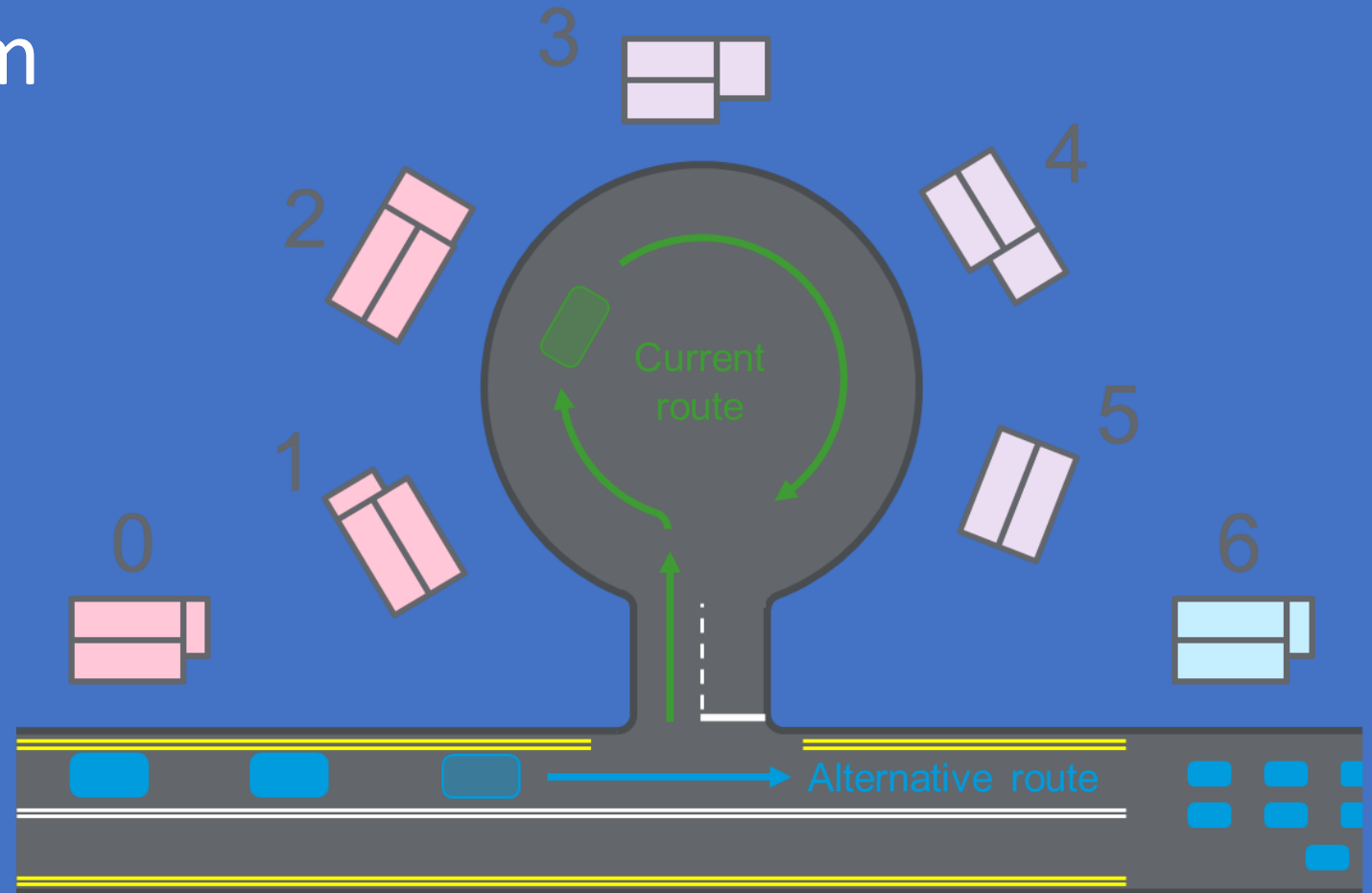


Defining Vehicle Automation Level 6

Automated Road System



...and a route to get there

V 15.9

Mark Waterman

DRAFT WIP

Road travel in the UK today

What do people want^[1]:

Today for £200 billion^[2] we get:

Ability to travel between locations	<input checked="" type="checkbox"/>		
As quickly as possible	<input type="checkbox"/>	}	• Average commute times of over an hour
When we want to travel	<input type="checkbox"/>		• Public transport requires multiple journey legs (walking, bus, walking) and is only coincidently at the right time
As reliably as possible	<input type="checkbox"/>		• Journey durations vary considerably during the day
As safely as possible	<input type="checkbox"/>		• Parking is often difficult and expensive
			• 78% commutes experience journey time variability
	<input type="checkbox"/>	}	• 817 killed
			• 17,682 seriously injured
			• 94,326 slightly injured
			Urban Road Traffic Accidents
With least environmental impact	<input type="checkbox"/>	}	• 3,700 premature deaths
			• 18,000 serious health conditions
			Air pollution from traffic
As pleurably as possible	<input type="checkbox"/>		• 120 million tonnes of CO2e emitted, 26% of total UK emissions
As cheaply as possible	<input type="checkbox"/>		• Often a mildly unpleasant overall experience
			• The average cost of owning a car is £3.5 - 5.8k a year ^[3]

☒ Meets objective ☐ Fails to meet objectives








^[1] Probably (not in any specific order)

^[2] Annual cost to consumers 2019 - revenues of car sales, aftermarket products and services, vehicle maintenance and repair, motor insurance, breakdown services, bus and tramway, taxis, petrol stations, road repair and car parks.

^[3] Depending on method of calculation and source

Personal transport is heading autonomous

Level 6 is materially different

						
L0	L1	L2	L3	L4	L5	L6*
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation	System Automation
Manual control. The human performs all driving tasks (steering, acceleration, braking etc.)	The vehicle features a single automated system (e.g. it monitors speed through cruise control)	The vehicle can perform steering and acceleration. The human still monitors all tasks and can take control at any time	Environmental detection capabilities. The vehicle can perform most driving tasks but human override is still required	The vehicle performs all driving tasks under specific circumstances. Geofencing is required. Human override is still an option	The vehicle performs all driving tasks under all conditions. Zero human attention or interaction is required	All vehicles within a geofenced area are controlled centrally. Human driving control is only possible under controlled conditions

Society Automotive Engineers (J3016) levels 0-5

*may also have L0-5 dual capabilities

Level 6 central control zone and fleet autonomous range

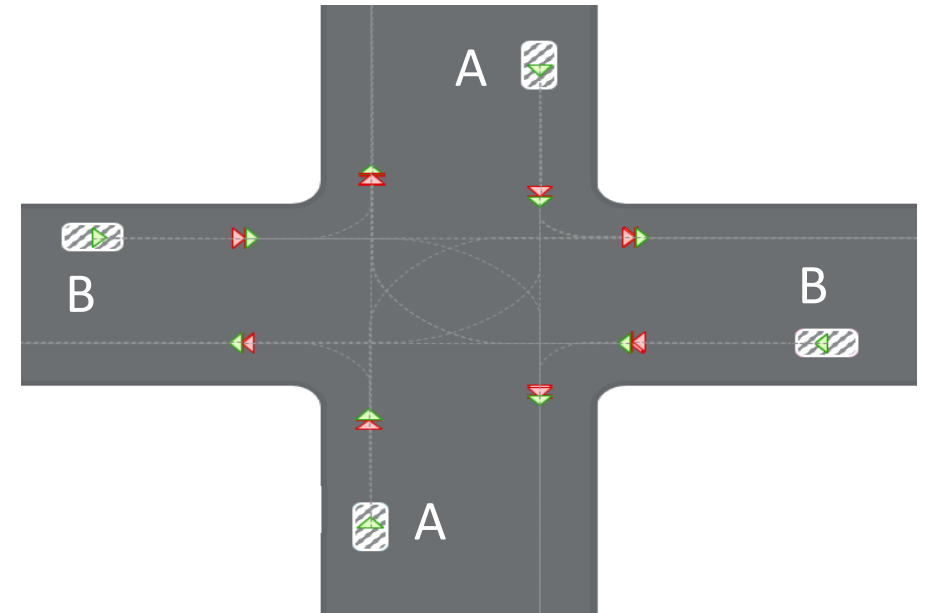


 **Central control only**  Fleet pick up and drop off range

Level 6 central control (and planning) system manages every junction



- Each junction can be considered like a gear wheel whose speed regulates the flow of traffic and ensures there can be no collisions

