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Report of Cross-City Comparison (February 2018)

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1 Introduction

1.1 Motivation and Goals

The primary aim of WP3 is to analyse the evolvement of travel behaviour and car use—as described in D2.1 (Jones 2016)—for the five Stage 3 cities, beginning with their Stage 1 condition, continuing to their peak car situation and finally to their current status as Stage 3 cities. The development of relevant travel indicators is mapped over time in order to quantify this trajectory and to identify the various factors which have contributed to the observed changes in behaviour—particularly the observed reductions in car driver trip rates.

The quantitative analysis in WP3 focuses on car ownership, car use (trip rates, mileage) and their determinants. These aspects of individual travel behaviour have the highest relevance for understanding the peak car phenomenon. Since car ownership and car use can only be understood in the context of overall travel behaviour, indicators describing the overall travel behaviour including all modes of transport are also part of the analysis scheme. Individual travel behaviour is analysed at the person and trip levels in order to provide insight into what happens underneath the "surface" of the aggregated trends over time from Stage 1 to Stage 3.

This deliverable builds on the definitions of congestion and network performance and on the analytical framework developed in WP2 / D2.1. The analytical framework to be provided by WP2 was expanded within D3.1 to specify the full technical details, resulting in a detailed scheme for quantitative data analysis in WP3.

The literature review carried out for the previous deliverables was updated and extended for this deliverable and is, next to the partners' expertise and data availability, the most important input for cross-city analysis. The main data sources for this deliverable were provided by the Stage-3-city partners via the individual city-specific reports D3.2 (Roider et al. 2016) and the harmonised household travel surveys (HTS) as described in Section 4.3. In addition, a qualitative data collection effort also contributes to the analysis to be reported in this deliverable.

Another important source of input is the meeting of all Stage-3-city partners and selected technical partners from the CREATE consortium in Paris in March 2017. The goal of this deliverable is to bring together the work done so far for each individual Stage 3 city and to progress forward from this cross-city comparison.

Similarities as well as differences in the developments are identified and conclusions are drawn for policy making. This deliverable provides inputs for the integrative evaluation of qualitative and quantitative results in WP5, as well as for WP6 and for dissemination purposes. Analysis with data from INRIX will be discussed only tentatively in this deliverable; this is elaborated in D3.4.

1.2 Outline

The report is structured into seven Sections. The first Section outlines the motivation and the goals of the cross-city comparison as well as the integration of this work into the context of the previous actions of WP3. Following that, results of the comprehensive literature review are presented, and the research approach chosen for cross-city comparisons is formulated in Section 2. This step also includes the development of a conceptual framework, key hypotheses, and research principles.

Section 3 contains the description of the methodological approach in addition to more specific explanations of the applied analysis techniques. The case-study cities are also introduced in Section 3. Necessary steps of data preparation are described in detail within Section 4. The data sources used for this project are discussed, the methodological background information of surveys (metadata) are compared, and the implementation of data harmonisation is explained.

The empirical results of the cross-city comparisons are presented and discussed in Section 5. Two different tracks of data are used: First, Section 5 starts with cross-city comparisons based on the already-mentioned work of Stage-3-city partners for the individual city-specific reports (Roider et al. 2016); second, HTS micro-data analyses are carried out specifically for this report. These are presented in Section 5.2. In addition, a semi-quantitative assessment for exploring the main factors underlying change in travel behaviour was carried out that is described in Section 5.4 of this report. Cohort analyses of travel behaviour patterns based on the harmonised HTS data complete the substantive discussions of outcomes in Section 5.3.

The insights gained from the different streams of work are combined into overall lessons learnt in Section 6. Section 7 concludes the methodological and contextual findings of the cross-city comparison task. Separate sections for references, figures, and tables are located at the end of the report.

2 Literature Review and Research Approach

2.1 Literature on Peak Car, Car Use, and Car Ownership

The peak car debate emerged from a long history of research on car use and car ownership and their determinants. Goodwin & Van Dender (2013) have provided a comprehensive overview about this line of research: Already in the 1950s, research predicted there will be a saturation level of car ownership. Research on car use dates back to the 1970s when HTSs were set up in many countries at the national level and also in cities around the world. The availability of these data substantially improved the opportunities for analysing travel behaviour and car use. By the end of the first decade of the 21st century—and related in many countries to the economic recession in this time—slower rates of growth and levelling off or decline of car use were observed in many countries. The phrase “peak car” was often used and is now an established (though not always clearly defined) term for describing this phenomenon.

Some influential papers were published between 2010 and 2012 (these are cited below), a Roundtable was organised around this topic by the International Transport Forum (Goodwin 2012, see also ITF 2013), a Special Issue “’Peak Car’ – Themes and Issues” was published in the 2013 Journal *Transport Reviews* (Goodwin & Van Dender 2013 for the editorial). In the following paragraphs, relevant insights from this research stream are summarised as the basis for developing the hypotheses and research approaches for this study. Literature on car use and on car ownership is included since both are closely connected. The latter is a mediating variable that is influenced by various factors such as sociodemographic or socioeconomic variables and which directly influences car use itself.

Vehicle Kilometers Travelled (VKT) (see, e.g., Bastian et al. 2015, Kuhnimhof et al. 2013) and trip rates (see, e.g., Buehler et al. 2016) are the most important indicators for describing the peak car phenomenon. VKT is used mainly on the national level whereas trip rates, also in combination with trip distances (see, e.g., Le Vine & Jones 2012, Stokes 2013), are used for cities and agglomerations. Modal split values are also referred to for demonstrating the peak car effect (see, e.g., Buehler et al. 2016), but these should be interpreted with caution. Changes in modal split values only assess relative shifts between transport modes.

Focas & Christidis (2017) discuss the peak car phenomenon in Europe from a countrywide and aggregate perspective. They analyse underlying factors affecting travel choices (level of car use in correlation with demographic and socio-economic factors) and attempt to extrapolate their future importance using a random forest classification technique. The literature section summarises main categories of factors for car use reductions which still need to be explored: (1) Economic factors, (2) Changes to the relative quality and reliability of different modes of travel, (3) Developments in land use planning, and (4) Demographic changes. They conclude that it is probably too early to assume that peak car has happened throughout Europe. They identify the younger generations as one main impetus for declining car use.

Buehler et al. (2016) specifically analyse the development of car dependency for large European cities (Munich, Berlin, Hamburg, Vienna, and Zurich) for different time periods between 1991 and 2013. With a combination of quantitative analyses of HTS data and qualitative discussions, they discuss the impact of various factors including policies on motorisation rates and modal shares of car use. Interestingly, a clear correlation between motorisation rates and car use shares could not clearly be observed for the studied cities. For example, Munich has by far the highest motorisation rate, but car use (assessed by the car modal share) is much lower than in Hamburg which is the city with the highest car share among all five cities. Berlin has the lowest motorisation rate, but the mode share of car use is higher than in Zurich or Vienna. The authors argue that a coordinated package of mutually reinforcing push and pull policies (including transport planning and land use) has been implemented in all case study cities and is one important reason for the observed peak car effects. Buehler et al. (2016) also stress the importance of considering not only the city in its administrative boundaries but the region as a whole in order to understand the overall transport demand and traffic in a city—generated by residents and by commuters from outside the city.

In an analysis for France (data from 1974-2010), Grimal et al. (2013) suggest that the peak car effect occurred in the 1990s and accelerated in the 2000s. They also conclude that the saturation of individual car use is a general phenomenon. The fact that the phenomenon has been observed in France for all income groups and all area types (core-cities, suburbs, low-density areas) at different levels and points in time is the reason for this assessment. They also discussed, based on the literature, what happens after saturation and argue that age-cohort models are frequently suggesting an initial slowdown followed by a peak in car use in the years after. Finally, Grimal et al. (2013: 297 & 307) state that motorisation rates are quite inelastic by variations of real incomes and fuel prices, but VKT are quite elastic. They conclude that the change in car use per motorised adult can be mostly explained by a significant shift in economic conditions.

Cornut & Madre (2017) study a similar research question (car ownership and use) also by adopting a longitudinal perspective (1974-2013) for the Paris metropolitan area. They compare different zones (city centre, inner-suburbs, and outer-suburbs) and economic situations including indicators describing inequality (using Gini-coefficient and income distribution indices). They find converging car-ownership behaviour for most residents but identify opposite trends according to the zone of residence. They also report a general stabilisation of car use since the early 1990s followed by a decrease starting at the millennium. Finally, they advocate for a progressive saturation of car use in each zone over time (first the city of Paris, then the inner-suburbs, and finally the outer-suburbs). While for the city of Paris and the inner-suburbs car use follows a downward trend for a long time (could be understood as a long-term phenomenon), the permanence of saturation for the outer-suburbs is a more complex question and might simply be a temporary phenomenon (once again increasing if the economic situation is improving).

For Great Britain, Metz (2013) identifies a cessation of the average per capita growth of daily travel (data from the early 1970s until 2011). He argues that due to invariant travel times and trip rates of the population, the annual distance travelled has changed across time thanks to higher travel speeds. He mentions that the demand for personal daily travel has ceased to grow and substantiates this assessment by the fact that needs for mobility-based access and choice are already sufficiently met and that speed can hardly be increased further.

Using aggregate time-series data between 2002 and 2012, Bastian & Börjesson (2015) investigate causes for the recent decline in Swedish car use, exploring the extent to which particular economic variables help to explain car use in Sweden. They found that that much of the development in VKT can be explained by changes in fuel price and GDP per capita. The elasticities, calculated based on aggregated data from 2002 and 2012, are in line with those in the literature and are able to reproduce VKT per adult trend back to the 1980s. Therefore, they conclude that elasticities have not changed since 2002 as compared to previous points in time. They suggest that is too early to assume fundamental changes in attitudes towards car driving to explain Sweden's car travel trends from 2002 to 2012. However, they suggest that adaptions of lifestyle factors (more urbanisation or education) or changes in preferences and attitudes are probably driven by economic incentives, and people are often not aware that the reasoning of their behaviour may also be driven by the effectiveness of economic incentives. There are higher elasticities among urban citizens than people living in rural areas since they have a better set of alternatives and more opportunities to adapt their behaviour (alternative modes and destinations).

In 2016, Bastian et al. amend and extend their above-mentioned study in a quite controversially discussed contribution with analyses for US, France, UK, Sweden, Australia, and Germany (using data from 1980 until 2013/14). Based on a very general and comprehensive literature review, they attempt to trace the whole peak car debate. This part is worth studying for interested followers of this research debate. As a result, they summarise that the simplistic models (only considering gasoline price and GDP) are remarkably able to predict VKT per capita in the investigated countries. They additionally found that elasticities with regard to GDP per capita are declining in all countries which could be interpreted as saturation of car use in the highest income segments.

Wadud & Baierl (2017) respond to the conclusions drawn by Bastian et al. (2016) and provide an interesting comment that also stresses causality and possible explanation factors. They argue that the execution of the model exercise has an important weakness: Use of the whole sample from 1980 to 2014 includes the data from the 'peak car' period during the parameter estimation; therefore, the model fits only as best as possible to the data, and "*predictions from a model that includes the data from the 'peak car' period must not be used to understand the ability of the model to predict 'peak car'*" (p. 382). Their models only include data until 2003 or use a dummy variable for the peak car event, leading to results which show that economic variables are not sufficient for explaining the stagnation in car travel for three investigated countries (UK, France, and US). However, they still remain as important predictors.

Bastian et al. (2017) directly respond in the same journal to the comments of Wadud & Baierl (2017). They reflect many judgments and respond quite convincingly. Finally, together with the comments on their 2016 article, this series of contributions underpin the complexity of the peak car discussions. Indeed, GDP and fuel prices are important factors for explaining car travel at aggregate and countrywide levels, but it is also clear that other causal factors are not ruled out by those assessments, and, obviously, elasticities and developments are quite different between high dense (urban) areas and areas with lower density.

Goodwin (2012) specifically stresses car use trends in cities, and, in urban areas where policies are most effective, alternatives to the car are available and physical barriers to car use exist. His brief literature review reveals that growth rates of car use per capita in cities have reduced substantially for decades. The discussed body of evidence by Goodwin (2012) suggests that responses of car use to policy initiatives exist even if these are rather small in the short run. They built up in the longer run by more flexible life-style choices and eroded habits.

Goodwin (2012: 9) lists the following factors suggested for explaining the clear growth reduction in car use:

- Traditional 'economic' factors of prices and incomes
- Changes to the relative quality and reliability of travel
- Developments in land-use planning
- New social/technical patterns and preferences seen as influences on behaviour
- New patterns of work, shopping, entertainment, and leisure
- Direct and indirect effects of technologies providing mobile internet access

Van der Waard et al. (2013) discuss developments in the Netherlands (data from 1995 until 2011) and conclude that car ownership, driving licence holding, and income have only minor effects on changes in car use unlike other Western countries. They explicitly mention labour participation as a factor of interest. The number of working young adults has declined, and a shift towards living in dense urban areas (re-urbanisation) has been observed. A lower car-ownership level among these people in combination with participation in higher education has led to fewer work-related car trips.

For England, Headicar (2013: 322) argues the trend of redistribution of residential locations (data from 1971-2011) as one important reason for changes in car use patterns and the distribution of non-residential activities being the other. He additionally points out that these factors are not independent of one another. The clearest reduction of per capita car driver's mileage rates has been observed for the Greater London Area followed by freestanding cities.

Le Vine et al. (2013) study the impact of tax regulations as a major contributing factor for a reduction in per capita male driving mileage for Great Britain (mainly using data from 1995/97-2008/10). They lay out the changes in taxation policy affecting the reduction of company car ownership (including free fuel) and further substitutional affects. They also discuss general effects for Great Britain such as that younger people drive less while older people drive more, and male driving is reducing while female driving is increasing. Le Vine et al. (2013) specifically highlight that company cars in Britain have never accounted for more than 10 % of the overall car fleet but they contribute disproportionately to overall traffic levels. Users of company cars have much higher incomes than all other adults. They report for London that the reduced company car usage contributes more to the overall reduction of car driving distances per capita than the personal car usage—particularly for middle-age men (again, company cars are clearly linked with high incomes). The company car effect seems to be a very convincing explanation. This does not explain the sharp decrease of car use amongst young men.

Van Wee (2015) discusses the issue of a possible shift towards ICT-based activities (and accessibility) replacing travel. He hypothesises that an increasing orientation towards those activities, together with other factors, could be an important element for explaining changes in car-usage patterns. Citing Lyons (2015), he writes "… *that ICT can substitute, stimulate, supplement, redistribute, and enrich travel, can improve the efficiency of travel and can indirectly affect travel via impacts on social practices and locational decisions.*" (Van Wee 2015: 2). A very interesting point of view is that ICT-based activities do not necessarily lead to a reduction in average travel time (violating the hypothesis of a constant travel time budget), when a shift to slow modes (maybe more active mobility) and shorter trips as well as perhaps more travel for recreational purposes may reduce or even compensate travel time gains.

Stapleton et al. (2017) suggest in an econometric analysis for the UK that change in income (economic difficulties mainly created by the 2009 recession), the fuel cost of driving and the increasing urbanisation level largely explain annual car distance travelled between 1970 and 2012. They also estimate an increasing rebound effect over time (i.e. because of fuel efficiency). They argue that peak car is mainly being driven by a combination of these factors. Evidence for influences through growing income inequalities or the diffusion of ICT is not found. As income elasticities of car travel are much larger than price elasticities in their study, economic recovery and low fuel prices could lead to a renewed (countrywide) car travel.

Various papers discuss young adults specifically since this person group has special relevance for understanding the peak car phenomenon. For the US, Garikapati et al. (2016) base their analysis on data from 2003 to 2013, tracking the travel of millennials (Gen Y, in their study defined as people born between 1979 and 2000)—the largest population segment assessed from a generational perspective. That differences exist between travel behaviour of millennials compared to their predecessors is widely accepted, but the question remains whether differences will persist or fade in next life stages. Therefore, they present an in-depth analysis of trends on activity and time use based on longitudinal data. The 11-year time span from 2003 to 2013 includes the recession, and therefore data can also be used to see how this important issue shaped these developments. In light of age-period-cohort analysis approaches, Garikapati et al (2016) make an important statement for the interpretation of their received results:

> *"Another important caveat is that the analysis […] effectively controls for ageing effects and cohort effects, but there are likely to be important period effects that are also at play in shaping activity-time use patterns. While the 11-year time span of the ATUS data series is short enough that there are unlikely to be any fundamental structural differences in societal form and function, the severe recession, the rapid evolution of technology, and the growth in the sharing economy and social media*

platforms experienced within this time span are likely to contribute to period effects. The analysis […] is unable to isolate such period effects, but differences in activity-time use patterns and trends are discussed in the context of potential period effects that may be at play." (p. 560)."

Interestingly, based on their activity time-use trend analyses for the US, they argue that it is more likely that the economic recession contributed more substantially to the decrease of car use and, therefore, to the observed peak car phenomenon, than to a potential, fundamental transformation in attitudes, values, and perceptions towards travel. Differences between generational cohorts can also be explained by socioeconomic and demographic differences as important determinants of activity-travel and time use patterns. They found that differences between generations (Millennials/Gen Y and Gen X) appear to fade with age. They conclude:

"*The findings […] suggest that the much-discussed and written-about transformative changes that millennials may bring about in society are not likely to occur, although additional cross-sections of data are needed to draw definitive conclusions. The longitudinal trend analysis conducted using the American Time Use Survey […] shows that, as millennials age into their 30s, they are increasingly exhibiting activity-time use patterns that resemble those of Generation X individuals when they were in their early 30s.*" (p. 578).

Another interesting assessment by Garikapati et al. (2016):

"*The generation that depicts remarkably different patterns in activity location is the younger millennial cohort born between 1988 and 1994. In total, younger millennials 18–24 years old are spending 40 more minutes at home per day than the older millennials did when they were 18–24 years old. It is unclear whether younger millennials will also begin to converge to the activity-time use patterns of prior generations as they age, as the older millennials are. […] However, during the period that differences do exist [between millennials and Generation X], millennials drive less; this period of lower car ownership and vehicle use yields tangible benefits in terms of reduced VMT, energy consumption, and emissions. These benefits are likely to be substantial and are worthy of explicit recognition in transportation planning processes through a specific accounting of the activity location and travel choices of the millennial generation. […] The differences do fade (as shown in the ageing effects section of this paper) as the millennials enter their early 30s, and any differences that persist are closely aligned with differences in socio-economic and demographic characteristics associated with delayed lifecycle milestones experienced by millennials (delayed marriage, child-bearing, and entry into labour force). In other words, after accounting for differences in socio-economic and demographic characteristics, and period-specific effects (state of the economy, fuel prices, technology and social media, and disruptive mobility services), there do not appear to be many cohort-specific effects (lifestyle preferences, attitudes, and values) contributing to differences in activity-time use patterns; if there were such effects, then differences in activity-time use patterns would not fade to the degree that they do.*" (p. 579).

Kuhnimhof et al. (2013) show in their case study for France, Germany, UK, and USA (different study periods for each case with data within the time span from 1976 to 2009) that all age classes except seniors have contributed to changes in per-capita car travel (car kilometres). Young adults show the strongest negative contribution to car use, and the increasing car availability of seniors has a dumbing effect on peak car. For analysis purposes, they use an insightful, although quite simple, trend decomposition methodology and several assumptions for breaking down age, car availability, mode choice, and travel demand effects. As a result, they find some similarities (prototypical patterns) for changes in car travel among France and USA (i.e., due to changes in total travel demand by drivers) on the one hand, and among Germany and the UK (i.e., due to levelling off of motorisation and modal shifts) on the other.

Delbosc & Currie (2013) carry out a review of existing evidence for declining numbers of car licences among young people. Their study refers to 14 countries of the developed world and also reviews evidence of causal factors (data within the time period from 1983 to 2010). Many countries (9 out of 14) show declining proportions of car driving licences among young people until the end of the observation period (mostly until 2008 and in some cases until 2010). They assess the magnitude of some casual factors linked to youth licence decline by scale of impact. Additionally, they categorise an increasing rate of educational participation, decreasing full-time employment rates, and insurance costs as medium-impact causal factors. For low-scale impacting factors, they mention aspects like delaying marriage/child-bearing, costs of petrol, recession/economy reasons, mode shift, moving to inner-cities or to more accessible areas, the fact that licencing regimes became more strict, lower household car access, and cars no longer representing a status symbol. As a conclusion, […] "*changes in life stage and household living arrangements show the most consistent influence on changes in youth licencing.*" (p. 286).

Metz (2013) supports this line of argument:

> "*Increased life expectancy allows the young to defer the transition to traditional adult life. More young people enter higher and further education, located mainly in urban centres. They continue in the urban lifestyle for employment and social life, facilitated by modern mobile technology—not cars but Internet and phones. Cars are expensive for young people to own, particularly the cost of insurance, parking is constrained, and do-it-yourself servicing difficult with modern vehicle technology. Driving licence holding by those in their 20s is in decline*." (p. 263).

Focas & Christidis (2017) use another formulation but argue in the same direction: "[…] *Generation Y does not want to be car-less but car-later*" (p.533).

Figueroa et al. (2014) investigate for the case of Denmark (data from 2006 to 2011) the role of the built environment and travel pattern among the two different age groups of younger adults (18–64) and older adults (64 years and above). Interestingly, they find that car use of older adults does not shift to other modes in high density areas as it can be observed for younger adults. High regional accessibility does not lead to lessened car use for older adults in Denmark, which is likely caused by different time availability and fewer limiting conditions as well as reflecting the convenience of private car use (even for shorter trips) for this group of people.

Hjorthol (2016) analyses the popularity of the car by examining changes in driving licence and car access using cohort analyses of young adults in Norway over a 25-year period (from 1985–2009). He presents societal factors that have impacted travel behaviour of young adults with a specific focus on the importance of driving licences and car access. Some important factors have changed along the observation interval (1985–2009): an increase in the number of people in urban areas, life expectancy, average age of first-time mothers, penetration with ICT, education, and decreasing size of households. Using this starting point, the author performed logistic regressions and cohort analyses on the basis of the Norwegian NTS for accessing his research questions. As a result, young people living outside the larger cities (frequently employed and married/cohabiting) show a greater propensity toward having driver's licences and car access than people in larger cities (competitive PT supply, frequently in education, and not married/cohabiting). Together with longer education periods and delaying family formation as well as more people living in larger cities, these factors likely contribute to the declining orientation towards cars. Cohort analyses also give first indications that today there are not as many young people reaching the high level of driving licence ownership as their predecessors. Interestingly, Hjorthol also supports the assessment that as soon as young people are living in urban areas (for example during their education period), this life stage can also be seen as a learning period for how to use PT, to walk or cycle, or to use smartphones for getting travel information. However, putting the Norwegian results into context, this study also lets degrees of freedom for interpreting possible future developments in terms of interrupted growth, saturation, or peak car.

Oakil et al. (2016) also investigate car ownership among young households in the Netherlands (two different pooled data sources from 2012). Descriptively, car ownership among young Dutch adults has slowly decreased in recent decades. They explore the dependency of household composition, urbanisation level, household income, employment, and ethnics on car ownership. Urbanisation and household compositions are the most influencing. Additionally, they find a significant interaction effect between them. These results also support the well-known circumstance that families with children have complex daily travel needs and therefore a high car-dependency compared with singles or couples. On the other hand, the cited research also highlights that (voluntary) childlessness is rising in the Netherlands, and if this trend continues, it is quite possible that this part of the young generation will not reach or catch up to the same level of car mobility later in their lifecycle.

Klein & Smart (2017) investigate car ownership among Millennials (born in the 1980s and 1990s) for the US. The application of a random-effects Poisson regression model in order to take into account the panel structure of the used database (US Panel Study of Income Dynamics from 1999 to 2013), together with descriptive cohort analyses, allow for the examination of generational trends for the number of cars in family units. As a result, Millennials own fewer cars than their predecessors, and the economic situation of Millennials (decreased employment, lower incomes, less wealth) plays a very large role and explains most of differences with older generations. They also mention that maybe younger Americans nevertheless use the car less than previous generations but this also could be reasoned by balancing their precarious budgets.

To summarise this literature review, one can say that despite a substantial body of literature that is now available about the peak car phenomenon, it is still not fully understood. The lack of detailed time-series data including all relevant variables is one reason for this. Another reason is the high dynamics of car use. The decline in car use that has been observed and analysed in the last years is developing currently towards more stable or even again increasing numbers (see e.g. TfL 2017).

Stokes (2013) discusses possible future developments of car use based on reflections on the importance of selected influencing factors:

- If economic factors are assumed to be the key drivers, a return to growth might occur.
- Little gain per capita by extra car travel can be expected seeing the already high car travel levels today—saturation might occur following this line of argument.
- If the lower car use of currently young people dominates and this behaviour is maintained throughout all subsequent life cycle stages, further declines in car use can be expected.

2.2 Research Approach

2.2.1 Conceptual Framework

The following Figure 1 shows the conceptual framework that was developed based on the literature review for this study. The framework explains travel behaviour at the person and trip levels as well as the system effects resulting from this individual behaviour.

Figure 1 shows first how policies influence short-term individual travel behaviour. The ‘4 Es’ are used in the figure for classifying measures for disincentivising car ownership and car use or for promoting the use of alternative modes (see for example Gerike & Parkin 2015, Winters et al. 2011):

- Engineering: Measures in this category address the built environment and the transport supply, and are mainly based in spatial/land-use planning, transport planning, and traffic engineering. Examples include the enhancement of infrastructure networks, the layout of streets and intersections and the provision of integrated transport services. In London, for example, improved public transport has been a major feature and has progressed alongside reductions to road capacity.
- Enforcement: Legal issues such as speed limits, rights-of-way, and regulation of parking availability are the focus of enforcement measures.
- Economy: This category includes monetary instruments for incentivising or discouraging specific behaviours. The London congestion charge is a prominent example for this category, but many more instruments exist such as schemes for parking management or tariff systems in public transport.
- Education: These measures are sometimes called “soft measures” and include all measures that do not touch on the transport supply itself but address the users. Examples for this category are information and knowledge provision, campaigning, personalised travel planning, training, and social marketing.

Some classification approaches add a fifth ‘E’, called “Evaluation” (see, e.g. State of Vermont 2018) in order to stress the importance of continuous monitoring and systematic evaluation of all implemented measures and also of the general development of transport demand. Another ‘E’, called “(built) Environment” might be suitable in order give higher importance to land-use planning by separating this issue from the above listed category “Engineering” with its broad scope.

Education measures not only directly impact individual travel behaviour but also influence a person’s mind-set thus leading to long-term behavioural changes. Measures in the categories Engineering, Enforcement, and Economy typically change the physical environment and lead via this “detour” again to changes in the short-term behaviour and also to changes in the persons’ mind-sets.

The macro trends include various developments outside the transport system. These might be general economic developments such as changes in income or in fuel prices. These might also be growth in population and/or workplaces that can be observed in many urban areas. Macro trends also include new societal trends when, for example, more and more people are keen on healthy lifestyles or when the shared use of services becomes more widely accepted.

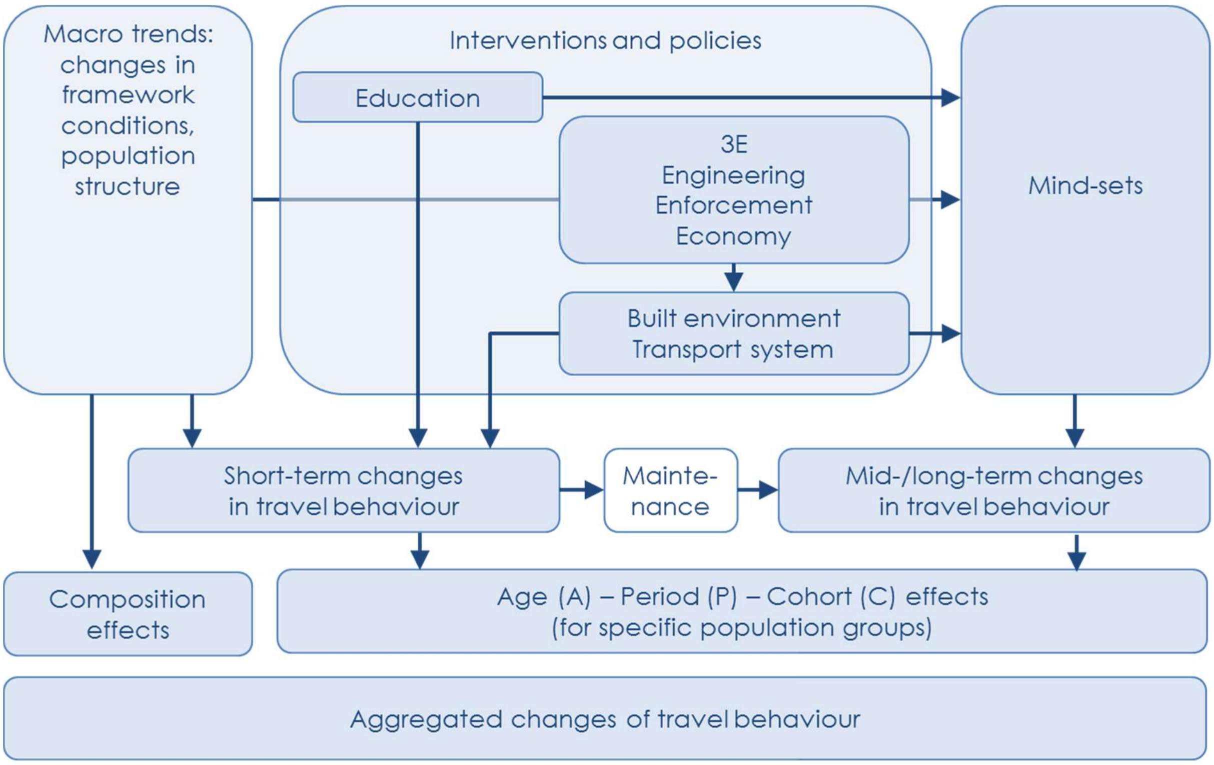
Technological developments such as the rise of ICT also belong to the macro trends. These general developments might directly impact travel behaviour or again via changed mind-sets. The new ICT devices seem, for example, to change young persons’ mind-sets. They seem to decrease the importance of car ownership compared to owning fancy ICT devices (Konings & Van Dist 2015). Changes in travel behaviour can be observed resulting from the changed mind-sets.

Overall, we see two main drivers for changes in individual travel behaviour: First, the population composition might change. Even if there are no behavioural changes within each specific person group, the population's travel behaviour might change because the size of the different person groups increases or decreases over time. When, for example, the number of seniors grows in a city, then their specific behaviour has more influence on the total population's travel statistics, and these statistics change even if each person group's behaviour stays the same. Second, specific person groups might change their behaviour, for example, resulting from changed mind-sets, macro trends, or transport policies. So we might see changes in the overall population's travel statistics even if there is no change in the population composition. Age-Period-Cohort (APC) analyses are suitable for identifying those effects; these will be introduced in Section 3.2.

General framework conditions such as the topography or climate conditions are not included into the conceptual framework. These barely change over time and, thus, are not useful in explaining diachronic behavioural changes. Nevertheless, these variables are important determinants of travel behaviour. They are included into the general description of the case study cities and into the interpretation of the findings.

The interface to WP4 is defined with the policy measures. This report considers only the outcomes of policy making, such as specific characteristics of the transport system. This report does not work on the governance settings that led to the policies and finally to the transport systems that evolved over time in all the case study cities.

Figure 1: General Conceptual Framework for Understanding Travel Behaviour



Source: Own elaboration.

2.2.2 Key Hypotheses and Research Principles

The peak car phenomenon is mainly described by the development of

- car ownership and
- car use over time.

These variables will therefore be used to determine the Stage 1 to Stage 3 conditions for each Stage 3 city in CREATE. From the policy perspective, policies and governance structures will be analysed in WP4 as the second key characteristic for the Stage 1 to Stage 3 conditions.

Based on the literature review and on the above described conceptual framework, the following hypotheses are formulated for the analysis in this report:

- Car ownership increased from Stage 1 to Stage 2 and decreased by Stage 3.
- The car driver trip rates increased from Stage 1 to Stage 2 and decreased by stage 3.

The following influencing factors for the peak car effect have been identified in the literature:

- Macro trends:
  - GDP and income, fuel prices
  - Information and Communication Technologies (ICT)
  - Company car taxation
  - Changing pattern of work
  - Changing pattern of shopping, entertainment, leisure
- Built environment and transport supply:
  - Densities, land-use
  - (comparative) speed, reliability, and comfort of trips with different transport modes
  - (comparative) prices public transport, car purchase, car use, parking
- Sociodemographic and socioeconomic factors:
  - Gender, age, cohort
  - Education
  - Car access as mediator variable, includes drivers licence
- Socio-psychological factors, mind-sets

In what follows, these factors are investigated as detailed as possible, based on the available data for the five CREATE Stage 3 cities. The analyses are carried out for the whole population but also for specific person groups in order to account for differences in behaviour change identified in the literature (e.g., for young adults and seniors, or for men and women). The development of the size of specific person groups will also be reported in order to identify possible composition effects.

Causes and effects will probably differ from city to city due to different contextual factors, transport supply and demand factors, mobility cultures, governance structures, etc. The analysis scheme aims to provide a minimum set of indicators to be examined in a consistent manner in all cities, allowing for comparisons between the cities. Additional indicators are included for individual cities if data is available and if the indicators help to better understand the transport policy evolution cycle.

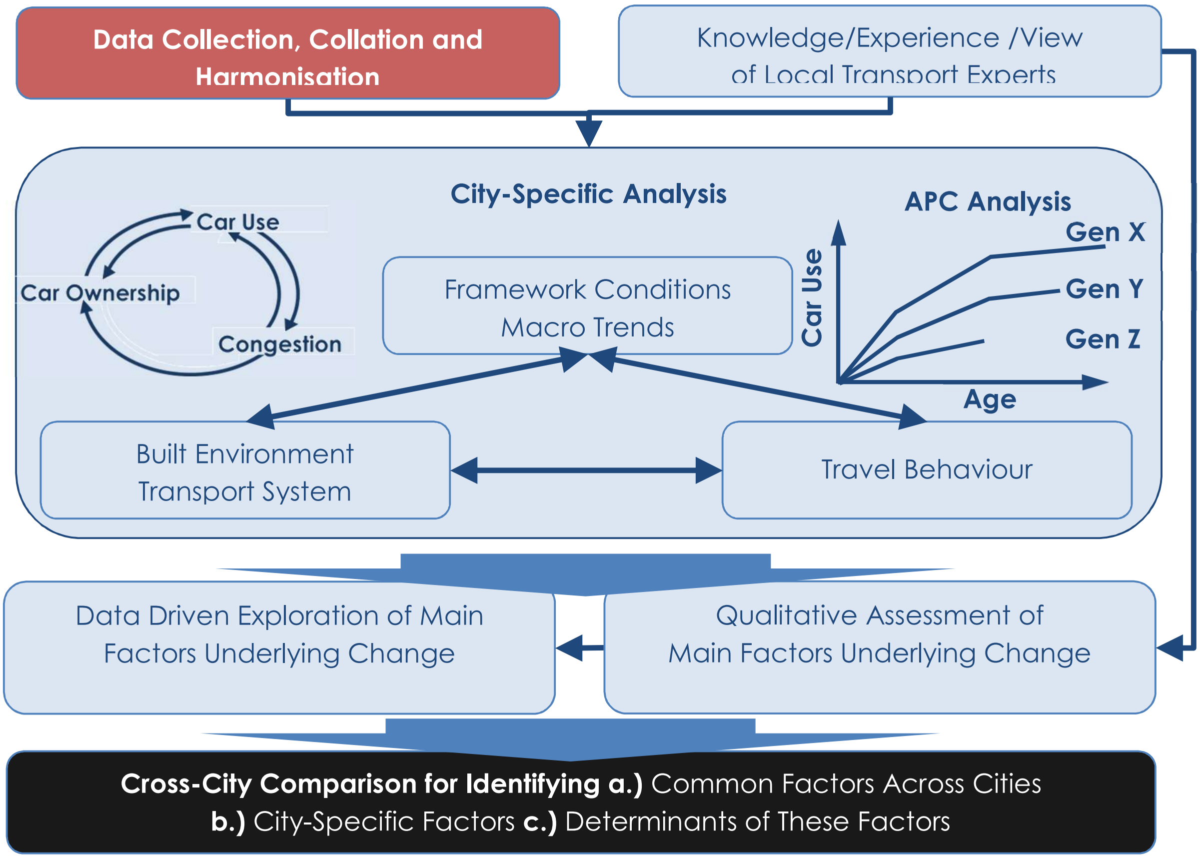
3 Methodology

3.1 Methodological Approach

This Section outlines the scientific approach specifically applied to the cross-city comparison. Figure 2 describes the structure of this methodology. First, quantitative data was collected, collated, compiled, and, specifically for the HTS data, also harmonised. Many discussions took place in order to come to an agreement on a manageable set of indicators for the different fields of interest. Specific knowledge and experience, contributed by local transport experts, were essential driving factors in these discussions. The views of these local transport experts and of different stakeholders for each of the five Stage 3 cities were also the basis for the qualitative or, more specifically, semi-quantitative assessment for exploring the main factors underlying change in travel behaviour. Both the approach itself and the obtained results are described in Section 5.4 of this report.

The quantitative data analysis in WP3 is based on two partly different sources of data. First, Stage-3-city partners were asked to collect data on their case study city for an agreed set of indicators. The indicators were categorised into "must have" and "nice to have" subsets in order to help prioritise the data collection effort and to ensure data availability for a consistent core set of indicators for all Stage 3 cites. Additionally, Stage-3-city partners were invited to provide further city-specific quantitative data which help to retrospectively explain the transport and travel developments and the transport policy evolution cycle already outlined in Jones (2016).

Figure 2: Methodology for Better Understanding the Factors for Successful Car-Use Reduction



Source: Own elaboration.

The results are described in the deliverable D3.2 (Roider et al. 2016) of the CREATE project. Many different data sources were used for collating information about framework conditions, transport supply, and travel behaviour. For the purpose of the city-specific analyses in D3.2 (Roider et al. 2016), administrative area types were the only possible and meaningful spatial categorisation. Therefore, all “must have” indicators were compiled at least at city level (city-wide within the administrative boundaries of each city). Inner-City and Peri-Urban area type information was always appreciated and “nice to have” indicators were compiled usually at city level.

Second, HTS data was collected, collated, and harmonised for all possible spatial categories. This approach allowed for the building of functional area types as described in Section 4.3.2. Functional area types such as “inner-urban”, “urban”, and “wider agglomeration” improve the comparability between the different cities substantially. The necessity of this step was one important outcome of the data harmonisation task described in Section 4.3. The use of functional area types would not have been possible for the city-specific analyses in D3.2 (Roider et al. 2016). Therefore, all city-specific comparisons in this report based on D3.2 always refer to the administrative boundaries of the cities (city-wide), whereas HTS analyses use the functional area types—mainly “urban area”. Thus particular care is needed for correct interpretation of the cross-city comparisons in this report.

City-specific analyses were carried out to explore main factors of underlying changes in travel behaviour. These preliminary and city-specific insights were enriched and reflected using the qualitative, or semi-quantitative, assessment described in Section 5.4. An additional meeting in Paris was organised for wider-ranging discussions of the city-specific results. The outcome of this meeting was the kick-off of more sophisticated cross-city comparisons. The cross-city comparison, based on both the aggregated indicators provided in D3.2 (Roider et al. 2016) and the harmonised HTS data, brought many insights into the peak-car phenomenon and its drivers and barriers. Microdata analysis of travel behaviour was shown to identify typical travel patterns and interdependencies of transport-related indicators, socio-demographics, and travel demand. These analyses were carried out in order to reveal common factors across cities, city-specific factors, and interactions between factors.

Finally, HTS data was also used to systematically investigate generational effects and particularities in terms of travel behaviour. Age-Period-Cohort (APC) analysis was applied as a city-specific analysis due to the widely differing survey periods across cities and due to the necessity of restructuring of HTS data for these types of analysis. The fundamental suitability and approach as well as basic assumptions of APC analyses are described in the next Section (3.2).

3.2 APC Analysis

3.2.1 Background and Introduction

Age-Period-Cohort analysis (APC) is a well-known approach for systematically studying the age-specific data collected at different points in time from different sets of individuals (e.g. different years of birth). An investigation of at least one dependent variable measured at two or more points in time in which at least two cohorts are compared is an overriding characteristic of a cohort analysis (Glenn 2005: 3). The analytic problem can be described as an investigation of different outcome contributions from three time-related changes (Yang & Land 2013a: 1). The challenge of APC analysis is to separate these changes into the three categories: age, time-period, and cohort components (Yang & Land 2013a: 2). It is important to note that this so-called identification problem has been intensively discussed—and is still being discussed—by the scientific community since the 1970s (Yang & Land 2013a: 3). The age, time-period, and cohort effects are three interrelated components: Cohort = Period – Age. Each of these is a linear function of the other two provided the time intervals have the same length for both the age and the period dimension (see Glenn 2005: 6 and Yang & Land 2008: 298). This leads to the above-mentioned identification problem that is widely discussed in many scientific contributions such as in Glenn (2005) and Bell & Jones (2013), and even controversially (see Yang & Land 2013b vs. Lou 2013). It is impossible to completely separate age, time-period, and cohort effects. An early review and critique of the age-period-cohort analysis given by Kupper et al. (1985) discusses the descriptive approach of APC analysis in detail.

Model-based approaches and attempts to solve the identification problem exist (see Bush 2003), but none of them allows a "mechanical" treatment of APC problems. Applications in the field of transport try either to establish more or less detailed a-priori assumptions (e.g. Dargay 2002, Dargay 2007, Kratukowski & Armoogum 2007, Sun et al. 2011) or to use a strong theoretically motivated or theory-guided background (e.g. in Gardiner et al. 2012, Bush 2003). Several model types are in use for analysing APC problems based on either aggregate population data (information aggregated into population-level contingency tables) or individual-level data from repeated cross-sectional surveys (see Yang & Land 2008: 299).

Alternatively, analysts carry out descriptive analyses, including careful context-based interpretations of the results, to avoid the identification problem. Contributions which perform descriptive cohort analyses for analysing travel behaviour usually choose the year of birth for defining cohort affiliation (see Krakutovski et al. 2007; Sun et al. 2011; Le Vine & Jones 2012; Garkapati et al. 2016; Newbold et. al. 2005).

Glenn (2005) outlines in detail the basic idea of cohort analyses as a quantitative method which measures the temporal effects of behaviour (see also TfL 2014). Through Glenn's description (2005), the concept of cohorts can be explained as people who experienced the same outside influences (i.e. the same social, cultural, and political changes, policies, or other external impacts) during a specific period of time. Bush (2003) defines cohorts as people who are born or enter into a particular system during the same time-period. Age cohorts (i.e. same time of birth) are often used in cohort analyses. Yang & Land (2013a: 8) introduce the conceptualisation of a birth cohort as individuals who move together through their lives and encounter the same events (historical, social events) at the same time and therefore with the same age.

Glenn (2005) points out that precaution and exactness in regard to terminology are necessary in cohort analyses. The term age cohort, frequently used in the social sciences, is therefore misleading because it "*[…] fails to follow the rule that each kind of cohort be identified by the event that defines it. Age is, of course a condition, and a changing one, rather than an event*" (Glenn 2005: 2).

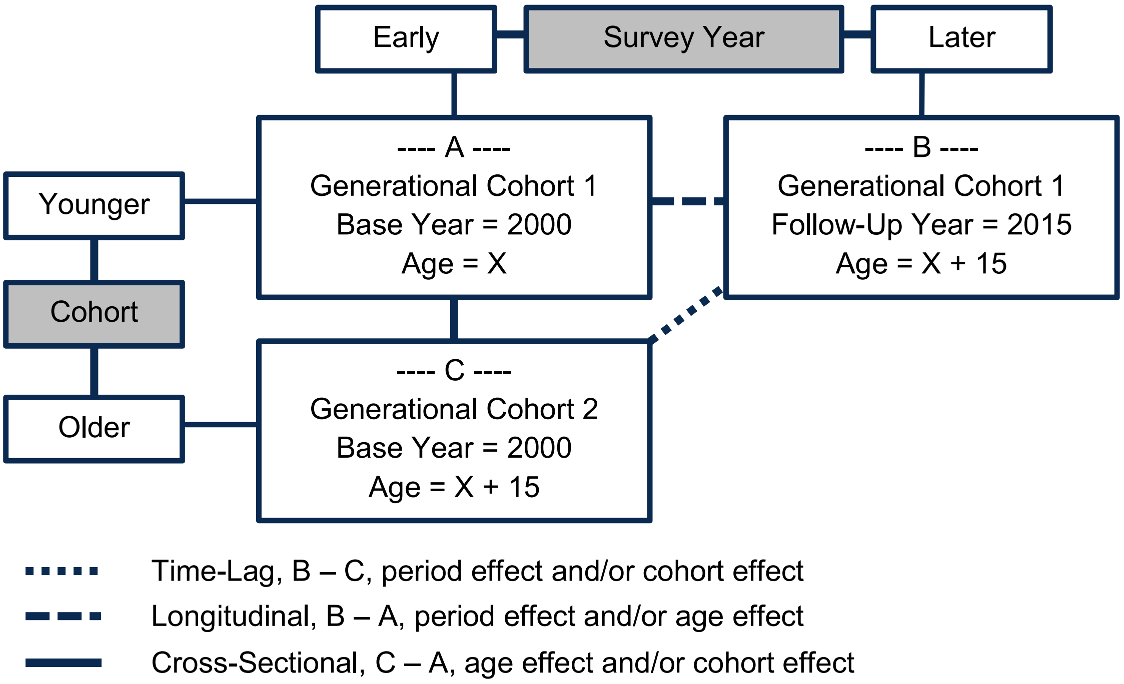
The following effects (travel-related for our application) can be distinguished in cohort analyses as:

Age effect: Respondents get older from one year to the next. Changes in their life-stage (e.g. the natural aging process and individual factors independent from the built environment) may lead to changes in their individual travel behaviour.

Period effect: Respondents show variation in travel behaviour between two points in time (time periods or calendar years) due to changes in the environment (e.g. social, cultural, or physical). This type of effect influences all age groups simultaneously.

