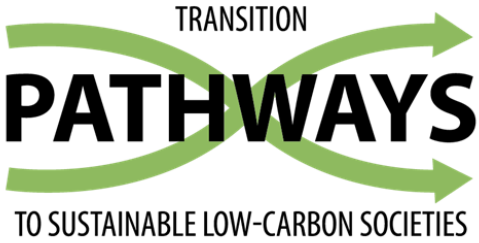


PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

Grant Agreement number 603942

Deliverable D2.5: 'Forward-looking analysis of transition pathways with socio-technical scenarios'

Mike Hodson, Frank Geels, Andy McMeekin
Sustainable Consumption Institute
University of Manchester

Country report 6: The UK mobility system

July, 2016

Executive summary

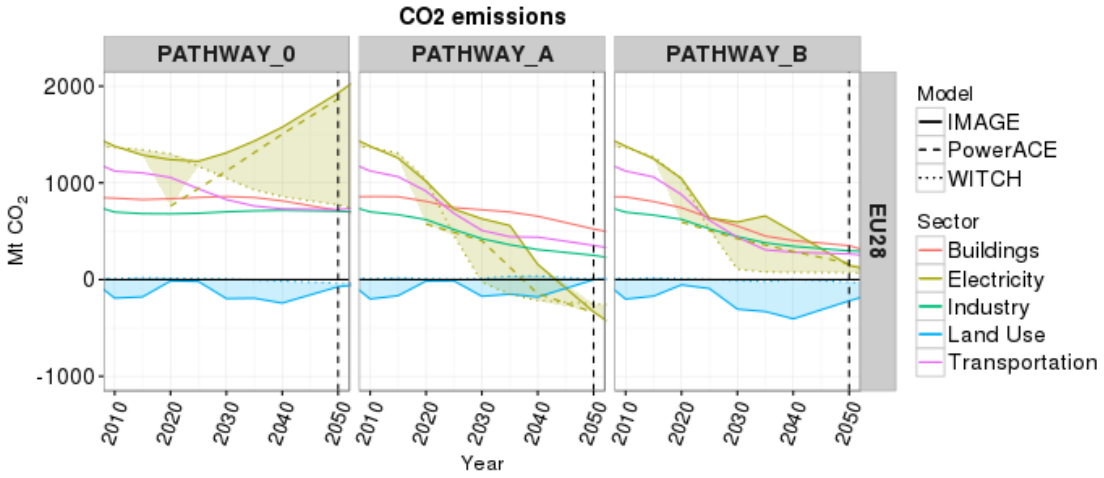
Contents

Executive Summary

This report develops qualitative socio-technical scenarios for land-based passenger mobility in the UK between 2015 and 2050. To do this it takes quantitative scenarios developed in WP1 of the PATHWAYS project, assesses what the key constraints are in achieving such scenarios and what processes of change to realising those scenarios might look like. Or in other words: what are the key socio-technical challenges in re-orientating current socio-technical trajectories to meet the pathways set out in the quantitative scenarios? In this respect, this report is 'service-oriented' in using socio-technical analysis (from WP2) in service of richer understandings of how quantitative scenarios (set out in WP1) may be achieved. Two stylised pathways, characterised as Pathway A and Pathway B provide an orientation for populating two future-oriented socio-technical scenarios in the UK context.

Three different pathways to CO2 emissions reduction in the transport sector are set out below (see Figure A). CO2 emissions reduction in each of the three pathways (0, A and B) is represented for 'transportation' and relative to other sectors. These representations illustrate that transportation is currently the second largest emitting sector.

Figure A: Changes required in the transport sector compared to the other domains



Source: WP1 PATHWAYS project

Socio-technical analysis sets out the 'transition challenges' (the constraints and possibilities) faced in trying to achieve these CO2 emissions pathways (Table A)

Table A: Tensions between future model scenarios for UK land-based passenger mobility and WP-2 findings of niche-momentum and path dependencies

Innovation /Challenge	Pathway A	Pathway B	Constraint
ICE:	Pathway A suggests a sharp reduction in ICE journeys from 2020 and phasing out of journeys by ICE by the 2040s	Pathway B suggests different paths - both involve a three decade process of continuously and massively reducing the share of trips by ICE	Inertia / stability in automobility regime are still substantial Dense entrenched infrastructure webs (e.g. roads, petrol stations, manufacturing facilities) Policy/ manufacturer coalitions

			committed to incremental efficiency improvements
HEVs	Pathway A envisages an increased role for HEVs, particularly growing until the early 2030s, then levelling off and reducing	Public Transport path - some substitution of ICE trips by HEVs from the early 2020s onwards, but particularly in the 2030s, levels out at c20% of trips in the 2040s Slow Modes path - 2030s onwards there remains c20% trip share for HEVs	Costs (largely batteries) of HEVs remain higher than comparator ICE vehicles - requiring reduction View still persists that more plug-in infrastructure is required even if not technically necessary
BEVs	Pathway A suggests a key role for BEVs in the medium and long-term, overtaking HEVs in the mid-2030s as providing the biggest single mode share of trips	Public Transport – BEVs account for very few journeys Slow Modes – some limited growth of BEVs in 2030s	Despite reductions in costs of batteries, remain significantly higher than ICE comparators Vehicle range remains an issue although there are increases Lack of regime integration of electricity producers a fundamental challenge Still some perceived need for new plug-in infrastructure
HFCVs:		Public Transport – accounts for very few trips Slow Modes – some small growth in trips by hydrogen in the 2040s, but less than 10% in total	Fundamental need for configuring new fueling production, transportation, distribution and storage infrastructures Vehicles significantly more expensive than similar ICEs Safety/ perceived safety of hydrogen use Lack of coordinated policy and governance capability
BIOFUELS:	Pathway A suggests around a 10% share of trips by biofuels until the mid-2030s when it declines to almost zero	Public Transport and Slow Modes – account for c10% of trips across the period	Significant lack of alignment between multiple regimes (automobility, food, land-use). Weak alignment between biofuels and existing automobility practices, in relation to legitimacy and the variety of interests in the governance domain
PUBLIC TRANSPORT:	Pathway A suggests public transport accounts for around 10% of trips across the time period	Public Transport – Huge growth in trips, rising from a very low level to over 20% of trips by 2030 and c45% by 2050 Slow Modes – Growth particularly in the 2030s, also as a buffer between the decline of ICE and the growth of slow modes	Infrastructural capacity problem Spatially selective prioritisation of parts of the network Costs increased significantly since privatisation Fragmented bus and train governance post-privatisation Dominance of ideology of private

			mobility Austerity
SLOW MODES:	Pathway A suggests slow modes accounts for around 10% of trips across the time period	Public Transport – c20% of journeys reducing to c10% by 2050 Slow Modes – c20% of journeys in to 2030s and then a huge upswing to over 70% by 2050	Cultural 'abnormality' of cycling Realisation of cycling infrastructure limited and variable - may be attributed to fragmented governance Significant spatial variations
CAR SHARING:	Pathway A car sharing accounts for a very, very small share of trips	Public Transport – Very limited role Slow Modes – Significant in buffering the shift from ICE to slow modes in 2020s and 2030s; at peak accounting for c30% of journeys; very small share by 2050	Significant re-alignment of socio-cognitive understandings of car use Need for significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors Requires new forms of governance

This provides a stepping stone between the quantitative CO2 emissions reduction scenarios and the articulation of socio-technical scenarios. The scenarios are between 2015 and 2050 and presented in two time periods: 2015-2030 and 2030-2050.

Scenario 1 (Pathway A) is characterised as 'BEV UK'.
In this section a socio-technical scenario (ST-S) is set out for Pathway A. The ST-S operates in service of the quantitative scenario for Pathway A, BEV UK (see Figure 2); to discursively and speculatively elaborate what changes might happen to achieve the change in socio-technical systems suggested by the quantitative scenario; but also to recognise the challenges and bottlenecks, opportunities and constraints, thrown up in the current direction of the land-based passenger transport system.

This involved a significant degree of substitution between ICE and alternative fuels between 2015 and 2050. It is primarily a story of the decline of ICE and its replacement by BEVs. In addition, there was a small, steady share of trips via public transport, slow modes and biofuels. The story is told in two time periods: from 2015 to 2030 and from 2030 to 2050.

2015-2030: the Decline of ICE and its Substitution by HEVs and BEVs
Pathway A suggested two very radical shifts. First, a very sharp reduction in ICE trips from around 75% in 2020 to c20% by 2030; and second, rapid growth in HEVs and BEVs from a very small share of trips in 2015 to c35% HEVs and c20% BEVs in 2030.

Between 2015 and 2030, this involved the following changes:

Policy: In this scenario, a radical shift in policy took place in 2019. The automobility regime, particularly policy and manufacturers, which hitherto was strongly committed to the ICE actively shifted to a twin-track strategy of promoting the decline of ICE and promoting the

growth of electrified automobility. Prior to 2020 EU targets had contributed to gradual year on year reductions in CO2 emissions, but these lagged some way behind those necessary under Pathway A. Following agreement between policymakers and manufacturers in 2018, targets were strengthened from the current level of CO2 emissions of 95g/km by 2020 to 60g/km by 2025 and 30g/km by 2030 to incentivise a more rapid shift from ICE and to electric mobility. The political underpinnings to this were weak growth in the EU, post-2007/8 crisis, political uncertainty caused by European citizens restless at elite power and creeping rises in oil prices. Following the Greek crisis and the divided British decision to leave the UK in 2016, to quell citizen-unrest a renewed emphasis was placed on promoting new forms of 'green' economic growth by the EU, of which intensifying the rapid growth of green automobility was a key sector. Leading ICE manufacturers, including Renault-Nissan, Volkswagen, BMW and Toyota not only embraced this strategy but were central to devising it. The sector as a whole, by the early 2020s had promoted HEVs as a primary response and BEVs as a secondary response. To disincentivise ICE use, a sliding scale UK road tax was strengthened and tapered so that older ICE vehicles became very expensive to use from 2025.

Technology: The promotion of HEVs, at a technical level was not hugely difficult given the high potential alignment techno-economically between (P-)HEVs and the incumbent automobility regime. The steady growth in HEVs in the UK, since the early 2000s, was intensified given high alignment between PHEVs and the existing automobility regime where both dominant regime interests and users of vehicles were broadly similar. Costs of HEVs remained higher than comparator ICEs, but the manufacturing premium was reduced from around £7,800 above the costs of conventional ICEs in 2013 to around £3,000 by 2020, until in 2028 there was cost equivalence. BEVs were even more expensive than ICEs. In 2013, BEV costs had a 50% price premium in comparison with similar ICE vehicles. A report commissioned by the UK Committee on Climate Change suggested at this time that the costs for a battery pack for a medium sized BEV with a range of 150km were estimated at $21,000. This was predicted to drop to $6,400, with a range of 250km by 2030. Purposive public-private investment in battery research and an increasing uptake of both HEVs and BEVs accelerated cost reductions until there was equivalence in cost by 2033 and BEVs generally had a range of 400km.

Manufacturing: Capacity to meet the over 20% trips by household of HEVs by 2025 saw a massive retrofitting of automobile manufacturing capacity from 2019 onwards in the global division of labour. This allowed the share of HEV trips to grow to around one-third of all trips by 2030. Extensions of existing electric automobile production facilities took place and new manufacturing capacity came on stream. Through the 2020s, this included the extension of Toyota's hybrid vehicle manufacturing facility in Derby and Nissan's electric vehicle manufacturing facility in Sunderland, and a new facility in the North-west of England. Existing ICE manufacturing facilities were either retrofitted to produce HEVs or were closed down. There were large job losses as UK's manufacturing output increased but the numbers employed in the sector reduced. In 2012 production had totaled almost 1.5 million cars, in an industry that directly employed 140,000 people and around 720,000 in the wider automobile industry. By 2025, the UK remained the fourth largest European manufacturer of cars, averaging output of 1.7 million cars through the 2020s, but advances in automation meant the number of those employed in the sector had reduced to around 500,000 by 2030.

Infrastructure: The dense infrastructure webs that supported ICEs (roads, road signs, repair and maintenance facilities, manufacturing facilities) in 2015 were largely interchangeable with the growth of HEVs (e.g. roads, petrol stations, manufacturing facilities); although there

was some retrofitting of manufacturing facilities from 2019 and a UK government-subsidised programme for enhancing and upgrading skills for repair and maintenance engineers. The UK's petrol stations, numbering 9,000 in 2011 rapidly reduced to 3,700 by 2025 and 1,100 by 2030 when ICE accounted for only around one-fifth of trips. Growth of plug-in points, from an estimated 11,000 in 2016, continued into the early 2020s when there were 35,000 charging points. By this time there was widespread recognition that a further mass roll-out of public charging points was not required. A public information campaign in 2021-2022 promoted the simplicity of plugging in electric vehicles at home and charging them overnight via a conventional 13amp plug, with the price being illustrated by the smart meter that had been installed in most homes by 2020.

Business models: A massive uptake in electricity generation from the early 2020s onwards meant that electricity generators and distributors were brought into a new institutional arrangement with national and urban energy and transport policymakers, car manufacturers and large scale business users of electricity. This, in reality, was a re-branding of The Office for Low Emission Vehicles (OLEV), which was set-up in 2009. The re-branding was deemed necessary to re-position electricity distributors and generators in a network that had historically been dominated by elements of the automobility regime. The Office for Accelerating and Managing Electric Vehicles aimed to try and plan the management of an emerging new large-scale, reconfiguration of electricity generation and consumption.

User: By the early 2020s, there had been clear movement beyond the archetypal user of HEVs being characterised as an eco 'first-mover' and the use of HEVs was 'normalised' in media and popular representations. BEVs, in the early 2020s, retained some of this 'first mover' status but this weakened significantly through the 2020s. The flip-side of this was that the ICE became more negatively portrayed and represented in media and film through the 2020s in tactics that echoed aspects of cultural efforts to stigmatise cigarette smokers in the early part of the century.

In addition to this major shift, between 2015 and 2030, biofuels accounted for around a 10% share of trips which meant a doubling of the share of biofuels as a transport fuel from 2015. This required a modest amount of work to reverse weak momentum in relation to biofuels in the UK. On a techno-economic dimension although there was potential alignment between biofuels and the incumbent automobility regime in the UK the growth of HEVs and BEVs meant that biofuels remained a constant and small contributor to trips. Furthermore, significant issues of lack of alignment between multiple regimes (automobility, food, land-use) remained through the period. There was also ongoing and weak alignment in relation to legitimacy issues of biofuels as a fuel versus food issue. Public transport accounted for around 10% of trips across the period, which meant a stability of provision. Slow modes of cycling and walking also accounted for around 10% of trips, which again was remarkably stable, but with some growth of cycling in urban centres in particular.