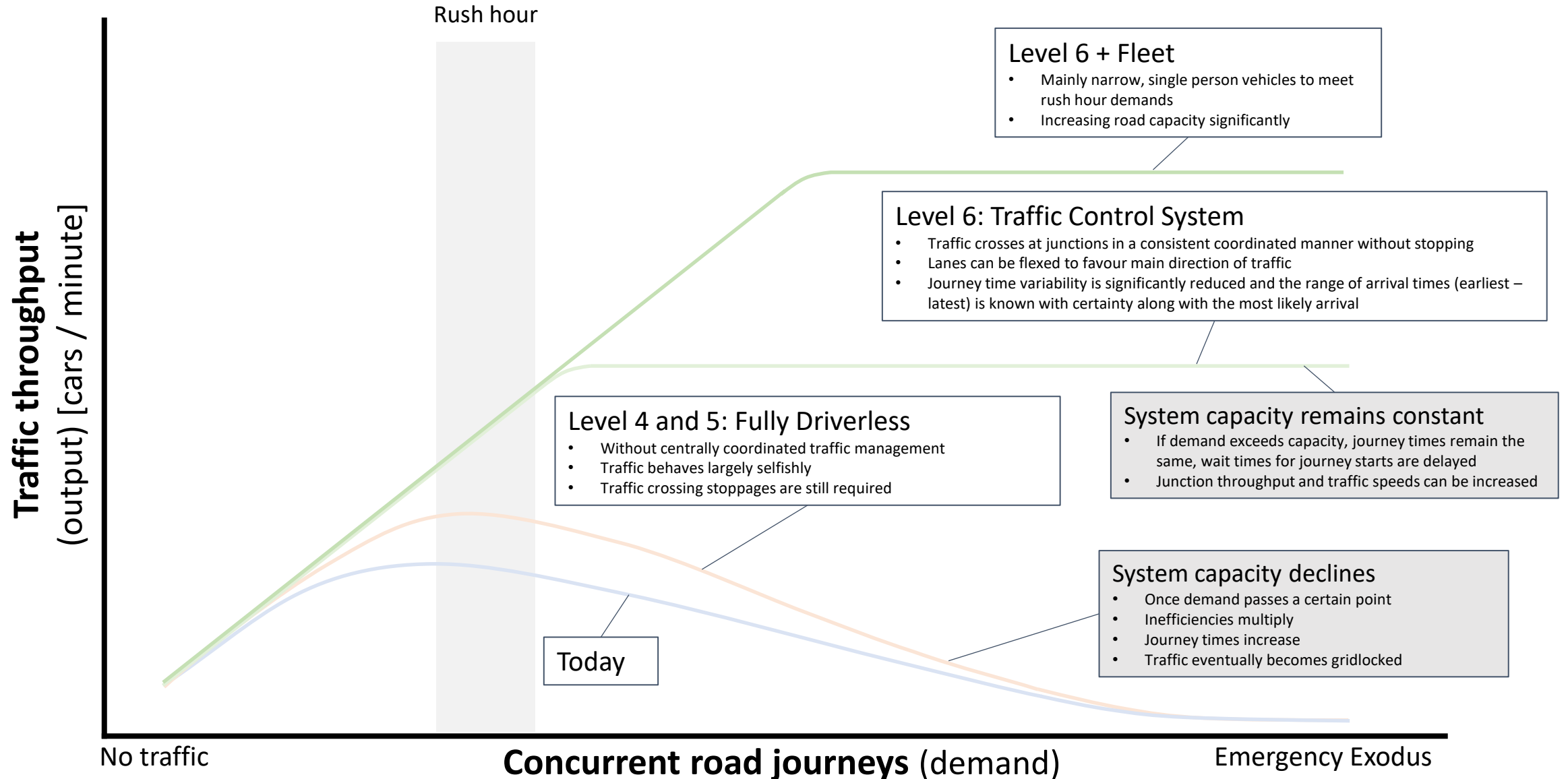


- Vehicles reach junction virtual entry points in alternating pairs at set time intervals
- They then follow paths that are designed to allow both to cross safely without stopping

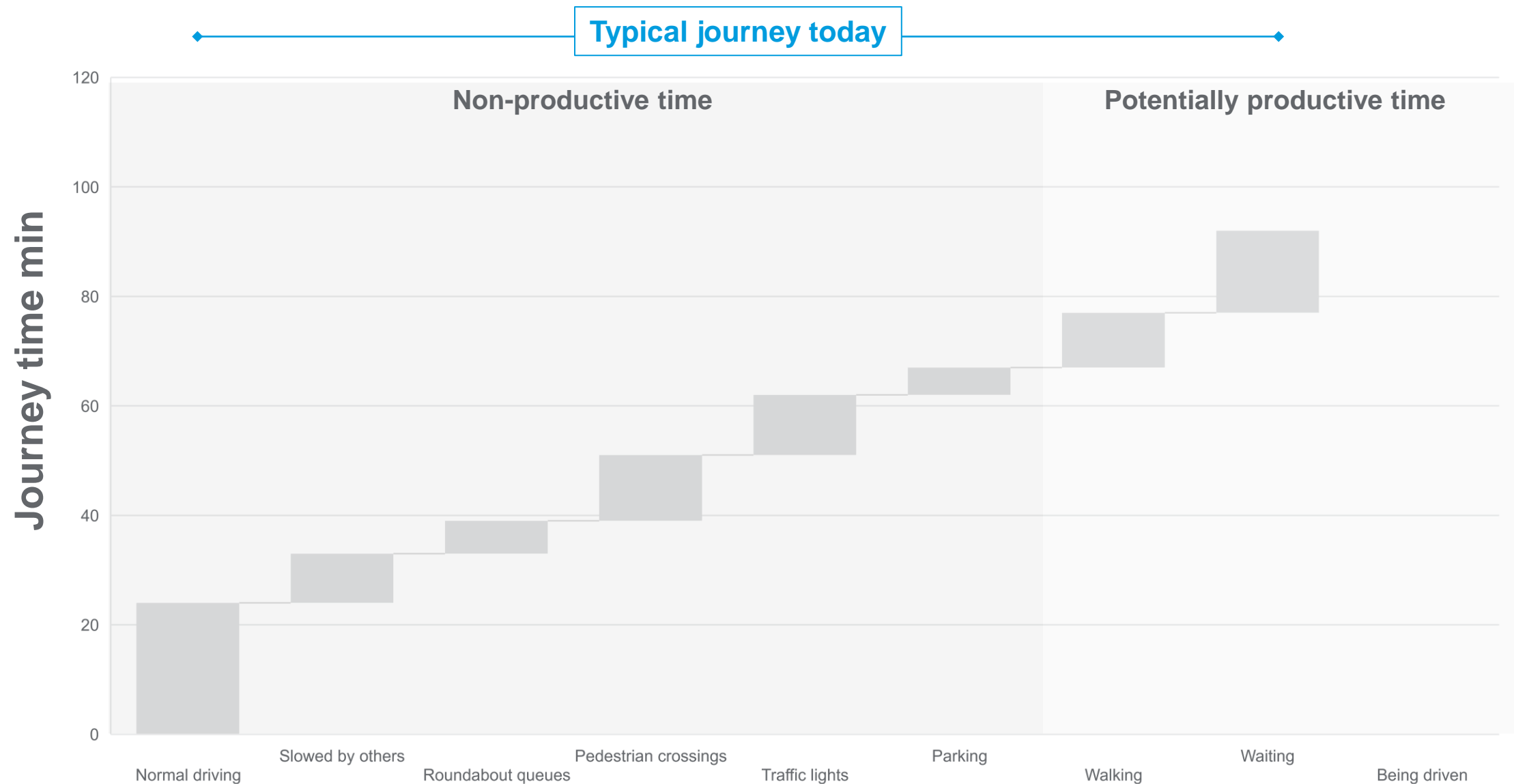
There is no requirement for traffic lights or stopping at intersections

Level 6 control massively improves city traffic capacity and demand response

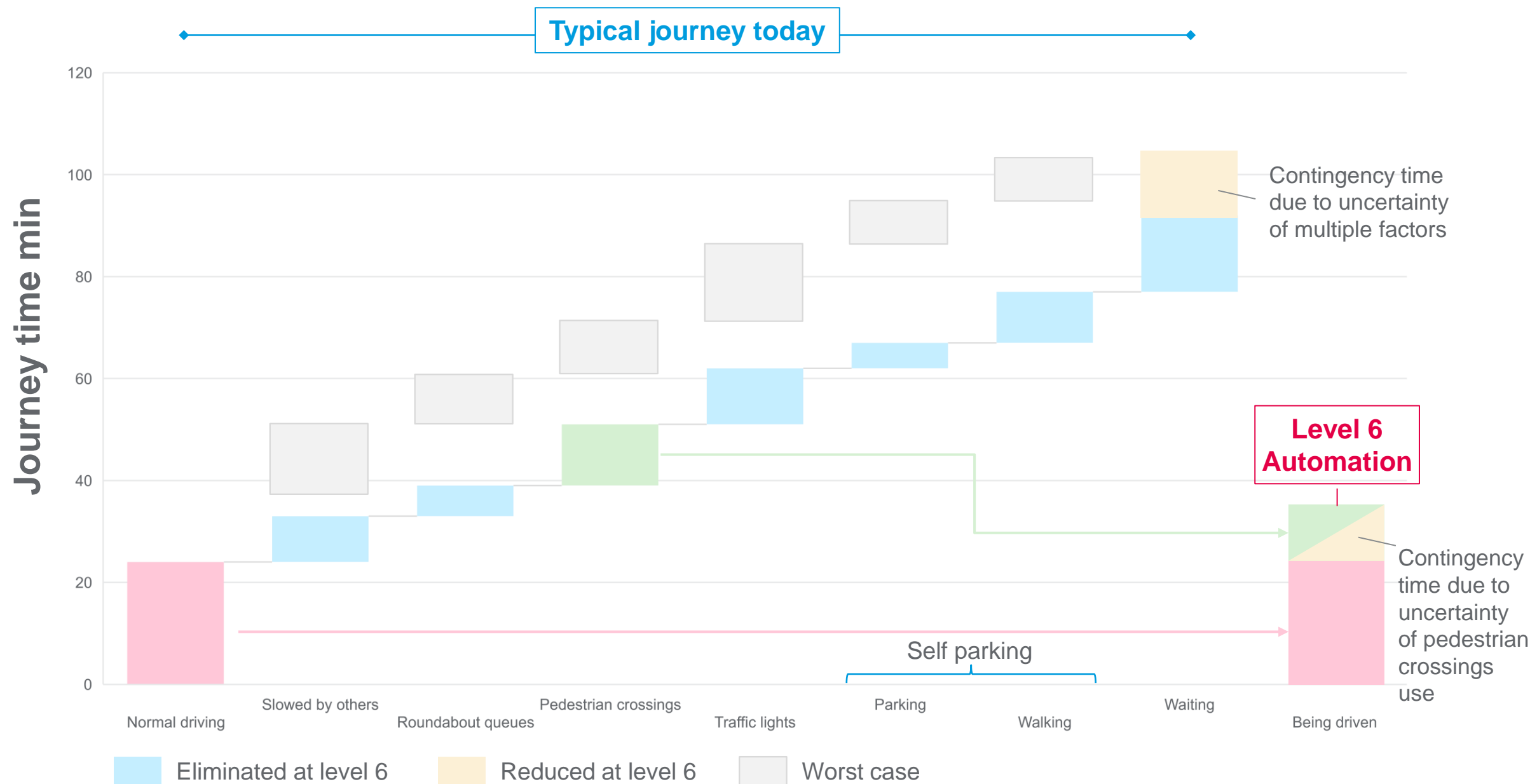
Large scale adoption of fleet vehicles further increases capacity



