# Completed Sections (First pass)

## Disadvantaged groups, active travel, and public transport dependence

Reduced auto-mobility can be a result of disability and impairment, which can adversely affect the ease of learning to drive, of driving, and the ease of using other transport modes, and so further compound socioeconomic disadvantage relating to disability and impairment.7,8 Conversely, socioeconomic disadvantage itself can lead to some forms of increased active travel, and some of its associated health benefits of less sedentary behaviour. In England and Wales, poorer socioeconomic groups tend to walk, but not cycle, more than richer socioeconomic groups. 1 Time use studies in the UK in 2005 have shown that young people, those without access to a car or van, the unemployed, and those from less affluent backgrounds, were all more likely to engage in active travel and meet recommended physical activity targets than the general population.37 When active travel options are not possible, lack of car access increases reliance on public transport, and so increasing public transport costs, which in Australia were found to be less cost-effective than private transport, can compound other forms of socioeconomic household disadvantage. 91 In the UK, there was some hope in the early 1990s that privatisation of British Rail’s assets would lead to an improvement in quality of service and so increasing attractiveness of rail as an alternative travel mode to car use. 9 Though passenger numbers increased, quality did not and ticket costs increased. The attractiveness of travel by rail can be increased somewhat by providing additional transport, such as electric station cars, from train stations to final destinations, but unless end-to-end public transport solutions are widely available cars may well remain much more attractive and convenient means of conveyance. 11

## Car dependency and urban form

A noted irony in the auto-mobility story is that concerns about the poor air and disease associated with high density living contributed emergence of proto-suburbs like Letchworth and Welwyn in the late 19th century through the Garden City movement, and now concerns about the public health and environmental concerns created by the vehicles driven by and to suburbs developed in their image are partly behind programmes of re-densification and Back to the City movements. 47,48 The UK, more so than many other European countries, is characterized by many decades of increasing physical separation between homes, workplaces and other trip destinations after the Second World War, in part due to long-term processes of housing de-densification and suburbanization, both causes and effects of increased car dependency. Schemes to increase the cost, if not the friction, of travelling greater distances, such as road pricing, are likely to be met with stiff public opposition in much of the UK. 21 Separation between where people live and work, and the role of the workplace as both a cause of car-dependency, and a possible site of intervention to reduce individual car use through either site relocation or car-sharing schemes, is important to consider. As well as travel to work being a key driver of private vehicle use, the workplace has also been considered as an important place from which greater active travel can be encouraged. 23 The evidence base in support of such workplace (or school) interventions, referred to as ‘organisational travel plans’ (OTPs) as a means of reducing car dependency, is currently mixed and of poor quality. 24

More compact urban forms, which reduce the physical distance between trip destinations, are known to encourage lower car dependence and greater use of multi-modal transportation. 22 People living in inner cities in Denmark tend to travel less by car to work, and less overall, but somewhat more at weekends for leisure purposes. 25 Similarly, policies to promote infill and redensification of urban places through re-use of brownfield sites may lead to more sustainable and less car dependent travel behaviour.27 Structural equation modelling based on four decades of data from many cities suggests that increasing urban density, as well as improving public transport, may both have a causative effect on reducing private vehicle use per capita, and that these effects may be stronger than reducing levels of car ownership or parking spaces. 83

It is important to consider the possibility of reverse causality, of people more inclined towards multi-modal transport moving to cities rather than the cities’ density inclining people towards increased multi-modality. In Canada, young adults are now making the decision to locate to high density areas more than in previous generations, leading to the suggestion that many inner cities may not be undergoing a process of ‘gentrification’ as much as ‘youthification’. 93 The declining economic prospects of today’s young adults, of which reduced car ownership may be both a consequence and a cause, could be an important explanation for these trends. 93 The link between living in low car-dependent neighbourhoods with good mass transit alternatives (called transit oriented developments, TODs), individual preference towards or against such neighbourhoods, and modal choice has been explored in a panel survey of ‘baby boomers’ (born between 1946 and 1965) in Brisbane, Australia in the late 2000s. This found that more car-inclined residents of low car-dependent areas (called ‘TOD dissonants’) had odds of car use 2.2 times higher than less car-inclined residents of the same neighbourhoods (‘TOD consonants’); such findings were taken to suggest that attitudes to car use or alternative modal choice may matter more than availability of alternative modes, that these attitudes remain fairly fixed over the life course, and perhaps that greater multi-modality in low car dependent areas may be due to selective relocation amongst those already inclined to multi-modality towards such areas. 90