2030-2050: Continuity in Phasing out ICE and Promoting BEVs

Post-2030, the scenario trend was one of continuity; decline of trips by ICE continued reducing from around 20% in 2030 to a phasing out of ICE in the early 2040s. Share of trips by BEVs continued to rise from around 20% in 2030 to over 50% by 2050. HEVs rose from 35% in 2030 to almost 40% in 2035 before reducing to c30% in 2050. Public transport and slow modes continued to account for around 10% of trips. In the late 2030s the 10% share of trips using biofuel reduced, phasing out by around 2045.

Policy: The EU emissions deal set out in 2020 - which the UK was shadowing - came to an end in 2030. In the build-up to this in the late-2020s EU decision-makers and automobility manufacturers agreed a continuation of a twin track strategy of working to phase out ICE and promote BEVs. Targets that were intended to lead to the phasing out of the ICE by 2045 were passed in 2028. Automobility manufacturers had become enthusiastic agents of managing the decline of ICE and the rise of BEVs, seeing that the decline of ICE and the growth of BEVs was heading to the latter overtaking the former in terms of share of trips by 2030. By the late 2030s, with ICE almost phased out and BEVs accounting for almost 40% of trips, ultra-low EU CO2 emissions targets began to bite in making BEVs more attractive than HEVs for manufacturers. Coalitions of policy and automobile manufacturers, mighty in the 1980s and 1990s, were reconfigured around this demise of ICE/promotion of BEV strategy.

Manufacturing: Among leading ICE manufacturers, most of whom embraced an electrification strategy from 2020, a small number had completely phased out their ICE production capabilities by 2030. Through the 2030s, this phasing out picked up momentum and post-2035 only a handful of ICE manufacturers remained to produce what had become a technology consumed by 'petrolheads', technological refuseniks and a small number of vehicles that owners refused to scrap.

Technology: The increasing loss of economies of scale for ICE as their production numbers fell meant that by 2030 the costs of purchasing ICEs had risen significantly as they became positioned both as 'yesterday's technology' and as a premium product for 'petrolheads'. By contrast, the costs of HEVs and BEVs continued to fall through the 2020s meaning that by the late 2020s, HEVs and ICEs had price equivalence and by the early 2030s, so did BEVs and ICEs. The increasing volume of production battery costs had significantly reduced from 2025 onwards. Technological breakthroughs had been made on vehicle range, which by the early 2030s meant that range had stretched to around 400km. This was perceived to be sufficient by many consumers and resonated with their use patterns with ICEs.

Business models: The huge growth in BEVs and HEVs that had taken place in the 2020s continued into the 2030s. The new institutional mechanism to integrate policy, automobile manufacturers, electricity distributors and generators and large business interests - The Office for Accelerating and Managing Electric Vehicles - set out its strategy in 2030 as to how it envisaged electricity generation and consumption as it related to the electrification of automobility. Alongside its programme of upgrading the UK's electricity generation capacity, it also set out the need for an acceleration of appropriate ways of incentivising consumer generation of electricity and feeding it back into the UK electricity grid.

Infrastructure: Much of the road infrastructure associated with the ICE remained in 2030. That said, there were only a small number of ICE manufacturing plants remaining in the UK, as part of a wider international trend of closing these plants down and/or retrofitting them to produce HEVs and BEVs. Throughout the 2030s, the number of UK petrol stations declined rapidly so that by the late 2030s there were fewer than 500 nationally. Repair and maintenance facilities for ICE vehicles had become a niche and specialised service by 2035. The surge in electric vehicle plug in points from 2015 had stabilised from the early 2020s and the widespread education programmes that had been commissioned to encourage users to engage with their domestic electric infrastructure for charging and to use plug-in points to power-up if they were 'caught short'.

User: By 2030, HEV users had become the dominant mode of land-based mobility trips in the UK. Users approximated to the wide range of users-types who had previously been ICE users. Users of BEVs had moved beyond archetypal eco 'first movers' and had become, by 2030, the choice of vehicle for those willing to pay more for the cost of their vehicle upfront than was the case with HEVs but where there were savings to be made from the huge running costs from petrol and diesel that HEVs faced. ICE users were increasingly older, male 'petrolheads' and a minority of those unwilling to move away from the ICE. Popular media representations presented these users as quirky refuseniks.

Within this scenario, public transport and slow modes remained stable at around a 10% share of trips each. These were primarily used for short commutes in urban areas where increasingly the volume of vehicle congestion meant that large areas of these urban centres were deemed no-go areas for private vehicles. Share of trips using biofuels remained at 10% in 2030 but dropped from around 2037 and was phased out in 2045. This was due to EU targets strengthening and prioritising pure electric vehicles from 2036 and developing a sanctions regime for the use of petrol, diesel and biofuels.

Scenario 2 (Pathway B) is characterised by two alternative scenarios: 'Public Transport' and 'Slow Modes'

These two scenarios implied radical change throughout the period from 2015 to 2050. In particular, they necessitated radical change in the period from 2015 to 2030 often with more gradual changes and stabilisation in the period 2030-2050. Both required a sharp reduction in trips by ICE. The (i) Public Transport scenario saw a major rise in the number of trips undertaken by public transport. There remained, in this scenario, a small but significant role for car-based automobility via HEVs and also for slow modes. As a response to the decline of ICE, in the (ii) Slow Modes scenario there was huge growth in trips undertaken by slow modes with a small but significant role for car-based automobility.

(i) Public Transport

2015-2030 Making the ICE obsolete and re-invigorating integrated public transport

The Public Transport scenario was based on a shift from private car ownership and use to a large increase in public transport. There were still small roles for HEVs, slow modes and biofuels. Between 2015 and 2030, the Public Transport scenario envisaged a sharp reduction in the share of trips undertaken by ICE; this was from c75% in 2015 to around 50% by 2030. Share of trips on public transport rose from a nominal amount in 2015 to over 20% by 2030. Within this time period, there was a steady level of trips via slow modes at around 20% and a c10% share of trips via biofuels (see Figure 3).

Policy: UK policy at national and local authority levels was aligned after 2017 to operate in pursuit of a twin-strategy of radically reducing ICE and car-based automobility and promoting the development of public transport to provide alternative modes of mobility. In 2017, UK government recognised that existing targets were an insufficiently radical means of reducing CO2 emissions and that incremental change was not enough. From 2019, the UK government shifted course from its greening automobility strategy to a long-term, 30 year phasing out of car-based automobility. Its 2019 'Transition to a Public Transport Future' strategy set out a generous scheme of public transport investment funding for local authorities prepared to trial congestion charging schemes, as part of a stepping stone to banning cars from identified urban areas by 2030. Feasibility studies were also undertaken to assess the effects of widespread road pricing on UK motorways and major highways.

Privatisation and liberalisation in the 1980s and 1990s had produced a serious fragmentation of public transport systems in the UK. The Transition to a Public Transport Future strategy signalled a major shift in government ideology, recognising that the level of trips required to be made by public transport required control over public transport systems and investment in them that are managed and controlled by strengthened local, integrated transport authorities. The strategy set out that these enhanced authorities were needed to develop both a strategic view of local transport that addressed 30 years of privatised, liberalised market-driven public transport and also to undertake an operational role. Greater Manchester and Greater Leeds were chosen as pilot authorities in 2019. A second wave of large city authorities were selected in 2021 and by 2028 enhanced modes of urban public transport governance were established across England, with similar developments taking place in the devolved administrations in Scotland and Wales. These authorities were also given responsibilities for maintaining levels of slow modes at around 20% of trips. This was an attempt to bring some strategic coherence to a range of cycling infrastructure investments and public promotion campaigns in cycling and walking which had resulted in around 20% of trips being by slow modes at the start of the period in 2015.

Business models: This strengthening of integrated public transport authorities was part of a wider process of decentralisation from central government to local levels. By the late 2010s, there had been growing recognition among both policymakers and the wider population that addressing the scale of carbon emissions reductions required a new model of economic development to address the ongoing post2007-8 economic malaise. This new economy went beyond the industrial and post-industrial economies that supported automobility. Re-making the economy was on the basis of more localised forms of economic activity in compact cities rather than through the stretched supply chains of globalisation. One of the key tasks of the new integrated urban transport authorities was to work with broader local and national governance interests to set out new visions for compact cities which integrated public transport networks with the economic and material re-design of towns and cities. Pilot visions were set out in Greater Manchester and Leeds in 2023 and by all major urban areas by 2030.

Infrastructure: These large scale plans meant that much of the infrastructure for compact cities was not in place prior to 2030. Where infrastructure was in place there was a reallocation of existing infrastructure (e.g. roads from cars to public transport and slow modes pre-figuring the 2030 banning of cars from urban centres). The electrification programme on the railways from 2015, aimed to electrify the two-thirds of the rail network that were not and meant that by 2030 the vast majority of the train network was electrified. By 2025, though, there were serious concerns that the 150% growth of passenger trips by rail travel, since privatisation in 1994, had met the capacity limits of the system. In addition to HS2, which became operational in 2026, the UK Department for Transport undertook a feasibility study to assess the re-opening of parts of the rail network closed down following the Beeching Report in 1963.

Manufacturing: From the early 2020s, there was a process of managed decline in the manufacture of ICE automobiles. The reduction from around 75% of trips being by ICE in 2015 to this being c50% by 2050 involved a process of consolidation of the industry with giants of the automobile sector, including General Motors and Renault-Nissan, reacting to the new policy landscape and being involved in a regular process of downgrading their facilities and making large-scale redundancies. The strategy of promoting public transport in the UK at the expense of ICE automobility was also variably undertaken by a range of different nation-

states, particularly in the West and in Europe as the commitment to public transport became widespread. There was growth in employment in the manufacture of new generations of primarily HEV buses but also a smaller number of BEV buses. There were also jobs in the manufacture of new rail rolling stock in factories in the North-east of England and Derby as well as employment on the construction of a new HS2 rail line out of London to the North of England. However, a huge level of net unemployment remained from the shift from ICE to public transport following the decline of automobile manufacturers and associated supply chains. By the mid-2020s, in a context of unemployment and under-employment, there was a strengthening drum beat for a universal basic income (UBI) for all citizens to address the precariousness of work.

Technology: The twin track strategy was to emphasise the obsolescence of the established technology of the ICE. But more than this it was to re-invigorate old bus and rail technologies that underpin public transport. These long-established modes of transport were promoted as part of a more integrated mode of public transport. Through the 2020s, integrated forms of smart card ticketing became the mode of accessing transport as cash on public transport was phased out by 2025. The UK rail network was upgraded to an almost fully electric network by 2025; moving from a one-third electrified network in 2015, through a process of electrification that commenced at the start of the period but which picked up momentum after 2020. The UK's 42,000 buses, the vast majority of which were diesel in 2015 were in the majority HEVs by 2025 with a significant and growing minority of BEV buses by 2030. In alignment with the promotion of congestion schemes, technology of automobility (roads) were made freely available in urban centres to public transport, bikes and pedestrians.

User: Denigration of the car user subtly began to permeate media and popular cultural representations from 2020. An active programme to construct an image of public transport users as positive and desirable took place through official government and local authority campaigns from 2020. The aim was to address negative perceptions, particularly of bus use, that built up around public transport following the promotion of Thatcher's individualised home owning, car owning democracy in the 1980s and 1990s. Increasingly levels of commuting mobility reduced through the 2020s as large-scale unemployment and underemployment became the norm. This was part of a slow shift towards more local forms of mobility.

2030-2050: Completing the transition to public transport

Policy: The long-term policy of a transition to public transport remained intact after 2030. The managed decline of automobility from c50% in 2030 to under 20% by 2050 caused serious policy dilemmas for national government. Large scale unemployment that had begun in 2020, from the UK's 720,000 employees in the automobile sector in 2015, had reduced to 375,000 by 2030. The UK government in 2028 recognised that its aim to eradicate private car use had limits both at the level of industrial policy, employment policy and for consumers. From 2028, automobile producers received government grants, subsidies and tax reliefs to promote HEVs. This was primarily seen to be for inter-urban travel where rail links were weak. This followed the reporting of the DfT on re-opening parts of the UK rail network. The report recognised the costs of this and suggested a selective re-opening of rail lines in areas where this could be incorporated into a wider integrated, compact city vision. Such an approach resulted in HEVs, through the 2030s and 2040s reaching a point where they accounted for around 20% of trips. This along with ICE by 2050 accounting for around 15% of trips meant that by the end of the period, still one-third of trips were by car-based

automobility. This growth of the role of HEVs also meant that there was some decline in trips via slow modes.

Business models: From the late 2020s, there were efforts across the UK to enact compact city visions. As a response to car-free urban areas and large-scale unemployment, compact cities that integrated an emphasis on public transport mobility and slow modes were organised around new economies. These new economies were increasingly centres of cultural activity rather than paid employment. Commuter travel had steadily decreased since the early 2020s and new forms of travel within these compact cities in the 2030s was a mixture of irregular, precarious work travel, volunteering and citizen activities and in a still vibrant cultural economy of events, food and drink. This economy was underpinned by a universal basic income, which was introduced in 2025, and which fundamentally changed the emphasis on work in everyday life.

Manufacturing: Automobility manufacturing continued its decline through the 2030s and early 2040s resulting in further plant closures and unemployment. There was, though, enhancement of manufacturing capacity around HEVs, particularly at Toyota's plant in Derby and its associated supply chains. Manufacturing output in relation to renewing the UK's 42,000 buses remained on an upward trend. Increasingly replacement of buses through the 2030s saw HEVs replaced by BEVs, meaning that by 2050 the entire bus fleet was a BEV fleet.

Technology: The ban on cars in urban areas had been complemented with trials on road pricing on the M1 motorway from 2027. By 2030 this pricing technology was rolled out onto most heavily used parts of the M1, M6, M25, M4, M5 and other major motorways. Despite being the object of a purposive, managed decline, the ICE and automobility more generally retained a role, accounting for over one-third of trips in 2050. Costs of batteries for BEVs fell through the 2020s and by the 2030s BEV buses reached equivalence with comparator ICE vehicles. HEV technology, previously thought to have been an intermediate, stepping stone technology, that was past its usefulness, was re-invigorated to provide an alternative means of or inter-urban travel where public transport was weak and where a dual source of potential fuel gave flexibility to users. It was also a recognition that despite efforts to create more local, compact cities that there would continue to be a need to conduct travel outside of these areas for domestic, business and leisure reasons.

Infrastructure: The UK's road infrastructure, while not physically being removed, was changing and became used in different ways. Urban roads in 2030 were used for public transport and bikes but also for cultural events. Major inter-urban roads became retrofitted with pricing technology so that by the end of the 2030s 1,000 miles of the UK's 2,200 mile motorway network was accessible via pricing. Old rail lines were re-opened up in the early 2030s where they connected into the vision of a compact city. This was particularly the case with lines that connected to the major urban areas of the North of England creating a bigger, 'compact' urban centre around the North. Following the splintered transport networks of the 1980s and 1990s, integrated transport authorities with their visions for compact cities and also for integrated use of networks through inter-modal ticketing had fundamentally changed relationships between transport infrastructure networks by 2040.

