ZENZIC

SELF-DRIVING REVOLUTION

UK Connected and Automated Mobility Roadmap to 2030

United Kingdom

Foreword

On behalf of all at Zenzic, I welcome you to to this first release of the UK Connected and Automated Mobility Roadmap to 2030 – a tool for decision makers, policy makers and investors in mobility.

We are in a period of dramatic social and economic change. Transport is fundamental to this change as it delivers 'mobility'; by which we mean the effective and efficient movement of people and goods. Simply put, mobility impacts every single one of us.

Mobility itself will soon be transformed by the new technologies associated with connectivity and automation, including 'self-driving'. Connectivity enables the flow refinement of data, leading to better information and smoother journeys for the travelling public. At the same time, automation yields increased safety and new ways of helping people become more productive.

The exploitation of these technologies through innovative operating and business models will bring economic benefits in terms of local and national efficiencies, as well as exports of UK skills and products. Hence, there is a strong economic argument for investing in connected and automated mobility (CAM). But more than this, CAM addresses the urgency for greater inclusion in society.

We each need to play to our strengths and join with others where they have capabilities that complement ours. Collaboration is critical.

The challenge we face in the UK is to safely deliver these benefits rapidly and competitively. If we break down the challenge and work sequentially, we will never succeed. We will increasingly require imported skills, products and services to fulfil our mobility needs and remain only moderately competitive on the world stage. However, what we have learnt on our journey thus far is that the UK is not only strong, but also globally respected in a number of key areas, such as cyber security, safety, legislation, standards and artificial intelligence.

Fortunately, the leading countries in mobility see this as a global challenge – a local solution will be neither successful nor competitive.

The only way to make progress at pace is for the whole sector to align on collective goals. Over 250 people from more than 150 organisations have worked with Zenzic to do exactly that. Together, we have built upon more than a dozen well-respected thematic roadmaps to deliver what is intended as a tool for policy makers and investors to assist in their decision making on the path to the mobile future.

For this tool to be effective, it had to consider implications across a broad range of perspectives. These include people, infrastructure, vehicles and, of course, the transport services from which society draws countless benefits. The tool incorporates not only outputs or Milestones, but also the interdependencies between them. Additionally, we've worked to ensure the tool takes into account interventions that will overcome obstacles, accelerate programmes and enable government, industry and academia to deliver real, tangible value as quickly and safely as possible.

Zenzic was created to lead the move to a safer, more inclusive and productive mobile future. This roadmap supports that goal by taking the broadest view of where the UK needs to be by 2030 to maintain its world-leading position. Focusing on key areas of UK capability for the future of connected and automated mobility, government and industry have committed an initial £200 million through Zenzic to develop a coordinated national platform of CAM testing infrastructure – known as Testbed UK. These facilities are at the heart of achieving the 2030 Vision by unlocking testing, development and validation of safe and secure products and services.

I am immensely proud of the substantial and highly collaborative effort by many individuals and organisations that has resulted in this, the first release of the UK Connected and Automated Mobility Roadmap to 2030.

There is a wealth of knowledge and insight in this roadmap. But more than that, I genuinely believe this tool will fulfil its useful purpose. The UK Connected and Automated Mobility Roadmap to 2030 will enable all organisations involved in CAM to maximise the return on their investments in time and money; to streamline the creation of targeted strategies and plans; and to deliver significant social and economic benefits for the UK by 2030.

I hope you find this useful, I hope you enjoy reading it and I welcome all feedback. No roadmap should be static, and this will be an evolving tool as we progress towards and beyond 2030.