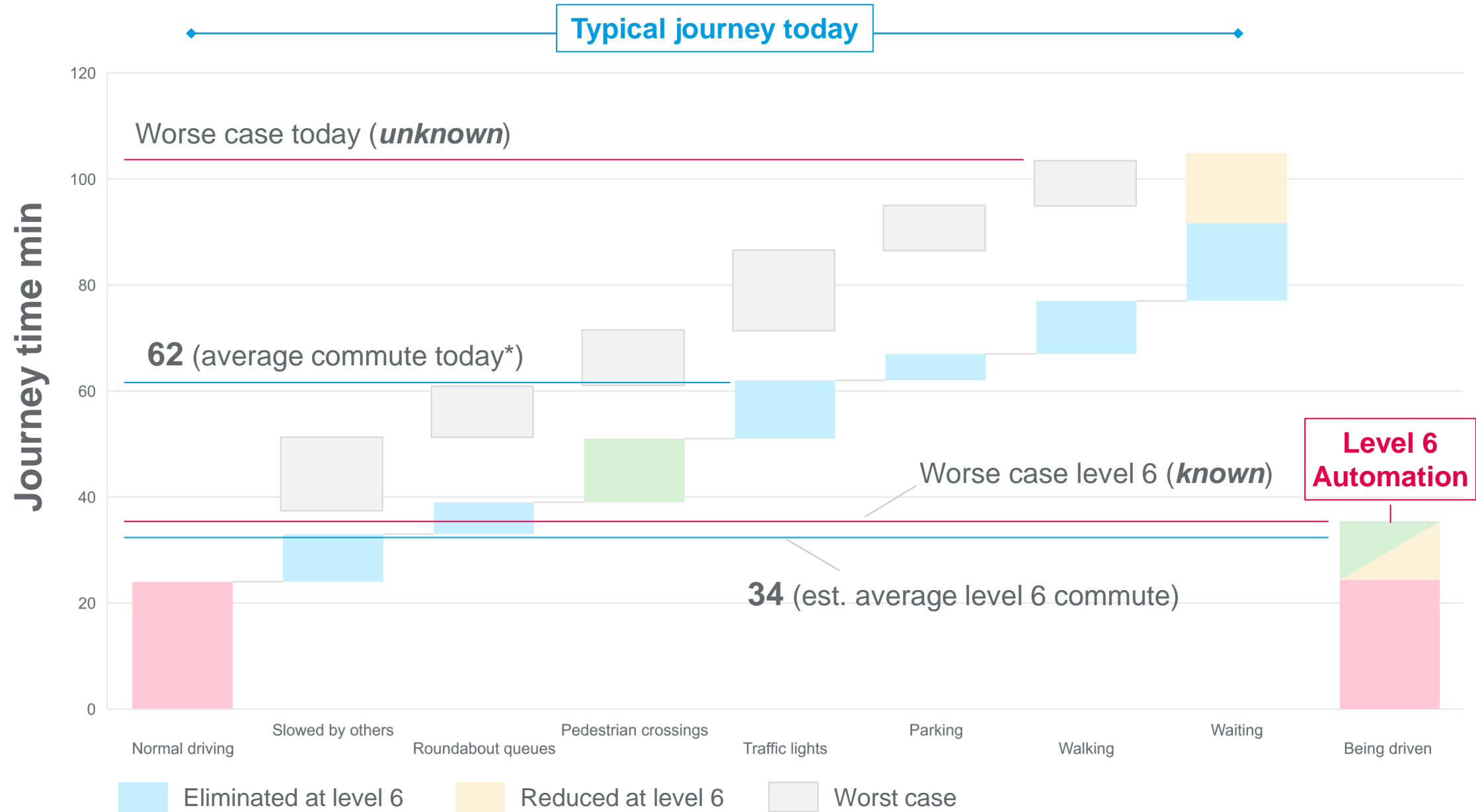
For many the overall journey is more than just driving



Level 6 significantly reduces overall time....



....and uncertainty

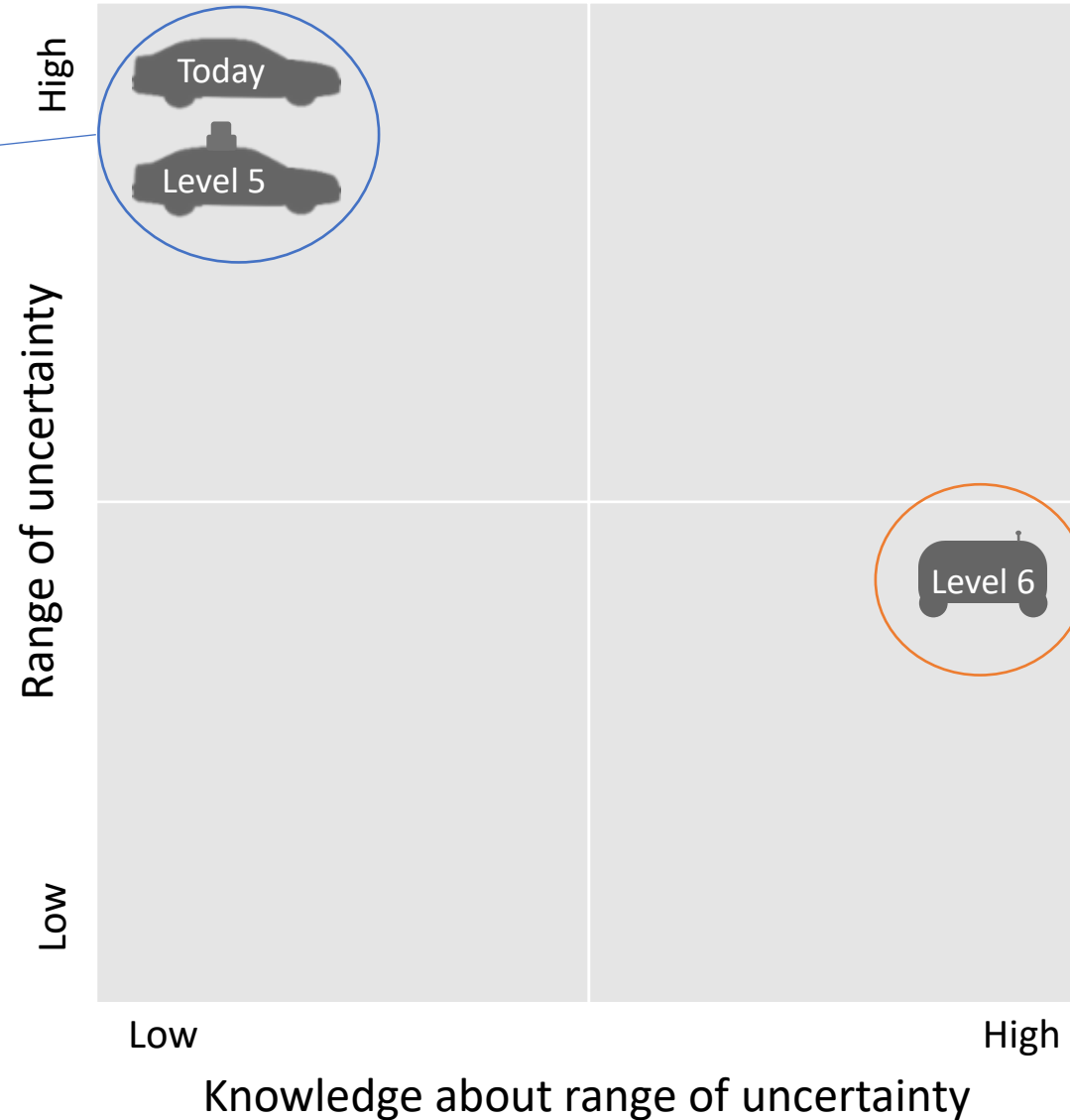


Journey knowledge allows better use of time

High range of uncertainty due to multiple mainly unpredictable potential delay points or events (poor driving, traffic lights, pedestrian crossing, traffic density, blockages etc.) combining for a potential very delayed journey.

For new journeys there is no understanding of how much delay there might be and therefore how much contingency time to plan for and when to start.

Net result **guessing** set off times and then either early and **wasted time** or **stressed** and **late**, rarely exactly right.



The best and worse case scenarios are known (barring any unplanned events) in advance with probable most likely based upon historical data. Pedestrian behaviour (use of road crossings) is responsible for the uncertainty, other factors are no longer present.

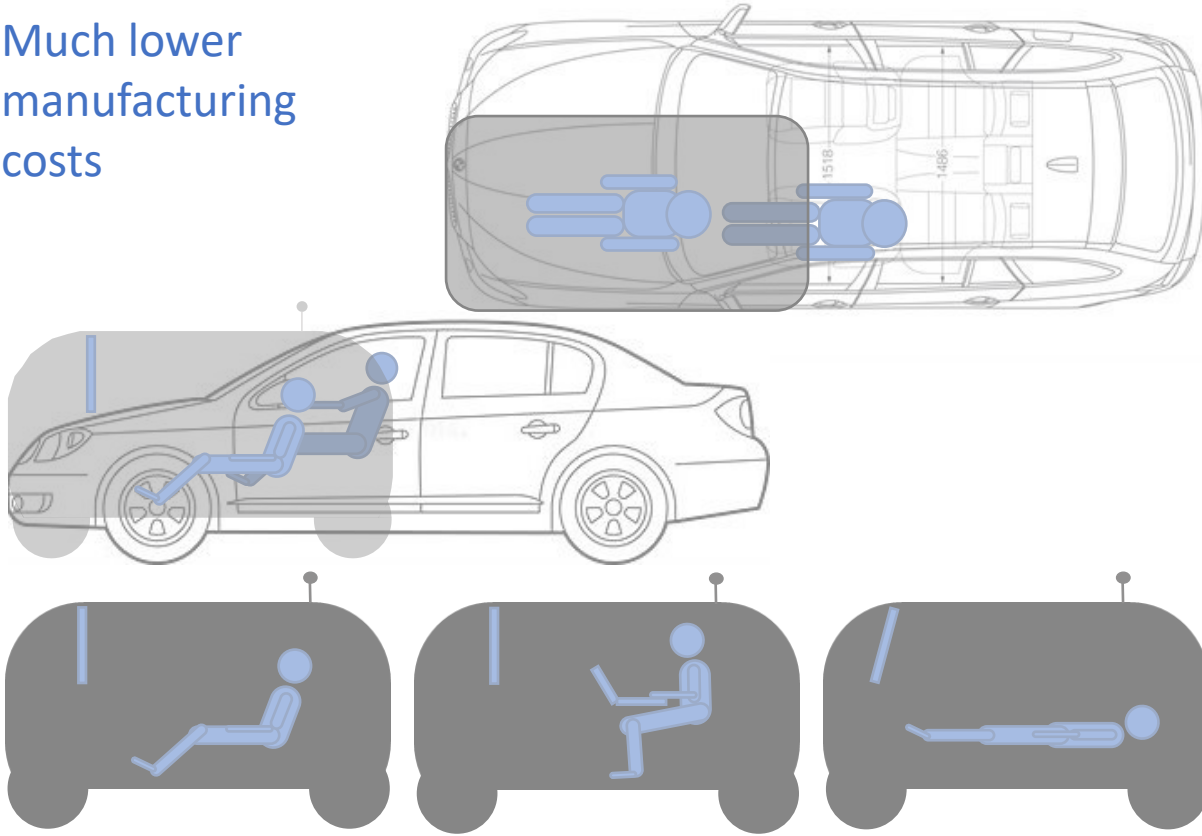
Net results, **knowing** when to leave to be **certain** of a specific arrival time.

