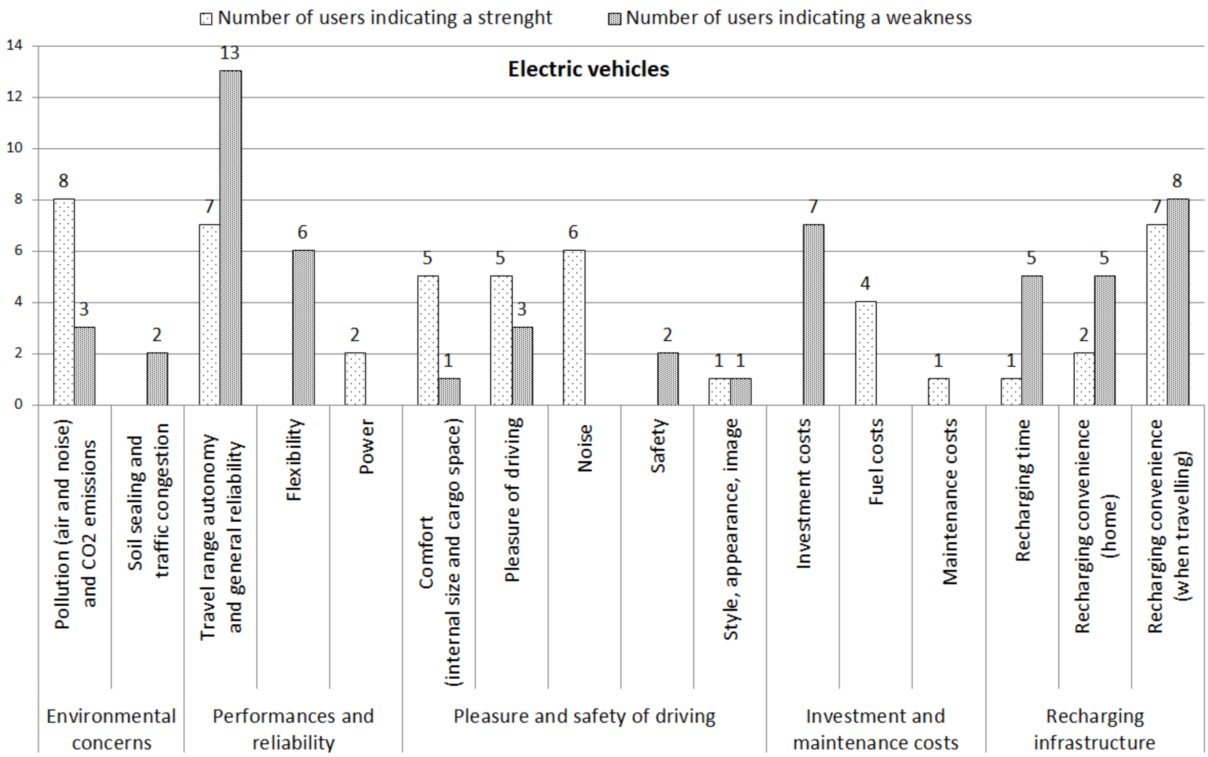


Figure 6-2 Strengths and weaknesses of electric cars according to participants to the e-mobiliTI living lab.

6.3 e-mobiliTI: potentials for a comprehensive transformation of individual mobility choices (modal change)

The last considerations, expression of environmental awareness, seem to pave the way for a wider transformation in mobility choices, favouring the use of other means of transport. Moreover, electric mobility itself may also turn into an effective leverage to promote a wider transition towards more sustainable mobility life-styles. The limitations in the range of autonomy of electric vehicles might in fact turn into a positive factor, acting as a trigger to push drivers:

- to take awareness of the daily kilometres travelled and plan their trips in advance,
- to drive only the really necessary kilometres

- and to use other alternative, energy-efficient means of transportation, if the range of autonomy is not wide enough to satisfy their needs.

The e-mobiliTI living lab only focused on modal transformation, since a transformation in the amount of kilometers travelled on a daily basis is too strongly dependent on exogenous factors, such as the place of living and working, the activities performed during leisure time, the family needs and so on - all aspects which were not directly influenced by the e-mobiliTI field test.

Data gathered during the experiment show that the hypothesized transformation towards different than the car modes of transport did not occur. Public transport, either alone or in combination with electric bicycles, car and bike-sharing, could not compete with cars (either ICE or electric): when a private motorized means of transport (PMT) was available, it markedly prevailed over the other mobility options. In some cases, the availability of the electric car even tended to produce a rebound effect, due to a general perception of being green, consuming less energy and spending less money for the fuel.

The e-mobiliTI experience tells us that the transformation of the dominant car-based mobility patterns needs to overcome really sturdy and consolidated barriers. To better understand them, we performed individual interviews and focus group sessions with the participants to the e-mobiliTI living lab, which allowed us to collect bottom-up, user-centred qualitative perceptions on the strengths and weaknesses of the mobility options being tested. This process allowed us to highlight the reasons for the lack of attractiveness of the means of transportation other than the car and to identify policy recommendations to foster the mobility transition.

The result is that in the Lugano area the transformation would require further improvements in the quality of the offer of the mobility options other than the car. The users in particular asked for a significant increase in their attractiveness in terms of flexibility, capillarity, comfort and safety.

6.3.1 Strengths and weaknesses of alternative means of transport: public transport

Main weaknesses for public transport are related to the increase in travelling time, together with the decrease in flexibility and comfort, if compared to private motorized means of transport (cars and motorcycles).

In particular, participants highlighted the complexity of performing trips across suburban areas and especially from one suburban neighbourhood to another: waiting times at junctions are judged too long, making the public transport far less attractive than the car ("*In general public transport connections are not optimized and transfers expand travel time: you know when you leave but not when you'll arriv*e"; "*I use public transport when I have no time constraints*"; "*When I work I cannot use public transport, since I need flexibility and promptness in case of emergencies*"). The problem of travel time reflects in the request for an increase in the frequency of the journeys.

Comfort is also very important: "*I often move with my three kids: public transport is uncomfortable when I travel with them*"; "*When going to work, I need to carry with me bulky material: PC, electric cables and other equipment*".

Finally, some of the participants lamented fares are too expensive: "*I don't like to pay 2.30 francs every time I use the bus; however I do not buy a public transport season ticket because I do not use it enough*".

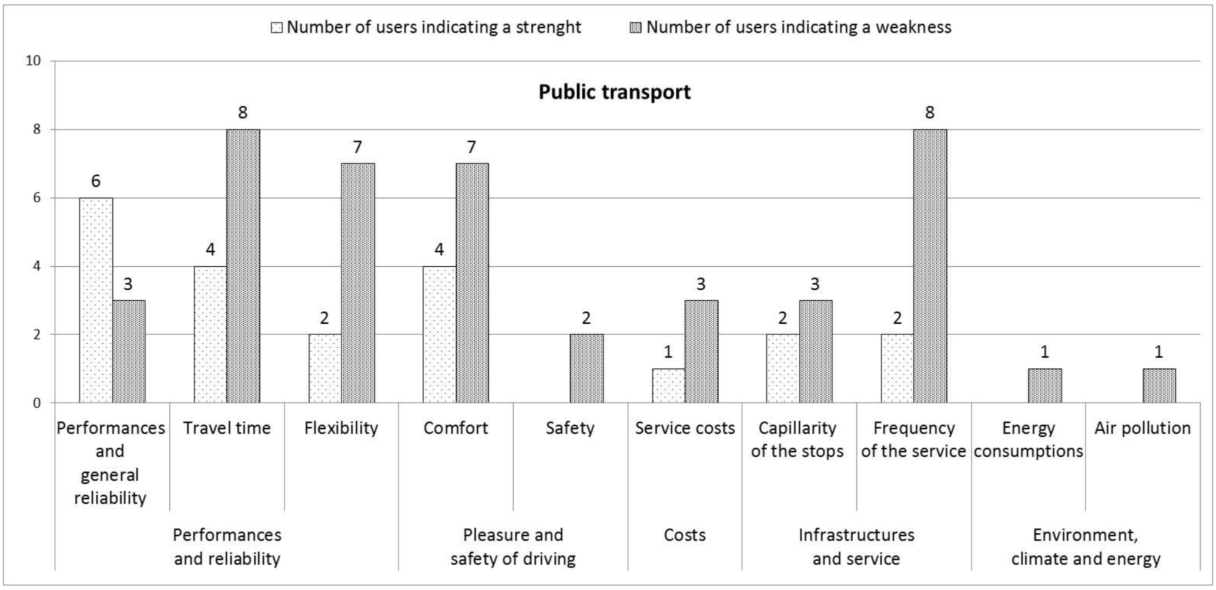


Figure 6-3 Strengths and weaknesses of the public transportation system according to the participants to the e-mobiliTI living lab.

6.3.2 Strengths and weaknesses of alternative means of transport: electric bicycles

Electric bicycles were used very seldom within the e-mobiliTI living lab, though they were given to every MC family. The reasons are essentially two. First, there is a comfort problem: using a bicycle, even if electric, implies a certain level of physical effort – especially in Lugano, which is characterized by frequent climbs up and down: "*Even though it is electric, you sweat a lot when going back home for lunch, especially if you are wearing a tie*". Also the weather conditions are considered critical from the comfort point of view: in Winter it is cold, in Summer it is hot – and, no matter about the season, when it rains using a bicycle is not attractive. Finally, using a bicycle mainly imposes to adopt a casual way of dressing, which is not always allowed, especially when travelling for job purposes: "*You cannot use it if you are supposed to wear an office outfit*".

Second, there is a safety problem: people do not like using the bicycle because there are not cycling lanes and bicycles are compelled to move along the roads together with cars, trucks, motorbikes and buses: "*I fear going by bike along congested roads: I would really prefer biking lanes*". A MC also indicated she does not like cycling in the traffic because "*It is very dangerous breathing cars' and trucks' exhaust gases*".

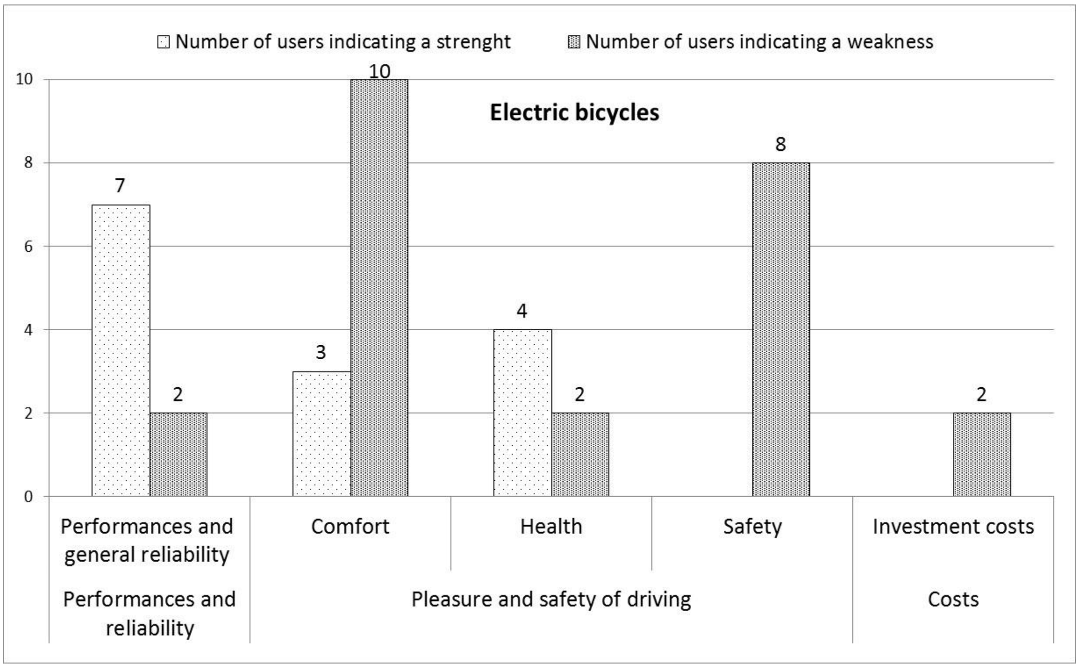


Figure 6-4 Strengths and weaknesses of electric bicycles according to participants to the e-mobiliTI living lab

6.3.3 Strengths and weaknesses of alternative means of transport: car-sharing

In Phase 2 all the e-mobiliTI participants were offered the possibility to test the car-sharing service provided by the Mobility company. Actually, only one of them (an EA) used it once, while two of them (an EA and a MC) declared they had tried it at least once in the past, before the e-mobiliTI experiment. All the other participants simply did not use it because "*There were no occasions I needed it*". Their perceptions regarding strengths and weakness of car-sharing therefore mainly reflect preconceived judgements and assessments, based on the information they received on car sharing working principles.

According to their indications, the main factors precluding the diffusion of car-sharing refer to both a general rigidity in the system and in the level of the rates, considered too expensive. Car-sharing is rigid because "*It compels you to return the car in the same place you picked it up"* and *"You need to indicate, at the moment of the reservation, how long you will use it. And what happens if you are late? You are fined!*". Moreover, some of the users "*live far away from the Lugano pick-up point: it is not easily accessible to us*".

Regarding the second barrier – tariffs are too expensive – one has to consider that all the e-mobiliTI users were already endowed with their own ICEV(s): using a car-sharing vehicle would therefore imply for them to afford both the indirect cost of their own vehicle(s) and the costs of renting the car-sharing vehicle.

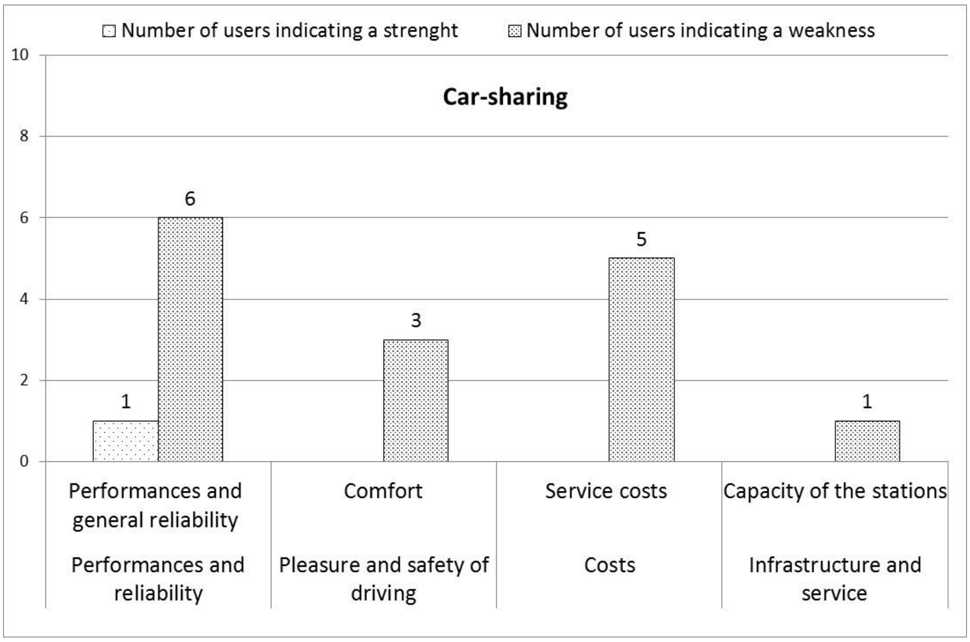


Figure 6-5 Strengths and weaknesses of car-sharing according to participants to the e-mobiliTI living lab

6.3.4 Strengths and weaknesses of alternative means of transport: bike-sharing

In Phase 2, all the participants were endowed with a personal, free season ticket for the Publibike service in Lugano. Also in this case, however, the number of those who actually used the service is very limited, equal to three MCs. Besides them, a fourth participant was already experienced with the bike-sharing service, having used it quite frequently in the past before a change in the public transport lines at the urban level made public transport much more effective for her needs. Therefore, also in this case comments and perceptions on strengths and weakness should be mainly considered as prior perceptions.

According to the e-mobiliTI panel, the main barrier to the diffusion of bike-sharing is related to the limited number of stations all over the city: it is rare to find a bike-sharing station exactly where it is needed, both to take and to return the bike ("*The closest station was usually farther from home than the place I was heading to*"). They also see a problem in the capacity of the stations, especially regarding the possibility to return the bicycle: what happens if all the places are already occupied by other bicycles? There is no possibility to leave it in other stations, since they are quite far away the one from the other: "*Sometimes I was in trouble in finding a free space to return the bike, especially in the city centre*"; "*I did not try this service because I feared I could not find the place to return the bike, once finished to use it*". Finally, bike-sharing suffers from the problems already mentioned for electric bicycles: lack of comfort, safety and negative impacts on health.

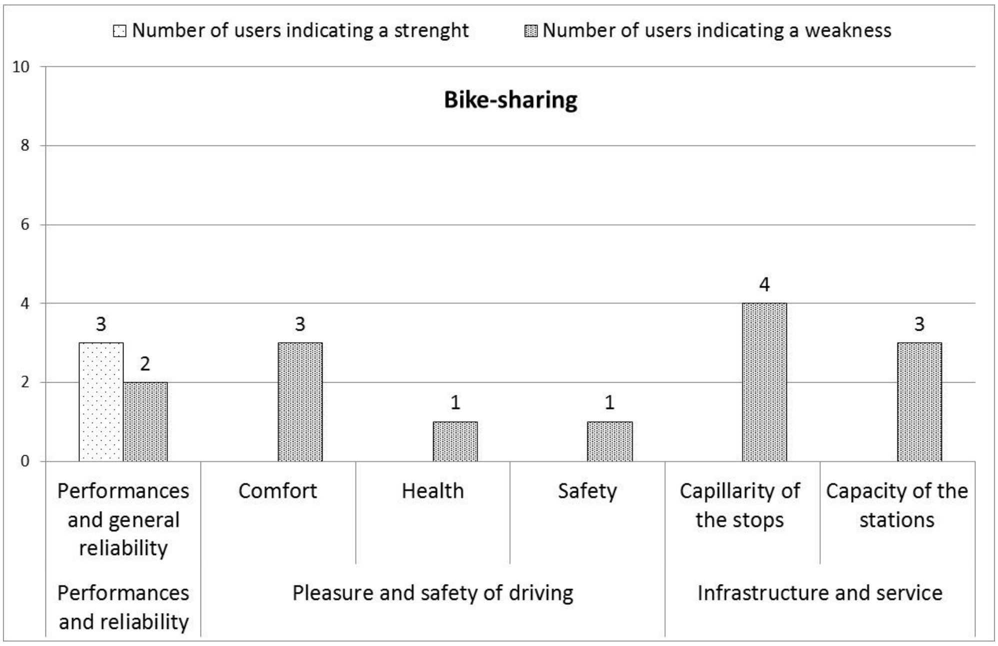


Figure 6-6 Strengths and weaknesses of bike-sharing according to participants to the e-mobiliTI living lab

6.4 MobAlt: potentials to decrease use of private motorized means of transport when commuting to work

A second case study we consider for the identification of potential and barriers for behaviour change at the individual level is offered by the “MobAlt” living lab.

Activities are developed in the Mendrisio district in Canton Ticino, a medium-sized city of 15’000 (FSO, 2014) inhabitants, characterized by important industrial and commercial settlements. The area offers in fact more than 12’700 workplaces (FSO, 2015), split in half between the secondary and tertiary sector, and workers primarily rely on individual cars when commuting to work. This implies high traffic volumes, with daily averages of 38’000 vehicles travelling every day on the main road axes (daily average traffic estimated by the Canton Ticino traffic model). Leaving the individual car in favour of energy-saving alternatives is quite difficult, since

- the large majority of the workers live abroad, in Italy. Daily distances they travel on average are not very long; however, trans-national public transport is not effective, especially via road;
- nearly all workers employed in the secondary sector work on shift and sometimes also in the weekends (for example from 05.45 to 14.00 and 14.00 to 22.15 or from 05.45 to 15.15 and 13.45 to 23.15). Their early morning and late night commute to and from work can therefore be hardly performed by public transport, because the offer is either very limited or not existing at all; also, when distances allow it, using the bicycle is dangerous because of the darkness and the lack of bike lanes.

Further, in some cases people are not aware of the existing alternatives to commuting by car, or do not use them simply because they have different habits and behavioural patterns.

Acknowledging that these are the main barriers precluding change, it is interesting to study how people react if they are offered mobility alternatives explicitly targeting such main barriers:

will they leave the car and opt for the new alternatives? If so, which elements will nudge them to change? And if not, which will be the remaining barriers precluding it?

To answer these research questions, between October 2015 and February 2016 we took part in the “MobAlt” living lab (where MobAlt stands for Alternative Mobility), an activity developed by the local transport planning office Planidea, on behalf of the City of Mendrisio, the Canton Ticino and the Swiss Federal Administration.

The project was carried out with the voluntary participation of seven companies, mainly operating in the secondary sector, settled in the industrial district of the City of Mendrisio, corresponding to a total number of 3’100 workers. The companies were specifically selected due to their close geographical position, which created a cluster of companies and workers allowing to exploit scale economies for mobility and transport needs.

Workers were invited to take part in a pilot study experimenting the MobAlt smartphone application (app). MobAlt identifies personalized alternatives to use of the individual car on the home-work commuting route, taking into account: public transport tickets and travelcards, car-pooling systems, inter-company buses and slow mobility options, including electric bicycles and folding bicycles for inter-modal use with public transport.

Research activities were performed according to an action research approach (Lewin,1946), during which the original workplan was significantly revised and updated in one occasion, in order to better fit the evolution of the pilot project. Figure 6-7 gives an overview of the action research activities, while the following section introduces them in more detail.

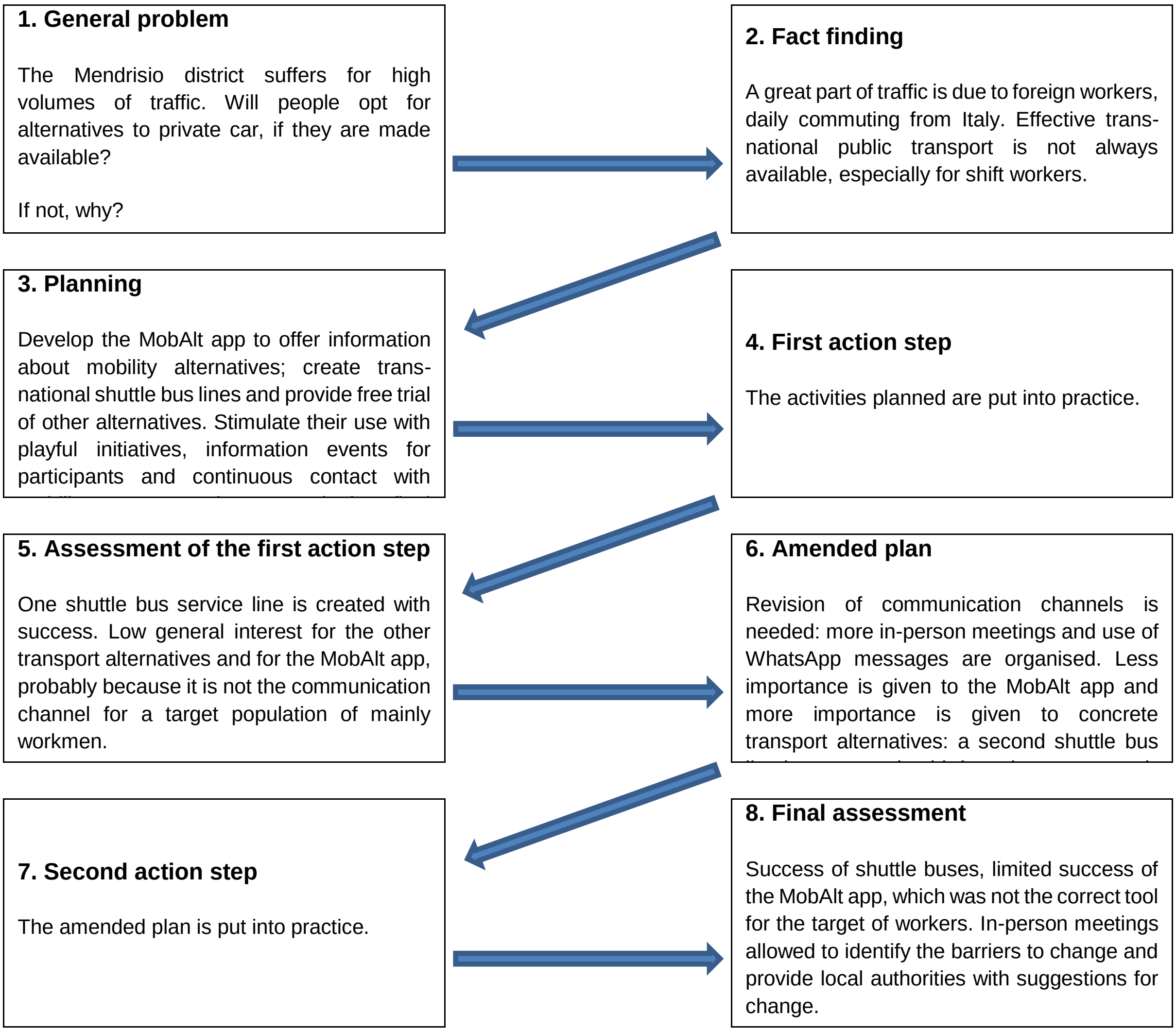


Figure 6-7 Scheme of the action research MobAlt pilot project

6.4.1 Main activities developed within the MobAlt action research pilot project

1. General problem: the district of Mendrisio suffers from high traffic congestion in the peak hours, that leads to air and noise pollution, increased risk of accidents, longer travel times and also high level of stress for the employees. In such a situation, what precludes people to opt for other mobility options than the car? Is it the lack of awareness of alternative mobility options or it is the lack of options themselves? And, in case new mobility options are made available, would people opt for them? Or else, which barriers would preclude them from changing?