In addition to simple measures of urban density, postcode level estimates of ‘walkability’ have been developed, with people in Ontario living in highly walkable neighbourhoods tending to be less likely to be overweight or obese than those living in more car dependent ‘low walkability’ areas in the same city. 89 Walkability of places, in terms of dense urban form, tends to influence adults of working age away from car use and towards active travel much more than adults above retirement age. 76 However, even in high density inner city areas, car use can be considered a more convenient travel mode than public transit or walking. 42 This may help to explain why, in and around Paris – the densest city in Europe - inequalities in car ownership between richer and poorer households tend to be greatest in more urban areas, as in less urban areas higher car dependence tends to homogenise levels of car use. 64

## Health and wellbeing correlates of car ownership; Positive Health Effects of Active Travel

Amongst older people, car ownership has been shown to be a more consistent predictor of quality of life in European cities than home ownership. 28 In Western Scotland, lack of car access remains associated with poorer general health, and in particular with increased prevalence of depression and anxiety. 100 Conditions experienced in both midlife and childhood can strongly affect outcomes at older age, including physical mobility and risk of depression. 59 A decades long longitudinal study of nearly 5,000 people in Reykjavik, Iceland, found lack of car ownership in middle aged predicted depressed mood thirty years later. 59 Similarly, older residents of Mediterranean islands were also assessed to have better levels of ‘successful ageing’ including lower prevalence of obesity and hypertension, as well as higher rates of physical activity, if they were regular car users, than similarly-aged residents without car access. 60

Despite these positive correlations between car use and well-being amongst older populations, there is evidence that walking, travelling by train, and cycling are more satisfying modes of travel than driving, travelling by bus, or travelling by underground. 85,86 However, in China, where most people are not car users, there is evidence that both driving and walking have amongst the highest satisfaction levels, whereas travelling by bus or underground amongst the least. 52 Multivariate analysis of the UKHLS, controlling for socioeconomic confounders, has shown public and active travel to be associated with lower BMIs for both males and females. 77 Longitudinal analysis of individuals in the BHPS found that, after controlling for SES, found that switching from private car use to public transport or active travel was associated with reduced BMI (-0.32 kg/m2), and converse switches to private car use associated with increased BMI of almost the same magnitude (0.34 kg/m2). 78

Large scale adoption of more sustainable, active travel modes can lead to large scale improvements in public health; if some but not most people switch to active travel modes, however, cyclists and walkers experience higher risks of harm from air pollution and traffic accidents due to the car-using majority. 43 A cost-utility analysis of cycling in the USA has, however, estimated that the health benefits of cycling are still likely to outweigh the additional health risks of these factors. 44 Health economic modelling suggests that reducing car use and increasing walking and cycling could lead to substantive increases in disability adjusted life years (DALYs) in UK populations, by reducing exposure to harm from air pollution, road traffic injuries, and low physical activity. 53 Similar research based on a cross sectional survey in Melbourne, Australia, has also estimated potential health benefits of increasing active in DALYs, and noted that people living closer to urban centres are more likely to have adequate levels of physical activity. 54 A similar exercise to estimate the health impacts (in DALYs) of road transport in New Zealand found lower levels of harm to health from air pollution and noise than in many other countries, but that heavy good vehicles were responsible for a disproportionately large share of attributable deaths. 55 A similar health impact assessment in the Belgian city of Flanders, which has both high air pollution but also high rates of cycling, also estimated that a modal shift from car use to active travel would confer greater health benefits than harms. 56 A large scale EU-funded project to explore these issues throughout Europe is currently in progress. 57 A paper published in the Lancet in 2016 identified eight city planning initiatives considered likely to improve public health by encouraging switching to active travel. 104