Knowing when you are most likely to arrive updated in real time with the range of uncertainty clear

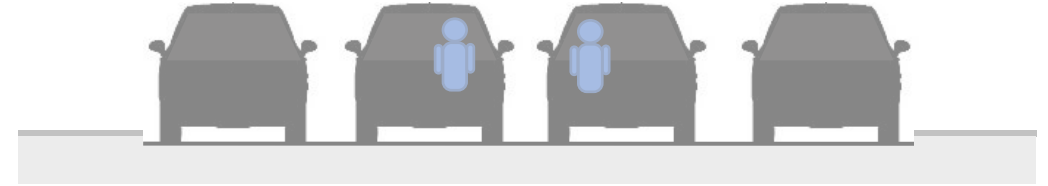
A fleet of mainly single occupancy vehicles further enhances road capacity

Single occupancy vehicle compared to a saloon car

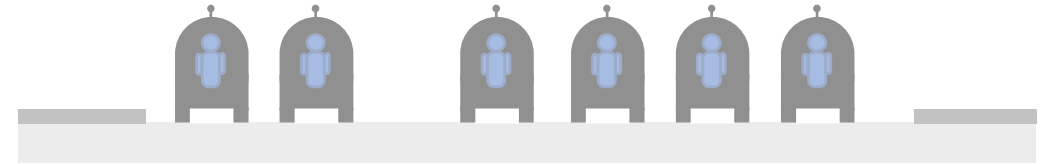
Much lower
manufacturing
costs



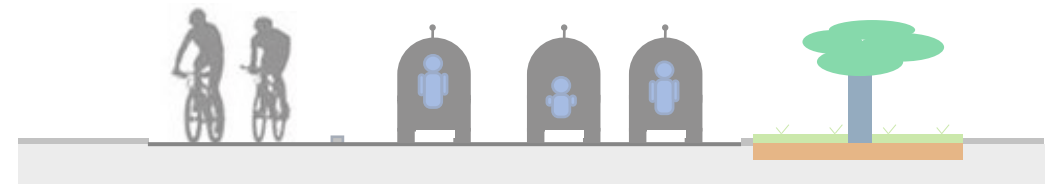
Today



Potential full use of road for vehicle traffic



Potential alternative road layout

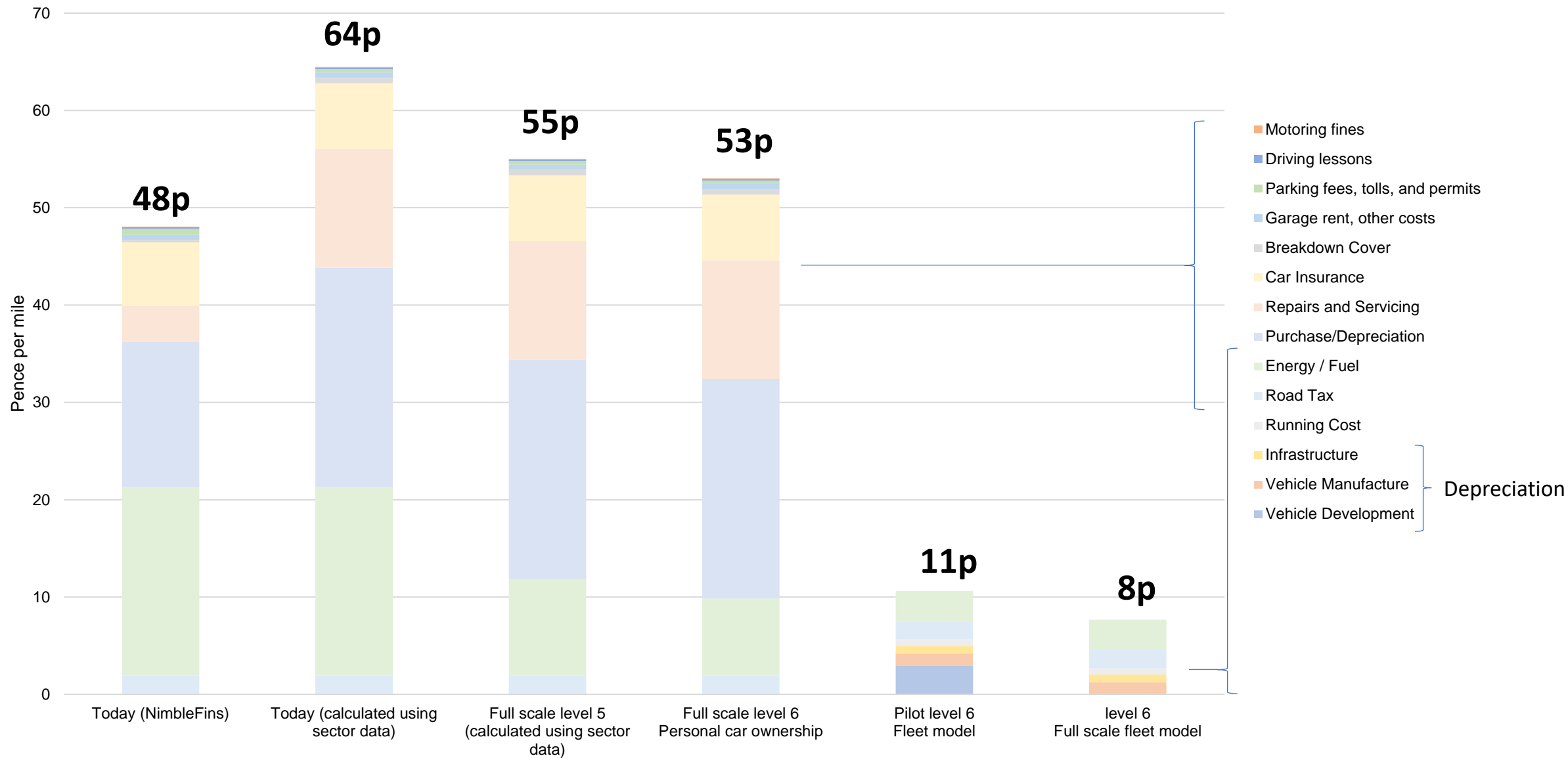


Designed with chassis and body life expectancy 50+ years (with maintenance).

This massively reduces the depreciation costs

Less mass leads to less energy consumption and smaller battery needs

Fleet motoring costs (pence per mile) 12-16% of today



Multiple personal and societal benefits

Society, environment and health

CO₂

Annual carbon emissions cut by up to 83 million tons
18% of total UK emissions



700 less road deaths
106,000 less road injuries



2,200 less premature PM2.5 deaths
10,600 less respiratory illnesses



Reduction in virus spread



999 response time halved
Reduction in vehicle enabled crime



Counter to social media
Facilitates more face to face meeting



Social levelling
Everyone uses the same high quality point to point travel

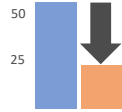


Rapid, gridlock free emergency egress

Personal



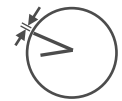
Motoring cost cut by 84-88%
(At the expense of ownership)



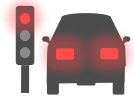
Average journey times cut by 65%



1 hour of extra usable time each day



Journey predictability to the minute consistently



Driving stress virtually eliminated

At the cost of....



Ability to drive in the city

Economy and business

UK
PLC

£9-12bn automotive trade deficit eliminated by 2032
(positive £30bn by 2040)



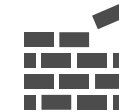
180 square miles of new land
(30% size of London)
Value > £100bn