2. Fact Finding: As it was mentioned above, the Mendrisio area of Ticino Canton is highly overloaded by vehicles, especially in the peak hours. This causes increased travel times, danger of accidents and negative environmental effects, both at the local and global level.

3. Planning: Activities of the MobAlt pilot project are developed by actively involving the mobility managers of the participating companies and their employees.

Intense use of the car is at first attributed to lack of information on the existence of alternative means of transport and to enduring habits of using the car. Therefore, employees are incentivized to reduce their use of the car by

- providing them information on the available alternatives for their own mobility needs,

- and offering them the possibility to try them out for free or at very low, subsidized tariffs, for a certain period.

Such incentives are provided by means of the MobAlt smartphone application (app), specifically developed for the MobAlt project. Users only need to indicate their home and workplace addresses and the app indicates possible mobility alternatives and also offers the possibility to book them for a trial period (see Figure 6-8).

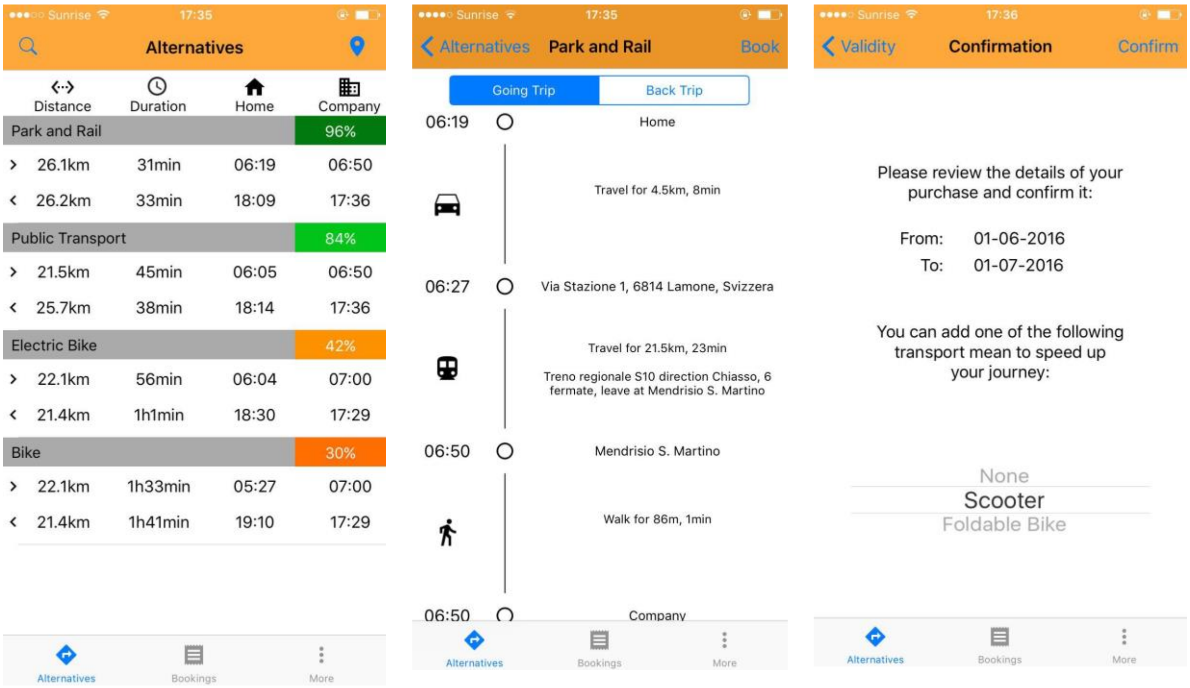


Figure 6-8 Screenshots of the MobAlt smartphone application

left: summary of the mobility alternatives from home to work; middle: details of a mobility alternative; right: reservations

The mobility alternatives offered by MobAlt are the following ones:

- free subscription to a car-pooling platform, allowing to join existing car-pooling teams or to create new ones;
- public transport daily and weekly travelcards;
- conventional and electric bicycles;
- kick-scooters and folding bicycles for inter-modal use with public transport.

To bridge the gap in the offer of trans-national public transport, especially for the early morning and night shift, a new offer of inter-company shuttle buses is also developed: based on preliminary analyses on the place of living and work shifts of the employees, two shuttle buses are programmed and offered among the MobAlt alternatives. Matching the interest by the workers and their work shift schedules, the two inter-company shuttle buses are planned for the early morning and whole day working shifts.

Accompanying game-like initiatives (photo contests, quizzes, random draws) rewarded by tangible prizes are planned to stimulate the employees to explore the MobAlt app and to use the mobility alternatives offered.

In order to inform the workers about the MobAlt app and the new mobility options made available, invite them to participate in the pilot project and informally collect their perceptions on opportunities and barriers to change, various information events are planned at the companies' headquarters, under direct coordination with the companies' mobility managers.

Communication with the recruited participants is performed both via e-mail and via a Facebook group. Also, a telephone hotline is made available for any technical problem they should face while using the MobAlt app.

Activities of the pilot project are planned to last for two months, from October to December 2015. At the end of the pilot project a survey is planned to assess the overall effectiveness of the activities performed, the users' satisfaction on the MobAlt app, the alternatives they tested and the remaining barriers. A closing workshop is planned with the local stakeholders (the Municipal and Cantonal administration and the companies involved), to present the overall results of the pilot project and the related survey and to discuss further steps of the project.

4. First Action Step: The pilot project is launched: the MobAlt app is released and new mobility options are made available, including also the activation of a shuttle bus line, after reaching the required number of subscribers to reach break-even. Playful supporting initiatives and information events are launched to stimulate their use and to invite participants to involve other colleagues.

Regular contact with the stakeholders is performed, to identify possible difficulties and adjust the mobility offers (especially, timetables of the inter-company shuttle buses) to the requirements of the participants.

5. Assessment of the First Action Step: At the beginning of the pilot project, workers of the involved companies show low interest for MobAlt: enrolling rates are low and the majority of the participants does not download the MobAlt app, does not try the new mobility alternatives offered and does not show much interest for the supporting initiatives launched. In total, in fact, only 31 participants answer the online quizzes offering three simple mobility questions and nobody participates in the photo contests we proposed.

One of the main reasons for this is identified in the communication channels used, which result incorrect respect to the segment of workers in the involved companies. During the information events we understand, in fact, that most of the workmen, mainly middle-aged women employed as tailors in the production line, are not familiar with e-mails, smartphone apps and computers. Even though most of them own a smartphone, in fact, they mainly use it for WhatsApp messages; neither Facebook has a large diffusion as an information channel. Therefore they do not really get informed about the MobAlt initiatives and, most important, they are not stimulated by the functions offered by the MobAlt app. Clerical workers, instead, are used to interact with digital services and, indeed, they tend to be more informed about MobAlt activities; however, they are only a small percentage of the workers of the companies participating in the pilot project, therefore they do not affect global results.

On the contrary, shuttle buses have some success and one of the two programmed lines is activated: workers who, thanks to their compatible working schedules and home along the route, decide to use them, are very satisfied and express their desire to keep using the service also after the end of the pilot project. This is due not only to the to the convenience of avoiding driving, which allows to get to work less tired and to work better, but also to the creation of pleasant community of shuttle-bus commuters.

Acknowledging these elements suggests for a revision both in the communication channels and in the focus of the project, moving it from the intangible MobAlt app to the definitely more tangible inter-company shuttle buses.

6. Amended Plan: The first change we introduce refers to the communication strategy: instead of favouring digital communications via e-mail, Facebook and the MobAlt app itself, in-person meetings are favoured. An additional series of interactive events, in the shape of informal information events ("info points") during lunch-breaks, is organised. Their aim is to inform workers about MobAlt and at the same time to let them express their personal mobility needs and to make their own barriers to participation in MobAlt and changing their commuting patterns arise. In parallel, WhatsApp, a smartphone-based messenger application is introduced as the main communication channel with the participants, especially those using the inter-company shuttle buses.

The second change refers to the focus of the project itself: instead of concentrating on providing information on the mobility options available, via the MobAlt app, MobAlt is re-oriented in order to focus on the creation of new, tangible mobility options, therefore filling in gaps of the present transportation system. The idea is to rely on the elements arisen in the "info point" meetings and on a more detailed analysis of the commuting needs of the workers of the companies involved in the pilot study (origins, working schedules, flexibility possibilities, family constraints), in order to identify possible new routes for the shuttle buses.

In order to provide for enough time to assess effectiveness of the new plan, the pilot project is prolonged of one month, until the end of January 2016.

7. Second Action Step: The WhatsApp smartphone application is introduced, both to support emergency situations as a hotline and to stimulate participants to take part in the playful initiatives launched.

The "info point" events are held and detailed analyses of commuting needs of the workers are performed: a new inter-company shuttle bus line is introduced and a third one is planned. Very interestingly, the new approach promotes capacity building and direct empowerment of the participants: the third shuttle bus line is in fact a bottom-up proposal by one of the workers (a tailor workwoman), who identified a possible route and raised interest in a number of colleagues of her company, who share the same work shift and live either in the same municipality or along the route to their workplace. Unfortunately, the shuttle line cannot be activated before the end of the pilot project, since it still lacks a few subscribers to reach break-even.

Finally, an unexpected decrease in production activities, due to a sales decrease for one of the companies involved in the project, leads to the re-organisation of the working schedule and shifts, making more workers' shifts compatible with the shuttle bus services and inducing a number of them to start exploiting the MobAlt shuttle buses.

8. Final assessment: Opting for the transport-option focus and the "info point" events proves to be a successful choice: it allows to make the workers' personal mobility needs explicit and to identify the main barriers precluding change in their commuting patterns, helping therefore to propose the effective mobility options satisfying their needs.

At the end of the three-months pilot project, in fact, five shuttle-bus lines are identified as potentially very attractive for the workers of the involved companies. Only two of them are activated but numbers of the interested workers are favourable and their activation is envisioned very soon. Also, a new flexible service of “car-based shuttle services” is proposed: workers who accept to commute with their own car along specific routes at specific timetables during the day can offer a “shuttle service” to other colleagues interested in the same route, under a fee. That is, a mixture between car-pooling and shuttle-buses is created, thus taking advantage of the flexibility of both the modes of transport and avoiding the main limitations characterizing them, that are high costs for the bus driver’s salary and the need to reach a certain number of passengers to make a financially sustainable service, as well as the lack of guarantee to have a car-pooling ride when travelling with colleagues in car-pooling teams.

Conversely, the MobAlt smartphone application has limited success: participants who download it are a small number, compared to the potential number of workers of the involved companies. Moreover, those who download it mainly use it for the visualization of their transport alternatives for home-work commuting and only very few reservations are made. As already acknowledged, this is mainly due to the digital-divide characterizing the workers themselves. We believe that if the same experiment had been performed in the tertiary sector, the MobAlt app would have been much more appreciated.

From our perspective, it is particularly interesting assessing how the MobAlt pilot project affected the commuting habits of the workers of the involved companies. The following section presents the results of our assessment.

6.4.2 Results of the MobAlt project and barriers to change when commuting

The seven companies involved in MobAlt account for a total of around 3’100 workers. Around 11% of them actively took part in the pilot project (348 voluntary participants). Tangible effects of MobAlt on reducing car use when commuting to work can be summarized as follows:

- 5 shuttle-bus lines were planned, for a total of 240 workers interested;
- 2 shuttle-bus lines were activated, for a total of 70 workers subscriptions;
- 7 car-based shuttle services were activated, for a total of 13 passenger workers subscriptions;
- 10 workers joined already existing car-pooling teams;
- 11 users tested folding and electric bicycles and kick-scooters for one week and public transport weekly season tickets.

To understand motivations of the mobility choices made by the participants, we performed a final survey, open to all the workers of the companies involved, and also gathered qualitative elements during the “info point” information events.

The survey, in particular, aimed at understanding:

- the effectiveness of using innovative digital tools to provide information aimed at supporting mobility behaviour change (the information on the existing mobility alternatives and the possibility to book them);
- the general satisfaction of the workers regarding the MobAlt pilot project and their intentions for future use of commuting alternatives;
- the perceived opportunities and barriers of the alternative options for commuting offered during the pilot project.

The survey was administered by means of both online and printed questionnaires, directly distributed in the companies’ canteens during lunchtime. All the workers were invited to fill the questionnaire in, independently of their participation to the MobAlt project. The aim was in fact to also get insights on the reasons why workers were not interested in trying the MobAlt proposals.

Even though a prize draw was offered to all those who filled the questionnaire in, the response rate was not very high: 48 persons completed the questionnaire, equivalent to 14% of the Mobalt participants (348 workers) and 1.5% of the overall number of workers of the MobAlt companies (around 3'100 workers). Due to the limited sample size, the data gathered therefore cannot be considered representative of the workers of the whole Mendrisio area. However, they give us some helpful indications.

The sample of respondents

Coherently with the distribution of the place of living of all the workers of the MobAlt companies, the large majority of the sample of respondents lives in Italy (85%, see Figure 6-9). Due to the already mentioned lack of a trans-national efficient public transport network, this element is to be taken into account when assessing the barriers to decreasing car use.

Also, 87% of the respondents are female (see Figure 6-10). Again, this reflects the structure of workers of the MobAlt companies (see Figure 6-9). In fact, the majority of the participants work in a company operating in the fashion industry as qualified dressmaker, a profession mainly chosen by women.

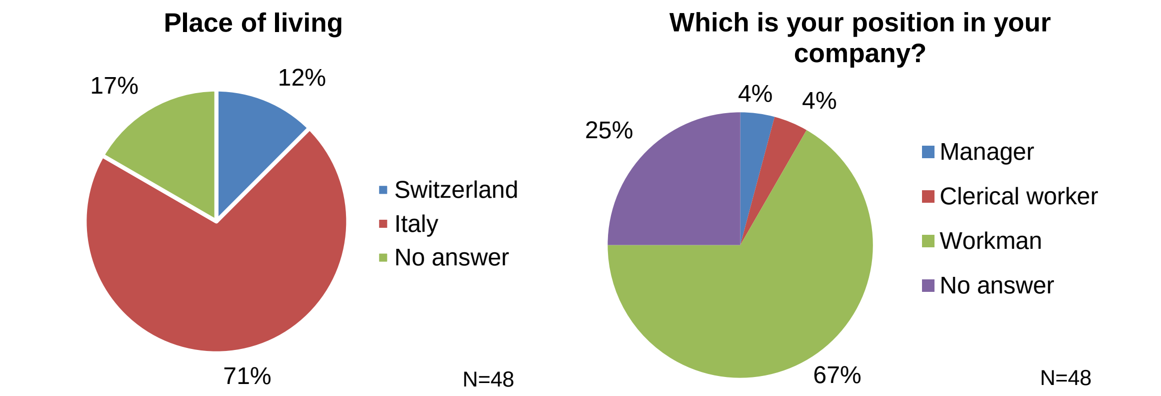


Figure 6-9 Characteristics of the survey respondents, place of living (left) and position (right)

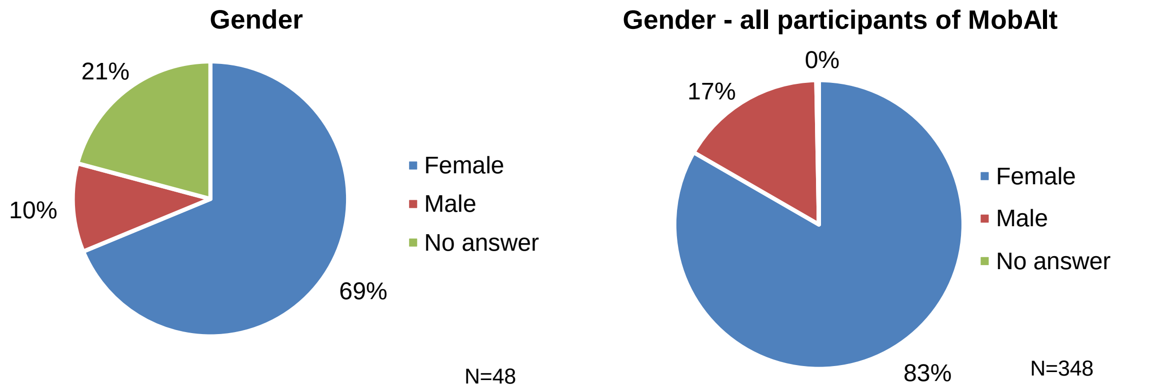


Figure 6-10 Gender of survey respondents (left), compared to project participants (right)

As it can be seen in Figure 6-11, the majority of respondents are more than 40 years old (64%), and indeed, a significant percentage of them is above 50 years (29%).

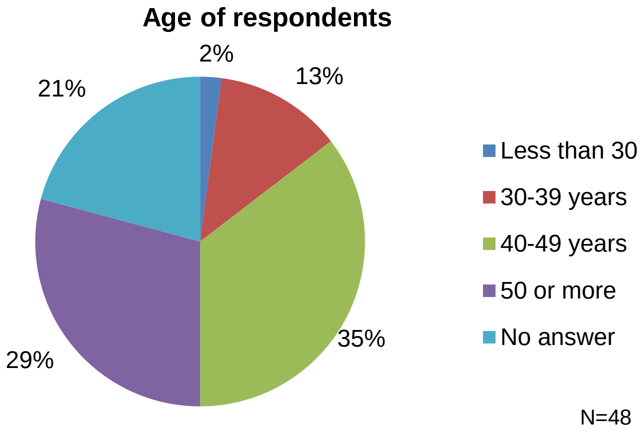
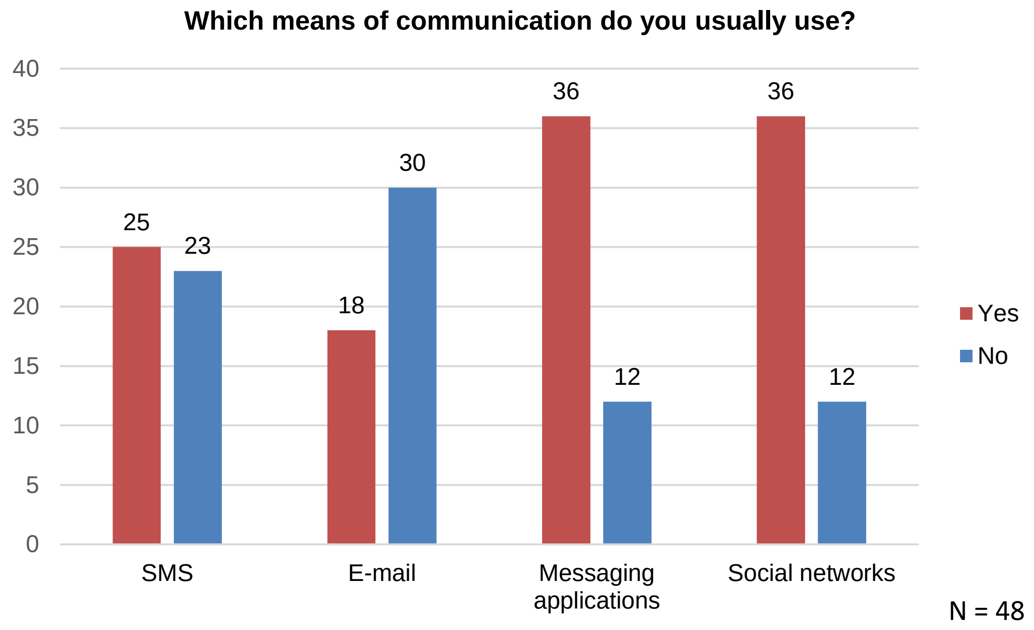


Figure 6-11 Characteristics of the survey respondents: age range

Further, the majority of respondents (at least 67%, without considering non-answered questions) are workmen, characterized therefore by an average low level of education. Also, they are characterized by a low level of confidence with information technologies such as e-mail and social networks, being instead experienced with the use of messaging applications such as WhatsApp and Viber (see Figure 6-12). This is confirmed by the answer they gave when asked why they did not download the MobAlt app: half of them declared they have no technological background and they are uncomfortable using smartphone apps. One of the participants, a tailor woman, in fact told us that *"Well, it is already an achievement for me owning a smartphone, but I would never be able to use applications, too complex to me. It's already a miracle that I use WhatsApp."*



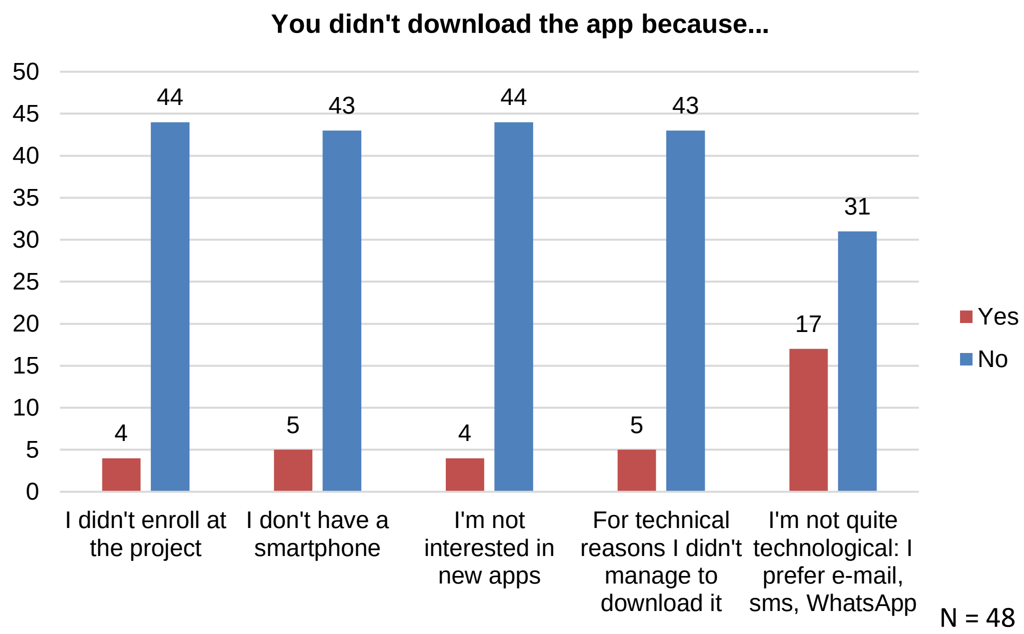


Figure 6-12 Characteristics of the survey respondents

use of means of communication (left) and reasons for not downloading the MobAlt app (right). The right chart only represents data of the respondents who declared they did not did not download the app.

These elements confirm the hypothesis that low use of the MobAlt smartphone app is not due to significant shortcomings in the app itself; instead, it simply is not the proper tool to deal with the targeted population. The generations of the respondents (and consequently of the participants to the project) is hardly motivated in using ICT tools.

For the same reasons, in particular for the age, our sample was probably not the proper target also for participating in playful challenges. As indicated above, in fact, notwithstanding the tangible prizes, only a negligible part of them was interested in the game-like activities launched to favour behaviour change.

Strengths and weaknesses of the commuting options tested

The survey asked to indicate the means of transport the workmen most frequently used to commute to work before, during and – presumably - after the MobAlt pilot project (see Figure 6-13). Answers gathered show that nearly all the respondents used the car as the primary means of transport to commute to work. The majority of them, however, was already car-pooling with other colleagues, since most companies had either already introduced car-pooling as a mandatory measure or strongly incentivized it, in parallel with a reduction of the parking lots. During the pilot project, instead, a significant number of the respondents opted for the inter-company shuttle buses and they reported their desire to use them also after the MobAlt project. In fact, during the “info point” discussions, shuttle bus users indicated they were quite satisfied with them and glad to have found a valid alternative to car on their route home-work. Interestingly, shuttle buses replaced both single car and car-pooling commuting. Moreover, during the pilot project the number of respondents travelling by car by themselves nearly disappeared.