Daniel Ruiz
CEO, Zenzic
September 2019

Contents

06 INTRODUCTION

08 CONTRIBUTIONS

10 THE 2030 VISION

12 EXTERNAL FACTORS AND INFLUENCES

14 CREATION AND STAKEHOLDER ENGAGEMENT

16 THE UK CONNECTED AND AUTOMATED MOBILITY ROADMAP TO 2030

18 WHAT DOES THE ROADMAP TELL ME?

19 ROADMAP STRUCTURE

20 Society and People

20 Vehicle Approvals

20 Licencing and Use

21 Legislation and Insurance

22 Public Desirability

22 Investment

22 Skills

24 Vehicles

24 Automated Driving Systems

25 Connectivity

26 Ergonomics and Design

26 Sensors

28 Infrastructure

28 Communications

29 Digital

30 Roads

30 Intelligent Network Management

31 Test and Development

32 Services

32 Personal Mobility

32 Freight and Logistics

34 Inclusive Transport

36 GOLDEN THREADS

36 What is a Golden Thread?

36 How can I use a Golden Thread?

PAGE **38** **GOLDEN THREAD 01: Legislation and Regulation**

38 Introduction

38 Contributing themes

40 Major deliverables

40 Deep dive: *Harmonised vehicle approval scheme established (LR57)*

42 Deep dive: *Highly-automated vehicles are able to be on public roads legally (LR30)*

44 Key enablers

44 Deep dive: *Digitisation of rules of the road (The Highway Code) (LR71)*

46 Deep dive: *Baseline policy and standards established (LR05)*

48 Critical waypoints

48 Deep dive: *Trials of CAM in multiple environments and differing economic models (LR37)*

51 Summary

PAGE **52** **GOLDEN THREAD 02: Safety**

52 Introduction

52 Contributing themes

54 Major deliverables

56 Deep dive: *Legislation for clearing road space for automated vehicles (HW17)*

58 Deep dive: *Validation process highly automated (SN15)*

59 Key enablers

59 Deep dive: *Law Commission final report (LR10)*

62 Critical waypoints

62 Deep dive: *Development of safety protocols for CAM services (LR19)*

63 Summary

PAGE **64** **GOLDEN THREAD 03: CAM Services**

64 Introduction
64 Contributing themes
66 Major deliverables
66 Deep dive: *Measurable growth of CAM services (MS18)*
68 Key enablers
68 Deep dive: *Launch public education programme (PA54)*
69 Summary

PAGE **70** **GOLDEN THREAD 04: Public Acceptability**

70 Introduction
70 Contributing themes
72 Major deliverables
72 Deep dive: *Evidence of safety record begins to show (PA55)*
74 Deep dive: *More self-driving vehicles than traditional vehicles registered per year (PA34)*
76 Critical waypoints
74 Deep dive: *CAM service licencing framework established (LR34)*
79 Summary

PAGE **80** **GOLDEN THREAD 05: Infrastructure**

80 Introduction
80 Contributing themes
82 Major deliverables
82 Deep dive: *New city planning methods enable more efficient CAM travel (IM18)*
84 Deep dive: *Safety messages protected by resilience (CM20)*
85 Key enablers
86 Deep dive: *Blueprint agreed for a CAM-ready town or city (HW01)*
88 Deep dive: *Communications definitions in highways standards (CM05)*
89 Critical waypoints
90 Deep dive: *Coverage plan in place (CM09)*
91 Summary

PAGE **92** **GOLDEN THREAD 06: Cyber Resilience**

92 Introduction
92 Contributing themes
94 Major deliverables
94 Deep dive: *Cyber security becomes a core part of vehicle approval (LR82)*
95 Key enablers
96 Deep dive: *Delivery of a cyber security centre of excellence (TD08)*
98 Deep dive: *UNECE cyber security regulations development (LR23)*
100 Critical waypoints
100 Deep dive: *UK safety case adoption feeds into global standards (LR80)*
101 Summary

102 WHAT'S NEXT FOR THE ROADMAP?
103 THE CHARTERED INSTITUTION OF HIGHWAYS AND TRANSPORTATION (CIHT) – REFLECTION
104 REFERENCES
106 DISCLAIMER

Introduction

It is clear, even from a glance at newspaper headlines and communications from those working in this space, that the potential benefits of CAM are staggering. Even if we only focus on two key statistics there is a compelling argument for investing time, energy and resources into supporting the growth of CAM.

Over 85% of road incidents are attributable to human error.

(DfT, 2018a)

By replacing human drivers with automation, we will harness the ability to vastly reduce the number of serious incidents. Enhancing connectivity between vehicles, drivers and cities will enable us to deliver road networks with increased efficiency. In addition, CAM offers improved access to transport across society, and will increase productivity by giving up to 225 hours back to drivers per year (DfT, 2018b).