Several new sectors



New flexibility and uses for road assets



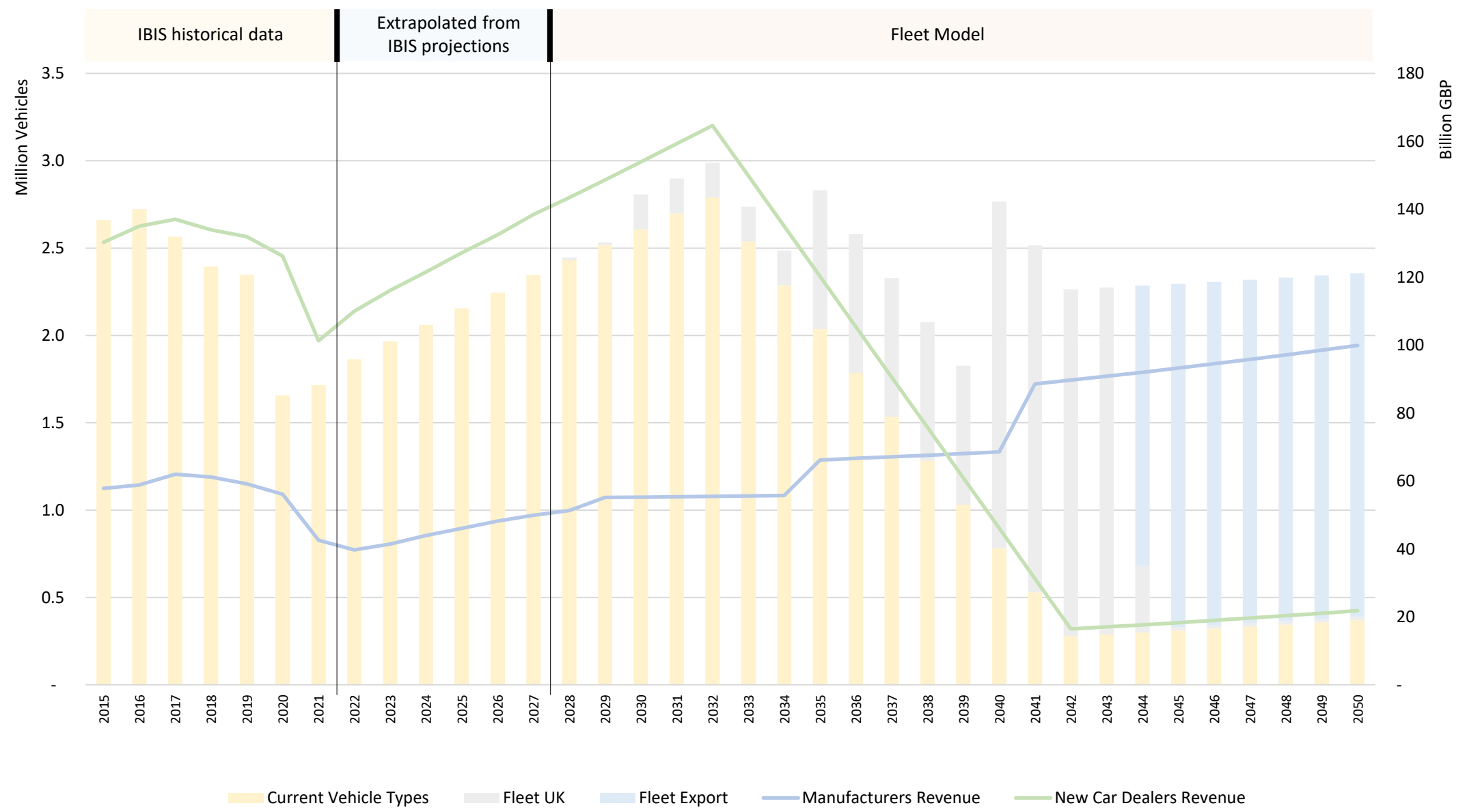
Stimulus to existing sectors



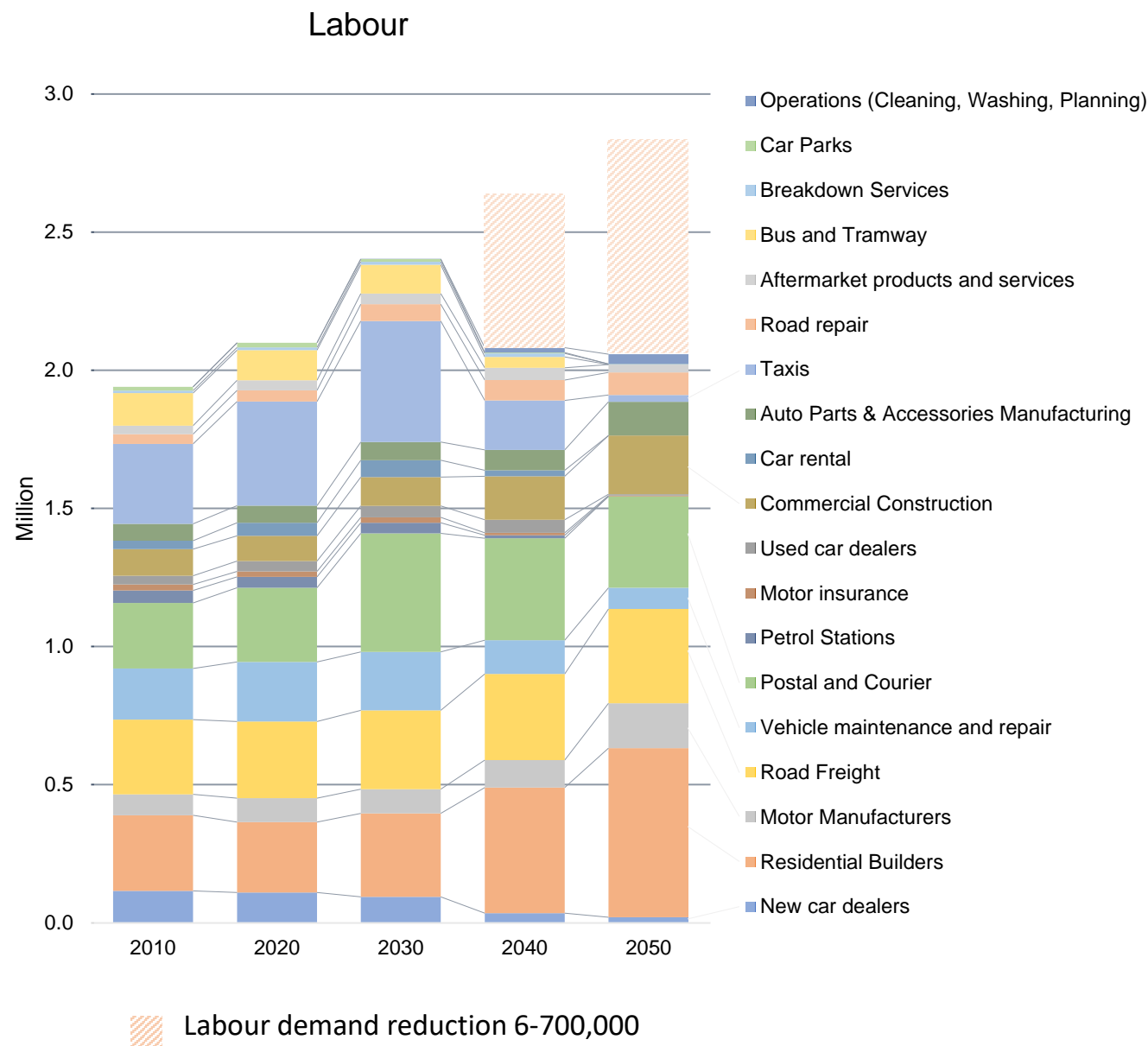
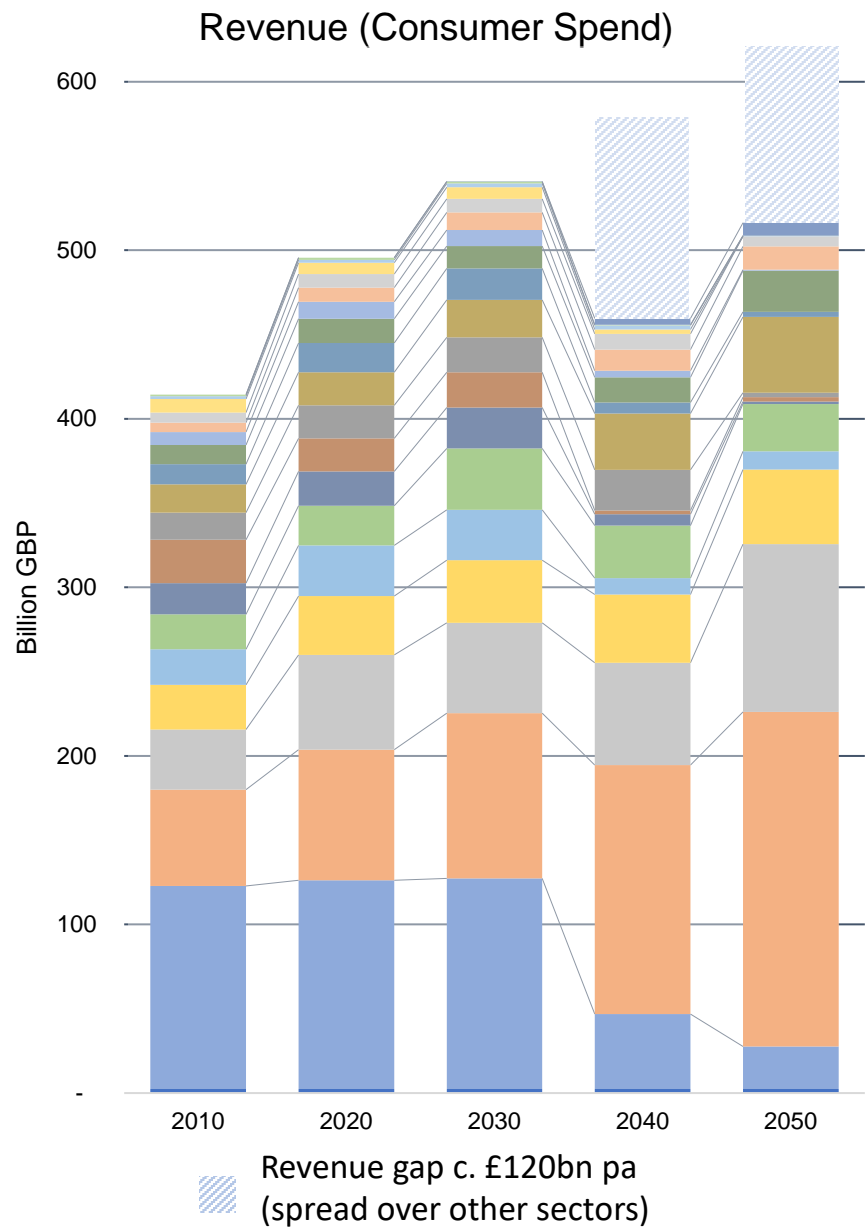
Value of travel time saved c. £100bn