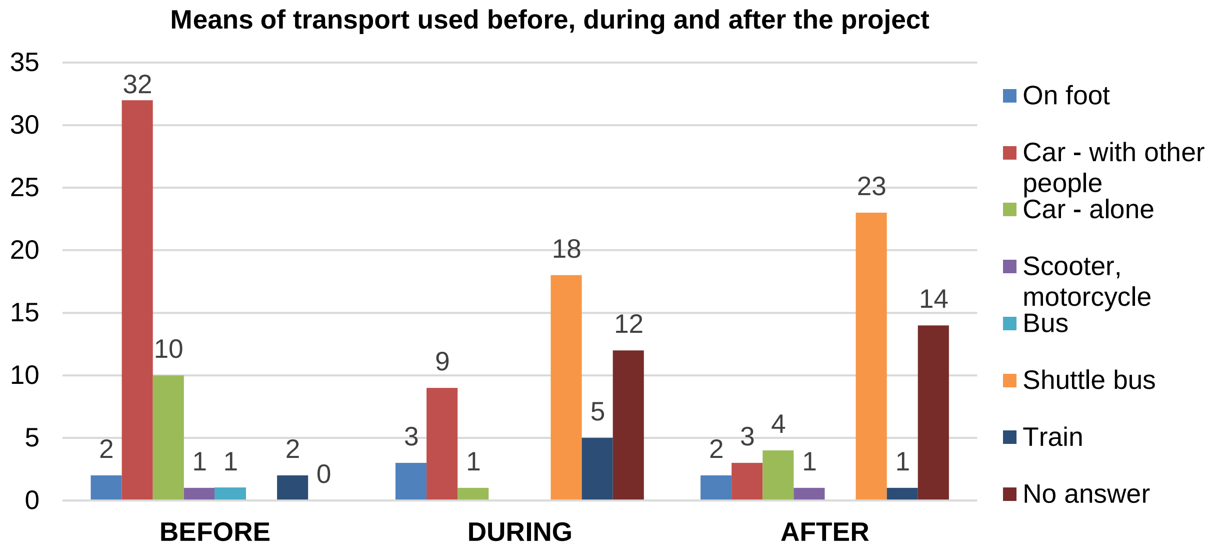


Figure 6-13 Means of transport used before, during and after the MobAlt pilot project

If we consider the total number of participants to the pilot project, users of the shuttle buses were 70 out of 348, that is around 20% of the participants. Therefore, the remaining 80% of the participants either commuted by car by themselves or commuted by car with other colleagues (car-pooling). This means that answers to the questionnaire are most probably biased: users of the MobAlt shuttle buses, pleased by the positive experience, were more willing to answer the survey than the other participants to the pilot project and, above all, than the other workers.

In the following we provide a summary of the main potentialities and barriers related to the mobility options offered during the MobAlt pilot project, according to the participants’ perceptions. Since the perception-related section of the survey received a lower number of answers, a thorough quantitative analysis of results cannot be performed. Therefore, even though in the next sections we present charts reporting answers to the perception-related section, we mainly focus on qualitative elements arisen during the “info point” meetings.

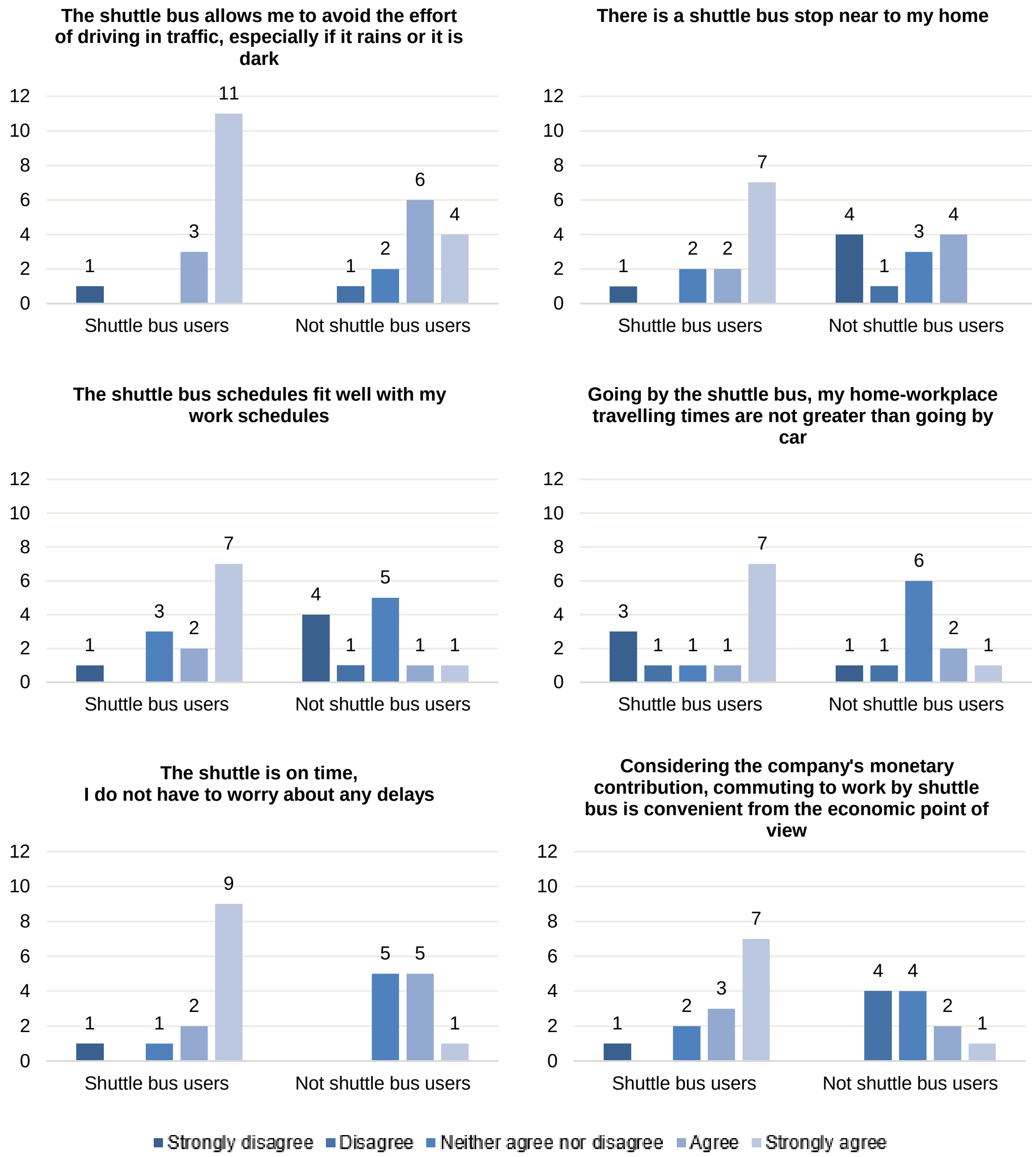
Use of inter-company shuttle buses: Comments gathered during the "info point" meetings show that users of the shuttle buses highly appreciated them and such assessment is confirmed by the results of the survey. The main positive aspect workers highlighted relates to the possibility of getting free from driving in traffic jams during peak hours and being less tired during the whole working day. Also, they reported to be less stressed, due to less fear of car accidents, and remarked that, due to the pleasant climate developed between the community of passengers, a quite favourable working environment was also created. As one of the workers said: *"It's very funny to travel together with my colleagues by the shuttle bus. Instead of focusing on the traffic, we just have fun: we can watch videos and photos and laugh a lot. We are already cheerful when we arrive at work."* All these factors can definitely have positive effects on the work performances of the employees.

Bus-shuttle users also reported to be quite satisfied with the punctuality of the buses, which is essential for the large majority of the workers. Independently of their effective performances, however, bus shuttles might not be appreciated because passengers lose direct control of their commuting time. During one "info point" meeting, in fact, one of the participants told us: "*I have been working in this company for more than twenty years and I always managed to arrive on time. I care for my company, I don't want to risk being late due to a delay of the shuttle-bus. I want to be fully responsible for my working performances and do not want to rely on other people, with the risk of getting into troubles with my boss*". Such a position is of course quite peculiar, but this shows that not subscribing for the shuttle buses might not only be due to time schedule incompatibilities or living too far from their route. The most effective way to answer to similar positions is to make the positive assessments by the users of the shuttle bus service publicly available.

The most common reason why participants did not use the shuttle buses was – unexpectedly – flexibility in their working hours. Flexible working hours in fact often imply flexibility in favour of the company: workers start at the same hour every day but leave the workplace when they conclude the amount of work they are assigned for the day: if work is more than usual, they need to extend their working time; if work is less than usual, they stop working earlier – and therefore would prefer to go back home instead of remaining at the workplace waiting for the shuttle bus. According to the participants to the "info point" meetings, this happens quite frequently, also for shift workers, making definitely little appealing the use of rigid alternatives such as the fix scheduled shuttle buses. *"My activities strictly depend on market and other colleagues' requests: daily I need to answer to all the requests I receive during the day. Therefore, it's quite frequent to me to stop working late in the afternoon, even though I arrive in the office at the same hour, quite early in the morning".*

Furthermore, numerous potential users decided not to use the inter-company buses due to significant increase in travel times: distances from home to the closest bus-stop were too high to make them an attractive alternative. "*The closest stop of the shuttle bus is at fifteen minutes of car from my home. Since I have to use the car in any case, I prefer to keep using it directly to arrive at work, which in total is around half an hour. I also avoid paying for the full shuttle service even though I would use it only for half of the route".* A further limiting factor emerged: during the pilot project the shuttle bus service had the same costs for all the users, independently on the length of the route. Taking account of the users' feedback and satisfaction, at the end of the pilot project the fares were modified, introducing "shuttle bus transport zones" and a related fares system based on the length of the route.

The last key barrier – again connected to flexibility – related to the use of shuttle buses by workers who, either before or after work, need to accompany other family members or do some tasks on the home-work route. This is especially a problem in the context of the MobAlt pilot project, where the majority of workers are women, frequently also challenged with taking care of young children or elderly parents or with the weekly shopping at the supermarket: *“How could I take the bus if I have to bring my son back home in the afternoon? He finishes school at 16.45, while the bus arrives in my village at 17.15, moreover quite far from the school.”*



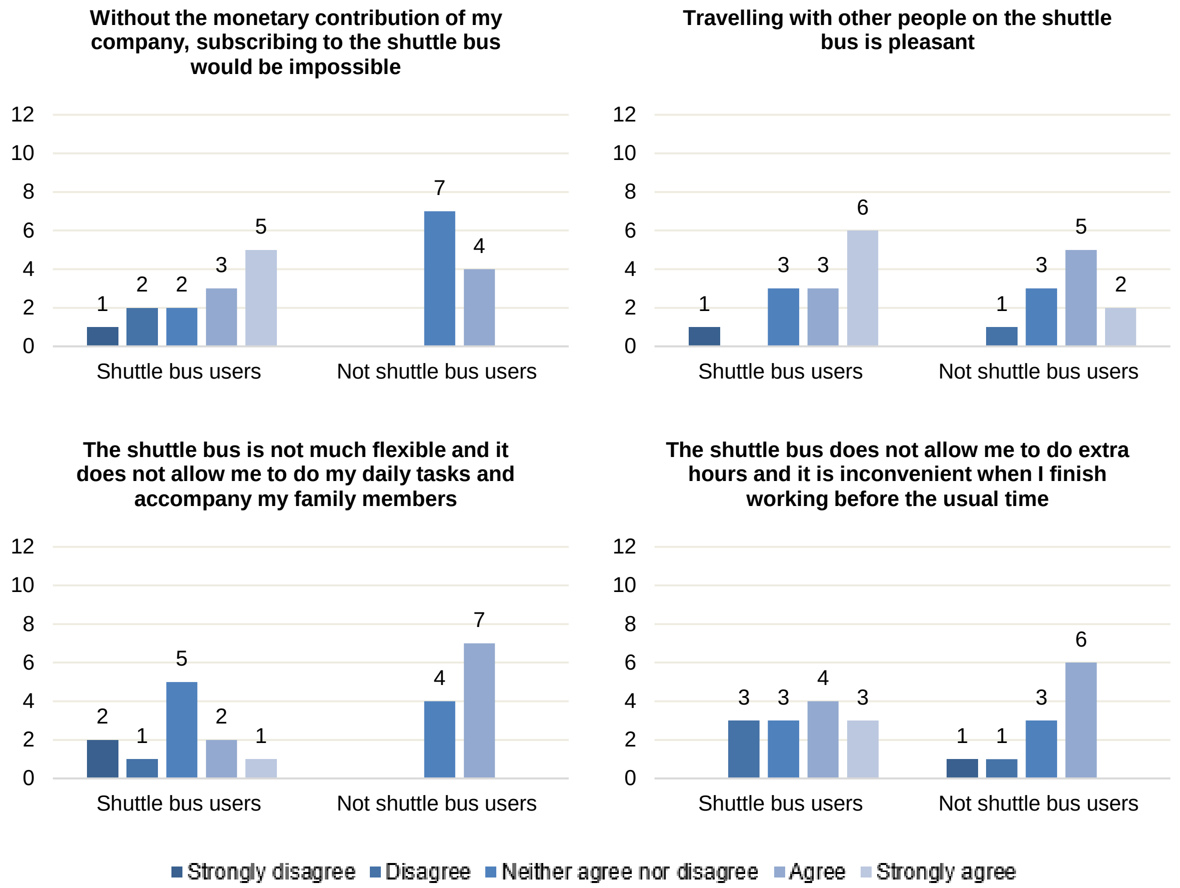


Figure 6-14 Perceptions of survey respondents about the inter-company shuttle buses

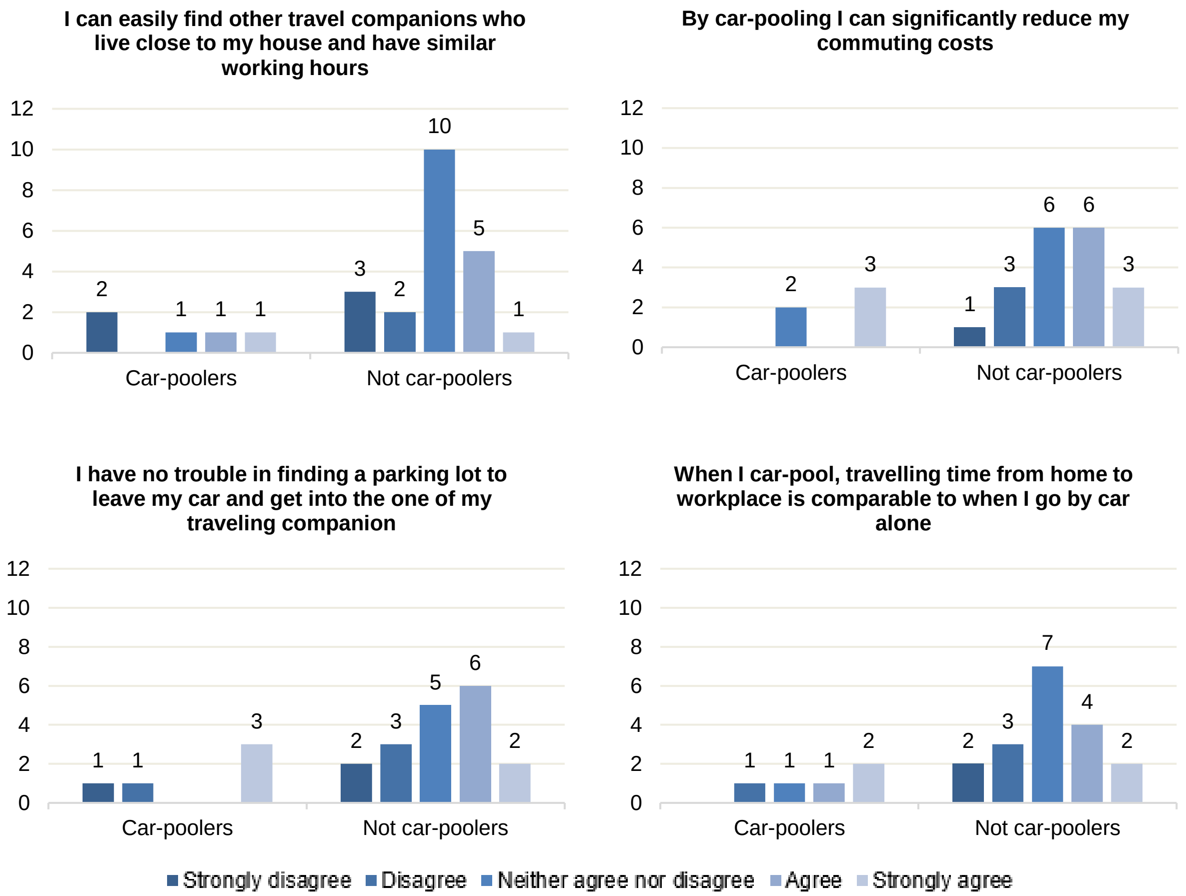
<u>*Use of car-pooling:*</u> car-pooling did not bring as much novelty in the pilot project as we had originally planned, since some companies had already introduced it as a compulsory measure for their employees, in parallel with a significant cut in the number of available parking lots. Such a regulation forced workers to adopt car-pooling habits, which in many cases they would have probably avoided. In fact, many workers complained about the lack of individual flexibility imposed by car-pooling ("*my travel companions need to wait for me if I'm compelled to end work later than usual, while I need to wait for them when I finish earlier*") or feared being unable to face emergencies, which might require unexpected and sudden travels back home, a problem especially perceived by workers with young children or elderly parents ("*what happens if my child's school calls me she is sick and I need to take her back home?")*.

Also, it is difficult finding the right travel companions, since not only one has to consider the colleagues' places of living and the working schedules, but also possible routes they have to travel in order to accompany familiars to their daily activities. "*Differently from the majority of my colleagues, I work part-time. Moreover, when I stop working I go to my five-years old daughter's kindergarten and then I directly bring her to the gym or to the music school. I could not do it if I had to adapt to other colleagues' needs. I'm lucky that, due to my part-time working schedule, my company did not compel me to car-pool*".

Even though maybe they were not fully satisfied by the car-pooling commuting option, because they were forced to adopt and it was not their free choice, many of them were not interested in changing the commuting patterns they had just adopted and for this reason they did not show much interest for searching other travelling companions by means of the MobAlt carpooling platform (in order to travel with four colleagues in a full car). In particular, searching for more colleagues was thought to introduce obstacles and losses of time.

All in all, however, they acknowledged car-pooling as a good option to significantly reduce travel costs (petrol costs, parking fees, car maintenance costs); shuttle buses, instead, require a monthly travelcard whose cost is nearly comparable to commuting by one's own car. Also, they indicated car-pooling does not imply much longer travel times, since considering the large number of workers in the MobAlt companies, it was possible to identify effective route and working schedule matches between at least two colleagues.

Also, all those who car-pooled report to be less stressed since, at least some days during the working week, they do not have to drive in congested traffic, and to enjoy travelling with other colleagues: *"It is quite comfortable for me to travel together with my colleagues. We're three travelling together and every week we change car and driver. So we don't have to drive and use our car every day and we can save effort and money. And travelling with colleagues is fun!"*



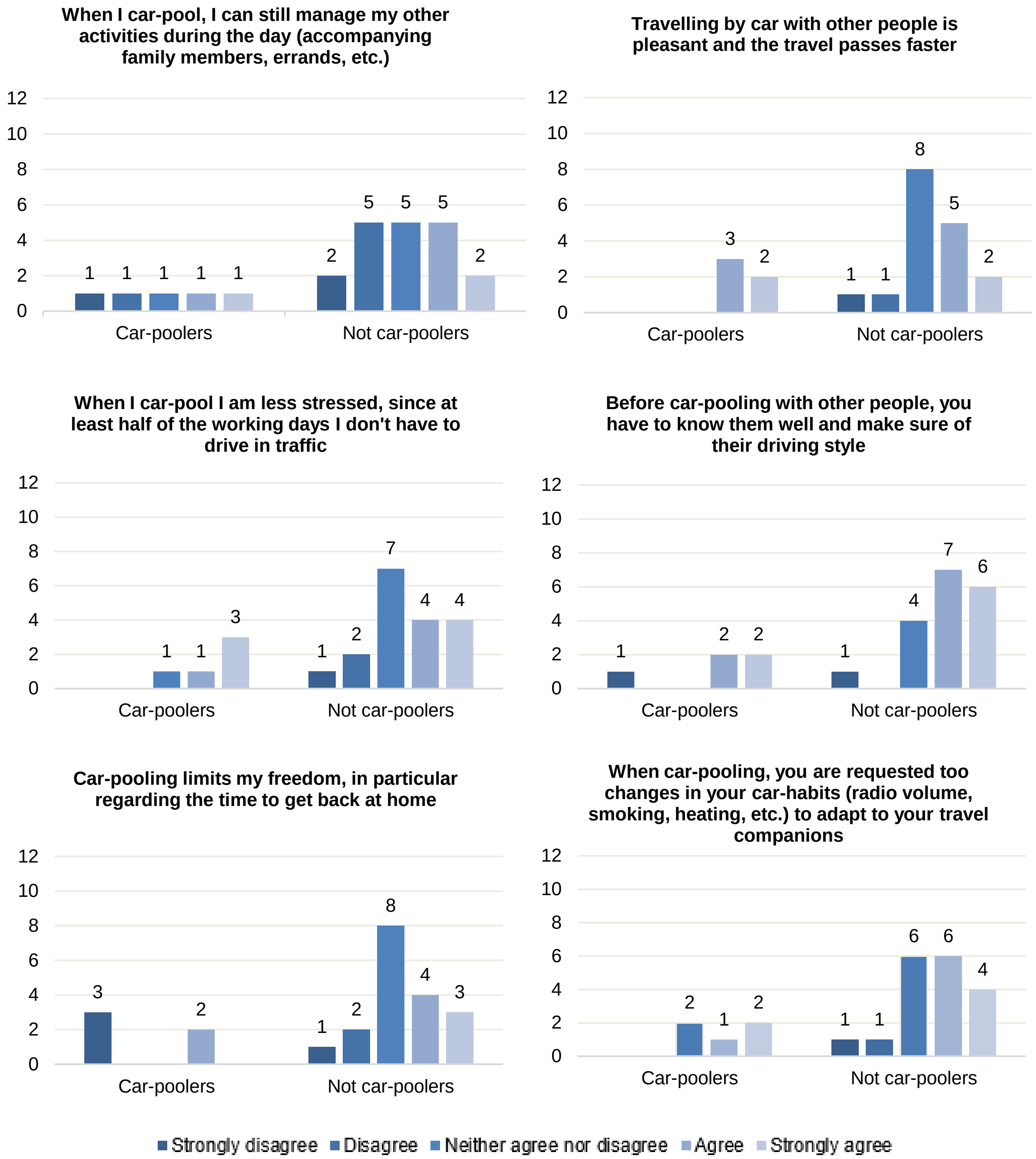


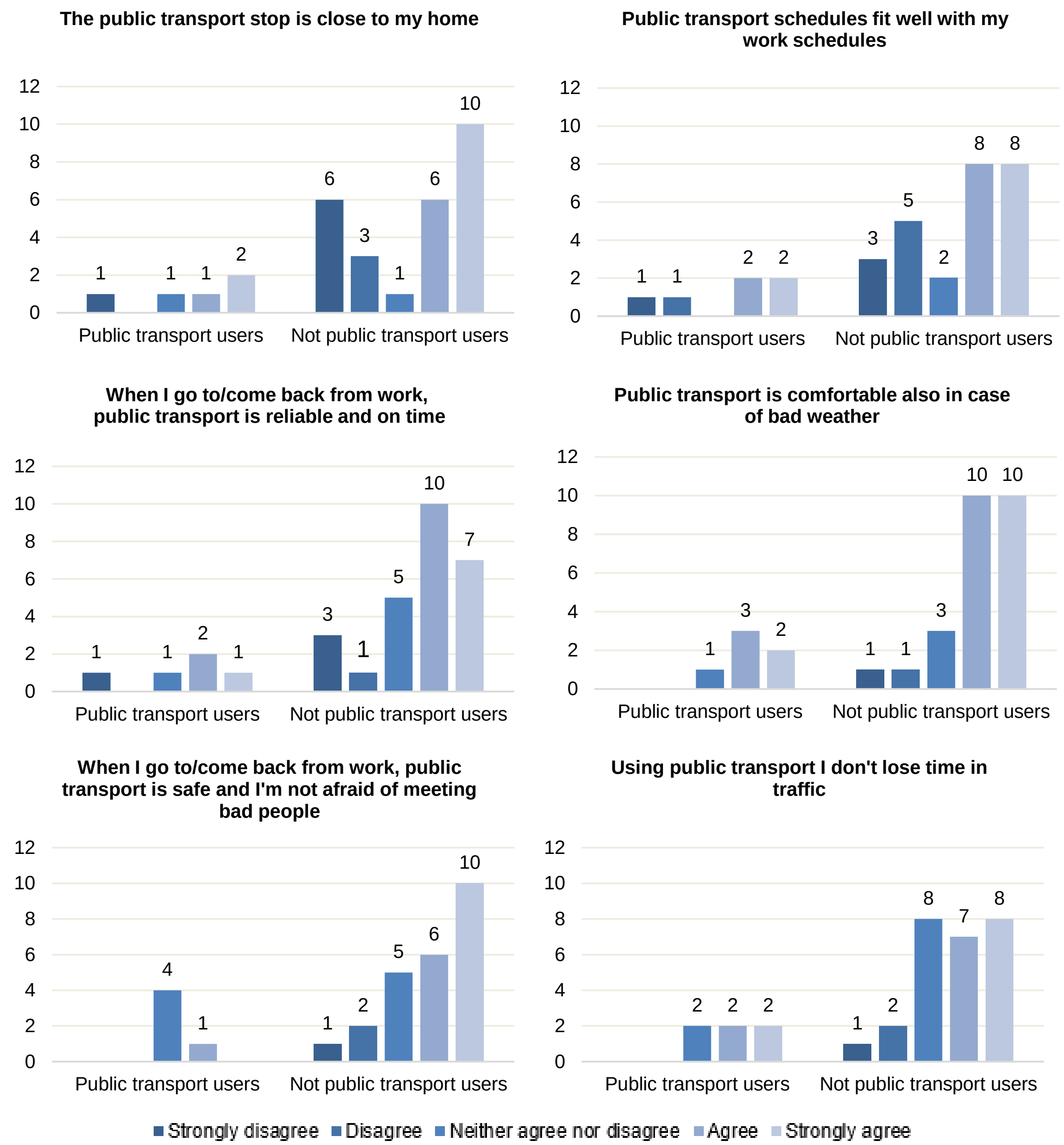
Figure 6-15 Perceptions of survey respondents about car-pooling

<u>Use of public transport:</u> Even though MobAlt offered free and discounted daily tickets and weekly travelcards for public transport, only a few participants tried them.