User: by the 2030s, users were not primarily seen as commuters. They were, using public transport to go about the business of being citizens. A more 'active' role for citizens saw them engaging in new social innovations and mobility-related experiments.

(ii) Slow Modes

2015-2030 The double shift transition to slow modes

The slow modes scenario suggested a huge growth in the number of trips via slow modes, from just under 20% in 2015 to over 70% by 2050. Alongside this there was a massive decline in trips by ICE from over 70% in 2015 to under 5% by 2050. The key change in the Slow Modes scenario between 2015 and 2030 was the huge decline of trips via ICE. This was down from over 70% in 2015 to just over 25% by 2030. Slow modes across this period accounted for around 20% of trips. There was, though, a significant growth of car-sharing from 2018 to 2030 from very few trips up to around 30% of all trips. Biofuels accounted for around 10% of trips. This provided a large amount of substitutability between ICE and car sharing and between car ownership and access to a vehicle. From around 2018 there was also some growth of public transport to around 10% of trips by 2030 (see Figure 4).

Policy: In the period between 2015 and 2030, the primary aim of UK government policy was to wean mobility away from ICE automobile-based mobility. From 2017, there was strong government policy to disincentivise use of privately-owned cars in urban areas. UK government sponsored, local authority pilot congestion charge schemes targeted private automobility and the use of private automobility in urban areas was made eye-wateringly expensive. Congestion charging price levels were increased throughout the 2020s. Rather than move from ICE private automobility to slow modes, UK policy was to promote the shift from ownership to access as an intermediate, stepping stone stage to weaken strong cultural attachments to automobility built up over almost a century. Generous incentives were provided by local authorities (supported by national grants) to car sharing companies in the form of promotion, partnering and providing free parking spaces in pursuit of a national target of reducing commuting trips (of less than 5km) by cars by 50% by 2030. National government, through the period, continued to champion the role of local authorities in promoting slow modes in local areas. This included the promotion of walking to work and walking to school schemes that were ongoing throughout the period. It also involved efforts to promote cycling and cycling infrastructure. Much of this was done in a preparatory way to pre-figure a future massive transition to a slow modes system of transport provision.

Business models: The shift to a slow modes transport system involved a double shift: from ownership to access to automobility and subsequently away from automobility to slow modes. Strong cultural attachments to a model of ownership of cars in the UK were weakened from 2020 onwards and the flexibility, accessibility, ease of use and displacement of running costs were promoted as virtues. This underpinned a huge growth in access to automobility that largely offset the decline of ICE. Biofuels and public transport also substituted for a small percentage of ICE trips, particularly those outside of urban centres and used for inter-urban travel. This shift to access was underpinned by a significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors in the late 2010s and early 2020s.

Manufacturing: In terms of manufacturing the story was one of the sharp decline of automobile manufacturing companies. The decline of automobile manufacturing from 2020 through to 2030 saw the loss of around half of the UK's 720,000 automobile industry employees over the time period. Some, of this decline was offset by a switch in manufacturing vehicles for the rapidly expanding car sharing fleet. Manufacturing required

some amendments to design because of the different forms of usage associated with car sharing and to integrate monitoring and payment technologies.

Technology: The shift to car sharing was not only as a stepping stone towards a slow modes transport system, it also involved a shift from ownership of ICE vehicles to access to combinations of HEVs and BEVs fleets. HEV prices, by 2027 became comparable with ICE, with a trend of HEVs becoming cheaper and ICEs more expensive. BEVs also saw significant cost reductions as battery prices reduced through the 2020s so that by the early 2030s there was comparability with HEVs. The UK fleet of car sharing grew from under 3,000 vehicles in 2015 to 150,000 by 2030.

Infrastructure: The big shift in infrastructure was in terms of the decline of manufacturing infrastructure, with the rapid downsizing of trip share by ICE. Though from 2020 there was the managed decline of automobile manufacturing facilities the enmeshed webs of other aspects of infrastructure remained intact. This included, importantly, roads. Congestion charging infrastructure was established in UK cities from 2023 and meant that the use of road infrastructure became re-prioritised from private car use to a fixed number of accessible automobiles. The decline of ICE trips and the shift to car sharing BEV and HEV vehicles meant that the numbers of UK petrol stations continued to decline from 2015 from 9,000 down to just over 2,000 petrol stations in 2030. The active configuration of an infrastructure for car sharing was subject to some experimentation in the late 2010s about how to configure the appropriate business model, the physical infrastructure of parking bays and the ICT infrastructure of monitoring and payment. By the early 2020s, when around 20% of trips were by car share much of this had settled around a ‘one way’ model of car sharing. The cycling infrastructure investment, in cycling lanes for example, which was an early signifier of preparation for slow modes between 2015 and 2020 was abandoned by 2030 as urban streets saw a huge reduction in private car travel.

User: One of the biggest challenges of the shift to slow modes was the deep cultural attachment of people to privately owned automobility. The recognition of this attachment was what underpinned the stepping stone strategy and the shift from ownership to access. This required a significant re-alignment of socio-cognitive understandings of car use. In a wide range of cultural media from the late 2010s onwards the normalisation of the fleeting, flexible consumption of automobility was constructed. Simultaneously, the desirability of the petrolhead owner was deconstructed and feelings of freedom attached to automobility were actively undermined. There was also a state and cultural strategy through the late 2020s to normalise cycling and promote walking in recognition of the coming shift to slow modes but also that cycling in particular was seen as abnormal and often incongruent with employment, family, leisure or other activities.

2030-2050 Completing the double shift

Between 2030 and 2050 trips by ICE fell from around 25% to under 5% and from 2035 trips by slow modes rose sharply from 20% to over 70% in 2050. The high point of car sharing at 30% of trips in 2030 continued to 2035, at which point there was a rapid decline with virtually no car sharing by 2050. From 2030 there was some growth in trips by HEVs to around 10% in 2040 and levelling out to 2050; there remained a 10% share of trips by biofuels and public transport trips decline in the 2040s to under 5%.

Policy: Policy and governance was the single most important shaper of the transition towards slow modes. UK government policy continued to manage the decline of ICE and private car

use. In 2030 the UK government announced a policy for all urban areas with populations over 30,000 that they must move to being completely car free in the boundaries of the core urban area (city or town centre) by 2040. The government suggested that the congestion charge zones had provided the stepping stone for the boundaries of these new car free areas. This policy announcement signalled a shift from managing the decline of private car use to managing the decline of all car use, including car sharing. The effect of the announcement was that from 2033 there was a rapid fall in the number of trips by car sharing to under 10% by 2040. Some car sharing remained in laggard local authority areas. The 2020s had seen a slowly growing ideology of autarky and local self-sufficiency in economic development infusing national policy. This was a response to what were widely seen to be the failures of economic globalisation and extended supply chains, since the global economic crisis of 2007/8 and the subsequent low growth and multiple recessions that the UK and other western nations had experienced. By 2030, the commuter society was beginning to be seen as a relic of another era as what paid work there was that remained, leisure activities and patterns of consumption became highly localised. The UK government, though, recognised the realities of a still significant need for travel outside of urban areas and permitted the use of alternatives to ICE, primarily HEVs and biofuels outside of urban areas on Britain's network of A roads and motorways, many of which had become toll roads in 2028.

Business models: By 2030 the UK had become increasingly organised into a plurality of often resurgent local economies. Though the world of paid work was increasingly precarious, the work that remained was largely performed by local people who lived, worked and played in what had become increasingly emergent local economies. Models of mobility based on private mechanised transport had been significantly weakened by policy and the increasing localisation of life. Particularly from 2030-2040 this saw the further decline of ICE to around a 10% share of trips and the almost terminal decline of car sharing.

Manufacturing: The UK's 350,000 workers in the automobile sector reduced rapidly in the 2030s and numbered under 80,000 by 2040. The wider manufacturing economy, much of which had been off-shored in the 1970s and 1980s, became increasingly automated and mechanized leading to massive unemployment in the 2030s. The campaign for a universal basic income (UBI) that had begun in the late 2010s, and that resulted in a scheme trialing universal basic income in 2023 had been rolled out across the UK by 2030. Levels of increase of UBI had been a source of political conflict but had risen in tandem with the re-localisation of life.

Technology: The massive upturn in trips by slow modes from 2035, as well as being underpinned by the promotion of walking and cycling was also underpinned by large-scale societal consumption of an old technology, the bicycle. Sales of bicycles, which had been at 3.7 million (including for export) in 2015 reached 9 million by 2040. The previous spatial unevenness of cycling in the UK became evened out after 2035 partly as a response to a complicated set of issues that included the ban on cars in urban centres, the growth of local economies and the new leisure time available in an era of post-paid-work.

Infrastructure: From 2030 the UK's 2,000 petrol stations were reduced in number to 200 by 2050. Many of the UK's 245,000 miles of road, from 2030, were incrementally retrofitted to either be mixed pedestrian and cycling highways.

User: The most telling aspect of users of transport by 2050 was the death of the petrolhead, whereby cultural attachments to the ICE were weakened in the 2020s and where ICEs

became culturally unacceptable by 2040. Travel beyond the immediate local area became seen to be exceptional and users became redefined as local rather than as travellers.

Conclusions

This report has developed qualitative socio-technical scenarios for land-based passenger mobility in the UK between 2015 and 2050. It took quantitative scenarios developed in WP1 of the PATHWAYS project, assessed what the key constraints were in achieving such scenarios and what processes of change to realising those scenarios might look like.

To do this, two qualitative scenarios - pathway A and B - were developed in service of these quantitative scenarios. Both scenarios are plausible and achievable but require multiple processes and facets of change to align. Both of these scenarios are difficult to realise but Pathway A, with its substitution is easier to achieve than Pathway B with its complex and often radical reconfiguration. In a nutshell, Pathway A involves a lot of substitution and Pathway B requires fundamental changes in the current economic and spatial organisation of UK society.

Both scenarios, though, involve massive changes to the status quo. Both involve the decline of ICEs. A technology that has been pervasive in the organisation of UK society, economy and ways of life and in other western nation states for a century is largely phased out in both scenarios in little more than three decades.

For Pathway A, this means a large reduction in ICEs but less change than Pathway B in that private automobility still reigns and infrastructure and coalitions of key actors are largely similar. Pathway B is different in that not only does it envisage the decline of ICE but also the replacement of private automobility with either public transport or slow modes of travel.

There are numerous core constraints to the achievement of Pathway A. These are:

- Technical and economic (the costs and performance of batteries);
- The politics of regime actor reconfiguration (from the dominance of the automobile manufacturer-policy-oil relationship to electricity generators and distributors becoming key regime actors organising the very resource - electricity - that supports the new mobility system);
- And the socio-cognitive shifts required to achieve widescale public acceptance of a large shift in the re-organisation of car-based mobility.

Core constraints around Pathway B are that:

- It envisages the decline of a massive employer and economic powerhouse, the automobility sector, without an alternative economic plan.
- The planned huge growth in public transport also meets limits to capacity in existing systems, particularly the fixed infrastructures of the rail system.
- There are also significant cultural constraints. The largescale plans for public transport require cultural reinvigoration of public transport after societal messages for more than 40 years trumpeting that private is best.
- This is also a governance challenge as the capacity that is needed to re-shape public transport systems has been privatized for decades and is fragmented. Not only is there this constraint but much of this governance capacity needs to be organised to act at an urban scale where the potential of public transport systems are pronounced.

- In respect of carsharing and road pricing, there is the need for a shift in public acceptability in two ways: from private ownership to public access to automobility; and to accept a combination of road pricing and areas that are car free.
- The biggest constraint is that mobility is a 'derived demand' and therefore local travel (which is what a slow modes scenario and much of a public transport scenario suggest) needs to be in service of a different kind of economy of that which currently exists and also suggests very different mobility patterns in everyday life than at present.

Both Pathways A and B illustrate numerous key decisions and policies. There was not one key branching point. What was critical was the role of policy in setting clear, long-term frameworks to underpin these transitions in their different ways. In particular, the intensification of carbon reduction targets was underpinned by a clear purpose: that there needed to be a relatively fast shift from ICE to electric vehicles. This provided the framework and clarity for public-private investment in battery technology and research, the reduction of battery costs, the improvement of range, the greater uptake of vehicles and further cost reductions from economies of scale. There was also a key role for policy in managing the effects of the decline of ICE automobility and in creating the institutional context through which electricity generators and distributors became fundamental players in the automobility regime. In Pathway A policy was critical through targets, visions and political will in making ICE unattractive and electric vehicles attractive. In Pathway A the fundamental regime shift was in the weakening of the automobile manufacturer-policy coalition and its extensions to electricity producers and generators. This fundamentally changed the orientation of the regime.

In Pathway B, policy was critical in creating frameworks that (a) set out the transition to a public transport based mode of mobility and (b) a slow modes system of mobility. A key development was the strengthening of integrated public transport authorities as the agents of enacting transition. Various stepping stones followed this new institutional context, but particularly a more strategic orientation to how transport systems should be organised in cities and towns. This resulted in congestion charging and road pricing trials. There was rapid upscaling of battery-powered public transportation, but also a key recognition that in a society that saw work become precarious, that new forms of travel needed to be integrated with local visions of post-work society. In Pathway B policy was fundamental in providing frameworks for transition through developing purposive radical visions of a very different society based on either public transport or slow modes. In Pathway B the policy-driven abolition of the dominant automobile manufacturer-policy coalition was replaced by various localised embryonic coalitions of public transport providers, manufacturers, electricity generators and distributors, businesses and citizens groups.

It is clear that the transitions to 2050 envisaged in both Pathway A and Pathway B scenarios are processes where much of the work of change needs to be concentrated in the years between now and 2030 and, in particular, the next 10 years. This has implications for policy.

Policy implications/robust advice are as follows:

1. Each of these transitions - whether to BEVs, public transport or slow modes - needs to be underpinned by a long-term, strategic vision.

2. This is needed as an orientation around which ‘political will’ can coalesce to achieve the social acceptability and legitimacy of the proposed transition. Political will needs to be constructed through a shared understanding around which policy, manufacturers, business, citizens and investment can coalesce.

3. This needs to be a multi-pronged strategy which is not just about targets and incentives - although these are important - but which sets out a clear vision of what society will look like once the changes have been enacted, the institutional mechanisms that will need to be constructed, the policy mechanisms for bringing about change and agreed ways of assessing if these have been successful.

4. There is a clear need in both scenarios for new institutional arrangements around which strategic change can be organised and implemented.

5. Although a vision is needed very ambitious carbon reduction targets to incentivise the achievement of that are necessary.

1. Introduction

This report develops qualitative socio-technical scenarios for land-based passenger mobility in the UK between 2015 and 2050. To do this it takes quantitative scenarios developed in WP1 of the PATHWAYS project, assesses what the key constraints are in achieving such scenarios and what processes of change to realising those scenarios might look like. Or in other words: What are the key socio-technical challenges in re-orientating current socio-technical trajectories to meet the pathways set out in the quantitative scenarios? In this respect, this report is 'service-oriented' in using socio-technical analysis (from WP2) in service of richer understandings of how quantitative scenarios (set out in WP1) may be achieved.