## Cycling and walking

Preferences for cycling and other forms of active travel can be influenced by substantial changes in life circumstances or environments.6 It is estimated that, amongst commuters to a UK university who use the bus as their dominant travel mode, around two fifths of trips could be substituted for active travel. 99 Amongst Cyprian teenagers, provision of cycle infrastructure can increase preferences to cycle, with increased cycling and walking preferences then leading to greater multi-mobility and less car reliance more generally. 49 Although even within the famously cycle-friendly Netherlands younger people tend to cycle more than older people, rates of cycling are increasing amongst the elderly, including ‘Baby Boomers’ found resistant to modal change in the UK; this has partly been attributed to the availability of e-bikes as well as cycle infrastructure, suggesting the potential for technological innovations to increase active travel at older ages.80

The weather can have a greater influence on the decision to travel by foot rather than car than fear of crime. 39 In Greater Rotterdam in the Netherlands, sunny, dry and warm but not hot weather was found to stimulate a preference for cycling over other transport modes. 40

## Gender Differences

Gender differences are observed in preference for many travel modes, not just car use. For example, a large study of Dutch individuals between 2004 and 2009 found notable differences in active travel preferences for a range of trip purposes between genders and age groups, with women more likely than men to choose active travel modes for shopping or transporting other people, and men more likely than women to use active travel to get to sports facilities; younger adults were also more likely than older adults to use active travel to transport goods or other people. Both higher educational qualifications and living in urban centres were also found to increase the likelihood of using active travel. 50 Though many trips by car are of short distance (8km or less), they are often multi-purpose (such as involving the transport of heavy goods or passengers), and as a result it is estimated that only around one tenth of such trips can be easily substituted for active travel modes. 58 Women often have greater caring responsibilities than man, and greater need to balance caring with work commitments, indicating an additional source of female car dependence in rural areas where other transport modes may make meeting such commitments unfeasible. 87

## Peak Car and trends in car use

Falling levels of driving licence ownership have been identified in at least nine developed world countries, with the largest declines reported in Australia, one of the most car dependent countries in the rich world.72 Long term trends in per-capita car use in France, Germany, Great Britain and the USA suggest car use increased from the 1970s to the mid-1990s in all four countries, before stagnating or decreasing from around 2000 onwards. In each country, sustained high levels of car use amongst older drivers have partially or wholly offset reduced levels of car use amongst young adults.69 Within Great Britain and amongst young adults, increasing levels of female car use have partially offset falling levels of car use amongst males.70 In recent years, young adult females now have greater weekly mobility than young adult males of the same age.71 A complex model designed by Gordon Stokes to produce long-term estimates of car use incorporates cohort membership in its inputs alongside differences by gender and by age within cohorts. Even with lower car use amongst more recent generations, given the persistence of car use preference into old age, increasing longevity, and increasing female driving trends likely to compensate for slightly reducing female driving trends, it estimates overall car use to remain broadly stable for around twenty years, before falling in the mid 2030s. 67

A synthesis of extant research identified six broad categories of potential explanation: life stage, affordability, location and transport, driving licence regulation, attitudes, and e-communication; it found somewhat stronger evidence for life stage explanations (such as having children later, and staying with parents and in full time education longer), and affordability explanations (such as rising costs of insurance, licencing, petrol, vehicles; against falling or stagnant household incomes) than other types, but with no clear single cause. 72 Analysis based on panel data in the USA also found lower incomes and delay in major life events (leaving parental homes later, having children later) largely explained lower car ownership amongst Millennials, and that after controlling for these factors Millennials were slightly more likely than expected to be car owners. 73 Amongst these explanations, insurance costs may be a particularly strong factor in the UK, as they have risen particularly sharply in recent years. 74,75 One UK-specific explanation for reduced car use amongst young is changes in taxation policy less favourable to users of company cars, and related to this falling trends in company car use. 70 Econometric modelling of Swedish car use trends found per capital GDP and fuel price alone may explain up to 80% of the decline since the 1980s. 88 There is evidence that broader environmental concerns are not a substantial reason for not travelling by car, with no significant differences in environmental concerns identified between people using cars compared with other travel modes in a sample of commuters to a UK university. 86 Qualitative research focusing on the relationship between auto-mobility and environmental concerns amongst younger adults (18-35) in New Zealand did not reach any definitive conclusions about this relationship. 97