Cohort effect: Respondents of dissimilar birth cohorts have diverse past experiences due to exposure to different external conditions over time. They are compared to each other under constrained external characteristics (e.g. at the same survey year) but as a result of behaviour-formative factors.

Figure 3: Observable Differences in Cohorts



Source: Adapted from Beldona (2005, p. 137), modified

Figure 3 shows how the three aforementioned effects can be analysed in cohort analysis:

1. Longitudinal analysis (B – A) = two age groups are analysed in a pseudo-panel approach as if the same person were analysed in two different points in time. The observed differences in travel behaviour can be attributed either to the age effect or the period effect or to both effects together (no cohort effect can be derived)
2. Cross-sectional analysis (C – A) = differences between generational cohorts (e.g. different age groups) are tested for one specific survey year. Age effects and cohort effects can be attributed.
3. Time-Lag analysis (B – C) = individuals of the same age group are tested (and compared) at different time periods. Time-lag differences might result from the period effect or the cohort effect or both together.

According to Beldona (2005: 137), these three analysis approaches give a holistic perspective of causes behind observed changes in behaviour but they do not enable the clear separation of the three effects (age, period, cohort). Most authors clearly support this common sense that statistical or mechanical attempts to separate those three effects do not work (see. Glenn 1976, Held & Riebler 2012, Bell & Jones 2013, Luo 2013).

3.2.2 Descriptive APC Analysis

Repeated cross-sectional data ('pseudo-panel' data) are well-suited for APC analyses. Repeatedly conducted cross-sectional studies are the most suitable type of cohort analysis because they can avoid panel-conditioning effects (Glenn 2005: 5).

Rectangular age-by-period arrays (e.g. see Table 1) can be formulated if all observations from all years are pooled into one database. Table 1 shows the three hypothetical data array structures for illustrating this age-by-time-period relationship.

Table 1: Hypothetical Data Arrayed by Age, Period, and Cohort

Array Type I

APC	Period 1980	Period 1990	Period 2000	Period 2010
Age 60	***Cohort 1920***	Cohort 1930	Cohort 1940	Cohort 1950
Age 70	Cohort 1910	***Cohort 1920***	Cohort 1930	Cohort 1940
Age 80	Cohort 1900	Cohort 1910	***Cohort 1920***	Cohort 1930
Age 90	Cohort 1890	Cohort 1900	Cohort 1910	***Cohort 1920***

Array Type II

CPA	Period 1980	Period 1990	Period 2000	Period 2010
Cohort 1920	***Age 60***	Age 70	Age 80	Age 90
Cohort 1930	Age 50	***Age 60***	Age 70	Age 80
Cohort 1940	Age 40	Age 50	***Age 60***	Age 70
Cohort 1950	Age 30	Age 40	Age 50	***Age 60***

Array Type III

CAP	Age 60	Age 70	Age 80	Age 90
Cohort 1890	Period 1950	Period 1960	Period 1970	***Period 1980***
Cohort 1900	Period 1960	Period 1970	***Period 1980***	Period 1990
Cohort 1910	Period 1970	***Period 1980***	Period 1990	Period 2000
Cohort 1920	***Period 1980***	Period 1990	Period 2000	Period 2010

Source: Own elaboration based on hypothetical data from Yang & Land (2013a: 10)

For the first array type (APC), columns correspond to age-specific observations in each survey year and rows with observations to compare specific ages across years. Diagonal cells link the people of the same birth cohort who age together over time (Yang & Land 2013a: 15). Cohorts can be traced for at least one period reading diagonally down from the left to the right.

The representation method of the second array type (CPA) contains cohort-specific observations for each survey year in the columns and observations of specific birth-age cohorts across survey years in the rows. For this case, diagonal cells link people with the same age together over time and cohorts can be traced for at least one period reading diagonally down from the left to the right.

The third type of array (CAP) shows columns of cohort-specific observations for each of the used years of age. Birth-cohorts are shown across different years of age within each row. Periods of time can be traced for at least one period reading diagonally upwards from the left to the right.

Tables with birth cohort, period, and age of the cohort help for illustration purposes (see: Krakutovski & Armoogum 2007). This form of presentation, or a graphical representation of those tables, is limited to descriptive cohort analyses.

For this project, individual approaches for cohort analysis need to be developed for each Stage 3 city because survey years differ among cities. Methods of cohort analysis are relatively easy to apply. The availability of the age of each individual in HTS is paramount for cohort analysis. The below short methodological introduction should also help to make Stage-3-city partners aware of the importance of providing correct age variables for all survey years.

3.2.3 Birth Cohorts in Travel Behaviour Studies

The next decision to be made is the categorisation into birth cohorts which represent different generations included in the HTS data. Extensive research allowed for the identification of five relevant transport studies of travel-related generational behaviour findings. Table 2 contains a short background description of the studies and the definition of cohorts in each of those studies.

Two studies (Newbold et al. 2005 and Sun et al. 2011) use secondary or content-related criteria, such as life-cycle attributes (status of labour force) or framework conditions (level of motorisation), for classification. Alternatively, three recent studies (Garikapati et al. 2016, Tilley & Housten 2016, and Pickup et al. 2015) apply a more general generational thinking (social generations) based on social changes, shared experiences, developments in societies, mentalities, and cultural circumstances.

Using generational cohorts for analysis purposes enables a closer look into different (travel) behaviour patterns while still being aware that there are as many differences (i.e. perceptions, attitudes, values, norms, and lifestyles) within each generation as between generations (see Taylor & Keeter 2010: 5).

The work of Garikapati et al. (2016) uses four segments and Tilley & Housten (2016) eight. Both are based on the typical concept of generations widely discussed in the literature of many research fields, most especially within the social sciences. Both sources differ in terms of the used birth years and timespans of each cohort as well as in denominations.

Pickup et al. (2015), as part of the European Union’s Horizon 2020 funded MIND-sets research project, work with six groups. Konings & Van Dist (2015) developed the technical background for the MIND-sets generational segmentation, justifying the use of those generations by describing the well-known elements of the generation theory and also by segmenting the generations into 15-years groups. These fixed 15-years intervals have also clear advantages from the A-P-C analysis perspective.

The authors of this report decided to use the segmentation done by Pickup et al. (2015), favouring the clear and comprehensible description of each cohort and the advantage of the fixed 15-year periods for cohort analyses.

Table 2: Cohort Definitions in the Field of Transport

Source				
Newbold et al. (2005)	**Sun et al. (2011)**	**Garikapati et al. (2016)**	**Tilley & Housten (2016)**	**Pickup, et al. (2015)**
Context (study background)				
Travel behaviour of Canadians based on 'life cycle' cohorts (labour force) according to their age at the first cross-section of used data in the year 1986 to follow them over a 13-year period (3 survey years)	Car accessibility and car use in Japan, defined 'automobility' cohorts in their study for analysing a 30-year period (4 survey years, first year 1970)	Activity patterns, time use, and travel in the US, defined 'generational' cohorts using repeated cross-sectional data for analysing an 11-year period starting in 2003 (3 survey years, pooled data 2003–04, 2007–08, and 2012–13)	Daily travel mobility of UK men and women, based on 'generational' cohorts using repeated cross-sectional household travel surveys for a 12-year period (2 survey years, pooled data 1995–97 and 2006–08)	Mobility mind-sets of Europeans based on 'generational cohorts' using
Cohort definition				
Old (65+) [<1921]	Pre-war (Up to 1945)	Silent Generation (born 1928–1945)	Grandparents of the boomers (1906–1915)	Silent generation (76+) *[born until 1939]*
Transitional old (55–64) [1922–1931]	Pre-motorisation (1946–1960)	Baby Boomers (born 1946–1964)	Parents of the boomers (1916–1925)	Master Boomers (or Front-End Boomers, Senior Boomers, Marshall Boomers) (61–75) *[born 1940–1955]*
Old labour force (45–54) [1932–1941]	Initial growth (1961–1970)	Generation X (born 1965–1978)	Great Depression (1926–1935)	Baby Bloomers (or Back-End Baby Boomers, Kennedy Boomers, Junior Boomers, Generation Jones) (46-60) *[born 1955–1970]*

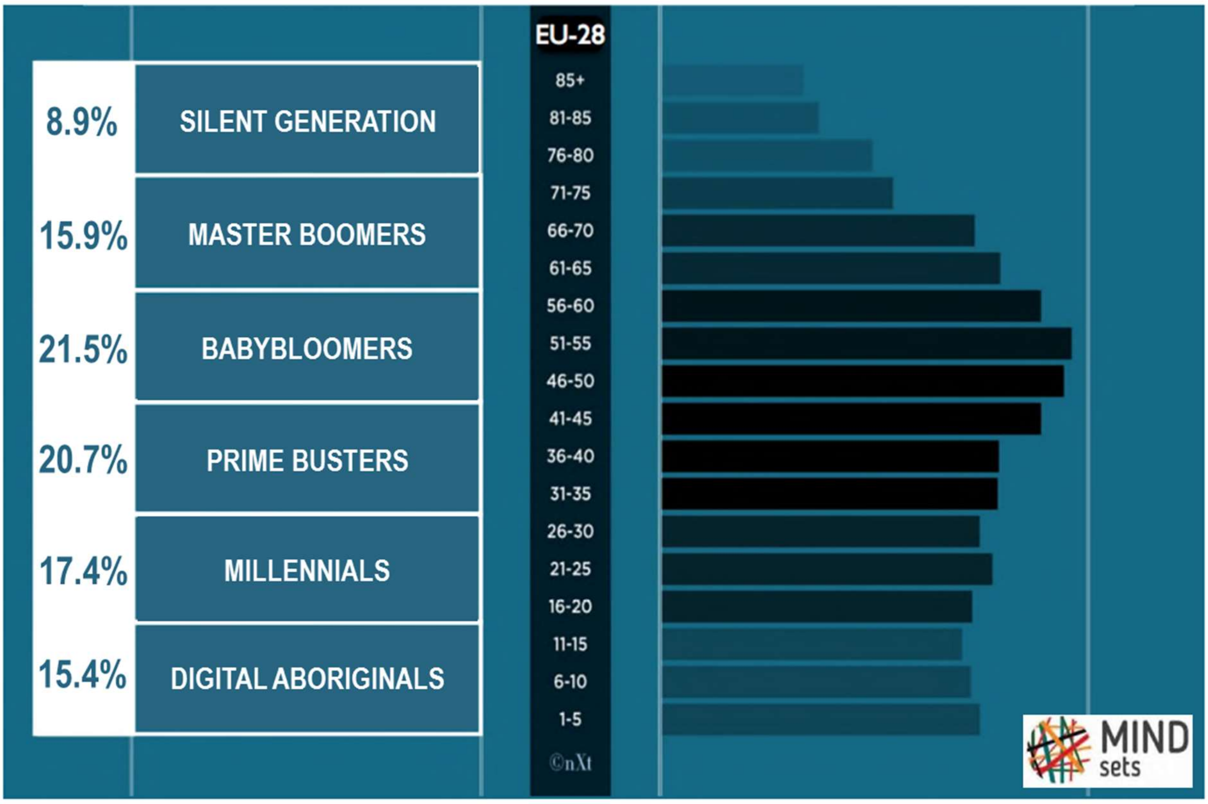
Continued

Mid-labour force (35–44) *[1942–1951]*	Mass-ownership (1971–1980)	Millennials (or Gen Y) (born 1979–2000)	World War II (1936–1945)	Prime Busters (or Generation X, Baby Busters, Generation Nexus, Generation Gap) (31–45) *[born 1970–1984]*
Young family (25–34) *[1952–1961]*	Multi-car ownership (1980–)		Post-War boomers (1946–1955)	Millennials (or Generation Y, Generation D, Digital Natives) (16–30) *[born 1985–1999]*
Young labour force (15–24) *[1962–1971]*[1]			1960s boomers (1956–1965)	Digital Aboriginals (or Generation I, Screenagers, Generation ADHD {Any Devices Head Down}) (until 15) *[born 2000–]*
			Generation X (1966–1975)	
			Generation Y (1976–1985)	
[19XX] own calculation of birth years based on age				

Figure 4 shows the distribution of the MINDsets segmentation across Europe. Nowadays, 80 % of the European Union citizens live in the Western part (see Konings & Van Dist 2015: 15; reference year 2015). The Silent Generation (born before 1939) represents almost 9 % of the inhabitants. Together with most people of the Master Boomers (born 1940–1954, about 16 % of population), this group represents the people who have already reached their age of retirement. Around one in five people belong to the Baby Bloomers (born 1955–1969), who represent the old labour force within the current society. Every fifth person is part of the Prime Busters (born 1970–1984). These people are also often referred to as Generation X; they are between 35–45 years of age and tend toward the family life. Most of the Millennials (born 1985–1999), often also labelled as Generation Y, are of adult age (young adults) and make up about 17 % of the population. People in 2000 or later are the second smallest group within the EU-28 population (about 15 %). Pickup et al. (2015) give a comprehensive and detailed description of the mindsets, attitudes, perceptions, and intentions for each of those person groups. Population shares differ from this overall distribution within our CREATE cities. This also should be considered for the interpretation of the analysis.

[1] In italics: Added by the authors of this report

Figure 4: Distribution of Generations Across the EU-28 European Member Countries



Source: Konings, H. and Van Dist, S. (2015), http://www.mind-sets.eu/

Konings & Van Dist (2015) also introduce very interesting verbal descriptions of typical members within the generations segmented in the MINDset Project. Table 3 summarises these characteristics and draws a comparison among those groups.

Digital Aboriginals are the youngest generation. These people grow up with permanent access to technology. They have a well-developed cognitive intelligence and they do not have too many concerns in terms of privacy. Their lives can also be described as placeless because the permanent availability of an internet connection brings them only one tap away from any service. They are less defined towards gender roles than previous generations.

Millennials are the most contradictory generation compared to all others. They are already highly engaged in technology but they are yearning to run away from it. Millennials show new attitudes towards car ownership and they like to share. Millennials are more highly educated than previous generations and good mentors for their parents and grandparents in technological issues. Millennials are often searching for new experiences and new tracks.

Prime Busters are quite different from the two previously described younger generations. Frequently they highly value local products and services, community and quality. They are relatively time poor and often living as couples or as a family with a double income. This generation is very efficient and pragmatic, and decisive. Prime Busters bridge the analogue and digital generations and are seeking a work-life balance while being less keen to try out new things.

The next generation is called the Baby Bloomers. This generation is very wealthy and quite adventurous. They are shaped by the hypercompetitive business environment of the 1980s. People of this generation are centred around youth, health, and lifestyle. Baby Bloomers are digital immigrants and can quite easily be taken advantage of inside the digital world. They appreciate privacy and real-life contacts.

Master Boomers are the generation with an outstanding well-being. They often have a lot of free time for leisure activities and consumer spending. This group is instinctively rebellious and is characterised by high individualism combined with self-confidence. They like brands, logos, and designs, dictating the entire field of consumer products and technology through their purchase power.

Last but not least is the Silent Generation. These people are specifically focused on their careers with a characteristically high employment rate of men within this period within their life cycle. People of the Silent Generation are rather encouraged to conform to social norms and have a traditional understanding of roles for men and women.

Table 3: Selected Characteristics for MINDSet Generations

Digital Aboriginals	Millennials	Prime Busters	Baby Bloomers	Master Boomers	Silent Generation
2000–	1985–1999	1970–1984	1955–1969	1940–1954	Until 1939
Gen I Screenagers ADHD	Gen Y Digital Natives	Gen X Baby Busters	Back-End Boomers	Front-End Boomers	
Technology permanently accessible Accelerated development of cognitive intelligence Transpa-rency and sharing of private life Placeless being Any service just a tap away Less defined gender roles	Most contradictory generation: Highly engaged in technology but most yearn to run away from it New attitudes towards car ownership Prone to sharing Well-educated/ experienced Good mentors for older generation Always in search of new experiences	Value local products and services, community, quality Relatively time poor, double income families with children Efficient, pragmatic, decisive Bridging the analogue and digital generations Search for work-life balance Less keen to try out new things	Wealthy and adventurous generation Shaped by a hyper-competitive business environment in the 1980s Centered around youth, health, and lifestyle “die young but as late as possible” Digital immigrants Vulnerable online Value privacy and real-life contact	Wealth of free time, dedicated to spending money Instinctively rebellious, high indivi-dualism, self-confidence Victims of symbolic consumption (brands, logos, designs, lifestyles) Dictate entire fields of consumer products and technology through their buying power	At its time focused on their careers rather than activism High employment rate of men Encouraged to conform to social norms Traditional understand-ding of roles for men & women

Source: adapted from Konings & Van Dist (2015) and amended

3.3 Description of the Case-Study Cities

The city-specific analysis was completed for the five Stage 3 cities for the D3.2-reports (Roider et al. 2016) which revealed valuable insights into and similarities among the cities. However, differences also exist, and it became clear that area-type definitions are very important for successfully running the cross-city comparison. The definition of the spatial level of analysis was guided by two hypotheses:

- Travel behaviour in the cities can only be understood in the regional context. It is not sufficient to investigate the city alone.
- Travel behaviour differs within the cities as a result of differences in spatial structures/densities, transport supply as well as transport users' characteristics.

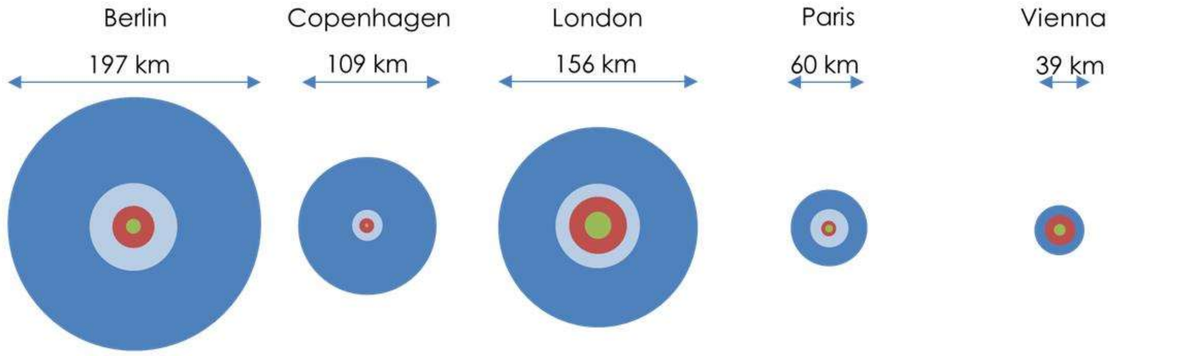
The following administrative area types are distinguished for the analysis whenever possible in order to acknowledge these spatial dependencies of travel behaviour:

- Inner-City: City center, Central Business District (CBD)
- Outer-City: City area beyond Inner-City but within the municipal borders
- Peri-Urban I: Area bordering the city (e.g. closest ring of municipalities) with high population density, a high density of workplaces, and a high number of commuters to and from the Inner-City and the Outer-City
- (Optional) Peri-Urban II (and further): Wider commuting catchment area

These administrative area types were the baseline for city-specific analyses (Roider et al. 2016). Many different data sources were collected by the Stage-3-city partners. For most of those data sources, the administrative borders were a specific selection and aggregation criterion. Administrative area types were built and defined individually by Stage-3-city partners based on densities, commuting pattern, and the availability of public statistics.

Figure 5 gives an overview of the study areas along the four administrative area types. Figure 5 and Figure 6 show that the study areas differ substantially in size in terms of square kilometres but also in population. In addition, substantial differences exist in the relative sizes of the administrative area types. For example, there are the two strongly populated, solitary cities Berlin and Vienna which have rather population-weak surrounding regions; Paris is rather small as a city but has a very strongly populated surrounding region; and Copenhagen and London both have a rather balanced proportion between the city and the surrounding areas but with different absolute sizes. Figure 6 gives further insight into the overall differences in population across city by building sums. London is by far the largest agglomeration with nearly 20 million inhabitants. The Inner-City of London has more inhabitants than the whole metropolitan area of Copenhagen including all Peri-Urban areas. The agglomeration of Paris is the second largest among the five Stage 3 cities with almost 11 million inhabitants. Most of them live outside but close to the administrative boarder of the city of Paris. The city of Berlin has almost the same number of inhabitants as the London Inner-City. Berlin is the third largest metropolitan area in this comparison with fewer inhabitants living in the Peri-Urban area than in the city of Berlin itself. Vienna and Copenhagen are the smallest of the five Stage 3 cities and are in addition different from each other. In Copenhagen, approx. 0.7 million citizens are located within the city, but almost two million people live in the Peri-Urban area. In Vienna, this ratio is reversed. Fewer than Inner-City half a million people are considered Peri-Urban inhabitants and almost two million citizens live in the city itself. Furthermore, and specifically for the HTS-data analysis, so-called functional area types were introduced in addition to the above-described administrative area types in order to acknowledge the importance of not only the administrative borders, but also of the spatial structures for travel behaviour. Comparability of the HTS should be improved if one succeeds in defining area types with similar spatial conditions shaping travel behaviour. These functional area types are introduced in Section 4.3.2.

Figure 5: Overview of the Study Areas (Population per Area)



1.05 Million	0.052 Million	3.40 Million	0.45 Million	0.50 Million
2.42 Million	0.63 Million	5.14 Million	1.78 Million	1.27 Million
0.93 Million	0.59 Million	5,47 Million	4.43 Million	N/A
1.53 Million	1.27 Million	5.79 Million	3.93 Million	0.27 Million

XX km (theoretical) diameter

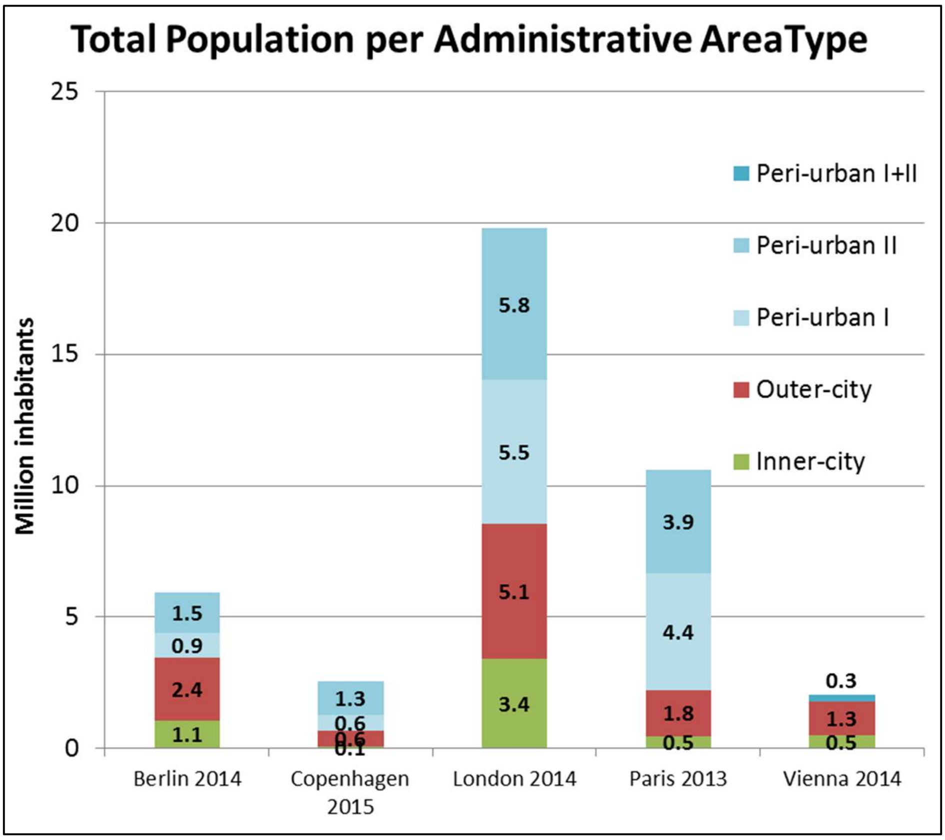
Inner-city

Outer-city

Peri-urban I

Peri-urban (II)

Figure 6: Total Population per Area Type (Cumulated)



4 Data Collection and Processing

4.1 Data Sources for Cross-City Comparisons

Stage-3-city partners provided quantitative information about the city-specific analysis of travel in their technical D3.2-reports (Roider et al. 2016). These reports include many indicators agreed on at an earlier stage of the CREATE project for explaining the “peak car” phenomenon and possible causes (drivers and barriers). Those indicators are based on the analysis scheme provided in D3.1, which attempted to ensure the generation of comparable figures and charts over time for all Stage 3 cities.

Table 4 contains the data sources and types of information provided in those city-specific reports. The cities used many official and semi-official city-specific data sources and statistics for providing information about framework conditions, transport supply side, quantifiable information for transport policies, and access to transport modes.

HTSs were used for describing individual travel patterns and travel demand within each city. Both independent streams will be used for the task of cross-city comparisons. Whereas information from city-specific data sources and statistics can only be extracted from D3.2 reports (Roider et al. 2016), information about travel patterns and travel demand are additionally available by analysing HTS microdata when ex-post survey harmonisation has been carried out successfully.

Both HTS data collection and processing were very ambitious tasks within the CREATE project. Therefore, the following Sections describe the methodological background of the project stages. First, the approach of ex-post survey harmonisation is explained. Second, the sensitivity of survey results regarding the impacts of methodological differences is discussed. Third, specific areas of ex-post harmonisation activities are summarised.

Table 4: Data Sources for Cross-City Comparison

City-specific data sources and statistics	**Household Travel Surveys (HTS)**
Information provided by these methods	
• Framework conditions • Transport supply side • Transport policies (quantifiable) • Access to transport modes	• Individual travel patterns and travel demands

Source: Own elaboration

4.2 Methodological Background of HTS Data Collection and Processing

4.2.1 Approach of Ex-Post Survey Harmonisation

HTSs have been conducted for more than 40 years all over the world. Big amounts of data exist, but often only pieces are used for research and policymaking. Time series for specific spatial areas rarely go beyond the modal split. Cross-area comparisons are mainly done for one point in time. Two main reasons exist for this limited use of the existing data. First, amalgamating data over time and across study areas is burdensome, and, second, it is not clear whether meaningful results can be achieved due to differences in the survey characteristics. Survey methods are shaped by local survey traditions and have been constantly adapted to changes in framework conditions (such as the availability of telephone numbers) and emerging survey technologies (such as computer-assisted techniques).

The literature consistently shows that survey methods matter. Different survey methodologies generate differences in the proportions of mobile persons, in the number of trips per person per day (trip rates), and in the specific trip characteristics. Madre, Axhausen, and Brög (2007; see also Armoogum 2014) find a high variance in the shares of immobile persons (persons without any trip on their reporting day) between different HTSs. An important reason for these variances is the deliberate (soft) refusal of the respondents to report any trip in order to reduce their response burden. In addition to the survey method, the quality of the field work and the survey protocol both contribute to these variances. The underreporting of trips has been analysed in the literature based on comparisons of different HTSs, or of HTSs and other survey types such as time-use surveys.

The results consistently show that mainly short and irregular trips are underreported in HTSs, resulting in higher differences in trip rates for discretionary (leisure) trips as compared to subsistence (work, education) and non-discretionary (e.g. shopping, errands) trips (Aschauer et al. 2018, Bose & Sharp 2005, Gerike et al. 2015, Richardson 2007). Daily travel times and distances are more consistent in the literature across survey methods; underreporting seems to be mainly an issue of trip rates and trip characteristics (Armoogum 2014, Hubert et al. 2008, Schüssler 2010).

The authors know that travel indicators depend on the survey method, as well as on the quality of field work, but have incomplete information about these characteristics for historical HTSs. Survey methods of the historic HTSs can neither retrospectively be harmonised, nor can missing information be imputed based on the limited available metadata for these surveys. Ex-post data harmonisation based on this limited metadata information is nevertheless necessary for any retrospective analysis of travel behaviour and its determinants.

To the authors' best knowledge, only a few studies exist in the field of HTS data harmonisation (Armoogum 2014/Christensen et al. 2014a, Kompil et al. 2013, Scheiner 2010). All these efforts have the same goal: They seek to improve the comparability of travel data between different data sources. Kompil et al. (2013) give a short overview and review about international projects and initiatives dealing with travel survey design, data harmonisation, and gathering at the European level since the 1990s.

Two different approaches of survey harmonisation exist (Christensen et al. 2014a: 2):

1. Ex-ante harmonisation of survey designs and measurement rules in advance of data collection
2. Ex-post harmonisation of survey microdata subsequent to the actual data collection

Defining the survey standards prior to conducting the HTSs is obviously the more promising and superior approach. However, various survey harmonisation rules can also be applied years after the surveys are carried out. All data harmonisation steps are based on a comprehensive knowledge about methodical survey details which is the starting point for correct implementation.

For this reason, collecting metadata information for all surveys and survey years is paramount for data harmonisation. Christensen et al. (2014a: 2) point out that ex-post harmonisation is a more pragmatic approach, but it recognises a big disadvantage of ex-ante harmonisation: Existing data from previous surveys cannot be included.

One major study was carried out that explicitly aims at ex-post harmonising national HTSs for various European countries. Partners of the COST Action “Survey Harmonisation with New Technologies Improvement” (SHANTI, see Armoogum 2014, Christensen et al. 2014a) implemented a set of steps for data harmonisation for each of their most recent individual national HTSs and delivered key travel indicators afterwards.

This work builds on the insights gained in SHANTI. The goal of the work within the CREATE project is to advance the methods for ex-post HTS data harmonisation by including additional harmonisation steps; harmonising data over time and across study areas; pooling the harmonised datasets into one common database; and by reporting additional indicators in the comparative analysis such as the proportion of trips back home and the number of home-based tours per person per day (sequence of trips beginning and ending at home, also called trip chains). The harmonisation method to be developed in this report should be applicable for HTSs of all types including paper-and-pencil questionnaires (PAPI), telephone interviews (CATI), web-based questionnaires (CAWI), personal interviews, and mixed-method approaches (Armoogum 2014).

Different from SHANTI, this contribution works not on the national level but for five European agglomerations: Berlin, Copenhagen, London, Paris, and Vienna. This scope reduces spatial heterogeneity and allows for the definition of comparable area types as one step of data harmonisation.

4.2.2 HTS Metadata for Stage 3 Cities

Metadata for the available survey years were collected for all five Stage 3 cities by TUD in September 2015. These metadata show differences and similarities in the methods for data collection between the cities and the survey years. Comprehensive and valid metadata is the prerequisite for correctly processing, analysing, and interpreting the HTS. In addition to the information concerning the organisational frame, general data availability and accessibility, the following metadata should be correctly and comprehensively provided by Stage-3-city partners:

- Survey frame and survey coverage
- Sample design and recruitment
- Survey methodology and data processing
- Definitions, particularly trip characteristics.

Table 5 to Table 8 show all metadata that was used for the necessary data harmonisation.

Table 5: Survey Frame and Survey Coverage

Content	Berlin	Copenhagen	London	Paris	Vienna
Temporal Coverage of Harmonised HTS Microdata	1998, 2002, 2008, 2013	annual cycle from 1998 2015	annual cycle from 2005–2014	1976, 1983, 1991, 2001, 2010	1993,1996, annual cycle from 1998–2014
Population	all people from 0 years of age	people from 10–84 years of age	trips are recorded for people aged 5 and over	from 6 years of age (2010: from 5 years of age)	all people from 0 years of age
Reporting Period (Travel)	single day	single day	single day	Two days, both weekday and weekend	single day
Reporting Day	predefined	variable	predefined	negotiated	predefined
Covered Days of the Week	1998, 2002: all weekdays 2008, 2013: workdays Tue until Thu	all weekdays	all weekdays	all weekdays (only workdays harmonised)	all weekdays
Holidays and Bank Holidays	excluded	included	included	excluded	excluded
Seasonal Covered	1998: spring others: all seasons (whole year)	all seasons (whole year)	all seasons (whole year)	all seasons (whole year)	until 1998: spring or autumn from 1998: all seasons (whole year)

Table 6: Sample Design and Recruitment

Content	Berlin	Copenhagen	London	Paris	Vienna
Type of Study	repeated cross-sectional	repeated cross-sectional	repeated cross-sectional	repeated cross-sectional	repeated cross-sectional
Survey Unit *(Reporting Unit)*	household *(all household members)*	individual *(single-person)*	household *(all household members)*	household (N/A)	household *(all household members)*
Sampling Stages	one stage (2002: two stages)	one stage	multistage (three stages)	N/A	one stage
Stratification	yes (area)	yes (Gender, age, area)	yes (area)	yes (area)	yes (area)
Clustering	yes, households	no	yes, sample control areas, household	yes, household	yes, households
Sampling Sources	register of residents	Danish civil registry (CPR)	postcode address file (PAF)	national census	until 2009: random route from 2010: register of residents
Recruitment Procedure	announce-ment letter	announce-ment letter	announce-ment letter	phone call for appointment	announce-ment letter
Overall Response Rates	1998: N/A 2002: ~40% 2008: 23% 2013: 19%	~60%	~50%	>50%	1993–2009: ~80% 2010–2014: 10–27%

Table 7: Survey Methodology and Data Processing

Content	Berlin	Copenhagen	London	Paris	Vienna
Mode of Data Collection	1998: phone 2002: mail-back/phone 2008: mail-back, phone, online 2013: phone/ online	phone/online	in-home, face-to-face	face-to-face	until 2009: mailback/ phone, face-to-face occasionally, from 2010: phone
Incentive	no	no	yes (voucher)	N/A	no
Imputation	no	yes, if values have been proven incorrect	yes, only age, sex and household income	no	no
Weighting Method	1998: N/A other years: transforma-tion, IPF-Weighting (raking)	IPF-Weighting (raking)	N/A	N/A	IPF-Weighting (raking)
Correction of Non-Response Effects	no (but from 2002 onwards checked by NRS-studies)	no	N/A	N/A	until 2009: yes from 2010: no
Geocoding (OD)	yes	yes	yes	yes	until 2009: no from 2010: yes

Table 8: Trip Characteristics

Content	Berlin	Copenhagen	London	Paris	Vienna
Travel Diary Approach	yes	yes	yes	yes	yes
Purpose-Orientated Trip Definition	yes	yes	yes	yes	yes
“Back to Home” Trips Coded	Yes	yes (but not in included in purposes)	yes (but not in included in purposes)	yes	yes
Information About Stages of Trips	1998, 2002: no 2008, 2013: partly	yes	yes	yes	no
Determination of Main Mode Trip	hierarchy of transport modes	hierarchy of transport modes	distance based main mode	hierarchy of transport modes	hierarchy of transport modes
Treatment of Short Distance Trips	included	N/A	N/A	N/A	included
Treatment of Long Distance Trips	≥ 100 km are excluded for calculation of distance, duration, and transport volume	all trips included	N/A	N/A	until 2009: ≥ 100 km are excluded for calculation of distance, duration, and transport volume, from 2010: distance only computed for Inner-City trips
Outbound Trips	yes	yes	yes	yes	yes

A brief comparison of HTS main characteristics is given in Table 9. Fortunately, many important survey characteristics are quite similar across survey years and cities. All HTSs are register-based, repeated cross-sectional studies that use travel diaries for collecting the information about travel estimates and their determinants. All time-series date back at least 20 years and cover the peak-car period well.

Further similarities exist in terms of the seasonal coverage of data and register-based sampling sources. Trip information is also similarly captured. Generally, all surveys used a trip diary approach or were able to provide trip diary data. The understanding of what is a trip and the determination of main transport modes is basically similar. London was able to provide additional variables for main travel modes, applying the determination rule of the other cities. Origin and destination of trips are geocoded for many, in particular recent, survey years.

Differences exist within the individual cities over time as well as between the cities (e.g. in the mode of data collection, in the included population, in the covered days of the week, and in whether data is collected for trips or stages). Consistent HTS data at the regional level only exist for Copenhagen and Paris. HTSs in Berlin, London, and Vienna only cover city residents. In the CREATE-project, further data sources are used for analysing travel behaviour on the regional level for these cities (Roider et al. 2016). For the analyses within WP3, only the city-wide HTS are used for these three cities as microdata was only available on the city level. Other differences had been detected in terms of methodological issues such as the mode of data collection, the survey frame and coverage, some technical matters in the treatment of long distance trips, and coding of back to home trips. However, metadata collection revealed that ex-post data harmonisation might be handled successfully.

Table 9: Comparison of HTS Main Characteristics in Stage 3 Cities

Similarities	**Differences**
Repeated cross-sectional studies	Included population (in particular age)
Seasonal coverage (whole year)	Mode of data collection
Register-based sampling sources	Covered days of the week
Trip diary approach	Treatment of long distance trips
Trip definition	Coding back to home trips
Determination of main transport modes (except for London)	Spatial coverage
OD geocoding	

4.2.3 Sensitivity of Survey Results

Christensen et al. (2014a: 4) categorise survey-design components with an impact on survey results into three groups. This categorisation may help for identifying tangible opportunities of ex-post data harmonisation. The following Section will briefly discuss the impact of these groups on survey results.

Impact of Survey Coverage

Differences in survey coverage mainly exist in the coverage of the population (e.g. exclusion of specific age or other sociodemographic groups), of time periods (e.g. field work periods of one whole year versus specific seasons, all days of the week versus workdays, including or excluding bank holidays and school holidays), and of certain types of trips (e.g. definition of minimum trip length, exclusion of frequent commercial trips or cross-border travel).

Survey coverage is typically understood as the way of including all parts of the target population into the sample. The applied sampling procedure and sampling frame have to evaluate whether the target population corresponds across different surveys. The most sensitive restriction is the coverage of age groups where lower and upper age limits differ. Travel behaviour differs substantially within the life cycle of people. Age is a good indicator for describing life stages.

In addition to coverage of age groups, the survey period (survey year), the seasonal coverage (entire year or only parts of the year), and the coverage of different days of the week impact survey results. As an example, travel behaviour is different in spring compared to winter time (e.g. cycling conditions); travel behaviour on the weekends, bank holidays, or other school holidays differs clearly from travel patterns on workdays.

The third important field of survey coverage is the inclusion of specific types of trips. The awareness of survey practises, in terms of excluding short walking trips and/or long-distance trips as well as cross-border travel, is important to avoid comparability issues for typical values of travel indicators.

Christensen et al. (2014a: 6) point out, that differences in coverage (if known) are fairly easy to handle. The approach is simply to find the lowest common denominator. Sample sizes are reduced by this approach, which can lead to losses in statistical precision and problems with the validity of survey weights. Possible side-effects are not considered by this harmonisation approach when, for example, respondents omit trips because they are unsure whether or not these fall into the survey definitions of trip distances to be reported. Consequently, it is always necessary to balance the pros and cons of harmonising survey coverage, including the loss of statistical precision (reducing sample sizes) and problems with the validity of already implemented survey weights

Impact of Survey Definitions

Survey definitions refer to the type of information asked for and to the requested level of detail. Definitions can differ with regard to the understanding of a trip as a whole, to the classification of travel modes including the definition of main modes, to the assignment of trip purposes, or to the spatial categories (e.g. rural versus urban). As with the survey coverage, data harmonisation needs to find the lowest common denominator for the survey definitions. This is relatively straightforward for some survey definitions, such as the travel modes. At least in the European context, there is a well-established and accepted common understanding of basic travel modes such as the car, public transport, the bicycle, and walking. Substantial differences exist in the definition of trip purposes and in the understanding of specific trip purposes. For example, the perception of what is a leisure trip might differ between different areas as well as across time periods. Data harmonisation has to be done with much care for such cases. As for survey coverage, a compromise between the aim of maximising the level of detail and of the necessity of exactly-matched definitions should be found.

In such cases, definitions and survey attributes should be carefully compared as long as the sensitivity of the survey results can only be partly evaluated. Christensen (2014: 6) assessed the situation that differences across surveys (if known) are relatively exposed to threat by post-harmonisation.

Impact of Survey Methodology

The concept of survey methodology comprises various aspects of the means of communication and interaction with respondents. A wider understanding also includes the way in which information is generated (e.g., methods for estimating or computing travel distances). The impact of survey methodology on respondent selectivity, response rates, non-response pattern, and travel indicators has been clearly demonstrated in the literature (Armoogum 2014, Chlond et al. 2015). However, survey methodology, field work procedures, and field work quality are very complex and are not fully detailed, specifically for historic HTS. Christensen et al. (2014) suggest the following two steps for ex-post harmonising survey methodology:

- To refer all analyses only to tripmakers: The proportion of mobile persons varies greatly between different HTSs with substantial impacts on travel indicators when these are computed on a per-capita basis (Madre, Axhausen and Brög 2007, Gerike et al. 2013). These differences might be caused both by survey methodology and actual differences in travel behaviour. The exclusion of respondents without any trip on the reporting day from the analysis and the inclusion of only mobile persons allows for the separation of the two aspects of travel behaviour: (1) whether or not a person leaves home on the reporting day, and reports at least one trip, and (2), how many trips with which characteristics a person has on their reporting day given that the person has at least one trip on this day. This approach eliminates the impact of survey methodology on the proportion of immobile persons from the analysis of the travel indicators and, thus, substantially improves comparability. Impacts of the survey methodology on the mobile persons' travel behaviour, such as selectivity and non-response issues, remain and need to be considered in the interpretation of the results.
- To apply provided weights: Weighting procedures are established for correcting selectivity issues and, in some cases, non-reporting issues, if these factors can be quantified. HTS weighting procedures mainly correct for socio-economic selectivity including variables such as age, gender, household size, and car ownership. Christensen et al. (2014a) recommend using the weights that have been provided with the microdata. Weighted data should be used for the analysis of the ex-post harmonised data instead of unweighted data regardless of differences in the weighting schemes. Most HTS surveys aim at producing representative figures for the travel indicators and develop their weighting procedures accordingly. Alternatively, new weighting schemes can be developed that correct biases uniformly for all considered HTSs. Considering the complexity of the issue and the difficulty of obtaining the historic-population data needed for implementing the weighting scheme, it is, however, unlikely that such a new and uniform scheme performs better compared to applying the original weights delivered with the individual HTS.

The steps for data harmonisation that Christensen et al. (2014a) recommend based on the above described categorisation of survey design components have been applied in other studies with only few differences (Kompil et al. 2013, Scheiner 2010, Sicks 2014). Scheiner (2010) completed the data harmonisation for the German national HTSs from the 1976 to 2002 using similar steps as described above, but the author did not succeed in producing comparable travel indicators. Differences, mainly in survey methodology, are found to be too substantial. Selectivity issues, for example, lead to too-low proportions of employed persons and consequently also of work trips in some survey years. Trips back home, and short trips that are embedded in more complex tours, are strongly underreported in other survey years. To deal with these problems, Scheiner (2010, see Sicks 2014 for a similar approach) uses modified travel indicators in addition to data harmonisation. The author does not report the frequency of trips but only whether or not a person has a trip (e.g. with a specific mode or purpose). The metric variable “number of work trips on the reporting day” is, for example, reduced for a specific person to the nominal variable: “at least one work trip on the reporting day yes/no”. Scheiner (2010) additionally recommends doing the analysis on the level of tours, rather than on the level of trips, if actual frequencies of travel activities should be compared. Analyses on tour level are more robust with respect to non-reporting of short or irregular trips. Main modes (and purposes) can be assigned to tours similar to trips. Scheiner (2010) also suggests the proportion of trips back home as one HTS quality indicator as he finds in his HTS many persons with trip diaries not ending at home in the evening, and many home-based trips to out-of-home destinations without a proper trip back home.

Kloas & Kunert (1993) set the respondent’s overall trip number to 100 percent and report proportions, such as trips with specific transport modes or purposes instead of absolute trip numbers. The goal of this standardisation is to account for differences in the absolute number of trips between the different survey years, but this approach only works when underreporting occurs evenly for all analysed trip characteristics.

Survey methodology is often put on a level with the mode of data collection (CATI, CAPI, CAWI, PAPI). A wider understanding also includes the manner in which information is generated (e.g. estimation of travel distance information). It is obvious that the means of data collection directly affect the willingness of the participants. Survey selectivity can occur as a result of unit or item nonresponse. The quality and precision of answers can be affected by the survey mode.

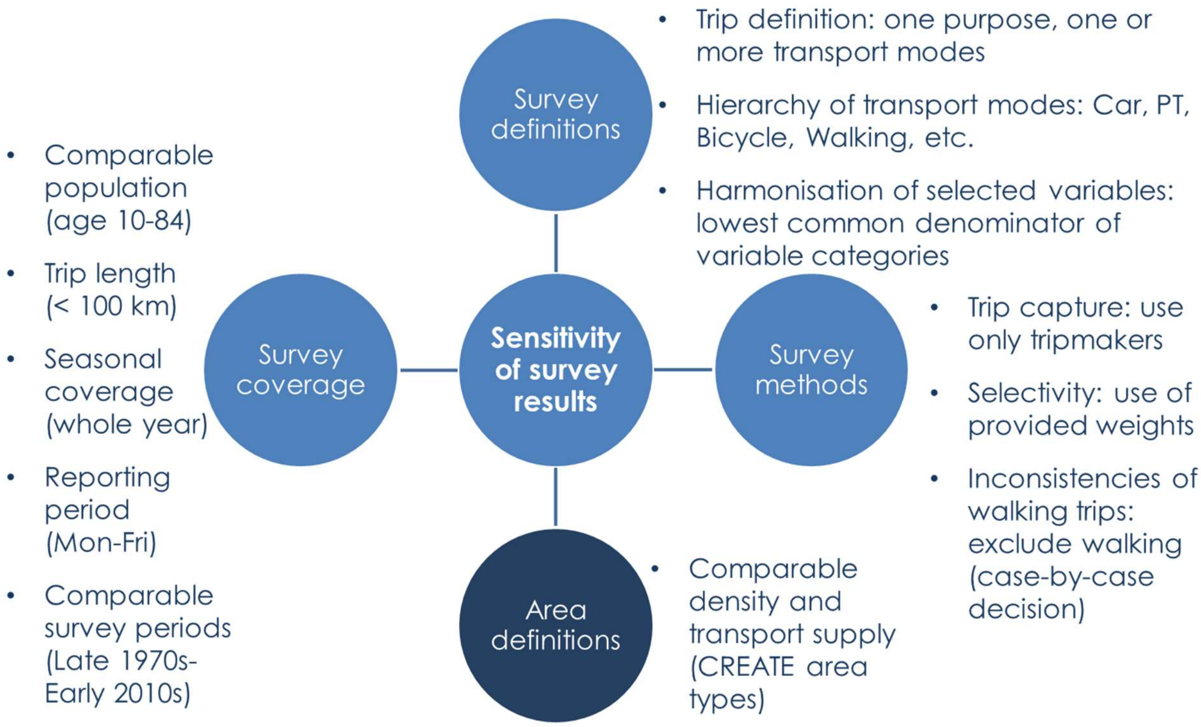
Armoogum (2014: 78) emphasizes that ex-post harmonisation of data collection methodologies is impossible. However, survey methodology often clearly influences the share of tripmakers—Christensen et al. (2014a) show this evidence using various examples. The wider impact of survey results is proven but can hardly be quantified: The approach of the least common denominator cannot be applied. Nevertheless, data should be compared and interpreted carefully as soon as differences in survey methodology arise.