CAM has the potential to save up to 225 hours a year per driver.

(DfT, 2018b)

The amount of effort being spent building the technology and defining the business models around CAM is monumental. Initial research showed us that over 30 roadmaps and other forward-looking studies have been published in the last three years.

Each organisation working in this space has been defining their own objectives and path to the future. This is entirely understandable, but these visions of the future and routes forward lack alignment – they are not pushing towards the same goal. There is a collective benefit in striving towards a single vision – combined with a common understanding of how we get there. This is the premise of the UK Connected and Automated Mobility Roadmap to 2030.

This tool is designed to be a neutral, independent, collaboratively-built and jointly-owned vision of the future we all want to see. This vision is reinforced by industry experts' articulation of the path to 2030, cohesively structured to account for the interdependencies that will bring together the future of CAM.

The UK Connected and Automated Mobility Roadmap to 2030 provides a single agreed view of the future. It is not intended to replace or replicate any existing technology or product roadmaps that already exist. It does, however, align details from supporting roadmaps, while providing structure and an umbrella for future updates.

This report seeks to provide insight into the creation of the roadmap and a high-level summary of the roadmap content, primarily through the lens of Golden Threads and the 2030 vision. I highly recommend reading the report in conjunction with the interactive online version available at **zenzic.io/roadmap**.

Mark Cracknell
Head of Technology, Zenzic

21 million

Bringing CAM forward by 49 years from 2079 to 2030, will save up to 21m person years in lost productivity

Contributions

The journey to deliver the UK Connected and Automated Mobility Roadmap to 2030, from its initial concept through to execution, has been an interesting and challenging exercise. Its creation was a truly cross-sector and cross-industry collaborative effort. Thank you to the many organisations and individuals who contributed throughout the various stages of the process.

Thank you to the steering group. Your input was vital when drawing together the final structure and form of the roadmap, whilst critically assessing the benefits and value to ensure it is truly the tool for decision-makers we set out to produce.

Opposite is a list of some of the companies that contributed to the research and content. Our thanks go out to all who have been a part of the roadmap's progress thus far.

600

The development process of the roadmap took over 600 person days

The curation of this roadmap, including the feedback and inputs, would not have been possible without the 250 individuals and over 150 companies that contributed.

5G Innovation Centre
Autonomous Drivers Alliance (ADA)
Addison Lee
Advanced Propulsion Centre UK
AESIN
Age UK
Aimsun
Altran
Angoka
AppyParking
Arrival
Arup
Association of British Insurers
Atkins
Atos
Aurrigo
Automotive Council UK
AVL
AXA
Bosch
Brake
Bruntingthorpe
BSI
Buckingham
Burges Salmon
BVRLA
Caroline Coates – independent Consultant and Lawyer
Chartered Institution of Highways and Transportation
Chordant
Clearview Intelligence
Confederation of Passenger Transport UK (CPT)
Connected Places Catapult
Costain
Coventry University
CyNam (Cyber Cheltenham)
DAC Beachcroft
Department for Transport
DG Cities
DVSA
Eatron Technologies
EDAG UK
Elgin
ERTRAC
FiveAI
Ford Mobility
Franklin Energy
Frazer-Nash Consultancy
Freight Transport Association
GoMedia
GSMA
Highways England
HORIBA MIRA
IDIADA
Immense
Innovate UK
Inrix
Institute for Digital Engineering
IRM Security
KPMG
Leeds University
Loughborough University
Met Office
Michigan Economic Development Corporation
Millbrook
National Cyber Security Centre
National Physical Laboratory (NPL)
Nominet
Nova Modus
Ofcom
OmniCAV
Ordnance Survey
Oxbotica
Oxfordshire County Council
Park IT Solutions Ltd
QinetiQ
RAC Foundation
Race
Reed Mobility
Ricardo
Sciencewise
Siemens
Smart Cambridge
Spectris
Synaptiv
Synthesys
Telent
Thales
Thatcham Research
Travel AI
TRL
UCL Centre for Transport Studies (UCL CTS)
University of Southampton – Transportation Research Group
Valerann
Valuechain
VCA
Visteon
Vivacity Labs
Warwick Manufacturing Group
Waze
Wireless Infrastructure Group
WSP
Xain

The 2030 Vision

'By 2030, the UK is benefitting from proven connected and automated mobility, with an increasingly safe and secure road network, improved productivity and greater access to transport for all. Next-generation services and technology are designed and developed in the UK, powered by high value skills and a strong supply chain, and driven by public demand, we are a world leader.'