Many of the benefits are disproportionately higher for the least advantaged

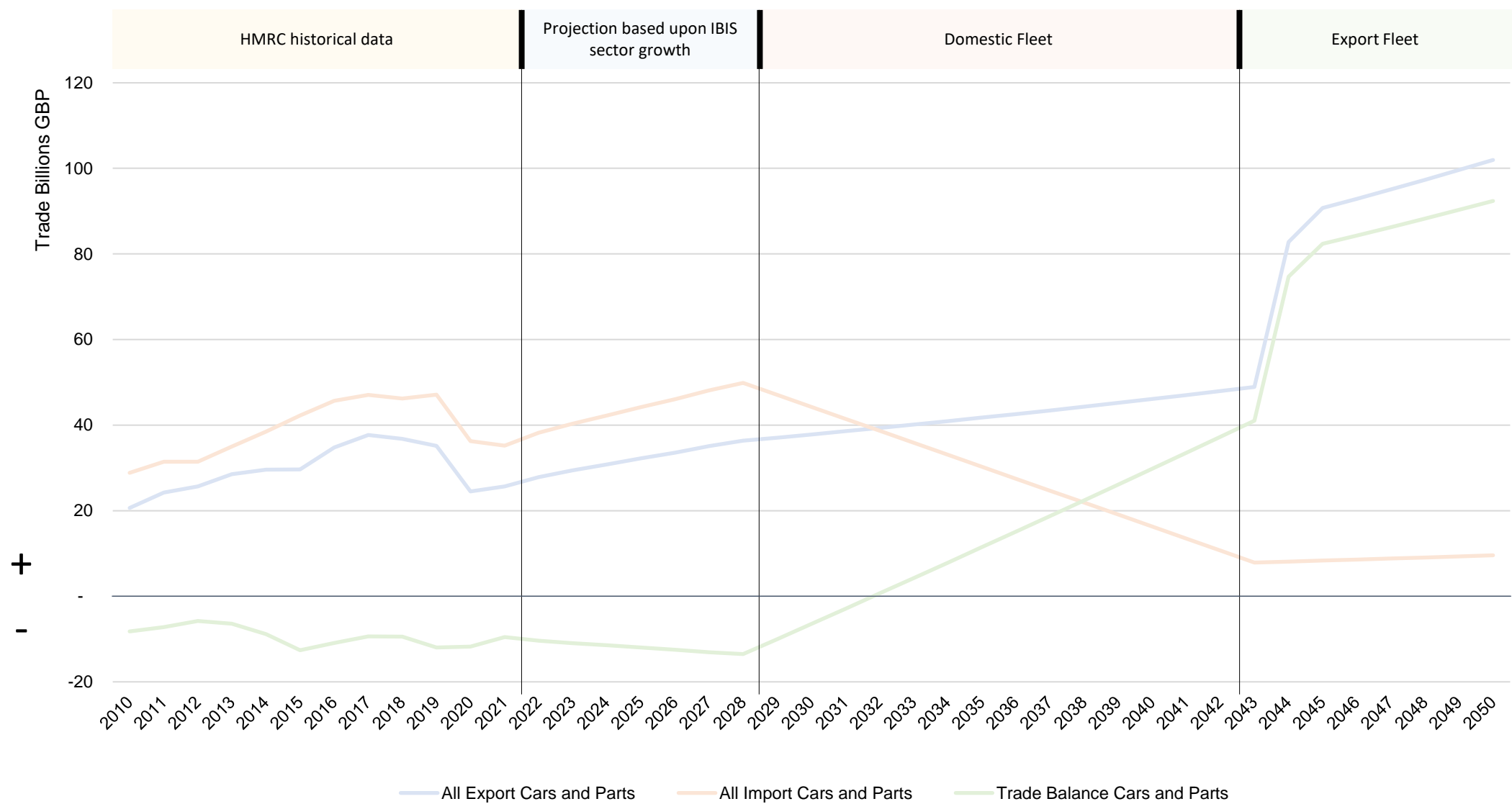
Annual vehicle volume and revenue



All impacted sectors revenue and labour changes



Trade Balance

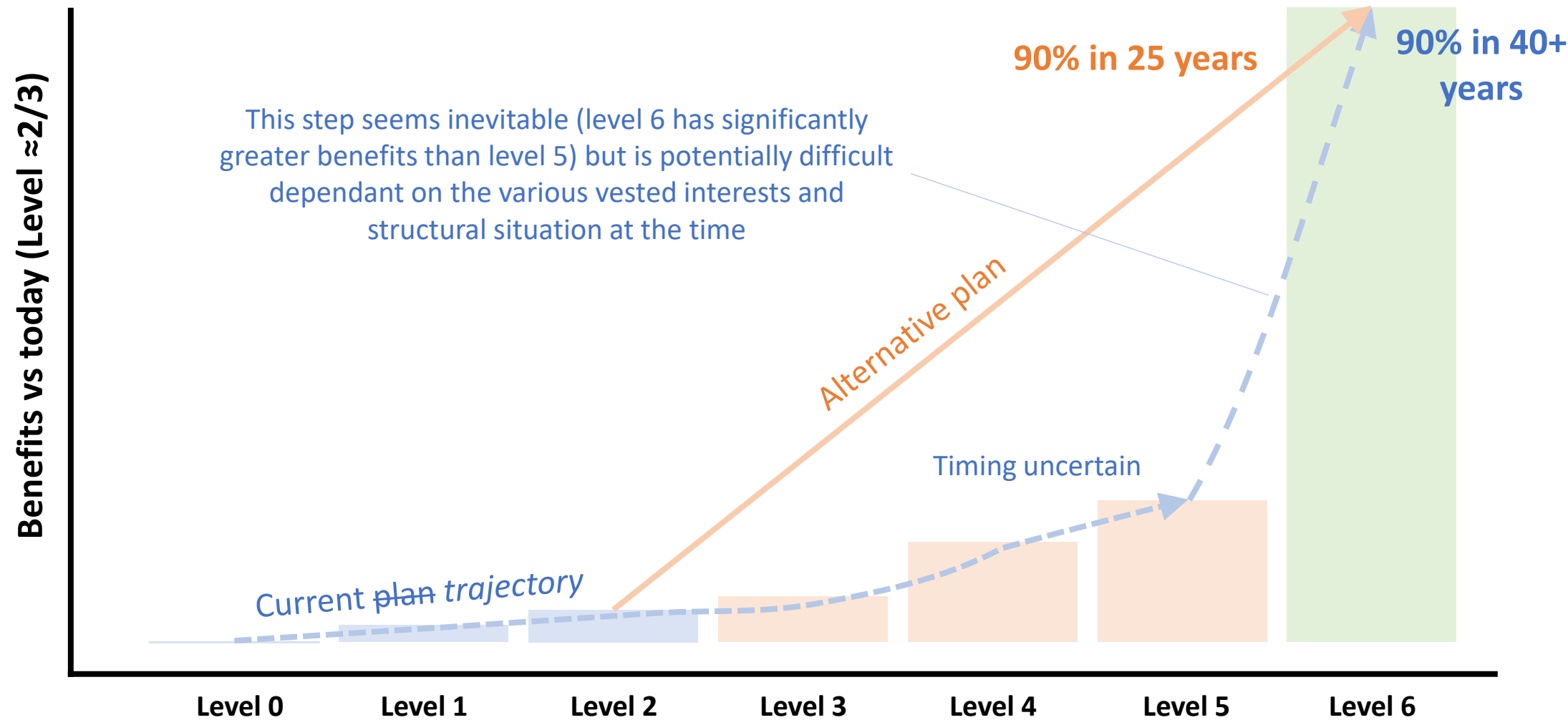


Can autonomous vehicles fix any of the transportation issues?

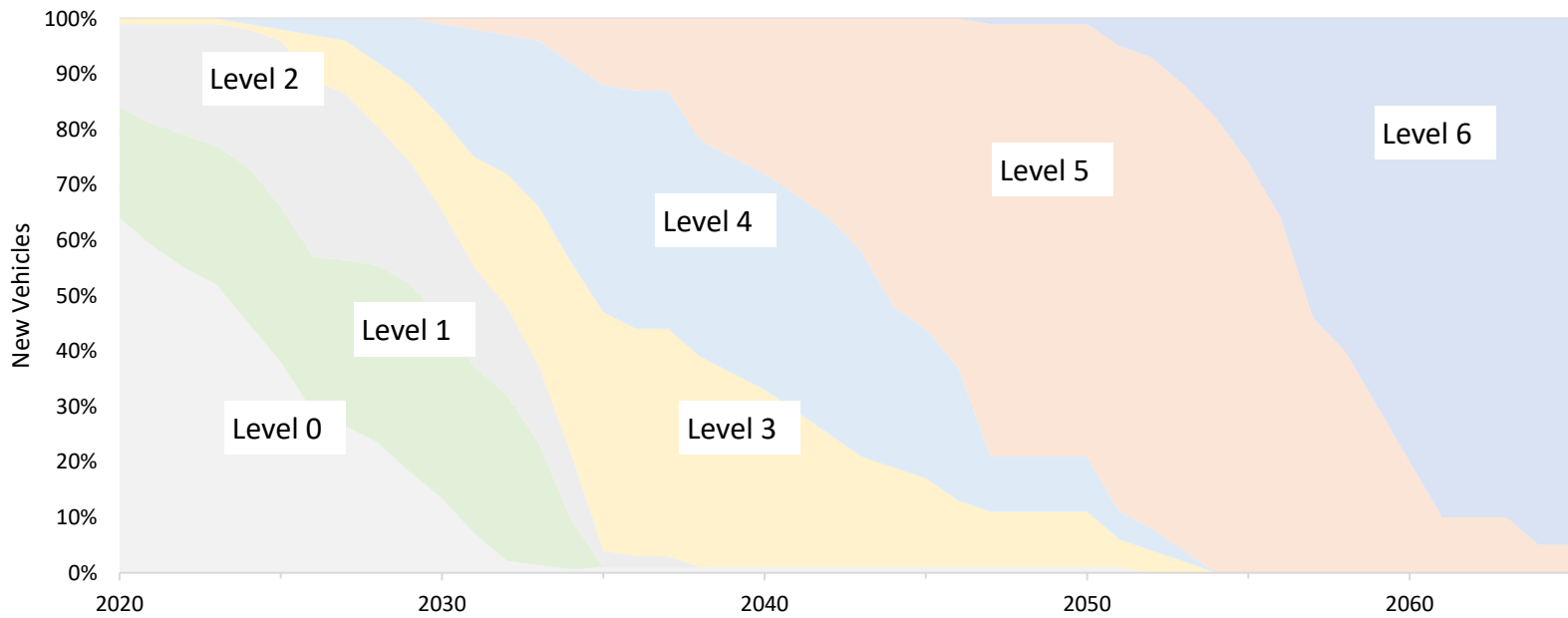
	Today	Level 5(e)	Level 6(e)	Plus Fleet
Ability to travel between locations	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
As quickly as possible	<input type="checkbox"/>	<input checked="" type="checkbox"/> Some improvements but not optimal	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
When we want to travel	<input type="checkbox"/>	<input type="checkbox"/> Little / no improvement (buses, peak times and parking)	<input checked="" type="checkbox"/> Congestion delays eliminated	<input checked="" type="checkbox"/>
As reliably as possible	<input type="checkbox"/>	<input type="checkbox"/> Little / no improvement	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
As safely as possible	<input type="checkbox"/>	<input checked="" type="checkbox"/> RTA's and particle emissions reduced	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
With least environmental impact	<input type="checkbox"/>	<input checked="" type="checkbox"/> Electrification reduces CO2e emissions but not optimal	<input checked="" type="checkbox"/> Vehicles still heavy	<input checked="" type="checkbox"/>
As pleurably as possible	<input type="checkbox"/>	<input type="checkbox"/> Some improvements but overall experience still poor for many	<input type="checkbox"/>	<input checked="" type="checkbox"/>
As cheaply as possible	<input type="checkbox"/>	<input type="checkbox"/> Likely to get more expensive	<input type="checkbox"/>	<input checked="" type="checkbox"/>