Finally, Figure 7 gives an overview of the specific areas for the proposed ex-post data harmonisation method. Following the literature and especially the insights gained from the COST Action SHANTI (Armoogum 2014, Christensen et al. 2014a, b), the harmonisation includes the areas of survey coverage, survey definitions, and survey methods. The spatial harmonisation based on densities of residents and temporal harmonisation based on the definition of comparable survey periods are introduced as additional harmonisation steps. These might prove effective and substantially improve consistency between the different surveys.

Data harmonisation typically leads to losses in sample sizes and in statistical precision, there will be no universally valid solution for this problem. The balance between data loss on the one hand and improved consistency between the surveys on the other hand, resulting from data harmonisation, needs to be found anew for each harmonisation effort.

Local expertise was fed into the harmonisation process by getting the local city partners involved; the coordination by TUD was important for establishing and implementing standards for the harmonisation. The coordinator needs to provide the analysis scheme (Wittwer & Gerike 2015) and template for the code plan to the partners as the basis for work to be done by individual city partners. The continuous contact between the coordinator and each city partner is paramount for successful harmonisation.

Figure 7: Specific Areas for Ex-Post Data Harmonisation



Source: Content adapted from Christensen et al. 2014a, and Armoogum 2014.

4.3 HTS Data Processing and Harmonisation

Figure 8 shows the tasks for the HTS data processing. The primary aim of this data processing was to create and finally upload city-specific databases which are consistent across years within each Stage 3 city as well as across those cities. These databases were also the basis for the city-specific analyses in the D3.2 reports (Roider et al. 2016). Subsequent, cross-city comparisons are carried out in this report. TUD ex-post harmonised the processed city-specific databases across cities and merged them into a pooled database.

The concept for data harmonisation was developed based on the insights gained from the literature review. Figure 8 shows the ten actions that were undertaken for data harmonisation, and that finally allow for cross-city analysis over time, based on the one harmonised and pooled database. Steps 1 to 8 were completed by the individual Stage-3-city partners within the CREATE project. Partners were provided with a detailed guideline prepared by the Technische Universität Dresden (TUD) (Wittwer & Gerike 2015). In addition to providing the guideline, TUD was in continuous contact with the individual city-partners so that problems could be directly solved without major obstructions and delays in the data harmonisation process in a collaborative effort.

Data processing guidelines were provided for the Stage-3-city partners by TUD in October 2015 (Wittwer & Gerike 2015). These guidelines contain a detailed concept for creating consistent HTS datasets across survey years and cities. The creation of consistent HTS datasets was needed to reinforce the necessity of strict data processing steps to achieve the established goals. Therefore, Stage-3-city partners were asked to use this concept to collate micro-datasets, to harmonise the data, and to prepare a uniform data file for all available HTS years within CREATE.

Enormous potentials can be exploited by applying a wide-range harmonisation method and pooling HTS data into one database. This allows more in-depth analyses with time-series data for a better understanding of developments in travel behaviour and of its determinants, not only over time but also across study areas. Those new insights enable reasonable transport policymaking to shape the future of transport systems in urban areas.

4.3.1 General Approach

Metadata (Step 1) was compiled, serving two purposes:

- Partners got an overview of the actual available microdata.
- The provided metadata are a vital input for data harmonisation and for interpreting the travel estimates computed in the cross-city analysis.

The collected metadata include information about the survey coverage and methodology, the sample design and recruitment, as well as details about the trip definitions. The metadata for all included HTSs are listed above in Section 4.2.2. Micro-datasets were collated in Step 2. This step involved non-disclosure agreements in some cities as well as modifications of database formats for some earlier HTSs. All HTS datasets for all years were readily available for data harmonisation as a result of Step 2.

The individual HTS datasets were harmonised in Step 3 based on coding instructions and a code plan provided by TUD (Wittwer & Gerike 2015). Unique identifiers were created on the levels of years, households, persons, tours, and trips using one common classification scheme. The coding scheme prepared by TUD defined the variables that should be provided and harmonised including variable names and characteristics. Only for selected categorical variables such as the trip purpose or transport mode, were levels pre-defined by TUD. For all other categorical variables, TUD provided only exemplary levels in the code plan template because city-partners needed to find the lowest common denominator of categories for their cities individually.

This detailed coding scheme proved to be a vital prerequisite for the successful data harmonisation as it ensured that core variables were harmonised in the same way for all years within a city and, finally, across all cities as well. Partners were invited to harmonise further variables, going beyond the coding scheme. Almost all partners had difficulties and met challenges with changes in variable definitions in their HTSs over the years (e.g.- modifications to the categories for trip purposes or employment status), mostly toward more detailed categories in recent years. These problems were discussed on a case-by-case basis with TUD in order to find a compromise between information loss (if the more recent richer information is reduced to the fewer categories of the former years) and consistency over the years.

In some cases, two variables with the same contents, e.g. the employment status, were generated for the harmonised datasets: One variable with a reduced set of categories that exists consistently for all years, and one with a more detailed set of categories that exists only for some years. Data harmonisation was done on a trip level as data on the level of stages was only collected for some HTSs. This part of data harmonisation was the most challenging part of all the data processing tasks. Inconsistent variables across survey years were harmonised whenever possible in terms of variable names, definitions, formats, ranges, scales, and categories.

After harmonisation, survey years were merged in Step 4 of the data harmonisation process shown in Figure 8 into one city-specific database. This step was straightforward and not burdensome since Step 3 had been completed properly. Step 4 was also a quality check since inconsistencies in variable names and characteristics occurred as error messages when data was merged. As a result, one common database per city should be available.

This common database was cleaned in Step 5. Partners checked for coding errors such as the validity of values, labels, categories, and scales. Missing values were coded with a standard coding scheme including a clear indication when values in specific variables have been imputed. Finally, the main travel mode and the trip purpose were recoded based on the coding scheme provided by TUD. A common hierarchy of transport modes was applied for determining the main transport mode for each trip. The following trip purposes were used for data harmonisation:

- Working/Education/Work-related/Business/Nursery
- Shopping and Errands, Drop-off/Pick-up
- Leisure
- Back home

"Back home trips" were treated as an own-purpose as well as a geographical information "end point of trip". This allowed TUD to compute the number and proportion of "back home trips" as one quality indicator in the cross-city analysis, and to assign the "back home trips" the purpose of the preceding trip (for cross-city trips per purpose) without the purpose "back home".

Data consistency checks followed in Step 6 based on instructions provided by TUD (Wittwer & Gerike 2015). Partners checked for implausible outliers (e.g. negative values for age), for consistency within one data level (e.g. persons ages below 18 years but having a driving licence) and between data levels (e.g. persons without a driving license or persons aged below 18 years reporting car driver trips, or an implausibly high speed of walking trips).

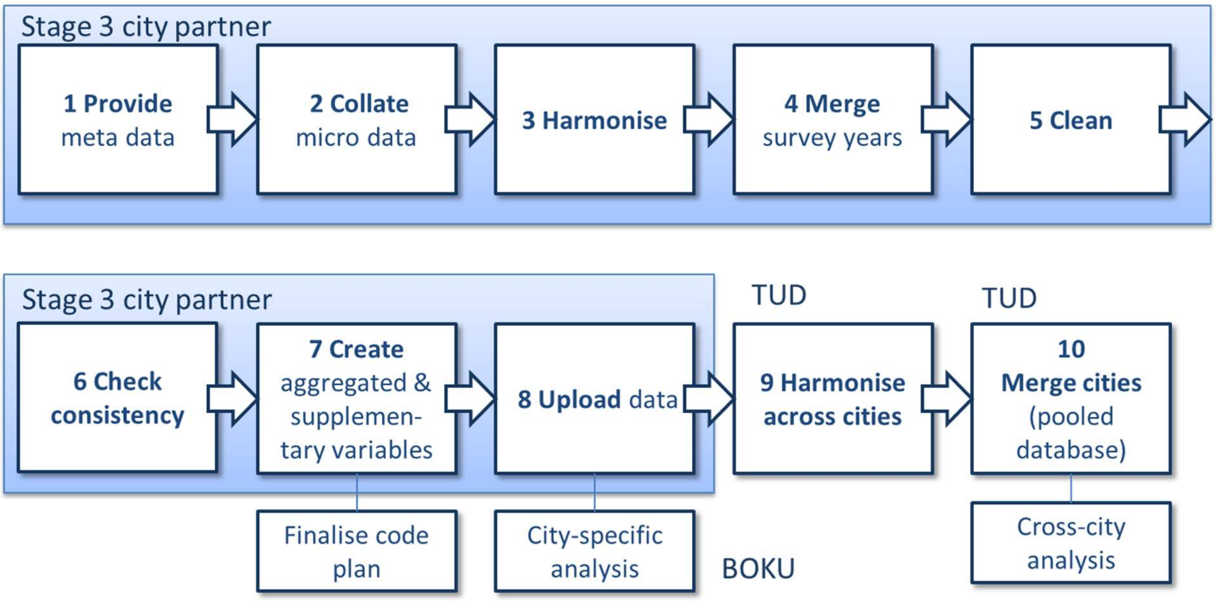
Data consistency checks were needed to ensure data quality and comparability across survey years. Many checks were indeed performed during the initial data collection process in the respective survey year. Nevertheless, additional consistency checks were proposed for outliers and possible ranges of values. These checks were carried out autonomously by Stage-3-city partners. It was not possible to systematically check the success of the application of rules provided by TUD.

New aggregated variables for key travel estimates on the trip level (e.g. main transport mode), and on the person level such as the number of trips per person per day as well as supplementary variables were computed in Step 7, again based on the code plan provided by TUD (Wittwer & Gerike 2015). Afterwards, partners finalised their individual code plan for all three data levels: household, person, and trip. This code plan was based on the one provided by TUD but included all individual particularities, such as additional variables going beyond the code plan provided originally by TUD.

Data were uploaded (Step 8) by the partners to a secure TUD data storage server once Step 7 had been completed. TUD extensively checked the uploaded databases in Step 9 with several feedback loops to the individual city partners. In addition, levels for selected categorical variables were harmonised. These were the variables that have been delivered by all cities, that had no pre-defined levels in the code plan template, and that were deemed relevant for better understanding the peak-car effect.

For more than a year, Stage-3-city partners were carefully collating and processing HTS data for the CREATE project. Data processing was a very time-consuming and challenging task, as had been expected. As a result, Stage-3-city partners did their best to harmonise as much of the household travel data as possible. Following this long-term effort, Stage-3-city partners were able to provide detailed and harmonised HTS microdata.

Figure 8: Steps of Data Processing for Stage-3-city Partners



Source: Own elaboration.

Data Storage and Security

Within all stages of the project, Stage-3-city partners are autonomously responsible for complying to the current legislation of data protection within their countries (e.g. data storage and security on their own computer systems). This notwithstanding, data holders and CREATE-partners (particularly Stage-3-city partners) have agreed to the transfer of microdata to TUD. Therefore, the Technische Universität Dresden (IVST) took over the responsibility of providing a secure data server for uploading all HTS data.

TUD has provided this server and thus ensures that all data protection regulations and privacy policies are complied with. Finally, the data can be stored to this safe TUD server with very restrictive access rights. As a result, Stage-3-city partners uploaded all databases for their city to this TUD server. This step included uploading code plans for each city. Each Stage-3-city partner has only received the access rights corresponding to their own city folder. There exists no possibility to view or download microdata from other Stage-3-city partners/cities.

All researchers and technical staff working on HTS microdata at TUD were obligated to carefully comply with all the legal provisions regarding data protection and data security. All researchers and technical staff with server access rights working on CREATE were informed and instructed about privacy policy, as well as other policies or terms that affect CREATE data protection by the leader of WP3.

4.3.2 Spatial Harmonisation

The spatial coverage of the HTS datasets was harmonised in order to acknowledge the importance of the spatial structures for travel behaviour.

Densities of residents and workplaces are essential characteristics of the built environment, and they were available for all cities and for most area types as introduced in Section 3. These densities were therefore used for harmonising the spatial level of analysis for the HTS.

Figure 9 shows the densities for residents and workplaces for the study areas, distinguished by the administrative area types introduced in Chaper 3. Differences in the absolute values of the densities are evident, with Paris having by far the highest values both for the density of residents and workplaces. Differences also exist between the administrative area types within the individual cities. For Berlin, London, and Vienna, the density of residents is more than twice as high in the Inner-City than in the Outer-City. For Copenhagen and Paris, however, the density of residents is almost the same in the Inner- and Outer-City but substantially lower in the Peri-Urban I area bordering the city. The density of workplaces differs in all cities substantially between the Inner- and Outer-Cities. This seems to be a typical characteristic, even if the residents' densities are equal in the Inner- and Outer-City.

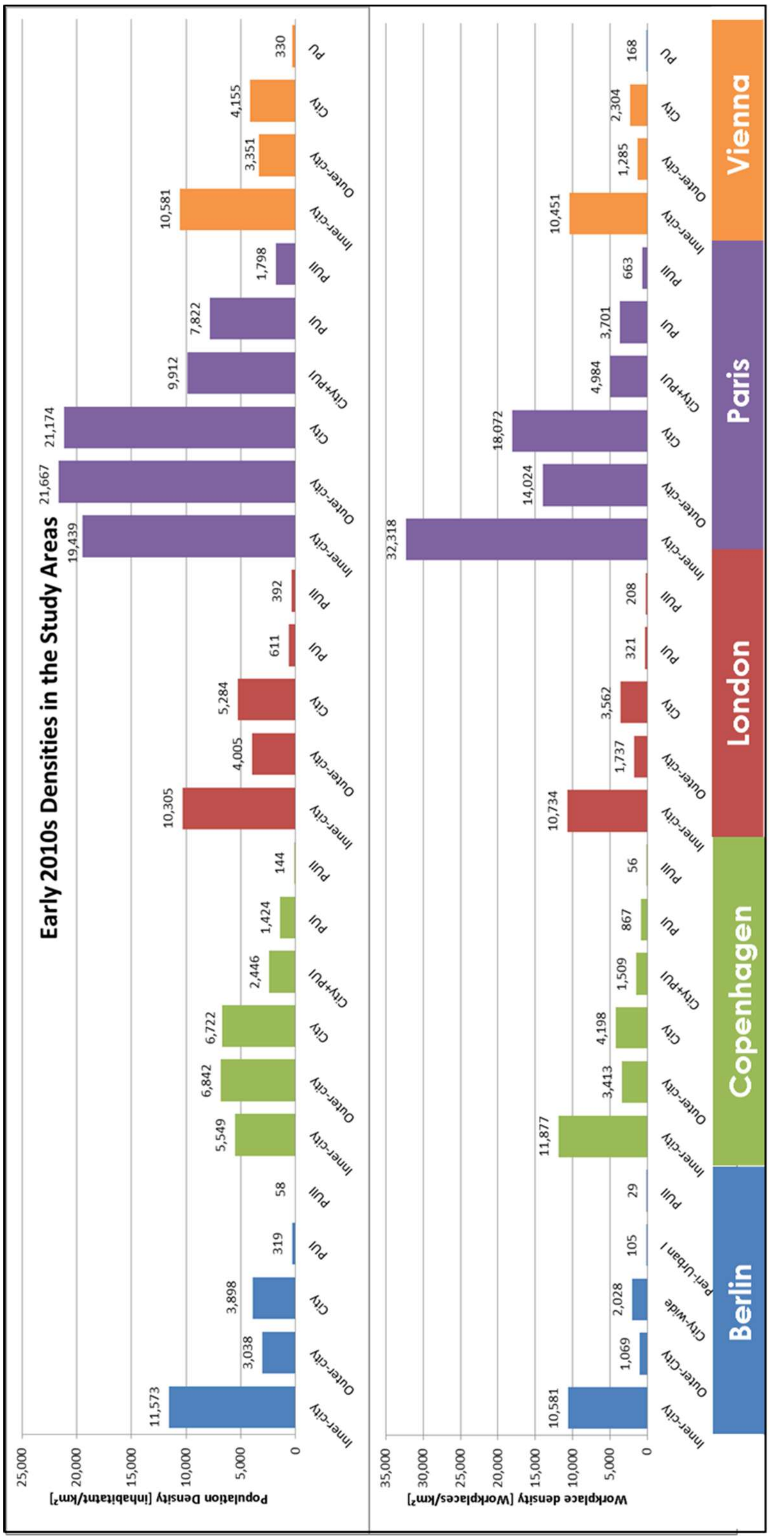
Seeing the substantial differences in the absolute densities between the cities, it was decided to do the spatial harmonisation for the HTS data based on the relative differences in the densities. Densities of residents were used for classification as these were considered a more important determinant of travel behaviour compared to the density of workplaces.

The following three functional area types were defined based on the administrative classification introduced in Section 3.3:

- Inner-Urban: This is the area with the highest densities of residents (Inner-City for Berlin, London, Vienna, and Inner plus Outer-City for Copenhagen and Paris).
- Urban: This is the area with the second highest density of residents (Outer-City for Berlin, London, Vienna, and Peri-Urban I for Copenhagen and Paris)
- Agglomeration: This is the low-density area surrounding the Urban area (Peri-Urban for Berlin, London, Vienna, and Peri-Urban II for Copenhagen and Paris)

Thus, it was decided not to use the administrative area types for data harmonisation, since the functions and characteristics of the individual administrative area types were too different. The inner-cities in Copenhagen and in Paris almost do not differ from the outer-cities. The Peri-urban I areas in these two cities are located outside the administrative municipal borders but their functions and characteristics are similar to the outer-cities in Berlin, London, and Vienna. The Peri-Urban I areas in Berlin, London, and Vienna, however, have similar functions compared to the Peri-Urban II areas in Copenhagen and Paris. These are clearly located outside the "actual" cities, and are not as focused on the city centre as the functional area type "Urban". In the Agglomeration, there are still high commuter flows to and from the Inner-Urban and Urban areas, but also centres and cities exist within the Agglomeration that attract and generate travel flows on their own so that travel flows are more decentralised compared to the Urban area.

Figure 9: Densities of the Study Areas: Residents and Workplaces



4.3.3 Temporal Harmonisation

Microdata was available for different years in the five cities. London, Copenhagen, and Vienna collect household travel data continuously but partly with small sample sizes. Berlin and Paris run their HTSs every five to ten years with differing durations between each of the two surveys. Only single surveys exist for earlier years for all cities. “Survey periods” were defined by TUD for dealing with these differences in temporal survey coverage.

Table 10 contains the unweighted sample sizes for the most comparable functional area type “Urban area” in each city. Paris has the most comfortable data situation with survey periods back to the Late 1970s. For Berlin and Copenhagen, the time series with successfully pooled data start from the Late 1990s.

Analyses for Vienna are possible back to the Early 1990s. Provided HTS microdata for London starts in the Late 2000s with the highest sample sizes per survey period compared to the other cities. Earlier values for London are included in some of the below figures; these were additionally provided by the London partners based on their local HTS (LATS 1981, LATS 1991, LATS 2001).

Table 10: Unweighted Net Cases (Persons) by Survey Period and Functional Area Type “Urban"

Survey Periods/ (Persons, Unweighted)	**Berlin City**	**Copenhagen City + PU I**	**London City**	**Paris City + PU I**	**Vienna City**
Late 1970s (1975–1979)	0	0	0	9,460	0
Early 1980s (1980–1984)	0	0	0	8,688	0
Late 1980s (1985–1989)	0	0	0	0	0
Early 1990s (1990–1994)	0	0	0	11,692	1,317
Late 1990s (1995–1999)	54,790	3,133	0	0	2,923
Early 2000s (2000–2004)	1,864	5,576	0	10,491	5,467
Late 2000s (2005–2009)	34,949	4,261	47,458	0	5,392
Early 2010s (2010–2014)	13,419	5,991	50,879	13,719	6,530
Late 2010s (2015–2019)	0	815	0	0	0

5 Cross-City Comparison

5.1 Macro Trends and Aggregated Indicators

5.1.1 Visualisation of Aggregated Cross-City Comparisons

This Section presents cross-city comparisons of aggregated indicators and macro trends based on the work done by each individual Stage 3 city for the D3.2-reports (Roider et al. 2016). Figure 10 shows the structure of the tables developed for this descriptive cross-city comparison.

The first column names the indicator to be compared, the spatial coverage (in round brackets), and the unit of measure (in square brackets). The other five columns are dedicated to each Stage 3 city with three indications for each indicator/row. The upper right cell shows the city-specific value of the indicator in this row for the most recent available year. The reference year is indicated below this city specific value. The arrow in the column to the left of these cells indicates the development over time.

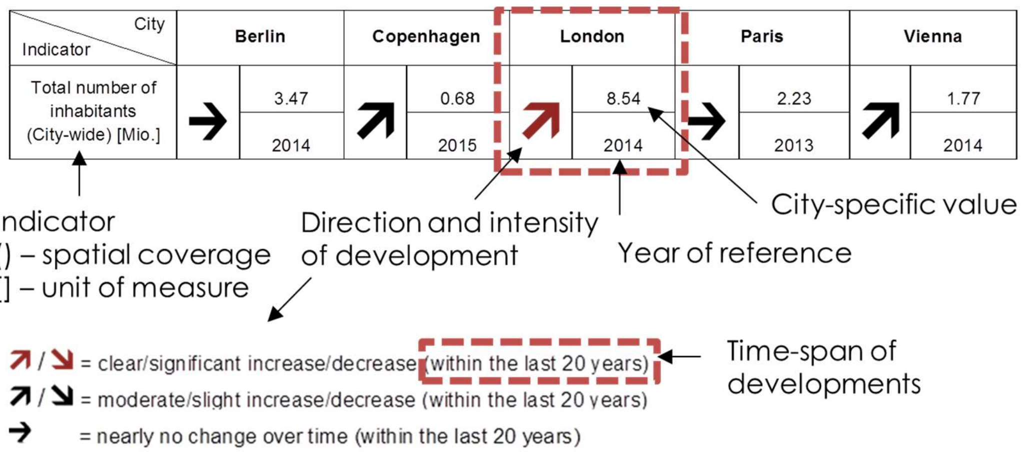
The direction and intensity of the developments are shown in the caption of the table. Red arrows indicate a clear/significant increase or decrease within a specific time-span. Black arrows indicate a moderate/slight increase or decrease as long as the arrow is not shown horizontal. The time-span of developments is also indicated in the caption of each table.

5.1.2 City-Specific Framework Conditions

Table 11 compares different population indicators on the aggregated level for the five Stage 3 cities. The current numbers of inhabitants per administrative area type have already been discussed in Section 3.3. The table below additionally shows the direction of developments within the last 20 years.

The numbers within the city boundaries increased for Copenhagen, London, and Vienna, with a slight increase in Berlin. The values are constant for the city-wide numbers of Paris. There is no difference in the direction of development within each of the cities other than Copenhagen, which shows opposing developments between Inner-City and Outer-City. The increase of inhabitants for the whole city of Copenhagen is driven by a population growth in the Outer-City area.

Figure 10: How to Read the Tables of Cross-City Comparisons



The number of residents within the Peri-Urban I areas increased for all five Stage 3 cities. Paris even shows a large growth of Peri-Urban I population numbers. Additional indicators are calculated for the assessment of importance of travel within and between the different area types. The ratio between the total number of inhabitants in Peri-Urban I areas and the total city population (city-wide) gives a first impression about the spatial composition of the overall Agglomeration.

All cities but Paris have more inhabitants within their cities than in the Peri-Urban I areas. In Paris, there are two inhabitants of the Peri-Urban I area for every inhabitant in the city. For the other four cases, this ratio is opposite and even stronger. In Vienna, the city is very dominant, with almost seven city inhabitants per Peri-Urban I inhabitant.

The proportion of seniors and young people (<18) within the city-wide population is another interesting statistic from the official population register, as each are characterised by very specific behaviours.

Therefore, Table 11 contains both absolute numbers and shares for those two population groups. The share of young people is highest for London where the proportion of seniors is lowest at the same time. The number of young people is increasing, whereas the number of seniors in London is declining. Copenhagen shows a similar development but to a lesser degree.

In Paris, the absolute numbers and proportion of the two population groups did not substantially change over time. The proportion of seniors in Paris is highest compared to the other cities. Only Berlin and, to a lesser extent Vienna show a relatively high share of seniors within their city-wide population. Differences between Berlin and Vienna also exist in terms of the trend direction. In Berlin, the number of seniors increased, whereas this number in Vienna decreased within the last 20 years.

The analysis of the individual person groups' specific behaviours below in Section 5.2 will show the importance of these structural indicators. Strong and still increasing habits of car driving in the elderly generations can be observed in all cities.

The substantial differences between the Stage 3 cities in the population structures, in the age composition, and in their developments over time need, therefore, to be a prime consideration for the subsequent analysis, and for the interpretation of the findings.

Some cities also provided data on tourists and stressed the importance of this topic for their city. In Berlin, many people visiting are domestic tourists from Germany, and they often arrive by car. It is not necessarily a given that they also use the car for trips within the city, but at least they have trips into and out of Berlin when arriving or leaving the city. When you are facing so many tourists, they overcrowd the PT system as well at specific times of the day (Stage-3-city Partners 2017).

Table 11: Comparison of Overall Indicators for Inhabitants

Indicator \ City	Berlin			Copenhagen			London			Paris			Vienna		
Total number of inhabitants (City-wide) [Mio.]	↗	3.47	2014	↗	0.68	2015	↗ (red)	8.54	2014	→	2.23	2013	↗	1.77	2014
Total number of inhabitants (Inner-City) [Mio.]	→ z	1.05	2014	→	0.052	2015	↗ (red)	3.40	2014	→	0.45	2013	↗	0.50	2014
Total number of inhabitants (Outer-City) [Mio.]	↗	2.42	2014	↗	0.63	2015	↗ (red)	5.14	2014	→	1.78	2013	↗	1.27	2014
Total number of inhabitants (Peri-Urban I) [Mio.]	↗	0.93	2014	↗	0,59	2015	↗	5.47	2014	↗ (red)	4,43	2013	↗	0.26	2014
Peri-Urban I population : Total City population	→	1 : 3.73	2014	↗	1 : 1.15	2015	↗	1 : 1.56	2014	↗ (red)	1.98 : 1	2013	→	1 : 6.8	2014
Total number of young people < 18 (city-wide) [Mio.]	↘	0.54	2014	↗	0,12	2016	↗	~2.00**	N/A	→	0.24	2010	→	0.34**	2014
Share of Young people (city-wide) [%]	↘	16	2014	↗	18	2014/15	↗	23	2011/14	→	11	2010/13	→	19	2010
Total number of seniors >=65 (city-wide) [Mio.]	↗ (red)	0.67	2014	↘ (red)	0,08	2014	↘	0,90	2011.	→	0.44	2010/13	↘ (red)	0.30	2014
Share of Seniors (city-wide) [%]	↗ (red)	19	2014	↘ (red)	12	2014/15	↘	11	2011/14	→	20	2010/13	↘ (red)	17	2010

* Peri-urban 1 + 2
** <20 years of age

↗ / ↘ (red) = clear/significant increase/decrease (within the last 20 years)
↗ / ↘ = moderate/slight increase/decrease (within the last 20 years)
→ = nearly no change over time (within the last 20 years)

Table 12 and Figure 11 describe the land-use patterns of the Stage 3 cities within their official city boundaries. The settlement areas are the dominant land use category for all cities. The share of settlement areas is almost 60 % of the total city area for the cases of Copenhagen and Paris. Berlin (42 %) and Vienna (36 %) have the lowest proportions where remarkable shares of forest areas and other "green land uses" exist. The proportion of transport infrastructure areas is similar with around 1 out of 8 square meters for all five cites. London and Vienna additionally have agricultural areas (both 14 %) within the city boundaries.

Table 12: Comparison of Overall Indicators for Land-Use

City / Land-use category	Berlin (2014)	Copenhagen (2016)	London (2014)	Paris (2013)	Vienna (2014)
Size of Total City area (km²)	891.7	97.0	1,602.4	105.3	414.9
Share of Settlement	42%	57%	49%	59%	36%
Share of Transport infrastructure	15%	18%	15%	14%	14%
Share of Recreational	12%	20%	15%	18%	8%
Share of Agricultural	4%	0%	14%	0%	14%
Share of Semi-natural	2%	1%	2%	0%	4%
Share of Forest	18%	1%	3%	7%	19%
Share of Water	7%	3%	2%	2%	5%

Figure 11: Comparison of Land-Use Categories in Stage 3 Cities

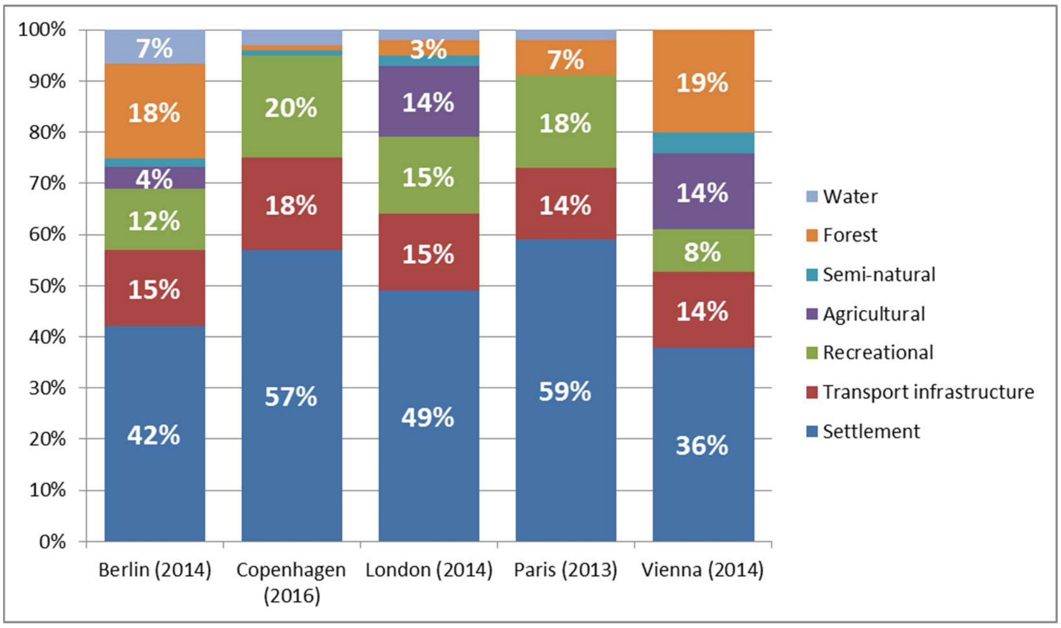


Table 13: Comparison of Overall Indicators for Spatial Conditions

Indicator \ City	Berlin			Copenhagen			London			Paris			Vienna		
	Trend	Value	Year	Trend	Value	Year	Trend	Value	Year	Trend	Value	Year	Trend	Value	Year
Size of total City area [km²]	→	891	2014	→	97	2016	→	1,572	2014	→	105	2013	→	415	2014
(1) Size of total City area – area for forest or water [km²]	→	669	2014	N/A	93	2014	→	1,493	2014	→	96	2013	↘	315	2014
(2) Size of Settlement and transport infrastructure area [km²]	→	508	2014	N/A	73	2014	→	1,006	2014	→	77	2013	↗	207	2014
Share of settlement and transport infrastructure area (2) / (1) [%]	→	76	2014	N/A	78	2014	→	67	2014	→	80	2013	↗	66	2014
Size of Inner-City area [km²]	→	90	2014	→	9	2016	→	319	2014	→	23	N/A	→	46	2014
Size of Outer-City area [km²]	→	801	2014	↗	88	2016	→	1,253	2014	→	82	N/A	↗	369	2014
Size of Peri-Urban I area [km²]	↗	2,864	2014	↗	406	2016	↗	8,801	2014	↗	567*	N/A	↗	797*	2014
Density of total City inhabitants per area (City area – area for forest or water) [persons/km²]	↗	4,995	2014	↗	7,302	2015/16	⇗	5,718	2014	→	23,272	2013	↗	5,614	2014
Density of total workplace jobs per area (City area – area for forest or water) [jobs/km²]	↗	2,028	2014	↗	4,198	2014/16	⇗	3,562	2014/16	→	18,072	2012/13	↗	2,304	2014

* Whole peri-urban area

⇗ / ⇘ = clear/significant increase/decrease (within the last 20 years)

↗ / ↘ = moderate/slight increase/decrease (within the last 20 years)

→ = nearly no change over time (within the last 20 years)

Table 13 includes a comparison of the absolute spatial indicators and the derived densities. The cities and Peri-Urban areas of Berlin and London cover the largest areas. The Inner-City area of London is greater than the cities of Paris and Copenhagen together. None of the cities have seen substantial change to their spatial extent over time. Only the Peri-Urban areas, which are specifically catchment areas for commuting, steadily grew for all five Stage 3 cities. Density increased in almost all cases. Population density within the city areas increased for Vienna and Copenhagen and heavily increased for London over time. Paris, with the highest densities compared to the other cities has been stable within the observed period of 20 years. Such high densities can hardly be further increased. Berlin saw a small increase of population density on city level.

Additionally, Table 13 also contains the workplace-job densities reported by the Stage-3-city partners in their D3.2-reports (Roider et al. 2016). Once again, Paris has as extraordinary position in terms of density compared to the other cities. Densities are between five and nine times higher for Paris than for the others. The density of Paris' city area seems to be saturated. This is one main reason why Paris' Peri-Urban area is the only significantly increasing area in this city comparison. Copenhagen with the smallest size in terms of inhabitants and workplaces is the second densest city (city-wide values). Interestingly, London is not only heavily growing in terms of population densities but also workplace densities.

These densities come along with many other traits, but seem to be one of the most important drivers of travel behaviour, and can easily be measured. Density is not a singular effect unto itself, but is a proxy for land use, city development, building structures, characteristics of public spaces, and transport supply as discussed above. These issues will be discussed further in Section 6.3.

Table 14 lists indicators that describe the framework conditions; these are developments in socio-demographic indicators and the population structure, but also in the absolute number of workplaces (e.g. collected from company statistics) and of workplace jobs (e.g. collected from statistics on insurable employments). Workplace jobs increased for Berlin, London, and Vienna and are quite stable for Copenhagen and Paris. London shows the most substantial growth in workplace jobs within the city boundaries.

There are differences in the gross domestic product (GDP) for the cities as an indicator for well-being and purchase power. Values in Copenhagen and London are highest. Berlin has the lowest GDP compared to the other. In three cases (Copenhagen, London, Paris), purchase power has clearly increased within the observation period of around 20 years. Nevertheless, the other two cities also have growing values. Car use of residents in all Stage 3 cities declined at city level (see Section 5.2.2) despite these increasing GDP values and despite the fact that typical transport model approaches assume that car use and GDP are closely related.

The CREATE Stage 3 cities suggest that this is not always the case. Income and car use generally demonstrate a positive relationship but can be counteracted by other factors such as density or transport infrastructure capacity. This leads to the fact that, despite increasing income, the increase of density driven by city development (among other factors) is related to a decrease in car use (see Section 5.2.2).

Table 14: Comparison of Overall Indicators About Framework Conditions (II)

Indicator \ City	Berlin			Copenhagen			London			Paris			Vienna		
	Trend	Value	Year	Trend	Value	Year	Trend	Value	Year	Trend	Value	Year	Trend	Value	Year
Total number of workplaces/work place jobs (city-wide) [Mio.]	↗	N/A/1.81*	2014	→	0.036/ 0.407	2014	⬈	N/A/5.7**	2016	→	N/A/1.80	2012	↗	0.086/ 0.474	2011/13
GDP per capita (city-wide) [€/capita]	↗	31,526	2014	⬈	65,467	2014	⬈	60,761***	2014	⬈	53,617	2013	↗	47,200	2014
Share of people >=18 with tertiary education level (city-wide) [%]	N/A	N/A	N/A.	⬈	45	2015	N/A	N/A	N/A	N/A	N/A	N/A	⬈	24	2012
Average household size [persons per household]	↘	1.7	2013	↗	2.0	2015	→	2.4	2011	↘	1.9	2010	↘	2.3	2011
Share of people living in single-person-households (city-wide) [%]	⬈	54	2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* Only the number of people in paid work (at place of work)
** Number refers to the number of workplace jobs
*** GVA – Gross Value Added (100 British Pounds = 128,73 Euro on 31/12/2014)
⬈ / ⬊ = clear/significant increase/decrease
↗ / ↘ = moderate/slight increase/decrease
→ = nearly no change over time

The provision of shares of people with higher education by official population statistics was not possible in all cases, though, Copenhagen and Vienna show great increases in this indicator. Household sizes are declining for all cities but London. The largest household sizes were found in London and Vienna. Berlin has the smallest number. In this case, the share of people living in single-person households has already reached 54 % for the city-wide area.

5.1.3 Transport Supply and Policies

Table 15 provides relevant indictors that describe the transport supply side for the Stage 3 cities quantitatively. The length of total road network largely depends on the city size. Therefore, a ratio of total road-network length and population (per 1,000 persons) gives a better impression of road-network density. Berlin, London and Vienna have very similar densities. Copenhagen has a comparably low road-network density. Similar developments for PT-network densities can be observed in all cities that were able to provide these numbers. Vienna has the densest PT-network of all these cities. The PT-network density of Vienna is almost six-fold higher than in Copenhagen. The scheduled public transport supply increased for all cases. This is a strong pull-factor because there is a common understanding that improving the attractiveness of Public Transport strongly influences mode choice behaviour. Overall, these indicators seem not to be as reliable as the above described indicators for the city-specific framework conditions. Definitions of the specific indicators and data availability differ, hampering the interpretation of these indicators between the cities.

Table 15: Comparison of Overall Indicators About Transport Supply

Indicator \ City	Berlin			Copenhagen			London			Paris			Vienna		
Speed limits at main roads [km/h]	→	50	2016	→	50-70	2016	→	48-64	2016.	→	50-70	2016	→	50	2014
Length of total road network (not considering multiple lanes) (city-wide) [km]	↗	5,585	2014	↗	562	2016	→	14,796	2015	→	N/A	N/A	→	2,814	2014
Length of total road network per capita [km/1,000 persons]	↗	1.6	2014	N/A	0.8	2016/15	N/A	1.7	2016/14	N/A	N/A	N/A	N/A	1.6	2014
Length of public transport network (sum of all urban lines in regular service on weekdays, length of infrastructure) (city wide) [km]	↗	1,860	2014	↗ (red)	85	2015	N/A	N/A	N/A	N/A	N/A	N/A	↗ (red)	1,357	2014
Length of PT network per capita [km/1,000 persons]	↗	0.53	2014	N/A	0.13	2015	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.76	2014
Scheduled public transport service supply, all types (city-wide) [seat-km per year]	↗	N/A**	2014	↗	N/A**	2014	↗ (red)	170,633*	2014	↗	N/A	N/A	↗ (red)	19,479	2014

* Only the number of place kilometres per year available
** Only the number of train kilometres per year available
↗ / ↘ (red) = clear/significant increase/decrease
↗ / ↘ = moderate/slight increase/decrease
→ = nearly no change over time

Transport policies also include pricing as one very effective push measure. Transport users directly perceive and pay their costs for Public Transport when they do not have public transport season tickets. The assessments and estimations of the real costs of car use are, on the contrary, often not rational and realistic. The initial cost of purchasing a vehicle, as well as the many indirect costs of car use (e.g. relatively high costs per kilometre owning a car), are often not considered at the moment of mode choice. However, PT prices are transparent. This also holds true for fuel prices and parking fees. Table 16 compares some of these key indicators of transport policies.

Nominal and subjectively perceived prices of Public Transport grew for almost all cities during the 20 year observation period. Copenhagen has the highest growth rates both for single-trip tickets and for annual tickets. In the frame of city comparisons, single trips are cheapest in Paris and most expensive in London. Differences in the spatial and temporal validity of single tickets need to be considered when interpreting these numbers. The price for an annual ticket in Vienna is extraordinarily competitive at 365 Euros per year (effectively 1 Euro per day). In Berlin, customers pay almost twice as much as

Vienna, and in Paris more than twice that amount. For London this number cannot be reported because of the Oyster Card.

In Paris the fares of PT increased more slowly than the costs. This seems to be a limiting factor for the future because the operators have to deal with the real costs, further development of PT systems is limited by public costs. While the fare is slightly increasing for an annual ticket, analysis of the travel patterns using annual tickets show that the mean fare per trip is decreasing. There are job tickets available, e.g. Paris companies pay half the price for their employees' tickets (Stage-3-city Partners 2017).

The fact that Berlin school children have access to hugely subsidised public transport tickets goes further than implementing job tickets, strategically teaching children to use PT systems during their adolescence, potentially affecting later life stages. Bringing children into the PT system instead of parents driving them by car is a kind of education policy (Stage-3-City Partners 2017).

Fuel prices showed a great deal of volatility, in addition to cyclical fluctuations, during the observation period. However, they were stable when adjusted for inflation and development. The absolute numbers differ only slightly across the Stage 3 cities. The average price for petrol was highest in Copenhagen. Diesel's price was highest in Vienna. In comparison to the perceived development of transport costs, fuel prices only increased nominally and not than fast as PT prices. Real annual fixed and variable prices for car use are highest in Paris.

The analysis of parking fees produced an interesting development. All cities have been introducing many parking management measures during the last decades. Parking fees substantially increased for all cases. Copenhagen and Paris show comparably high parking fees. London has an outstanding price for car use specifically in central London due to their congestion charge in addition to regular high parking fees.

Data on parking provision could not be provided consistently for any of the Stage 3 cities. However, all city partners agreed that restricted parking space availability (and parking space accessibility due to constraints such as time restrictions, price, location, parking guidance, etc.) is a huge push factor to use other transport modes. This is also a key issue in the political discussions. A clear consensus also exists that reliable data about parking supply would be helpful in order to show that reductions may have positive effects for travel patterns of inhabitants and commuters. In all cases, there is a lack of arguments supporting substantive car parking supply reduction within the cities (Stage-3-City Partners 2017).

In addition, there are different responsibilities for parking—and, thus, for data collection. In Berlin, for example, parking is mainly managed by each individual borough. There is a city initiative (launched by the Senate of Berlin) to manage and harmonise parking regulations across the boroughs, but each borough retains responsibility. Nearly 15 years ago, Berlin was the first German city to eliminate the requirement that private parking lots be created when constructing a new building. However, regulations for providing cycle parking exist. The city of Berlin is currently discussing the reintroduction of parking regulations for private housing because if you do not regulate the parking issue at all, you cannot minimize it either (Stage-3-City Partners 2017).

Table 16: Comparison of Overall Indicators About Transport Policies

City Indicator	Berlin		Copenhagen		London		Paris		Vienna	
Price for a PT single-trip ticket (central zone) (city-wide) (development is shown inflation adjusted) [Euro]	↗	2.60 2014	⬈	3.22 2015	↗	3.90* 2014	↗	1.90 2016	↗	2.20 2014
Price for a PT annual ticket (central zone) (city-wide) [Euro]	↗	722 2014	⬈	684 2015	↗	N/A N/A	↗	770 2016	↘	365 2014
Annual average fuel prices diesel/petrol (development is shown inflation adjusted) [€ per litre]	→	1.17/1.39 2015	→	1.21/1.50 2016	→	N/A/ 1.34** 2016	→	1.15/1.35 2015	→	1.30/1.35 2014
Average variable and fixed costs of private car (development is shown inflation adjusted) [€ per car-km]	N/A	0.50 2015	↗	0.38 2016	N/A	N/A N/A	→	0.64 2010	N/A	0.47 2010
Highest parking fee per hour (public streets, Inner-City) [Euro/h]	⬈	3.00 2017	⬈	4.70 2017	⬈	~13.50*** 2015	⬈	4.00 2015	⬈	2.00 2014

* Underground 1-4 Oyster Card
** 1 British Pound = 1,3394 Euro on 31/12/2016
*** Congestion charge
⬈ / ⬊ = clear/significant increase/decrease
↗ / ↘ = moderate/slight increase/decrease
→ = nearly no change over time

5.1.4 Access to Travel Modes

Access to travel modes and the influence of different mobility options and tools are comprehensively discussed below in Section 5.2. At this point, only a few numbers from official statistics are compared on aggregate level. These numbers track essential developments and, thus, support the interpretation of changes in travel behaviour on the micro level in Section 5.2.

First, the number of private cars per inhabitant is a common indicator describing travel mode access. Paris and Copenhagen have currently the lowest rates of private car ownership, and Vienna the highest. Remarkably, the number of private cars per inhabitant is clearly increasing for Copenhagen but decreasing for Paris.

The reason for Copenhagen's development (especially from a number of 234 in 2014 to 250 in 2015) is most likely a recently modified tax regulation for purchasing cars which leads to more car purchases (especially small cars) within the last years of the observation period. Even with this increase, Copenhagen retains a low rate compared to the other cities. These changes show the substantial influence of the economic framework conditions. The comparably high car purchase taxes in Copenhagen might even be one impetus for the impressive development of cycling in Copenhagen within the last decades as the most flexible, time-table independent, cost-efficient, and fastest alternative transport mode.

The number of driving licenses per 1,000 inhabitants was only reported by three cities. Berlin has the highest access rate (Table 17). On average, 729 out of 1,000 people had a licence in 2015. The number for Paris is lower, but interestingly, London has a very low rate of driver licences compared to the other cities. Car-driving licences increase for all cases relative to the whole population.