Regarding affordability as an explanation, vehicle registration taxes increased in the USA in the 1980s; these increases were found not to have decreased the proportion of people registering for new vehicles, but to substitution of newer and more expensive vehicles for older and cheaper priced vehicles, 10 suggesting both that cars were a somewhat inelastic commodity, and that there can be unintended consequences, in terms of moving to more polluting and fuel inefficient vehicles, to incentive structures intended to reduce car use. Similarly, in Japan it is estimated that falling population size and household size may both lead to increasing car ownership. 107 It is also estimated that the average age of cars, like the average age of the population, is increasing in Japan, and that use of older cars (12 or more years old) is more sensitive to increase in fuel price than use of newer cars. 107

Regarding location as an explanation, important regional differences in car use trends have been observed. In England, car use trends from the 1970s, defined as miles driven per person per year, differ depending on whether people live in Greater London, other cities or conurbations, or elsewhere. Car use peaked in Greater London in the early 1990s and in other cities in the early 2000s; in less urban areas they have plateaued rather than fallen substantially since the early 2000s. 63 The changing shares of the population living in these three urban groupings of place is therefore expected to influence the extent of future trends in car use. 63 Like Greater London, car ownership in and around Paris, France, peaked in the 1990s. 64 Regional lags in Peak Car have also been found in the USA, with peak car travel being reached in Washington State in 1992, another 10 states by 2000, and almost all states by 2011. 65

There are some compelling theories for why ICT use may have been partially responsible for declining car use, and why this decline occurred largely within younger cohorts. In the USA, nearly 90% of shopping trips are made by car, 94 and so increasing use of online shopping amongst young adults may be one reason for declining car use overall. With ever improving ICT, teleworking has ever more potential to reduce the need for physical travel long distances for work purposes, but remote working remains marginalized in Ireland. 81 ICTs may both reduce the need for motor travel, and also allow for better organization and utilization of private vehicle stock through apps and information sharing platforms like Uber, enabling what’s sometimes referred to as ‘collaborative consumption’. 4 Despite this, when compared with other factors, ICTs do not appear a predominant explanation for the decline, with economic constraint and deferred life events appearing more powerful explanatory factors.72

Despite these long-term trends, England and Wales remains car dependent, with 67% of commuters using cars or vans as their main commute mode in 2011.1 The cost of car or van ownership and use leads to a socioeconomic gradient in modality, with those from more deprived areas more likely to walk or use public transport, but not to cycle, than those from less deprived areas.1 In the USA, falling levels of driving levels in the 2000s have not been accompanied by commensurate increases in use of alternative travel modes, leading to reduced mobility overall. 108 While car use is reducing in much of Europe and North America, it is increasing substantially in China, 52 creating competing demands on urban land currently used for walking and cycling. 66 In Beijing, China, most people use public transport rather than private vehicles to travel to work, although car use is increasing rapidly. 52

## Automated vehicles, car share schemes, other technological fixes

Cars are an expense asset in many ways, including the cost of passing driving tests, the cost of insurance, the cost of fuel, and the cost of ownership, notwithstanding the long-term cost on health to self through sedentary behaviour, and to others through air pollution. A series of technological and cultural shifts offer the hope for their use in ways that are both more economically efficient and harmful. Car sharing schemes are one of the earliest means by which the car can be used more efficiently as an asset, and the potential for accelerating car sharing behaviours through ICTs is as yet unrealised. . In 1999 around 38,000 people were registered in car sharing schemes in European cities. 12 Increasing car sharing scheme adoption could potentially save around 84,000 tonnes of CO2 being emitted in Dublin per year, and over 200,000 tonnes of CO2 emission per year in Ireland as a whole. 13 Car sharing could encourage other transport modes, including active travel, and so has potential health benefits, as well as allowing an expensive and rapidly depreciating asset to be used more efficiently. 82 Car-sharing schemes have been shown to be more attractive to people who are already multi-model in their travel behaviour, rather than mono-modal car users. Given that most, but not all, car trips by elderly people in the USA are of relatively short distance (8km or shorter), electric vehicles may be attractive within a car-sharing fleet for older drivers as long as non-electric vehicles are also available in the fleet for longer trips. 106