In order to work together on the journey towards a safe and sustainable future, the destination must first be defined. It is important to set a common goal, a vision of the future, towards which all can align and collaborate. The 2030 Vision, which frames the entire roadmap, sets out an aspiration of where the ecosystem aims to be and the benefits to be realised by 2030:

The 2030 Vision itself is a product of two core elements; societal benefits and industrial productivity. For the societal benefits the Department for Transport's (DfT) 'Future of Mobility: Urban Strategy' provides nine core principles from which the foundations of the 2030 Vision were built (DfT, 2019a). These are distilled through the Centre for Connected and Autonomous Vehicles' (CCAV) three core priorities of safety and security, productivity and access to transport. The industrial productivity element of the 2030 Vision recognises the need to maintain the UK's position as a world leader in CAM innovation, and develop desirable products and services.

Ten Core Deliverables

01

UK legal and regulatory framework is world-class and mature, promoting and enabling CAM to be deployed at scale

02

An enviable and robust safety record has been established in the UK and replicated around the world

03

A significant number of highly-automated vehicles are delivering mobility in the UK

04

Society understands, accepts and is adopting CAM

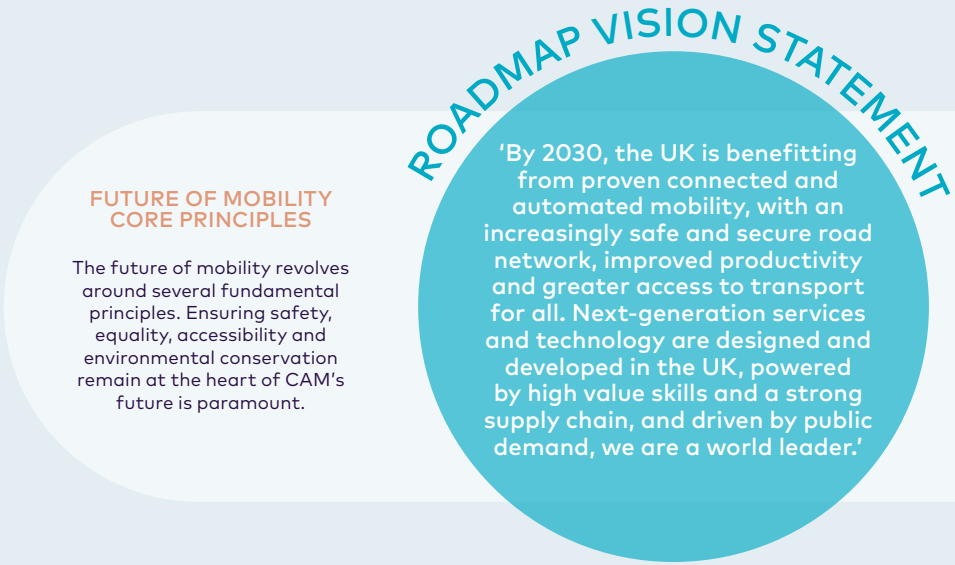
In order to use the 2030 Vision to tangibly impact the roadmap and define its Milestones, a set of ten core deliverables to achieve by 2030 have been identified (please see below).

These core deliverables paint a clearer picture of what 2030 could look like, help to define how the roadmap is structured and what it seeks to achieve through its interconnected web of Milestones.

"Age UK's interest in autonomous vehicles is ensuring that older people's needs are central to the design and development of this emerging technology."