The number of people with PT-yearly-season passes has been also reported by Stage-3-city partners. As expected, Vienna has the highest number with more than 350 passes per 1,000 inhabitants in 2014. Numbers are increasing for all cities except London. The previously mentioned modification to the London ticketing system by introducing the Oyster Card results in underreported PT yearly season passes for London. However, the Oyster Card can be treated as a season ticket as a monthly cap is automatically charged then this is the best price for the traveller.

Table 17: Comparison of Overall Indicators of Access to Travel Modes

City / Indicator	Berlin		Copenhagen		London		Paris		Vienna	
Number of private cars per inhabitant within the last 20 years (city-wide) [cars per 1,000 persons]	→	326*	⬈	250	→	333**	↘	243	→	387
		2015		2015		2011		2010		2014
Number of driving licences per 1,000 inhabitants (city-wide) [%]	↗	729	↗	648	↗	454	↗	642	N/A	N/A
		2015		2015		2014/15		2010		N/A
Number of people with PT yearly season pass (city-wide) [passes /1,000 inhabitants]	⬈	172	↗	265***	↘	260****	⬈	278	↗	368
		2014		2014		2014		2010		2014

* private and commercial passenger cars
** calculated by cars/household and average household size
*** yearly season pass does not exist; number based on monthly PT passes.
**** including period travelcard, station to station season ticket, Local authority OAP concession pass, Local authority disabled concession pass, Staff/Police free pass
⬈ / ⬊ = clear/significant increase/decrease
↗ / ↘ = moderate/slight increase/decrease
→ = nearly no change over time

5.2 Cross-City Comparisons of Travel Patterns and Travel Demand Using HTS Microdata

5.2.1 Overall Travel Statistics

This section initially carries out a cross-city comparison based on overall travel indicators. Therefore, Figure 12 shows the number of trips per tripmaker per day both with and without walking. City values are plotted in different colours. These colours are consistently used for all graphical representations within this report. The cities are always represented based on the following colours: London 'Red', Vienna 'Orange', Paris 'Violet', Copenhagen 'Green', and Berlin 'Blue'.

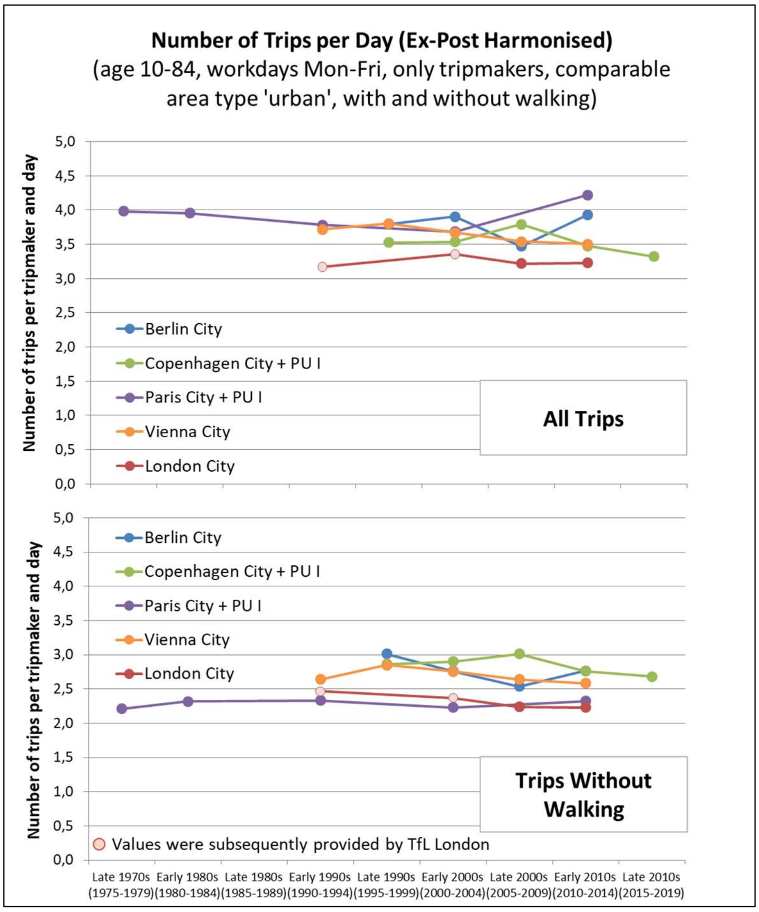
After data harmonisation, Stage-3-city trip rates are in a plausible range and show smooth developments over time. With regard to all trips and across comparable area types (urban area), around 3.5 trips per tripmaker per day are performed. In the Early 2010s, Paris has with 4.2 trips per tripmaker on the reporting day the highest trip rates and London with 3.2 the lowest trip rates. Based on the findings from the literature, the authors hypothesise that these variations are caused by a mixture of actual behavioural difference as well as by differences in survey characteristics. The number of tours per tripmaker is, with values between 1.4 and 1.6, almost identical in the three cities for which this number could be computed. This shows that underreporting is an issue here. There is a clear consensus in the literature that underreporting is mainly a problem of trips that are missing within tours that consist of more than two trips. Underreporting is not (or less) a problem of complete missing tours (e.g. in the end of the reporting day) (Aschauer et al. 2018). The proportion of trips back home corresponds almost exactly for all five cities and has a plausible magnitude. This is a positive quality criterion of the HTSs as back-home trips are likely to be underreported.

Without walking trips, the values of Berlin, Copenhagen, and Vienna are very close to each other (around 2.6 trips per tripmaker per day in the Early 2010s). London and Paris have slightly lower numbers of around 2.4 trips per tripmaker per day within the same survey period. The authors hypothesize that these variations are mainly cause by differences in behaviour. Paris is e.g. a very dense city and known for its walking culture.

Table 18 gives an overview of the key travel estimates for the harmonised HTSs. The table shows each absolute value for two points in time so that temporal developments are also visible. The proportion of immobile persons is within the usual range reported in the literature (Armoogum 2014). The high proportion, 19 percent, of immobile persons in Vienna might result from the survey methodology which was mostly phone-based in the early 2010s. However, the proportion of immobile persons was already at 19 percent in the Early 1990s when the Viennese surveys were conducted as mail-back surveys with only motivation by telephone following the NEW KONTIV-design (Socialdata 2009). For the other cities, the values of immobile persons range from five percent to 14 percent. The values are relatively stable for all cities across time.

Daily travel time per tripmaker is within the expected range. It is stable in London and Vienna but increasing in the other cities. The substantial increase of the daily travel time in Berlin, together with the decreasing daily travel distances, indicate a shift from faster to slower transport modes which will be elaborated in the following Section. The low daily travel time per tripmaker in Copenhagen might be a methodological artefact from differences in the survey methods, but also it might result from the fast access to destinations, with less congestion compared to the other cities. The comparable daily travel distance per tripmaker confirms this assessment. Another interesting detail is the difference in daily travel distances per tripmaker between Paris/London and the other three cities. While Paris and London show relative stable values at 15 kilometres per person per day, the other cities have values between 20 and 23 kilometres. In Paris, the high densities and walking shares in the modal split might be an explanation for this difference. In London, some parts of the city are also very dense and their city morphology seems to also support walking trips.

Figure 12: Number of Trips per Tripmaker per Day (All Trips and Without Walking)



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

The values in the last two rows for the morning and the afternoon peak are calculated by the hour in which the highest proportion of trips begins. At the Late 1990s, the morning peak starts earlier in in Berlin than all other cities, whereas the afternoon peak starts latest in Paris. These values are close to each other and stable across time. The variances might result from cultural differences in the rhythms of the residents' daily activities and trips.

Mode-specific analysis reveals further insights about travel behaviour, but also about possible reasons for the differences in the key travel estimates described above. Table 19 shows the key travel estimates per tripmaker per day separately for all transport modes.

The number of car-driver trips is in the same magnitude for all five cities. It differs for the earlier survey period by 0.3 trips per tripmaker per day with 1.2 car driver trips per day in Berlin as the maximum and 0.9 in London as the minimum. One reason for the low value in London might be that the earlier survey period in London is Late 2000s, in contrast to all other cities with the Late 1990s as earlier survey period. The number of car driver trips per tripmaker per day in London might have been higher and thus more consistent with the other cities in the Late 1990s. The number of car-driver trips per tripmaker per day in the more recent time period, Early 2010s, is almost equal for all cities with a difference of only 0.1 trips per tripmaker per day between the cities. The trip numbers for car-passengers are also almost identical in all cities. The peak-car effect is visible in all cities. It mainly occurs for car-driver trips whereas the number of car-passenger trips per person per day is almost stable over time.

Table 18: Key Travel Estimates in the Study Areas

Travel Behavior Indicators in the Urban Area of Five Europan Capital Cities

Ex-post harmonised (Age 10-84, Workays Mon-Fri, Comparable area types)	**Berlin City**			**Copenhagen City + PU 1**			**London City**			**Paris City + PU 1**			**Vienna City**		
	L90s ('95-'99)		E10s ('10-'14)	L90s ('95-'99)		E10s ('10-'14)	L00s ('05-'09)		E10s ('10-'14)	E90s ('90-'94)		E10s ('10-'14)	E90s ('90-'94)		E10s ('10-'14)
Out of home at reporting day	90%	↗	92%	92%	→	91%	87%	→	86%	95%[1]	→	94%	81%	→	81%
Number of daily trips per tripmaker	3.8	→	3.9	3.5	→	3.5	3.2	→	3.2	3.8	↗	4.2	3.7	↘	3.5
thereof trips without walking	3.0	↘	2.8	2.9	→	2.8	2.2	→	2.2	2.3	→	2.3	2.6	→	2.6
Number of daily trip chains (tours)	1.5	→	1.6	1.5[2]	→	1.4	N/A		N/A	N/A		N/A	1.5	→	1.5
Proportion of Home trips	39%	→	39%	38%	↗	40%	41%	→	40%	39%	→	38%	40%	→	40%
Daily travel time per tripmaker [min]	80	↗	94	60	↗	66	91	→	92	92	↗	104	92	→	90
thereof time without walking	71	↗	79	54	↗	58	78	↘	75	72	↗	80	75	→	76
Daily travel distance per tripmaker [km]	29	↘	25	30	↘	24	16	→	16	14	→	15	23	→	23[3]
thereof distance without walking	29	↘	24	30	↘	23	15	→	15	14	→	14	23	→	23[3]
Morning Peak [Starting hour]	7am	→	7am	8am	↘	7am	8am	→	8am	8am	→	8am	8am	→	8am
Afternoon Peak [Starting hour]	16pm	→	16pm	17pm	↘	16pm	15pm	→	15pm	17pm	→	17pm	16pm	→	16pm

[1] Overall value, reporting day of people without trips on reporting day not indicated
[2] Value from Late 2000s ('05-'09), information not surveyed in earlier survey periods
[3] Value from Early 2000s ('00-'04) due to inconsistency of the most recent survey period

The number of public transport trips is in the same magnitude for all cities except Copenhagen, with Vienna having slightly more public transport trips per person per day, as well as a stronger increase over time compared to the other cities. Public transport use increases in London, Paris, and Vienna over time. It is stable in Berlin at a high level. In Copenhagen, public transport use is comparably low and stable over time.

The number of bicycle trips per person per day increased in all five cities but the absolute levels substantially differ. Bicycle use is very low in London and Paris, followed by Vienna, Berlin, and Copenhagen with, by far, the highest trip numbers for the bicycle and also the strongest absolute increase over time. London shows a substantial increase over time, starting from a very low level of bicycle use.

Walking trips are not as consistent as the other modes. Substantial differences exist in the absolute walking trip numbers in each city, and the changes over time are neither consistent nor smooth. The authors hypothesise that these inconsistencies result both from behavioural differences and different survey methods in the five cities. The number of walking trips per person per day is by far highest in Paris, which confirms the literature showing that people in Paris actually walk a great deal

(Roider et al. 2016). Looking at the complete picture of walking trip numbers/distances/durations for each point in time, and over time, observing the “jumps” in the temporal developments, the authors conclude that differences in the survey methods and protocol, as well as the quality of the field work, are additional causes for differences in walking besides actual behavioural differences. This conclusion is supported by the literature that consistently finds that walking trips are heavily affected by under-reporting if deficits in the survey method and/or quality exist (Armoogum 2014, Gerike et al. 2015).

Overall, the daily trip numbers per transport mode per day confirm the typical characteristics of the cities (Buehler et al. 2016, Focas et al. 1998, Roider et al. 2016). Copenhagen with the highest number of cycling trips and Vienna with a high number of public transport trips stand out. Berlin and London have a more balanced distribution of trips between the transport modes and Paris has a high number of walking trips. It is interesting that the differences in the overall trip numbers shown above in Table 18 are mainly caused by public transport, bicycle, and walking, but far less by car trips. The biggest differences in trip numbers exist for cycling.

Daily travel times and distances show similar magnitudes and developments as identified above for the trip numbers, except for walking where inconsistencies occur. The peak-car effect is visible also for these indicators with decreasing travel times and daily distances over time for car trips in all cities, again, with a more stable pattern for car-passenger trips compared to car driver trips. Travel times and daily distances are self-reported variables in most HTSs, used for this study. This needs to be considered when interpreting these indicators.

Magnitudes of the travel estimates, as well as developments over time, are smooth within all cities for car, public transport, and the bicycle, but not for walking. Walking trips are, therefore, excluded from subsequent analysis for selected travel estimates, and on a case-by-case basis in order to disentangle, as much as possible, the behavioural peculiarities from methodological artefacts caused by differences in the survey methods.

Figure 13 illustrates the developments over time in more detail for the key travel indicator “car trips per tripmaker per day”. The peak-car effect is visible in all five cities. It happened first in Paris between the 1980s and the Early 1990s, followed by Vienna in the Late 1990s and Copenhagen in the Early 2000s. The peak-car effect in Berlin and London cannot be assigned to a specific time period based on the HTS data as this data is only available from the Late 1990s (Berlin) and Early 1990s/Late 2000s (London) onwards. At that time, the peak-car effect obviously had already happened in Berlin. Seeing the special history of Berlin with the re-unification of the formerly divided city in October 1990, it is highly likely that car use peaked in Berlin in the Late 1990s because of the substantial increase in car use in the Eastern parts of the city in the Early 1990s like in all other Eastern German cities (Wittwer & Hubrich 2016). In London, it is also highly likely that peak car happened in the Late 1990s (personal conversation with CREATE London partners). No HTS data point exists for the Late 1990s for London but other data (e.g. from transport models) shows peak car effects in this period and local experts support this hypothesis.

The absolute numbers of car trips per tripmaker per day are almost the same across all five Stage 3 cities for the functional area type “Urban”. Differences in the Inner-Urban areas can be explained by actual behavioural differences: Car use in the Inner-Urban areas is lowest in Paris with its very high densities of residents and workplaces in the Inner-City. Car use is highest in Copenhagen with the lowest densities of residents in the Inner-Urban area compared to all the other four cities under investigation.

Table 19: Number of Trips, Daily Travel Time, and Distance per Tripmaker on the Reporting Day, by Transport Mode in the Study Areas

Travel Behaviour Indicators in the Urban Area of Five Europan Capital Cities

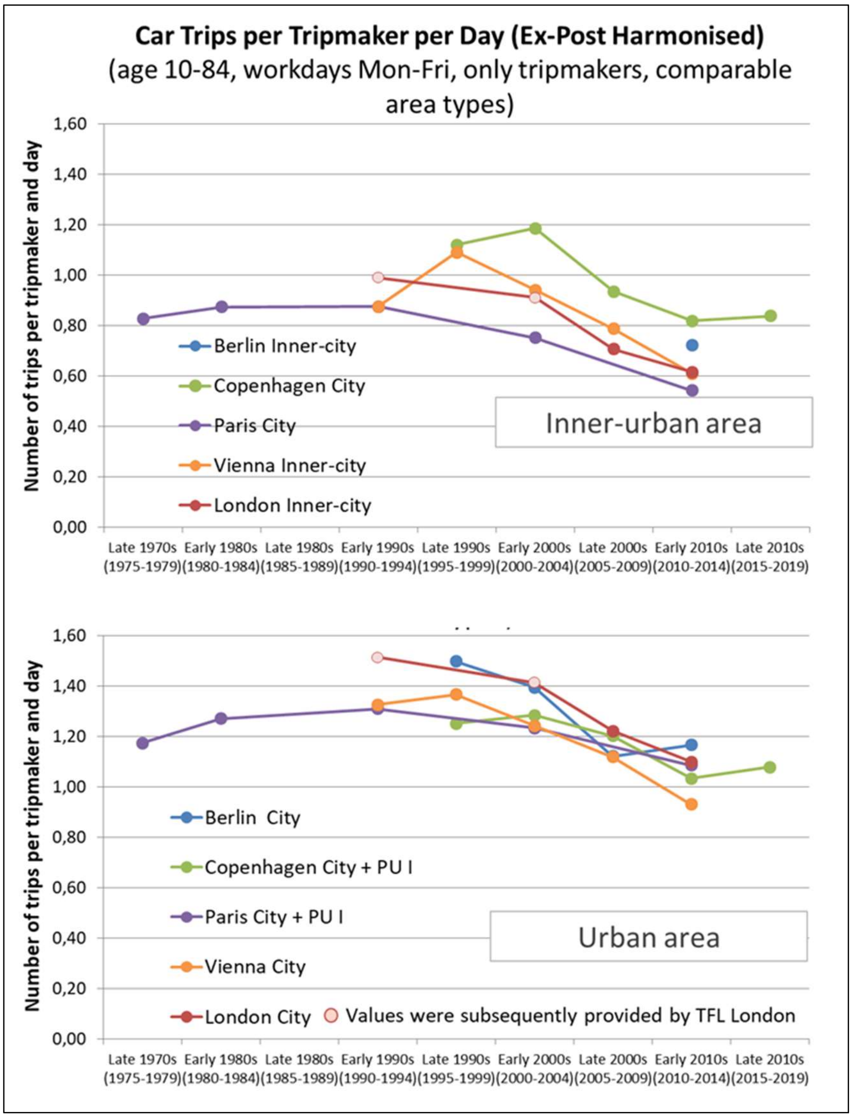
Ex-post harmonised (Age 10-84, Workays Mon-Fri, Tripmaker only, Comparable area types)	**Berlin City**			**Copenhagen City + PU 1**			**London City**			**Paris City + PU 1**			**Vienna City**		
	L90s ('95-'99)		E10s ('10-'14)	L90s ('95-'99)		E10s ('10-'14)	L00s ('05-'09)		E10s ('10-'14)	E90s ('90-'94)		E10s ('10-'14)	E90s ('90-'94)		E10s ('10-'14)
Car driver trips	1.2	↘	0.9	1.0	↘	0.8	0.9	↘	0.8	1.0	↘	0.8	1.1	↘	0.8
Car passenger trips	0.3	↘	0.2	0.2	→	0.2	0.3	→	0.3	0.3	↘	0.2	0.2	→	0.2
Public transport trips	1.1	→	1.1	0.7	↘	0.6	0.9	↗	1.0	1.0	↗	1.1	1.2	↗	1.4
Bicycle trips	0.4	↗	0.5	0.8	↗	1.1	0.06	↗	0.09	0.02	↗	0.08	0.1	↗	0.2
Walking trips	0.8	↗	1.2	0.7	→	0.7	1.0	→	1.0	1.5	↗	1.9	1.1	↘	0.9
Daily trip chains with car driver as first transport mode	0.6	↘	0.4	0.2[1]	→	0.2	N/A		N/A	N/A		N/A	0.4	↘	0.3
Daily car driver travel time [min]	34	↘	24	17	↘	14	23	↘	20	24	↘	22	26	↘	17
Daily car passenger travel time [min]	7	↘	4	4	→	3	7	→	6	5	→	5	5	→	4
Daily PT travel time [min]	23	↗	40	20	↗	23	45	→	46	41	↗	50	43	↗	50
Daily bicycle travel time [min]	6	↗	10	11	↗	17	1	→	2	0.5	↗	2	0.4	↗	4
Daily walking travel time [min]	9	↗	16	6	↗	8	14	↗	17	20	↗	24	17	↘	14
Daily car driver travel distance [km]	18	↘	9	13	↘	9	6	↘	5	6	↘	5	11	↘	9[2]
Daily car passenger travel distance [km]	3	↘	2	3	↘	2	2	→	2	1	→	1	2	→	2[2]
Daily PT travel distance [km]	6	↗	11	10	↘	8	7	↗	8	6	↗	7	9	↗	10[2]
Daily bicycle travel distance [km]	1.0	↗	1.9	2.9	↗	4.4	0.2	↗	0.3	0.04	↗	0.18	0.1	↗	0.5
Daily walking travel distance [km]	0.6	↗	1.0	0.7	↗	0.8	0.6	↗	0.9	0.8	↗	0.8	0.9	↘	0.8

[1] Value from Late 2000s ('05-'09), information not surveyed in earlier survey periods

[2] Value from Early 2000s ('00-'04) due to inconsistency of the most recent survey period

The Inner-Urban areas of Berlin, London, and Vienna are in between those extremes for their number of car trips per tripmaker. Even though Copenhagen has, by far, the lowest density of dwellings in the urban area, the number of urban area car trips is still low among the Copenhagen citizens compared to the other denser cities. Whether the numbers for "Late 2010s" illustrate a new tendency or just a minor deviation is uncertain as the period only includes figures for 2 years.

Figure 13: Number of Car Trips per Tripmaker per Day (Inner-Urban and Urban Area)

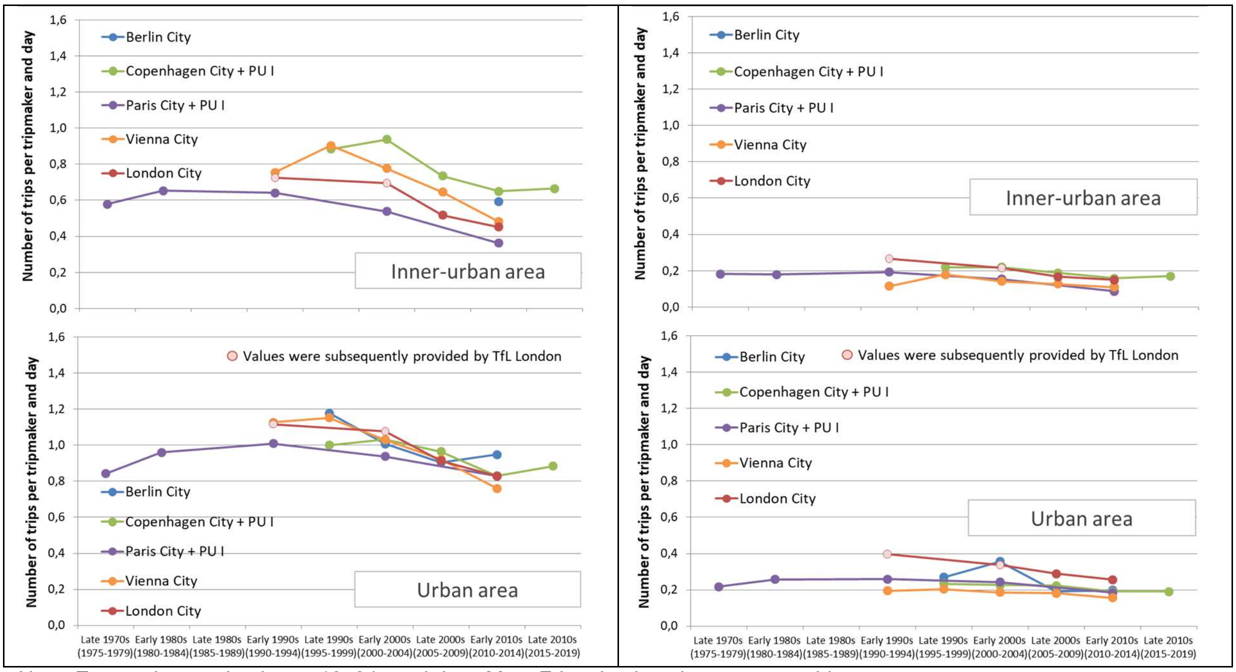


Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area types

The Figure 14 below separates the overall car trips into car driver and car passenger trips. The figure shows that the number of car driver trips is much higher compared to the number of car passenger trips, and that the peak car effect is more visible for car driver trips.

In addition, car driver trips are more important for transport planning as each of these trips actually generates a car in the street whereas the car passenger trips do not generate additional cars in the street, but instead increase the ridership within the moving cars. Against this background, the subsequent analyses will focus on car driver trips.

Figure 14: Number of Car-Driver Trips (left) and Car-Passenger Trips (right) per Tripmaker per Day (Inner-Urban and Urban Area)



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area types

Figure 15 presents trip rates per tripmaker per day distinguished by the individual trip purposes for reaching the activities at the trips' destinations. The three trip purposes that could be harmonised for all HTS are listed below. The back-home trips were assigned to the purpose of the previous activity.

Mandatory trips include trips for

- Working,
- Education,
- Work related activities,
- Business, and
- Nursery.

Shopping trips refer to

- Shopping
- Errands, and
- Drop off/pick up people.

Leisure trips summarise

- All trips related to leisure activities.

In addition, there exists a category for "Other Purposes" which contains all trips that could not be assigned to any of the three above listed categories. "Other" varies between zero (Copenhagen and Paris) and a maximum of five percent of all trips (Berlin, Early 2000s). This category is therefore negligible for analyses purposes.

Trips for mandatory activities are declining for almost all Stage 3 cities (Figure 15). Between the Early 1990s and the Early 2010s, mandatory activities have reduced on average by almost 20 %. Copenhagen is the sole exception to this trend. The need for mandatory activities leads these activities play an important role in travel behaviour on work days.

The development of shopping trips is not as clear as it is for mandatory trips. Paris and Berlin show increasing figures, whereas the values for Copenhagen are obviously declining. Vienna and London show a quite stable development across time. The number of leisure trips is almost constant, or only slightly decreasing, for Copenhagen and Berlin. The other three Stage 3 cities show increasing values. It should be pointed out that walking plays a very important role for shopping/errands and leisure. To avoid misinterpretation of these two purposes, Figure 15 still includes walking trips.

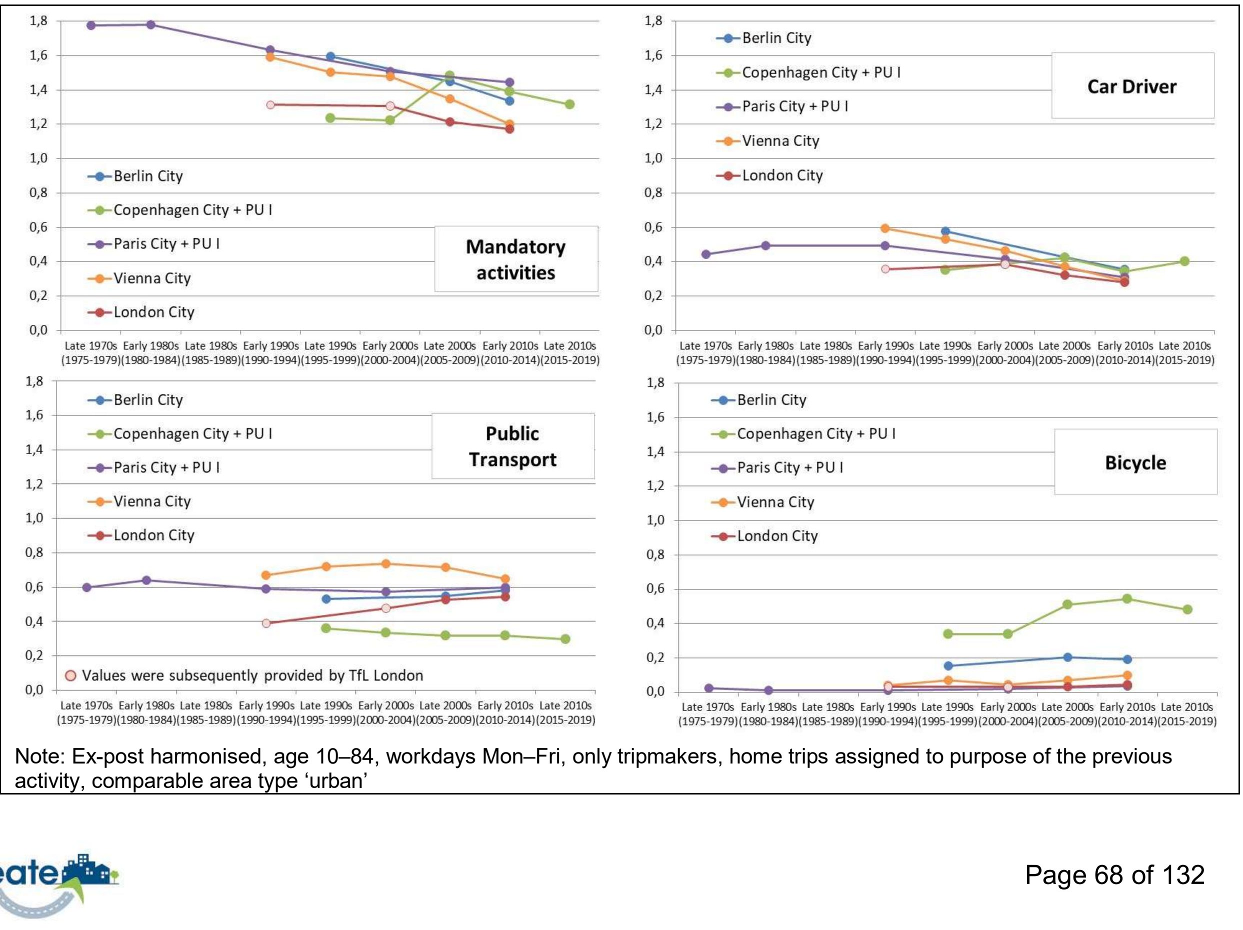
Figure 15: Number of Trips per Tripmaker per Day by Purposes (Including Walking Trips)

Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', home trips assigned to purpose of the previous activity

For a more in-depth analysis of the overall activity behaviour, mode choice is viewed separately for each of the harmonised trip purposes. Figure 16 contains the overall numbers of mandatory trips as already discussed, distinguished by car driver, public transport, and bicycle. Car-driver trips are declining clearly for all cities, except Copenhagen for the most recent period. However, this development needs to be interpreted with caution because of the small size of the Copenhagen sample in the most recent period. In the Early 2010s, car-driver trips for mandatory purposes are really close to each other for all five cities. On average, around 0.3 trips per tripmaker per day are performed as car driver for mandatory trips (range 0.28-0.36). In contrast to the car driver trips, substantial differences between the five cities exist for public transport and cycling. About 0.6 trips per tripmaker per day are realised with public transport in all Stage 3 cities, except Copenhagen. In Copenhagen, this value is located slightly below its car-driver value (0.30 to 0.34). Copenhagen contrasts with the other cities, having fewer public transportation trips and more bicycle trips. The city of Copenhagen more than triples the values of the other cities for cycling. In Copenhagen of the Early 2010s, cycling is the dominant transport mode for mandatory purposes. Berlin shows the second highest, and slightly increasing, number of bicycle trips for this purpose. Regarding the whole population, cycling for mandatory trips plays only a minor role in the other three urban areas. In general, nowadays the car plays a much more minor role for mandatory trips than in recent decades.

The overall trip number for purposes of shopping, errands, and drop off/pick up varies between the cities, particularly so long as walking trips are still considered. Figure 17 shows how different and how important walking is for these kinds of activity needs. The car driver trip rates for shopping are quite stable for all Stage 3 cities. On average, only around 0.35 trips per tripmaker per day are counted as car driver at the Early 2010s for the purpose shopping/errands. Again, the values are close to each other for all cities and, interestingly, more or less stable across time. On the other hand, the public transport usage for shopping differs across cities. In the Early 2010s, Vienna shows the highest value (0.4 trips) and Copenhagen the lowest value (around 0.1).

Figure 16: Overall Number of Mandatory Trips (Including Walking) and by Chosen Transport Modes



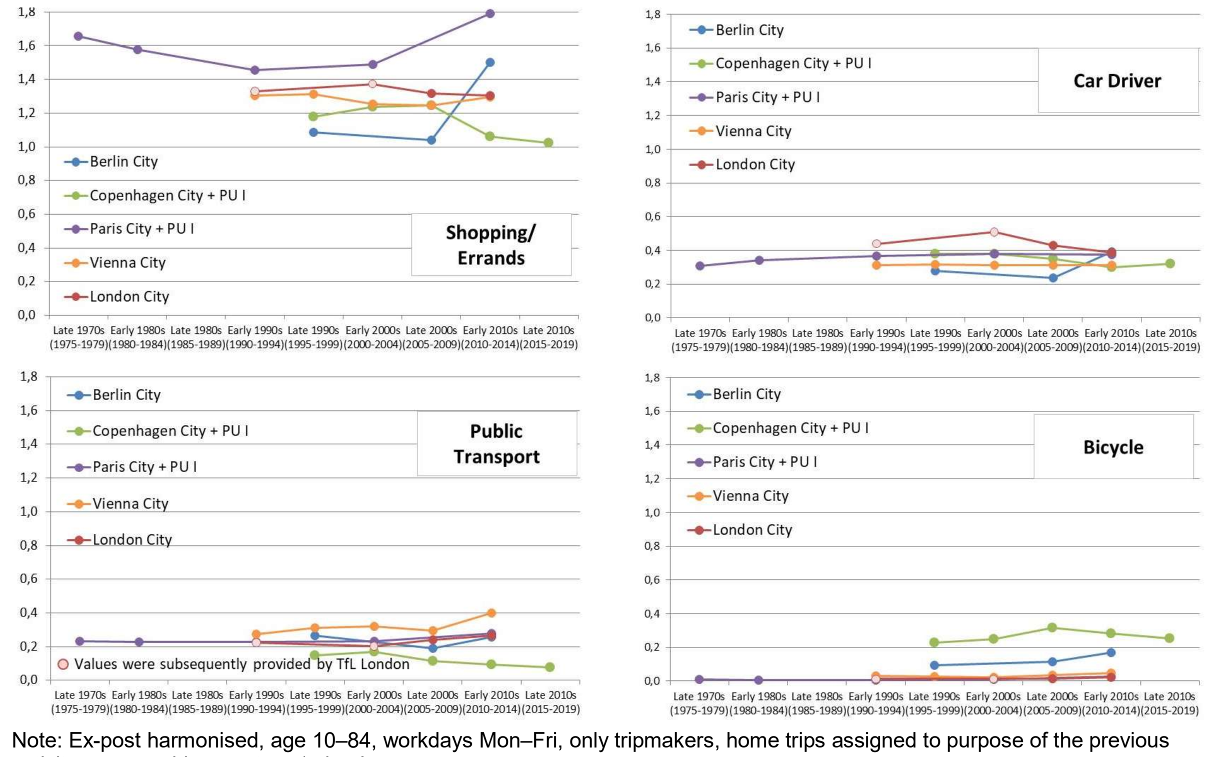
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, home trips assigned to purpose of the previous activity, comparable area type ‘urban’

Paris, London, and Berlin have similar numbers of around 0.25 trips per tripmaker per day. There is no clear tendency across cities, but the developments are smooth for all of them. Cycling plays a role for shopping in Copenhagen and Berlin. London, Paris, and Vienna have negligible numbers of cycling for these purposes. Walking is highest in Paris, and all cities, except Copenhagen, have comparatively high numbers of walking trips. One possible explanation for Copenhagen's low walking rate may be substitution effects between walking and cycling.

Leisure activities as the last of the three harmonised purposes are analysed in Figure 18. First, overall leisure trip rates including walking are mapped for comparison purposes. Mode choice is again indicated by distinguishing trip rates by the main means of transport. Car-driver rates are relatively low at around 0.2 trips per tripmaker per day in the Early 2010s. Whereas car driver trips for leisure seems stable for London and Paris across time, a small decrease can be observed for the other three Stage 3 cities. On average, mode choice is almost evenly distributed across all vehicle-based travel modes and walking. Some particularities are visible in terms of public transport, where Vienna shows the highest numbers, and for cycling, where once again Copenhagen shows many leisure trips per tripmaker per day. The development of leisure trips by public transport and cycling across survey years is all in all stable, or slightly increasing, for the observed Stage 3 cities.

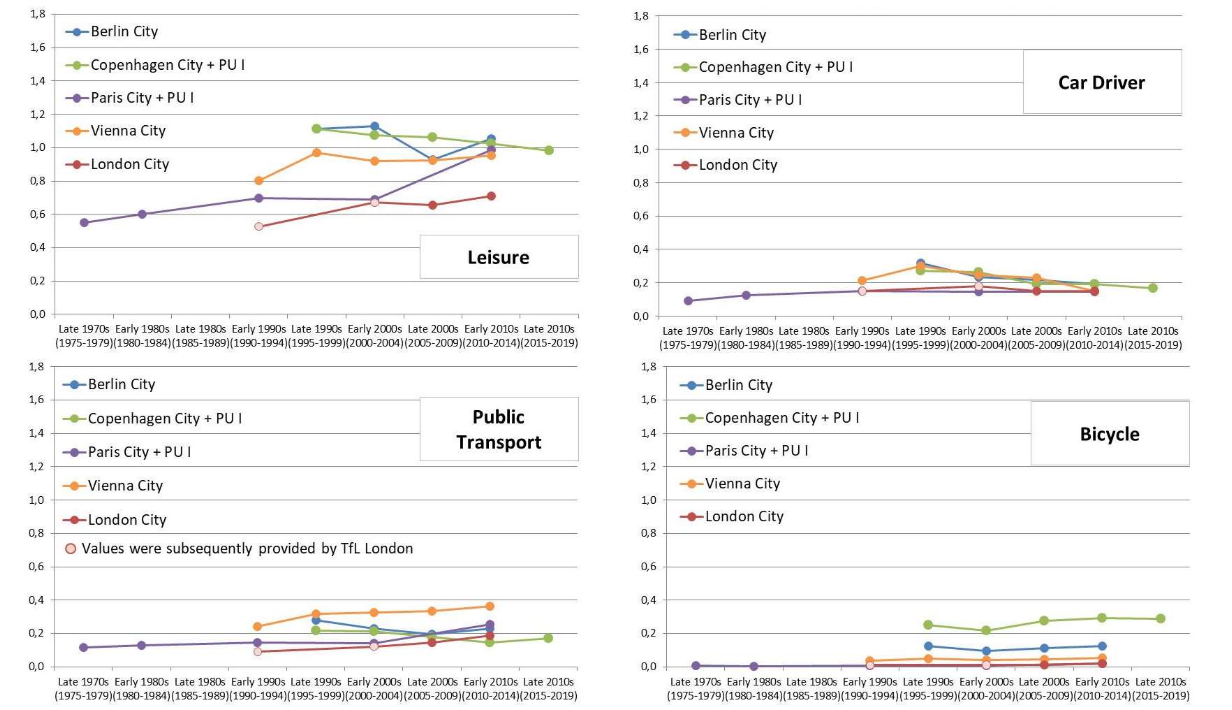
First impressions into cross-site developments are gained from travel patterns and travel demand within the whole population. Besides the methodological insights on data harmonisation, insights were gained into travel behaviour in the five European capital cities across time. Key travel estimates match well between the cities and the developments over time are smooth, except for walking. All analyses including walking trips require, therefore, special care. It might be advisable to remove walking trips entirely for selected analyses. The peak-car phenomenon could be traced for all cities and the cities' typical characteristics could be confirmed with, e.g., the highest bicycle trip numbers in Copenhagen.

Figure 17: Overall Number of Shopping/Errands Trips (Including Walking) and by Chosen Transport Modes



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, home trips assigned to purpose of the previous activity, comparable area type 'urban'

Figure 18: Overall Number of Leisure Trips **(Including Walking)** and by Chosen Transport Modes



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, home trips assigned to purpose of the previous activity, comparable area type 'urban'

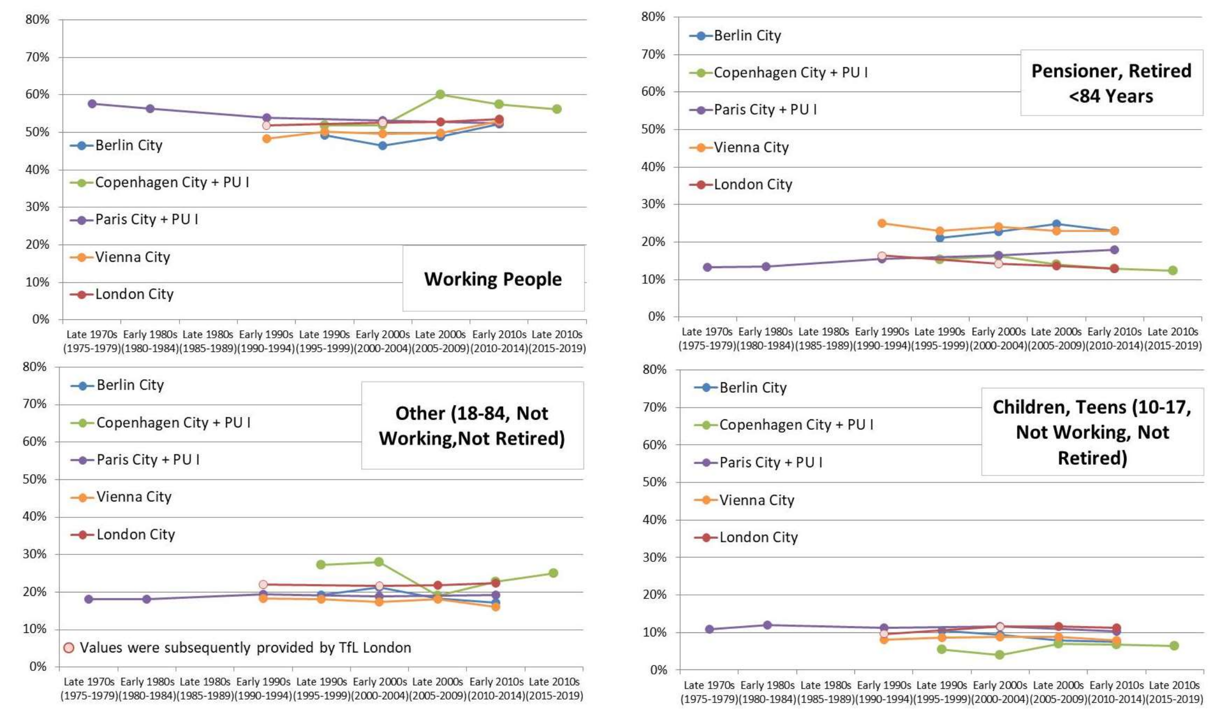
Trip rates are suitable for mapping the peak-car effect and the effect is clearest for mandatory trips. Mandatory activities play a very important role for activities during work days across the population. For both shopping/errands trips as well as leisure trips, other transport modes, including walking, are interestingly the backbone for the functioning of transport in European capital cities. The clear peak-car phenomenon within the mandatory trips and its great importance in travel behaviour on work days are the reasons for further investigating travel patterns of specific person groups in the next section of this report.

5.2.2 Travel Behaviour of Specific Person Groups

The literature suggests that the peak-car phenomenon occurs differently across various person groups; young persons and seniors have been the most analysed. Therefore, the next Section examines travel behaviour of specific person groups in more detail. First, Figure 19 distinguishes the Stage-3-city population into four groups by occupation status. For all survey periods, the share of working people in the population has been around 50 % until today. In Copenhagen, data suggest an even higher proportion of around 60 % at the Late 2000s.

The other half of the city's population spreads across other adult persons (not working, not retired), pensioners (retired persons), and children/teens. The proportion of other adults (not working, not retired) moves around 20 % and children/teens around 10 % across all cities and survey periods. The proportion of pensioners/retired persons differs slightly across cities. For the recent survey periods, Vienna and Berlin show the highest shares (more than 20 %), Copenhagen and London have just over 10 % pensioners/retired persons within their population. For all five Stage 3 cities, working people are the largest group and, thus, play a dominant role for travel and traffic within the urban and metropolitan areas.

Figure 19: Share of Specific Person Groups by Occupation Status



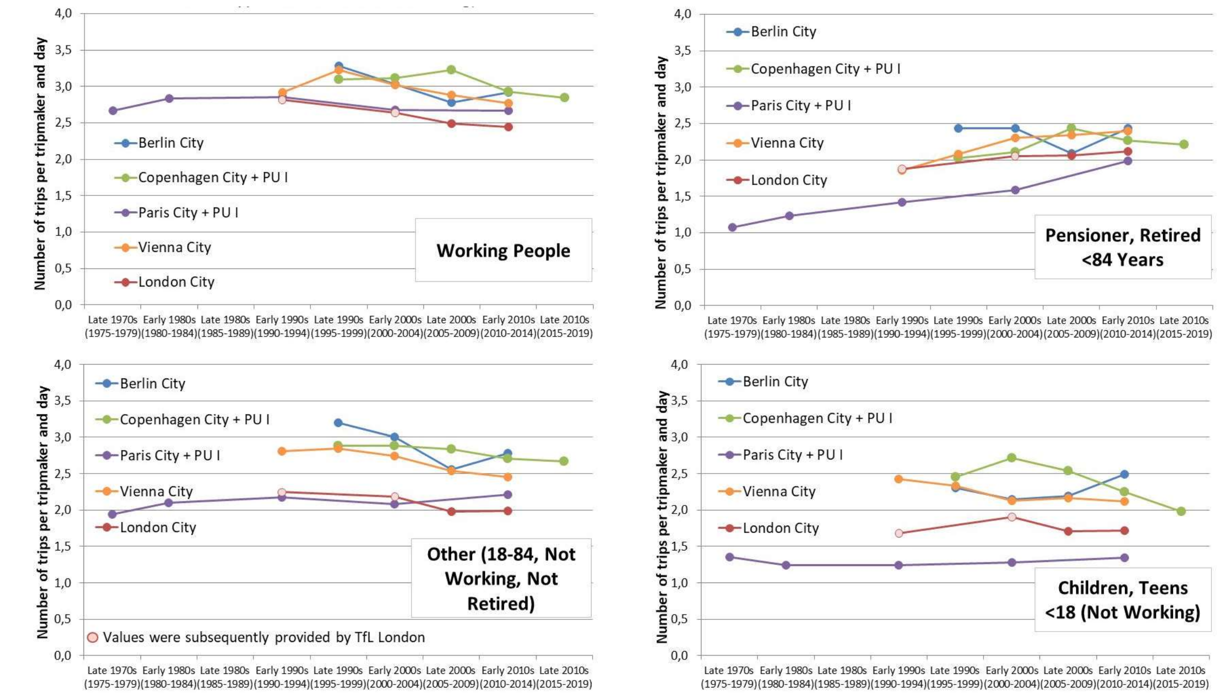
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 20 shows the number of trips per tripmaker per day for the four already mentioned person groups. Walking is excluded here because of the already highlighted differences of capturing walking across time. Vehicle trip rates of working people are highest in all observed time periods. Across all Stage 3 cities, around 2.5 to 3.0 trips per worker are performed per day in the Early 2010s. This small range of trip rates shows the overall stability of mandatory activities for different study areas. Trip rates of working people are very close to trip rates of the whole sample—again an indication for a high proportion and significance of this person group within the population (see above). Vehicle trip rates of working people are stable or slightly decreasing.