Car sharing schemes long predate autonomous vehicles as a viable means of shifting car use towards being a shared commodity. At least one car manufacturer has entered the car-sharing market, with a marketing strategy focused on ‘selling mobility instead of cars’.46 The price of ride-sharing could be reduced, and so the attractiveness of ride-sharing more attractive, if the dominant platform operators (such as zimride, blablacar, and carpooling.com) who provide the information infrastructure to enable such schemes, were to improve their algorithms to better accommodate ‘multi-hop’ ride sharing. 96 Higher densities of both asset providers (car users) and asset providers (passengers) can also be expected to reduce prices and waiting times for this emerging travel mode, and so make them more economical and attractive in comparison to fully private car use. 61

Automated vehicles, like car sharing schemes, offer not just the possibility for replacing or blurring the public/private distinction in car ownership, but for augmenting train and coach use as well. 5 Autonomous car use and technology is still in its infancy, but offers the potential for cars to become more of an efficiently used shared asset rather than a private asset parked, and so not used, for most of the day. 98

## Car Society

Auto-mobility has long been the dominant transport mode in rich countries, to such an extent that it has been argued demand for car use has become self-reinforcing, in opposition to a more sustainable ‘postautomotive mobility paradigm’.16 It has been argued that the ‘car system’, or ‘automobile society’ is a key element for understanding processes of globalisation more generally, and exhibits a high degree of both path dependent and autopoietic (self-reproducing) qualities;17 these qualities create a societal ‘lock-in’ which may be strongly resistant to external factors which could otherwise bring paradigmatic change, such as urban transport planning policies, vehicle use saturation, and reducing car use amongst young adults. 18 The kind and scales of policies required to bring about substantial vehicle-based emission reductions may be untenable in the modern political climate both within the UK and the rest of Europe. 79 Some recent academic commentary has suggested, however, that we may be undergoing a long-term and large-scale paradigm shift in both levels of and preferences towards car ownership. 19,20

Preference for travel by car, like many other preferences, is culturally transmitted, and so it is important to understand the role of childhood socialization in the development of such preferences. 29,30 Monomodal car-use is habit-forming, and has been likened by public health researchers to tobacco use, in terms of both dependence and damage to the health of both users and those nearby. 45 [Something about cohort effects in tobacco use] It has been noted that, though median incomes for many households have fallen, and fuel prices risen in recent decades, not all populations – defined by cohort membership, geographic location and other attributes – have responded to such changes in the same way. 68 Transport mode ‘inertia’ has been demonstrated in travel behaviour to work. When a workplace was relocated from an out-of-town location to the city centre in Lisbon, Portugal, for example, little change was found in rates of commuting to work by car, while residents of the inner city experienced additional inconvenience as a result of increased traffic. 62 It has been argued that much of the difference in auto-mobility between different cohorts in the UK and similar countries could be due to each cohort’s differential experiences and exposure to a range of multi-level forces, each operating over broadly different timescales. Faster-acting changes include periods of economic growth and recession, referred to as ‘period effects’; changes operating at intermediate rates include changes in technology, demography, and average household income and wealth, collectively referred to as ‘structural effects’; and changes operating over the longest timescales including changing gender roles, and changing cultures of mobility and social/familial relations, collectively referred to as ‘deep structure’. 109

Decades of expanding car use, and the development of extensive travel infrastructure for cars and vans, has both led and followed strong and often obdurate preferences for private car travel amongst much of the affluent world. Analysis of data from the British Social Attitudes survey in 2000 suggested high levels of car preference amongst working age men, people with higher incomes, people living in rural areas, and in particular in people with children; these groups were both most responsible for vehicle pollution, as well as least concerned about their impact. 14 Such concerns relate to broader issues of environmental and social justice, where households exposed to higher levels of vehicle-produced air pollution also tend to be less likely to be car-owning producers of such pollution. 15 In North America there is a strong preference for ‘ageing in place’, and remaining in car dependent residences even as capacity for personal mobility and auto-mobility starts to deteriorate has been described as a ‘symbolic goal’ for many elderly suburbanites. 34,35 A similar preference for continued car ownership and use amongst the old has been found in Australia, despite the greater viability and availability of public transport as an alternative travel mode, and private car use still considered a more convenient mode of travel. 36 Being the dominant travel mode in the USA, as well as the UK, car users are more likely to be mono-modal than multi-modal in travel model choice. 51 This is in contrast to China, where most people do not own cars, and so car use is associated with greater multimodality. 52