The most important reasons for this were already mentioned: the majority of MobAlt workers comes from Italy, from places poorly covered by the (trans-national) public transport network. Also, shift working implies starting very early in the morning (around 6 a.m.) or late in the evening (around 10 p.m.), when public transport is not frequent even along the main lines.

In both the survey and discussions during the “info point” events, public transport was indicated as critical also due to the increase in travel times it produces, mainly due to the need to change at least two lines, and its lack of flexibility, especially, again, in case people need to accompany their family members: “*How can you use public transport when you live in a small village and* *you also have two young children to bring at school?", "Have you ever tried to reach the bus stop on a rainy morning, when you are certainly late and the kids try to run away in all directions apart for the correct one? This certainly doesn't work for me and my family*".

During the "info point" events, workers also mentioned that one of the problems of public transport is related to its cost, in particular its price-comfort ratio: "*I could even try it, but it's not a valid alternative to me, since it costs much more than car-pooling with others. And what about the comfort?*"



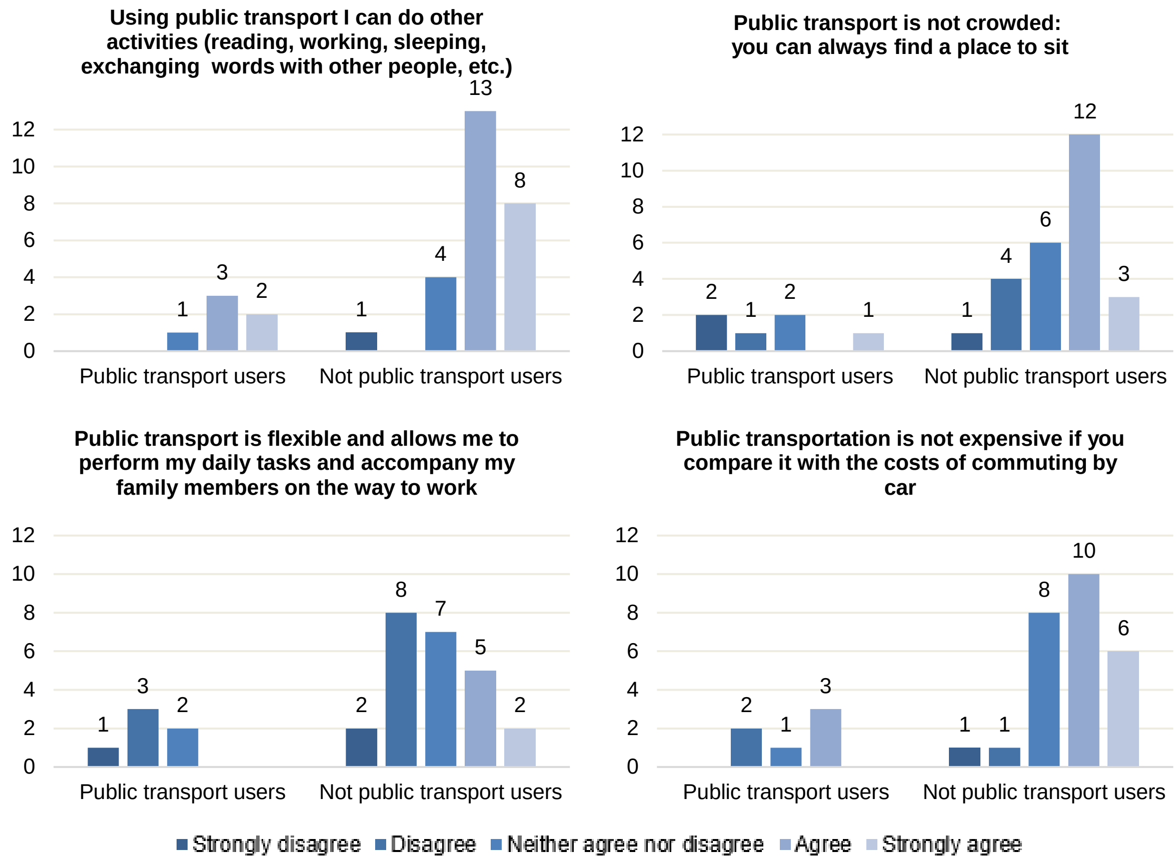
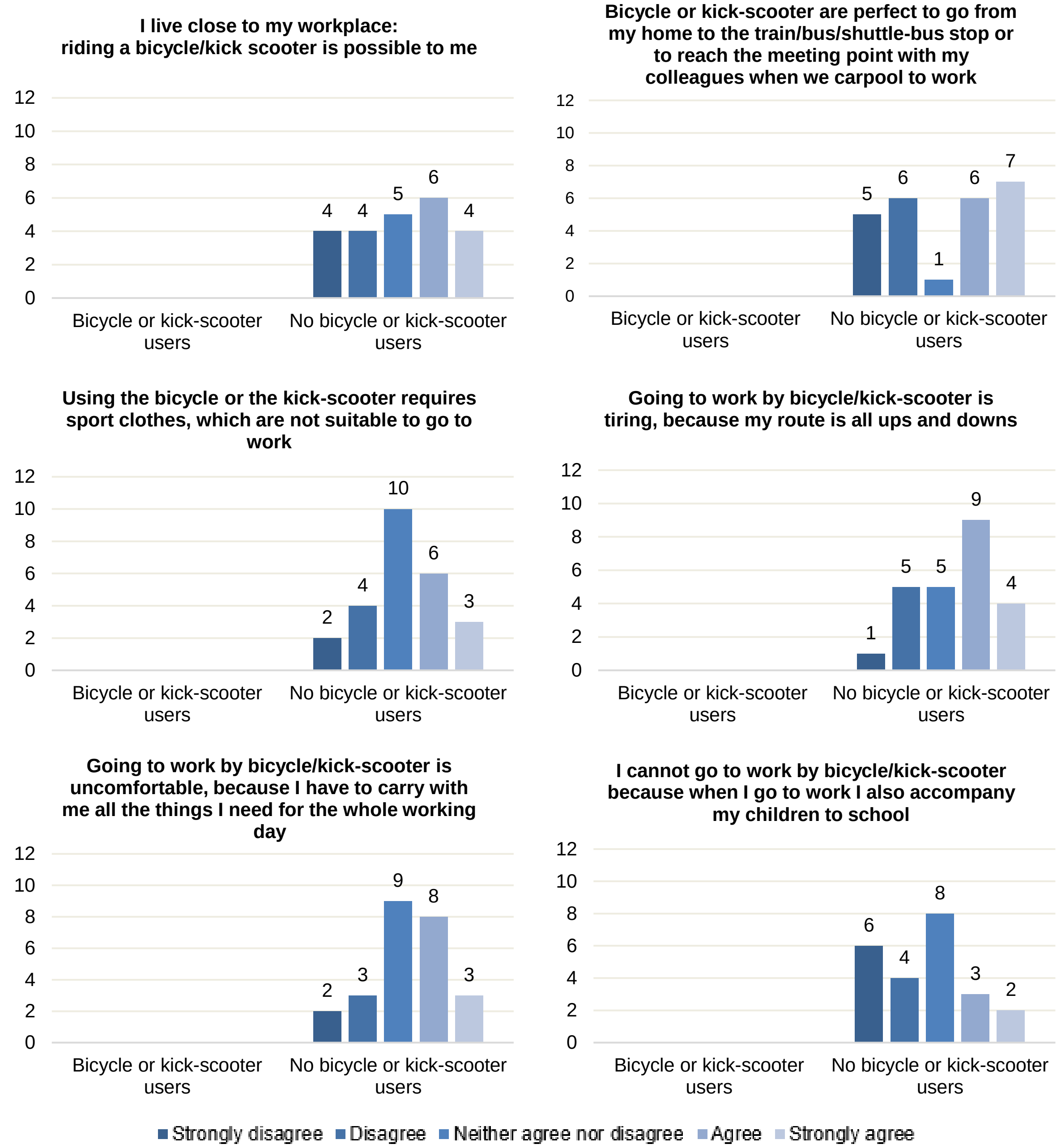


Figure 6-16 Perceptions of survey respondents about public transport

<u>*Use of slow mobility*</u>: MobAlt made freely available to the employees also means of transport for slow mobility: participants could freely rent traditional, electrical and folding bicycles and kick scooters for whole weeks, taking them home and using them as they preferred. However, their use was negligible. Such means were not considered interesting due to distances between one's home and workplace. Since the majority of the employees come from Italy, their commuting routes are generally longer than 10 kilometres. Slow mobility options alone are therefore not valid mobility alternatives for them. However, they could become more interesting if combined with other mobility options, such as shuttle buses, public transport or car-pooling, in an inter-modal way. *"I cycle to the shuttle bus stop and then I load the bike on the bus: it is quite heavy to me, actually, but the driver is so kind… he always helps me"; "I travel every day by car from Milan and it is really a long route! I have a traditional working day schedule, therefore the kick-scooter, coupled with the train, is the right solution for me. It allows me to get very fast to the office from the railway station, on a route of little less than 800 meters".*

An important barrier that they indicated was the inefficiency of the infrastructure: the lack of cycling paths make it quite dangerous to use the bicycle: "*I really would fear cycling along the cantonal road when it is dark – and, with my working shifts, only in Summer I could cycle under the light*". Moreover, also basic parking infrastructures are lacking: "*I would like to leave a bicycle at the station, to use it for the final route segment to reach my workplace. However, I cannot do it, because there are no secure bike racks to leave the bicycle!" "…and, to tell you the truth, also in may company I'd have the same problem: at the moment there are no places to securely lock the bicycle outside – and, unluckily, I'm not allowed to bring it with me in the production area!".*

Again, limitations related to accompanying their family members were mentioned. Also, they indicated they need to carry quite a lot of things for the working day (lunch etc.), which definitely makes cycling commuting less appealing. Finally, the MobAlt pilot project ran during the Winter period, when it was quite cold and the days were quite short: the meteorological conditions therefore discouraged using the bicycle, either traditional, folding or electrical: *"I like cycling in the weekend when the weather is nice but I wouldn't come to work by bike if it is dark or it rains."*



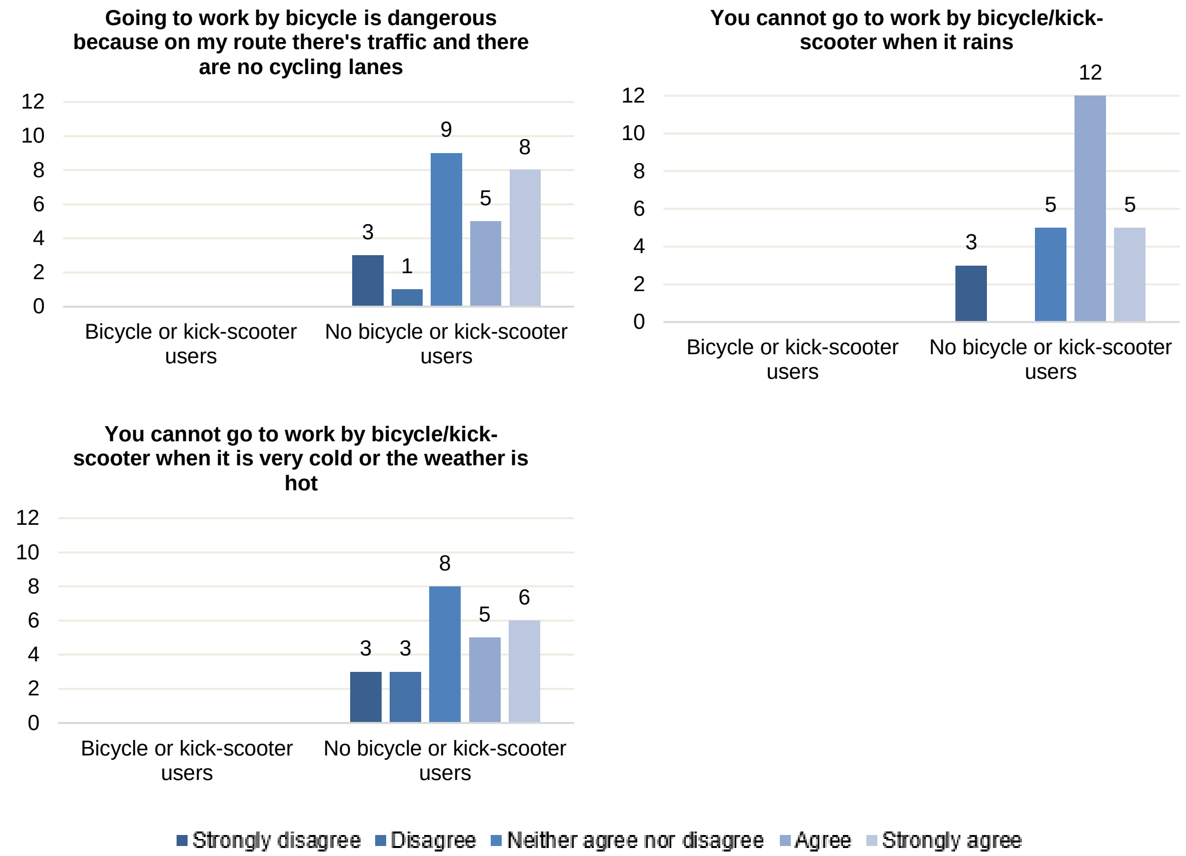


Figure 6-17 Perceptions of survey respondents about slow mobility

6.5 *GoEco!:* potentials to reduce car use by means of eco-feedback and peer comparison information

In the third living lab we have activated, in close cooperation with IKG-ETH Zurich (Prof. Martin Raubal, Paul Weiser, Dominik Bucher, who also contributed to the elaboration of the present chapter), we are investigating the effectiveness of playful approaches to foster changes in personal mobility behaviour. In particular, in *GoEco!* we aim at understanding if, and how, information feedback and social interactions (social comparison and peer pressure) can help people to reduce dependency from car use, encouraging to go by bike or walk, use the public transportation system, rely on emerging alternatives such as car-sharing and car-pooling systems or even organize virtual meetings to avoid traveling all together.

In *GoEco!* we overcome traditional awareness-raising approaches and, by taking advantage of the wide acceptance of smartphones and tablets, propose an innovative, community-based approach, directly addressing citizens and their everyday mobility choices. Research in social and environmental psychology has in fact shown that one of the most powerful triggers for sustainability transitions lays in providing bottom-up personal feedback (on one’s own performances and progress towards personal goals for change) (Fogg, 2003; Thaler and Sunstein, 2008; Darby, 2000, 2006 and 2010; Fischer, 2008; Burgess and Nye, 2008; Faruqui et al. 2009; Hargreaves et al. 2010 and 2013; Ai He et al., 2010; Weiß et al., 2010; Froehlich et al., 2010; Schleich et al., 2011; Degen et al., 2013; Vine et al. 2013; Bull et al., 2013) and comparison with the behaviour and performances of other members of one’s community (Mankoff et al., 2007, 2010; Lehrer and Vasudev, 2011; Petkov et al. 2011; Foster et al. 2010, 2011; Weiß et al., 2012; Foster and Lawson, 2013; De Luca, 2013). In fact, individual feedback and social comparison activate competition and the urge to stand out among peers.

To test these hypotheses in the mobility sector, we created a living lab experiment involving a few hundred real-life users, inviting them to use a smartphone application, which tracks their trips and uses game elements to challenge them to modify their mobility patterns.

To get a broader understanding of the effectiveness of such an approach, the living lab is run in Canton Ticino and in the City of Zürich. The two regions are very different with respect to the availability of mobility options and the socio-cultural attitude of the population towards mobility: the Zürich region is in fact a dense urban area, characterized by high levels of accessibility to public transport and infrastructures for slow mobility, while Ticino in Southern Switzerland is a vast area characterized by urban sprawl, in many cases lacking effective alternatives to individual car use.

6.5.1 Theoretical background: persuading behaviour change by eco-feedback and gamification

GoEco! investigates if and how ICT-based persuasion, exploitation of eco-feedback, social norms, and peer pressure can foster changes in personal mobility behaviour. Our research is grounded in the “captology” framework, i.e., the “study of Computers as Persuasive Technologies (CAPT)” developed by (Fogg, 2003). Here we briefly introduce captology, review the most effective motivational elements for behaviour change, comment on current pro-environmental smartphone apps implementing them, and discuss their limitations.

6.5.1.1 Persuading individuals to change their preferences

According to the behaviour model developed by (Fogg, 2009), an individual performs a specific behaviour depending on:

- her *motivation*,
- her *ability*,
- and the presence of a *trigger* (a prompt to actually perform the behaviour).

This model argues that if the *motivation* is high, a change in behaviour can be achieved even if it is difficult. Conversely, if motivation is low, even easy changes in behaviour are difficult to achieve. Behaviour can either be extrinsically or intrinsically motivated: extrinsic motivation is generated by environmental, social, or cultural background, while intrinsic motivation is produced by a number of mental processes, in particular one’s goals, expectations and the self. *Ability* refers to an individual capability to perform some behaviour and it is determined both by individual skills and by the context. *Triggers* are anything that stimulate users to perform a certain behaviour: they can either increase motivation (*sparks*, in Fogg’s jargon), for example by providing awareness on the consequences of one’s actions, or ability (*facilitators*, in Fogg’s jargon), for example by providing information on how to perform a certain action. Fogg’s persuasion appears therefore as a process that supports individuals in changing their behaviour by active cognitive processes: the desired behaviour is the result of new convictions by the individuals (Bell et al., 2010) and requires their active engagement (Mols et al., 2015).

General mental processes that occur when persuading individuals to change can be explained by the Transtheoretical model, developed by (Prochaska and Velicer, 1997). Individuals start from a *pre-contemplation stage*, during which they have low motivation and/or ability for change. By providing (framed) information or pointing to social norms, their awareness is raised, so that they move in a stage in which they *contemplate* change. If they are stimulated this way for a sufficiently long period of time, they enter the *preparation* stage, during which they develop a plan, and then actually start changing their behaviour. The following stage (*maintenance*) is of crucial importance, as individuals need to be motivated and actively stimulated, so that behaviour is constantly performed, until it is internalized, resulting in the creation of new a habit. When this happens, the cycle begins back at the *pre-contemplation* stage.

6.5.1.2 Effective persuasion techniques

Froehlich (2015) and (Anagnostopoulou et al., 2016) discuss the most effective persuasive techniques to stimulate pro-environmental behaviour. In the following, we give a short summary of their work:

- *Provide information*: When providing information to a user, it is most valuable if it is related to the user's behaviour and is given as timely as possible (close to the triggering cause, in both space and time). This makes it easier to understand and remember. Possible information could be on available transport alternatives tailored to the individual's needs, interests or living context.
- *Provide occasions for social comparison*: Offer individuals the opportunity to compare their choices and performances with the ones of other people or groups, which users perceive as comparable to themselves (e.g., members of the same community). This generates both peer pressure and a desire for imitation.
- *Provide goal setting opportunities*: If behavioural targets are really challenging for the individual, self-setting goals can have powerful effects, because they create a self-competitive setting in which the individual strives for personal progress and mastery (intrinsic motivation for change).
- *Provide feedback*: Since individuals require a baseline to assess their performances, giving feedback is complementary to and essential for goal setting activities.
- *Provide rewards (incentives) or punishment (disincentives)*: These can be either tangible or intangible, expressed in monetary terms or in physical units, and reflect an intrinsic or extrinsic motivation for change. Provided as an outcome of the individual's performances, they can either reinforce individual motivation to adopt a certain behaviour (reward of good performances) or stimulate a user to strengthen his or her efforts, in case of poor performances. The use of punishment, however, is controversial (Foster et al., 2011), since it might quickly lead to the unwanted effect of demotivating users.

In such a framework, persuasive approaches frequently exploit *gamification* techniques, namely the "use of game design elements in non-game contexts" (Deterding et al., 2011). Typical gamification mechanics and elements are competition, cooperation, assignments, quests, goals, points, levels, badges and leaderboards (Weiser et al., 2015).

6.5.1.3 Persuasive smartphone apps for behaviour change

Due to their promising potential, a fast growing body of literature studies the effects of coupling persuasion and gamification techniques with information and communication technologies (ICT). ICT allows applying these techniques in an effective and timely manner, often providing users with real-time and bi-directional interaction possibilities. A prominent example is the use of web-based platforms or smartphone apps to promote electricity and water savings, accompanying the roll-out of smart meter devices to measure real-time electricity and water consumptions. This is often performed within the bounds of a so-called smart city framework (among others, see (Darby, 2000, 2006 and 2010; Fischer, 2008; Burgess and Nye, 2008; Sergici and Faruqui, 2011; Hargreaves et al. 2010 and 2013; Weiß et al., 2010; Fischli et al., 2011; Schleich et al., 2011; Degen et al., 2013; Tiefenbeck et al., 2013a and 2013b; Novak et al., 2016). Many such platforms and apps provide users with a number of the above elements for effective persuasion identified by (Froehlich, 2015). Not only do they give feedback on consequences of individual choices (usually, energy consumptions and CO_2 emissions), but they also allow users to define personal goals for change, engage in challenges, and interact and compare their performances with virtual communities of users, frequently addressing the users' social network relationships by direct interaction with Facebook (Mankoff et al., 2007, 2010; Foster et al. 2010, 2011; Froehlich et al., 2010; Lehrer and Vasudev, 2011; Petkov et al. 2011; Weiß et al., 2012; Bull et al., 2013; Foster and Lawson, 2013; Wemyss et al., 2016).

As mentioned, persuasive apps within the electricity and water domains rely on fixed metering infrastructures, which provide consumption data. Automatic monitoring of individual mobility patterns, instead, is much more complex, since static monitoring systems are not sufficient: flexible tracking systems, able to follow individuals along their movements, are necessary. In 2010, first pilot projects, aiming at automatic mobility data tracking, were developed. They usually exploit smartphone apps and GPS devices embedded in smartphones (Schüssler and Axhausen, 2009; Jariyasunant et al., 2012; Nitsche et al., 2012; Kiukkonen et al., 2010; Ythier et al., 2012; Raubal, 2011; Yuan and Raubal, 2012; Yuan et al., 2012; Cellina et al., 2013). Thanks to the fast progress in the quality of automatic mobility tracking, several persuasive apps promoting mobility behaviour change were released since then. For an in-depth discussion, one can refer to (Shaheen et al., 2016) or (Anagnostopoulou et al., 2016); here, we only mention a selection of apps aiming at reducing individual car use (see Table 6-1).

Table 6-1 List of persuasive apps developed in the mobility field with the aim of reducing individual car use

App	Reference
UbiGreen	Froehlich et al., 2009
Tripzoom	Bie et al., 2012
SuperHub	Wells et al., 2013
MatkaHupi	Jylhä et al., 2013
Peacox	Bothos et al., 2014
GoEco!	Bucher et al., 2016

Even though such persuasive apps become more widely available, their development is still a young discipline. Experiments assessing their effectiveness are often based on small samples of volunteers (understandably, sometimes heavily biased towards university students), involve short periods of time and often lack a control group (Hamari et al., 2014; Anagnastopoulou et al., 2016). This implies that:

- results cannot be generalized to the whole society;
- long-term behaviour change cannot be measured;
- possible changes in their mobility behaviour cannot be univocally attributed to the app alone, since they might also be influenced by other external factors.

6.5.1.4 General critiques of persuasion

The persuasive approach towards behaviour change received some critiques. First of all, some authors notice that it relies on a *technology paternalistic* vision (Huber and Hilty, 2015), according to which the designer of the persuasive system knows what is good and right, while individuals do not. This recalls the elitist assumption that ordinary people tend to make wrong decisions, while experts are making the right ones (Mols et al., 2015).

Also, some applications of persuasion principles are criticized, since they do not acknowledge that there is no "one size fits all" solution (Huber and Hilty, 2015) (the best actions usually heavily depend on the individual). Designers of persuasive systems should use different triggers to promote different target behaviours. As a strategy which always works, we suggest that individuals define their own goals and share them with the persuasive system (Huber and Hilty, 2015; Froehlich, 2015): in doing so, they can independently decide if, and how much, they want to change. The persuasive system then becomes a useful tool to support and motivate the change users autonomously set for themselves. Finally, offering suggestions and challenges based on the data collected about each user's behaviour and the context the individual lives in, improves persuasion effectiveness (Anagnostopoulou et al., 2016).

6.5.2 Design and functionalities of the *GoEco!* apps

The *GoEco!* project builds on lessons learnt from the literature cited above, both regarding critiques of persuasion approaches and limitations of past experiments assessing the effectiveness of persuasive apps. In this framework, we developed two mobility tracking apps, to be tested in a "living lab", which is a field study involving real-life users in complex, real-world settings (Bergvall-Kareborn and Stahlbrost, 2009). Descriptions of the experiment and of results gathered so far are shown in Sections 6.5.3 and 6.5.4; here, we introduce the apps.

The first one, named *GoEco! Tracker*, simply monitors the mobility patterns of its users, identifying the routes they travel and the means of transport they use. The second one, named *GoEco!,* also employs eco-feedback and gamification elements to stimulate users to reduce car use. Users are supposed to interact with *GoEco! Tracker* for a period of at least four weeks, to collect baseline data, after which they can upgrade to the full *GoEco!* app.