The daily trip rates of seniors are generally increasing. Early 2010, between 2.0 and 2.5 vehicle trips are daily performed by pensioners. Only a small variation occurs for the five Stage 3 cities at this point in time. Data suggest more variation for the other two person groups. Whereas vehicle trip rates of other adults (not working, not retired) are highest for Berlin, Copenhagen, and Vienna, trips rates are comparatively low for London and Paris. This does not implicitly mean that those people have less activity needs. Instead, Londoners and, particularly, Parisians get to their activities frequently by foot. Similar reasons may be named for the wider spread of work-daily trips across cities by children and teens.

At this point, an initial conclusion can be drawn to inform subsequent steps of the analysis: Working people are not only the dominant person group within the population, but also have the highest work-daily vehicle trip rates of all examined person groups.

Figure 20: Number of Trips per Tripmaker per Day by Occupation Status (Without Walking)

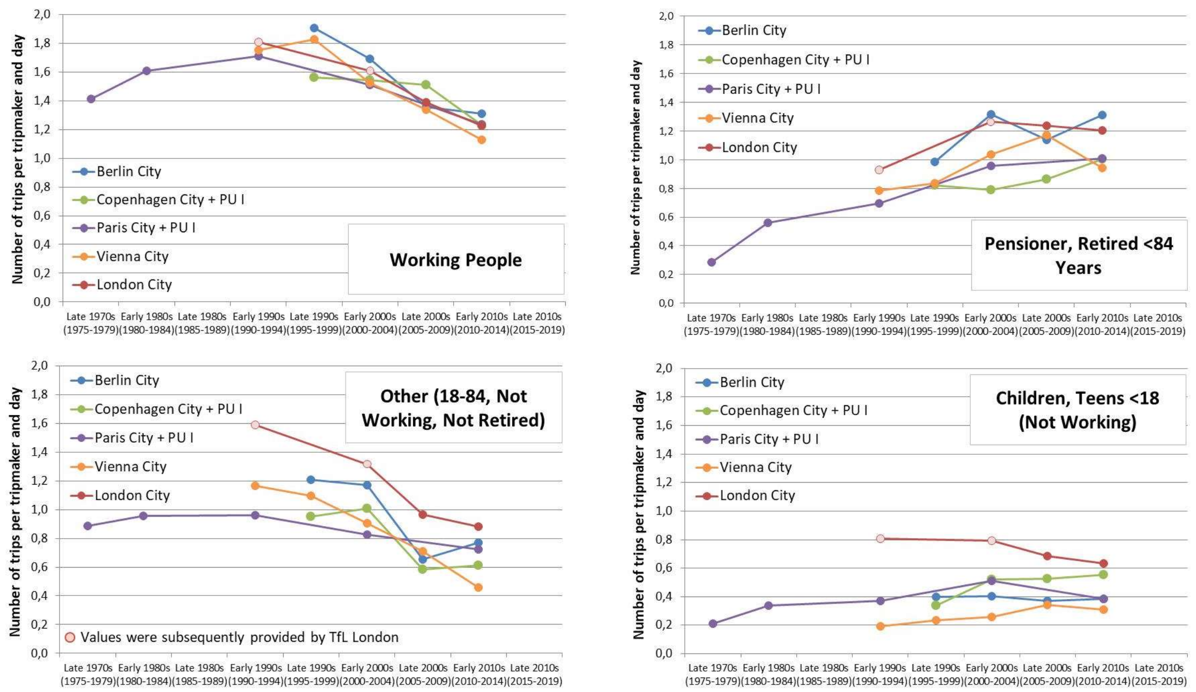


Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', without walking

Figure 21 illustrates car trip rates by occupation status. Immediately, one takes note of the fact that the clear peak-car phenomenon is highly visible for working people, and other adults (not working, not retired) on very different absolute levels. Working people sharply reduced their daily trips by car in the observation period. HTS data have a very small variation for this person group. The variation for other adults is significantly larger but this group is very heterogeneous. It includes students, unemployed persons, housewives etc. While there is a general trend of sharply increasing car trip rates for pensioners (retired persons), children, and teens show a marginal increase. For the recent survey period, pensioners have more trips by car than the other adults (not working, not retired). The number of car trips by children and teens are comparatively low. These numbers are a clear indication of the importance of the changes in travel behaviour by working people.

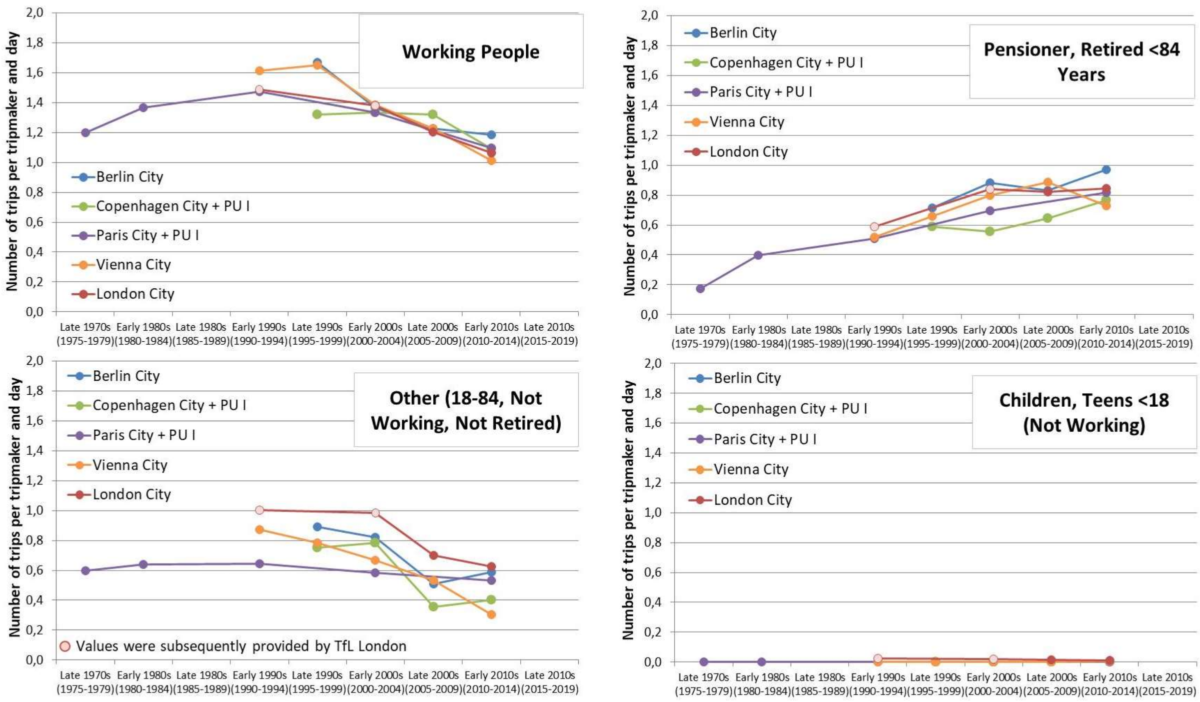
Figure 22 and Figure 23 distinguish car trips into car-driver and car-passenger trips. Car-driver trips are dominant for all groups but children/teens. Very few car-driver trips are performed by teens in the recent survey periods, where “accompanied driving under 18” is possible in some countries. The trend of decreasing car use by working people on the one hand, and increasing car use by pensioners on the other, can be clearly observed in all cases. For car-driver trips, the variation across cities is even smaller than for all car trips. Car-passenger trips have the highest values for children/teens (Figure 22). For Copenhagen, Vienna, and Paris, car-passenger trips of children/teens are slightly increasing. For Berlin and London these values are relatively stable or even slightly decreasing.

Figure 21: Number of Car Trips per Tripmaker per Day by Occupation Status



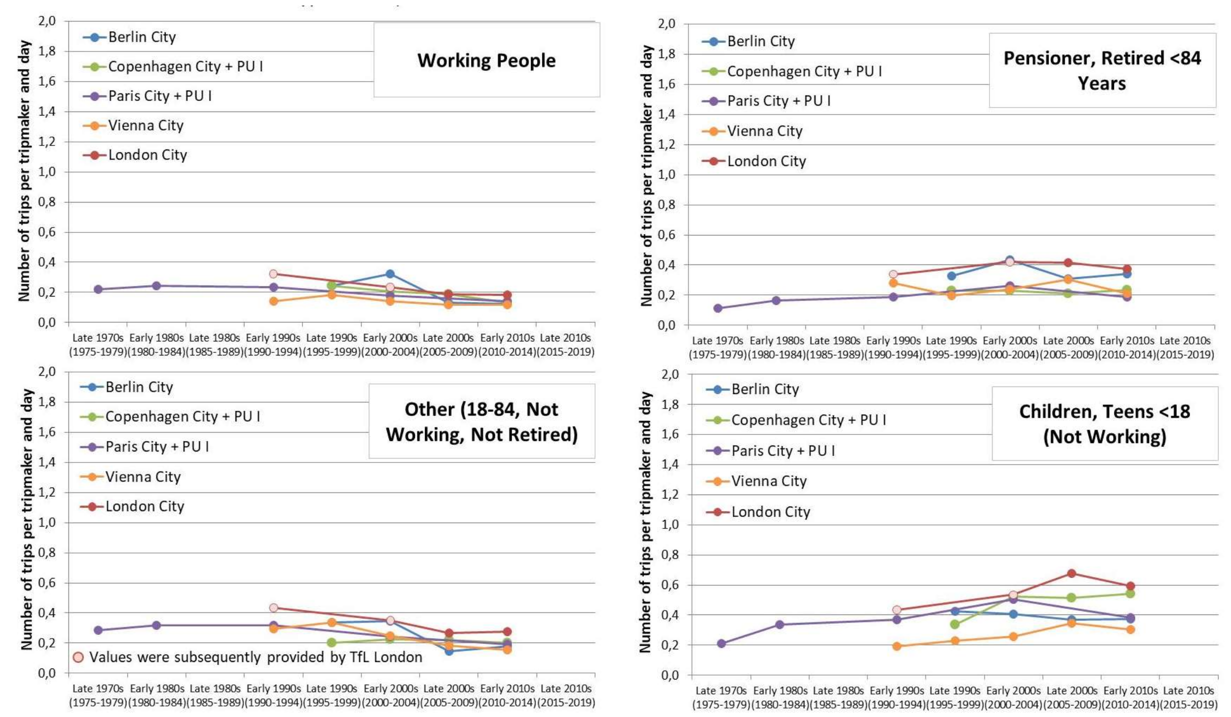
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', Late 2010s values for Copenhagen not shown due to small sample sizes for these cases.

Figure 22: Number of Car-Driver Trips per Tripmaker per Day by Occupation Status



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', Late 2010s values for Copenhagen not shown due to small sample sizes for these cases.

Figure 23: Number of Car-Passenger Trips per Tripmaker per Day by Occupation Status



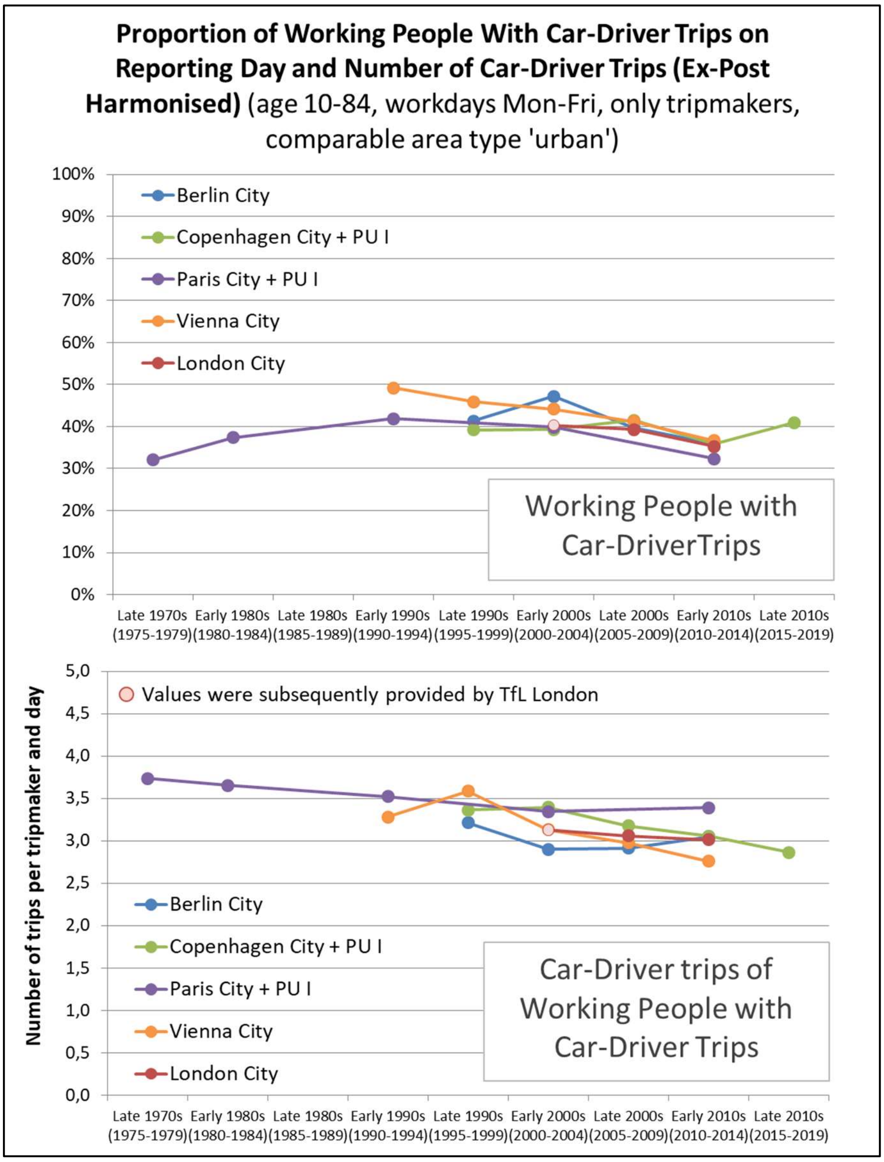
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', Late 2010s values for Copenhagen not shown due to small sample sizes for these cases.

The analysis so far leaves open the question of whether the peak car effect results from fewer people having the same car driver trip rates over time or if it results from the same number of persons reporting at least one car driver trip but with each of them having fewer car driver trips. Figure 24 shows these two indicators separately. The upper part of the figure looks very similar to the above figures with the car driver trip rates for working persons.

However, the upper part of Figure 24 does not show trip rates but the proportion of working persons having at least one car driver trip on their reporting day. This number decreased clearly in all five cases in the observation period. Those working persons with at least one car driver trip on their reporting day show slightly decreasing car driver trip rates. Hence, the peak-car phenomenon for working people mainly comes from fewer persons reporting at least one car driver trip rather than a reduction in car driver trip rates for those who remain car drivers.

The importance of car-use developments has already been shown for working people and pensioners. However, Figure 25 examines these groups by gender in more detail. Within the group of working people, males have a generally higher car-driver trip rate than females, and the peak-car effect is very marked. Females also show the effect, but the curvature is flatter. Interestingly, the number of car-driver trips of males and females are quite close to each other at the very last survey period (Early 2010s).

Figure 24: Proportion of Working People with Car-Driver Trips on Reporting Day and Number of Car-Driver Trips of Those People

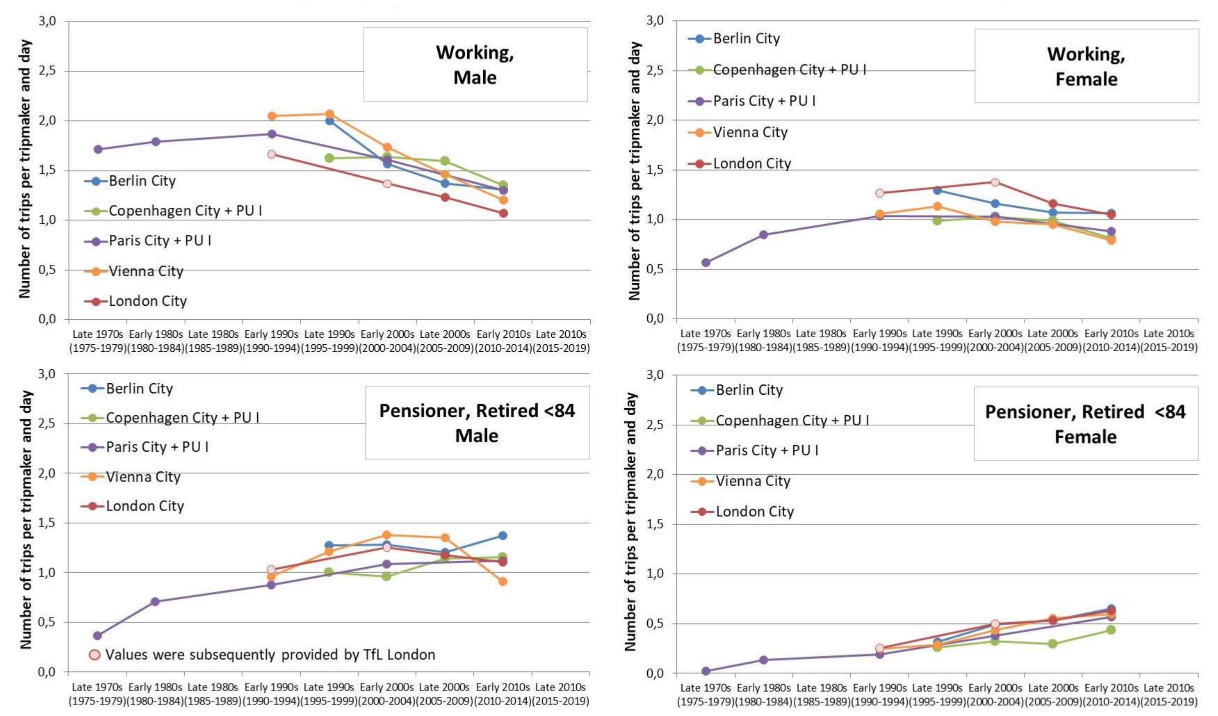


Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

For pensioners/retired persons of the recent survey period, car-driver trip rates of males still double the trip rates of female consistently. Both curves—male and female—are steadily increasing across time. Car-driver trip rates of females are interestingly very close to each other across cities. As a result, working males are responsible for a large part of the peak-car effect for all study areas.

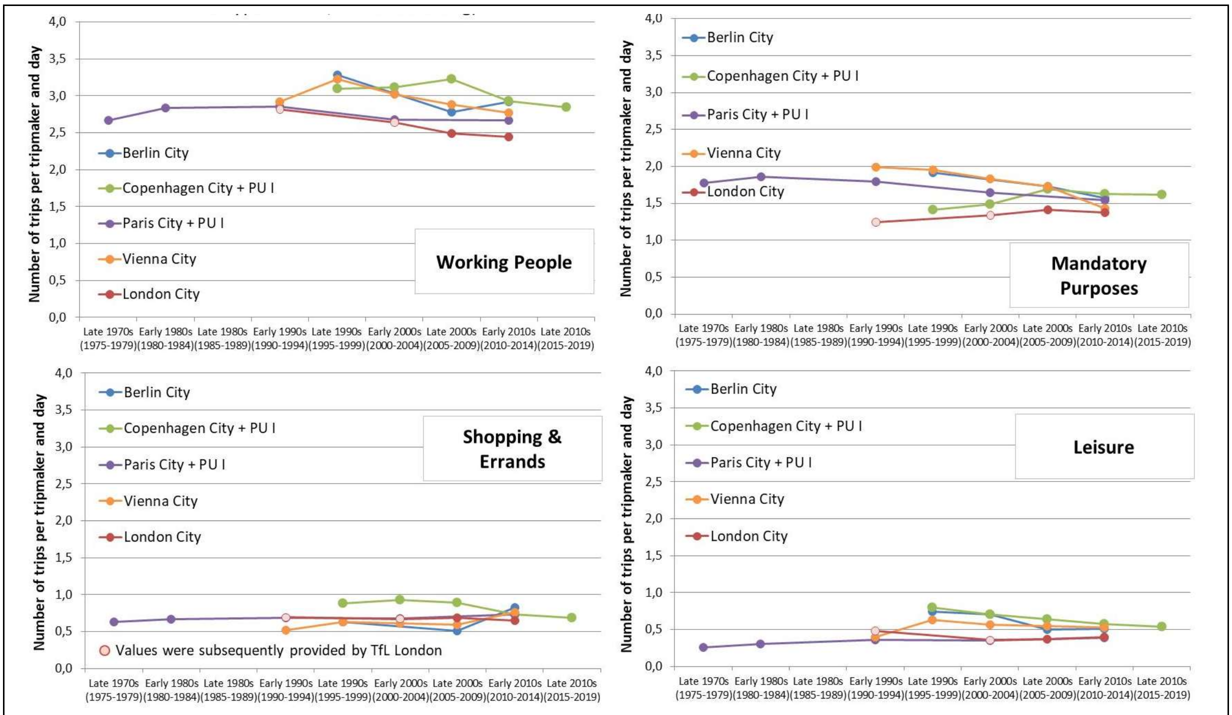
The following second main conclusion can be drawn at this point: The analysis of the peak-car phenomenon should mainly focus on working persons. Workers are the largest person group within the population, and they have the highest vehicle trip rates over all modes, particularly for car-driver trips. Working men show a more distinct peak-car effect than working women. The slope of the curve is much sharper for men than for the females.

Figure 25: Number of Car-Driver Trips of Working People and Pensioners by Gender



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 26: Number of Trips of Working People by Purpose **(Without Walking)**

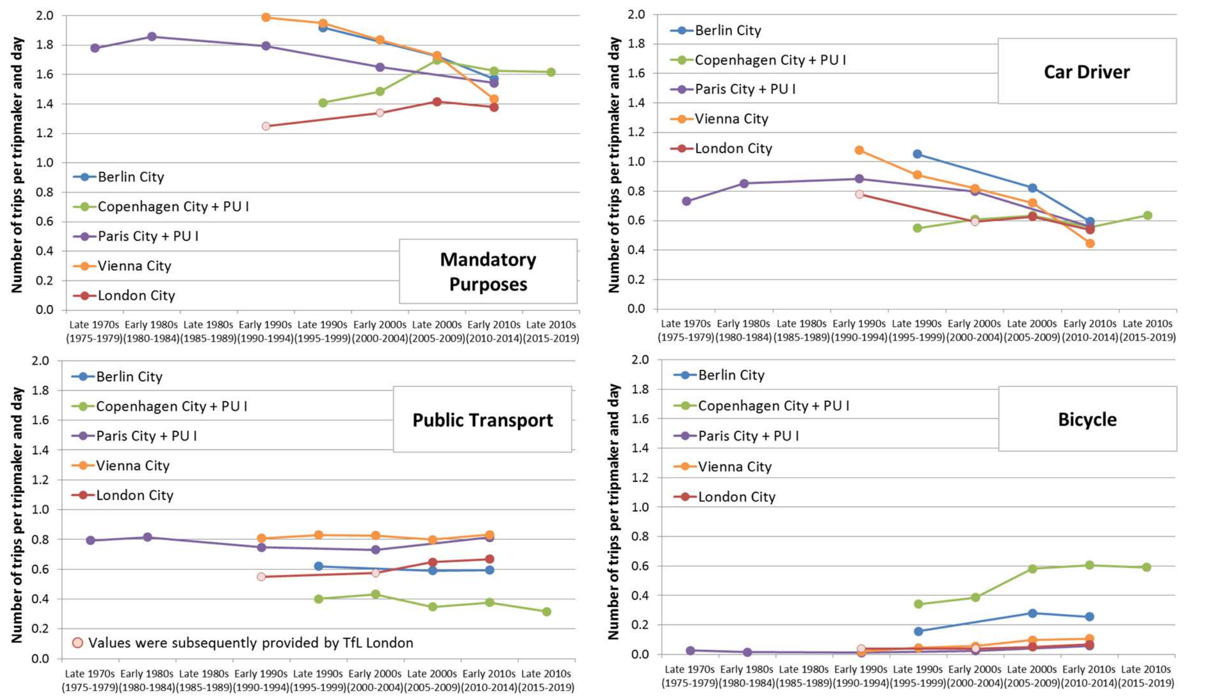


Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, home trips assigned to purpose of the previous activity comparable area type 'urban'

Based on the above analysis and conclusions, a more in-depth analysis is carried out for working persons from now on. Figure 26 analyses the trip rates of working people by purpose. For better classification, the figure also includes the total number of vehicle trips per worker per day. Trip rates are highest for mandatory purposes. In Early 2010, around 1.5 vehicle trips per employee and day are for mandatory purposes. These trips capture around 55 % of daily mobility on average. The other vehicle trips are distributed among shopping/errands and leisure. There are slightly more vehicle trips for shopping/errands than for leisure. Except for Copenhagen, data suggest a slightly decreasing development for mandatory vehicle trips along the timeline. Instead, vehicle trips of the other two purpose groups are rather constant over time.

The below Figure 27 distinguishes mandatory vehicle trips by transport modes (car driver, public transport, bicycle). Once again, all vehicle trips for mandatory activities are also included for comparison purposes. Car driver trip rates decrease for mandatory activities of working people in all cities except Copenhagen where these are quite stable from the Early 2000s on. Trip rates for public transport keep constant for all cities. Cycling is increasing for all cases. This analysis suggests that the peak-car effect for mandatory activities is driven by a mixture of fewer vehicle trips for mandatory activities, and a modal shift, particularly towards more cycling. Car-passenger trips might have increased incrementally, as well. In recent survey years, car-driver trips rates are actually below the public transport trip rates, except for Copenhagen. In Copenhagen, trips for all shown modes are quite stable from the Late 2000s on. Cycling trip rates for mandatory purposes in Copenhagen are almost as high as car-driver trips rates in recent years for this person group.

Figure 27: Number of Trips of Working People for Mandatory Activities **(Without Walking)** by Chosen Transport Mode



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, home trips assigned to purpose of the previous activity comparable area type 'urban'

As already highlighted above, mandatory vehicle trips are most important for understanding the peak-car effect. Figure 28 to Figure 30 distinguish car-driver, public transport, and bicycle trips by age for digging deeper into travel behaviour of working people.

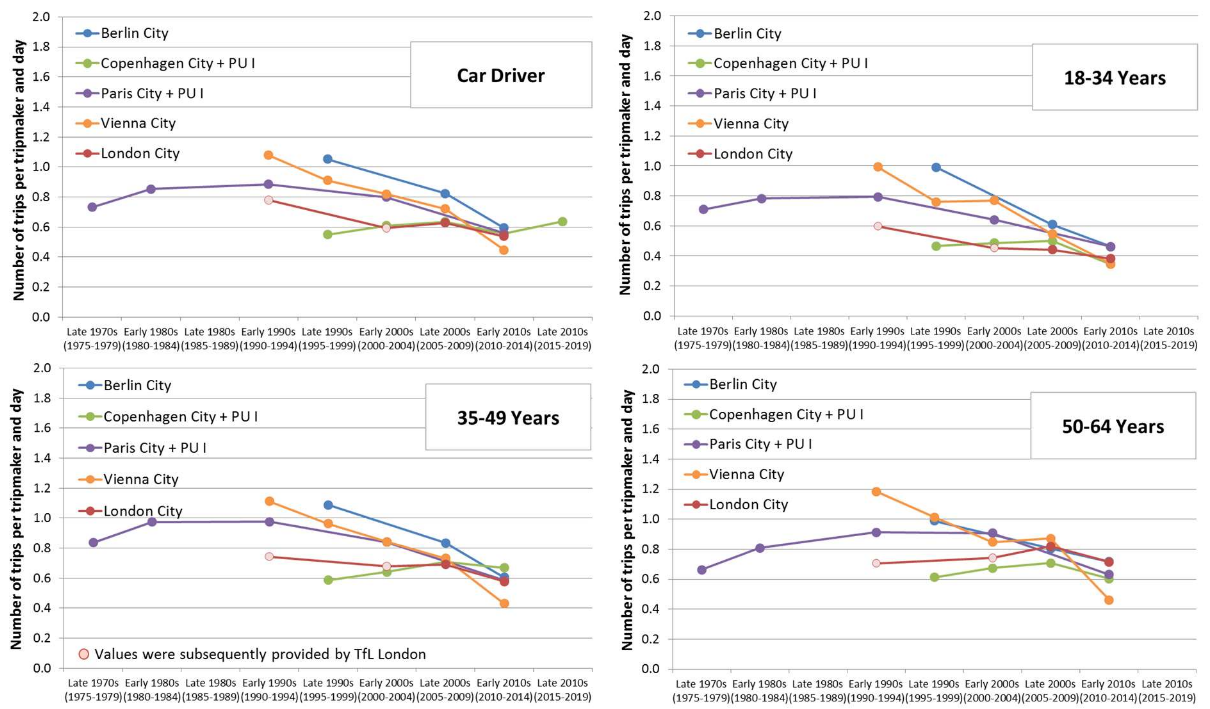
Similar developments are visible in terms of car-driver trips across the different age groups (Figure 28). Working people among the group of young adults (18–34 years of age) show a clear decrease of car-driver trips for all five study areas until the Early 2010s. Mid-agers (35–49 years of age) also consistently decrease their car-driver rates for mandatory activities. Only Copenhagen shows an incremental increase for that person group. Working people between 50 and 64 years of age also show declining car-driver trip rates. These developments happen at a substantially lower level for the youngest age group (18–34 years of age) compared to the two older age groups.

Figure 29 differentiates the number of public transport trips for mandatory activities by age. Overall, these numbers did not change significantly across years, and age groups are quite stable over time. Only the group of young adults show indications of slightly increasing public transport usage.

The last comparison in Figure 30 distinguishes cycling trips by age of working people. For this case, an increase of cycling affects all age groups in a similar manner. Growth rates are very sharp for all five Stage 3 cities. London and Paris, in particular, still show low absolute numbers of cycling.

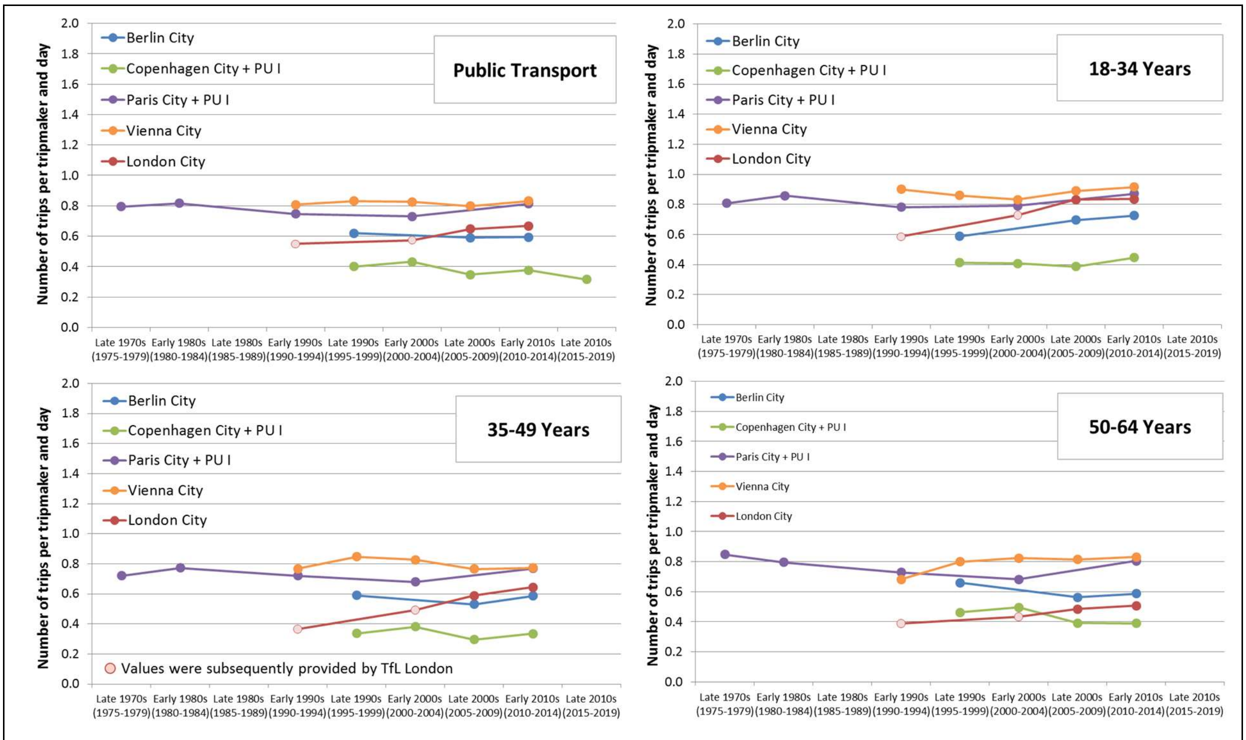
A third conclusion is that the differences are smaller than expected between the age groups of working people in mode choice for mandatory activities.

Figure 28: Number of Car-Driver Trips of Working People for Mandatory Activities by Age



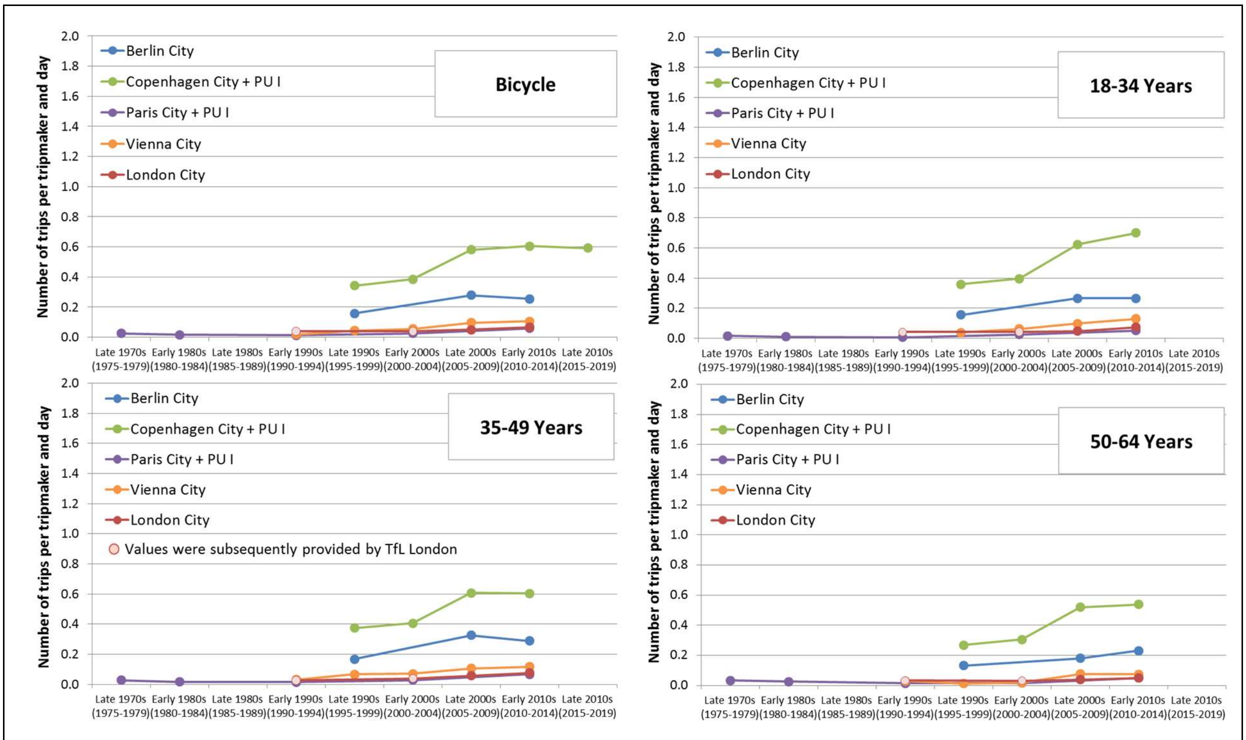
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', Late 2010s values by age groups for Copenhagen not shown due to small sample sizes for these cases.

Figure 29: Number of PT Trips of Working People for Mandatory Activities by Age



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', Late 2010s values by age groups for Copenhagen not shown due to small sample sizes for these cases.

Figure 30: Number of Bicycle Trips of Working People for Mandatory Activities by Age



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', Late 2010s values by age groups for Copenhagen not shown due to small sample sizes for these cases.

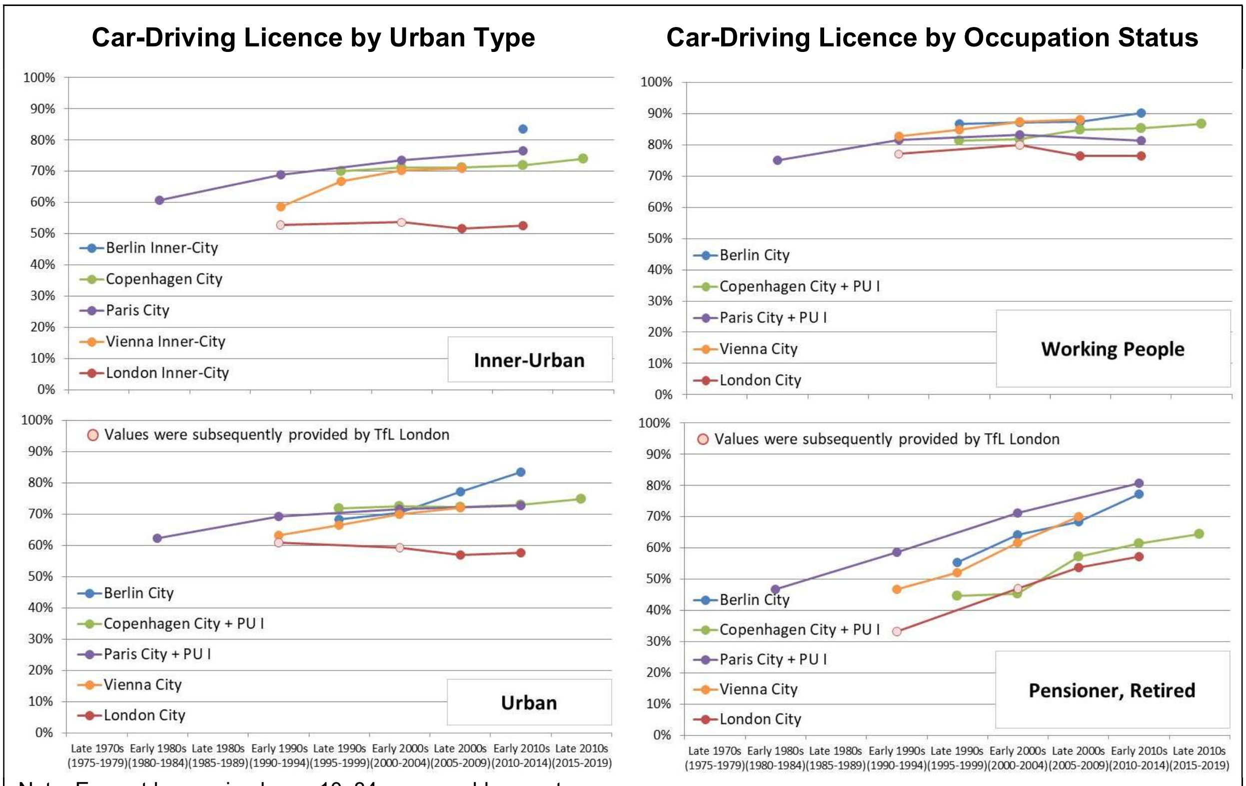
5.2.3 Drivers of Behavioural Change

The next Section explores some drivers of behavioural change as far as covariates are available in the HTS data. The analyses look into the drivers of change in general initially, and then for working persons. In the HTS data, mainly sociodemographic variables and mobility tools are available as explanatory variables; insights will be combined with those from other data sources in the discussion in Section 6.

Figure 31 illustrates the possession of car-driver licences for the whole population by urban type (left) and car-driver licences possession of working people and pensioners/retired persons for the comparable area type 'Urban' (right).

For both Inner-Urban areas and Urban areas the possession of car-driving licences is still slightly increasing for the whole population across study areas. Berlin shows the highest car-driving licence possession among the five Stage 3 cities. Instead, London has significantly lower overall numbers. For working people in Urban areas, data show a saturated demand of car-driving licences at a quite high level during the recent survey periods (since the late 1990s). The values for working people show less variation in comparison to the whole population. For pensioners/retired persons, the proportion of driving licences increased sharply within the last decades. In the Early 2010s, pensioners in Berlin, Paris, and Vienna show the same high numbers of driving licences as working people. Driving licence possession of pensioners in Copenhagen and London is comparatively low.

Figure 31: Car-Driving Licence by Urban types (Left) and Occupation Status (Right)

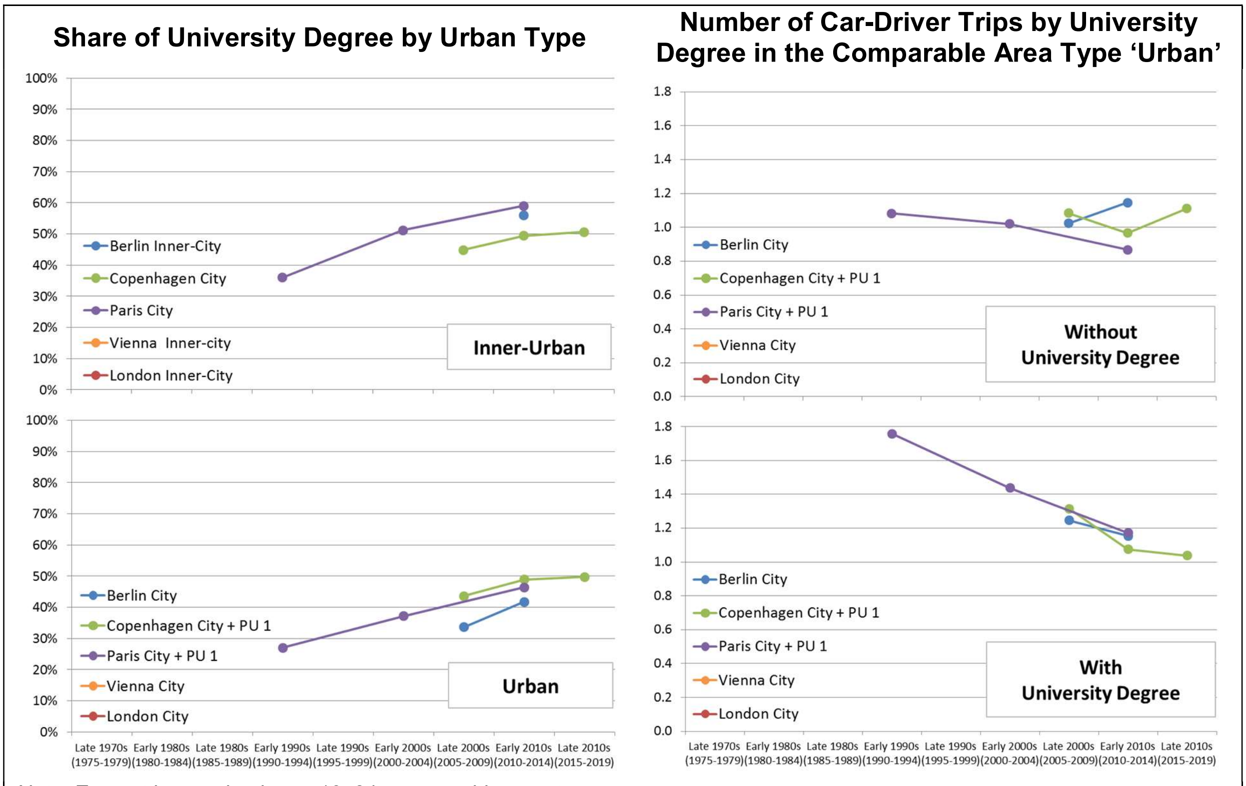


Note: Ex-post harmonised, age 10–84, comparable area types

Berlin, Copenhagen, and Paris were able to provide a variable for education within the HTS data set. Figure 32 illustrates the proportion of population with university/college degree across time. Education status rose for all three study areas in recent decades. People living in the Inner-Urban areas have even a slightly higher education than people living in Urban areas. On the right side of Figure 32, a clear time-related correlation between education status and number of car trips has been observed. For people without university degree, no significant changes in car-driver trip rates appear in the data. Around one trip per inhabitant per day is completed by car on average. Referring to the Paris data, people with higher education completed almost 1.8 car trips per day in the Early 1990s. This number dropped sharply to 1.2 car trips per day in the Early 2010s. This corresponds with a car-use reduction of one third of those car trips.

As a result, higher educated people changed their travel behaviour of car use quite drastically, whereas the corresponding values of less educated people remained almost constant on a lower level. On the other hand, developments indicate that for the last survey periods many more people are higher educated than only a few decades ago, and those people reduced their car use. However, education might not be a direct predictor of less car use but it seems to be a moderator variable which is, of course, correlated with income.