(e) electric / hydrogen

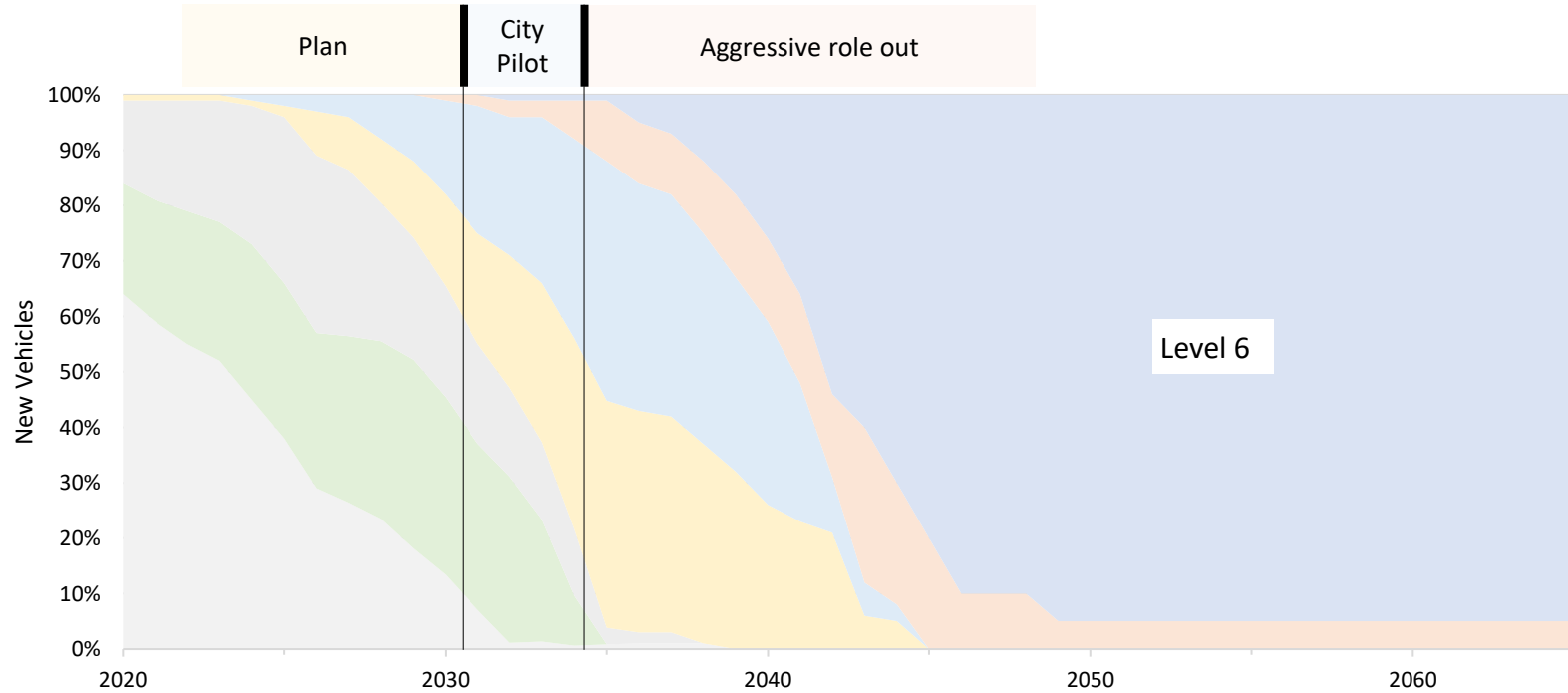
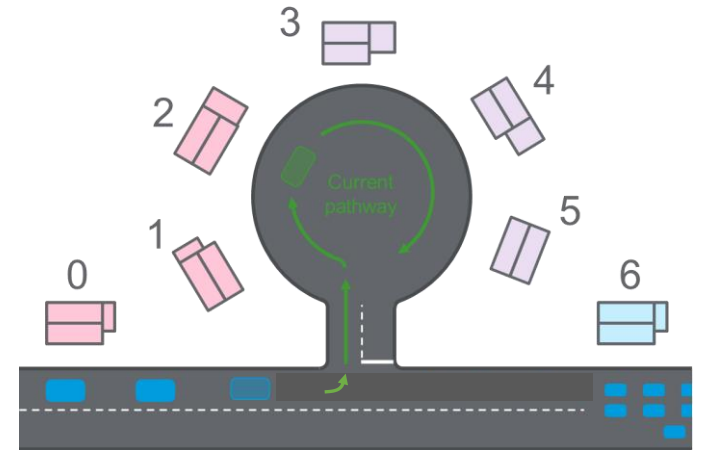
There is a faster alternative to the current autonomous vehicle pathway



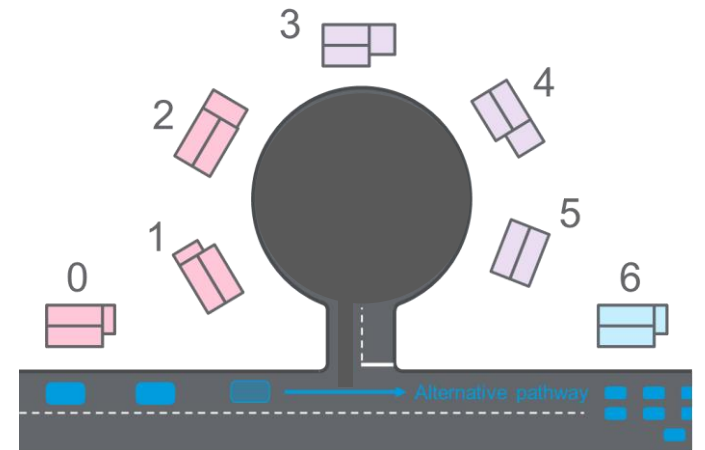
The barriers to level 6 are not technical



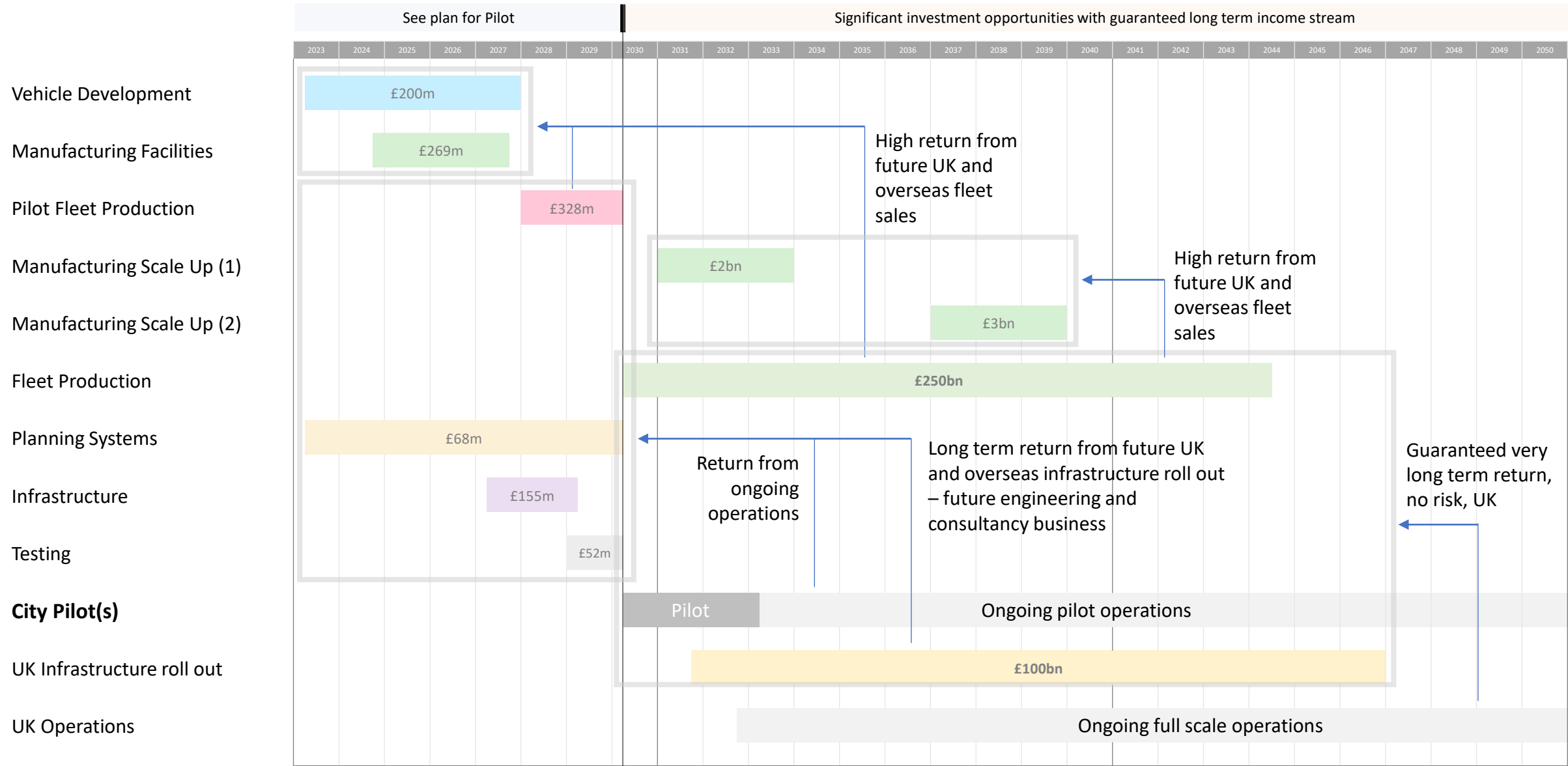
Current Timescales



Alternative Timescales



Investment Roadmap



← Investment payback

Potential investment models – railways in 19th century might be a good analogy?