To do this, the report draws on a combination of: (a) quantitative scenarios produced in WP1; (b) rich and detailed empirical material from WP2 assessing recent socio-technical developments in green mobility niches and in regime (in)stability in the land-based passenger transport system in the UK; and (c) a productive bringing together of these techno-economic scenarios with the socio-technical in the national context of the UK to produce scenarios that flesh out two speculative, qualitative socio-technical scenarios.

Two stylised pathways, characterised as Pathway A and Pathway B will provide an orientation for populating two future-oriented socio-technical scenarios in the UK context. These pathways are structured through four criteria: departure from existing system performance, lead actors, depth of change and scope of change (see Table 1).

Table 1: Ideal-type transition pathways and their defining elements

	Pathway 0: Business as Usual	**Pathway A: Technical component substitution**	**Pathway B: Broader regime transformation**
Departure from existing system performance	Minor (no transition)	Substantial	Substantial
Lead actors	Incumbent actors (often established industry and policy actors)	Incumbent actors (often established industry and policy actors)	New entrants, including new firms, social movements, civil society actors.
Depth of change	Incremental change	Radical technical change (substitution), but leaving other system elements mostly intact	Radical transformative change in entire system (fundamentally new ways of doing, new system architectures, new technologies)
Scope of change	Dynamic stability across multiple dimensions	1-2 dimensions: technical component and/or market change, with socio-cultural and consumer practices unchanged	Multi-dimensional change (technical base, markets, organisational, policy, social, cultural, consumer preferences, user practices)

Drawing on rich socio-technical analysis in the UK context, the report suggests key constraints in the quantitative scenarios set out for both Pathways A and B. These constraints are detailed and potential for overcoming them is set out in socio-technical scenarios for Pathways A and B up until the year 2050.

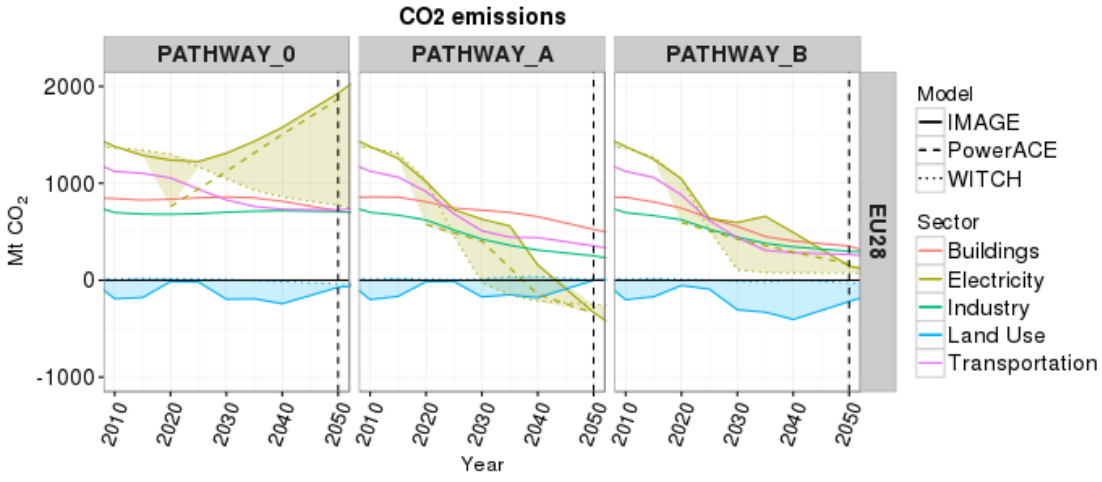
The structure of the report is as follows: Section 2 sets out two quantitative scenarios for the land-based passenger mobility system in the UK to 2050. Section 3 summarises current socio-technical trends in respect of niche innovations, regime developments and landscape pressures in the UK land-based passenger transport system in the decade and a half from 2000 onwards. Section 4 presents the transition challenges facing each pathway and in particular the key constraints facing particular niche innovations. Section 5 sets out the first socio-technical scenario, that approximates to Pathway A. Section 6 develops the second socio-technical scenario (split into two parts) that approximates to Pathway B. Section 7 presents Conclusions.

2. Quantitative scenarios from WP-1

In this section we illustrate and summarise two quantitative scenarios developed in WP1 for land-based passenger mobility for the UK,Pathway A, characterised as BEV UK (Battery Electric Vehicles), and Pathway B, which focuses on Public Transport and Slow Modes. The broader context within which we can understand these scenarios is the need for significant reductions in CO2 emissions in the transport sector.

As context, the changes that are required in the transport sector in terms of reducing CO2 emissions are set out below (see Figure 1). CO2 emissions reduction in each of three pathways (0, A and B) is represented for 'transportation' and relative to other sectors. These representations illustrate that transportation is currently the second largest emitting sector. CO2 emissions in Pathway 0 - the business-as-usual scenario – are projected to decrease through an increase in efficiencies and an expected shift to battery electric vehicles. Pathway A illustrates greater emissions reductions than Pathway 0. This can largely be attributed to substitutional change in the private car-based land-based passenger transport system. Pathway B represents stronger emissions reduction still, largely due to 'behavioural changes' and efforts to shift away from the dominance of the private car through the reconfiguration of multiple systems within the wider system of land-based passenger transport.

Figure 1: Changes required in the transport sector compared to the other domains



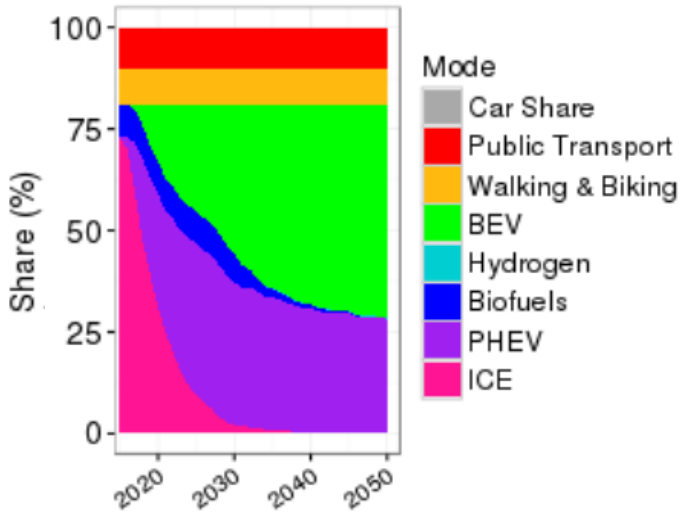
Source: WP1 PATHWAYS project

The wider methodological approach, assumptions and discussion of these scenarios is articulated in a WP1-WP2 interaction discussion document for the mobility domain (Carrara et al, 2016).

UK Results from MATISSE-KK Model

CO2 emissions reductions set out in Pathways A and B suggest the need for significant changes in the current organization of land-based mobility systems. In this section, these two pathways and the kinds of changes in the passenger transport system that they suggest are represented for the UK.

Figure 2: Pathway A - Distribution of households' choices of mobility lifestyle under a Battery Electric Vehicle (BEV) scenario (shares are in number of trips), UK.



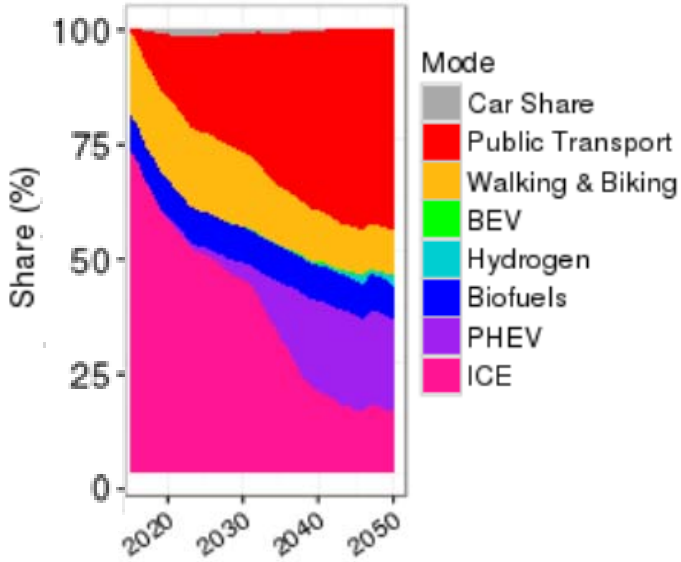
Pathway A (Figure 2) is characterised by a transition to battery electric vehicles (BEVs) in the UK. Within the time period, there is a sharp reduction in ICE trips through the 2020s, into the 2030s, reducing to close to zero by 2040. From the early 2020s, there is rapid growth of trips by HEVs and slightly less rapid growth of trips by BEVs. This upward trajectory for BEVs continues to the end of the time period in 2050. Growth in HEVs begins to gently downturn in the early 2030s resulting in BEVs overtaking HEVs sometime shortly after 2035. Throughout the period public transport and slow modes each account for around a 10% share of trips. Biofuels account for a similar share of trips until the mid-2030s when its share declines to almost zero by 2050. Car sharing accounts for a very, very small share of journeys. The story is one of substitution of car-based mobility rather than a move away from it.

There are many possible alternatives to this pathway of substitution of ICEs with BEVs. Pathway B presents two possibilities: enhanced public transport and a promotion of slow modes of travel. It can be summarised as follows:

In Pathway B, in one possibility, a largescale programme of public transport improvements is enacted in the UK. This programme is underpinned by powering public transport through

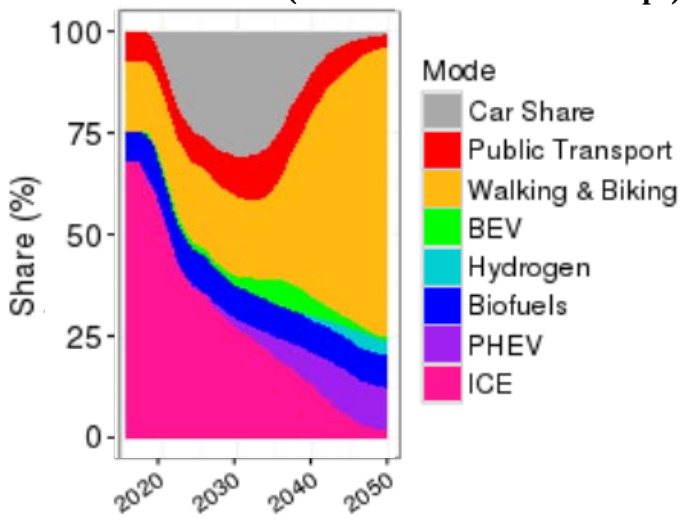
renewables in a context of urban reconfiguration. In this view, car use - both private and through car - share are limited (see Figure 3). This scenario sees a rapid decline in trips by ICE from 2020. By 2030, only around 50% of trips are via ICE, falling further to under 20% by 2050. There is huge growth in trips by public transport, rising from a very low level to account for over 20% of trips by 2030 and around 45% by 2050. There is some substitution of ICE trips by HEVs from the early 2020s onwards, but particularly in the 2030s, and that levels out at around 20% of trips in the 2040s. Slow modes account for around 20% of trips reducing to around 10% by 2050. Biofuels account for around 10% of trips throughout the period. Hydrogen and BEVs account for very few trips.

Figure 3: Pathway B(i) - Distribution of households' choices of mobility lifestyle under a public transport scenario (shares are in number of trips)



Another scenario in Pathway B is a slow modes scenario underpinned by a desire for a lifestyle predicated on a shift away from owning a car, largely on environmental grounds. This pathway shows a dramatic reduction in trips by ICE, down to under 30% by 2030 and to around 5% by 2050. There is a central role for slow modes, which account for around 20% of trips into the 2030s and then a huge upswing where by 2050 over 70% of trips are undertaken by slow modes. There is a significant role for car sharing in buffering the transition from ICE, privately owned cars to slow modes in the 2020s and 2030s; at peak car sharing accounts for around 30% of trips. Growth in public transport and BEVs, particularly in the 2030s, also buffer between the decline of ICE and the growth of slow modes. There is a steady role for biofuels in around 10% of trips through the period. Towards the end of the period when ICE has decline and slow modes has grown there remains a small but significant amount of automobility, primarily HEVs, but also biofuels and hydrogen.

Figure 4: Pathway B(ii) - Distribution of households' choices of mobility lifestyle under a slow modes scenario (shares are in number of trips)



3. Current socio-technical trends (2000-2015)

Pathways A and B, set out above, represent potential understanding of the ways in which choices of mobility lifestyle translate in to future, relative shares of different modes of transport trips. This suggests changes in the overall organisation of the land-based passenger mobility system and in the relative emphasis on different mobility modes over time. In the UK, this means that there is a need to understand not only what is required in terms of these future pathways, but also what the current socio-technical trends are in respect of land-based passenger mobility.

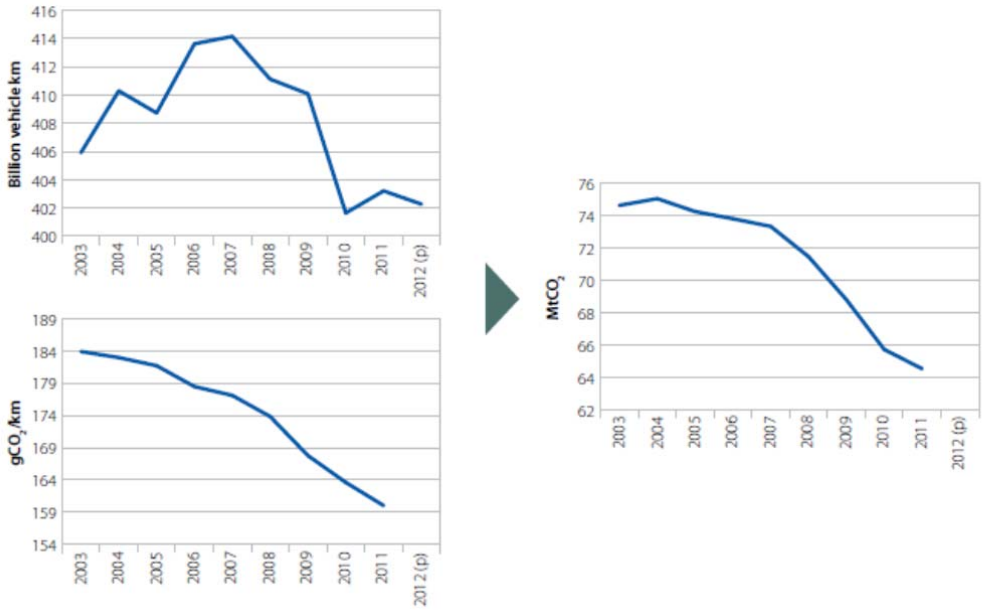
In this section, we summarise these current trends drawing on developments in the last 10-15 years in the UK. We mobilise material that was produced through Deliverables 2.1, 2.2 and 2.3 in the PATHWAYS project and specify four dimensions: the broader context, niche innovations, regime developments and landscape trends. This overview will provide a context and a reference point against which we can analyse the challenges (or 'constraints') of realising the quantitative scenarios set out above. In short, an understanding of the socio-technical trends (current direction of travel), when set alongside the trajectories in the quantitative scenarios (required direction of travel) in section 2 provides a contrast between current trends and what is required to meet future carbon emissions reductions. To do this, it also requires interpretation of the challenges in re-shaping the current direction of travel to meet those emissions reductions.