Figure 32: Share of University Degree by Urban type (Left) and Number of Car-Driver Trips by University Degree (Right)



Note: Ex-post harmonised, age 10–84, comparable area types

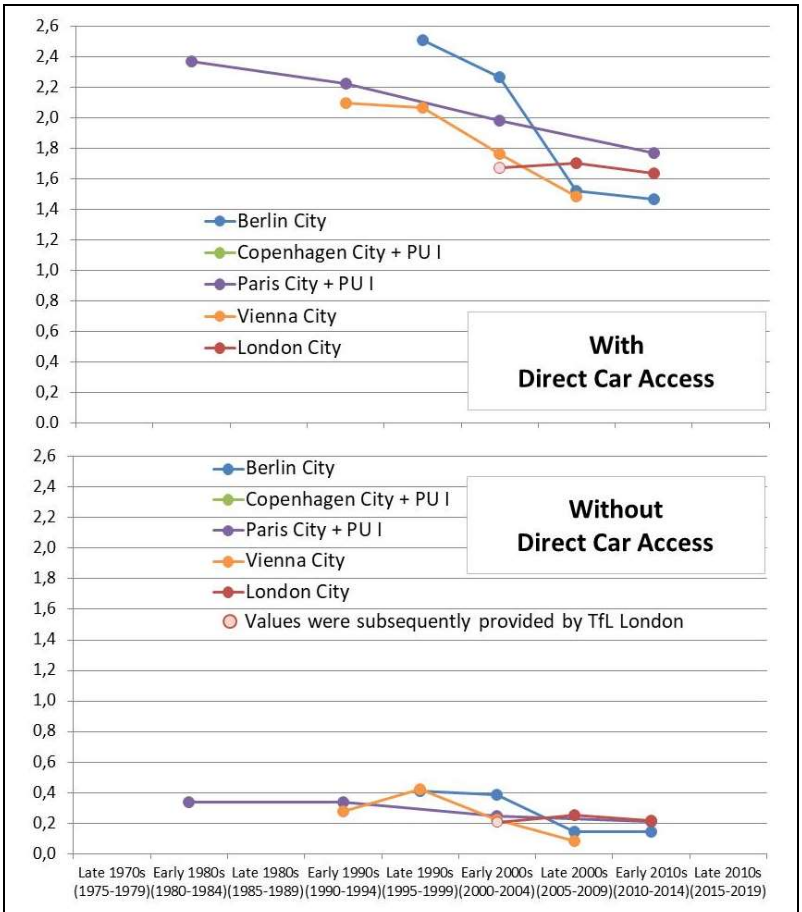
Literature often suggests that car use strongly depends on the availability of, or direct access to, cars. Direct access to cars is understood as persons with a driver's licence and at least one car available within the household. This evidence has been already supported by the previous analyses carried out within this study. People with car access have many more daily trips by car than people without car access. Car-use reduction intuitively takes place as soon as car access is decreasing within a population.

Figure 33 to Figure 35 examine car-trip rates distinguished by car-access of three different age groups

- Young adults (18–34 years),
- Mid-agers (35–64 years), and
- Seniors (65–84 years).

Copenhagen has not been able to provide a variable for car access within their HTSs. For all other study areas, young adults decrease their car-use. The proportion of young adults with direct car access dropped clearly. In the case of Berlin, young adults with car access show more than 40% fewer trips by car in the Early 2010s in comparison to Late 1990s. Young adults without car access also reduced their car use but at a much lower level. The absolute numbers do not matter so much but, using Berlin as an example, young adults without car access even reduce their car use by 65 %. In a nutshell, young adults reduce their car use for both cases, with and without direct car access.

Figure 33: Car Trips of Young Adults (18-34) by Car Access



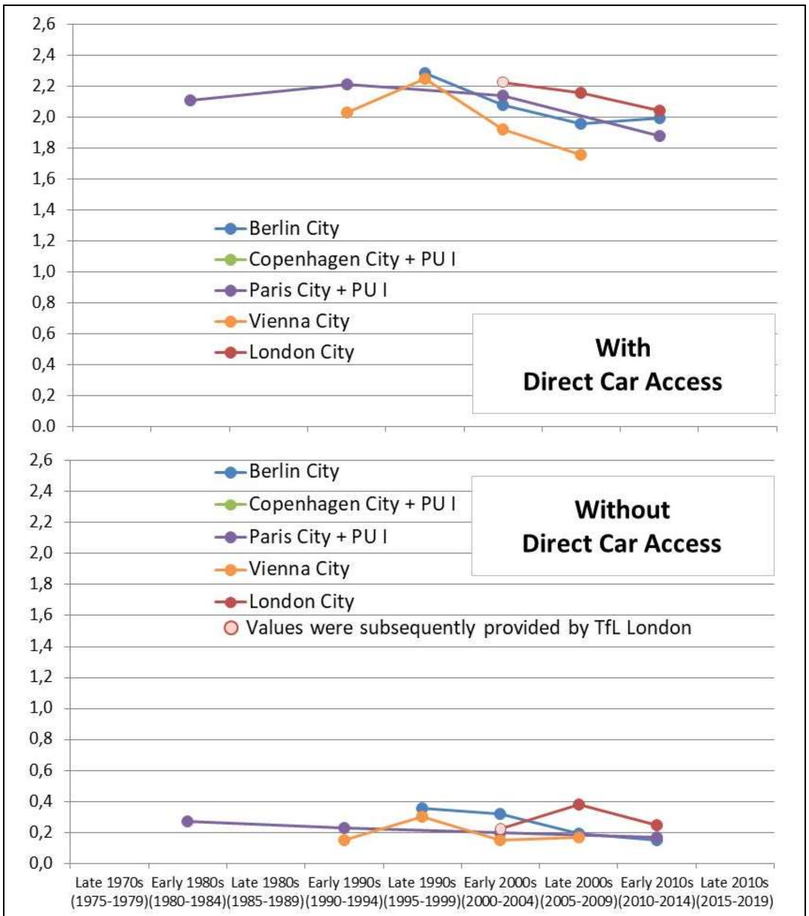
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', without Copenhagen

Figure 34 presents the number of car trips distinguished by car access for mid-agers. The differences for mid-agers are less pronounced than for young adults over time. Mid-agers with direct car access have only slightly reduced their daily car travel until the recent survey period (Early 2010s). People within the 35 to 64 years of age range without car access have few daily trips by car and there are almost no changes across time for most study areas.

Seniors within the age span of 65 to 84 years are the last person group to be analysed. Seniors with direct car access have constant or a slightly increasing number of car trips across the time-line. Regardless of some outliers, seniors without car access did not change their car-use behaviour within the last few decades.

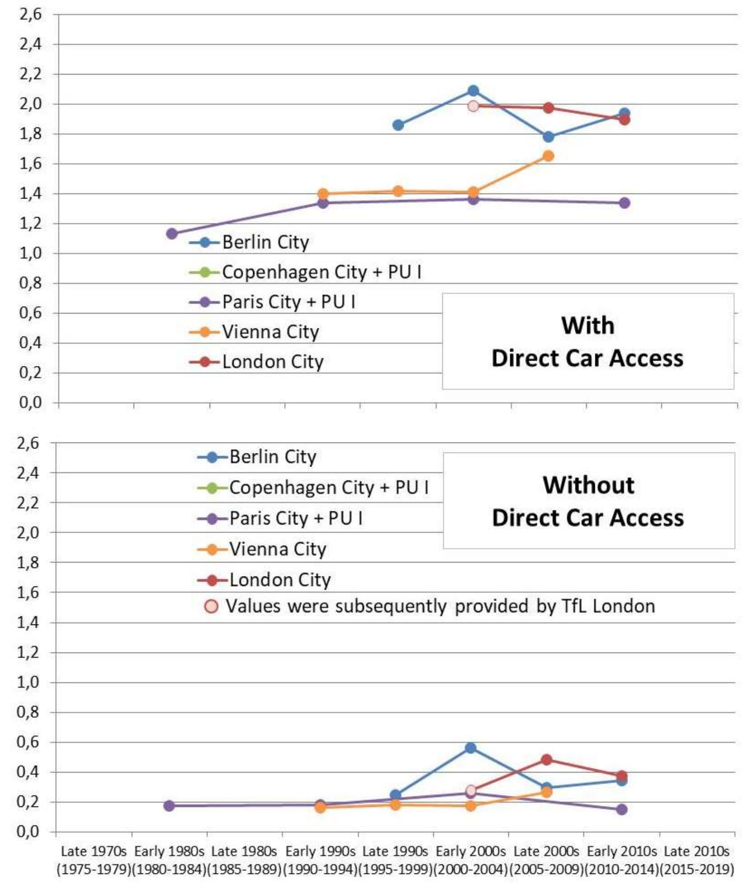
All in all, Figure 33 to Figure 35 once again show the strong dependency of car-trip rates and direct access to a car. Car-use reduction has been notable for the group of young adults and significantly less so for mid-agers. Seniors do not reduce their car use. The higher access to cars due to more drivers' licences among seniors, and more cars in households, underpin the assessment that seniors counteract the peak-car effect.

Figure 34: Car Trips of Mid-Ager (35–64) by Car Access



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', without Copenhagen

Figure 35: Car Trips of Seniors (65–84) by Car Access



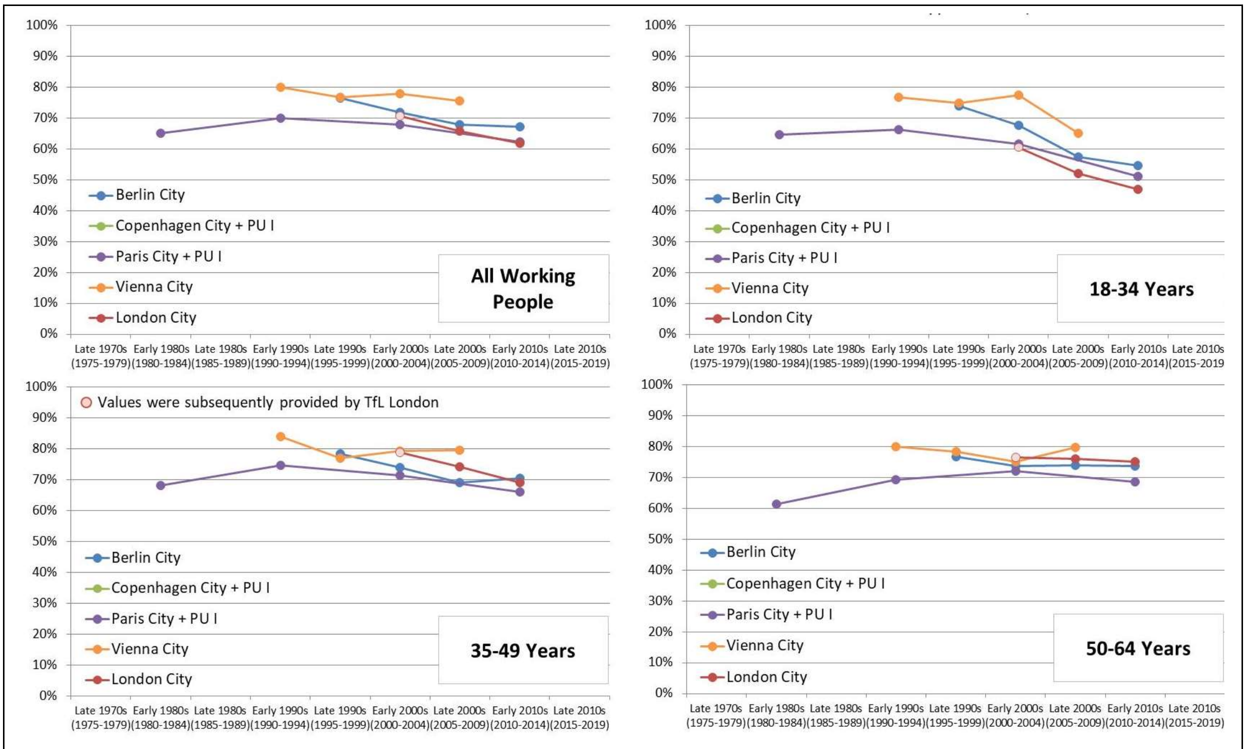
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban', without Copenhagen

The previously presented analyses examined car use reduction with regard to the whole population. The last figures demonstrated clearly that age also matters. As composition effects have already been shown above: Working persons are the largest person group, and the proportions of the specific person groups are quite stable over time. Consequently, drivers of car use reduction will subsequently be analysed specifically for working people by age. Again, three age groups were chosen for analysis purposes. As professional life regularly ends around 65 years of age for most cases, age groups are formed into

- 18–34 years of age,
- 35–49 years of age, and
- 50–64 years of age.

Figure 36 shows the proportion of people with direct car access for all working people differentiated by age groups. Once again, as Copenhagen was not able to provide a variable for household motorisation with their HTSs, data points are missing for Copenhagen. Direct car access of all working people is generally slightly declining, but still at a quite high level. The youngest age group shows the clearest decline of car access. Early 2010, only around 50 % of young workers living in Urban areas have direct access to a car. Car access of working people between 35 and 49 years of age only slightly decrease. Across all study areas, those people have with 70 % a higher access than younger working people on average. The oldest person group of working people (50–64) shows the highest car access (around 75% on average) and these numbers do not decrease. The lattermost person group will soon retire and likely carry those high car-access rates into the next life cycle stage.

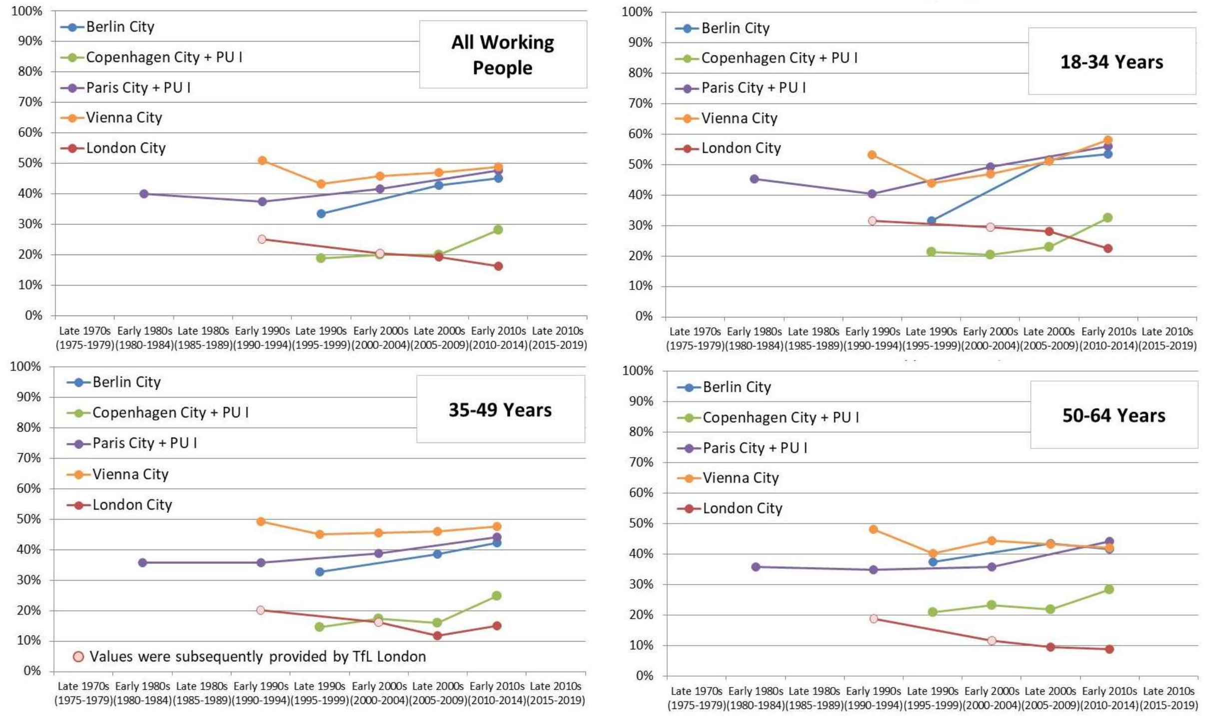
Figure 36: Direct Car Access of Working People by Age



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

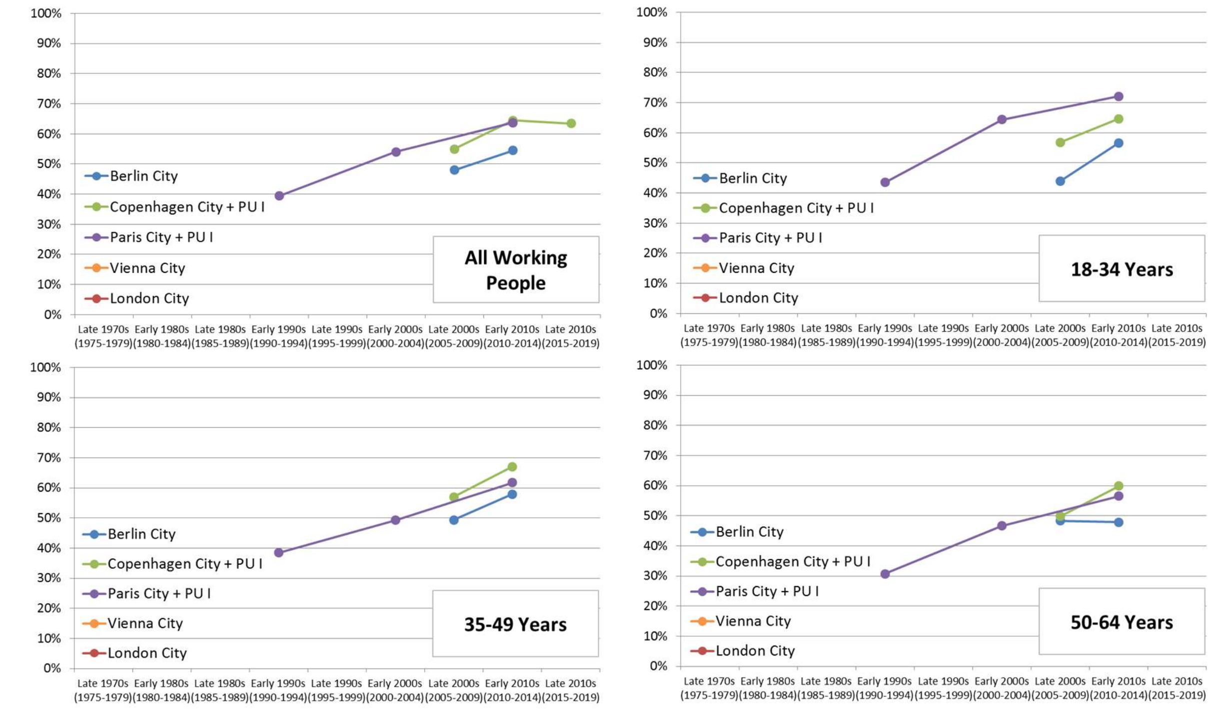
Figure 37 shows the availability of PT season tickets for working people, in general and by age. The definition of PT season tickets differs substantially among the five cities (see Roider et al. 2016 for details). It is especially different for London where the Oyster card was introduced in 2003. All study areas but London show increasing numbers of PT-season-ticket ownership. For Berlin, Paris, and Vienna the most recent values are comparatively high, around 50 % of all working people. Copenhagen is also increasing, but at a lower level. For London, the assessment of PT season ticket availability is not very meaningful as the payment method in London is very different from the other cities (Oyster card, introduced in 2003). Young adults (18–34 years of age) show the highest rate of access to PT season tickets. For Vienna, almost 60 % of young working adults have a PT season ticket. Comparative values for Berlin and Paris are only slightly lower. Young adults in Copenhagen also increase their PT season ticket ownership rates (around 30 % at Early 2010s). Working people between 35 and 49 years of age have slightly lower access to PT season tickets. Values slightly increase throughout the last years. Vienna reached the highest value yet of around 50 % at the Early 2010s. A clear tendency of increasing PT season ticket ownership is not evident for working people within the age span of 50 to 64 years. Values are slightly lower than for the mid-agers (around 40 %) in Berlin, Paris, and Vienna.

Figure 37: PT Season Ticket Availability of Working People by Age



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 38: College/University Degree of Working People by Age



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 38 analyses the education status of working people, generally and by age group. For all cases, the education status increased over time. Looking at Paris and Copenhagen, the proportion of working persons with college/university degree has reached almost 65 % (Berlin 55 %). In Paris, values have increased by 25 percentage points since the Early 1990s (Starting point 40 %). Young adults (18–34 years of age) show the highest education. In Paris, more than 70 % of all young working persons have a college/university degree. Copenhagen and Berlin show slightly lower numbers. Workers from 35 to 49 years of age also have much higher education levels in the Early 2010s than the Early 1990s. The gaps between this group and the oldest group within working people are declining.

5.3 Cohort Analysis

5.3.1 Analytical Approach Using the Example of Paris

Different perspectives can be taken for applying descriptive APC analyses. As already described in Section 4, and taking into account the final HTS data availability after completing the temporal harmonisation task (see Section 4.3.3), Paris has the best data situation in terms of provided microdata among all five Stage 3 cities. Micro-data harmonisation for Paris has been successfully completed back to the Late 1970s. Therefore, all important (generational) cohorts are available with an adequate sample size for each group. Previous data analyses have highlighted that developments are frequently very similar for many indicators, and across study areas. These, and further reasons, have led to the decision to carry out cohort analyses specifically for the example of Paris.

The main idea of this analytic approach is to support and amend previously found analytic results. Two different types of calculations are presented below:

- Interdependency of age and cohort (generational approach) and
- Interdependency of age and period of time (survey period approach).

The first approach directly shows the development of specific indicators for different generational cohorts across age groups (CAP data arrays, see Section 3.2). For this case, the survey period is only indirectly assessable, and generations move across time while aging. A certain age group of a cohort can be included either in one survey period or in the next one. For example, millennials (born 1985–1999) can be observed as young adults (18–34) in the Early 2000s but also in the Early 2010s. A person who is born 1985 was already 19 years of age in 2004 (Early 2000s) but 29 years of age in 2014 (Early 2010s) and therefore remains still within the group of young adults. In this case, a young adult from the millennial generation can be surveyed at different points in time.

The first attempt to disentangle cohort-specific travel behaviour relationships will be conducted for

- Trip rates,
- Daily distances,
- Average trip distances,
- Direct car access and
- PT season ticket ownership.

The second approach focusses more on the interrelationship of age, cohort, and period of time. For this case, data management, preparation, and presentation are slightly more sophisticated. The same distances between survey periods and age groups are chosen to be able to follow generations across time (APC data arrays, see Section 3.2). For the city of Paris, a ten-year interval of survey periods exists from the Early 1980s until the Early 2010s. This advantageous fixed interval can simply be applied for age groups as well.

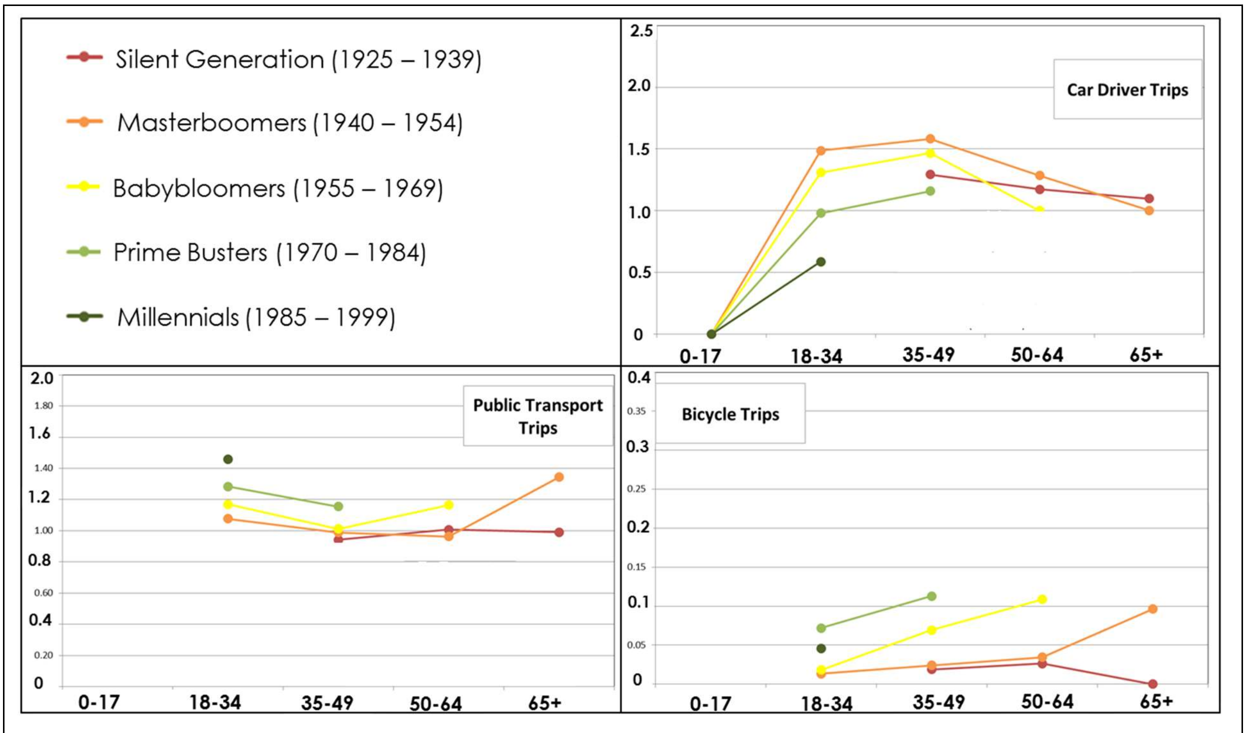
5.3.1 APC Analysis Focussed on Age and Cohort (Generations)

The following figures (Figure 39 to Figure 42) analyse travel behaviour patterns and framework conditions of different generational cohorts. Cohorts are defined base on the H2020 Mindset project according to the rules described in Section 3.2 as follows:

- Silent Generation (born from 1925 until 1939, red line),
- Master Boomers (born from 1940 until 1954, orange line),
- Baby Bloomers (born from 1955 until 1969, yellow line),
- Prime Busters (born from 1970 until 1984, bright green line) and
- Millennials (born from 1985 until 1999, dark green line).

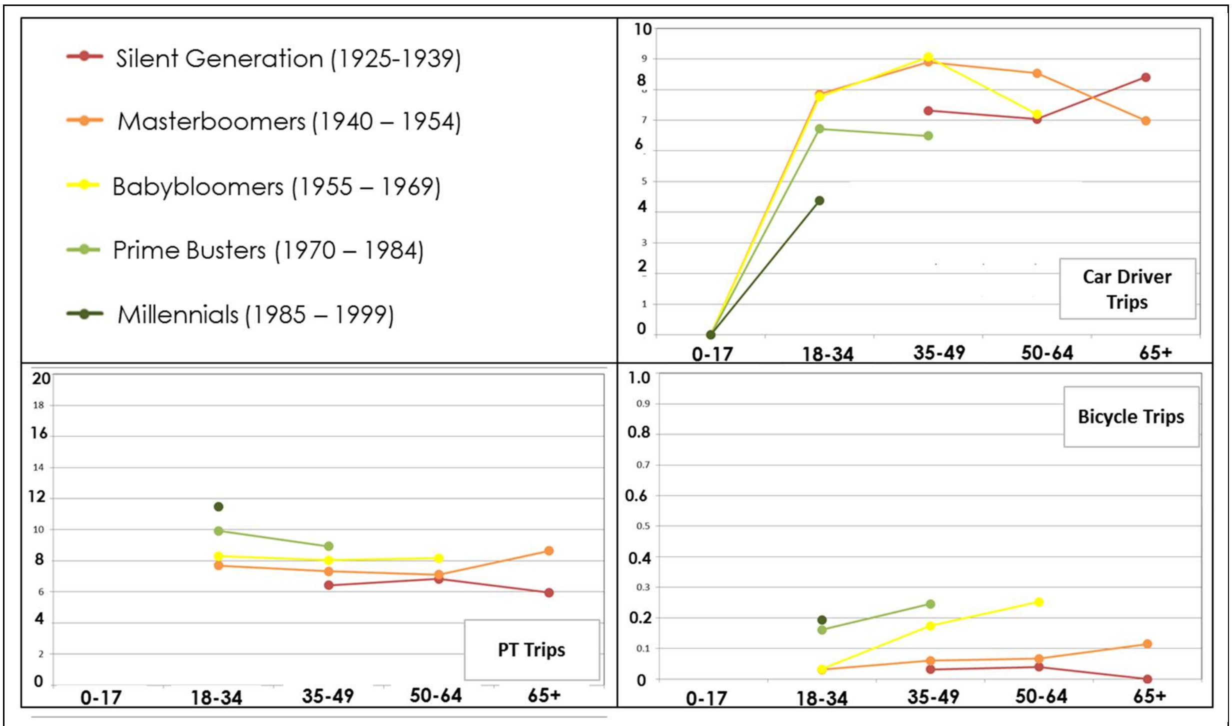
Figure 39 illustrates trip rates of Parisians by generation and main mode of transport. Some data points are not included in the diagrams as not every age group of generations is available within each survey period. With regard to car-driver trips per tripmaker per day, clear cohort-specific travel patterns occur. The younger a generation is, the fewer car-driver trips it has. This rule particularly applies for young adults (18–34 years of age). This tendency is also observable while aging into the next stage. Prime busters show significantly fewer car-driver trips even at their middle ages (35 to 49). Only the Silent Generation has fewer car-driver trips at this age group. This is intuitively comprehensible, because data points for people of the Silent Generation mainly result from survey years where generally motorisation, driving licence ownership, and therefore car access, were lower than for later generations at the same age. The use of public transport and cycling is opposite to the described generational relationships for car-driver trips. Younger generations have systematically more public transport and bicycle trips than their predecessors. These correlations are also visible in the later life stages. Remarkably, Baby Bloomers and Prime Busters show a significantly increasing cycling behaviour across their lifetime. Nevertheless, the number of bicycle trips in Paris is low in comparison to the other Stage 3 cities of CREATE.

Figure 39: APC Analysis – Trip Rates of Working People in Paris by Generations and Mode of Transport



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 40: APC Analysis – Daily Distances of Working People in Paris by Generations and Mode of Transport

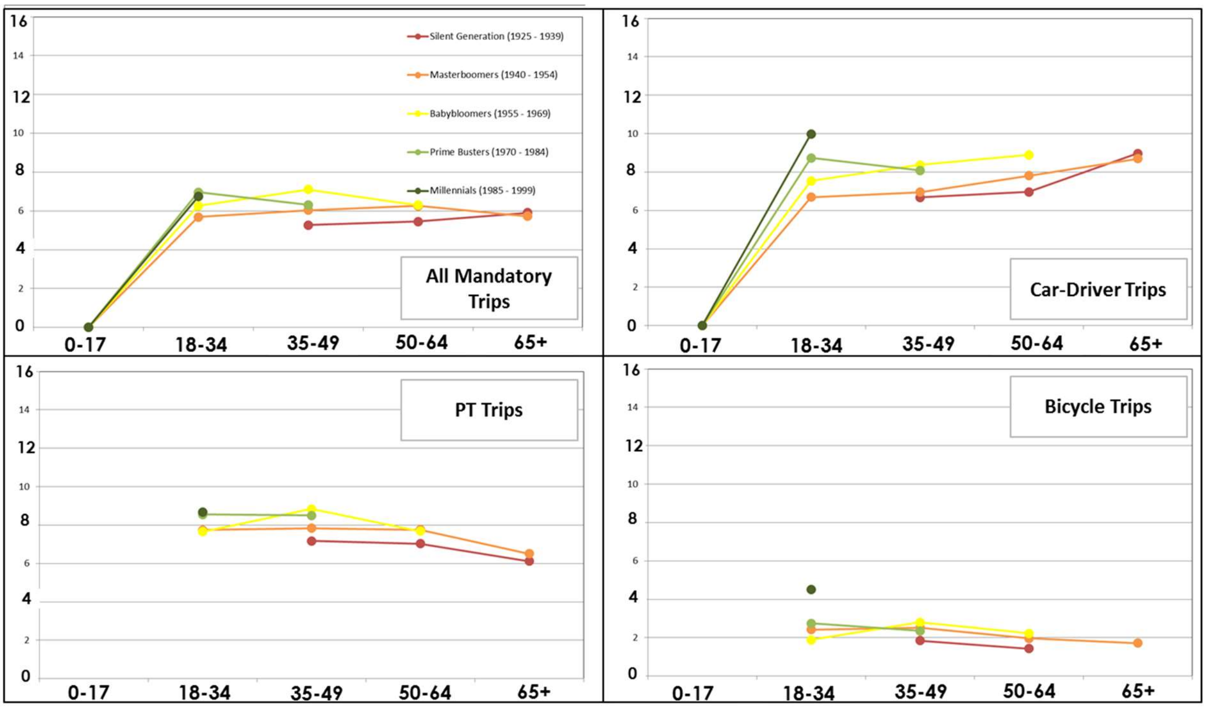


Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 40 analyses the daily distances of working people by generation, sorted into main modes of transport. The daily distances of car-driver trips performed by working people (averaged across the whole group) show that younger generations drive noticeable less as young adults than previous generations. Data suggest that Prime Busters did not show a growth rate of car-driver trips as mid-agers compared to the Baby Bloomers and Master Boomers. For the latter two groups, very similar car-driver travel patterns are observable for daily distances. Daily distances of public transport and cycling show qualitatively more similar patterns than for trip rates. com. This assessment is also driven by the fact that daily distances of cycling are almost negligible for Parisian working persons.

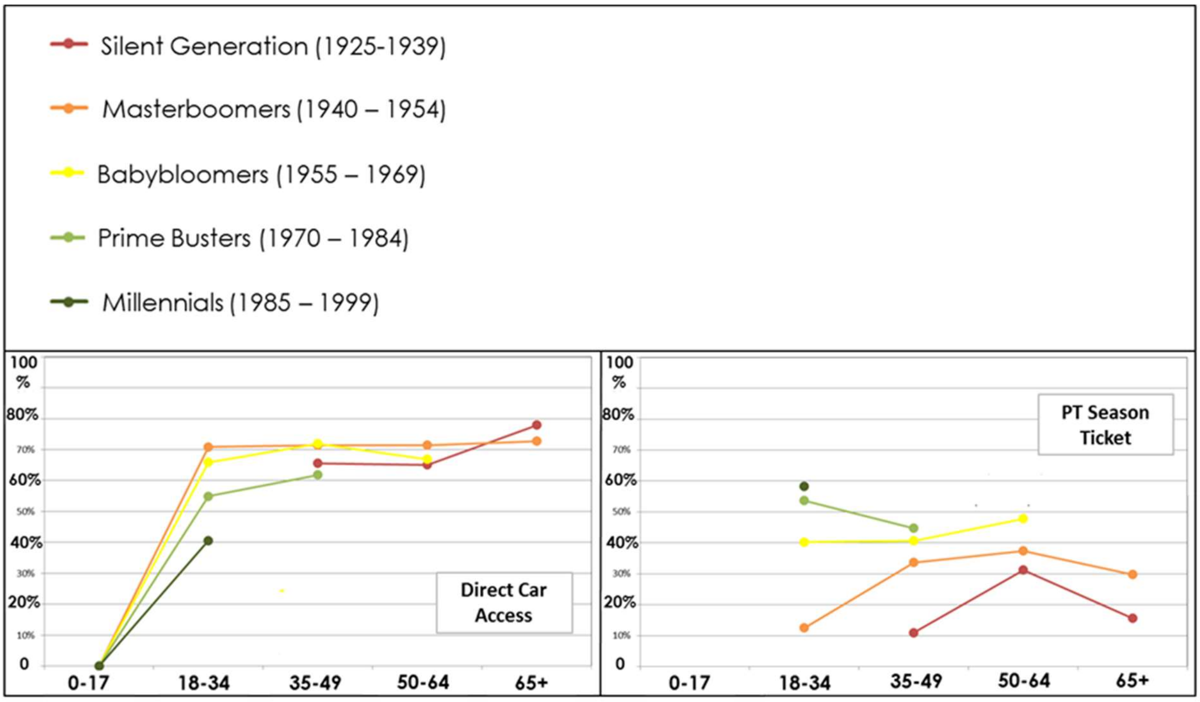
Figure 41 specifically examines the average distances per trip of working people for mandatory activities at trip level. The indicators are distinguished by generation and main mode of transport. In relation to all mandatory trips, general trip distances are only slightly larger for younger generations than for older ones at a young adult life stage. Strong dependencies over time are not observable for distances in terms of mandatory activities. Regarding car-driver distances, younger generation even have longer distances when driving than their predecessors—so the reduction in daily car distances (Figure 40) are entirely due to reductions in car driver trip rates, not trip lengths. This development could be interpreted as modal shift from car to public transport, as PT tends to be the common method for shorter mandatory trips. Working persons with longer distances to work seem to still be car-dependent. The origin and destination of residence locations and workplaces are probably in less dense urban areas of Paris, where still quite good opportunities for car parking exist. In other words, the modal shift from car-driver to public transport occurs in the denser City and Inner-City areas. Interestingly, for the few cases were a bicycle is chosen for mandatory trips, trip distances are quite short (around 2 kilometres per trip) for almost all generations and ages. Only the most recent generation (Millennials) shows higher (almost twice as much) average trip distances for mandatory activities. Following, direct car access and PT season ticket ownership are analysed as two obviously important variables describing travel behaviour related framework conditions (Figure 42).

Figure 41: APC Analysis – Average Trip Distances of Working People for Mandatory Activities in Paris by Generations and Mode of Transport



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 42: APC Analysis – Direct Car Access and PT Season Ticket of Working People in Paris by Generations



Note: Ex-post harmonised, age 10–84, comparable area type 'urban'

Paris HTS data suggests, convincingly, that the main driver of fewer car-driver trips and distances among young employees (18–34 years of age) is the declining car access. Even the saturation curve seems to have a lower peak at the age of 35 to 49 years. Prime Busters at this age have 10 percentage points less direct car access than their two predecessors (Baby Bloomers and Master Boomers). Opposing effects have contrary developments of public transport season ticket ownership among working people in Paris. A very strong relation occurs between the belonging to a generation and the proportion of public transport season ticket ownership. Almost 60% of millennials between 18 and 34 had a public transport season ticket, and therefore a low barrier to access the public transport system, versus around 10% of Master Boomers at the same life stage. These changes in accessibility may have a strong influence on mode choice and travel behaviour.

5.3.2 APC Analysis Focussed on Age and Period

Tendencies of car-use behaviour and modal shift have already been observed. Developments are clear and comprehensible, but their distinction into age, period, or cohort effects is still difficult due to confounding variables and survey year affiliation of generations within the previously examined cases. Therefore, the perspective of the following analysis shifts towards age and period. Table 20 contains the data of car-driver trips for working people in Paris by age and period. This data representation is, by definition, not suitable to completely disentangle age, period, and cohort effects, but gives further insights into generational behaviour across life stages.

For better understanding of the triangular circumstances within APC analyses, authors added the birth cohort ranges in the lower part of Table 20. In APC data arrays, cohorts move diagonally from the upper left part of the table to the lower right part. The upper part of the table contains the car-driver trip rates by age and survey period.

Figure 43 shows the same numbers in a diagram form. For interpretation purposes, the APC measurement approach is also included into the picture. The colours chosen for the earlier survey period are red (Early 1980s) and orange (Early 1990s).

Table 20: APC Array of Car-Driver Trips of Working People in Paris by Age and Period

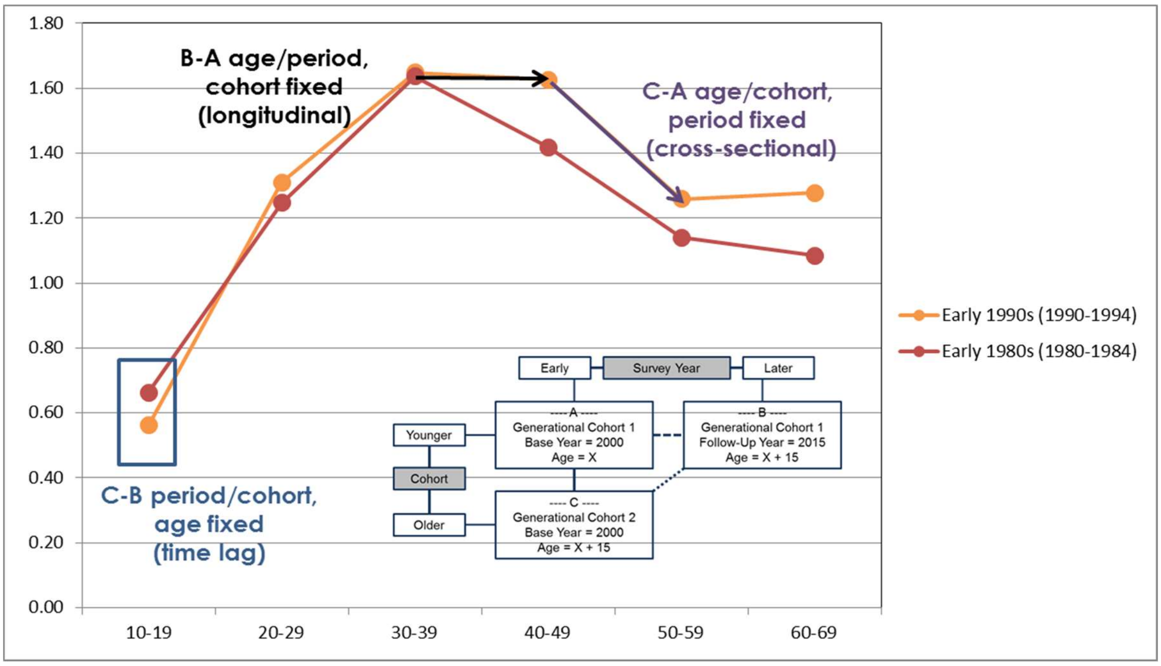
Car-Driver Trips of Working People in Paris		**Survey Period**			
		Early 1980s (1980–1984)	Early 1990s (1990–1994)	Early 2000s (2000–2004)	Early 2010s (2010–2014)
Age Groups	10–19	**0.66**	**0.56**	**0.26**	**N/A**
	20–29	**1.25**	**1.31**	**1.00**	**0.76**
	30–39	**1.64**	**1.65**	**1.44**	**1.10**
	40–49	**1.42**	**1.63**	**1.48**	**1.30**
	50–59	**1.14**	**1.26**	**1.35**	**1.04**
	60–69	**1.08**	**1.28**	**1.11**	**1.25**
Birth Cohorts		1961–1974	1971–1984	1981–1994	1991–2004
		1951–1964	1961–1974	1971–1984	1981–1994
		1941–1954	1951–1964	1961–1974	1971–1984
		1931–1944	1941–1954	1951–1964	1961–1974
		1921–1934	1931–1944	1941–1954	1951–1964
		1911–1924	1921–1934	1931–1944	1941–1954
		1899–1914	1911–1924	1921–1934	1931–1944

The most recent survey years are draw in bright green (Early 2000s) and dark green (Early 2010s). For better explanations, meaningful information is introduced into the following three graphs. Using this type of presentation, car-driver trip behaviour of cohorts can be easily tracked over time. The first examination (Figure 43) tries to explain various interesting issues and relationships only for the comparison of the first two survey periods, the Early 1980s and Early 1990s. The figure shows car-driver trip rates for working people of different age groups surveyed at these two points in time. For a specific age group, differences are measured as period/cohort effects (C-B) at two different points in time (time lag). It is also possible to track an aging cohort over time. In the present case and the chosen 10-years interval of periods and age groups, age/period effects (B-A) can be traced in a longitudinal manner. Finally, two age groups —and in this case two cohorts—, can be cross-sectional compared at the same point in time (C-A).

Interestingly, only slight differences occur at the first two survey periods by age. Car-driver trip rates increased for working people until an age of 40 and dropped afterwards. Paris employees between 40 and 69 had more car-driver trips at the Early 1990s than 10 years before. If the cohort of an age within 30-39 years is fixed and traced towards the next age group, the high car-driver trip rate of the Early 1980s is carried into the next survey period (Early 1990s). The next Figure 44 adds the two most recent survey periods and focusses on time-lag and cross-sectional assessment of changes in travel behaviour. People of the same age decrease very sharply their car-driver trips across time. Until 40 years of age, a very systematic development over time and less growth rates of car-driver trips by age are observable. From a cross-sectional perspective, people decrease their car use significantly between 40 and 60 years of age but with different intensities. Independently from period or age, cohort specific behaviour patterns are assumable.

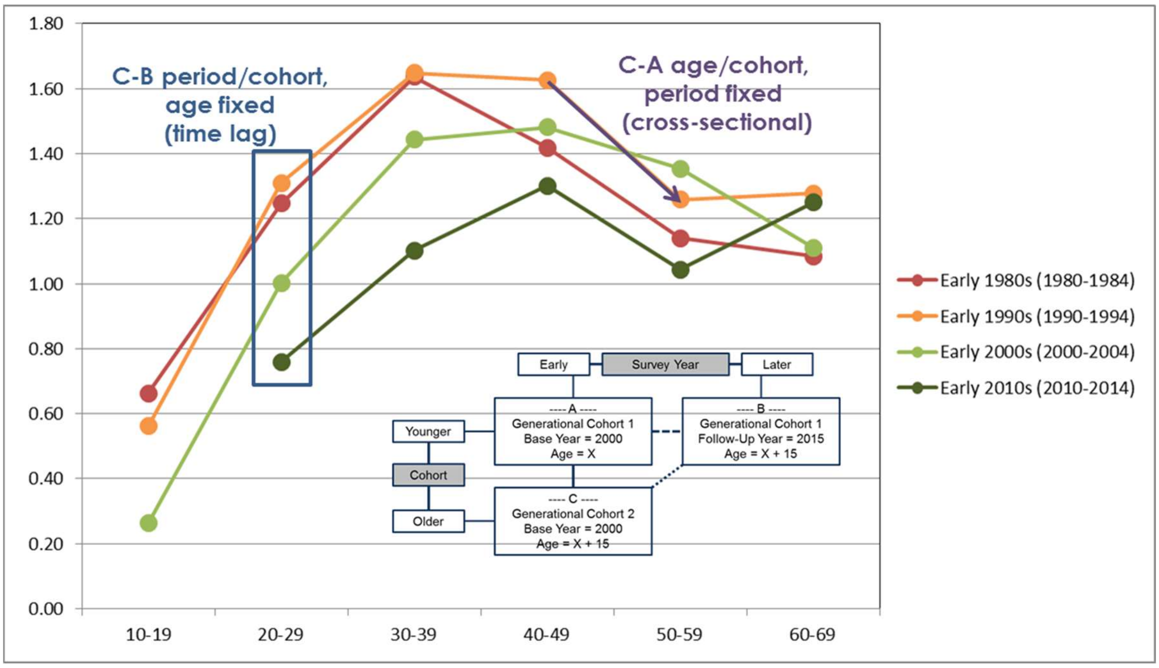
Finally, Figure 45 introduces specific birth-year cohorts. Very uniform and comprehensible developments are observable. Tracking different cohorts over time and across age reveals that younger cohorts have much less car-driver trips per mobile working person and day than older cohorts. Car dependency seems to become less important for younger generations and particularly in the recent survey periods.