6.5.2.1 Tracking mobility patterns: the GoEco! Tracker app

In order to track mobility patterns, *GoEco! Tracker* exploits the API of the commercial, free fitness tracker App *Moves* (https://dev.moves-app.com). *Moves* records a user's position at various locations (*track points*) and it is able to determine whether the user was walking, running, cycling, or taking another form of transport between them. As explained in depth in (Bucher et al., 2016), we opted for *Moves* instead of developing our own mobility tracker, so we could focus our efforts on developing the eco-feedback and gamification functionalities.

However, *Moves* alone was not enough: being developed for fitness purposes, it is not able to distinguish between all the different means of transport. Since we needed a fine-grained distinction between different means (such as bus, train, tram or car), we built a classifier based on a naïve Bayes algorithm (Russel and Norvig, 2003). Our classifier takes into account several route characteristics, such as travel speed, acceleration, or the overlay between visited points and the public transport network (stops and lines) (Bucher et al., 2016). Every day, users are asked to check and validate the means of transport for every route tracked. The Bayes classifier uses these validations to improve its future predictions, reducing the interactions with users as time goes by: after a few days of use, the accuracy of the algorithm reaches 83% of correctly identified modes, so that users are requested to correct the means of transport only for 17% of their routes (Bucher et al., 2016).

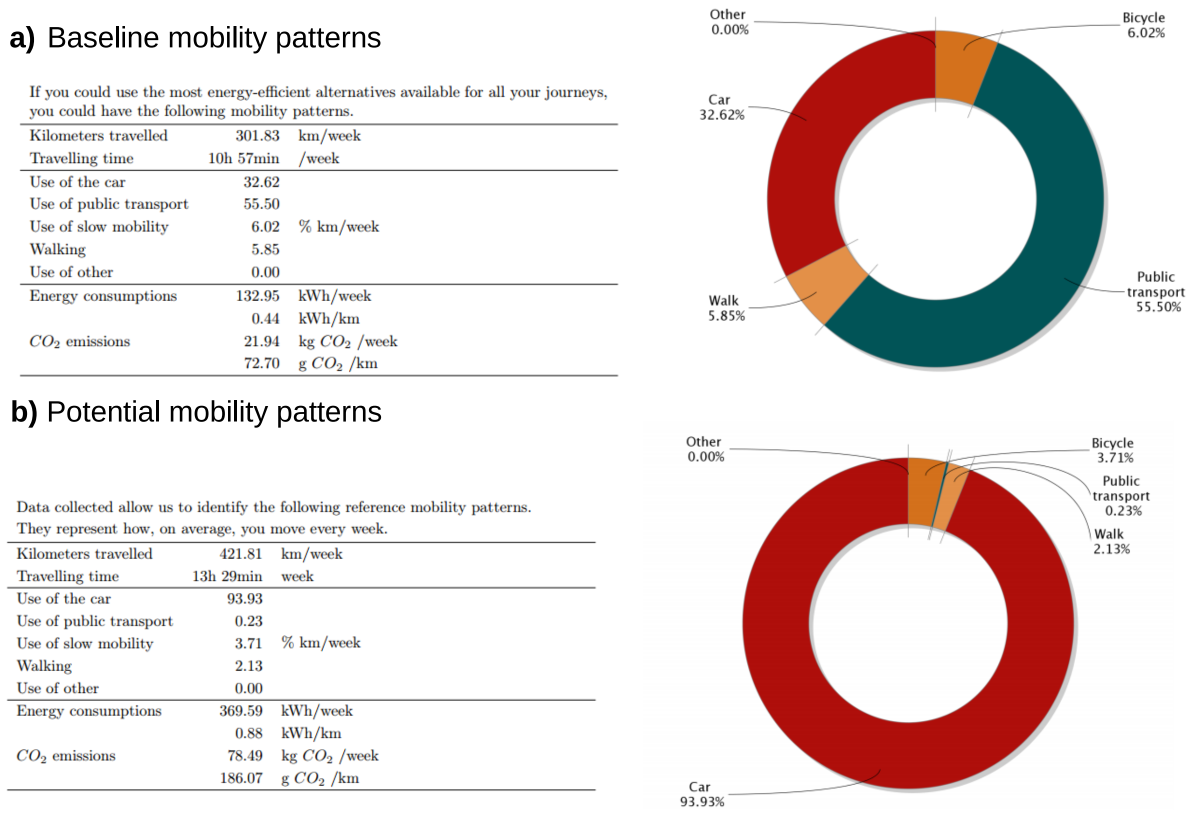
In *GoEco! Tracker*, feedback on users' mobility choices is as limited as possible. In fact, to collect unbiased baseline data, it would be better not to provide users with any feedback at all. However, considering present limitations in automatic mobility tracking, this cannot be avoided completely: a validation for both the route they travel and the means of transport they use is required, especially during the initial training phase of the Bayes classifier.

6.5.2.2 Identifying mobility patterns and potentials for change

Post-processing the data gathered by the *GoEco! Tracker* app allows us to identify the present mobility patterns of the users (baseline data) and their potentials for change. Once four weeks of mobility data are collected, we determine regular trips and assess the feasibility of replacing their transport mode with a more energy-efficient one. A report summarizing personal mobility patterns and potential for change is sent to each user as a PDF document (see Figure 6-18).

Mobility patterns are expressed on a weekly basis, referring to the average kilometres travelled, the average time spent travelling and the usage percentage of each means of transport (aggregated into the following categories; car, public transport, bicycle, walking, other). Details regarding total kilometres travelled, travelling times, energy consumption and CO_2 per means of transport are also provided. Complementing this, the *potential for change* represents the possible mobility patterns a user could have, if she would always replace her trips with the most energy-efficient mobility option available. To identify them, an analysis with respect to several criteria is necessary: we first distinguish systematic from non-systematic trips. For every systematic trip, such as the daily commute to work, we identify a specific, path-dependent alternative, while for non-systematic trips we simply consider general, path-independent alternatives (only based on the length of the trip and the means of transport used). Since users will seldom repeat non-systematic trips, regarding them, the report simply suggests aggregated potentials, obtained by general rules such as: for trips shorter than 1 kilometre, one could walk; for trips shorter than 3 km, one could use the bicycle, and so on.

We developed various tools to perform these analyses. For the distinction of systematic and non-systematic routes, we employ a clustering algorithm that detects important places for every user (cf. Miller and Han, 2009), followed by a frequency analysis of the routes taken. To determine the availability of energy-efficient alternatives for systematic trips, we combine an expert system with a custom route planner: while the route planner tries to find routes using various means of transport, the expert system determines when a journey should actually be considered as a viable alternative. Figure 6-19 shows an example of how viable alternatives for systematic routes are shown to the users in the PDF report.



a) Baseline mobility patterns

If you could use the most energy-efficient alternatives available for all your journeys, you could have the following mobility patterns.

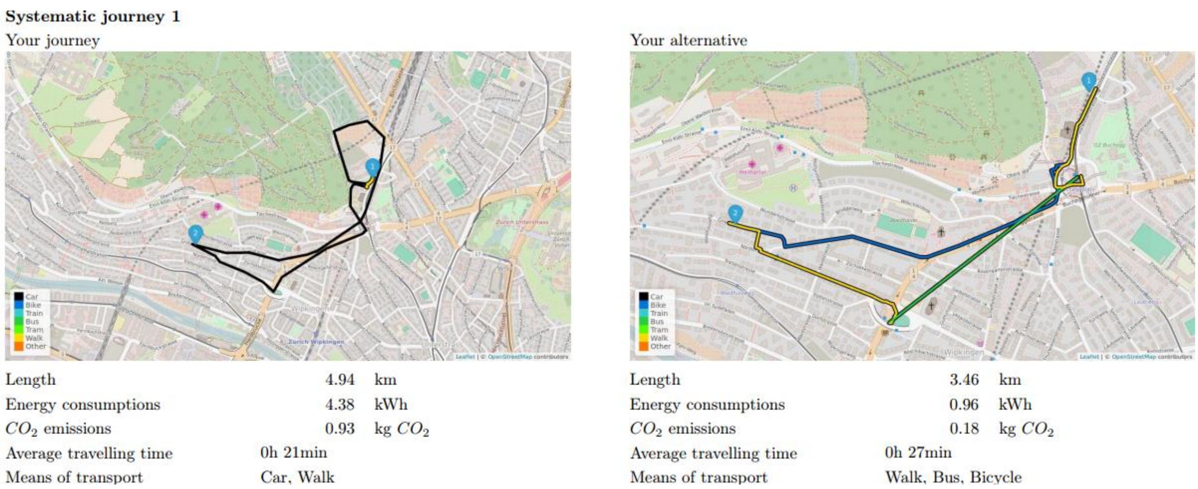
Kilometers travelled	301.83	km/week
Travelling time	10h 57min	/week
Use of the car	32.62	
Use of public transport	55.50	
Use of slow mobility	6.02	% km/week
Walking	5.85	
Use of other	0.00	
Energy consumptions	132.95	kWh/week
	0.44	kWh/km
CO_2 emissions	21.94	kg CO_2 /week
	72.70	g CO_2 /km

b) Potential mobility patterns

Data collected allow us to identify the following reference mobility patterns.
They represent how, on average, you move every week.

Kilometers travelled	421.81	km/week
Travelling time	13h 29min	week
Use of the car	93.93	
Use of public transport	0.23	
Use of slow mobility	3.71	% km/week
Walking	2.13	
Use of other	0.00	
Energy consumptions	369.59	kWh/week
	0.88	kWh/km
CO_2 emissions	78.49	kg CO_2 /week
	186.07	g CO_2 /km

Figure 6-18 A user's baseline and potential mobility patterns, as provided in the printed PDF report generated after four weeks of use of the *GoEco! Tracker* app



Systematic journey 1

Your journey

Length	4.94	km
Energy consumptions	4.38	kWh
CO_2 emissions	0.93	kg CO_2
Average travelling time	0h 21min	
Means of transport	Car, Walk	

Your alternative

Length	3.46	km
Energy consumptions	0.96	kWh
CO_2 emissions	0.18	kg CO_2
Average travelling time	0h 27min	
Means of transport	Walk, Bus, Bicycle	

Figure 6-19 Example of an alternative for systematic routes sent to the users in the PDF report

the left shows the original route performed by the user, the right the alternative route suggested by *GoEco!*

6.5.2.3 Motivating mobility behaviour change: the GoEco! app

The *GoEco!* app performs mobility tracking in exactly the same way as the *GoEco! Tracker* app. In addition, it implements a gamification approach based on individual achievement and competitive game mechanics.

Since mobility choices are individual and they depend on a variety of circumstances, such as daily schedule, weather, or other people involved, gamification elements have to be chosen carefully (Weiser et al., 2015). Points, for example, are difficult to use, as a fair distribution of points is a very delicate task in such a heterogeneous environment, if one wants to respect all individual circumstances and stay transparent. For example, users have different access to alternatives for the car, depending on the places they live and work, or might have different family requirements influencing their mobility needs. As remarked above, there is no one-size-fits-all mobility solution to be promoted by a super-imposed scoring system. Our use of gamification thus revolves around personal goals for change with respect to the baseline mobility patterns: users are invited to choose a personal goal towards sustainable mobility patterns, selecting it from a list of possibilities ("reduce car use", "increase slow mobility", "reduce energy consumption", etc.), and also to set the quantitative target they want to achieve. For this purpose, the app supports them, showing values of both their "baseline" and "potential" mobility patterns, coherently with the PDF report (Figure 6-21.a).

Progression towards an own goal is therefore the key motivational factor, and it gives a measure of success both at the individual level and in the competition with the other participants. Users are free to progress at their own pace and in their own direction, while being stimulated by *GoEco!* to achieve their personal goal for change.

The full set of motivational elements we exploit is presented in Figure 6-20.

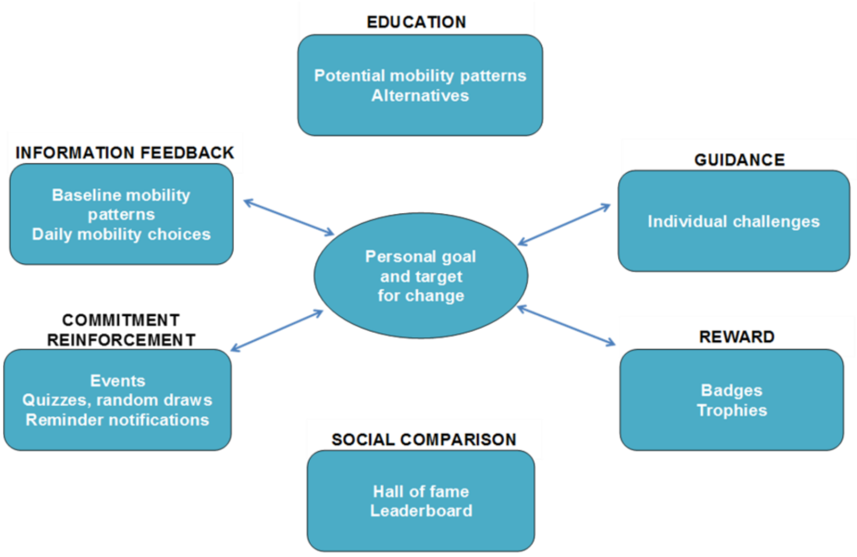


Figure 6-20 Components of the *GoEco!* motivational mechanics

The first one is "information feedback". When using feedback and gamification, optimally, the feedback is given in a well-timed manner (Froehlich et al., 2010; Tiefenbeck et al, 2016). However, because we rely on *Moves* for the activity tracking, this is difficult (the data *Moves* provides gets updated at unknown points in time). As such, we encourage users to interact with *GoEco!* once per day, at which point they receive feedback on their daily activities (distance travelled, means of transport used, travelling time) and related impacts (energy consumption and CO_2 emissions) (see Figure 6-21.b). Progression towards their goals, instead, is shown on a weekly basis (updated every Monday in the early morning), since daily goals would not be significant from the mobility perspective: individual mobility demand often varies a lot from one day to another and the achievement of daily goals might simply be due to external factors conditioning demand, and not to a real change in the users' mobility patterns. The level of achievement of one's goal is shown by a simplified bar chart, where the height of the bar is proportional to the percentage of the goal having been achieved in the past seven days.

Further motivational elements are "education", "guidance" and "rewards": besides supporting users by indicating their potential for change and providing them with personalized alternatives for systematic trips, as we do in the PDF report, *GoEco!* also guides users by challenging them to adopt specific, sustainable mobility patterns and to repeat them for a sufficient period of time. Individual challenges compatible with the personal goal chosen, such as "I will not use the car during peak hours for five days out of the next seven days", "I will not use either cars or planes for the whole week-end" or "This week I will travel by slow mobility all my short routes", are offered every week to the user, who is free to choose the one(s) she prefers or to ignore them. Challenges help users to "unfreeze" their habitual mobility patterns (which are related to *automatic* mental processes, performed without premeditation or deliberative reasoning) and to turn them into different mobility patterns, related to *controlled* mental processes, moved instead by intention, cognitive effort and awareness (Johnson and Hasher, 1987).

The completion of challenges is automatically assessed by checking a set of rules, which are previously communicated to the user. If a user achieves a challenge, she is rewarded with a bronze trophy. Successfully repeating the same challenge over time allows levelling up: the duration of the challenge increases from one week to longer periods and successful achievements are rewarded with higher-level trophies (silver, gold and platinum). Repetition is essential, since it helps users to "freeze" their new mobility patterns until they become new habits. Users are also rewarded with surprise badges, which are attributed when specific sustainable mobility choices are detected by the system, such as using the bicycle every day for at least five consecutive days or travelling long trips by train. This also has a guidance effect: receiving an unexpected reward for spontaneously performed actions makes users aware of positive actions they perform and stimulates them to repeat them in the future. Moreover, badges reinforce commitment and rekindle user interest.

The possibility of comparing one's performances with the other members of a community ("social comparison") is considered a powerful tool to increase motivation for change (Alcott, 2010). Typically, in gamified contexts this is performed by means of a leaderboard. Introducing a leaderboard in *GoEco!*, however, is not straightforward, since we opted for avoiding a point-based system. Coherently with the choice to put personal goals for change at the center of our motivational mechanics, comparison between members of the *GoEco!* community is therefore based on each individual's level of achievement, combined with the number of challenges she completed and the number of badges she obtained. The leaderboard is updated every week, when the top-3 members of the week are also posted in the "Hall of fame" section (Figure 6-21.c). Regardless of the complexity of the goals, users can still be listed in the Hall of fame if they achieved their goals. The system does not judge goal complexity, which depends on the users' initial mobility patterns, on their potential for change, on external, personal constraints and on their level of engagement. To provide users with comparisons which are valuable and meaningful, the leaderboard section also allows users to show only the subset of members of the *GoEco!* community who are pursuing the same personal goal for change or those who are living in similar places with respect to accessibility to public transport (based on the classes of accessibility to public transport developed by ARE, 2011).

A final motivational element exploited by *GoEco!* is “commitment reinforcement”, which is performed both by a notification system inside the app and by supporting activities and events outside the app. The notification system reminds users to check and validate their routes on a daily basis, notifies them about updates of the weekly statistics, congratulates them whenever they achieve good results (goal achievement, challenge conclusion, attribution of badges, visibility in the Hall of fame) and encourages them to try again the following weeks if they fail their goals or challenges.

The stimulation generated by virtual communities may be low, especially in the long term, if no direct and in-person interactions among the users are possible. To anticipate a critical decrease of interest of users and to prevent them from uninstalling the app before they change their mobility patterns, the virtual activities are backed up with physical, in-person meetings, open to the whole *GoEco!* community. On a monthly basis, users are invited to join recreational events related to sustainable mobility topics, such as visits to exhibitions, slow mobility and public transport treasure hunts across the city or lazy bicycle rides in natural areas. During such events, app users get to know each other, share their experiences and tips to overcome difficulties in achieving challenges and, in general, support each other towards their own goal for change. Additionally, monthly quizzes and random draws with tangible prizes addressing the active members of the community are used to reinforce their commitment over time. They are the only tangible motivational elements in the whole *GoEco!* experience. By explicit choice, prizes have low monetary value (around 100€ vouchers for public transport, supermarkets and stores or charity donations, according to preferences of the winner). In fact, the general *GoEco!* aim is to stimulate mobility behaviour change as a personal, intrinsic choice of app users, instead of buying them in exchange for money or other tangible goods, which has been found to only have temporary effects (Deci et al., 1981).

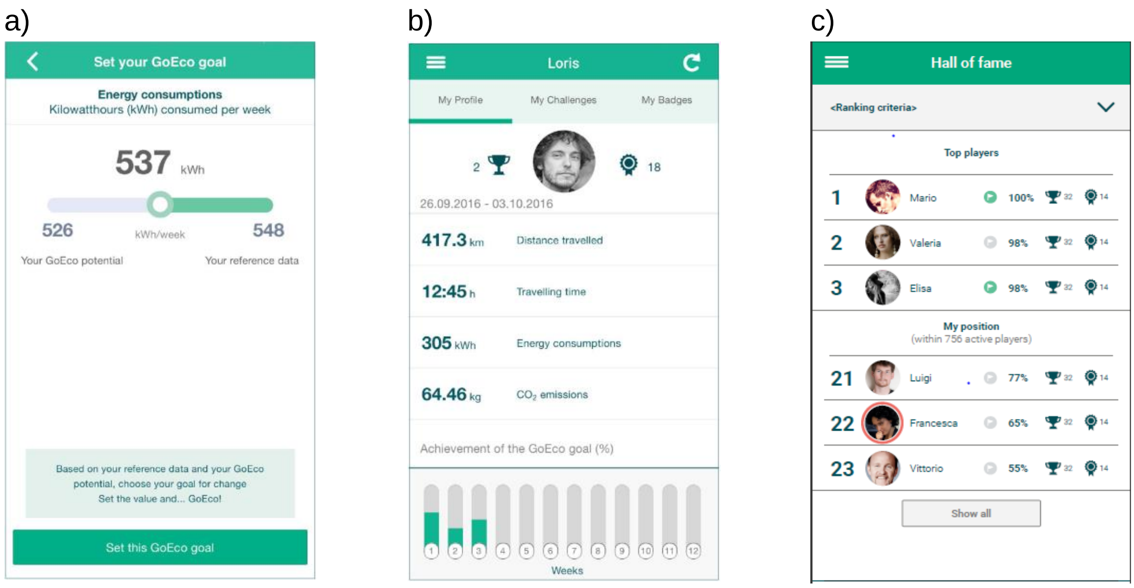


Figure 6-21 A selection of screenshots from the *GoEco!* app

a)The starting point in *GoEco!*: setting one’s goal for change; b) the eco-feedback on kilometres travelled and related impacts, together with the weekly level of achievement of one’s goal for change; c) the weekly leaderboard with the three top players of the week in evidence in the Hall of fame section.

6.5.3 Design of the *GoEco!* living lab experiment

The effectiveness of the *GoEco!* apps is currently being tested in a living lab experiment conducted across Switzerland. To get a wider insight on the potentials and limitations of our approach, the experiment is being run in two contexts differing both in the supply of mobility options and in the socio-cultural attitude of the population towards mobility: the Swiss city of Zürich, a dense urban area, characterized by high levels of accessibility to public transport and infrastructures for slow mobility, and the Canton Ticino, a Swiss region characterized by urban sprawl, where effective alternatives to individual car use are often missing.

Overall, about 600 volunteer users were recruited to join the project, by means of a public communication campaign held between December 2015 and March 2016, which exploited local mass media and social networks available at the two experimental sites.

The *GoEco!* experimental design envisions three mobility tracking periods (see Figure 6-22), allowing the assessment of the long-term effect of the *GoEco!* app in stimulating changes towards less car-dependent mobility patterns , and includes both an intervention and a control group, thus overcoming key limitations of similar experiments highlighted in Section 6.5.1.3.

During the first tracking period (period A, March – April 2016) all the participants are invited to use the *GoEco! Tracker* app. Analysis of the data gathered allows to classify their baseline mobility patters in four categories, as presented in Section 6.5.4.3.

In the second tracking period (period B, October 2016 – January 2017), the participants of the experiment are split into an intervention and a control group by means of a stratified random sampling, based on the classification of their baseline mobility patterns and on the class of accessibility to public transport of their place of living, as identified in (ARE, 2011).

During Tracking B members of the intervention group are invited to use the *GoEco!* app, thus exploiting the potential of eco-feedback and gamification functionalities, while members of the control group are requested to keep using the *GoEco! Tracker* app. In the third monitoring period (period C, March – April 2017), all participants are again monitored with *GoEco! Tracker.*

Comparison of the quantitative data gathered between tracking periods B and A, performed with the “difference in differences” approach (Sergici and Faruqui, 2011), provides us with the short-term effect of the *GoEco!* app, that is its direct effect when it is used. Comparison of data gathered between tracking periods C and A, instead, provides us with the indication of the long-term effectiveness of the app in producing enduring changes in the users’ mobility patterns and habits. To gain additional insight on the perceptions and attitudes of the participants and on their experience in using the *GoEco!* app, focus groups and semi-structured interviews with randomly selected participants are also planned for Spring and Summer 2017.

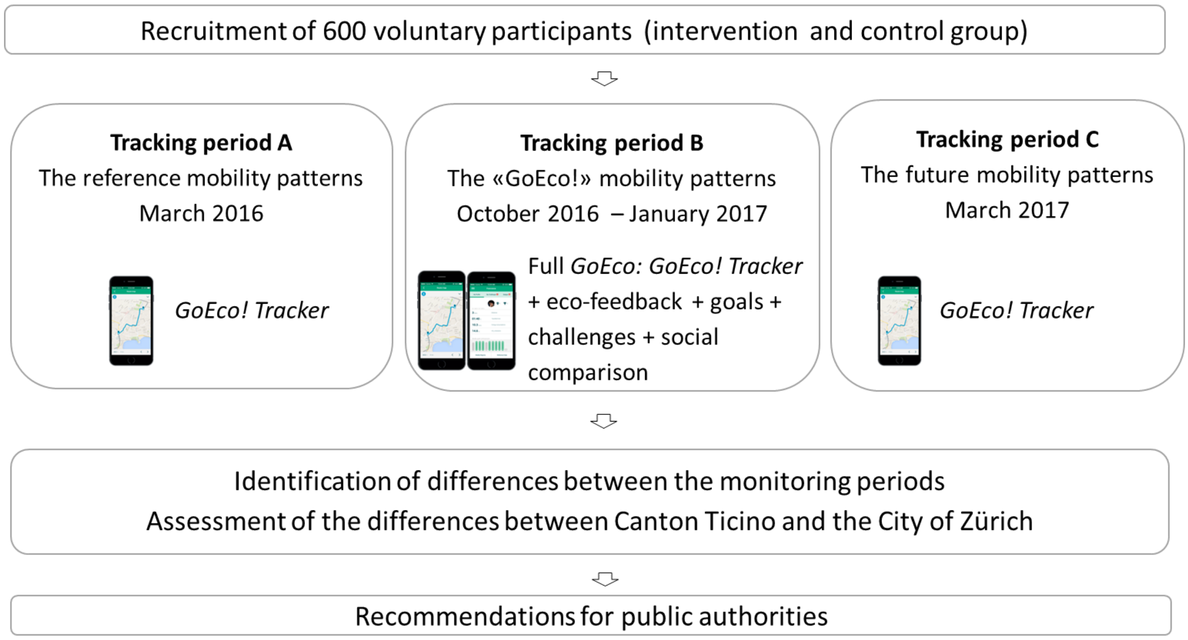


Figure 6-22 Design of the *GoEco!* living lab experiment

For the sake of simplicity, here no distinction between intervention and control group in tracking period B is shown. However, please consider that in tracking period B, participants attributed to the control group were asked to use the *GoEco! Tracker* app

6.5.4 Analysis of adoption response data

At the time of writing, the experiment is in the middle of tracking period B. We can therefore already provide insights on the characteristics of the sample of recruited participants, on their baseline mobility patterns and on their level of interaction with the *GoEco! Tracker* app. Such elements teach us valuable lessons on the general appeal of our approach and allow us to draw suggestions for future similar experiments.