Mervyn Kohler, Age UK

Delivering and supporting 'CCAV priorities' and 'Future of Mobility core principles'



05

Infrastructure is ready for increased deployment of CAM and has areas with highly connected roads

06

UK-based high-value jobs with rich skills pipeline in place

07

Capabilities and benefits are delivered by the UK throughout the CAM supply-chain

08

Greater certainty in emerging business models

09

Road networks are managed using new methods, delivering more efficient use of road space

10

UK is recognised as a leader in innovation in this developing ecosystem

External factors and influences

Roadmaps help to demonstrate how a range of factors combine over a period of time, whilst the process of thinking about and discussing these factors makes decision-making more resilient to future challenges. Roadmaps build understanding of and confidence in the priority, sequence, and scale of decisions and investments being planned today.

In order to provide focus and pace, certain ambitious but evidence-based assumptions have been made within the roadmap. The insights can be translated into a tangible set of effective actions that lead towards the future-unlocking and maximising social and economic benefits. Such evidence-based thinking also helps to recognise the early signs of negative outcomes in time to intervene, avoid, or manage them.

A global period of unprecedented technological change is taking place and is beginning to disrupt existing systems and services. The proportion of 16-75 year olds using smartphones has increased from 52% in 2012 to 85% in 2017, and users are increasingly expecting to be able to plan, book and pay for transport through mobile applications (CCAV, 2019b).

These changes are not taking place in isolation or uniformly, but in the context of emerging patterns (trends) and less well understood uncertainties (drivers). New, unexpected products and business models are being created from the convergence of emerging and existing technologies, and are increasingly powered by the vast amounts of transmitted and conducted data (GO-Science, 2017).

An open, evidence-based discussion about the trade-offs between technologies is required. Public trust and acceptance of the potential benefits of technology-driven innovation are key, meaning implications for safety, inclusivity, and employment are crucial.

The roadmap should also be viewed in the context of the needs and expectations of an ever-evolving society and economy: the UK has a growing, ageing and urbanising population, which is experiencing increasing health-related issues.

The UK's population is projected to increase by 6.4% over the next 10 years to nearly 70 million by 2026 (ONS, 2017a). In 2017, 83% of Britons were living in urban areas (The World Bank, 2018). The number of those aged 65+ is set to grow by around 50% in both urban and rural areas between 2016 and 2039, while the number of 85+ year olds is set to double to over 3 million in a similar timeframe (ONS, 2018).

> Safety is the most widely-cited advantage of self-driving vehicles, while simultaneously being the most widely-cited disadvantage.
> (Kantar Public, 2019)

Society is increasingly digitally integrated, but this does not guarantee fairness. The trend towards 'asset-light' lifestyles differs greatly from the values of previous generations, whether driven by choice or necessity (KPMG, 2016). By using technology intelligently, there is an opportunity to help reduce digital divides and social inequity, as seen in global poverty levels (MoD, 2018). Alternatively, misuse of technology could lead to inequality, concentrating power and wealth among an ever-decreasing group.

There are some concerning trends regarding independent transport options. Fewer young people are acquiring driver's licences (DfT, 2019b) – only 30% of 17-20 year olds – despite one in five job adverts requiring a driving licence

(Makwana, 2018). 22% of people reported having a disability in 2016/17, equivalent to 13.9 million people in the UK, whilst 51% of people cited mobility as an issue, making it the most prevalent impairment (DWP, 2018).

Climate change is increasing the frequency and severity of extreme weather events, while concerns about congestion (DfT, 2014) and air quality (DEFRA, 2017) are heightening. On 1 May 2019, the UK became the first parliament in the world to declare a 'climate emergency' (BBC, 2019).

In 2009, the Government's Chief Scientific Adviser was warning of a "perfect storm" by 2030 (BBC, 2009). Increasing populations, urbanisation, and climate change converge with a 50% increase in global demand for energy and food and a 30% increase in demand for water, creating destabilising factors and dangerous outcomes. These risks have prompted political and investment decisions to mitigate and adapt to these changes, which would have been considered radical a generation ago.

This continues global leadership by the UK in this area since the ground-breaking 2008 Climate Change Act, committing the nation to an 80% reduction in carbon emissions by 2050.