Figure 43: APC Analysis – Car-Driver Trips of Working People in Paris by Age for the Early 1980s and the Early 1990s



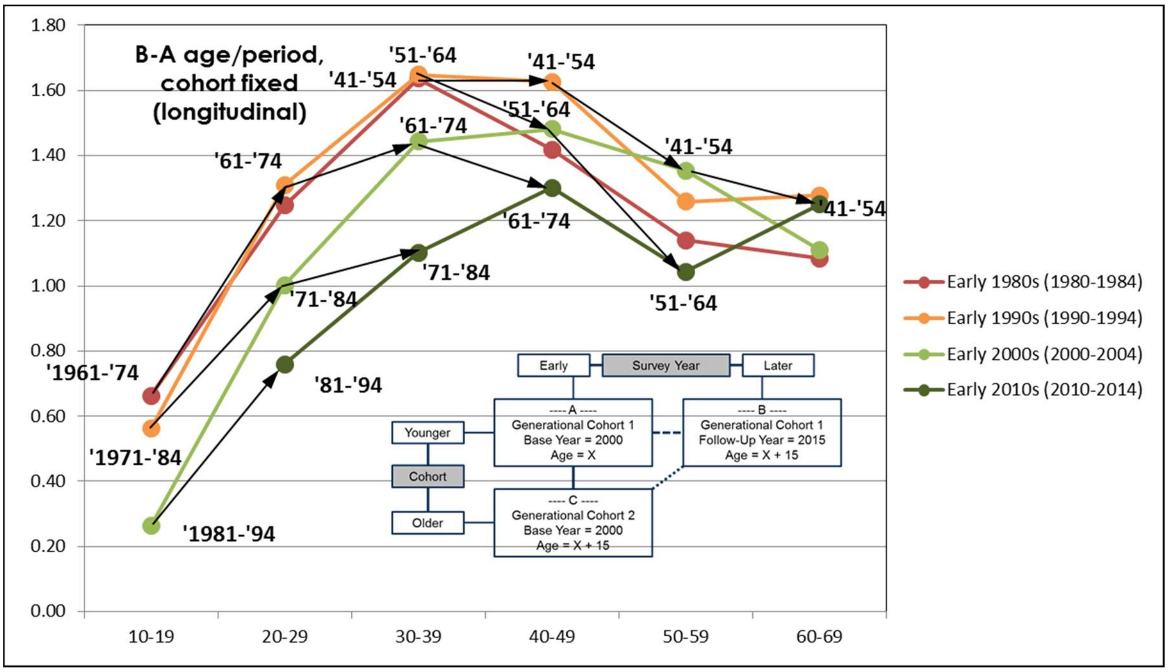
Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 44: APC Analysis – Car-Driver Trips of Working People in Paris by Age for all Survey Periods



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

Figure 45: APC Analysis – Car-Driver Trips of Working People in Paris by Age and Period with Representation of Specific Birth Cohorts



Note: Ex-post harmonised, age 10–84, workdays Mon–Fri, only tripmakers, comparable area type 'urban'

5.4 Qualitative Assessment of Drivers and Barriers for Car-Use Reduction

5.4.1 Motivation

The primary focus of Work Package 3 is on the analysis of quantitative data relating to travel trends. At an early stage of the quantitative analysis it became clear that the observed travel trends in all five Stage 3 cities were strikingly similar. Whilst some explanation for this can be sought in the principal 'drivers' of travel demand—for example land use and car ownership levels, the interesting question of the influence of non-quantifiable factors relating to transport policy also arose.

How is it that five capital cities, separated geographically, differing greatly in morphology, history and culture, and free to pursue their own transport policies, have arrived at broadly the same point independently?

It seemed that this could not be answered by the quantitative data alone, which would itself partly reflect features such as city structure and policies. Are there therefore 'meta factors', beyond immediate quantification, influencing change that transcend these essentially 'local factors'? If so, what are the implications for the role of local transport policy? Could local policy perhaps be a less-relevant factor influencing change than previously thought, for example less important at determining outcomes than factors such as technological change or, perhaps, does local transport policy largely (just) respond to these meta-factors, having the effect that all cities 'pull in the same direction' ? An example of the latter might be global concerns about climate change, influencing all cities to include policies to tackle the issue in their transport plans. A wider examination of these factors, which could only be conducted on a qualitative basis, would therefore be informative, in particular helpful in interpreting the outputs from the quantitative analysis in Work Package 3.

The outputs of Work Package 4 primarily address the over-arching political and policy context in each city. The interface between Work Package 3 and work Package 4 are the so-called policy results such as specific transport systems or also policy measures. It was recognised that a qualitative analysis of the impacts of these policy results would be a valuable addition to the quantitative work done in Work Package 3. It was also recognised that experienced senior practitioners in each Stage 3 city would have a view, based on their own personal experience, of the prominence, role and influence of the various factors—both structural and policy-related—in contributing to change in the main travel outcomes, in particular the mode shares. The time period covered by CREATE is within the living professional memory of some senior practitioners, who are likely to remember well the prevailing policy context through the latter years of the last century, and have an acute appreciation of how it has changed since.

In London, for example, practitioners cite the creation of the London Mayor in 2000 as the catalyst for a period of rapid and sustained change, and contrast it with the preceding 15 years when specific transport governance and vision for the city was lacking. But they also cite less-tangible factors such as 'generational change', affecting a multiplicity of factors such as availability of disposable income, changed use of leisure time and attitudes towards car ownership and use, that underlie observed changes in travel behaviour by this group. These 'less tangible' factors are also likely to be present in all Stage 3 cities, as they transcend geographical boundaries.

Looking forward also, for example as being considered by Work Package 6, the future impacts of connected autonomous vehicles is very much a current preoccupation and the impact of this emerging technology on travel patterns is largely at present unknown. The fact that this is now 'on the radar' of policymakers in all of the cities is a future example, perhaps, of the 'policy following external developments' effect alluded to above.

5.4.2 Approach of Qualitative Assessment

To explore these aspects further, an exercise was conducted among Stage 3 cities alongside the main quantitative analysis work of Work Package 3.

A simple template was created in Excel, which was circulated to appropriate 'senior' practitioners in each city to complete. The template sought their response, on a simple five-point qualitative scale, to a range of propositions in terms of their impact on a specific transport outcome—the observed trend in car use in each city. The propositions covered a range of potentially-causative variables grouped, for practical reasons, into the following broad categories:

- Transport supply factors, for example the provision of various types of transport.
- Socio-demographic factors, for example incomes and car ownership.
- Structural factors – related to land use and the wider economy
- Selected policy factors – complimentary to the analysis in Work Package 4.

The worksheet was divided into columns representing the broad 'decades' of interest for CREATE, starting with the period before 1980, and also looking into the future—on both a short- and longer-term basis.

The worksheet was also divided into two sections. The left-most half concerned the *direction and extent of change in the causative factor under consideration*. Here, the five point response scale ranged from -2 to +2, with the following meanings:

- -2 = Substantial negative change in variable, i.e. it decreased substantially over the decade.
- -1 = Negative change in variable, i.e. it decreased, but to a less substantial degree
- 0 = The variable broadly remained the same over the decade, in terms of direction and extent.
- +1 = The variable increased in magnitude or intensity over the decade.
- +2 = The variable increased substantially in magnitude and intensity over the decade.

The extract in Table 21 illustrates this process and shows the response in this section for London under the heading 'transport supply factors', in this case specifically considering the change in effective road network capacity in the three CREATE zones for London. This is defined as the ability of the road network to carry a given level of traffic at a given level of service (in terms of average speed or congestion). A reduction to capacity would therefore result either in a reduction of the level of service for an equivalent level of traffic demand or, in the longer term through mode shift, a reduction in the level of traffic demand for a given level of service—as has been observed particularly in central London over much of the last three decades.

London example. Extract from qualitative worksheet. Extent and direction of change in potentially causative variables in relation to observed trend of car use. Extract relating to effective road network capacity. City practitioner qualitative evaluation.

Table 21: Extract from London's Qualitative Worksheet for Direction of Change

	Pre 1980	1980s	1990s	2000s	2010-date	Future <10yrs	Future >10yrs
Road network capacity (effective) - Zone 1	0	-1	-2	-2	-2	-2	-2
Road network capacity (effective) - Zone 2	0	0	-1	-2	-2	-2	-1
Road network capacity (effective) - Zone 3	1	1	1	0	0	-1	-1

Thus according to the above response, the period before 1980 was characterised by a broadly stable level of road network capacity, reflecting a largely stable (in terms of physical length) 'legacy' road network in the two city zones itself, with some additions in the Peri-Urban area, reflecting new urban development in this area. Policies familiar today such as giving over road space to urban realm improvement, restrictions to parking availability, public transport and cyclist priority and various safety initiatives, such as reduced speed limits, were not then widely in evidence.

In the 1980s however the tide decisively tuned in the two city zones in London, with substantial reductions to effective road network capacity characterising all subsequent decades, and also projected to continue into the future. However, it is crucial to note that few if any roads were actually physically 'closed' completely during this period. Rather, the negative evaluation reflects changes to the ability to carry given volumes of traffic at a given speed, i.e. it relates to level of service provided.

In London it is considered that these reductions to effective road network capacity, and the increasing congestion pressures that have resulted, has been a major factor influencing the observed pattern of mode shift away from the car. Put simply, as journeys by car become more costly, in terms of generalised cost, the alternative public transport services become relatively more attractive, thus underpinning the observed change in overall mode share.

The extract in Table 21 also illustrates another crucial aspect of this exercise. Consideration of road network length only, as in the Work Package 3 quantitative analysis, would not reveal this aspect. The physical extent of the road network in London has not fundamentally changed over the period, yet the ability of the road network to accommodate traffic has substantially reduced—estimated at by up to 50 per cent in the central area of the city over the review period (see Roider et al. 2016 for more information about this issue).

The extract in Table 22 shows the equivalent response for the city of Paris. In this case the same pattern is broadly recognisable; however it is notable that it started at a later point in the period under review.

The right hand half of the worksheet (shown in Table 23) *is concerned with the relative influence of the factor under consideration (i.e. row) in reducing car use*. Note that this is a 'directional' question, a positive evaluation would therefore mean that the factor worked to reduce car use; a negative evaluation would mean that it worked against reduced car use, i.e. acted to increase it.

<u>Paris example</u>. Extract from qualitative worksheet. Extent and direction of change in potentially causative variables in relation to observed trend of car use. Extract relating to effective road network capacity. City practitioner qualitative evaluation.

Table 22: Extract from Paris' Qualitative Worksheet for Direction of Change

	Pre 1980	**1980s**	**1990s**	**2000s**	**2010-date**	**Future <10yrs**	**Future >10yrs**
Road network capacity (effective) - Zone 1	**1**	**0**	**0**	**-1**	**-2**	**-2**	**-2**
Road network capacity (effective) - Zone 2	**2**	**1**	**0**	**-1**	**-2**	**-2**	**-2**
Road network capacity (effective) - Zone 3	**2**	**2**	**1**	**0**	**-1**	**-1**	**0**

This is an important distinction and care was taken to communicate these meanings to respondents in each city. For clarity, the exact meaning is reproduced below. Note also that a causative relationship is implied—the question seeks an evaluation specifically about the extent to which the change affected the observed car use trend.

- -2 = Change in factor strongly works against reduced car use, i.e. works in favour of increasing car use.
- -1 = Change in factor works against reduced car use, i.e. works in favour of increasing car use.
- 0 = Changes in the factor had a broadly neutral impact on car use.
- +1 = Change in factor works in favour of reduced car use.
- +2 = Change in factor strongly works in favour of reduced car use.

Looking at the extract from this section of the workbook for London (Table 23), again focusing on effective road network capacity, the city practitioner evaluation of its impact on the observed trend in car use is clear. In the early periods, when capacity was either stable (inside city) or new capacity was created (Peri-Urban area), and when traffic levels were such as to be more comfortably accommodated within the available capacity envelope, car use grew (negative values).

In later periods however reductions to effective road network capacity were considered to strongly influence the observed trend of reduced car use in London. This effect was most intense in the central areas of the city—CREATE zone 1, as it was here that the capacity was most limited to start with, and where the reductions have been of the greatest intensity. In CREATE zone 2, relating to the outer part of Greater London, capacity reductions have been less intense, and the balance between traffic levels and road capacity over most of the day means that more traffic can be accommodated without directly impacting the level of service provided, in terms of average vehicle speeds or delays (congestion).

In the London Peri-Urban area, the available capacity in relation to traffic demand is sufficient that, despite incremental reductions to effective network capacity also happening here, the overall level of service is not significantly affected,

London example. Extract from qualitative worksheet. Qualitative city practitioner evaluation of significance of change in leading to observed trend of reducing car use. Extract relating to effective road network capacity. City practitioner qualitative evaluation.

Table 23: Extract from London's Qualitative Worksheet for Significance of Change

	Pre 1980	1980s	1990s	2000s	2010-date	Future <10yrs	Future >10yrs
Road network capacity (effective) - Zone 1	0	1	2	2	2	2	2
Road network capacity (effective) - Zone 2	-1	0	1	1	1	1	1
Road network capacity (effective) - Zone 3	-1	0	0	0	0	0	0

Paris example. Extract from qualitative worksheet. Qualitative city practitioner evaluation of significance of change in leading to observed trend of reducing car use. Extract relating to effective road network capacity. City practitioner qualitative evaluation.

Table 24: Extract from Paris' Qualitative Worksheet for Significance of Change

	Pre 1980	1980s	1990s	2000s	2010-date	Future <10yrs	Future >10yrs
Road network capacity (effective) - Zone 1	-2	-1	0	1	2	2	2
Road network capacity (effective) - Zone 2	-2	-1	0	1	2	2	2
Road network capacity (effective) - Zone 3	-2	-2	-1	0	0	0	0

The equivalent response for Paris is shown in Table 24. Here, a generally similar pattern can be discerned. It is however noticeable that the Paris respondent generally more intense impacts from the change in this variable than is the case with London. This is an interesting feature that characterises this analysis, and the implications are considered further below.

5.4.3 Some Key Methodological Considerations

This was intentionally a 'simplified' exercise, intended to be completed by city practitioners over e-mail. It is supplementary to both the more rigorous quantitative analysis in Work Package 3 and the qualitative analysis in Work Package 4. However, it is potentially very powerful. It gives a supplementary view of the data considered by each of these work packages, and sits between the two, in terms of being a qualitative evaluation of quantitative trends.

However, the method does have some distinct limitations, which need to be properly understood in order to understand and use the outputs. These are summarised below.

The exercise sought the view of only one experienced individual in each city. A guideline was given that the exercise should take no more than one half of a day to complete, and should rely on the 'instant' evaluation of the practitioner concerned. It was not intended that this exercise would require debate or protracted consideration on behalf of several practitioners in each city, although it was important that the respondent had the correct level of knowledge, experience and understanding of the requirements of the exercise. Prior to circulating the template, two practitioners in London completed the worksheet well within the recommended time, thereby validating the assumption that 'a sufficiently experienced practitioner should not have difficulty in responding to the whole worksheet, on the basis of their own personal evaluations, within a typical half day period'. This of course raises the question of whether different practitioners would give different evaluations. It was recognised at the outset that this was in fact to be expected, and this was in fact demonstrated by the London trial. This is not considered to be a major problem however; the point is that a suitably experienced practitioner would give a set of responses that are 'right' from their own viewpoint, and 'about right' in terms of the 'reality' (which cannot of course be objectively defined). The overall closeness of the two trial responses for London was, in this context, reassuring, but the differences were neither surprising nor, in the context of the overall analysis, significant.

Another limitation was the clarity with which the respondents in each city clearly understood the nature of the responses that were being sought. Care was taken to clearly explain the requirements, which were potentially complex, but it is likely that there are differences between the city responses, perhaps just differences of emphasis, that reflect differing levels of understanding of the precise requirements of the exercise.

A third limitation is that the creation of the template pre-defines the universe of variables that are taken into consideration. It is possible, perhaps on a case by case basis for each city, that other factors not identified in the template might well have been very significant locally. In this context the reunification of Berlin in the Early 1990s stands out as an example. To partially address this, it was made clear to respondents that they were free to add rows to the worksheet, as appropriate to their city, although in general this did not result in significant additions to the variable list. On the contrary, it became clear that the respondents in some cities did not feel able to address all of the requested aspects, as some were outside their range of knowledge. This was particularly the case for Berlin, where direct experience of conditions in both of the former sectors of the city was not historically available.

5.4.4 Outcomes from the Exercise

The city responses can be analysed in various ways, each of which is potentially useful to assist with the outputs from the formal quantitative analysis under Work Package 3. This section illustrates the kinds of insight that can be gained from the responses. Further results are included in the discussion in Section 6. One way of analysing the responses is to simply visually check for apparent trends or 'clusters' of similar or related trends. In this sense the colour coding, generated automatically by Excel on the basis of the score entered into the cell, is very helpful. The extract below, for London, shows this approach in terms of the practitioner evaluation of the influence transport supply factors—in this case socio-demographic factors—on car use. In this case it is seen that in the early period the whole, range of socio-demographic factors were considered to act in a direction favourable to increasing car ownership and use. In the latter periods and into the future, population and employment growth are forecast to continue to act in this direction, whereas other factors such as car ownership and the increasing densification of housing developments are forecast to act in the opposite direction, i.e. towards lower levels of car use. The equivalent grouping for Copenhagen, also copied below, shows a different emphasis, with reductions in household car ownership being a evaluated as a consistent driver of lower car use levels across the period under review.

London example. Extract from qualitative worksheet. Qualitative city practitioner evaluation of significance of change in leading to observed trend of reducing car use. Extract relating to socio-demographic factors. City practitioner qualitative evaluation.

Table 25: Significance of Change for Socio-Demographic Factors (London)

	Pre 1980	1980s	1990s	2000s	2010-date	Future (<10yrs)	Future (>10yrs)
Socio-demographic factors							
Total population - Zones 1 and 2	-1	0	-1	-1	-2	-2	-2
Total population - Zone 3	-1	-1	-1	-1	-1	-1	-1
Net ageing of population	-1	-2	-1	0	0	-1	-1
Increased participation of women	0	-1	-1	0	0	0	0
Increased inernational migration	0	0	1	1	1	1	1
Household size	0	0	1	1	1	2	2
Household car ownership - Zone 1	-1	-1	0	1	1	2	2
Household car ownership - Zone 2	-2	-1	0	0	1	1	1
Household car ownership - Zone 3	-2	-2	-1	-1	-1	0	0
Driving licence holding	-2	-2	-1	1	1	1	1
Education level of residents	0	0	0	0	0	0	0
Total jobs available	-1	-1	0	0	0	-1	-1
Unemployment	0	0	0	0	0	0	0

Copenhagen example. **Extract from qualitative worksheet. Qualitative city practitioner evaluation of significance of change in leading to observed trend of reducing car use. Extract relating to socio-demographic factors. City practitioner qualitative evaluation.**

Table 26: Significance of Change for Socio-Demographic Factors (Copenhagen)

	Pre 1980	1980s	1990s	2000s	2010-date	Future (<10yr	Future (>10yr
Socio-demographic factors							
Total population - Zones 1 and 2	-1	-1	1	1	2	1	1
Total population - Zone 3	-1	-1	-1	-1	0	-1	-1
Net ageing of population	0	0	0	0	0	0	0
Increased participation of women	-1	0	0	0	0	0	0
Increased inernational migration	0	0	0	0	0	0	0
Household size	-1	-1	0	0	0	0	0
Household car ownership - Zone 1	-2	0	-1	-1	-1	0	-1
Household car ownership - Zone 2	-2	0	-1	-1	-1	0	-1
Household car ownership - Zone 3	-2	-1	-1	-1	-1	-1	-1
Driving licence holding	-2	-1	-1	-1	-1	-1	-1
Education level of residents	0	0	0	0	0	0	0
Total jobs available	1	0	-1	-1	-1	-1	-1
Unemployment	-1	1	0	0	0	0	0

Another way of analysing the data is to compute average values across all five cities, and examine how each city deviates from the average. This would serve two purposes in terms of the formal quantitative evaluation. First, it would give a measure across all of the cities that can be used in a collective sense to generate hypotheses for the equivalent quantitative analysis, and to help validate the findings of the quantitative analysis. Second, at the level of the individual cities, the extent to which they deviate from the average across all cities can be used as a potential explanatory of specific city trends. In this regard, although all of the five cities conform to the overall broad trend of declining car use, there are differences in extent and intensity of this trend. Furthermore, it is interesting to explore the extent to which differences between cities are reflected in the actual trends—at first sight the commonality of the decline in car use across the cities suggests that this will not be the general case—a potentially interesting finding that relates to the idea proposed above that city-specific factors may be of less influence in determining overall travel demand outcomes than might have at first been expected.

Table 27 shows an example of the averaged response across all five cities, in the context of the extent to which socio-demographic factors are considered to have contributed to the trend of reduced car use. The first thing to observe here is that there is a high degree of commonality across the cities, as shown by the colour patterns. Thus, all five cities were characterised by decentralisation and increasing access to cars, strongly acting, as shown by the colour coding, against the observed trend towards reduced car use, i.e. in the early part of the period under review these factors were considered by respondents to be significantly responsible for an increase in car use. In the latter part of the period these factors tended to diminish with, typically, population returning to denser new developments in the heart of the city and with lifestyles that were not so dependent on the ownership and use of cars.

<u>Combined five cities example</u>. Extract from qualitative worksheet. Average of qualitative city practitioner evaluation of significance of change in leading to observed trend of reducing car use. Extract relating to socio-demographic factors.

Table 27: Average Evaluation of Significance of Change for Socio-Demographic Factors (All Five Cities Combined)

Socio-demographic factors	Pre 1980	1980s	1990s	2000s	2010-date	Future (<10yrs)	Future (>10yrs)
Total population - Zones 1 and 2	-0.20	-0.20	-0.20	0.20	0.20	-0.20	0.00
Total population - Zone 3	-1.00	-1.00	-1.00	-1.00	-0.80	-1.00	-0.60
Net ageing of population	-0.50	-0.75	-0.20	0.00	-0.20	-0.20	0.00
Increased participation of women	-0.80	-0.80	-0.60	-0.40	-0.20	-0.40	-0.40
Increased inernational migration	0.00	0.00	0.40	0.20	0.40	0.40	0.20
Household size	-0.60	-0.40	0.20	0.40	0.40	0.40	0.20
Household car ownership - Zone 1	-1.20	-0.40	-0.40	0.40	0.80	1.00	0.80
Household car ownership - Zone 2	-1.60	-0.80	-0.80	0.00	0.40	0.60	0.40
Household car ownership - Zone 3	-1.20	-1.40	-1.20	-0.80	-0.80	-0.60	-0.40
Driving licence holding	-1.60	-1.40	-1.00	-0.40	-0.40	-0.20	-0.20
Education level of residents	-0.50	-0.40	0.20	0.20	0.60	0.60	0.40
Total jobs available	0.40	0.20	-0.20	-0.60	-0.60	-0.20	-0.20
Unemployment	0.20	0.80	0.60	0.40	0.00	0.00	0.00
	Pre 1980	1980s	1990s	2000s	2010-date	Future (<10yrs)	Future (>10yrs)
Structural factors							

Population growth and structure change

Decentralisation, increasing access to and use of cars

The second example below is an equivalent extract—this time looking at average evaluations for transport supply factors across the five cities. Here the patterns are less clear, although there are significant groupings around the changed emphasis given to road network capacity and the public transport networks across the five cities, following the broad shifts in policy emphasis as described by Work Package 4 (see mark ups on extract below). Given these average values, it is then possible to explore how individual cities deviate from them, in terms of factors being evaluated as experiencing greater or lesser relative change, or of greater or lesser relative importance, compared to the average. It is also possible to undertake further specific analysis and also to re-contact respondents in the cities to seek further information on factors that appear, from this exercise, to be particularly insightful or significant.

<u>Combined five cities example</u>. Extract from qualitative worksheet. Average of qualitative city practitioner evaluation of direction and intensity of change Extract relating to transport supply factors.

Table 28: Average Evaluation of Direction and Significance of Change Transport Supply Factors (All Five Cities Combined)

General growth in road network and parking availability followed by decline in both.

	Magnitude and direction of change (general trends)						
	Pre 1980	1980s	1990s	2000s	2010-date	Future (<10yrs)	Future (>10yrs)
Transport supply factors							
New road infrastruture - Zones 1 and 2	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
New road infrastcuture - Zone 3	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Road network capacity (effective) - Zone 1	0.20	-0.20	-0.60	-0.80	-1.20	-1.00	-1.00
Road network capacity (effective) - Zone 2	1.20	0.60	0.00	0.20	-0.60	-0.60	-0.40
Road network capacity (effective) - Zone 3	1.75	1.75	1.40	0.80	0.40	0.40	0.25
Parking availability - Zone 1	0.80	-0.20	-0.40	-0.80	-0.80	-1.00	-1.00
Parking availability - Zone 2	1.00	0.40	0.40	-0.20	-0.60	-0.60	-1.00
Parking availability - Zone 3	1.00	0.80	0.80	0.40	0.40	0.40	0.20
Fuel costs (motoring)	1.40	0.40	0.60	2.00	0.00	0.00	-0.25
Other motoring costs	0.40	0.60	1.20	0.60	0.40	0.20	0.20
Public transport fares - Zones 1 and 2	0.75	0.00	0.60	0.20	0.00	1.00	1.00
Public transport fares - Zone 3	0.50	0.00	1.20	0.60	0.40	1.00	1.00
Bus capacity - Zone 1	0.75	0.20	0.00	0.60	0.60	0.40	0.60
Bus capacity - Zone 2	0.50	0.00	0.00	0.60	1.00	0.40	0.20
Bus capacity - Zone 3	0.25	0.20	0.20	0.40	0.60	0.60	0.40
Metro (rail) capacity - Zones 1 and 2	0.40	1.00	0.60	1.00	1.00	1.80	1.40
Suburban rail capacity - Zones 1 and 2	0.40	0.60	1.00	1.00	0.20	1.60	1.20
Suburban rail capacity - Zone 3	0.80	1.40	1.00	0.40	0.20	1.40	1.20
Light rail (tram) capacity - Zone 1	-0.75	0.00	0.20	0.20	0.40	0.60	0.40
Light rail (tram) capacity - Zone 2	-1.25	-0.20	0.40	0.60	0.80	0.80	1.00
Quality aspects of public transport	0.20	0.20	0.40	1.20	0.60	1.20	1.00
Integration of public transport - Zones 1 and 2	1.00	1.00	0.40	0.40	0.40	0.80	0.40
Integration of public transport - Zone 3	1.00	0.20	0.00	0.20	0.00	0.60	0.40
Public transport access levels (coverage)	0.75	0.60	0.60	0.60	0.40	0.60	0.60
Public transport reliability	0.00	0.20	0.80	0.20	0.20	0.60	0.75
	Pre 1980	1980s	1990s	2000s	2010-date	Future (<10yrs)	Future (>10yrs)

Declining PT. Expanding PT

6 Discussion of Main Findings and Look Outside the Box

6.1 Working Persons as Main Generators of Car Travel and the Peak-Car Phenomenon

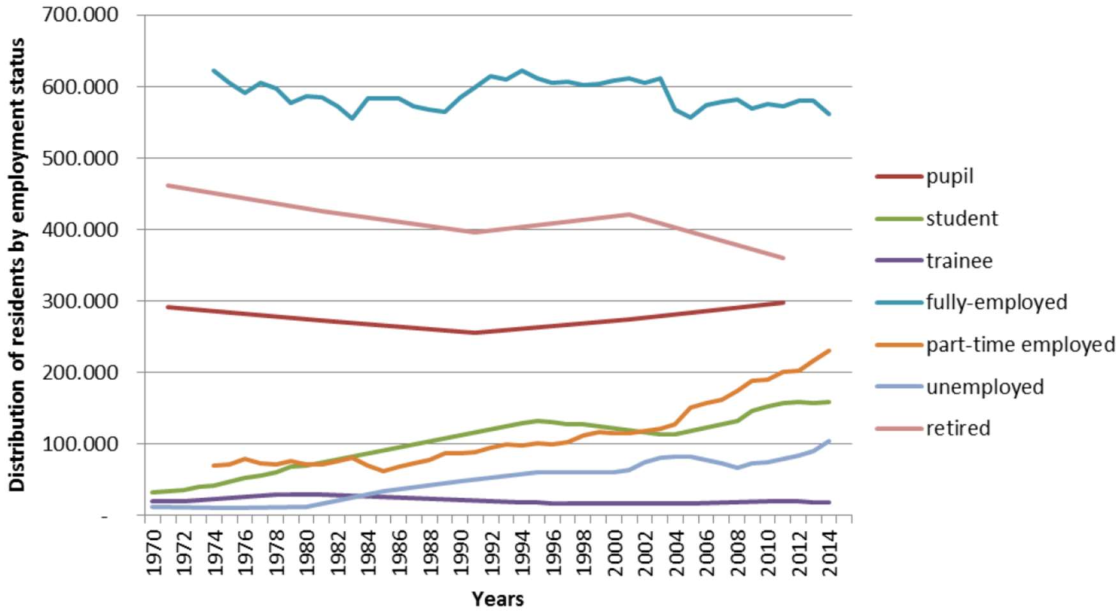
The group consisting of working people has been identified as the most influential person group for explaining the observed peak-car phenomenon for the five examined Stage 3 cities. As result of its considerable size and the behaviour change, this group more than compensates for the increased car use of retired persons. Developments in labour markets, shifts in employment structure and conditions, as well as occupation patterns can be reasonably accepted as the main impetus for the observed peak-car phenomenon of working people. This Section discusses these background conditions for explaining changes in travel behaviour of employees and, particularly, in car use of younger employee cohorts. Employment structures in all the Stage 3 cities, each of them located in a different EU country, have displayed dynamic development in the last decades (see Eurofound 2017: 1 ff.):

- The share of employment in primary and secondary sectors has shifted towards tertiary/service sectors.
- Domestic labour has been increasingly replaced by foreign labour as a result of globalisation processes and migration.
- The workforce group was characterised by an increase in the participation of women as well as by an increase in so-called white collar occupations (requiring of higher skill levels, education, etc.).
- The patterns of job polarisation and upgrading have contributed to a wider increase of wage inequity, with greater gains in jobs at the top and greater losses at the bottom of the wage distribution.

These developments in employment relations also imply the risk of precariousness (in-work poverty and low income). The financial crisis and its aftermath have been additional factors influencing the risk of precariousness in Europe. Job insecurity, involuntary temporary work or part-time work, and other drivers (such as the absence of a statutory national minimum wage) influence current and expected purchase power (Policy Department A 2016: 10).

Almost all Stage-3-city partners reported that the number of people in part-time positions increased substantially in the last decades. Berlin reported, that the number of people in part-time positions doubled between 1991 and 2008 (Roider et al. 2016, Berlin, p. 18). London highlighted a progressive trend towards greater part-time employment from 14 % (423,646 out of 3,076,529 M jobs) in 1981 to 18%.(673,549 out of 3,839,890 M jobs) in 2011 (Roider et al. 2016, London, D3.2: 30). As factors influencing work-related travel patterns, Paris identified an increase in part-time jobs, a growing number of holidays, a reduction of the legal work time (currently 35 hours/week), and fewer returns for lunch (Roider et al. 2016, Paris: 38). The city of Vienna provided comprehensive information about the development of employment conditions and specifically pointed out that part-time employment rose by 220 % over the last 40 years (see Figure 46; and Roider et al. 2016, Vienna: 12). Only Copenhagen did not specifically mention the development of part-time employment in its city-specific report. The specific role of atypical employment or so called non-core employment (self-employed, on temporary contracts, working part-time, or any combination of these categories) in contrast to core employment (permanent full-time contracts) for travel patterns has been rarely discussed in the travel behaviour literature body so far. Many interesting questions arise when following up these topics. In many sectors today, more flexible working hours exist which are not necessarily within the usual office hours.

Figure 46: Development of Employment Conditions in the City of Vienna



Source: Roider et al. (2016, Vienna, p. 13)

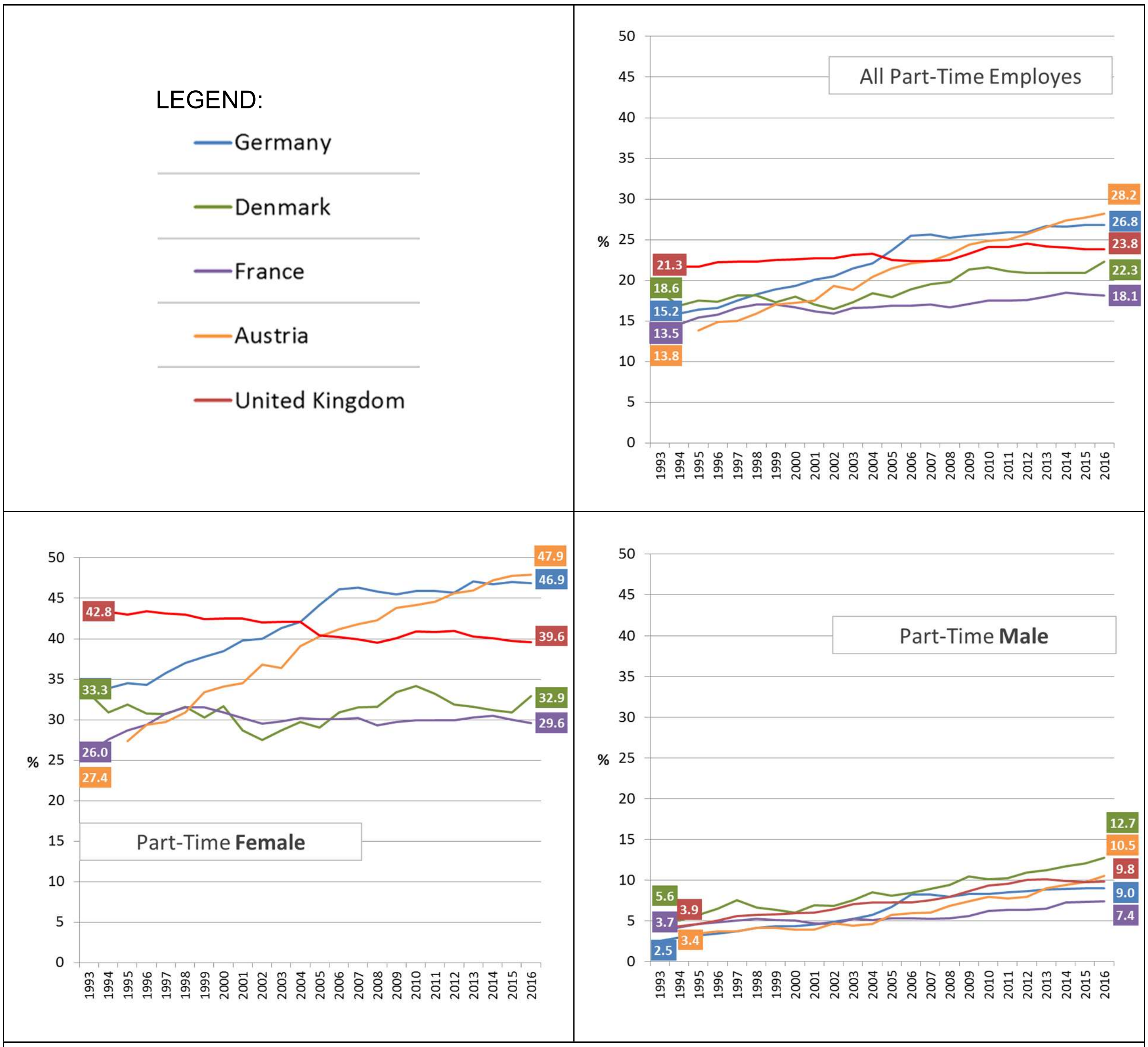
Germany is affected by rising levels of self-employment, but not all EU 28 Member States show this issue. Another line of thought follows the spatial location and distribution of workplaces. If jobs in service sectors are more frequently located in denser inner-city areas and an increasing number of people are working in this sector, the accessibility of jobs may also be affected; there is the potential for worse accessibility by car due to congestion in the inner cities, fewer parking spaces, or parking fees, contrasted by the potentially better accessibility by public transport as well as active modes of transport (walking, cycling, etc.), also including incentives such as subsidised job tickets, etc. These are just some of the influencing factors; naturally, not all can be discussed in this Section, but it is apparent that these dramatic changes in employment structures affect travel behaviour.

Initially, an investigation into the proportion of part-time employees compared to all employees was planned with the HTS data in order to analyse these issues based on the original microdata. Unfortunately, part-time occupation could not be harmonised across the Stage 3 cities. Therefore, the relation between employment patterns and travel behaviour cannot be directly observed using the harmonised HTS data; official statistics have been utilized instead.

Figure 47 shows the proportion of part-time employees in official population statistics for the whole countries of the set of Stage 3 cities. Part-time employment increased for all five cases. Austria shows the most dynamic development, increasing from 13 % in 1993 to 28 % in 2016 for the whole population. UK has the smallest increase of part-time employment across the observed period with only around 2.5 %.

Figure 47 also sheds light on differences according to gender. As expected, more women are employed part-time than men. Germany and Austria experienced the heaviest increases of part-time employment of women. In both countries, almost 50 % of female employees worked part-time in 2016. Surprisingly, men also show a dynamic development of part-time employment but at a much lower level. For Denmark, the proportion of part-time employed men increased from 5.6 % in 1993 to 12.7 % in 2016 whereas the value for women kept constant at a level slightly higher than 30 %.

Figure 47: Proportion of Part-Time Employees to all Employees



Source: Eurostat (Online-Datencode: lfsi_eppga), Age Group Employees 20-64 Years

Part-time employment intuitively means a lower income. Combined with potential debts from student loans, this delayed entry into a full-time or permanent position may also mean fewer financial resources and decreasing capabilities to afford a car (particularly for younger generations), potentially fewer work-related trips, and/or other working time schedules.

Figure 48 additionally underpins the fact that particularly young adults are affected by changes in the labour markets. Using the example of Germany, Figure 48 shows the proportion of temporary employment (including people in professional formation) from 1995 until 2005 by age. With a particular focus on young adults from 20 to 34 years of age, a very significant increase in temporary employment is clearly observable. In the subsequent life-cycle, the differences between the two periods reduce and the fact becomes less important.

All these developments are important drivers for the above-reported developments in travel behaviour and its determinants. For example, a drastic decrease of the number of car-driver trips of working people for mandatory activities (Figure 28) and also for the direct car access of working people (Figure 36) was shown for young adults between the ages of 18 to 34 years. The car use of young adults currently differs sharply from the preceding generations. Data also suggest that young adults today will not reach the high levels of car use of their predecessors in their later life-cycle stages.

However, socioeconomic changes in employment patterns do not necessarily mean that attitudes and perceptions towards cars have substantially changed. Assuming that the above-mentioned employment circumstances (and therefore external factors or obligations) have been the predominant influence on mode choice decisions of employees until now, it is most important to incentivise and to support these more environmentally friendly transport modes in order to maintain the desired behavioural patterns.

From a policy perspective, embracing measures of employer-based Transportation Demand Management (TDM) is a logical consequence for effectively initiating long-term and permanent changes in the travel behaviour of young adults. Employment status transitions also influence non-work related daily travel patterns when, for example, shopping activities get reorganised across the week (see Rasouli et al. 2015, for further discussions on this issue).

Figure 48: Proportion of Temporary Employment in Germany by Age

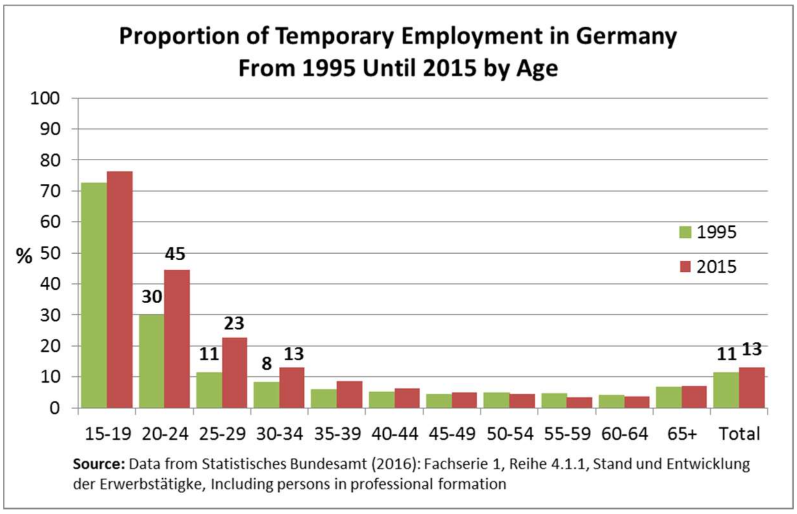


Table 29: Prevue Employment

Concepts	Description	Main Source
Changes in employment patterns	Trip rates of employees are slightly declining. This development coincides with the transformation of employment patterns with more part-time employment and other temporal and locational requirements on work-related travel (home office, out-of-peak travel, less work trips per week in part-time employments)	D3.3
Working persons' peak car use	Employed persons show the most distinct peak car use over time. Working people dominate car travel demand in cities both in terms of travel volume and vehicle kilometres.	D3.2

6.2 Social and Cultural Changes – Cohort-Specific Framework Conditions

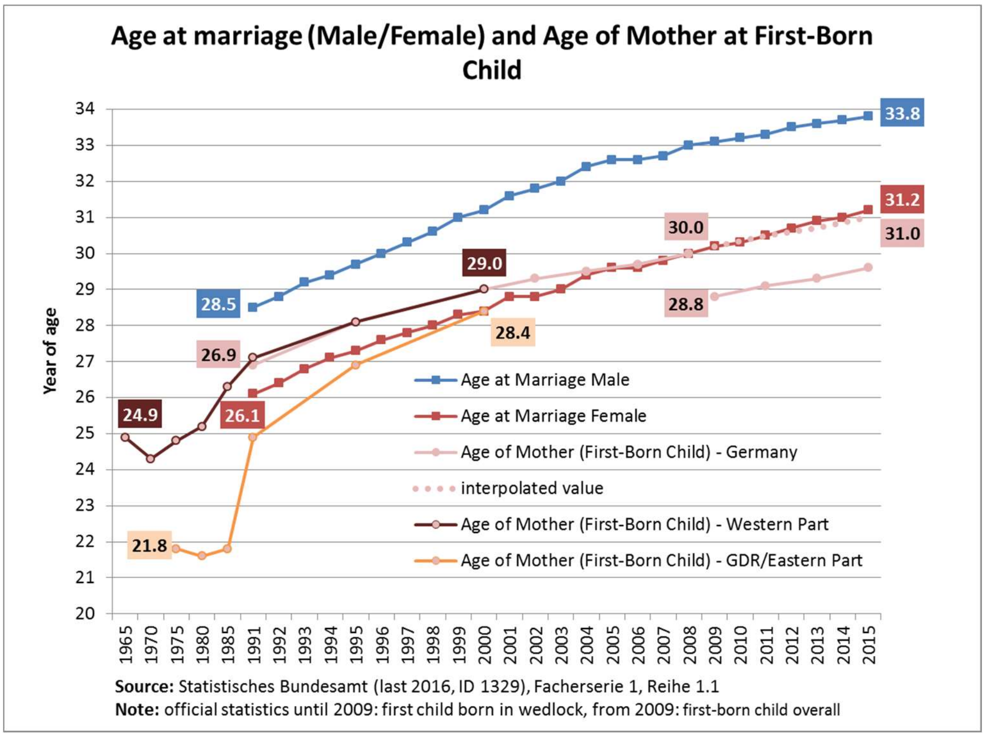
Empirical evidence clearly shows that cohorts behave differently (see Section 5.3). Social and cultural progress has been ongoing particularly in but not limited to European Societies since World War II. Societies are continuously affected by such developments, and these changes concern every area of life including education, labour and trade, characteristics of social classes and family structures, social norms and behaviour, social institutions and relations, traditions and much more.

As a result, each cohort shows a specific socio-demographic and socio-structural composition and differs also in the cohort-specific framework conditions. Naturally, the socialisation conditions change over time, but often internal variations within cohorts are larger than inter-cohort variations. Socialisation has often been social-class dependent and gender specific.

Such societal developments directly and indirectly affect individual (travel) behaviour and they also may shape mind-sets. From a conceptual perspective, this type of change can be mainly assigned to period and/or cohort effects. Both effects across time are interrelated and appear simultaneously. In many cases, interactions between cohort effects and period effects are so close that it is not possible to separate them.

A quite illustrative and explanatory approach of social change is given by indicators for life-cycle events. It is scientifically well known and accepted that life cycles have shifted towards later age periods within the last five decades. Figure 49 shows an example for Germany using the two indicators of "Age at Marriage" and "Age of Mother at First Born Childbirth". There are clear and continuous developments towards entering into the family stage at a later point in life. Many societal reasons influence these numbers. For instance, today there exists a new understanding of social roles and conditions; a development which clearly influences the network of family relationships as well. For quite some time, further or extended education has been a reason why people have a later entry into their first employment. Delayed family formation and longer periods of education lead mainly to period effects as a reason for changes in travel behaviour.