6.5.4.1 Characteristics of the sample of participants

For the recruitment of the sample of participants we used a variety of communication channels: press conferences, participation in radio and television programs, articles in newspapers and magazines, posts in social networks (Facebook and Twitter) and payment advertising on Facebook. Our goal was to get a large sample of around 800 users: even if, due to self-selection, we could not consider it statistically representative for the whole population, it would have been wide and varied enough to include different attitudes, perceptions and habits. In any case, however, we were aware that the sample would have been biased, since the experiment explicitly targets smartphone users. We also expected to attract individuals already having a high intrinsic motivation to change their own mobility patterns. Our expected target was therefore made by individuals:

- living in urban areas;
- aged between 25 and 44 (according to (Nielsen, 2013), this is the segment of population more familiar with everyday use of smart device applications);
- in the “contemplation” stage according to the “transtheoretical model” for behaviour change (Prochaska and Velicer, 1997).

Acknowledging this, the recruitment campaign was built around such a starting level of intrinsic motivation (the key message being “*I have had enough with traffic, stress, pollution, and energy* *consumption*"), together with a call to social consideration ("*I can have a leading role in changing my community*"). Even though prizes are available to the participants who will remain active until the end of the field experiment (the random draws introduced in Section 3.3), in the campaign we explicitly decided not to focus on them. Also, we decided against paying citizens for their participation. In fact, to assess the real-life effectiveness of the *GoEco!* app, we needed to reproduce the same conditions in which it could be used in the future, outside the field study: in real life, no external institutions would be available to fund prizes or incentives for app users.

At the conclusion of the campaign, we got a number of 602 applications in total (278 in Ticino – TI – and 324 in Zurich – ZH), plus another 35 outside the study areas.

Figure 6-23 shows that nearly two thirds or the participants are male, both in the TI and in the ZH living lab. Regarding their age range, in both living labs the majority of the participants (approximately, half of them) is middle-aged, between 30 and 50 years. The ZH sample has a more regular distribution of participants for the age ranges from 20 to 59 years old, while the TI sample has a predominance of 30 to 49 years old participants.

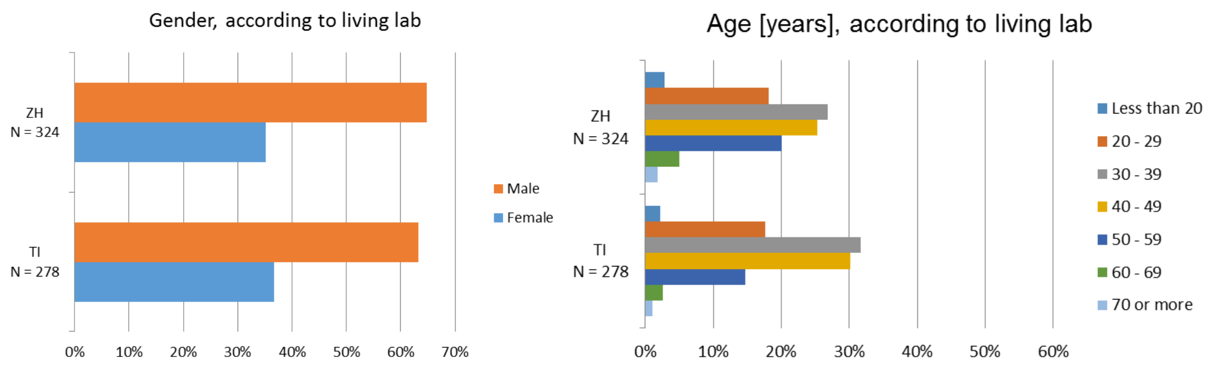


Figure 6-23 General characteristics of the participants to the *GoEco!* living lab, in the Zurich (ZH) and in the Canton Ticino (TI) area

6.5.4.2 Activity rates of the participants and drop-out rates

A very important insight on the overall appeal of the experiment, and therefore on its effectiveness at the society level, is given by the activity rates of the participants during tracking period A. Of the 602 applicants, 576 owned either an iOS or an Android smartphone (which were the only two operating systems supported by the *GoEco! Tracker* app), and therefore could enter tracking period A. However, only 461 of them downloaded the *GoEco! Tracker* app: about one fourth of the participants, who had voluntarily signed up for the project, did not even start with the experiment. Moreover, only 209 of them, equally distributed between Ticino and Zurich, were as active as expected in collecting their routes and validating the means of transport suggested by the app. The other participants either quit the project early or downloaded the app late. In any case, they did not provide us with the minimum set of data we had decided to collect in order to produce representative baseline mobility patterns (we set the threshold to four "active weeks", where a week is considered "active" if data are available for at least four days). This means, that even before entering the real part of the experiment (namely, before being stimulated by the gamified *GoEco!* app), two thirds of the participants had dropped out of the experiment.

According to the feedback we got by the helpline we set up to support participants during tracking activities, the main reasons for such an early and numerous drop-out can be summarized as:

- a lack of understanding of the living lab “terms and conditions”: participants applied just to get the app, because they were attracted by innovations, without being aware that we asked them to perform (simple) interactions throughout the experiment;
- too busy daily routines: participants applied because they were intrigued by the idea, but then were overwhelmed by their daily activities, lacking time to download the app or to perform the basic daily interactions to validate the collected data;
- lack of satisfaction with the quality of the tracked data and/or of the app itself (since it was a prototype, it still had some bugs, which participants helped us to discover);
- discomfort and annoyance due to sensitive data being recorded (privacy concerns);
- high battery consumption, due to enabled location tracking;
- incompatibility between the smartphone operating system and the minimum requirements needed to install and run the app.

6.5.4.3 The baseline mobility patterns of the participants

The data collected by the 209 active participants during racking period A were analysed at the individual level to summarize each participants’ baseline mobility patterns for their individual PDF report. To this purpose, we considered all the data gathered during the “active weeks”, apart from some exceptions regarding air travel. Whenever a user had not validated a means of transport, we considered the one computed by the recognition algorithm; data collected during “inactive weeks” were not considered. The decision about including air travels in the baseline mobility patterns was highly controversial, since Easter holidays were included in tracking period A: should they be included among the baseline patterns, considering that they might have been due to an occasional holiday around Easter? We decided to adopt a flexible approach: if users only had a single two-way plane journey, we did not include it in the estimate of their baseline mobility patterns; otherwise, we included all the plane routes as essential components of the users’ mobility patterns and not as a result of occasional holiday journeys.

Within this setting, we performed an aggregated analysis, aimed at sketching an overview of the baseline mobility patterns of all the active participants. Figure 6-24 shows the whole dataset, while Figure 6-25 summarizes some of the analyses, by comparing results to data from the Swiss Mobility and Transport Census (OFS-ARE, 2012). We used the following two indicators to summarize the mobility patterns of the users:

- the average number of daily kilometres travelled;
- the percentage of the average daily kilometres travelled by private motorized means of transport (PMT), namely: car, electric car and motorbike.

The most recent SMTC data refer to the year 2010 and are available for both the specific region of Zurich and for the Lugano area, which is the largest urban agglomeration in Canton Ticino and contains the living or workplaces of most of the study participants. Therefore, SMTC data are suitable to frame the baseline mobility patterns of the *GoEco!* sample with respect to the average mobility patterns of the population of the same areas.

The average values of the indicators are presented in Figure 6-2. The indicators clearly show that the average citizen in Zurich has already adopted less car-dependent mobility patterns as compared to the Ticino ones, even though they tend to travel more.

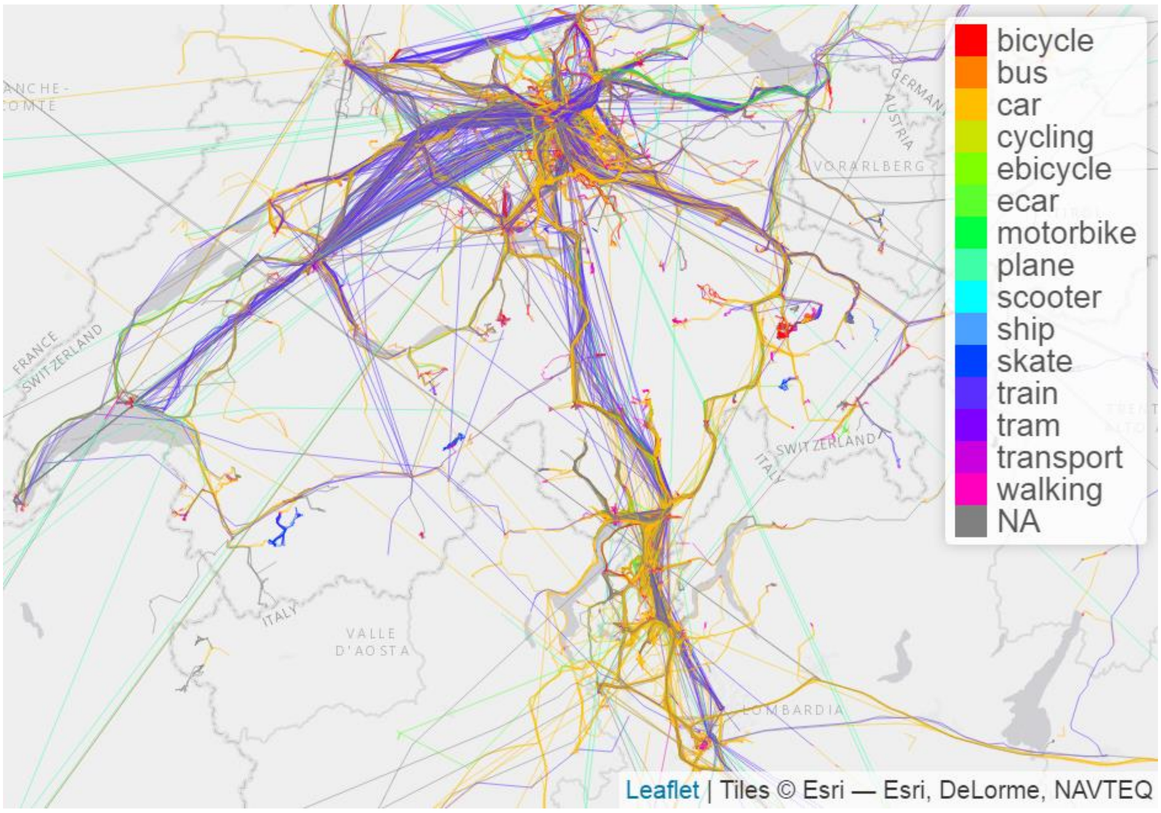


Figure 6-24 The full set of routes registered by *GoEco! Tracker* for all the living lab participants during Tracking period A

(from March 7, 2016 to April, 4 2016)

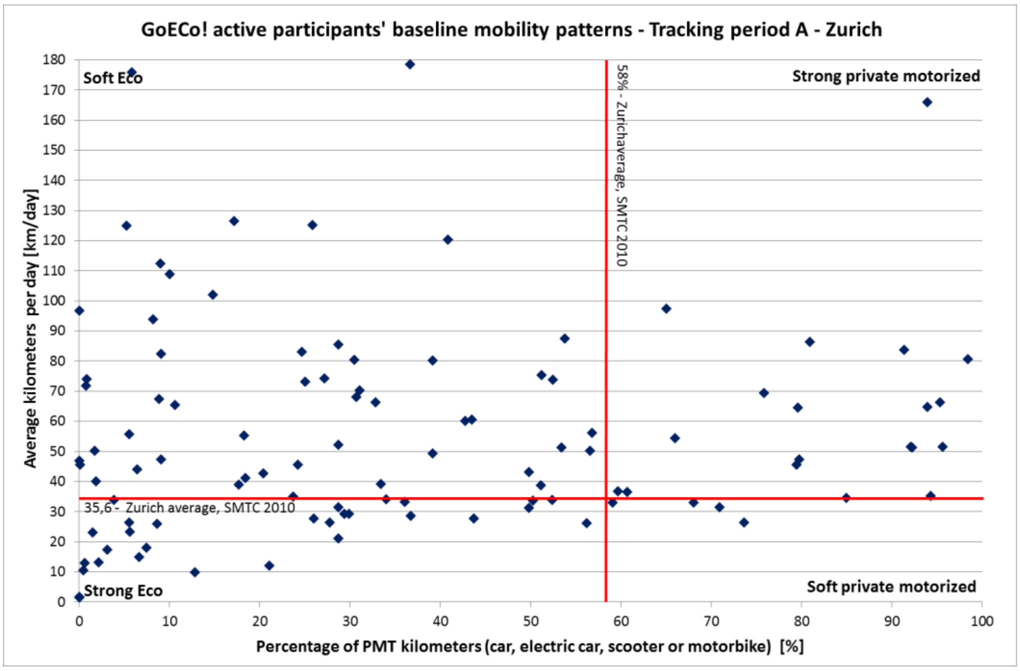
Table 6-2 Key indicators summarizing the average mobility patterns of the Swiss population

(OFS-ARE, 2012), compared to data gathered for the *GoEco!* sample in tracking period A. Data regarding the *GoEco!* samples are expressed by their mean and standard deviation.

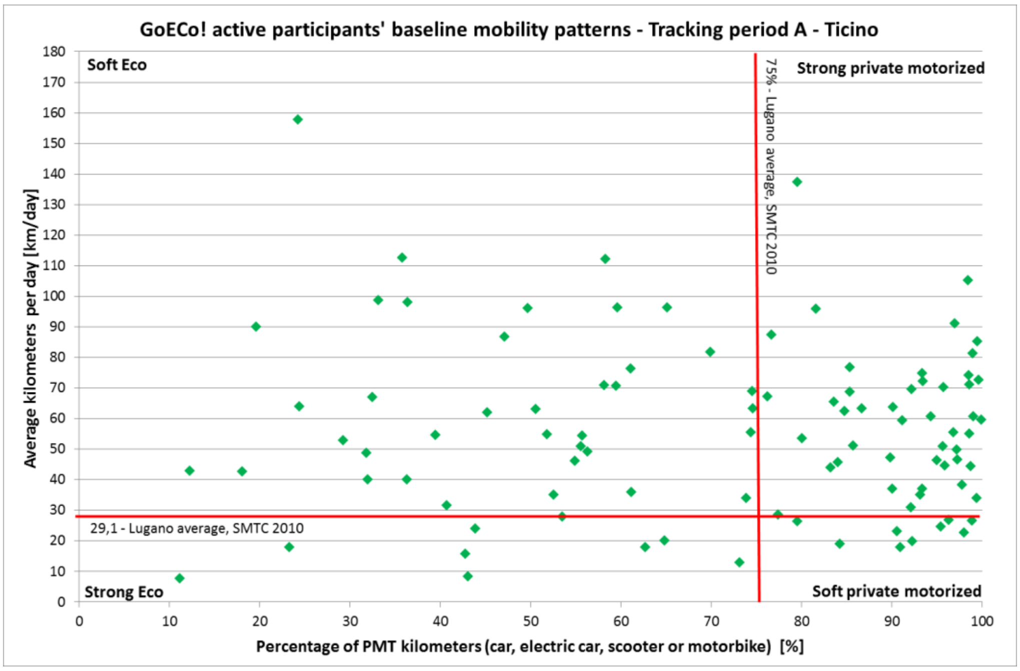
	SMTC 2010 Zurich agglomeration	*GoEco!* sample Zurich	SMTC 2010 Lugano agglomeration	*GoEco!* sample Ticino
Average daily kilometres (km)	35.6	65 (± 63)	29.1	70 (± 82)
PMT percentage of the average daily kilometres (%)	58	37 (± 30)	75	71 (± 26)

Using the SMTC data as a reference point, we can classify the *GoEco!* sample in four categories, as represented in Figure 6-25:

- “Soft eco” users: they use PMT means of transport less than the average population in their area, however they travel more kilometres per day than the average;
- “Strong eco” users: they use PMT means of transport less than the average and also travel less kilometres per day than the average;
- “Soft private motorised” users: they use PMT means of transport more than the average, however they travel less kilometres per day than the average;
- “Strong private motorised” users: they use PMT means of transport more than the average and also travel more kilometres per day than the average.



a)



b)

Figure 6-25 Classification of the *GoEco!* participants

by comparison between data collected during tracking period A and key indicators of the 2010 Swiss Mobility and Transport Census: a) Zurich, b) Canton Ticino.

6.5.5 Synthesis of preliminary results at the end of Tracking period A

The above classification shows that part of the active *GoEco!* participants already have the mobility patterns that we wanted them to reach by using the *GoEco!* app, especially in the Zurich region. In fact, if the focus of the project is to stimulate individuals to reduce car use, we should address “Private motorized users” with the aim of turning them into “Eco users”. However, baseline mobility patterns indicate we are starting with a largely biased sample towards “Eco users”: They make up 76% of the Zurich sample and 46% of the Canton Ticino sample (see Figure 6-26).

According to these data, we make the case that many of our participants are already beyond the “contemplation” stage of the transtheoretical model mentioned above, having instead already achieved the “maintenance stage”, during which new mobility patterns have already been consolidated and are being frozen into new habits. Another option is that they have never been “Private motorized users”, having favoured public transport and slow mobility.

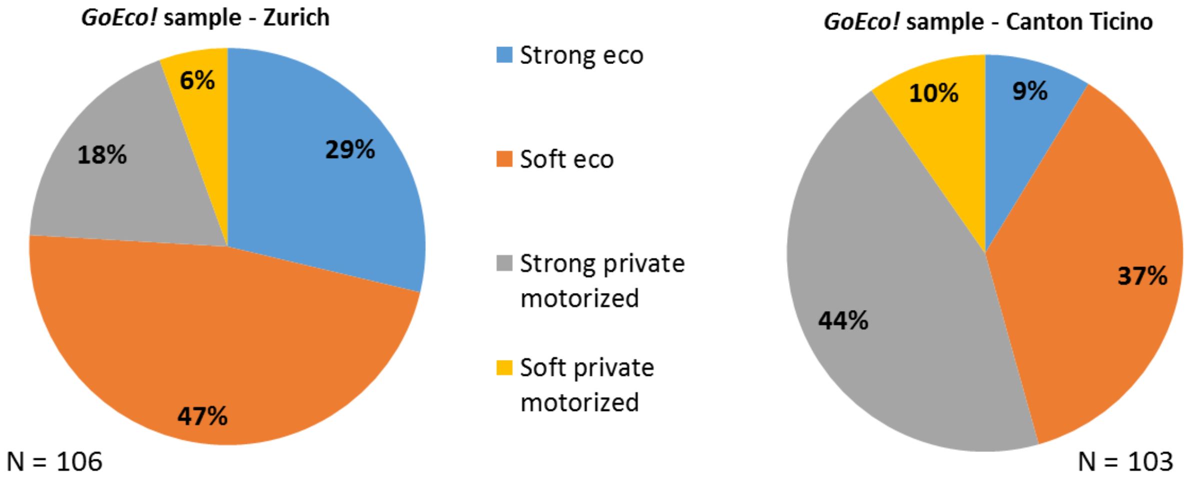


Figure 6-26 A classification of the *GoEco!* sample of active participants, based on data collected during tracking period A compared to SMTC 2010 data.

This leads us to two considerations. The first one is that use of the *GoEco!* app in tracking period B might turn out not to be very interesting for a large part of the active participants, since possible changes and mobility improvements the app suggests would mainly refer to an increase in slow mobility - which might however be a positive result, both from the individual and the society perspective. If they do not appreciate slow mobility, there is a risk that some of them will further abandon the field experiment. The second one, even more significant to us, is, that those who could largely benefit from an app such as *GoEco!* (namely car users in the “pre-contemplation” or “contemplation” stage), were not motivated enough to apply for using it: initial barriers to even start thinking of changing one’s own mobility patterns remain very high, even if a playful, informal approach is proposed.

One may argue that the latter consideration is not correct: the classification of the baseline mobility patterns is performed on the active users resulting at the end of Tracking period A – that is, in our definition, users who collected at least four active weeks of data. It might in fact be that “Private motorized users” were interested in the project and were among the 602 initial applicants, but, due to one of the reasons supposed in Section 6.5.4.2, they lost interest in using the app. The lack of “Private motorized users” might therefore be due to weaknesses in the app and its performances, instead of being due to the lack of appeal of the overall *GoEco!* approach. To check this, we analyzed answers provided by the applicants in an initial survey aimed at investigating their prior perceptions about their own mobility patterns. The survey was performed when applying to the project, therefore we have answers for all the 602 *GoEco!* applicants, plus the other 35 applicants living outside the study areas. We also include answers by the latter 35 applicants, since they are useful to investigate characteristics of the individuals attracted by the *GoEco!* approach.

In the initial survey we asked applicants to indicate all the means of transport or travel subscriptions they own. Based on such answers, we classified them in three main categories:

- “PMT owners”: this category represents applicants who only own private means of transport (PMT), i.e., cars or motorbikes;
- “multimodal PMT owners”: this category represents applicants who own both PMT (either cars or motorbikes) and public transport (PT) travel subscriptions;
- “no PMT owners”: this category represents applicants who only own PT travel subscriptions.

As Figure 6-26 shows, the Zurich sample of *GoEco!* applicants has nearly no “PMT owners” and 34% of them are “no PMT owners”. The Canton Ticino sample of applicants, instead, has only 5% of “no PMT owners” and 17% of “PMT owners”. The remaining applicants (78%) are “multimodal PMT owners”.

Again, we can compare these data with 2010 SMTC data (OFS-ARE, 2012), as shown in Table 6-3: the sample of the Zurich applicants appears more oriented towards “no PMT owners”, with respect to the average Swiss-German population. To the contrary, the Canton Ticino sample of applicants appears more oriented to “PMT owners”, as compared to the whole Swiss-Italian population.

Table 6-3 Percentage of Swiss no-car households according to SMTC 2010, compared with percentage of “no PMT owners” in the sample of *GoEco!* applicants

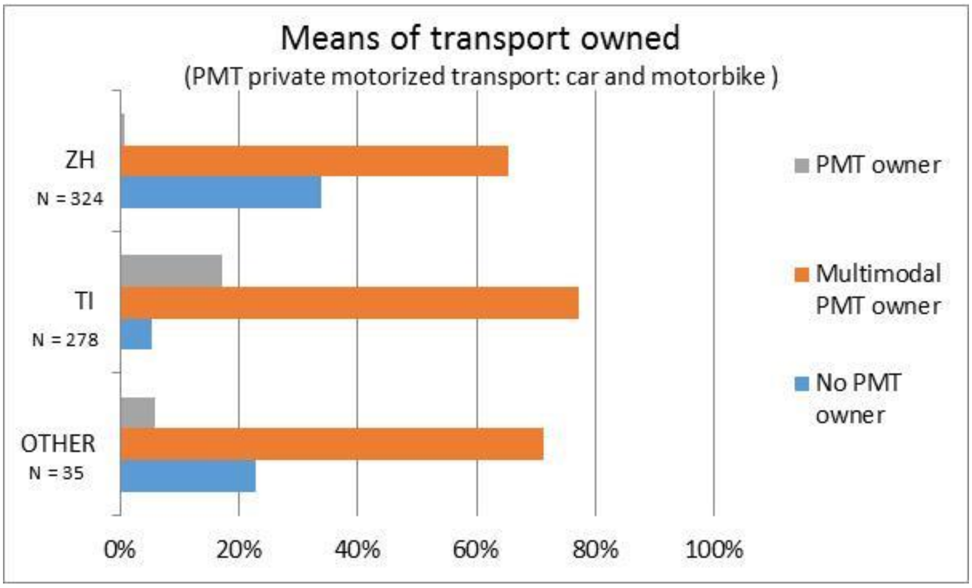
To compare such data, consider Zurich lies in the German-speaking part of Switzerland, while Canton Ticino lies in the Italian speaking part of Switzerland.