UK Context

In 2012, UK, domestic transport CO2 emissions were 116.9 MtCO2 (25% of total UK CO2 emissions). Total CO2 emissions fell by 11.9% from 2007 to 2012, but only 0.2% in 2013. Given this, there is discussion as to what extent these emissions reductions are attributable to the economic crisis from 2007/8 onwards. Surface transport CO2 emissions are responsible for the majority of domestic transport emissions with domestic aviation and shipping accounting for 3%. Road transport accounts for the majority (96%) of surface transport, with cars being the largest contributor (58%), vans 14% and heavy goods vehicles 22%. Overall

CO2 emissions from cars have been in decline over the last decade and more, as have emissions per km, and vehicle km travelled were slightly less in 2012 than in 2003 (see Figure 5). Underpinning falls in CO2 emissions have been developments in the efficiency of new vehicles, where to 2013 new car CO2 emissions fell annually over a 16 year period (SSMT, 2014), often driven by EU targets. (This, though, has been questioned in light of the 'emissions scandal' that became apparent in 2015, where Volkswagen had intentionally tried to manipulate parts of the emissions testing process. This was subsequently seen to extend to other companies beyond VW, but there remains an issue as to the extent of the scandal).

Figure 5: Historical trends of vehicle km, MtCO2 and gCO2/km for cars (2003-2012)



Source: Committee on Climate Change Progress Report 2013

Cars have become (by far) the dominant transport mode since the Second World War, accounting for 83% of all distance travelled (including vans and taxis) in 2013[1]. Interestingly, however, car travel seems to have peaked by 2005 and declined since, a development that has given rise to the 'peak car' debate. Rail travel increased substantially since the mid-1990s, suggesting that some modal shift may have occurred (from cars to trains). In comparison to car-travel, however, rail travel is still small, accounting for about 8% of passenger kilometres in 2012. A full modal shift would thus require rail travel to increase ten-fold, which is highly unlikely, given heated political debates about the construction of new rail lines since the announcement of a plan for a new high-speed link from London to the north. Cycling has also increased significantly since about 2005, increasing passenger kilometres by about 35% to 2012. Nevertheless, cycling accounted for only 1% of overall passenger kilometres in 2012, which means that even a doubling or tripling of cycling would have very limited effects on greenhouse gas emissions and modal shift.

[1] Department for Transport Statistics, Table TSGB0101 [accessed 21/04/2015]

Niche-innovations

Niche innovations are often presented as fundamental to changes in the organisation of a socio-technical system. Of the eight green niche-innovations that were assessed as part of WP2, none were assessed to be about to breakthrough more widely in the UK. Each of these niche-innovations can be understood as aiming to contribute to either a form of technological substitution in an incumbent regime (Pathway A) or a broader regime transformation (Pathway B). In this section, the alignment of each of these niches with regime and landscape developments is summarised and an assessment of breakthrough feasibility is made (see Table 2).

Table 2: Breakthrough analysis of niche-innovations in the mobility domain in the UK

Niche-innovation	**Internal momentum**	**Strong or weak alignment with broader regime characteristics and developments**	**Likelihood of imminent breakthrough (and/or future potential)**	**Pathway A or B (or mixed)**
(Plug-in) Hybrid Electric Vehicles	Moderate	High potential alignment, but: - Needs plug-in infra - High battery costs - Hedging by dominant regime interests	Moderate to high	A
Battery Electric Vehicles	Moderate	Weak to moderate alignment: - 'Greening' of automobility - Needs plug-in infra - Higher costs than ICE comparators - Absent electricity regime actors - Policy promotion but governance experimentation	Weak to moderate	A (with some B)
Inter-Modal Ticketing	Low	Unclear which regime might align with - Promotes public transport v private car use - Low alignment with automobility regime - Breakthrough in London but weak alignment elsewhere	Weak to moderate	B
Car-Sharing Clubs	Low	Weak to moderate alignment - Aligns but also needs ICT systems - Ltd evidence of significant re-alignment of cultural understandings - Ltd new governance experimentation	Weak to moderate	B
Biofuels	Low	Weak alignment - Potential alignment	Weak	A (with some B)

		between biofuels and automobility - Questions of process/source of biofuel generation - UK biofuel policy strongly shaped by shifting wider discourse, pressure from NGOs & Euro legislation		
Hydrogen Fuel Cell Vehicles	Low	- Fairly significant alignment - fundamental need for new fuel infra - Socio-cognitive alignment - though H2 safety issues - Large-scale infra requires coordinated policy & governance	Weak	B (and A)
Urban Cycling/Sharing	Very Low	Not intended to align with automobility regime but to provide an alternative to short car and public transport journeys	Moderate	B
Compact Cities	Very Low	Involves fundamental reconfiguration of a city through designing in public transport and designing out car use - This has been limited in the UK	Weak	B

Generally, these niches have limited (if spatially variable) momentum. There is moderate momentum in relation to (Plug-in-) Hybrid Electric Vehicles and Battery Electric Vehicles and low or very low momentum among the other six niches. Many of the eight niches involve some substitution and also some reconfiguration of a wider regime. That each niche is attributable to a single pathway is thus not clear cut. None of these niches suggests that it is about to breakthrough more widely at a general UK level. The two niches with most momentum (HEVs and BEVs) promote continuity with motoring. With the possible exception of biofuels and HFCVs, the other six niches can all be understood as involving often complicated reconfiguration of regimes. It is also often not clear which regime's reconfiguration niches contribute to. Is bike-sharing an extension to the rail regime or bus regime, if a focus is taken on the 'last mile' issue? Does it strengthen or alter the cycling regime? There is a blurring of the boundaries of both niches and regimes. The distinct nature of them becomes more permeable. There is also a question about whether some of the eight should be seen as niches; where rather than aiming to overthrow the regime they may offer a defence of the dominant regime rather than potential challenges to it. This may be the case, for example, for HEVs and BEVs. Furthermore, a niche - such as inter-modal ticketing - is not a challenge to a regime and system but an add-on to it in attempts to solve problems (Parkhurst et al, 2012). Yet, not only are these niches being mobilised by regime actors to defend regimes but in doing so they do provide some challenge to the regime, not in the sense of replacing it but in forcing it to change through symbiotic relationships with complicated multiplicities of other regimes and niches.

Regime developments

WP2 analysed automobility, rail, bus and cycling sub-regimes in the UK, as constitutive of the socio-technical land-based passenger transport regime. It assessed the degree of lock-in and path dependency of these regimes, the possible cracks and tensions that arise within them, their orientation towards environmental problems and the main socio-technical regime problems they exhibit (see Table 3).

Table 3: Assessment of regime trends in the mobility domain in the UK

	Lock-in, stabilizing forces	**Cracks, tensions, problems in regime**	**Orientation towards environmental problems**	**Main socio-technical regime problems**
UK auto-mobility regime	Strong	Weak/moderate	Moderate (some incremental change)	Dominance of regime actors - industry and policy Sunk investments Cultural dominance of automobility
UK railway regime	Moderate	Moderate	Limited change	Deeply fragmented rail system Network capacity limits Costs to tax payers and customers
UK bus regime	Moderate	Weak	Slow, incremental change	Fragmented system with no point of control Disproprionate use by the poor, elderly and disadvantaged
UK cycling regime	Weak/moderate	Weak	Incremental but very limited contribution to overall emissions	Unclear whether there is a cycling 'regime' in the UK Cycling remains marginal. Realisation of cycling infrastructure has been limited.

The main findings are as follows:

Although it faces several problems, the automobility regime is still dominant and stable, although less so than twenty years ago. Some tensions and cracks have appeared such as: a) public concerns about Peak Oil and climate change, b) government policies (European CO2 regulations, national innovation programs) aimed at the 'greening' of cars, c) some urban policies that restrain cars and encourage alternatives to cars (often for reasons of urban regeneration and quality of life), d) green innovation strategies by automakers, which are mainly focused on incremental innovation, but also explore alternative options ((Battery electric vehicles (BEV), hybrid electric vehicles (HEV), fuel cell vehicles (FCV)), e)

decreasing overall car-mobility (Peak car), stagnant car sales, and some indication of less car desires amongst young people. But these tensions are not yet very strong, whereas the mechanisms of inertia and stability are still substantial.

Alternatives to the automobility regime in the UK remain marginal. This is the case even with rail, where passenger journeys have more than doubled since 1994/5, where rail passenger miles have increased 51% since 2001, but which still accounted for only around 3% mode share of surface transport trips in 2013 and just over 8% of 'total inland passenger km' in 2012. Overcrowding and congestion on the railways have highlighted a capacity problem. This capacity problem is not being addressed in a systemic-strategic way. Instead, there is spatially selective prioritisation of parts of the network (e.g. HS2, Crossrail) for large-scale infrastructure investment in corridors and enclaves - notably within London and connecting to London.

Similarly, passenger kilometres and trips by bus remain marginal relative to automobility, as part of a long-term trend of decline that has levelled off and in some cases begun to reverse over the last decade. The neoliberal reformulation of transport, from the 1980s, prioritised the car and portrayed car users as 'successful' and bus users as economic 'failures'. This resonates with the dominance of bus use by 'lower' socio-economic classes and the young and elderly. The bus regime has been shaped since the 1980s by the idea and principles of competition, through deregulation and fragmentation. In London, where there was no deregulation and where there was a well-developed range of modal alternatives, bus usage performed well (45% increase in bus trips between 1995/7 and 2013) vis-à-vis other parts of the UK.

Cycling, likewise, remains marginal in a UK context, despite small increases in distance travelled by cycling in recent years. The longer-term trend shows the scale of decline since the Second World War where cycling accounted for 33% of all vehicle miles travelled in 1949 and only 1% by 2009. Though a similar trend affected many European countries, cycle use remains comparatively low in the UK. In the last two decades there has been a developing policy-push around cycling and associated infrastructure particularly through national programmes focused on urban areas, and also the development of a wider UK cycling economy. Realisation of cycling infrastructure has been limited and cycling is still seen as an 'abnormal' activity which is often incongruent with employment, family, leisure or other activities. There is a gap between policy-push and limited realisation which can be attributed to policy being embedded in a wider, fragmented governance of multiple private agencies and actors. There are though examples of significant spatial variations in use where, again, cycling in London has grown significantly over the last decade and, to a lesser extent, other urban areas.

Landscape trends

Landscape pressures variably condition different systems in the land-based transportation system in the UK. This is important as it suggests that decarbonisation should be understood within a multiplicity of different pressures which may collectively and differentially shape the land-based passenger transport system. This can be summarised as follows:

1. Neoliberal ideology: The dominance of neoliberal ideology in British society generally since the 1980s and specifically in terms of transport has promoted market-based responses, competition, individualism and freedom (Turner, 2008), which have aligned with discourses around automobility. Neoliberal ideology led to pressures for

fundamental re-organisation of rail and bus systems in the 1980s and 1990s and efforts to condition public transport systems with market-based competition, privatisation and liberalisation (Jupe, 2010; Haubrich, 2001; Cowie, 2002; Langridge and Sealey, 2000). It is not clear whether a cycling regime actually exists in the UK, making a discussion of respective pressures difficult. It is not surprising, however, that in neoliberal times, cycling is predominantly viewed in terms of its value to the UK economy (Grous, 2011).

2. Climate change: Climate change is a landscape development that is recognised by a wide range of system actors (policymakers, car manufacturers, NGOs). There are particular regulatory pressures that follow from this, for example in relation to automobile production and greenhouse gas emissions. The sense of urgency in the UK has varied over time, with high attention from 2005-2009, and some weakening since then, because the political struggle that followed the financial-economic crisis resulted in changed priorities. Within this temporal context, pressures for decarbonisation gains from rail are much weaker than automobility given that, relative to other modes of surface transport, carbon emissions directly attributable to rail accounted for around 2% of emissions in 2011 (Committee on Climate Change, 2013). There is some pressure to reduce carbon emissions from buses, which accounted for 4% of surface transport in 2011 (Committee on Climate Change, 2013). The potential (rather than the reality) of cycling to contribute to decarbonisation environmental improvement is frequently symbolically promoted (ECF, 2011).

3. ICT: The diffusion of ICT and the possible shift towards an information society with ubiquitous computing are pervasive landscape trends that are likely to give rise to the integration of ICT devices into cars and highway systems but also in re-shaping the 'demand' for mobility through new forms of working and consumption patterns (Howe, 2013). Pressures for 'smarter' transport systems, integrating ICTs to generate real-time data, that is used to plan and control systems (Kitchen, 2013) are felt across automobile, rail, bus and cycling systems. The generation of 'big data' creates pressures for seeing new opportunities for creating services within existing systems through, for example, integrating ICTs and new business models, with cars, bikes or ticketing systems.

4. Financial Crisis and Austerity: The financial-economic crisis of 2007/8 and austerity programmes contributed to a sharp decline in UK car sales. Although there has been recovery in sales, there remains strong competition between car manufacturers (SSMT, 2015[2]). The financial crisis created pressures for state intervention to defend the automobile industry as a key economic agent and employer. The wider UK political response to the crisis promoted austerity as a solution, with the effect that public spending, including on public transport, has been cut. That said, specific transport infrastructure responses, such as high-speed rail developments (HS2), are promoted as fundamental to long-term national economic security, particularly in and out of London and across London. The pressures on the cycling system from austerity are less easy to identify due to the fragmented nature of the cycling 'regime' and its multiple sources of public funding.

[2] http://www.smmt.co.uk/2015/01/uk-new-car-registrations-december-2014/ [accessed 02/03/2016]

5. Oil/peak oil: Rising oil prices from the mid-2000s gave rise to concerns about Peak Oil, which refers to the peaking of maximum rates of conventional oil production. Since then, however, unconventional oil (e.g. shale oil, tar sands) production has increased, especially in the US, giving rise to substantial price decreases. Despite this recent reduction, most analysts expect that the price of oil and gasoline is likely to rise in the coming decades, which is likely to affect mobility behaviour or lead to stronger policy action with regard to renewable alternatives. The question of the future of oil creates strongest pressures for automobility. Though it is relatively less for rail and bus regimes given their size, this still creates pressures on these regimes for alternatives to oil with limited pressures on the cycling regime.

These landscape pressures highlight multiple political, economic, and ecological pressures. They create the wider conditions in which dynamics of continuity and change in automobility, rail, bus and cycling regimes unfold.