There are also important differences in attitudes to car use, and alternatives to car use, both within and between countries. A survey of nearly 900 individuals with cars in Norway found that perceptions about the social status of different transport mode users was important, with car users who did not consider public transport users to be of low social status also more likely to use public transport themselves. 105 A comparison between Germany and the USA, both countries with very high vehicle ownership, shows that Germans travel less by car and much more by other modes, and that American preferences to drive persist even for those living in dense, mixed use areas with close public transport. 41

## Life stages and cohort effects on car use

There are complex but compelling links between life stage and car use, as well as with household wealth. In the USA, both type of residence and the life-stage of household members are shown to influence how often and how far people tend to travel, as well as each other. 31 Car dependency tends to increase in households after the birth of a child. 38 Households with high income tend to be ‘car loyal.’101 Households with no children are more likely to use bikes and other modes of active travel, and households with children more likely to be car users.101 Analysis of car registration data for Dutch young adults in 2012/2013 found that the effect of living in more urban areas on car ownership was much weaker for young adult couples with children than without children. 102

At younger ages, there is a tendency towards reduced car use and greater multi-modality. In Montreal, Canada, use of public transport tends to fall as people enter their early thirties, consistent with patterns of realized auto-mobility in the UK. 2 In the USA, where mass transit users are disproportionately likely to be non-white as well as younger adults, there are concerns that similar falls in transit use may occur in newer cohorts in the USA as they age. 3 Staff travelling to work at universities have been found to be less than half as likely to use active travel modes as students travelling to study at the same institutions, likely due to a factors such as greater age, greater income and perhaps greater travel distances 26

The UK population is ageing, with important implications for both social care and transport planning. 95 Continued auto-mobility at older ages presents multiple challenges, including those related to increasing age-related impairment and capacity to drive safely. In Germany, as well as the UK, there is no compulsory medical retesting of elderly drivers, leading to some concern about elderly driver safety given the effects that diseases of old age may have on driver aptitude. 32 Neuropsychological testing of nearly 500 older drivers in Sweden found that increasing age was associated with deterioration in performance in all seven of the domains tested to assess driving performance. 33

One reason why cohort membership is predictive of auto-mobility could be due to homophily, the tendency for people to affiliate and associate themselves with others who are in many ways like themselves, and one of the important ways people distinguish themselves is by cohort membership, as such membership may also be predictive of having broadly similar experiences at various stages in the life course, and broadly similar attitudes and beliefs. This suggests there may be a complementary role for social network analysis alongside cohort analysis. Indeed, an analysis of Dutch commuting behaviour based on a survey of around 750 people in 2011 suggested that both social network composition and life-cycle events, such as moving home or forming a partnership, influenced levels of active travel, as well as each other. 84 Amongst these life-cycle events, starting university and residential relocation were found to lead to the largest change in composition of social network in terms of both the number of existing social ties lost and new ties established. 84 In the UK it is more common than in many other European countries for people to relocate when starting university, meaning that this life cycle event in particular can influence transport mode preference through both changing social network composition, changing residence, and through this also changing urban form. [NOTE: Summarise Salomon 1983; Lanzendorf 2003; Brown 1970; Oakil 2011; Sharmeen 2013]

In terms of travel behaviour, the Millennials have been described as the ‘Go-Nowhere’ generation. 92 Although in the USA there have been some falls in auto-mobility from the mid 1990s onwards in many cohort groups, Millennial-specific factors such as changing attitudes to car use and increasing ICT use may also have a significant role in their declining auto-mobility. 92 Comparisons in the USA between ‘younger millennials’ (born 1999-1994) and ‘older millennials’ (born 1979-1985) suggest that many important life events – such as finishing fully time education, marrying and having children – occur at later ages for this generation than earlier generations, but that once such events occur, auto-mobility increases. 103 However, analyses on UK data suggests that people who start driving at a later age then continue driving less than those who first started driving at an earlier age, suggesting that there will not be complete ‘catch-up’ in auto-mobility amongst Millennials compared with previous generations even once life event deferral has been taken into consideration.67

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