The Government announced its "Road to Zero" ambition in 2018, for at least 50% of new car sales to be ultra-low emission by 2030, alongside up to 40% of new vans.
(DfT, 2018c)

The UK is a leader amongst a dozen leading countries in CAM across the globe. The UK competes and partners with many of the leading countries; it influences and is influenced by them. However, with shifting balances in power and trade, particularly towards the southern hemisphere, there are broader issues beyond the control of the UK that have implications for intellectual property, standards and international rules-based systems (MoD, 2018).

"A recent Sciencewise public dialogue for DfT (https://sciencewise.cavdialogue) explored public perspectives on the acceptability of autnomous vehciles. The roadmap will help policymakers navigate the rapidly evolving CAM landscape and assist the framing of future public engagement."

Steve Robinson, Sciencewise

Creation and stakeholder engagement

Although the curation was led by Zenzic, the roadmap is truly cross-organisational thanks to input from a diverse set of stakeholders at every stage of the process. Collaboration ensured the wealth of expertise within the UK was recognised and used. The roadmap is not a duplication or recreation of existing work, but instead aims to be the single best collective understanding of CAM in the UK.

A comprehensive literature review of existing, high-quality reports and roadmaps was undertaken, followed by collaborative stakeholder workshops held across six months. The workshops considered simulation and cyber security, as well as exploring the Themes: Society and People, Vehicles, Infrastructure and Services. Cross-sector attendees contributed more than 1000 data points during the workshops.

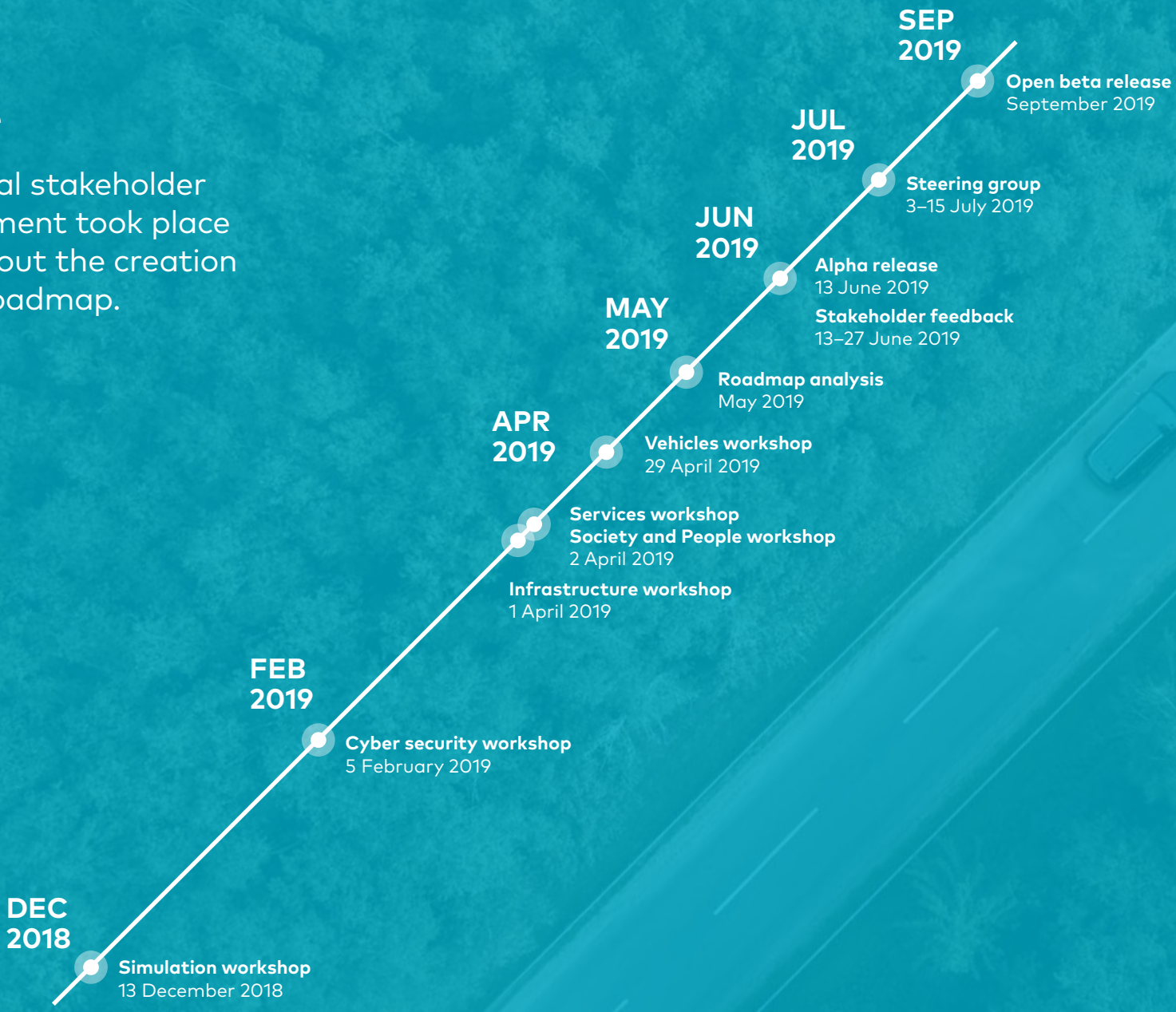
A comprehensive data analysis process was then undertaken, this involved the aggregation and grouping of data across the four roadmap Themes. Interdependencies were identified across the entire roadmap, informing the dates for Milestones.