Summary

Multiple processes are contributing to the slow, incremental and spatially selective reconfiguration of the land-based passenger transport system in the UK as a response to pressures for more sustainable mobility. Integrating niche and regime analyses, findings suggest that in the land-based passenger mobility domain in the UK, there is a slow and spatially selective reconfiguration rather than a transition beginning to unfold. Such change as it is happening in the UK mobility sector is coming not from privileging green niche innovations but through *multiple* processes that primarily involve dominant regime interests. These are: (a) incremental change within transport regimes, (b) some substitutional changes between niches and regimes, (c) limited change in relationships between transport regimes, and (d) some change to transport regimes from symbiosis with non-transport regimes. Change in the land-based passenger transport system can be understood as a process that includes gradual, incremental and spatially uneven change producing slow reconfiguration.

The main reason for this is the ongoing dominance of a neoliberal discourse in relation to land-based mobility and a lack of political will amongst dominant regime actors for radical transformation. Many niches have limited internal momentum in the UK. Furthermore, the regime and sub-regimes of the land-based passenger mobility system in the UK are still, generally, locked-in rather than exhibiting significant cracks and tensions. As such, a transition to sustainable mobility is not imminent. Changes in the overall land-based passenger transport system prioritise efficiency and incremental change in existing regimes and systems rather than radical change within and between regimes. While the scale of the required change is significant, existing regime interests often act as a ‘brake’ on more radical reconfiguration.

4. Specifying ‘transition challenges’

There are a variety of challenges and constraints that are raised by trying to understand the different pathways in the context of current socio-technical trends. These are summarised in Table 4:

Table 4: Tensions between future model scenarios for UK land-based passenger mobility and WP-2 findings of niche-momentum and path dependencies

Innovation /Challenge	Pathway A	Pathway B	Constraint
ICE:	Pathway A suggests a sharp reduction in ICE journeys from 2020 and phasing out of journeys by ICE by the 2040s	Pathway B suggests different paths - both involve a three decade process of continuously and massively reducing the share of trips by ICE	Inertia / stability in automobility regime are still substantial Dense entrenched infrastructure webs (e.g. roads, petrol stations, manufacturing facilities) Policy/ manufacturer coalitions committed to incremental efficiency improvements
HEVs	Pathway A envisages an increased role for HEVs, particularly growing until the early 2030s, then levelling off and reducing	Public Transport path - some substitution of ICE trips by HEVs from the early 2020s onwards, but particularly in the 2030s, levels out at c20% of trips in the 2040s Slow Modes path - 2030s onwards there remains c20% trip share for HEVs	Costs (largely batteries) of HEVs remain higher than comparator ICE vehicles - requiring reduction View still persists that more plug-in infrastructure is required even if not technically necessary
BEVs	Pathway A suggests a key role for BEVs in the medium and long-term, overtaking HEVs in the mid-2030s as providing the biggest single mode share of trips	Public Transport – BEVs account for very few journeys Slow Modes – some limited growth of BEVs in 2030s	Despite reductions in costs of batteries, remain significantly higher than ICE comparators Vehicle range remains an issue although there are increases Lack of regime integration of electricity producers a fundamental challenge Still some perceived need for new plug-in infrastructure
HFCVs:		Public Transport – accounts for very few trips Slow Modes – some small growth in trips by hydrogen in the 2040s, but less than 10% in total	Fundamental need for configuring new fueling production, transportation, distribution and storage infrastructures Vehicles significantly more expensive than similar ICEs Safety/ perceived safety of hydrogen use Lack of coordinated policy and governance capability
BIOFUELS:	Pathway A suggests around a 10% share of trips by biofuels until the mid-2030s when it declines to almost zero	Public Transport and Slow Modes – account for c10% of trips across the period	Significant lack of alignment between multiple regimes (automobility, food, land-use). Weak alignment between biofuels and existing automobility practices, in relation to legitimacy and the variety of interests in the governance domain
PUBLIC TRANSPORT:	Pathway A suggests public transport	Public Transport – Huge growth in trips, rising from a	Infrastructural capacity problem

	accounts for around 10% of trips across the time period	very low level to over 20% of trips by 2030 and c45% by 2050 Slow Modes – Growth particularly in the 2030s, also as a buffer between the decline of ICE and the growth of slow modes	Spatially selective prioritisation of parts of the network Costs increased significantly since privatisation Fragmented bus and train governance post-privatisation Dominance of ideology of private mobility Austerity
SLOW MODES:	Pathway A suggests slow modes accounts for around 10% of trips across the time period	Public Transport – c20% of journeys reducing to c10% by 2050 Slow Modes – c20% of journeys in to 2030s and then a huge upswing to over 70% by 2050	Cultural 'abnormality' of cycling Realisation of cycling infrastructure limited and variable - may be attributed to fragmented governance Significant spatial variations
CAR SHARING:	Pathway A car sharing accounts for a very, very small share of trips	Public Transport – Very limited role Slow Modes – Significant in buffering the shift from ICE to slow modes in 2020s and 2030s; at peak accounting for c30% of journeys; very small share by 2050	Significant re-alignment of socio-cognitive understandings of car use Need for significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors Requires new forms of governance

5. Scenario 1 (Pathway A) is characterised as 'BEV UK'.

In this section a socio-technical scenario (ST-S) is set out for Pathway A. The ST-S operates in service of the quantitative scenario for Pathway A, BEV UK (see Figure 2); to discursively elaborate what changes might happen to achieve the change in socio-technical systems suggested by the quantitative scenario; but also to recognise the challenges and bottlenecks, opportunities and constraints, thrown up in the current direction of the land-based passenger transport system.

This involved a significant degree of substitution between ICE and alternative fuels between 2015 and 2050. It is primarily a story of the decline of ICE and its replacement by BEVs. In addition, there was a small, steady share of trips via public transport, slow modes and biofuels. The story is told in two time periods: from 2015 to 2030 and from 2030 to 2050.

2015-2030: the Decline of ICE and its Substitution by HEVs and BEVs

Pathway A suggested two very radical shifts. First, a very sharp reduction in ICE trips from around 75% in 2020 to c20% by 2030; and second, rapid growth in HEVs and BEVs from a very small share of trips in 2015 to c35% HEVs and c20% BEVs in 2030.

Between 2015 and 2030, this involved the following changes:

Policy: In this scenario, a radical shift in policy took place in 2019. The automobility regime, particularly policy and manufacturers, which hitherto was strongly committed to the ICE actively shifted to a twin-track strategy of promoting the decline of ICE and promoting the growth of electrified automobility. Prior to 2020 EU targets had contributed to gradual year on year reductions in CO2 emissions, but these lagged some way behind those necessary under Pathway A. Following agreement between policymakers and manufacturers in 2018, targets were strengthened from the current level of CO2 emissions of 95g/km by 2020 to 60g/km by 2025 and 30g/km by 2030 to incentivise a more rapid shift from ICE and to electric mobility. The political underpinnings to this were weak growth in the EU, post-2007/8 crisis, political uncertainty caused by European citizens restless at elite power and creeping rises in oil prices. Following the Greek crisis and the divided British decision to leave the UK in 2016, to quell citizen-unrest a renewed emphasis was placed on promoting new forms of 'green' economic growth by the EU, of which intensifying the rapid growth of green automobility was a key sector. Leading ICE manufacturers, including Renault-Nissan, Volkswagen, BMW and Toyota not only embraced this strategy but were central to devising it. The sector as a whole, by the early 2020s had promoted HEVs as a primary response and BEVs as a secondary response. To disincentivise ICE use, a sliding scale UK road tax was strengthened and tapered so that older ICE vehicles became very expensive to use from 2025.

Technology: The promotion of HEVs, at a technical level was not hugely difficult given the high potential alignment techno-economically between (P-)HEVs and the incumbent automobility regime. The steady growth in HEVs in the UK, since the early 2000s, was intensified given high alignment between PHEVs and the existing automobility regime where both dominant regime interests and users of vehicles were broadly similar. Costs of HEVs remained higher than comparator ICEs, but the manufacturing premium was reduced from around £7,800 above the costs of conventional ICEs in 2013 to around £3,000 by 2020, until in 2028 there was cost equivalence. BEVs were even more expensive than ICEs. In 2013, BEV costs had a 50% price premium in comparison with similar ICE vehicles. A report commissioned by the UK Committee on Climate Change suggested at this time that the costs for a battery pack for a medium sized BEV with a range of 150km were estimated at $21,000. This was predicted to drop to $6,400, with a range of 250km by 2030. Purposive public-private investment in battery research and an increasing uptake of both HEVs and BEVs accelerated cost reductions until there was equivalence in cost by 2033 and BEVs generally had a range of 400km.

Manufacturing: Capacity to meet the over 20% trips by household of HEVs by 2025 saw a massive retrofitting of automobile manufacturing capacity from 2019 onwards in the global division of labour. This allowed the share of HEV trips to grow to around one-third of all trips by 2030. Extensions of existing electric automobile production facilities took place and new manufacturing capacity came on stream. Through the 2020s, this included the extension of Toyota's hybrid vehicle manufacturing facility in Derby and Nissan's electric vehicle manufacturing facility in Sunderland, and a new facility in the North-west of England. Existing ICE manufacturing facilities were either retrofitted to produce HEVs or were closed down. There were large job losses as UK's manufacturing output increased but the numbers employed in the sector reduced. In 2012 production had totaled almost 1.5 million cars, in an industry that directly employed 140,000 people and around 720,000 in the wider automobile industry. By 2025, the UK remained the fourth largest European manufacturer of cars,

averaging output of 1.7 million cars through the 2020s, but advances in automation meant the number of those employed in the sector had reduced to around 500,000 by 2030.

Infrastructure: The dense infrastructure webs that supported ICEs (roads, road signs, repair and maintenance facilities, manufacturing facilities) in 2015 were largely interchangeable with the growth of HEVs (e.g. roads, petrol stations, manufacturing facilities); although there was some retrofitting of manufacturing facilities from 2019 and a UK government-subsidised programme for enhancing and upgrading skills for repair and maintenance engineers. The UK's petrol stations, numbering 9,000 in 2011 rapidly reduced to 3,700 by 2025 and 1,100 by 2030 when ICE accounted for only around one-fifth of trips. Growth of plug-in points, from an estimated 11,000 in 2016, continued into the early 2020s when there were 35,000 charging points. By this time there was widespread recognition that a further mass roll-out of public charging points was not required. A public information campaign in 2021-2022 promoted the simplicity of plugging in electric vehicles at home and charging them overnight via a conventional 13amp plug, with the price being illustrated by the smart meter that had been installed in most homes by 2020.

Business models: A massive uptake in electricity generation from the early 2020s onwards meant that electricity generators and distributors were brought into a new institutional arrangement with national and urban energy and transport policymakers, car manufacturers and large scale business users of electricity. This, in reality, was a re-branding of The Office for Low Emission Vehicles (OLEV), which was set-up in 2009. The re-branding was deemed necessary to re-position electricity distributors and generators in a network that had historically been dominated by elements of the automobility regime. The Office for Accelerating and Managing Electric Vehicles aimed to try and plan the management of an emerging new large-scale, reconfiguration of electricity generation and consumption.

User: By the early 2020s, there had been clear movement beyond the archetypal user of HEVs being characterised as an eco 'first-mover' and the use of HEVs was 'normalised' in media and popular representations. BEVs, in the early 2020s, retained some of this 'first mover' status but this weakened significantly through the 2020s. The flip-side of this was that the ICE became more negatively portrayed and represented in media and film through the 2020s in tactics that echoed aspects of cultural efforts to stigmatise cigarette smokers in the early part of the century.

In addition to this major shift, between 2015 and 2030, biofuels accounted for around a 10% share of trips which meant a doubling of the share of biofuels as a transport fuel from 2015. This required a modest amount of work to reverse weak momentum in relation to biofuels in the UK. On a techno-economic dimension although there was potential alignment between biofuels and the incumbent automobility regime in the UK the growth of HEVs and BEVs meant that biofuels remained a constant and small contributor to trips. Furthermore, significant issues of lack of alignment between multiple regimes (automobility, food, land-use) remained through the period. There was also ongoing and weak alignment in relation to legitimacy issues of biofuels as a fuel versus food issue. Public transport accounted for around 10% of trips across the period, which meant a stability of provision. Slow modes of cycling and walking also accounted for around 10% of trips, which again was remarkably stable, but with some growth of cycling in urban centres in particular.

2030-2050: Continuity in Phasing out ICE and Promoting BEVs

Post-2030, the scenario trend was one of continuity; decline of trips by ICE continued reducing from around 20% in 2030 to a phasing out of ICE in the early 2040s. Share of trips by BEVs continued to rise from around 20% in 2030 to over 50% by 2050. HEVs rose from 35% in 2030 to almost 40% in 2035 before reducing to c30% in 2050. Public transport and slow modes continued to account for around 10% of trips. In the late 2030s the 10% share of trips using biofuel reduced, phasing out by around 2045.

Policy: The EU emissions deal set out in 2020 - which the UK was shadowing - came to an end in 2030. In the build-up to this in the late-2020s EU decision-makers and automobility manufacturers agreed a continuation of a twin track strategy of working to phase out ICE and promote BEVs. Targets that were intended to lead to the phasing out of the ICE by 2045 were passed in 2028. Automobility manufacturers had become enthusiastic agents of managing the decline of ICE and the rise of BEVs, seeing that the decline of ICE and the growth of BEVs was heading to the latter overtaking the former in terms of share of trips by 2030. By the late 2030s, with ICE almost phased out and BEVs accounting for almost 40% of trips, ultra-low EU CO2 emissions targets began to bite in making BEVs more attractive than HEVs for manufacturers. Coalitions of policy and automobile manufacturers, mighty in the 1980s and 1990s, were reconfigured around this demise of ICE/promotion of BEV strategy.

Manufacturing: Among leading ICE manufacturers, most of whom embraced an electrification strategy from 2020, a small number had completely phased out their ICE production capabilities by 2030. Through the 2030s, this phasing out picked up momentum and post-2035 only a handful of ICE manufacturers remained to produce what had become a technology consumed by ‘petrolheads’, technological refuseniks and a small number of vehicles that owners refused to scrap.

Technology: The increasing loss of economies of scale for ICE as their production numbers fell meant that by 2030 the costs of purchasing ICEs had risen significantly as they became positioned both as ‘yesterday’s technology’ and as a premium product for ‘petrolheads’. By contrast, the costs of HEVs and BEVs continued to fall through the 2020s meaning that by the late 2020s, HEVs and ICEs had price equivalence and by the early 2030s, so did BEVs and ICEs. The increasing volume of production battery costs had significantly reduced from 2025 onwards. Technological breakthroughs had been made on vehicle range, which by the early 2030s meant that range had stretched to around 400km. This was perceived to be sufficient by many consumers and resonated with their use patterns with ICEs.