	Amount (circa)	Timing	Payback (circa)	Model	Risk	Possible investors
Vehicle development and pilot manufacturing facilities	£500m	2023-8	3-5 yrs	Development is funded against guaranteed demand and an expectation of future sales upon successful pilot	Associated with technology failure to work	OEMs
Pilot fleet	£325m	2028	15-20 yrs	Third party purchases fleet and leases to operator		Lessor
Central vehicle control and planning systems	£70m	2023-9	3-5 yrs	Self funding upon award of pilot based on significant ongoing opportunity		Tech firms Could be included within infrastructure
Pilot Infrastructure and operation set up	£150m (depends on pilot(s) selected)	2028-9	15-20 yrs	Operator funds infrastructure changes on the basis of long term operating contract and significant advantages in infrastructure roll out		Engineering / construction Amec, Balfour Beatty, Babcock
Vehicle development and manufacturing facilities	£ several bn	2030+	3-5 yrs	Development is funded against future sales with clear demand growth	Low	OEMs
UK Fleet	Various sizes in blocks of several hundred million up to a total of £250bn	2030-45	10-15 yrs	Lessor funds purchase of fleet and leases them to operator who is responsible for maintaining their value	Extremely low	Pension Funds Lessors
UK Infrastructure and fleet operations	Various sizes in blocks of several hundred million up to a total of £100bn	2029-45	15-20 yrs	Operator funds asset changes and infrastructure build and leases vehicles	Extremely low	Pension Funds Operators

Report Structure

1. Overview Level 6

- Automated traffic flow
- Vehicle range
- Single occupancy vehicles
- Permanent road & land changes
- Dynamic street changes
- Flexible work space
- Local business
- Health, safety & security
- Borders

2. Benefits

Personal

- Time Saving
- Journey Time Variation
- Usable Time Gained
- Motoring Costs
- Driving Stress

Economy and Business

- Space Liberated
- Value of Travel Time Savings
- Stimulus to Existing Sector
- New Sectors
- New flexibility and uses for road assets
- Balance of Trade

Society, Environment and Health

- Emergency Egress
- Road Traffic Deaths and Injuries
- Emergency Response Time
- Social levelling
- Counter to social media?
- Pandemic Spread
- Crime Rate
- Pollution Deaths and Injuries
- Carbon Emissions

Benefits contribution

3. Infrastructure

Facilities

- Maintenance, repair and overhaul
- Liquids exchange
- Fill and drain water tanks
- Cleaning
- Catering
- Planning and control

EPC Plan blocks

- Front end engineering design
- Procure
- Manufacture
- Construction

Resources

- Capex
- Opex
- People
- Operational Structure

4. Vehicles

Model range

- Chassis sizes
- Volume assumptions
- Basic specifications
- Life assumptions
- Unit production costs
- Operating costs

Development Plan

- Plan blocks with main project phases
- Design
- Manufacture
- Supply chain setup

Resources

- Linked to the plan blocks
- Capex
- People

5. Sector Implications

- Automotive sector
- Employment
- Sector value observations
- Fleet production
- Vehicle sales
- Motor manufacturers
- Motoring sector changes
- Driving related sectors changes
- Other impacted sectors changes

References

Technical Report

Benefits

Methodology

- Data sources
- Uncertainty
- Breakdown of benefit contribution
- Travel habits today

Calculations

- Time Saving and Journey Time Variation
- Emergency Response Time
- Car ownership
- Road Traffic Accidents
- Carbon Emissions

Sectors

Automotive

- Motor Manufacturers
- New car dealers

- Used car dealers
- Aftermarket products and services
- Vehicle maintenance and repair
- Motor insurance
- Breakdown Services

Driving Related Sectors

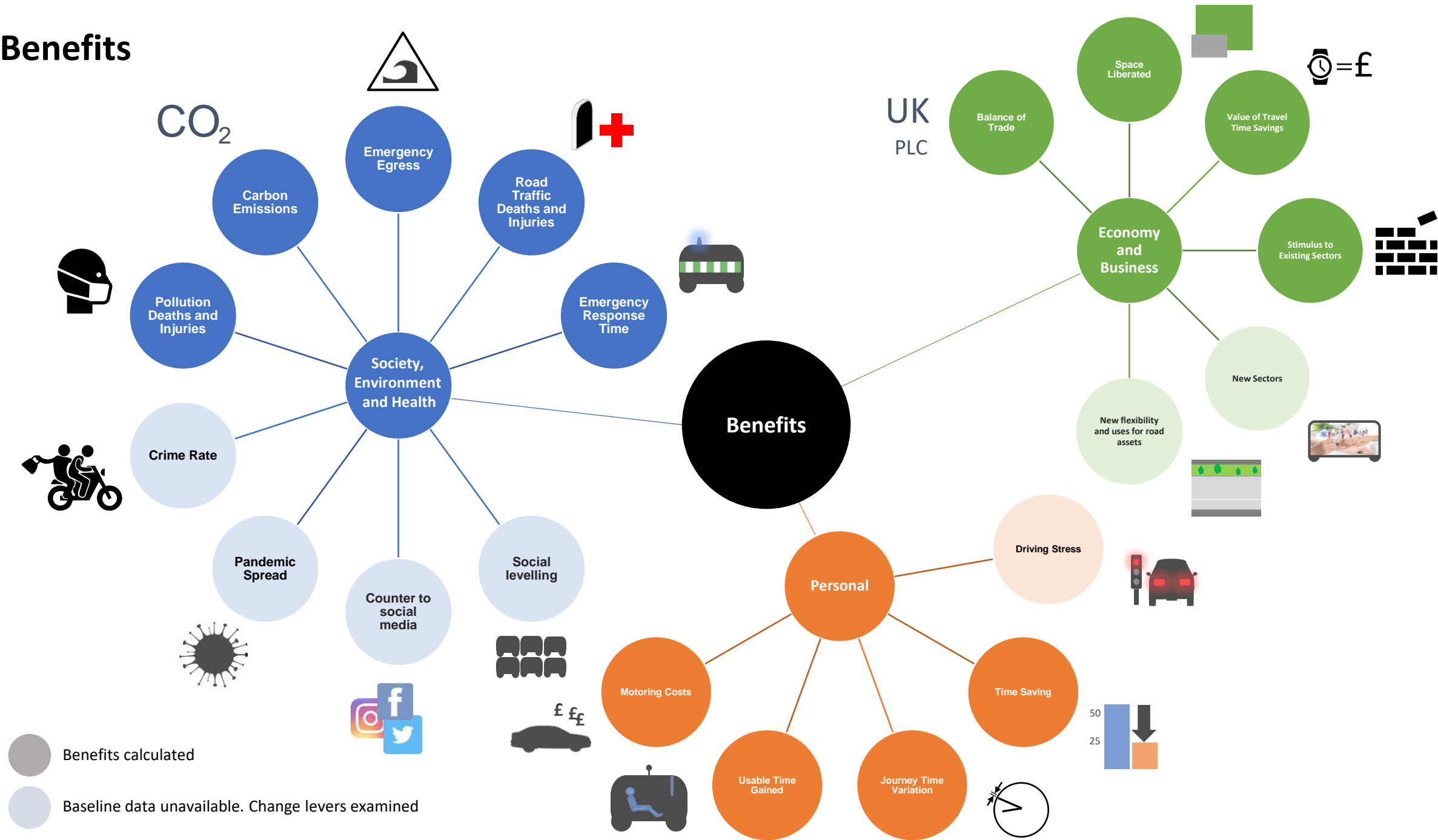
- Road Freight
- Postal and Courier
- Bus and Tramway
- Taxis

Other Impacted Sectors

- Car rental
- Petrol Stations
- Road repair
- Operations (Cleaning, Washing, Planning)
- Residential Builders
- Commercial Construction
- Car Parks

References

Benefits



Journey to work

In the first scenario a future journey to work is imagined...

My journey starts the evening before with a reminder appearing on my phone to confirm the regular booking I have set for pick up the next morning. Tomorrow there is a slight change to the normal routine because I need to be at work half an hour earlier. After adjusting the required arrival time in the transport app, I get informed of the new pick up time which I accept. I also confirm my usual car type, like most commuters I always get a single person standard fit (about half length and width of a standard saloon car) and my usual black coffee and a croissant. The great thing about the majority of people using single occupancy vehicles for the commute is the extra lane generated, three cars can easily fit where there used to be two.

I chose to use the on-demand fleet service rather than purchase or lease a vehicle due to the significant cost savings I get plus the lack of stress from not having to

The following morning I am reminded by text that my car will be arriving in 30 minutes with options to delay if required, I choose not to. Exactly 30 minutes later I leave the house as my car is pulling up. My phone's proximity to the car unlocks it and the door slides open. As I step inside what I see looks a bit like a first class plane seat mounted inside a smooth curved pod. The seat allows me to lie flat, sit-up or any position in between and has a wide retractable table and warm side storage for my breakfast.

My computer automatically syncs my default morning settings to a wrap around interior display, in my case this is News 24 on the left with sound at 20%, my emails, social media and journey map (with arrival time to the second) on the right and my currently opened files in the middle.

I settle down to prepare for the start of my working day which includes a 15 minute video conference (no napping this morning!). Exactly 23 minutes later I arrive and step out into the covered drop off bay at work and my day begins. I reflected as I walked to the meeting how the same journey 10 years would had taken 45 minutes to an hour and a half!

Journey to school

Since the age of 6, my children have been able to travel on driverless networks unattended by an adult – what a blessing in the mornings and for the ever increasing number of play dates, extra curricula activities and parties they seems to be going to!

The car must be confirmed and booked with a valid account number and will only drop off, i.e. the doors open, in proximity of a designated adult or safe space such as the entrance to the school.

The early development of autonomous vehicles was focussed around a shared driving space, individual control model which was inherently flawed. The human element was essentially unpredictable and incapable of consistently driving with the precision and coordination required to make the system properly efficient. The real benefits from this technology were realised when we removed individual human driving control from the system. However much we tried to develop more sophisticated sensors and control algorithms the human factor was always going to be the weak link and a source of avoidable legal controversy.

During the introduction of the system, there was much debate around safety, security and privacy and as the law currently stands real time remote monitoring of the interior is optional for those booking the journey for children above 10, but compulsory below that age. In the unlikely event that the child has some sort of incident in the car I am responsible for notifying the emergency services who will route it rapidly to the nearest hospital if needed.

Similarly emergency services obviously have route priority over regular traffic and higher speed limits which means that response times to and from non transport related incidents is a fraction of what it was in the past. The net result has been countless lives saved and health and financial impacts mitigated where rapid response is critical to the outcome.

Going shopping

Having decided to look for a tent to go camping in the summer I book a four seater with some luggage space.

Once in the car, I reflect that aside from the obvious journey time benefits we all get, one of the biggest noticeable changes is the amount of open space suddenly freed up - many roads have been designated closed off to through traffic outside of peak time which suddenly opens up the space once devoted to parked cars.

Many pavements have effectively been removed and the whole “road” now useable for pedestrians and it would seem impromptu kids tennis courts if the view from my window was anything to go by.

Similarly huge areas of land once used for commercial parking have been converted to other purposes, which has proved a boon for new house building and commercial expansion. The net gain in property value is estimated to be an eye watering amount.

Some existing parking facilities have been converted to charge centres where some of the vehicle fleet is parked during down time - many more automated cars can be fitted into the same space because they can be closely stacked with the front section of each queue always fully charged for use. Overall battery demand is controlled by the central vehicle control.

The new shopping centre where we are looking for the tent is located in what was formally a supermarket car park.

Having found the right camping equipment, we leave the store, pick up a car from the rank and we are on our way home again. Great not to have to walk to find the car or push a trolley in the rain.

I glance at the traffic map during the journey back and zoom out to get a bigger perspective. The concept of fixed lanes has disappeared and rather like bridges, traffic lanes can be diverted to flow in either direction depending on demand. I can see cars flowing across junctions from all directions without stopping, something that is only possible with machine control of all vehicles.