A draft of the roadmap was distributed to stakeholders to provide an opportunity to feed back on the emerging content and structure. Two steering group sessions gave the opportunity for a small, diverse group to further review and finalise the roadmap.

This roadmap report has been released with an interactive roadmap, which can be accessed via **zenzic.io/roadmap**.

Timeline

Continual stakeholder engagement took place throughout the creation of the roadmap.



The UK Connected and Automated Mobility Roadmap to 2030

The UK Connected and Automated Mobility Roadmap to 2030 provides direction for decision makers, investors and policy makers for the mobile future. The roadmap is a tool, created by and intended for multiple sectors, forging new relationships and achieving collaboration across industries. With a single vision of interdependencies, the roadmap addresses developments needed to achieve connected and automated mobility (CAM) at scale by 2030.

Roadmap Structure

Inevitably, in a field as complex and emergent as CAM, any single roadmap structure will not be perfect. The roadmap uniquely addresses this through Golden Threads which allow cross topic narratives to be found.

It is important when using the roadmap to understand the language used. To support reading, key terminology is defined:

THEME	Highest level grouping within the roadmap.
STREAM	A topic which sits under a specific Theme.
MILESTONE	An individual item within a specific Stream. This could be a process (activity to be undertaken), output (tangible deliverable) or outcome (result of a process and/or output).
INTERDEPENDENCY	A relationship between two Milestones.
CROSS THEME DEPENDENCY	An Interdependency which includes Milestones from different Themes.
GOLDEN THREAD	A sequence of cross theme-related Milestones, which allow cross topic narratives to be found.
STRAND	A single interdependent collection of Milestones, which are part of a Golden Thread.
MILESTONE GROUP	To highlight the key messages, the chevrons seen within the flat roadmap (shown opposite) are collections of related Milestones. The interactive roadmap accessed at zenzic.io/roadmap shows the full Milestone view.