Business models: The huge growth in BEVs and HEVs that had taken place in the 2020s continued into the 2030s. The new institutional mechanism to integrate policy, automobile manufacturers, electricity distributors and generators and large business interests - The Office for Accelerating and Managing Electric Vehicles - set out its strategy in 2030 as to how it envisaged electricity generation and consumption as it related to the electrification of automobility. Alongside its programme of upgrading the UK’s electricity generation capacity, it also set out the need for an acceleration of appropriate ways of incentivising consumer generation of electricity and feeding it back into the UK electricity grid.

Infrastructure: Much of the road infrastructure associated with the ICE remained in 2030. That said, there were only a small number of ICE manufacturing plants remaining in the UK, as part of a wider international trend of closing these plants down and/or retrofitting them to produce HEVs and BEVs. Throughout the 2030s, the number of UK petrol stations declined rapidly so that by the late 2030s there were fewer than 500 nationally. Repair and

maintenance facilities for ICE vehicles had become a niche and specialised service by 2035. The surge in electric vehicle plug in points from 2015 had stabilised from the early 2020s and the widespread education programmes that had been commissioned to encourage users to engage with their domestic electric infrastructure for charging and to use plug-in points to power-up if they were 'caught short'.

User: By 2030, HEV users had become the dominant mode of land-based mobility trips in the UK. Users approximated to the wide range of users-types who had previously been ICE users. Users of BEVs had moved beyond archetypal eco 'first movers' and had become, by 2030, the choice of vehicle for those willing to pay more for the cost of their vehicle upfront than was the case with HEVs but where there were savings to be made from the huge running costs from petrol and diesel that HEVs faced. ICE users were increasingly older, male 'petrolheads' and a minority of those unwilling to move away from the ICE. Popular media representations presented these users as quirky refuseniks.

Within this scenario, public transport and slow modes remained stable at around a 10% share of trips each. These were primarily used for short commutes in urban areas where increasingly the volume of vehicle congestion meant that large areas of these urban centres were deemed no-go areas for private vehicles. Share of trips using biofuels remained at 10% in 2030 but dropped from around 2037 and was phased out in 2045. This was due to EU targets strengthening and prioritising pure electric vehicles from 2036 and developing a sanctions regime for the use of petrol, diesel and biofuels.

6. Scenario 2 (Pathway B) is characterised by two alternative scenarios: 'Public Transport' and 'Slow Modes'

These two scenarios implied radical change throughout the period from 2015 to 2050. In particular, they necessitated radical change in the period from 2015 to 2030 often with more gradual changes and stabilisation in the period 2030-2050. Both required a sharp reduction in trips by ICE. The (i) Public Transport scenario saw a major rise in the number of trips undertaken by public transport. There remained, in this scenario, a small but significant role for car-based automobility via HEVs and also for slow modes. As a response to the decline of ICE, in the (ii) Slow Modes scenario there was huge growth in trips undertaken by slow modes with a small but significant role for car-based automobility.

(iii) Public Transport

2015-2030 Making the ICE obsolete and re-invigorating integrated public transport
The Public Transport scenario was based on a shift from private car ownership and use to a large increase in public transport. There were still small roles for HEVs, slow modes and biofuels. Between 2015 and 2030, the Public Transport scenario envisaged a sharp reduction in the share of trips undertaken by ICE; this was from c75% in 2015 to around 50% by 2030. Share of trips on public transport rose from a nominal amount in 2015 to over 20% by 2030. Within this time period, there was a steady level of trips via slow modes at around 20% and a c10% share of trips via biofuels (see Figure 3).

Policy: UK policy at national and local authority levels was aligned after 2017 to operate in pursuit of a twin-strategy of radically reducing ICE and car-based automobility and promoting the development of public transport to provide alternative modes of mobility. In 2017, UK government recognised that existing targets were an insufficiently radical means of

reducing CO2 emissions and that incremental change was not enough. From 2019, the UK government shifted course from its greening automobility strategy to a long-term, 30 year phasing out of car-based automobility. Its 2019 ‘Transition to a Public Transport Future’ strategy set out a generous scheme of public transport investment funding for local authorities prepared to trial congestion charging schemes, as part of a stepping stone to banning cars from identified urban areas by 2030. Feasibility studies were also undertaken to assess the effects of widespread road pricing on UK motorways and major highways.

Privatisation and liberalisation in the 1980s and 1990s had produced a serious fragmentation of public transport systems in the UK. The Transition to a Public Transport Future strategy signalled a major shift in government ideology, recognising that the level of trips required to be made by public transport required control over public transport systems and investment in them that are managed and controlled by strengthened local, integrated transport authorities. The strategy set out that these enhanced authorities were needed to develop both a strategic view of local transport that addressed 30 years of privatised, liberalised market-driven public transport and also to undertake an operational role. Greater Manchester and Greater Leeds were chosen as pilot authorities in 2019. A second wave of large city authorities were selected in 2021 and by 2028 enhanced modes of urban public transport governance were established across England, with similar developments taking place in the devolved administrations in Scotland and Wales. These authorities were also given responsibilities for maintaining levels of slow modes at around 20% of trips. This was an attempt to bring some strategic coherence to a range of cycling infrastructure investments and public promotion campaigns in cycling and walking which had resulted in around 20% of trips being by slow modes at the start of the period in 2015.

Business models: This strengthening of integrated public transport authorities was part of a wider process of decentralisation from central government to local levels. By the late 2010s, there had been growing recognition among both policymakers and the wider population that addressing the scale of carbon emissions reductions required a new model of economic development to address the ongoing post2007-8 economic malaise. This new economy went beyond the industrial and post-industrial economies that supported automobility. Re-making the economy was on the basis of more localised forms of economic activity in compact cities rather than through the stretched supply chains of globalisation. One of the key tasks of the new integrated urban transport authorities was to work with broader local and national governance interests to set out new visions for compact cities which integrated public transport networks with the economic and material re-design of towns and cities. Pilot visions were set out in Greater Manchester and Leeds in 2023 and by all major urban areas by 2030.

Infrastructure: These large scale plans meant that much of the infrastructure for compact cities was not in place prior to 2030. Where infrastructure was in place there was a reallocation of existing infrastructure (e.g. roads from cars to public transport and slow modes pre-figuring the 2030 banning of cars from urban centres). The electrification programme on the railways from 2015, aimed to electrify the two-thirds of the rail network that were not and meant that by 2030 the vast majority of the train network was electrified. By 2025, though, there were serious concerns that the 150% growth of passenger trips by rail travel, since privatisation in 1994, had met the capacity limits of the system. In addition to HS2, which became operational in 2026, the UK Department for Transport undertook a feasibility study to assess the re-opening of parts of the rail network closed down following the Beeching Report in 1963.

Manufacturing: From the early 2020s, there was a process of managed decline in the manufacture of ICE automobiles. The reduction from around 75% of trips being by ICE in 2015 to this being c50% by 2050 involved a process of consolidation of the industry with giants of the automobile sector, including General Motors and Renault-Nissan, reacting to the new policy landscape and being involved in a regular process of downgrading their facilities and making large-scale redundancies. The strategy of promoting public transport in the UK at the expense of ICE automobility was also variably undertaken by a range of different nation-states, particularly in the West and in Europe as the commitment to public transport became widespread. There was growth in employment in the manufacture of new generations of primarily HEV buses but also a smaller number of BEV buses. There were also jobs in the manufacture of new rail rolling stock in factories in the North-east of England and Derby as well as employment on the construction of a new HS2 rail line out of London to the North of England. However, a huge level of net unemployment remained from the shift from ICE to public transport following the decline of automobile manufacturers and associated supply chains. By the mid-2020s, in a context of unemployment and under-employment, there was a strengthening drum beat for a universal basic income (UBI) for all citizens to address the precariousness of work.

Technology: The twin track strategy was to emphasise the obsolescence of the established technology of the ICE. But more than this it was to re-invigorate old bus and rail technologies that underpin public transport. These long-established modes of transport were promoted as part of a more integrated mode of public transport. Through the 2020s, integrated forms of smart card ticketing became the mode of accessing transport as cash on public transport was phased out by 2025. The UK rail network was upgraded to an almost fully electric network by 2025; moving from a one-third electrified network in 2015, through a process of electrification that commenced at the start of the period but which picked up momentum after 2020. The UK's 42,000 buses, the vast majority of which were diesel in 2015 were in the majority HEVs by 2025 with a significant and growing minority of BEV buses by 2030. In alignment with the promotion of congestion schemes, technology of automobility (roads) were made freely available in urban centres to public transport, bikes and pedestrians.

User: Denigration of the car user subtly began to permeate media and popular cultural representations from 2020. An active programme to construct an image of public transport users as positive and desirable took place through official government and local authority campaigns from 2020. The aim was to address negative perceptions, particularly of bus use, that built up around public transport following the promotion of Thatcher's individualised home owning, car owning democracy in the 1980s and 1990s. Increasingly levels of commuting mobility reduced through the 2020s as large-scale unemployment and underemployment became the norm. This was part of a slow shift towards more local forms of mobility.

2030-2050: Completing the transition to public transport

Policy: The long-term policy of a transition to public transport remained intact after 2030. The managed decline of automobility from c50% in 2030 to under 20% by 2050 caused serious policy dilemmas for national government. Large scale unemployment that had begun in 2020, from the UK's 720,000 employees in the automobile sector in 2015, had reduced to 375,000 by 2030. The UK government in 2028 recognised that its aim to eradicate private car use had limits both at the level of industrial policy, employment policy and for consumers. From 2028, automobile producers received government grants, subsidies and tax reliefs to promote HEVs. This was primarily seen to be for inter-urban travel where rail links were

weak. This followed the reporting of the DfT on re-opening parts of the UK rail network. The report recognised the costs of this and suggested a selective re-opening of rail lines in areas where this could be incorporated into a wider integrated, compact city vision. Such an approach resulted in HEVs, through the 2030s and 2040s reaching a point where they accounted for around 20% of trips. This along with ICE by 2050 accounting for around 15% of trips meant that by the end of the period, still one-third of trips were by car-based automobility. This growth of the role of HEVs also meant that there was some decline in trips via slow modes.

Business models: From the late 2020s, there were efforts across the UK to enact compact city visions. As a response to car-free urban areas and large-scale unemployment, compact cities that integrated an emphasis on public transport mobility and slow modes were organised around new economies. These new economies were increasingly centres of cultural activity rather than paid employment. Commuter travel had steadily decreased since the early 2020s and new forms of travel within these compact cities in the 2030s was a mixture of irregular, precarious work travel, volunteering and citizen activities and in a still vibrant cultural economy of events, food and drink. This economy was underpinned by a universal basic income, which was introduced in 2025, and which fundamentally changed the emphasis on work in everyday life.

Manufacturing: Automobility manufacturing continued its decline through the 2030s and early 2040s resulting in further plant closures and unemployment. There was, though, enhancement of manufacturing capacity around HEVs, particularly at Toyota's plant in Derby and its associated supply chains. Manufacturing output in relation to renewing the UK's 42,000 buses remained on an upward trend. Increasingly replacement of buses through the 2030s saw HEVs replaced by BEVs, meaning that by 2050 the entire bus fleet was a BEV fleet.

Technology: The ban on cars in urban areas had been complemented with trials on road pricing on the M1 motorway from 2027. By 2030 this pricing technology was rolled out onto most heavily used parts of the M1, M6, M25, M4, M5 and other major motorways. Despite being the object of a purposive, managed decline, the ICE and automobility more generally retained a role, accounting for over one-third of trips in 2050. Costs of batteries for BEVs fell through the 2020s and by the 2030s BEV buses reached equivalence with comparator ICE vehicles. HEV technology, previously thought to have been an intermediate, stepping stone technology, that was past its usefulness, was re-invigorated to provide an alternative means of or inter-urban travel where public transport was weak and where a dual source of potential fuel gave flexibility to users. It was also a recognition that despite efforts to create more local, compact cities that there would continue to be a need to conduct travel outside of these areas for domestic, business and leisure reasons.

Infrastructure: The UK's road infrastructure, while not physically being removed, was changing and became used in different ways. Urban roads in 2030 were used for public transport and bikes but also for cultural events. Major inter-urban roads became retrofitted with pricing technology so that by the end of the 2030s 1,000 miles of the UK's 2,200 mile motorway network was accessible via pricing. Old rail lines were re-opened up in the early 2030s where they connected into the vision of a compact city. This was particularly the case with lines that connected to the major urban areas of the North of England creating a bigger, 'compact' urban centre around the North. Following the splintered transport networks of the 1980s and 1990s, integrated transport authorities with their visions for compact cities and

also for integrated use of networks through inter-modal ticketing had fundamentally changed relationships between transport infrastructure networks by 2040.

User: by the 2030s, users were not primarily seen as commuters. They were, using public transport to go about the business of being citizens. A more 'active' role for citizens saw them engaging in new social innovations and mobility-related experiments.

(iv) Slow Modes

2015-2030 The double shift transition to slow modes

The slow modes scenario suggested a huge growth in the number of trips via slow modes, from just under 20% in 2015 to over 70% by 2050. Alongside this there was a massive decline in trips by ICE from over 70% in 2015 to under 5% by 2050. The key change in the Slow Modes scenario between 2015 and 2030 was the huge decline of trips via ICE. This was down from over 70% in 2015 to just over 25% by 2030. Slow modes across this period accounted for around 20% of trips. There was, though, a significant growth of car-sharing from 2018 to 2030 from very few trips up to around 30% of all trips. Biofuels accounted for around 10% of trips. This provided a large amount of substitutability between ICE and car sharing and between car ownership and access to a vehicle. From around 2018 there was also some growth of public transport to around 10% of trips by 2030 (see Figure 4).

Policy: In the period between 2015 and 2030, the primary aim of UK government policy was to wean mobility away from ICE automobile-based mobility. From 2017, there was strong government policy to disincentivise use of privately-owned cars in urban areas. UK government sponsored, local authority pilot congestion charge schemes targeted private automobility and the use of private automobility in urban areas was made eye-wateringly expensive. Congestion charging price levels were increased throughout the 2020s. Rather than move from ICE private automobility to slow modes, UK policy was to promote the shift from ownership to access as an intermediate, stepping stone stage to weaken strong cultural attachments to automobility built up over almost a century. Generous incentives were provided by local authorities (supported by national grants) to car sharing companies in the form of promotion, partnering and providing free parking spaces in pursuit of a national target of reducing commuting trips (of less than 5km) by cars by 50% by 2030. National government, through the period, continued to champion the role of local authorities in promoting slow modes in local areas. This included the promotion of walking to work and walking to school schemes that were ongoing throughout the period. It also involved efforts to promote cycling and cycling infrastructure. Much of this was done in a preparatory way to pre-figure a future massive transition to a slow modes system of transport provision.