Percentage of no-car households (%) SMTC 2010		Percentage of “no PMT owners” (%) *GoEco!* applicants	
German-speaking part of Switzerland	Italian-speaking part of Switzerland	ZH	TI
22%	16%	34%	5%

Another question of the initial *GoEco!* survey shows interesting answers: we asked applicants to indicate the means of transport they regularly use, according to their prior perceptions. Based on answers to this question, we also classified applicants into the following three categories (see Figure 6-27):

- “PMT users”: applicants who declare they only use PMT means of transport;
- “multimodal PMT users”: applicants who declare they use both PMT and PT means of transport;
- “no PMT” users: applicants who declare they only use PT.

a)



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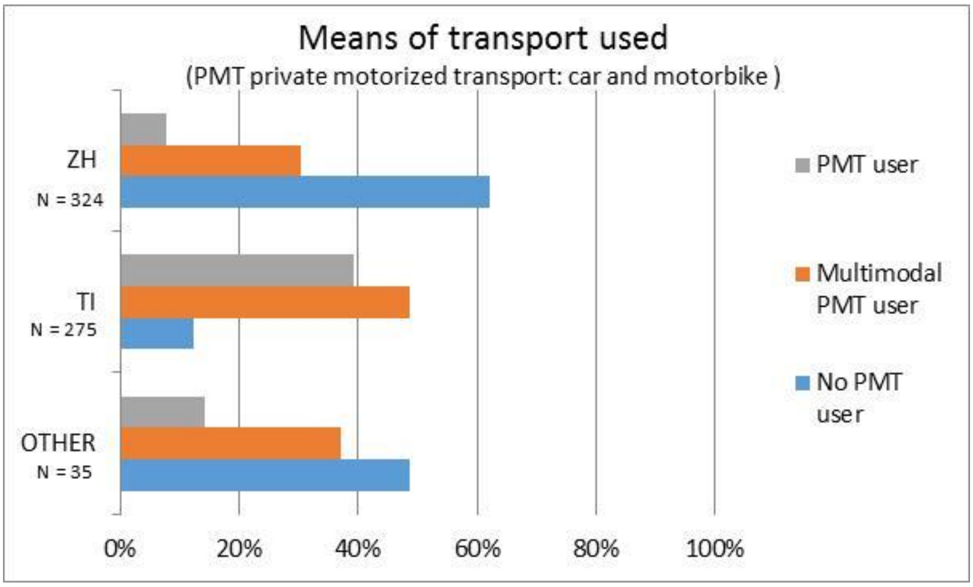

Figure 6-27 Characteristics of the *GoEco!* applicants

means of transport owned (a) and used (b). "ZH" stands for Zurich, while "TI" stands for Canton Ticino.

As Figure 6-27 shows, the Zurich sample of *GoEco!* applicants has 7% of "PMT users" and more than 60% of "no PMT users". The Canton Ticino sample of applicants, instead, is characterized by nearly 40% of "PMT users" and only 12% of "no PMT users".

Such indicators are not directly comparable with those available in the 2010 SMTC. However, we argue we could compare them to those related to the percentage of routes travelled by each means of transport, shown in Table 6-4. The comparison suggests that both the Canton Ticino and the Zurich sample of *GoEco!* applicants are less dependent on private motorized transport than the average population in the respective geographical areas.

Table 6-4 Use of different means of transport, estimated as percentage of the routes travelled, in the regions of Zurich and Canton Ticino, according to SMTC 2010.

	Means of transport used (% of the routes travelled) 2010 Mobility and Transport Census	
	Zurich	Ticino
PMT	28%	47%
PT	20%	6%
Slow mobility	53%	47%

Such numbers therefore confirm that even the sample of *GoEco!* applicants was biased towards less car-dependent people as compared to average citizens, in particular in the Zurich region.

Given this situation, however, we think there is no univocal reason for it. In fact, such a bias in the applicants' mobility patterns might be due to a combination of the following reasons:

- the recruitment campaign was not always effective in reaching the real target groups of an experiment such as *GoEco!;*
- the overall *GoEco!* approach is not effective enough in motivating car-dependent people to contemplate changing their mobility patterns.

Additional insight about these reasons might come both from the qualitative analyses (interviews and focus groups) that will be developed for *GoEco!* by Autumn 2017 and by further research activities which we are about to start, adopting *GoEco!*-like approaches.

6.5.6 Discussion on preliminary results at the end of Tracking Period A

The assessment of data collected during tracking period A provides us with valuable insights about the level of use of the *GoEco!* app over time and characteristics of its main users. While the interest in *GoEco!* by the public and communication media is generally high, about one fourth of the participants, who had voluntarily signed up for the project, did not even start with the experiment. Also, only one third of the remaining participants regularly validated the tracked trips. This might be due to personal reasons, dissatisfaction with the quality of the tracked data or privacy concerns. Moreover, it appears that the sample of *GoEco!* participants is slightly biased towards higher environmental awareness than average, which already led them to reduce car use before entering the experiment.

Of course, all these points taken together raise some doubts on the effectiveness and a future up-scaling of a solely persuasive approach to changing mobility behaviour. However, many aspects play a role in the adaption and longevity of a system and community like *GoEco!*. In Table 6-5, we summarize our findings and possible strategies to overcome the limitations of the current approach. They are discussed in more detail in the following sections.

Table 6-5 Limitations that emerged in the *GoEco!* experiment so far, and suggestions on how to overcome them.

Limitations emerged in tracking period A of the *GoEco!* experiment	Suggestions for future ICT-based persuasion experiments
Self-selection procedures to recruit apps users tend to mainly attract individuals who are already in a "ecologically good" state, instead of "mainstream" citizens in the "pre-contemplation" stage ("preaching to the converted").	Offer prizes and tangible incentives to app users and, during user recruitment campaigns, exploit already existing real life groups and communities, for example targeting schools and companies.
Individuals tend to quit using apps early.	Anchor use of persuasive apps in already existing real life groups and communities (schools, companies, associations): due to real-life relationships among them, they are more likely to keep their commitment in using the apps.
Citizens might refuse using persuasive apps fearing their privacy is negatively affected.	Develop fully transparent user agreements, explaining how personal data will be treated by the apps and which types of active data protection are guaranteed.
Flaws in mobility tracking infrastructure and tools might preclude app effectiveness and reinforce users' tendency to quit.	App developers cannot overcome such technical problems. However, they need to keep apps as plain and simple as possible, limiting interactions with critical elements.

6.5.6.1 *Stimulate "Mainstream Car Drivers"*

How can we encourage participation of "mainstream car drivers", namely citizens without specific environmental awareness? This will heavily influence future recruitment campaigns, which in our case was based on open advertising and communication activities (traditional mass media, social networks, distribution of flyers throughout the city) and *self-selection* of the participants: whoever is interested in participating, is provided with the app. When such self-selections are performed, applicants tend to be already environmentally aware individuals, who sometimes have even already performed behaviour change processes persuasive technologies aim at (Wemyss et al., 2016). In fact, such open calls for participation might mainly stimulate individuals in the "maintenance" stage of the transtheoretical model, who would in fact look for a public confirmation of how good their behaviour is, while mainstream citizens would simply ignore invitations to challenge themselves with the app.

So, favouring self-selection might be a barrier to effective involvement of the target citizens. However, in the end, self-selection is the only possibility available, since no obligations to use persuasive apps can be put into force. Therefore, solutions to overcome these limitations need to come from the recruitment strategy itself. One strategy might be to provide app users with prizes and monetary (i.e., tangible) incentives, aimed at raising the interest of mainstream citizens. Prizes should be attributed only to those who remain active for a sufficiently long period of time, and should gradually leave room for the other intrinsic motivational elements offered by persuasive apps. That is: gamification elements exploiting extrinsic motivational factors should mainly be used at first, to hook attention and engagement of mainstream citizens; then, they should be gradually put aside, orienting gamification towards intrinsic motivational elements.

Another strategy would be to exploit social relations already existing in society and to explicitly target them during the communication campaign for user recruitment.

We believe that the high drop-out rates observed in *GoEco!* might have been lower, if participants had been fully anchored in the *GoEco!* community by previously existing personal, real-life relationships. Exploiting the power of social norms and the network of formal relations of individuals within their community might help to create a stronger commitment for participants to remain active within the project, at least until they manage to adopt new mobility patterns.

For example, use of the app might be proposed to schools, companies or even formal networks such as those by sport clubs (Moser et al., 2015), besides individual citizens: managing to involve whole school classes (i.e., a number of students and their families), companies or departments (i.e., a number of colleagues) or groups of friends active in the same sport club, instead of targeting single individuals, could make a big difference. Also, targeting such groups would allow to start with a wider level of diversity in attitudes and behaviour, increasing probabilities that they have no higher environmental awareness than the average population.

6.5.6.2 Keep Interest alive for a Sufficient Period of Time

Data collected during tracking period A highlight difficulties to retain the interest of users for long periods of time, coherently with results from previous experiments, which are characterized by the short duration of the mobility monitoring period (limited to a few weeks). This is critical for two reasons: on the one hand, collecting data for short periods of time might lead to include too many non-systematic mobility patterns, such as for example holidays performed exactly in the tracking periods, which might influence correct understanding of the baseline mobility patterns. On the other hand, it does not allow enough time for the persuasive elements to produce their effect and stimulate a behaviour change.

In scientific experiments like *GoEco!*, we believe this might happen because individuals soon get tired of the novelty of apps, and they are not motivated enough to feel morally obliged to remain in the experiment. If dropouts occur so frequently in research experiments, one can expect that use of behaviour change apps in real life would be flawed by even stronger dropout rates, which would prevent attaining any tangible benefit to mobility problems at the city level. Again, a strategy to avoid this might be to anchor use of persuasive apps in already existing in real life groups and communities, thus explicitly exploiting the power of social norms. As indicated above, apps might in fact be tailored for use within groups of colleagues in companies or groups of students in schools or friends in sport clubs. Once individuals will be included in such groups of users, presence of other real-life relationships among them is more likely to keep their commitment and interest in using the app (due to both a moral obligation prescribed by social norms and an increased appeal by social comparison and competitive elements) – at least until they manage to unfreeze their present mobility patterns and to freeze them again in more sustainable mobility ones.

6.5.6.3 Overcome Privacy Concerns

Inclusion of a wide variety of citizens is also limited by privacy concerns: individuals might prefer to avoid using mobility tracking apps, since they have not enough guarantees about the way sensitive information on their own mobility patterns will be treated. In some cases, data are even shared between apps, just like it happens in *GoEco!*, where participants' data are first recorded by Moves®. Even though this might be explicitly mentioned during the app installation process and requires formal user agreement, such data sharing policies might not be fully transparent to the users. To increase number and variety of active users and reduce dropout rates, app developers are therefore called to take particular care in drafting user agreements: they need to be plain and easy to read on mobile devices, so that users are reassured on who and how will use, and eventually access, their personal data.

6.5.6.4 Improve Mobility Tracking Infrastructure and Tools

Finally, poor quality in the mobility data produces a lack of trust in the app itself and reinforces individuals' tendency to drop out. Poor mobility tracking might be due to poor quality of GPS signals and poor and low speed Internet connection, which might be particularly critical in less urbanized areas. Also, specific operating systems and specific phone models might negatively affect quality of user interaction with the app: use of the same app might produce different quality data depending on the smartphone operating system or even on the smartphone specific model, since not all GPS devices offer the same level of accuracy in data tracking. Old operating systems might even preclude possibilities to install certain mobility tracking apps or their upgrades. Overcoming such kind of technical barriers cannot be performed by the developers of the app alone, since it also concerns GPS and Internet network providers; they are however called for keeping their apps, and their software code, as plain and simple as possible, in order to limit critical interactions with other mobility tracking infrastructures and tools.

6.5.7 Conclusions based onTracking Period A

In this chapter we introduced the *GoEco!* apps and experiment, and our ICT-based approach, aimed at persuading people to reduce car use and opt for more energy efficient mobility alternatives. Findings from four weeks of large scale testing of the *GoEco! Tracker* app highlighted a variety of critical aspects, which call for specific attention, since they might limit the overall effectiveness of the app in persuading individual behaviour change. Main critical aspects relate to the difficulty of actively engaging the effective app target users (mainstream car drivers) and of keeping their interest high for a sufficiently long period of time. Since gamification mechanics that support intrinsic motivation alone turned out not to be enough to overcome them, we suggest to prudently open to extrinsic gamification mechanics as well. More importantly, however, we suggest to overcome individualistic visions of mobility behaviour change and to fully exploit the power of social norms. Lessons learnt from *GoEco!* prompt us to put individuals and their mobility patterns at the center of their network of social relations: in future works exploiting ICT-based persuasive actions and tools towards mobility behaviour change, we will definitely address real-life groups and communities instead of single individuals.

6.6 Lessons learnt by the three living lab experiments: future scenarios for Southern Switzerland (SUPSI)

Elements collected during case studies presented in the previous chapters, based on real-life users and their everyday mobility needs (living lab field experiments), are rich enough to sketch feasible and realistic short to medium term scenarios for mobility transition in Southern Switzerland, with a time horizon of 10-15 years from today (2025 - 2030). Indeed, such a transition process would initially involve families who already performed the transition (i.e.: people in the "maintenance" stage according to the transtheoretical model or "early adopters" according to Rogers' model of Diffusion of innovation) or are at least interested in new mobility options ("early majority of mainstream consumers", according to Rogers, or people in the "contemplation" stage, according to the transtheoretical model). These households are well represented in the sample of participants to our living lab experiments, even though they are not representative of the whole Swiss population.

Main potentials for change refer to:

- adoption of electric vehicles (EVs);
- increasing use of public transport (PT) and slow mobility;
- increasing sharing routes and vehicles, that is increasing both car-pooling (sharing a route with other persons, instead of driving alone) and car-sharing (sharing a vehicle with other persons, instead of owning a personal one).

We built the corresponding scenarios according to a narrative and bottom-up perspective, referring to an average Swiss household: two parents and two children, owning either two internal combustion engine vehicle (ICEVs) or an ICEV and a season ticket to public transport. The scenarios show possible evolutions in the dotation of means of transport of the family and are accompanied by policy recommendations suggesting the measures that public authorities, private companies and single citizens can actuate in order make the transition happen. In order to identify them, we adopted a back-casting approach: we identified the desired configuration of the future, described it with a narrative text, and, going backward, we identified the actions and measures to be introduced in order to guarantee actuation of the desired configuration.

In line with the technological trend registered in the past years (see Section 2.3.1), all the scenarios share the following common hypothesis: we expect that the automotive industry will keep working on battery efficiency, with the aim of increasing EVs mileage autonomy and decreasing investment costs to purchase them.

The realistic transitions we identified are summarized in Figure 6-28. We first made assumptions about the current ownership of means of transport of the household, represented on the left: today a type-household might own either two conventional cars or one conventional car and one or more public transport subscriptions. Starting from these situations, we hypothesized realistic and reasonable short to medium term scenarios for change. According to the level of change with respect to the mobility options initially available to the family, we called them either ''substitution'' or ''transformation'' scenarios: in the first case, depending on the initial conditions, at least one of their ICEVs is substituted by an EV or a PHEV; in the second case, they sell one of their ICEVs and move either to an EV/PHEV in combination with public transport or to car-sharing (better if PHEV operated), in combination with public transport and slow mobility. Car-pooling is always possible in all the scenarios. Company shuttle buses are not explicitly mentioned here; however, they are considered equivalent to public transport. Finally, driverless cars are not included in these short-medium term scenarios, since their introduction on the market is expected not earlier than 2025.

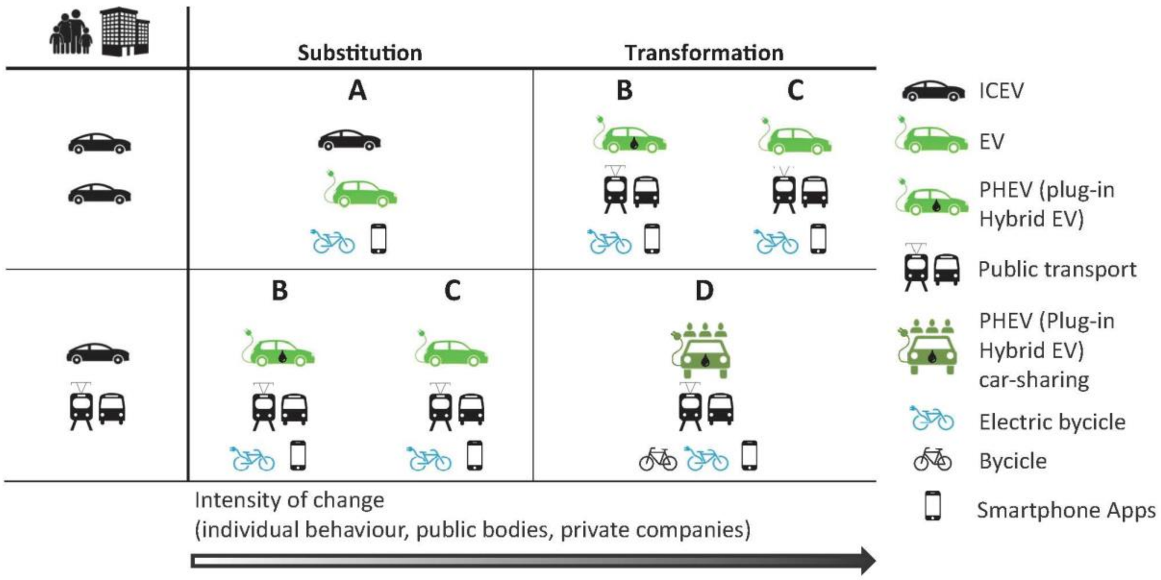

Figure 6-28 Realistic short to medium term scenarios

(years 2025 – 2030) regarding the means of transport used by an average four-persons household in Southern Switzerland

Moving from left to right in Figure 6-28, that is moving from *substitution* to *transformation* scenarios, difficulty of actuation of the scenario increases - from the point of view of public bodies, private institutions and, above all, individual behaviour change. Note that the same scenario is characterized by different difficulties of implementation, depending on the starting conditions of the family model. For example, the “C” scenario is quite ambitious and it is the result of a very complex transformation for a family that today only travels by conventional car. The same “C” scenario, instead, can be a substitution scenario, that is less complex to implement, for a family which today already travels by both conventional car and public transport.

According to the e-mobiliTI experience, a family can easily substitute an ICEV with an EV, provided that another ICEV is still available (scenario A). If not, substitution can be better achieved opting for a PHEV in combination with public transport (scenario B). Scenarios A and B are in fact the conditions that, during the focus groups in which the scenarios were presented, e-mobiliTI participants (both EAs and MCs) indicated as more suitable to their mobility needs. In fact, they mainly require intervention by public authorities or private companies (such as monetary incentives for electric vehicles, regulations to favour charging in apartment blocks, increase in the fast-charge public charging points or increase in the frequency, capacity and capillarity of public transport) and require very low effort in terms of individual behaviour change. However, only scenario D, based on public transport in combination with slow mobility and car-sharing (if possible, PHEV operated) would produce the paradigm shift we are now in need of - and that’s what forward thinking political choices should promote.

In the next sections we present each scenario in detail and introduce the measures that could be undertaken to support the related transition: mainly driven by transport-related policies and interventions, such transitions will be favoured and pushed through by policies and interventions also addressing the whole system of the driving-factors influencing mobility demand (see Chapter 2).

6.6.1 Scenario A: Electric car and conventional car

Scenario A consists in the substitution of one of the two ICE vehicles owned by the household with an electric car. The electric bicycle may be added as a support.

In this case, the parent needing for greater flexibility, or living farther from the workplace, uses the ICE for the majority of the routes he/she needs to travel, while the other parent uses the electric car. When they move together, for shorter or medium distances they use the electric car. Instead, for longer trips (including holidays), they use their ICE car. They decided to buy an electric car because cantonal financial incentives (subsidies) were available, making the investment to purchase an electric car comparable to the investment to purchase an ICE car.

Living in an apartment block, the family could not access a private charging unit at home: this problem was solved thanks to the availability of cantonal monetary incentives (subsidies), which allowed to install an electric charger directly connected to their electricity meter. Now that, thanks to such grants, other citizens have made similar choices in favour of EVs, the network of public electricity charging stations is beginning to be insufficient. To face this problem, the number of fast public charging points is being increased, together with the related parking areas. To avoid additional land consumption, whenever possible fast chargers are located at already existing stations of the fuel distribution network. The investment costs for the increase of public charging stations are at first funded by public bodies (mainly cantonal authorities), while later on they are entirely paid by private companies (mainly utility companies). Recharging at public stations is now based on a pay-per-use tariff and interactive booking systems based on smartphone apps provide real-time information on the degree of utilization of the stations, as well as on the times and costs for recharging. Such a system makes less attractive use of the public charging stations as a trick to park in the city centre for free. Finally, all the charging stations in Switzerland and in Europe are easily accessible by credit cards and smartphone applications. Specific access keys are no longer requested, so that anyone can use any charging station.

Members of the family are proud of their electric car also from an environmental point of view: they have recently purchased a certified eco-friendly electricity package "Nature made star" to cover the annual mileage their travel with their EV.

<u>Measures required for the implementation of the scenario (policy recommendations)</u>

- Subsidies for the purchase of electric vehicles
- Subsidies for the private charging network in existing buildings
- Obligation to make private charging stations available in all the new buildings (stated by the local Building Code and/or by the Cantonal Building Law)
- Extension of the network of the public charging stations, exploiting public investments (and, later on, also investments by private companies)
- Introduction of pay-per-use tariff systems to access the public charging network
- Exploitation of ICT systems to regulate access to public charging network (reservations, information) and payment for the actual amount of electricity consumed
- Availability of certified ecological electricity packages to be directly purchased by end-users

6.6.2 Scenario B: Plug-in hybrid car and public transport

Scenario B involves using a plug-in hybrid electric car (PHEV) and public transport. It can be regarded either as a *substitution* scenario or as a *transformation* scenario. In the first case, the family already owned an ICE car and a subscription to the public transportation: the scenario implies substituting the ICE car with a hybrid one. In the second case, the family owned two ICE cars: scenario B implies replacing one of the two ICE cars with a hybrid car and signing in for a season ticket to public transport (the “Arcobaleno” ticket, in Southern Switzerland), instead of the other ICE car. Also in such Scenario B, an electric bicycle might be added as support in both cases.

Under Scenario B, the parent needing for more flexibility, or living farther from the workplace, uses the hybrid car for the majority of the routes he/she needs to travel. The other parent uses public transport, with an Arcobaleno subscription. Basically, he/she uses public transport only for systematic trips to reach his/her workplace. When the family moves together, including holiday periods, they use the hybrid car. All members of the family move together by public transport only in particular occasions (and this is more likely to happen only if both parents have an Arcobaleno subscription).

The family decided to buy the PHEV thanks to financial incentives (subsidies) made available by the Canton, which make the investment to buy a plug-in hybrid electric car comparable to the investment for an ICE car. Since the range autonomy of the hybrid electric car is high, there is almost no need to recharge it at public stations and owners usually recharge it at home. In this case, however, the family was living in an apartment block, without direct access to a private charging unit. The problem was solved thanks to cantonal monetary incentives (subsidies), which allowed them to install an electricity plug, directly connected to their electricity meter, in the parking lot of the apartment block.

Switching to public transport was the hardest challenge, especially for family members who had never used it before. The decision to subscribe to an Acrobaleno season ticket was encouraged by improvements in the quality of the service:

- a new high capacity and frequency transit line (tram) was introduced in the city of Lugano;
- new bus lanes were introduced in the main cities of the Canton;
- SBB and the road public transport companies increased the frequency of trips, also for trans-national connections;
- SBB increased the number of coaches on the trains.

Moving by public transport became more and more comfortable and fast: the new SBB smartphone application is extremely effective in helping people to find, in real time, the fastest combination offered by public transport and other means of transport. In addition, people can directly buy tickets from their smartphone.

For some of them, a great advantage was related to the possibility to safely use the bicycle (either their own or one offered by urban bike-sharing schemes) to reach the train station from home and also to move from the station to their final destination: they finally opted for the bicycle because the new bike paths made getting around cities by bicycle far less dangerous than in the past. Bus public transport companies also put into service efficient and low emission buses: riding alongside a bus is no longer as harmful to health as in the past. Finally, the main stations are now equipped with safe bicycle racks, and bicycles can be carried on all trains for a cheap fee, in all periods of the day. SBB has in fact made available new train coaches for bicycles. Some people carry their folding bike even on the bus.

<u>Measures required for the implementation of the scenario (policy recommendations)</u>

- Subsidies for the purchase of plug-in hybrid electric vehicles
- Subsidies for the private charging network in existing buildings

- Obligation to make private charging stations available in all the new buildings (stated by the local Building Code and/or by the Cantonal Building Law)
- Increase of the frequency and capacity of public transport
- Changes in traffic circulation and increase in preferential lanes for public transport and for bicycles
- Smartphone application providing real-time information on transport options available
- Substitution of the circulating bus fleet
- Secure interchange parking lots for bicycles at the railway stations
- Admission of bicycles on public transport in all periods of the day

6.6.3 Scenario C: Electric car and Public Transport

Scenario C consists in owning only one vehicle for the whole family, an electric one. Besides such an EV, the family relies on public transport – or to the limit on electric bicycles. Such a scenario might either be a *substitution* scenario or be a *transformation* scenario, depending on the starting conditions of the family. In the first case, the family already owned both an ICE car and a subscription to public transportation: if so, scenario C implies substituting the ICE car with an electric one. In the second case, the family already owned two ICE cars and scenario C implies replacing one of the two ICE cars with an electric car and shifting to at least one subscription to public transport, instead of the other ICE car. Also in such Scenario B, an electric bicycle might be added as support in both cases.

Also under Scenario C, the parent needing for more flexibility uses the electric car for the majority of the routes he/she needs to travel. The other parent uses public transport, with an Arcobaleno subscription. He/she is already used to it and considers it a comfortable and effective solution for systematic trips. When the family moves together for distances shorter than about one hundred kilometres, they use the electric car. All members of the family move together by public transport only in particular occasions (and this is more likely to happen only if both parents have an Arcobaleno subscription).

They enjoy the same conditions described for the Scenario A regarding subsidies to the purchase of electric vehicles and for home and public charging network. Moreover, if the parent who habitually uses the electric car works in a place far from home, he/she can recharge the car at the workplace during the day, using a private charging station installed by his/her company. The charging unit was recently installed by his/her company, who opted for the investment thanks to cantonal monetary incentives (subsidies) available.