Figure 49: Age at Marriage and Age of Mother at First-Born Childbirth in Germany



Higher education could also mean social change. Socialisation is a process where individuals take up values, attitudes, and behaviour from the society (e.g. by accepting social norms and the value system of someone's social environment). This may imply cohort effects. Car-socialisation in western societies supported the pro-car attitudes of Master Boomers (born 1940–1954) and Baby Bloomers (born 1955–1969) which was brought on by the rapid economic development and constantly increasing car access in the 1970s and 1980s. On the other hand, it can be reasonably assumed that an increase in college and university education, normally at institutions located in large cities and metropolitan areas, supported the transition to other means of transport in the education phase, particularly to public transport. Such developments may have positively influenced the use of public transport in later life cycle stages together with the shift in planning focusses and policies towards public transport since the 1980s. The above HTS analysis supports this line of argument. Figure 32 shows that persons with university degrees have a higher but decreasing car use compared to persons without university degrees. Only in Paris there was a slight peak car effect identified for persons without university degrees; whereas for persons with university degrees, car use decreased substantially for Paris, Berlin, and Copenhagen. Car use of both person groups is almost at the same level in the most recent years. However, it is still an open question as to how these developments will continue in the coming years.

Table 30: Prevue Social and Cultural Background

Concepts	Description	Main Source
Increased education levels (Longer education with lower incomes, experiences with PT)	The number of people with a university degree has increased significantly within recent decades. Education is important for travel experiences, socialisation, and losing reservations. Experiences with public transport in cities with universities or other higher education facilities may influence the mind-sets of people formerly living in rural areas and smaller cities.	D3.3
Delayed life cycle stages	One main reason for the differing travel behaviour in young generations today is delayed life cycle stages.	D3.2
Car use and car ownership/car access	Car use decreases even with growing or stable car ownership, but car access still dominates car use.	D3.2
Elasticity on fuel prices is less important than expected	Data analysis shows that there has been a large variability in fuel prices within the last decades. Car use travel patterns have changed slowly, and travel behaviour shows no immediate change.	D3.2 for high variability of fuel prices, Stage-3-City Partners (2017)
Cohorts behaviour matters	Travel behaviour learnt at a young age impacts later life cycle stages. Empirical evidence shows that travel experiences and external impacts on travel (e.g. environmental impacts) influence travel patterns. Younger generations have a different travel socialisation and other constraints than older generations.	D3.2

6.3 Density Matters – High Densities Open Track for Active Mobility

All Stage 3 cities within CREATE are capital cities with an outstanding role in urban development within their countries. They outperform other cities and regions in their surroundings and are hubs for competitiveness, employment, and therefore drivers of innovation, centres for education, research, and social and cultural diversity. Statistically, capital cities are characterised by a high concentration of comprehensively and highly educated people (Eurostat 2016: 12, 13). Contrary to other parts of the world, Europe has a considerably high number of relatively small and poly-centrically distributed cities and towns (Eurostat 2016: 9). Interestingly, the share of the capital city metropolitan region on national total GDP is very different among the CREATE Stage 3 capital cities. The metropolitan regions of Copenhagen (40.8 %), Paris (29.9 %), London (30.2 %), and Vienna (34.9 %) have a high contribution on national GDP (reference year 2014), whereas Berlin contributes only 5.3 % to the total national value (Eurostat 2016, 87). It needs to be considered that the spatial definition in Eurostat (2016: 28) is based on NUTS Level 3 regions which, in part, differ from the functional CREATE area type definitions.

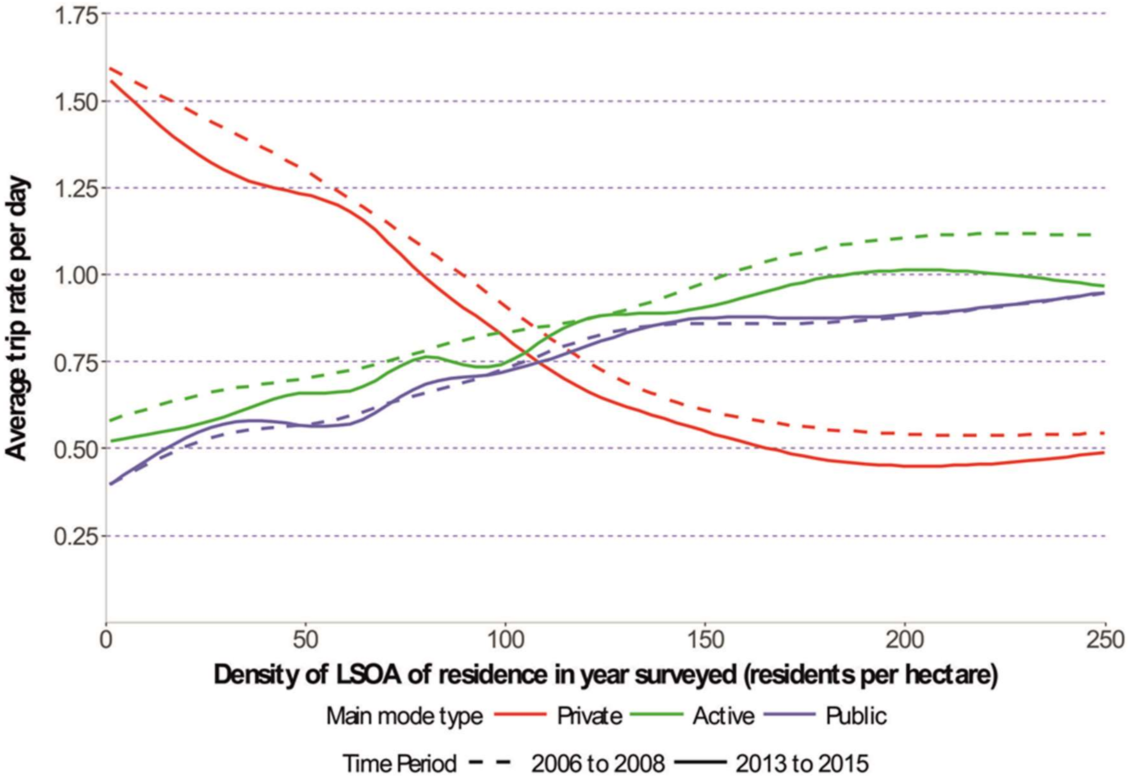
Density has a clear impact on travel behaviour. High densities and a mixture of uses (attractive and mixed-use inner-city and district centres) support more sustainable travel behaviour patterns and open the track for active mobility. Density is also associated with lower car ownership rates (Roider et al 2016). One the other hand, density evolves very slowly over time. In so doing, density evolution can explain neither the growth of car ownership and car usage nor their decline; and within a given density, very different mobility schemes can appear (Stage-3-City Partners 2017).

Figure 50 contains an analysis for the city of London in terms of density and mode choice. Both show a clear statistical relationship: On the one hand, the use of private motorised vehicles drops clearly with increasing density, measured in residents per hectare. On the other hand, average trip rates by public transport and by the active modes walking and cycling are increasing with higher densities. Overall, density should be understood as a proxy for many different determining factors of urban structure and transport supply.

Intuitively, there is clear correlation between PT supply and densities as well as a higher probability of congestion in high density metropolitan areas. Both factors are highly influential on the mode choice of travellers. Notwithstanding, high densities often support and imply a wider mix of land uses and short distances between different activity locations. Policies of proximity and strengthening the place function of public realms as well as urban living spaces enable active transport mode alternatives such as walking and cycling. The cross-city comparisons empirically show that both overall trip distances and single trip distances of all transport modes except cycling are no longer increasing for urban citizens.

Compact and dense structures are also not compatible with high vehicle speed levels. A harmonious and collective use of public realms by different transport modes needs similar speed levels. Lower inner-city speed levels for private motorised travel modes will not only help to increase safety but also promote alternative transport modes (walking and cycling). The high number of walking trips for residents in the city of Paris may be used as a good indicator for the importance of the morphology on travel behaviour. Particularly within the last two decades, density and mixed uses have increased in most European Capital cities.

Figure 50: Relationship of Density (Persons per Hectare) to Average Trip Rate by Main Modes of Transport (Administrative Area Type: City of London)



Source: Transport for London Strategic Analysis. Included in Roider et al. (2016, Part: London, p. 18)

Berlin is a special case in terms of spatial structures and densities, especially in the Inner-City. The former separation of the city strongly marks the city structure still today. As an example, the developments before and after reunification led to at least three city centres (Zoologischer Garten/Kurfürstendamm, Alexanderplatz, and Potsdamer Platz) instead of one city centre. Separation had also the effect that two totally different transport infrastructures have been developed in both parts of the city. After the reunification, people were able to move to suburban/peri-urban areas around the city of Berlin, whereas suburbanisation was not a topic until 1990. The suburbanisation that followed the reunification changed mobility and commuter patterns substantially. Today, both commuting into Berlin and out of Berlin are relevant factors for transport planning. Berlin has been affected by an increase of 80 % of cars entering and leaving the city since 1991 until 2014, and this trend appears to be persisting. Large infrastructure investments took place between 1990 and 2000 for closing gaps in road and rail networks and for enlarging infrastructures, for re-establishing a regional and long distance rail network. Substantial investments took also place for adding new bus lanes and cycle lanes. Parking management was introduced and a common collective PT pricing scheme including also the whole region around Berlin was established in 1999. The year 2000 was the starting point for Berlin to cope the negative impacts of increasing car traffic and inefficient public transport. This shift in transport policies came along with the first Urban Transport Development Plan, with a particular focus on transport (Stage-3-City Partners 2017).

Since the beginning of the 1990s, car ownership has been declining clearly within the city of Paris but also in the surrounding suburban areas. In the rest of the Paris region, car ownership has remained constant for the last 15 years. Car traffic in the city of Paris has clearly reduced since the year 2000. In the Peri-Urban area of Paris, car traffic has been stable or has increased only slightly in the same time period. Paris is attempting several approaches to reduce car traffic: land-use planning, road network management, multimodal policies, and economic instruments. Attitudes and perceptions among people of younger generations are changing. Today, urban places and inner-city locations are favoured more than in past decades. There is a strong belief among planners that public transport has the potential to attract car users. Policy planning for achieving a modal shift from car traffic to public transport is still an ongoing task. Since the mid-1990s, planning has been supported by new law regulations such as the law on air quality and rational use of energy (1996) that forces municipalities with more than 100,000 inhabitants to work out SUMPs with the common aim of less car traffic in urban areas. Since 1999, there exists a law on municipal cooperation to develop inter-municipal structures of governance with a transfer of competencies. In 2000, a law on cohesion and urban renewal was implemented to promote urban densities at the scale of masterplans (social and functional mixes at the local level). As an example, the integration of land use and transport planning were engaged by the claim that local developments are only allowed if access to the public transportation system already exists or is planned for construction in the near future. The main goal is to shift from an extensive urbanization approach to an intensive one. Within the last 20 years, a small extension of the urban area has taken place in Paris with a steady growth of the functional area. This has led to shorter trip distances than before, making other modes of mobility more viable. Regulations in terms of developing housing locations have helped to create opportunities for enforcing minimum densities close to rail stations, to exceed density norms for highly energy efficient buildings, to reduce parking facilities close to rail stations, and to provide bicycle parking facilities as well as electric charging stations for cars. Probably the most important issue for reducing car traffic within the city of Paris is the sharp reduction of on-street parking within the city. By 2015, almost 40 % of on-street parking facilities were removed, as compared to the 1995 numbers. Today, free-parking within the city of Paris no longer exists. Common sense among citizens and stakeholders is needed to promote and implement sustainable ‘Stage 3 City’ transport policies (Stage-3-City Partners 2017).

Table 31: Prevue Density and Morphology

Concepts	Description	Main Source
Density Matters	Travel behaviour and transport systems are shaped by densities for inhabitants and workplaces.	D3.2
High urban densities support active mobility	High densities and mixed land use support short travel distances and modal shifts	D3.2
Travel distances are no longer increasing	Empirical evidence shows that both overall trip distances and distances for all transport modes except cycling are no longer increasing for urban citizens.	D3.2 and D3.3
Lower inner-urban speed levels for more liveable cities	Compact and dense structures are not compatible with high speed levels. A harmonious and collective use of urban realms by different transport modes needs similar speed levels.	D3.2
Public transport supply matters	High quality and efficient public transport services are the prerequisite for the re-allocation of road space towards active modes and place functions	D3.2
Inter-municipal governance helps to promote urban densities and to support urban renewal	Municipal cooperation to develop inter-municipal structures of governance with a transfer of competencies influence urban developments into a desired direction.	Stage-3-City Partners (2017)

Urban land-use planning is very useful but to be efficient it must coincide with an overall reduction of speed in the road network. A compact and dense city is not compatible with high speed levels. In the Paris region, the development of public transport with low fares, in comparison to other European capital cities, helps to promote environmentally friendly mode choices, but its financial sustainability remains in question for the future (Stage-3-City Partners 2017).

6.4 Variety of Options, Digitalisation, and Decision Making

The mobility market has sharply changed in European metropolitan areas within the recent decades. New tools and services enter the market and are more frequently used by a wider range of the population. Early adopters share their experiences and push these mobility options towards a greater public awareness. Multimodality is increasing as people regularly use more than one mode of transport for their daily travel. Improved integration and availability of mobility options (due to the availability of different transport solutions and services) support such multimodal travel behaviour. This does not necessarily mean that people abandon car use, but that usage patterns are changing when, for example, the private car is utilized more for long distance leisure travel on weekends instead of for workday travel purposes. An increasing level of information due to the permanent availability of an internet connection and an increasing number of smartphone applications for reliable and transparent multi-modal travel information extends the decision-making environment. Digitalisation particularly affects and influences the travel behaviour of younger generations.

Younger generations have ever increasing expectations towards smart mobility solutions and their ubiquitous availability. Millennials (born 1985–1999) and Digital Aboriginals (born post2000) are accustomed to using digital devices and services. These aspects are also drivers for a changing mobility culture for both younger generations, as a peer-group, and preceding generations which are often mentored in the use of technology by their children.

The impact of ICT on accessibility is obvious. Additionally, smart devices make traveling by public transport more productive and/or attractive. Therefore, ICT impacts not only travel times but also may have an influence on the perception of travel time (see van Wee 2016: 10).

Table 32: Prevue Mobility Options and Digitalisation

Concepts	Description	Main Source
Increased variety of mobility tools	Within recent decades, more and more mobility tools enter the market and are more frequently used by a wide range of the population. Early adopters share their experiences and push these mobility options towards a greater public awareness	Stage-3-City Partners (2017) D3.2 (e.g. carsharing services in Berlin)
Strong relation between car ownership and car use is weakening	Multimodality is increasing. More mobility options and the availability of different transport tools support multimodal travel behaviour. This does not necessarily mean that people abandon car use, but the usage patterns are changing (e.g. more for long distance travel at weekends)	D3.3 Section 5.1.4, Stage-3-City Partners (2017)
Easier access to travel information	Impact of ICT on accessibility is a given, ICT makes travelling easier, and particularly in the case of PT more productive and attractive.	Pickup et al. (2016), Stage-3-City Partners (2017).

Further developments, such as the implementation of electric bicycles, will support mode shift from car to active transport modes. Cairns et al. (2017: 341) reviewed literature concerning travel behaviour impacts of e-bikes. They show that this development in cycling technology is not only responsible for a shift in transport mode choice from the automobile but also results in longer travel distances than with conventional bikes.

6.5 Human Beings as Creatures of Habit – The Necessity of Push & Pull

Voluntary changes in travel behaviour patterns are difficult to reach but not impossible. Bamberg & Rees (2017) discuss the impact of voluntary travel behaviour change measures and particularly the intervention called Personal Travel Planning (PTP) as an important element of a car-use reduction strategy. Evaluation studies in the context of transportation research often conclude that PTP can be seen as an effective intervention to reduce car use.

Research conducted by public health researchers discusses the effectiveness of PTP more controversially and even sceptically or negatively (Bamberg & Rees 2017:17). Nevertheless, Bamberg & Rees show a relatively small but reliable effectiveness of PTP measures based on a meta-analytical re-analysis of effect sizes from previous studies and from an own 'true' experimental PTP evaluation study.

It is consensually understood among transport researchers and practitioners that the combination of so called "push & pull" measures is highly effective for influencing travel behaviour. All Stage-3-city partners have documented that parking management, reduction of on-street parking as well as of road-space capacity for motorized transport are push measures with visible impacts on the travel behaviour of residents, commuters, and tourists (among others), particularly in the high density inner-city mixed-use areas.

Table 33: Prevue Push & Pull Policies

Concept	Description	Main Source
Change needs time	Changes rarely happen quickly	D3.2
Push measures	Push measures are a prerequisite for achieving car use reductions. Strong habits in travel behaviour hinder voluntary changes.	D3.2
Parking management/Reducing on-street parking	The impact of parking management (prices, capacities, regulation) on car use is demonstrated in all study cases.	D3.2
Road space capacity for motorized transport matters	Reducing road space capacity for individual motorized transport also supports car use reductions (shown specifically in London).	D3.2
Bicycles are a competitive replacement for car trips	Cycling is fast and flexible and thus shares many advantages with car use.	Woods & Masthoff (2017: 2020)
Generations think differently?	Behavioural differences have been identified between different cohorts resulting from period, cohort and age effects.	D3.2 Pickup et al. (2016)
Cause-effect relationship between attitudes and behaviour	Causality direction between changes in travel behaviour and attitudes is not fully understood.	

Consequently, policies with purpose-specific traffic control or steering effects at the activity destination are widely accepted and commonly applied in the recent decades by the CREATE Stage-3-city partners but also by many other cities and other institutions with planning responsibilities around the world. Regulation strategies using day-time and price-related restrictions and constraints lead to changes in destination choice, departure time choice, and mode choice. They allow for the reflection on travel behaviour under different decision-making situations.

Interestingly, recent research has been found which supports the wisdom that the effects of travel behaviours on attitudes are much larger than vice versa (Kroesen et al. (2017: 190). Acknowledging this hypothesis, Kroesen et al. (2017) point out that, in that case, policy should focus on changing behaviour directly (e.g. with constraints, regulations, pricing policies, etc.) for the indirect influence on attitudes rather than trying to influence travel behaviour by implementing promotional or information campaigns targeting the attitudes of travellers itself (p. 191).

These different explanations show that the evidence of causes and effects regarding an attitude-behaviour-relationship is multidimensional yet still not fully clarified. Attitudes and behaviours influence each other, in both directions and with varying intensities.

6.6 Opposing Forces Through Changes in Population Composition and Economic Factors

Changes in population composition clearly influence aggregated values of travel behaviour. Even if one specific population group, such as working people, that influences the peak-car phenomenon exist and continuously reduce their car use, emerging behaviours of other person groups (e.g. pensioners, people with children in their households) also contribute to the overall changes in travel behaviour. Two person groups have been identified as opposing forces for car use reduction. First, pensioners or retired persons clearly increased their car use over the observation periods. They carry car use habits from their period of employment into the next life cycle stage as a pensioner and therefore the car often is still the basis for mobility of elderly people. This development is ongoing and will assumedly concern transport planners for at least the next one or two decades.

Another well-known and accepted cause-effect relationship is the high probability to own a car as a family (couples with at least one child). In Germany, almost all families have a car or decide to purchase a car when a family is formed. These tendencies are observable particularly among the family formation process of young adults (18–34 years) (see Wittwer 2014).

(International) migration also influences travel behaviour within European capital cities. Migrants have usually less direct access to cars and therefore different travel patterns. Migration often affects larger cities and metropolitan areas more than rural areas. European capital cities will have to deal with more immigration in the near future which affects the population composition. Depending on the specific local situation, changes in the composition of a city's' population led to weakening effects in terms of car use reduction in the past. Cities with aging populations or cities with a high proportion of elderly people, such as Berlin, Paris, and Vienna, have shown and will show more opposing forces with regard to car use reduction than cities like London and Copenhagen which have an increasing number of younger people and a quite low proportion of seniors within their population (see Section 5.1). Population forecasts have to be monitored carefully for identifying such developments and should be included in the interpretation of travel phenomena.

Aside from the opposing forces introduced in the aforementioned specific population groups, economic developments and future developments of fuel prices also have potential damping effects on car-use reduction. It cannot be ruled out that, even for Stage 3 capital cities, an economic recovery together with increasing prosperity of those population groups, which currently show clear car-use-reduction patterns, could once again lead to an increase in the automobile as the mode of choice. Therefore, household travel data are particularly necessary for carefully tracking travel behaviour in the near future.

Table 34: Prevue Opposing Forces

Concepts	Description	Main Source
Seniors increase in car use	Seniors damp the peak car effect. Seniors are more mobile than ever before. Ever increasingly, they carry their pro car attitudes into the senior life stage.	D3.2
Composition effects	Population structure matters. In many cities population structure is changing. Different population groups show clear differences in travel behaviour.	D3.2
Family formation clearly correlates with car access	Data analyses show that almost all households with mandatory activities and errand necessities (mainly households with at least one child) have cars	Wittwer (2014)
Increasing population does not necessarily mean increasing car use	Space and capacity is limited. Therefore in many metropolitan areas there is a push from individual travel to alternative transport modes such as PT, cycling, and walking	D3.3 Section 5.1.3
Economic recovery, fuel prices, and fuel efficiency might slow down car use reductions	Recent research indicates that the phenomenon of car use reductions is possibly a more temporal one. Despite the fact that literature is mostly suggesting caution, specifically for countrywide developments; also the continuation of the peak car phenomenon for high density urban areas is still not fully proofed.	Klein & Smart (2017), Stapleton et al. (2017, Focas & Christidis (2017) Cornut & Madre (2017)

6.7 Traffic and Traffic Congestion is More Than the Travel Behaviour of Residents

The traffic load of a street is composed of many different segments of travel demand. Urban residents are without a doubt one important group which causes traffic, but there are other factors to be considered in order to have a comprehensive picture of urban traffic and reasons for congestion. External commuters from Peri-Urban areas affect local urban travel situations. Capital cities and metropolitan areas are becoming ever increasingly the primary destinations for tourists. Overnight stays have been increasing for decades and metropoles often have problems to accommodate such a high number of visitors, particularly on certain dates throughout the year (Roider et al. 2016, part Berlin). In many inner-city areas, alternatives to classic hotel accommodations have been established (e.g., AiRBnB or commercial hostels in former family apartments). The behaviour of tourists is notably different from other travellers and, particularly, in contrast to the residents. In some European inner-city areas, exchange processes between residents and tourists clearly influence the local housing structures which could have an influence on the overall travel demand.

Freight traffic is another demand segment that influences urban traffic. The management of freight traffic loads on urban streets has been a main issue for transport planners for many decades. Future challenges but also opportunities exist thanks to technological developments, innovative concepts in logistics, ICT, etc. Indeed, the mix of travel demand segments is diverse and evolving over time. Therefore and in the meantime, forecasting and transport modelling is a very important task for urban transport planning. Researchers and practitioners continuously advance their models to incorporate the mutual interdependencies of demand and supply as well as to include all the different travel segments, thus addressing the issues of travel demand more adequately today than some years before. Further advancements of transport models and of the assessment methods that are developed out of models are crucial for future transport planning.

In the following discussion, the issue of traffic and traffic congestion is illustrated for the London case study based on the minutes from the deliberations at the Technical Meeting in Paris in March 2017. All measures and their results that are described below for London are Stage-3-city policies. These can be also found in the other Stage 3 Cities; thus, the below findings for London illustrate developments that are typical for Stage 3 thinking and policy making. Road traffic kilometres across the Greater London Area (Inner-City and Outer-City) have, for example, fallen by 10 % between 2000 and 2015. In comparison, traffic in Great Britain is still largely increasing. Car traffic has fallen at a faster rate with almost 4 billion fewer kilometres driven in London in 2015 as compared to the peak in total road traffic in 1999. This is despite the population increasing by 1.3 million (18 %) and the provision of 1 million extra jobs over the same period. On the one hand, mode share of car for personal travel has also fallen by 10.4 percentage points since 2000. On the other hand, the share of PT has increased by 11.1 percentage points. Bus, rail, and underground traffic have been expanding at a faster rate than the population. Changes to other transport modes have been minor in mode-share terms. The supply of public transport has increased by almost 2 % per year since 2000. Despite a fall in car use, car ownership has remained relatively stable in London. Road network supply has reduced substantially despite strenuous efforts to improve the operation of an effectively 'fixed' road network in terms of its physical extent. There are therefore both 'push' and 'pull' factors operating to influence demand for car travel in London. One really relevant 'push' factor seems to be the reduction of 'effective road network capacity'. The concept of 'effective road network capacity' is the network that is seen from a driver's point of view. This includes a wide range of temporary and more permanent interventions that reduce the actual performance of the road network. Therefore, the increase in pedestrian spaces, the optimization of times at junctions, the reduction of speed limits, extension and advancement of PT, and the prioritisation of cycling and pedestrian modes as well as urban realm schemes, infrastructure, and more general construction schemes all act to reduce 'effective capacity' for a given road network. Each aspect alone may have only a minor effect on operative network capacity but these factors leads to a very large impact over time.

Traffic calming and displacement are very much a part of the policy canon in London. London's estimations suggest that almost a quarter of effective road network capacity in Central London was removed from 1992 to 2009 and almost 50 % by 2016. In Inner London (30 %) and Outer London (13 %) similar tendencies have been found but on a lower level. This reallocation of network capacity has large impacts on individual transport patterns.

Grand schemes for pedestrianizing iconic central London 'squares', massive expansion of bus priority, and a growing emphasis on road safety engineering were bringing transformative benefits in other areas of policy, but all of them were reducing capacity for general traffic. With the development of Stage 3 thinking in London, capacity removal will typically become more widespread even though single effects are typical small and incremental. There is a large cumulative and compounding effect so that individuals may not at first realise the larger effect of their own small scheme. Policy attention then turns to 'maximising' the efficiency of the road network (e.g. through technological means). These measures typically have only a very limited effect, and, as a result, congestion continues worsen. Therefore, a re-appraisal of priorities for the road network is required, and this could offer the foundation for a Stage 4 perspective.

Nevertheless, London does need a functioning road network for ensuring 'priority' traffic such as freight, emergency vehicles, and buses. Therefore, a natural limit seems to exist with which the network can be reduced to when the core functions of a city should be guaranteed.

Two suggestions or provocative hypothesises have appeared, respectively, as a conclusion of London's city-specific analysis in terms of traffic and congestion:

1. When faced with increasing traffic congestion, cities often try to 'maximise the resilience of the operation of the road network', e.g. through advanced signal control, enhanced operational response to incidents, travel advice, and various forms of traffic demand management. However, analysis in London has suggested that the large majority (about 75 %) of congestion is caused by the simple magnitude of (and daily variation in) background traffic demand. It is therefore not susceptible to operational and technical measures and, in a sense, will 'always be present'. There are also limits to the amount that the remaining 25 % can be eliminated. Furthermore, in a capacity-constrained network, an incremental improvement in performance (speed) will induce more traffic, thus counteracting the benefits. Although it is difficult to see how cities could reasonably not implement such measures, perhaps the emphasis is better placed elsewhere (e.g., further investment in public transport).
2. How bad is traffic congestion really? Congestion is usually considered purely a 'road network phenomenon'. This is reminiscent of Stage 2 thinking. If it gets worse—even if traffic demand is falling—then that is considered to be unambiguously unacceptable. However, the London, population has grown rapidly and traffic has declined. Meanwhile, public transport has also grown rapidly—much more in line with the population. Some former drivers will transition to public transport. If traffic congestion is analysed in the wider context, for example, per person, per job, or per trip, then the 'quantum' of congestion for each of these will have fallen—or at least not have worsened. It could, therefore, be argued that the emphasis of policy should be directed toward the provision of alternatives rather than on 'curing' congestion because the evidence suggests that it is, to a degree, 'self-righting'.

Table 35: Prevue Traffic Congestion is More Than the Travel Behaviour of Residents

Concepts	Description	Main Source
Urban citizens are only one instigator of urban travel	Urban citizens are only one, yet important, part of daily travel in metropolitan areas. They are many more demands for urban travel: tourists, visitors, peri-urban commuters, service, delivery, business passenger traffic, freight, etc.	Stage-3-City Partners (2017), Semi-quantitative analysis
Changes in commuting patterns	Temporal and spatial commuting patterns are changing. Employments in the service sector have steadily increased during the last decades. Those workplaces are often located in city centres or urban areas and are less attractive to be accessed by car.	Stage-3-City Partners (2017)
Tourists play an important role in urban trips; additionally, the inner-city apartment structure is transforming	Inner-cities in touristic towns often provide more accommodations for tourists and visitors where family apartments formerly stood (Hostels, AirBnB, etc.). Tourists behave completely differently than other user groups, such as, in particular, residents.	Stage-3-City Partners (2017)
Freight traffic stresses the network	Freight traffic load of urban streets has been a main issue for transport planners for many decades. Future challenges exist and clearly interact with technological developments. Delivering and optimisation through digitalisation become increasingly more important.	D3. 2

6.8 Cycling Versus Public Transport – Competitors or Mutual Supporters?

The above-examined analyses have shown similarities in car travel for the five case study cities, but, at the same time, the analyses have also demonstrated substantial differences in cycling and in public transport ridership. Vienna is the most distinguished “public transport city” with relatively low cycling shares in the modal split. Copenhagen confirmed its status as a “cycling city” with low public transport ridership. The other three cities are in between these extremes. In what follows, some background information is given about these issues based on the minutes from the Paris Technical Meeting in March 2017.

Copenhagen’s bicycle traffic (kilometres driven) increased by 19 % from 2005 to 2015 whereas car traffic declined by 3 %, and inhabitants and jobs and even car ownership increased during the same time. Copenhagen has a specific type of ‘vision planning’. The city plans particularly for bicycle traffic but at the same time does not demonize cars. Car ownership is still relatively low in comparison to the other capital cities in other countries but has increased within the recent years.

Looking back, the development of the daily number of cyclists in Copenhagen is very interesting. After World War II cycling levels were high with a peak between 1945 and 1950; cycling decreased continuously afterwards until the late 1970s. From the 1980s onwards, the number of cyclists in Copenhagen increased again steadily until today.

In the 1980s the public opinion changed towards the recognition of the role of cycling (a first wave) and a wish of not building more roads for car traffic. A second wave of specific promotion of the ‘vision of cycling’ started since 2006 and is still ongoing. The vision for Copenhagen is accompanied by measurable goals. For 2025 the overall goals are

- 50 % of all journeys to work and education in Copenhagen by bicycle (Eco-metropolis vision)
- 75 % of all trips in Copenhagen are not done by car (Climate plan)
- Distribution of traffic in Copenhagen with at least 1/3 by bicycle, at least 1/3 by public transport

When a goal is not reached by the year where it was set, administration gets more time (e.g. 10 years more for achieving the bicycle goal) for reaching it. The priority is to move safe and easy by bicycle through the city. There exist many specific solutions at intersections (e.g. withdrawn stop lines for car traffic, blue safety lanes, pre-green for cyclists, LED warning lights at the ground) but also general solutions for providing a flexible and connected mobility network (e.g. bicycles for free in local trains and taxis are obliged to carry bikes on cycle racks on car).

Some other interesting details: 75 % of people using the bike in the summer period also use it in the winter. 26 % of all families with two or more children in Copenhagen own a cargo-bike (17 % instead of a car). Cyclists answer as reasons for their mode choice that it is faster, easier, and is for exercise. Fewer people mentioned that it is cheap and convenient, and even fewer people cycle because it is an environmentally friendly transport mode. GIS analyses suggest that 54% of road space in Copenhagen is for car lanes and only 7 % are bicycle lanes.

From a planning perspective this means that Copenhagen has planned and built provisions for bicycles and cars for a long time and still pursues this strategy. This continuous priority setting resulted in step-by-step development. Copenhagen is a cycling island in a more car-oriented region. A lot of car traffic within the city is caused by people living in the Peri-Urban area of Copenhagen. So called super-cycle highways are currently being established in order to provide a more regional cycle network (plans for more than 300 km) and for achieving a modal shift from the car to the bicycle—also for commuters from outside the city. In Denmark public opinion is really important; communication and dialogues with citizens and other stakeholders and even with the media are big success factors.

The tram network in Vienna is one of the largest ones worldwide. Until 2001, Viennese PT belonged to the city administration. Since then, the 'Wiener Linien' as part of the Viennese Holding (stock company) was founded—100 % owned by the city government. The priority for public transport led to many improvements (i.e., priority at traffic lights, acceleration due to separation, and reliability improvements) since the implementation of the Transport Masterplan in 1994. The city of Vienna introduced not only denser intervals (in particular in off-peak periods) but also extensions of operation times during the whole night and bus nightlines.

Parking regulations have already been implemented in the first district of Vienna since 1993 and were continuously extended. Prices have risen sharply in recent years. The extension of parking management zones to other districts of Vienna is still ongoing. The PT service supply for the metro/underground has nearly tripled since the early 1990s. Who has a PT transport ticket in their pocket is more likely to use it than someone without direct access to this transport mode; and the implementation of the subsided annual ticket of 365 Euros (2012) was a great success: The share of season-pass holders increased by more than 20 % by 2014.

At the moment, Vienna seems to have reached a threshold where both the modal share of car use and the modal share of PT are quite stable. There is also a new need identified to extend the underground network in the dense inner-city area, but financing these PT network extensions has yet to be solved. The actual goal of the urban development 2025 plan is ambitious: a Modal Split of 80 % green modes (walking, cycling, PT) against only 20 % car use.

6.9 Monocausality Rarely Exists

Travel behaviour of urban citizens is influenced by manifold factors. Decision-making processes are complex and vary from individual to individual. The transport planning evolution cycle has been trying to adapt planning approaches with regard to the specific situational and cultural zeitgeist (mobility culture) during the last decades until now.

Funding has differed across time and today investments in the field of transport are much more than that of road infrastructure funding. The principle of enhancement, reconstruction, and optimisation of current infrastructures and transport supplies prior to expansion and new building is, meanwhile, a pillar for supporting sustainable travel solutions and behaviours.

Each city is different and car-use reductions happened partially at different points in time. Long time series in data on travel behaviour are necessary for monitoring the processes and evaluation. These data help to trace developments over time for identifying undesirable developments because the peak-car phenomenon is not a natural law, and the next turn-around (e.g. by changes in taxes, political turn arounds, or other external constraints and restrictions) cannot be ruled out due to the lack of monocausality.

Many different factors are influencing people's behaviour, and Household Travel Surveys are one important piece for identifying these respective trends. In the meantime, planners are openly discussing the role of modal splits as proportions of travel modes based on transport volume (trips) for describing the evolution of travel behaviour.

Such indicators give an insightful impression about relative preferences towards transport modes as population average but are not useful for monitoring the entirety of people's individual travel behaviour. Absolute trip numbers and distances are much more meaningful and allow for easier projections and extrapolations of aggregated travel loads.

Table 36: Prevue No Monocausality

Concepts	Description	Main Source
Funding is necessary	Continuous funding is needed, also in Stage 3 and beyond for road infrastructure	D3.2
Enhancement, reconstruction, and optimisation prior to expansion and new building	Financial and spatial resources are limited. Maintenance requirements for infrastructure are increasing continuously in most metropolitan areas. Decisions for new infrastructure projects are increasingly more challenging.	Stage-3-City Partners (2017)
Individual character	Each city is different; car use reduction happened partially in different points in time but the peak-car phenomenon is no longer a single event in only few cases/cities. Overall, in many parts of the world, cities experience similar developments in travel behaviour.	D3.2
Long time series in data on travel behaviour	Long time series in data on travel behaviour help to understand behaviour and to foster evidence-based transport planning. They help to trace developments for indicating undesirable developments and also allow a benchmarking with other cities or regions.	D3.2
The role of the modal split for describing travel behaviour change should be critically reviewed.	The modal split is problematic for describing travel behaviour; absolute mode-specific trip rates are much more insightful.	D3.2

7 Conclusion

This report aimed to provide a cross-city comparison based on the city-specific reports (Roider et al. 2016) and findings as well as by additional analyses mainly based on HTS data for the five Stage 3 cities within CREATE. Therefore a comprehensive literature review has been conducted for the scientific foundation of the empirical section of CREATE. Key hypotheses and research principles were derived using the provided evidence throughout the literature review and the theoretical backgrounds of D3.1.

The methodological part of this report is specifically described with an emphasis on APC analyses which are comparatively rare in the transport research of travel behaviour. The generational approach chosen for the empirical analyses within this report builds on the birth-cohorts introduced in the H2020 European MINDSets project. A brief description of the five Stage 3 case study cities aimed towards a better understanding of spatial conditions and interpretational particularities and prepares for data harmonisation and data processing.

Metadata collection has been the fundament for a successful ex-post data harmonisation effort in close collaboration of the five Stage-3-city partners and the Technische Universität Dresden. Data harmonisation was a very time-consuming and challenging task. Data harmonisation took place for survey definitions, survey coverage (including a temporal harmonisation), survey methods, and spatial conditions (area definitions). Stage-3-city partners performed all necessary steps individually with feedback loops and many interactions with the authors of this report. As a result, a broad consistency across cities was reached, and HTS data were pooled into one uniform database.

The above-presented results show that it is possible to ex-post harmonise historic HTS data even if there are major differences between the HTS in terms of all survey characteristics. Harmonisation is, however, burdensome, and success is not guaranteed. Harmonisation might fail for other HTSs. In such cases, the causes for identified problems or inconsistencies should be analysed in detail, and all available information on metadata and previous data processing activities should be gathered. With those detailed analyses and comprehensive harmonisation, the authors think that HTS data harmonisation will be successful in almost all cases. Simplified travel estimates must be used for the analysis if harmonisation fails (see Scheiner 2010, Sicks 2014).

The harmonised HTS database has been the starting point for cross-city comparisons based on HTS microdata as a second step of cross-site analyses after comparing macro trends and aggregated indicators for Stage 3 cities. The comparison of macro trends included city-specific framework conditions, transport supplies and policies, and access to travel modes; it also led to preliminary findings and insights on the spatial reference “city-level” as an administrative area type.

On this basis and mainly driven by Transport for London (TfL), a qualitative or semi-quantitative assessment of drivers and barriers for car-use reduction was carried out. Stage-3-city partners have provided contributions through diverse expert knowledge of practitioners and transport experts with many decades of working experience within their cities. These insights also fed into the cross-city comparisons of travel patterns and travel demand using HTS microdata.

Key travel estimates for the CREATE functional area type ‘urban’ allow for insight into both the technical quality of harmonisation and contextual circumstances of the peak-car phenomenon. Without walking, the number of trips per tripmaker per day is quite stable across Stage 3 cities throughout the last decades. The very close numbers for daily trip chains (tours) and for the proportion of trips back home reinforce the data harmonisation success. Mode-specific analyses have shown that car-driver trips, car-driver travel time, and daily car-driver travel distances decreased significantly. An overall car-use reduction referring to the travel volume of citizens (trips per day) of about 25 % on average has been overserved for the functional area type ‘urban’ between the late 1990s and the early 2010s. In absolute numbers, the reduction of car-driver trips contributes much more than the reduction observed for car passengers. For revealing the causes behind the observed car-use reduction patterns, purpose-specific analyses were introduced. Thereafter, mandatory activities were revealed as the main impetus for car-use reduction. Such cross-city findings were neither found for activities linked to shopping/errands nor for leisure activities. As mode choice for mandatory trips and the total number of mandatory trips of working people (employees and self-employed persons) were identified as main drivers for car-use reduction, person-group specific analyses followed and generated further insights into the peak-car phenomenon.

HTS analyses suggest that working males are much more likely to reduce car trips. Those people started at a higher-level of car use than working women. Women have, if at all, slightly decreased their car use. Pensioners are an opposing force against the reduction in car use: Both male and female pensioners substantially increased their car use across the observation periods.

Age-group specific analyses have been carried out for a better understanding of travel behaviour patterns within the group of working people. As a result, all age groups systematically reduced their car use for mandatory activities. Nevertheless, young adults (aged 18–35 years) have reduced car use the most in relative terms. It is particularly fascinating to note that this observation takes place across all five Stage 3 cities within a very small range. Bicycles are the transport mode with the most substantial increasing developments across time.

For mandatory activities, public transport is a heavily used transport mode in five cities (with lower figures for Copenhagen compared to the other cities). The number of public transport trips for mandatory purposes of working persons was very stable for all five Stage 3 cities across the observation periods. This might be unsatisfactory upon first glance, but, due to the fact that the overall number of mandatory trips decreased over time, this development can be perceived as success because, relatively calculated, the share of public transport would have been increased.

Notwithstanding, cycling is today competitive to cars in many travel occasions. Cycling is perceived as a very flexible, cheap, enjoyable, and in many cases the fastest mode of transport. Only weather conditions may negatively influence the comfort of cycling (Roider et al. 2016). Electric bicycles could support and extend the potential of mode shifts through an extension of journey distances (see Woods & Masthoff 2017). Already existing discussions about approximating inner-city speed levels of different transport modes—mainly for safety reasons—could presumably make cycling even more competitive.

Some drivers of behaviour change could be identified. Car-use reductions are particularly visible for higher educated individuals (university degree). The share of these individuals is substantially increasing for Stage 3 cities across time. Direct car-access of young people (18–34 years) is declining. People without direct access to a car have only 10 % to 20 % of car use compared to people with car access. Nevertheless, data also suggest that young adults (18–34 years) with car-access reduced their car trips clearly. This tendency is not that strong for mid-agers (35–64 years), and seniors show opposite effects. Today, access to alternative travel modes is higher and access barriers are lower than in recent decades. More working people have a public transport season ticket (in some cases subsidised by the employer), and new mobility services and tools enter the market. Not only early adopters are using those offers.

Cohort analyses for Paris suggest that different travel patterns and reduced car use in early life stages of younger generations also influence travel behaviour at the later life stages. The car use of younger generations (i.e. observable for Millennials) peaks at lower levels than for the preceding generations. The authors of this report reasonably assume that those tendencies and developments are appropriately transferable to the other four Stage 3 cities because most travel behaviour patterns and changes were quite similar for many indicators across the cities.

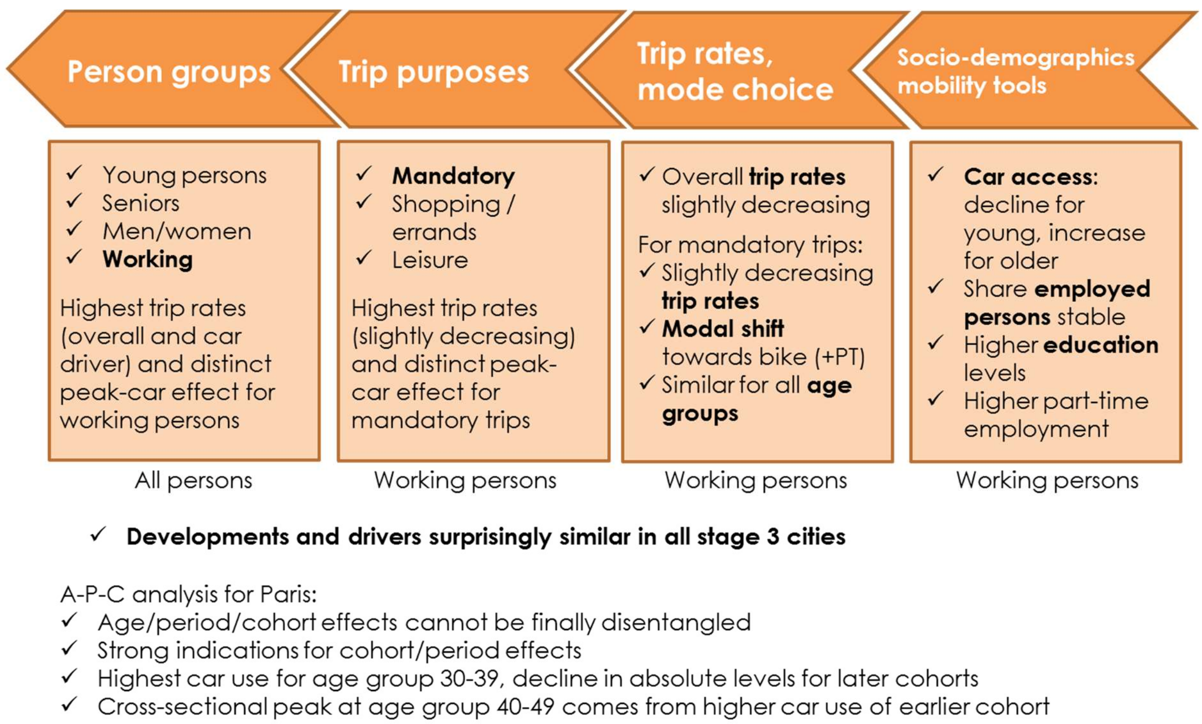
These observations of changed car-use patterns are quite plausible as well as explainable by changing cohort-specific framework conditions (e.g. part-time employment), urban developments (e.g.

density and mixed-land-uses), improvements in terms of the mobility tool box and digitalisation, and because of the well-documented shift in planning strategies introduced as the transport policy evolution cycle in CREATE (see the CREATE WP4 reports).

Travel behaviour is being successfully influenced by push policies mainly restricting car use and pull policies towards enhancing transport alternatives of PT, cycling, walking, car sharing, bike sharing, multimodal interfaces (connection points), etc. Because of the natural replacement of cohorts and cohort-specific travel mind-sets, the authors of this report assume that the current opposing trend of increasing car use of elderly people will be weakened within the next decade. In many parts of the population, women already have reached similar travel behaviour patterns as men. In the same manner as the currently pro-car-orientated travel socialisation of current generations of pensioners, next generations will most likely carry their travel behaviour into the next life-cycle stage; less car-orientated travel behaviours might be the outcome.

Figure 51 concludes this report with an overview of the most important of the many identified drivers of the peak-car phenomenon in the Stage 3 European capital cities of CREATE. Within the quantitative work of CREATE, both population structures and trip characteristics have been identified as main reasons behind the peak-car phenomenon. Less mandatory trips of working people due to changes in employment conditions and a clear mode shift towards bicycle (and PT) have been identified. These developments have appeared for all age groups of the working population and particularly for young adults (18–34 years). Younger generations might have developed new perceptions and attitudes towards cars and alternative mobility services. The higher education levels might be combined with (positive) experiences with other travel options besides cars at the places of education and formation. These are usually high density metropolitan areas with balanced, high-quality, and suitable transport supplies of PT, cycling, and walking. All these issues support different travel behaviours of the younger cohorts compared to previous generations.

Figure 51: Drivers of Peak-Car Phenomenon in Stage 3 Cities of CREATE



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9 Figures and Tables