Business models: The shift to a slow modes transport system involved a double shift: from ownership to access to automobility and subsequently away from automobility to slow modes. Strong cultural attachments to a model of ownership of cars in the UK were weakened from 2020 onwards and the flexibility, accessibility, ease of use and displacement of running costs were promoted as virtues. This underpinned a huge growth in access to automobility that largely offset the decline of ICE. Biofuels and public transport also substituted for a small percentage of ICE trips, particularly those outside of urban centres and used for inter-urban travel. This shift to access was underpinned by a significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors in the late 2010s and early 2020s.

Manufacturing: In terms of manufacturing the story was one of the sharp decline of automobile manufacturing companies. The decline of automobile manufacturing from 2020 through to 2030 saw the loss of around half of the UK's 720,000 automobile industry employees over the time period. Some, of this decline was offset by a switch in manufacturing vehicles for the rapidly expanding car sharing fleet. Manufacturing required some amendments to design because of the different forms of usage associated with car sharing and to integrate monitoring and payment technologies.

Technology: The shift to car sharing was not only as a stepping stone towards a slow modes transport system, it also involved a shift from ownership of ICE vehicles to access to combinations of HEVs and BEVs fleets. HEV prices, by 2027 became comparable with ICE, with a trend of HEVs becoming cheaper and ICEs more expensive. BEVs also saw significant cost reductions as battery prices reduced through the 2020s so that by the early 2030s there was comparability with HEVs. The UK fleet of car sharing grew from under 3,000 vehicles in 2015 to 150,000 by 2030.

Infrastructure: The big shift in infrastructure was in terms of the decline of manufacturing infrastructure, with the rapid downsizing of trip share by ICE. Though from 2020 there was the managed decline of automobile manufacturing facilities the enmeshed webs of other aspects of infrastructure remained intact. This included, importantly, roads. Congestion charging infrastructure was established in UK cities from 2023 and meant that the use of road infrastructure became re-prioritised from private car use to a fixed number of accessible automobiles. The decline of ICE trips and the shift to car sharing BEV and HEV vehicles meant that the numbers of UK petrol stations continued to decline from 2015 from 9,000 down to just over 2,000 petrol stations in 2030. The active configuration of an infrastructure for car sharing was subject to some experimentation in the late 2010s about how to configure the appropriate business model, the physical infrastructure of parking bays and the ICT infrastructure of monitoring and payment. By the early 2020s, when around 20% of trips were by car share much of this had settled around a 'one way' model of car sharing. The cycling infrastructure investment, in cycling lanes for example, which was an early signifier of preparation for slow modes between 2015 and 2020 was abandoned by 2030 as urban streets saw a huge reduction in private car travel.

User: One of the biggest challenges of the shift to slow modes was the deep cultural attachment of people to privately owned automobility. The recognition of this attachment was what underpinned the stepping stone strategy and the shift from ownership to access. This required a significant re-alignment of socio-cognitive understandings of car use. In a wide range of cultural media from the late 2010s onwards the normalisation of the fleeting, flexible consumption of automobility was constructed. Simultaneously, the desirability of the petrolhead owner was deconstructed and feelings of freedom attached to automobility were actively undermined. There was also a state and cultural strategy through the late 2020s to normalise cycling and promote walking in recognition of the coming shift to slow modes but also that cycling in particular was seen as abnormal and often incongruent with employment, family, leisure or other activities.

2030-2050 Completing the double shift

Between 2030 and 2050 trips by ICE fell from around 25% to under 5% and from 2035 trips by slow modes rose sharply from 20% to over 70% in 2050. The high point of car sharing at 30% of trips in 2030 continued to 2035, at which point there was a rapid decline with virtually no car sharing by 2050. From 2030 there was some growth in trips by HEVs to

around 10% in 2040 and levelling out to 2050; there remained a 10% share of trips by biofuels and public transport trips decline in the 2040s to under 5%.

Policy: Policy and governance was the single most important shaper of the transition towards slow modes. UK government policy continued to manage the decline of ICE and private car use. In 2030 the UK government announced a policy for all urban areas with populations over 30,000 that they must move to being completely car free in the boundaries of the core urban area (city or town centre) by 2040. The government suggested that the congestion charge zones had provided the stepping stone for the boundaries of these new car free areas. This policy announcement signalled a shift from managing the decline of private car use to managing the decline of all car use, including car sharing. The effect of the announcement was that from 2033 there was a rapid fall in the number of trips by car sharing to under 10% by 2040. Some car sharing remained in laggard local authority areas. The 2020s had seen a slowly growing ideology of autarky and local self-sufficiency in economic development infusing national policy. This was a response to what were widely seen to be the failures of economic globalisation and extended supply chains, since the global economic crisis of 2007/8 and the subsequent low growth and multiple recessions that the UK and other western nations had experienced. By 2030, the commuter society was beginning to be seen as a relic of another era as what paid work there was that remained, leisure activities and patterns of consumption became highly localised. The UK government, though, recognised the realities of a still significant need for travel outside of urban areas and permitted the use of alternatives to ICE, primarily HEVs and biofuels outside of urban areas on Britain's network of A roads and motorways, many of which had become toll roads in 2028.

Business models: By 2030 the UK had become increasingly organised into a plurality of often resurgent local economies. Though the world of paid work was increasingly precarious, the work that remained was largely performed by local people who lived, worked and played in what had become increasingly emergent local economies. Models of mobility based on private mechanised transport had been significantly weakened by policy and the increasing localisation of life. Particularly from 2030-2040 this saw the further decline of ICE to around a 10% share of trips and the almost terminal decline of car sharing.

Manufacturing: The UK's 350,000 workers in the automobile sector reduced rapidly in the 2030s and numbered under 80,000 by 2040. The wider manufacturing economy, much of which had been off-shored in the 1970s and 1980s, became increasingly automated and mechanized leading to massive unemployment in the 2030s. The campaign for a universal basic income (UBI) that had begun in the late 2010s, and that resulted in a scheme trialing universal basic income in 2023 had been rolled out across the UK by 2030. Levels of increase of UBI had been a source of political conflict but had risen in tandem with the re-localisation of life.

Technology: The massive upturn in trips by slow modes from 2035, as well as being underpinned by the promotion of walking and cycling was also underpinned by large-scale societal consumption of an old technology, the bicycle. Sales of bicycles, which had been at 3.7 million (including for export) in 2015 reached 9 million by 2040. The previous spatial unevenness of cycling in the UK became evened out after 2035 partly as a response to a complicated set of issues that included the ban on cars in urban centres, the growth of local economies and the new leisure time available in an era of post-paid-work.

Infrastructure: From 2030 the UK's 2,000 petrol stations were reduced in number to 200 by 2050. Many of the UK's 245,000 miles of road, from 2030, were incrementally retrofitted to either be mixed pedestrian and cycling highways.

User: The most telling aspect of users of transport by 2050 was the death of the petrolhead, whereby cultural attachments to the ICE were weakened in the 2020s and where ICEs became culturally unacceptable by 2040. Travel beyond the immediate local area became seen to be exceptional and users became redefined as local rather than as travellers.

7. Conclusions

This report has developed qualitative socio-technical scenarios for land-based passenger mobility in the UK between 2015 and 2050. It took quantitative scenarios developed in WP1 of the PATHWAYS project, assessed what the key constraints were in achieving such scenarios and what processes of change to realising those scenarios might look like.

To do this, two qualitative scenarios - pathway A and B - were developed in service of these quantitative scenarios. Both scenarios are plausible and achievable but require multiple processes and facets of change to align. Both of these scenarios are difficult to realise but Pathway A, with its substitution is easier to achieve than Pathway B with its complex and often radical reconfiguration. In a nutshell, Pathway A involves a lot of substitution and Pathway B requires fundamental changes in the current economic and spatial organisation of UK society.

Both scenarios, though, involve massive changes to the status quo. Both involve the decline of ICEs. A technology that has been pervasive in the organisation of UK society, economy and ways of life and in other western nation states for a century is largely phased out in both scenarios in little more than three decades.

For Pathway A, this means a large reduction in ICEs but less change than Pathway B in that private automobility still reigns and infrastructure and coalitions of key actors are largely similar. Pathway B is different in that not only does it envisage the decline of ICE but also the replacement of private automobility with either public transport or slow modes of travel.

There are numerous core constraints to the achievement of Pathway A. These are:

- Technical and economic (the costs and performance of batteries);
- The politics of regime actor reconfiguration (from the dominance of the automobile manufacturer-policy-oil relationship to electricity generators and distributors becoming key regime actors organising the very resource - electricity - that supports the new mobility system);
- And the socio-cognitive shifts required to achieve widescale public acceptance of a large shift in the re-organisation of car-based mobility.

Core constraints around Pathway B are that:

- It envisages the decline of a massive employer and economic powerhouse, the automobility sector, without an alternative economic plan.
- The planned huge growth in public transport also meets limits to capacity in existing systems, particularly the fixed infrastructures of the rail system.

- There are also significant cultural constraints. The largescale plans for public transport require cultural reinvigoration of public transport after societal messages for more than 40 years trumpeting that private is best.
- This is also a governance challenge as the capacity that is needed to re-shape public transport systems has been privatized for decades and is fragmented. Not only is there this constraint but much of this governance capacity needs to be organised to act at an urban scale where the potential of public transport systems are pronounced.
- In respect of carsharing and road pricing, there is the need for a shift in public acceptability in two ways: from private ownership to public access to automobility; and to accept a combination of road pricing and areas that are car free.
- The biggest constraint is that mobility is a 'derived demand' and therefore local travel (which is what a slow modes scenario and much of a public transport scenario suggest) needs to be in service of a different kind of economy of that which currently exists and also suggests very different mobility patterns in everyday life than at present.

Both Pathways A and B illustrate numerous key decisions and policies. There was not one key branching point. What was critical was the role of policy in setting clear, long-term frameworks to underpin these transitions in their different ways. In particular, the intensification of carbon reduction targets was underpinned by a clear purpose: that there needed to be a relatively fast shift from ICE to electric vehicles. This provided the framework and clarity for public-private investment in battery technology and research, the reduction of battery costs, the improvement of range, the greater uptake of vehicles and further cost reductions from economies of scale. There was also a key role for policy in managing the effects of the decline of ICE automobility and in creating the institutional context through which electricity generators and distributors became fundamental players in the automobility regime. In Pathway A policy was critical through targets, visions and political will in making ICE unattractive and electric vehicles attractive. In Pathway A the fundamental regime shift was in the weakening of the automobile manufacturer-policy coalition and its extensions to electricity producers and generators. This fundamentally changed the orientation of the regime.

In Pathway B, policy was critical in creating frameworks that (a) set out the transition to a public transport based mode of mobility and (b) a slow modes system of mobility. A key development was the strengthening of integrated public transport authorities as the agents of enacting transition. Various stepping stones followed this new institutional context, but particularly a more strategic orientation to how transport systems should be organised in cities and towns. This resulted in congestion charging and road pricing trials. There was rapid upscaling of battery-powered public transportation, but also a key recognition that in a society that saw work become precarious, that new forms of travel needed to be integrated with local visions of post-work society. In Pathway B policy was fundamental in providing frameworks for transition through developing purposive radical visions of a very different society based on either public transport or slow modes. In Pathway B the policy-driven abolition of the dominant automobile manufacturer-policy coalition was replaced by various localised embryonic coalitions of public transport providers, manufacturers, electricity generators and distributors, businesses and citizens groups.

It is clear that the transitions to 2050 envisaged in both Pathway A and Pathway B scenarios are processes where much of the work of change needs to be concentrated in the years between now and 2030 and, in particular, the next 10 years. This has implications for policy.

Policy implications/robust advice are as follows:

1. Each of these transitions - whether to BEVs, public transport or slow modes - needs to be underpinned by a long-term, strategic vision.

2. This is needed as an orientation around which 'political will' can coalesce to achieve the social acceptability and legitimacy of the proposed transition. Political will needs to be constructed through a shared understanding around which policy, manufacturers, business, citizens and investment can coalesce.

3. This needs to be a multi-pronged strategy which is not just about targets and incentives - although these are important - but which sets out a clear vision of what society will look like once the changes have been enacted, the institutional mechanisms that will need to be constructed, the policy mechanisms for bringing about change and agreed ways of assessing if these have been successful.

4. There is a clear need in both scenarios for new institutional arrangements around which strategic change can be organised and implemented.

5. Although a vision is needed very ambitious carbon reduction targets to incentivise the achievement of that are necessary.

References

Committee on Climate Change Progress Report, (2013) Meeting Carbon Budgets – 2013 Progress Report to Parliament, June.

Cowie, J., (2002) Acquisition, efficiency and scale economies: An analysis of the British bus industry *Transport Reviews: A Transnational Transdisciplinary Journal*, 22:2, 147-157.

ECF, (2011) Cycle More Often 2 Cool Down the Planet! Quantifying CO2 savings of cycling, European Cyclists' Federation: Brussels.

Grous, A., (2011) *The British cycling economy: 'gross cycling product' report*, Sky and British Cycling.

Haubrich, D., (2001), UK rail privatisation five years down the line: an evaluation of nine policy objectives *Policy & Politics*, Volume 29, Number 3, 1 July 2001, pp. 317-336(20).

Hodson, M., Geels, F., McMeekin, A., (2015), Integrated analysis of D2.1 and D2.2 to assess feasibility of different mobility transition pathways in the UK. Deliverable 2.3 for the EC FP7 PATHWAYS project. Available at http://www.pathways-project.eu/output

Hodson, M., Geels, F., McMeekin, A., (2015), Analysis of stability and tensions in incumbent sociotechnical regimes. Country report 6, Regime analysis of the UK mobility system Deliverable D2.2 for the EC FP7 PATHWAYS Project. Available at http://www.pathways-project.eu/output

Hodson, M., Geels, F., McMeekin, A., (2014), Green niche-innovations in the UK mobility system. Country report 6, Analysis of green niche - innovations and their momentum in the two pathways. Deliverable D2.1 for the EC FP7 PATHWAYS Project. Available at http://www.pathways-project.eu/output

Howe, J., (2013) Prototype boulevard, *New Left Review*, 82, 85-96, July-August.

Jupe, R., (2013) New development: Going off the rails? Rail franchising after the cancellation of the West Coast franchise competition, *Public Money & Management*, 33:5, 337-341.

Kitchen, R., (2013) The real-time city? Big data and smart urbanism, *GeoJournal* 79, 1–14.

Langridge, R., and Sealey, R., (2000) The demand for public transport: The effects of fares, quality of service, income and car ownership, *Transport Policy*, 7, 105–115.

Parkhurst, G., Kemp, R., Dijk, M., and Sherwin, H., (2012), Intermodal Personal Mobility: A Niche Caught Between Two Regimes, in Geels, F.W., Kemp, R., Dudley, G., and Lyons, G., (eds) *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*, Routledge: New York, pp.308-334.

SMMT, (2014) The Society of Motor Manufacturers and Traders Motor Industry Facts 2014, SSMT: London.

Turner, R. (2008) *Neo-Liberal Ideology: History, Concepts and Policies* Edinburgh, Edinburgh University Press.