In this scenario, many other citizens chose public transport and bought an Arcobaleno subscription. To keep offering a competitive service, transport companies and city governments introduced all the improvements described in Scenario B. The only remaining problem for the family was managing long and holiday trips. In fact, they have two young children and when they leave for overnight stays, they are used to carry with them “half of their house". They thought travelling by train was almost impossible, besides being expensive. Fortunately, it does not happen often! But they did not get discouraged: one summer holiday they tried to travel light and use the train: they did it and they managed to go through the whole holiday! They realized in fact that in the past they had never used the majority of the things that, to be on the safe side, had brought with them. Later on, they started to prefer holiday destinations close to home: using SBB Junior Card and daily offers for families turned out to be very convenient even from the economic point of view. Finally, they discovered flexible possibilities to rent a car (both for ICE and also for PHEV vehicles), that allow returning the car in a different country respect to the one where it was rented. Some of them even offer affordable rates for electric car owners. In this way they can reach their holiday home in Tuscany, paying car rental only for the actual days they travel; once they reach their destination, they use public transport.

Measures required for the implementation of the scenario (policy recommendations)

- All the measures proposed for Scenario A that encourage diffusion of electric cars and enlargement of private and public charging networks
- All the measures proposed for Scenario B that encourage use of public transport
- A change in individual travelling habits: try to 'travel light'
- A change in individual travelling habits: prefer holiday destinations close to home (in Switzerland), taking advantage of SBB “family offers”
- Public transport companies provide additional offers for families
- Car rental companies offer flexible rental possibilities and discounts for electric vehicle owners

6.6.4 Scenario D: Car sharing (plug-in hybrid electric car), bicycle and public transport

Scenario D implies all family members use public transport, in combination with bicycle and car-sharing services (and maybe even with electric bicycles). This scenario does not include car ownership. It requires the largest transformation respect to the current situation and it is plausible for those families who were already used to public transport and previously owned only one ICE car.

Living without a private car is possible since both parents are lucky enough to have a well-served by public transport workplace. Actually, one of them was quite far from home; however, her company participate in a national programme to reduce mobility demand and rented some working places in a co-working space close to the railway station in the city centre: productivity of the employees does not decrease at all – to the contrary, they are fresher when they arrive at work and, thanks to ICTs, they interact with their colleagues just like if they were in the same room. Also,- not by chance- they chose their home also considering its close proximity to public transport services. Both parents, in fact, were used to the Arcobaleno season ticket – one of them was also highly subsidised by his/her company. In addition, they recently sold their car and subscribed to a car-sharing service to cover travel needs that public transport is not able to satisfy. Finally, very often they exploit possibilities to work directly from home: their companies joined cantonal programmes that give fiscal incentives to companies who formally adopt at least one day of tele-working per week.

Usually their travel needs are pretty short, because even leisure time activities of their children are held at reasonable distances from home: by bus, train or bicycle they can reach the majority of their destinations. In the past, they almost exclusively used public transportation to get to work, for their systematic trips. Now that an effective real-time information system (smartphone app) is available, and that public transport companies have increased frequency and number of routes and bus lanes were introduced throughout the city, they manage to use public transport also for their free time. They use bus and train even in the evening: since many people use public transport at any time, they feel safe. It is not expensive, since they bought an SBB Junior Card, which allows they children to travel for free, when they are together.

Often they use the bicycle (or the bike-sharing service available in town) for the route from their home to the train station and from the station to their destination; sometimes they also carry the bicycle on the train or on the bus (it is a folding bicycle and it is allowed on all public transport means). If it rains, they use a raincoat and do not fear facing the rain. Since the number of bike lanes across the city increased, in fact, they feel safe and use the bicycle much more than before, even in the dark. In addition, bus public transport companies put into service efficient and low emission buses: riding alongside a bus is now not as harmful to health as it was in the past. Once a week they go to the supermarket: to carry their shopping bags home, they bought a trailer that can be attached behind the bicycle, which they can leave exactly in front of the mall entrance: it is quite comfortable.

Sometimes they also use the new car-sharing system that offers plug-in hybrid electric cars (PHEV). Since now there are many car sharing users, many cars are now available, located within the car sharing boundary: a large area across the city where they can pick up or leave the car wherever they want. The new free-floating car-sharing scheme is a very practical, flexible system for both picking the car up and returning it, since it does not impose limitations on handing back time. Everything is managed in real time, with the help of a smartphone application. Recently they also enrolled in a new car-sharing service between private persons: once, for an emergency, they also used the car of their neighbour, who entered the same collaborative mobility community. Sharing a vehicle is made easier by availability of free wi-fi coverage across the city, recently realized thanks to federal funding to promote diffusion of "smart city" initiatives.

Finally, when they go on holiday, they behave like the family of Scenario C.

<u>Measures required for the implementation of the scenario (policy recommendations)</u>

- Subsidies for the purchase of plug-in hybrid electric vehicles (attributed only to car-sharing companies)
- Subsidies for the private charging network in existing buildings
- Measures of Scenario B to encourage use of public transport
- Measures of Scenario C to facilitate holidays with public transportation or rented cars
- Discounts for public transport season tickets, paid by the companies and affordable public transport tariffs for children
- Use of bicycle trailers for children and goods and availability of rainproof equipment
- Incentives to companies favouring tele-working
- Diffusion of free-floating car-sharing systems, which also offer plug-in hybrid electric vehicles
- Diffusion of car-sharing systems between private persons
- Federal and cantonal funding to favour full, free Wi-Fi coverage across the city

6.6.5 A support for all scenarios: electric bicycle

In all the scenarios, the electric bicycle offers a valuable support to move faster and more efficiently from the energy point of view. Some families purchased one electric bicycle taking advantage of the incentives provided by Cantonal and Municipal authorities. Other hired one for Spring and Summer periods, thanks to the availability of favourable conditions for long-term hire developed by private companies. So, they enjoy using the bicycle during good weather and do not have to care of maintenance.

Electric bicycles are used instead of ICE cars, motorcycles/scooters and also public transport, for regular commuting to and from work and for their travel needs for leisure purposes. With the help of the electric engine, in fact, they can reach their home located in the hills, without much effort. They are happy to practice some exercise for their health. Since in the city the number of cycle lanes increased, in fact, moving by bicycle is much safer. And if they decide to move by train, they do not have to take the bicycle with them, since they can leave it in the safe bike racks at the railway station.

Bus public transport companies have also entered into service efficient and low emission buses: riding alongside a bus is not as harmful to health as it was in the past. To move with small children, some families also attached a child trailer behind the bicycle: they can now travel together by bicycle without much effort. When it rains, a waterproof kit allows them not to get wet. In cold weather, they wear a jacket and suitable gloves and they feel comfortable, because riding the bicycle warms them. Also, they do not risk their safety because they exploit the new cycle lanes separated from car traffic. And when it's hot, they do not sweat too much because they are supported by the bicycle engine, so they can use the electric bicycle also to attend job meetings.

<u>Measures to promote diffusion of electric bicycles in all the scenarios (policy recommendations)</u>

- Subsidies for the purchase of electric bicycles
- Offers and discounts for long-term hiring of electric bicycles
- Changes in traffic circulation and increase in bicycle lanes
- Substitution of the circulating bus fleet
- Use of bicycle trailers for children and goods and availability of rainproof equipment

6.6.6 A support for all scenarios: car-pooling and ride-sharing

Another measure that could be highly beneficial to all the scenarios is the diffusion of car-pooling or ride-sharing possibilities. Even though it does not imply a shift in the dominant car ownership paradigm, it might be particularly effective especially in low-density areas, where high frequency and high coverage public transport facilities cannot be offered.

Availability of smartphone applications greatly contributes to the diffusion of car-pooling services, since they allow to easily match demand and offer. In the past, available apps were targeting two different types of mobility needs:

- car-pooling apps mainly focused on systematic trips and daily commuting to work, with the creation of stable team of persons sharing most part of their travel;
- ride-sharing apps mainly focused on occasional trips, such as longer trips for leisure purposes during the week-end.

And in any case, they mainly focused on car, as the only means of transport both for the user asking for a ride (passenger) and for the user offering a ride (driver). Nowadays, instead, much more powerful apps are able to offer ride-sharing services combining cars, bicycles and public transport, in a multi-modal fashion. Namely, if a person asks for indications regarding how to move from point A to point B, the app might now suggest to ride a bicycle from point A to the railway station, then to take a train for the longest part of the route and finally to share a car ride for the last part of the route, until destination at point B is reached. This is possible since all public transport companies allow open access to real time data (position of the means of transport, delays, changes respect to the schedule). Diffusion of such apps, and availability of a sufficiently large mass of users offering rides, allows to always find a good combination of the means of transport, so that driving by car alone has now become a very uncommon activity. Diffusion of such apps also allows for a lot of flexibility, since one can look for a lift in nearly real-time, and paths and travelling times can easily be re-scheduled, simply by making a new query to the data-base of the available connections. This is made easier by availability of free Wi-Fi connections throughout the city, thanks to investments by municipal authorities exploiting “smart city” funding programmes. Also, payment is made easy, by means of an integrated payment system, directly offered within the app: once the user selects a route, she can automatically pay for both route segments travelled by public transport and those travelled by car. Everything works as a pre-paid credit system, which can be recharged whenever needed: there is no exchange of physical money, but monetary transactions directly take place between the current accounts of the users.

The most critical part to favour diffusion of such apps, however, was not related to developing algorithms that match route demand and offer in real-time, nor to developing the payment system. In fact, the critical factor was related to the suspicion and fear related to travelling with unknown persons. This was solved thanks to an internal scoring system, directly connected with social network accounts by the users, which allows every app user to assess performances of the other app users (be they the drivers offering rides or the passengers asking for rides), from different points of view (friendliness, driving capability, punctuality, cleanliness and so on). Moreover, ride-sharing apps offer *SOS* functionalities to easily launch an alarm if a driver or a passenger fears a dangerous situation is taking place. Since the car position is always being monitored in real-time, the closest rescue units can soon be notified about problems.

<u>Measures to promote diffusion of car-pooling and ride-sharing services, in all the scenarios (policy recommendations)</u>

- Fare integration between all public transport companies and ride-sharing services operating on the same area, based on a pre-paid credit system
- Federal and cantonal funding to favour full, free Wi-Fi coverage across the city
- Agreement between public transport companies, institutions and private companies to guarantee access to real-time public transport data

6.6.7 Discussion and conclusion

Each one of the above scenarios is developed considering a coherent framework and a specific mobility model to refer to: namely, they only include the set of measures that allow implementing each specific mobility model, thus taking into account limits in the availability of resources (both public and private ones). A summary of the measures under each scenario (guidelines) is shown in Table 6-6, which provides an overview of the scenarios and allows to compare them. Basically, there are no scenarios composed by only infrastructural measures or by only behavioural measures - however, all scenarios include technological measures aimed at increasing range autonomy for electric vehicles and, consequently, decreasing their investment price. In general, acting through a mixture of tools is necessary, and they must be integrated and coherent in order to be effective and avoid a waste in resources.

The four proposed scenarios are, therefore, alternative to each other, and a political decision is needed to choose between them. Choice of the future scenario is in fact in the hands of public authorities, who are called to decide about investments, policies, regulations, subsidies and awareness raising campaigns over a certain area.

Elements arising from qualitative research within the e-mobiliTI and MobAlt projects showed that scenarios A and B could be more easily implemented: according to the current conditions for the majority of households (with reference to a family of four persons: owning two ICE cars or an ICE car and at least a subscription to public transport), they are *substitution* scenarios. However, a real change scenario compared to the current situation, and therefore the most difficult to implement, would be scenario D. By proposing a mobility system in which owning a car is replaced by an integrated use of public transport, (electric) bicycle and car-sharing, it outlines a true paradigm shift with respect to the way we move today and the dominant concept of private ownership of the means of transportation.

Forward-looking political choices made today could steer our mobility system towards scenario D. Of course, the other three proposed scenarios are sensible and reasonably practicable. Choosing “not to choose” between possible future scenarios, thus leaving the system evolve spontaneously, would instead be quite dangerous: it would imply the risk of wasting resources on measures that are not consistent with each other and, consequently, it would prevent to exploit the benefits offered by the new mobility options that are already available today.

Table 6-6 Overview of the measures composing the four future mobility scenarios identified

Elements in brackets refer to measures favouring diffusion of the electric bicycle and ride-sharing apps, which could be included in every scenario.

(In brackets elements related to electric bicycles and ride-sharing apps)		**Scenario A. Electric car + ICE car**	**Scenario B. Plug-in Hybrid Electric car + Public transport**	**Scenario C. Electric car + Public transport**	**Scenario D. Car-sharing (Plug-in Hybrid Electric car) + Bicycle + Public transport**
Electric vehicles and recharging infrastructure	Monetary subsidies to private persons	X *(electric vehicles and charging at home)*	X *(plug-in hybrid electric vehicles and charging at home)*	X *(electric cars and charging at home)*	X *(plug-in hybrid electric vehicles and charging at home)*
	Regulations	X	X	X	X
	Extension of the public charging network	X		X	
	New regulations to access and payment at public charging stations	X		X	
	Smartphone App to charge in public stations	X		X	
	Ecological electricity	X		X	
Public transport	More frequency and capacity		X	X	X
	Increase in bus lanes		X	X	X
	Replacement of the circulating bus fleet		X	X	X
	Real-time data to favour multi-modal ride-sharing apps		X	X	X
	Fare integration between public transport companies and ride-sharing companies	(X)	(X)	(X)	(X)
	Increase in bicycle transport on trains		X	X	X

(In brackets elements related to electric bicycles and ride-sharing apps)		**Scenario A. Electric car + ICE car**	**Scenario B. Plug-in Hybrid Electric car + Public transport**	**Scenario C. Electric car + Public transport**	**Scenario D. Car-sharing (Plug-in Hybrid Electric car) + Bicycle + Public transport**
	Discounts on family season tickets				X
	Company discounts on public transporttravelcards				X
Bicycles (even electric ones and bike-sharing)	Increase in cycle paths	(X)	X	X	X
	“Park and Ride” car parks		X	X	X
	Incentives/Long-term rental for electric bicycles	(X)	(X)	(X)	(X)
Car rental and car-sharing	Incentives for vehicle rental			X	X
	Free-floating car-sharing				X
	Peer to peer car-sharing (between private persons)				X
Individual behaviour	Tele-working and co-working facilities				X
	Travelling light			X	X
	Inland holidays in Switzerland			X	X
	Bicycle trailer to carry children and shopping bags	(X)	(X)	(X)	X
Smart city equipment	Free Wi-Fi coverage across the city	(X)	(X)	(X)	X

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Appendix

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Additional tables

Table 0-1 Relevant publications reviewed in section 3.5

Review step	*Author*	*Intervention*
1	Aarts, Dijksterhuis (2000)	No
1	Abou-Zeid et al. (2012)	Yes
1	Abou-Zeid, Ben-Akiva (2012)	Yes
1	Alfonzo (2005)	No
1	Anable (2005)	No
1	Avineri, Bovy (2008)	No
1	Avineri (2004)	No
1	Avineri, Chorus (2010)	No
1	Avineri, Prashker (2005)	No
1	Bamberg et al.(2011)	Yes
1	Bamberg, Rölle & Weber (2003)	Yes
1	Bamberg (2006)	Yes
1	Bamberg, Schmidt (1998)	Yes
1	Bamberg, Schmidt (2003)	No
1	Bamberg, Ajzen & Schmidt (2003)	Yes
1	Bamberg (2007)	No
1	Bamberg, Hunecke & Blöbaum (2007)	No
1	Ben-Elia, Ettema (2011b)	Yes
1	Bockarjova, Steg (2014)	No
1	de Bruijn et al. (2009)	No
1	Carrus, Passafaro & Bonnes (2008)	No
1	Ceder et al. (2013)	Yes
1	Chen, Fan & Farn (2007)	No
1	Chen, Chao (2011)	No
1	Collantes, Mokhtarian (2007)	No
1	Connors, Sumalee (2009)	No
1	De Groot, Steg (2009)	No
1	De Groot, Steg (2007)	No
1	Dijst, Farag & Schwanen (2008)	No

Review step	*Author*	*Intervention*
1	Domarchi, Tudela & González (2008)	No
1	Donald, Cooper & Conchie (2014)	No
1	Eriksson, Forward (2011)	No
1	Eriksson, Garvill & Nordlund (2006)	Yes
1	Eriksson, Garvill & Nordlund (2008a)	Yes
1	Eriksson, Nordlund & Garvill (2010)	Yes
1	Forward (2004)	No
1	Forward (1998)	No
1	Forward (2014)	No
1	Franke, Krems (2013b)	No
1	Franke, Krems (2013a)	No
1	Fujii (2006)	No
1	Galdames, Tudela & Carrasco (2011)	No
1	Gardner, Abraham (2008)	No
1	Gardner (2009)	No
1	Gärling et al. (2002)	No
1	Gärling, Axhausen (2003)	No
1	Gehlert, Dziekan & Gärling (2013)	No
1	Harland, Staats & Wilke (2007)	No
1	Haustein, Hunecke (2007)	No
1	Haustein, Klöckner & Blöbaum (2009)	No
1	Haustein, Hunecke (2013)	Yes
1	Heath, Gifford (2002)	Yes
1	Hensher, Li & Ho (2015)	No
1	Hunecke et al. (2001)	Yes
1	Jakovcevic, Steg (2013)	No
1	Jaśkiewicz, Besta (2014)	No
1	Jou, Chiou & Ke (2011)	No
1	Klöckner (2013)	No
1	Klöckner (2014)	No
1	Klöckner, Blöbaum (2010)	No

Review step	*Author*	*Intervention*
1	Klöckner, Friedrichsmeier (2011)	No
1	Mallat et al. (2008)	No
1	Matthies, Klöckner & Preißner (2006)	Yes
1	Nayum, Klöckner & Prugsamatz (2013)	No
1	Nkurunziza et al. (2012)	No
1	Noblet, Thøgersen & Teisl (2014)	No
1	Nordfjærn, Şimşekoğlu & Rundmo (2014)	No
1	Nordlund, Garvill (2003)	No
1	Nordlund, Westin (2013)	No
1	Osman et al. (2012)	No
1	Panter, Jones (2010)	No
1	Parkes et al. (2013)	No
1	Passafaro et al. (2014)	No
1	Rasouli, Timmermans (2014)	No
1	Rose, Marfurt (2007)	Yes
1	Schade, Schlag (2003)	Yes
1	Schuitema, Steg & Rothengatter (2010)	Yes
1	Schwanen, Ettema (2009)	No
1	Schwanen, Banister & Anable (2012)	No
1	Senbil, Kitamura (2004)	No
1	Spears, Houston & Boarnet (2013)	No
1	Staubach et al. (2014)	Yes
1	Taniguchi et al. (2003)	Yes
1	Thøgersen (2006)	No
1	Thøgersen (2009)	Yes
1	Tsai (2010)	No
1	Tulusan et al. (2012)	Yes
1	van de Kaa (2010)	No
1	Wall, Devine-Wright & Mill (2007)	No
1	Wolf, Seebauer (2014)	No
1	Xu, Zhou & Xu (2011)	No

Review step	*Author*	*Intervention*
2	Ben-Elia, Ettema (2011a)	Yes
2	Eriksson, Garvill & Nordlund (2008b)	Yes
2	Gärling et al. (2009)	Yes
2	Gärling, Friman (2012)	Yes
2	Gärling, Fujii (2009)	Yes
2	Taniguchi, Fujii (2007)	Yes
4	Bamberg (2013a)	Yes
4	Beale, Bonsall (2007)	Yes
4	Loukopoulos et al. (2005)	Yes
4	Steg, Schuitema (2007)	Yes

Table 0-2 Publications analysing on the effects of interventions on travel behaviour (N=34)

Author	*Theory*	*Type of study*	*Intervention type*	*Techniques*	*Longitudinal analysis*	*Sample*	*Control group*	*Country*
Abou-Zeid et al. (2012)	PT	Empirical	Experience	Enforced public transport use during 2-3 days	Yes	30	No	Switzerland
Abou-Zeid, Ben-Akiva (2012)	TPB	Empirical	Experience	Enforced public transport use during 2-3 days	Yes	67	No	USA (and Switzerland)
Bamberg et al. (2011)	TPB+NAT+SRT	Conceptual						
Bamberg (2013a)	TPB+NAT+SRT	Empirical	Information	Phone calls	Yes	625	Yes	Germany
Bamberg (2006)	TPB	Empirical	Conditions	Introduction of bus semester ticket	Yes	1036	No	Germany
Bamberg, Ajzen & Schmidt (2003)	TPB	Empirical	Experience & Information	One-day free public transport ticket & public transport information	Yes	169	Yes	Germany
Bamberg, Rölle & Weber (2003)	TPB	Empirical	Experience & Information	One-day free public transport ticket & public transport information	Yes	169	Yes	Germany
Bamberg, Schmidt (1998)	TPB	Empirical	Conditions	Introduction of semester ticket	Yes	1036	No	Germany
Bamberg, Schmidt (2001)	TPB	Empirical	Conditions	Introduction of semester ticket	Yes	1036	No	Germany
Beale, Bonsall (2007)	TPB	Empirical	Information	Marketing material for bus use	Yes	103	Yes	United Kingdom
Ben-Elia, Ettema (2011a)	TPB+PT+TIB	Empirical	Reward	Money or credits for smartphone if car is not used in rush hours	Yes	341	No	Netherlands
Ben-Elia, Ettema (2011b)	TPB+PT	Empirical	Reward	Money or credits for smartphone if car is not used in rush hours	Yes	341	No	Netherlands
Ceder et al. (2013)	PT	Empirical	Conditions	Public transport transfer time and facilities	No		No	New Zeeland

Author	*Theory*	*Type of study*	*Intervention type*	*Techniques*	*Longitudinal analysis*	*Sample*	*Control group*	*Country*
Eriksson, Garvill & Nordlund (2006)	VBN	Empirical	Conditions, Information & Dissuasion	Three scenarios: 1) Campaign 2) Taxes on fuel 3) Cheaper and better public transport	No	460	No	Sweden
Eriksson, Garvill & Nordlund (2008a)	VBN	Empirical	Conditions & Dissuasion	Three scenarios: 1) Taxes on fuel 2) Cheaper and better public transport 3) Subsidies for renewable fuel	No	616	No	Sweden
Eriksson, Garvill & Nordlund (2008b)	VBN	Empirical	Planning	Car diary with all car trips planned for the following week & commitment to reduce car use using suggested strategies	Yes	51	Yes	Sweden
Eriksson, Nordlund & Garvill (2010)	TPB+VBN	Empirical	Conditions & Dissuasion	Three scenarios: 1)Taxes on fuel 2) Cheaper and better public transport 3) Combination of both	No	1753	No	Sweden
Gärling et al. (2009)	TPB+NAT+SRT	Conceptual						
Gärling, Friman (2012)	TPB+TIB	Conceptual						
Gärling, Fujii (2009)	TPB+NAT+SRT	Conceptual						
Haustein, Hunecke (2013)	TPB+NAT+TTM	Conceptual						
Heath, Gifford (2002)	TPB	Empirical	Conditions	Introduction of universal bus pass for students	Yes	309	No	Canada
Hunecke et al. (2001)	TPB+NAT	Empirical	Experience	Free PT tickets	No	160	Yes	Germany

Author	*Theory*	*Type of study*	*Intervention type*	*Techniques*	*Longitudinal analysis*	*Sample*	*Control group*	*Country*
Loukopoulos et al. (2005)	TPB	Empirical	Dissuasion & Information	Three scenarios: 1) Prohibiting car traffic in city centre 2) Road pricing 3) Individualised marketing	No	291	No	Sweden
Matthies, Klöckner & Preißner (2006)	NAT	Empirical	Experience & Planning	Free PT tickets & plea for commitment	Yes	297	Yes	Germany
Rose, Marfurt (2007)	TTM	Empirical	Information	"Bike to work day" (event including oral recommendations for cycling)	Yes	1952	No	Australia
Schade, Schlag (2003)	TPB+NAT	Empirical	Dissuasion	Car pricing (combining fuel taxes, road pricing and parking fee)	No	952	No	4 European cities
Schuitema, Steg & Rothengatter (2010)	GFT	Empirical	Dissuasion	Two scenarios: 1) Road pricing in congested areas 2) Mass/Km dependent pricing	No	507	No	Netherlands
Staubach et al. (2014)	TAM	Empirical	Information	Device informing on fuel efficiency of driving when shifting gears and acceleration/deceleration	Yes	30	No	Germany
Steg, Schuitema (2007)	NAT+VBN	Conceptual						
Taniguchi et al.(2003)	NAT	Empirical	Information	Travel feedback program: Educational pamphlets to explain the purpose of intervention, i.e. reduction of CO2 emissions. Evaluation of travel behaviour, recommendations and comparison with a later evaluation	No	263	Yes	Japan
Taniguchi, Fujii (2007)	TPB+NAT	Empirical	Information	Travel feedback program: Lecture about global warming, role of CO2 and car emissions. Evaluation of travel behaviour, recommendations and comparison with a later evaluation	Yes	208	No	Japan

Author	*Theory*	*Type of study*	*Intervention type*	*Techniques*	*Longitudinal analysis*	*Sample*	*Control group*	*Country*
Thøgersen (2009)	TPB	Empirical	Experience & Planning	A free month public transport travel card, alone or combined with customised travel plan or planning intervention	Yes	597	Yes	Denmark
Tulusan et al.(2012)	FIT	Empirical	Information	Mobile application that recommends gear and calculates ecological driving based on acceleration, braking and speed	No	15	No	Switzerland