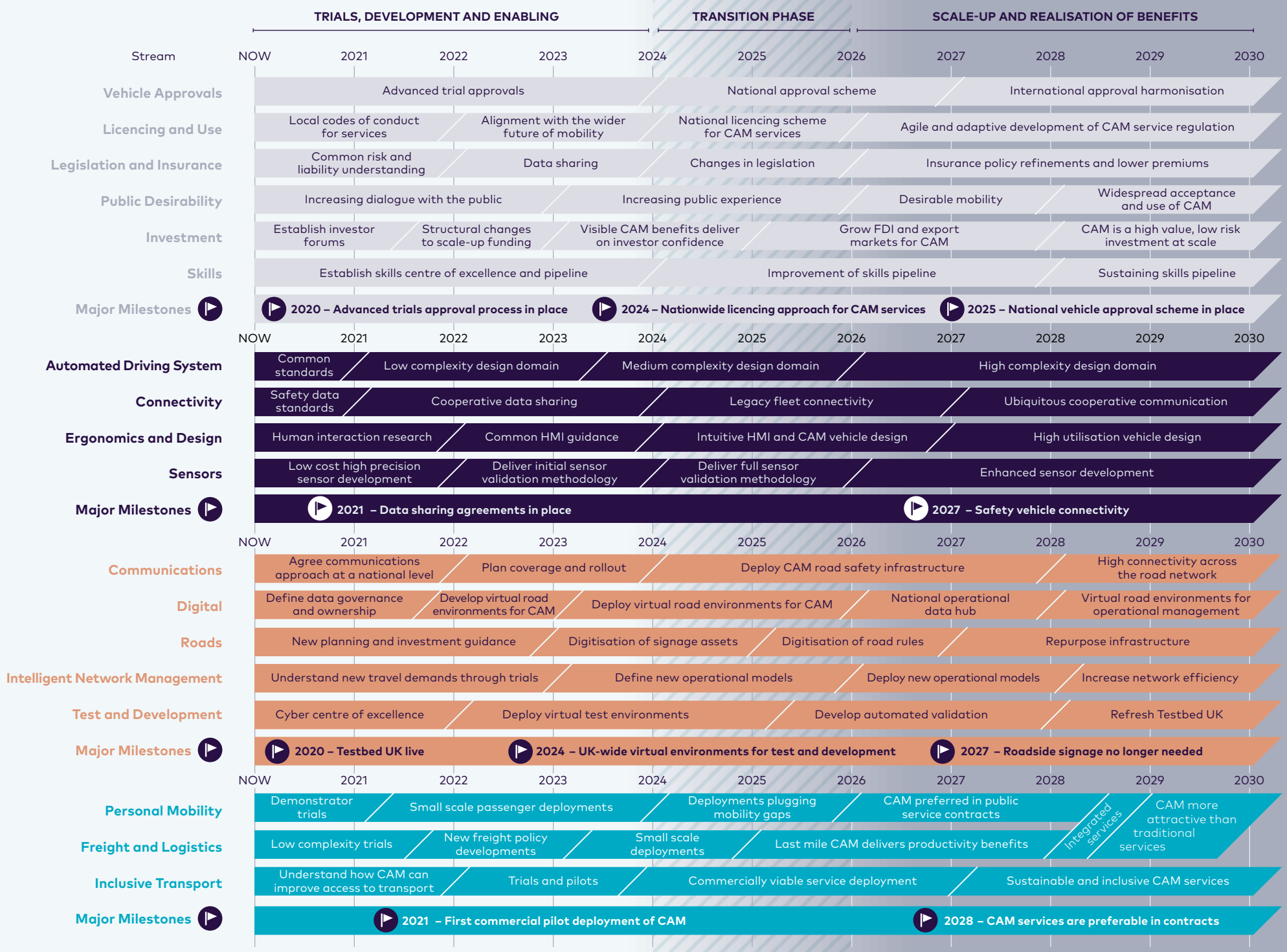
THEME

Society and People

Vehicles

Infrastructure

Services


TRIALS, DEVELOPMENT AND ENABLING
TRANSITION PHASE
SCALE-UP AND REALISATION OF BENEFITS
Stream
NOW
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Vehicle Approvals
Advanced trial approvals
National approval scheme
International approval harmonisation
Licencing and Use
Local codes of conduct for services
Alignment with the wider future of mobility
National licencing scheme for CAM services
Agile and adaptive development of CAM service regulation
Legislation and Insurance
Common risk and liability understanding
Data sharing
Changes in legislation
Insurance policy refinements and lower premiums
Public Desirability
Increasing dialogue with the public
Increasing public experience
Desirable mobility
Widespread acceptance and use of CAM
Investment
Establish investor forums
Structural changes to scale-up funding
Visible CAM benefits deliver on investor confidence
Grow FDI and export markets for CAM
CAM is a high value, low risk investment at scale
Skills
Establish skills centre of excellence and pipeline
Improvement of skills pipeline
Sustaining skills pipeline
Major Milestones
2020 – Advanced trials approval process in place
2024 – Nationwide licencing approach for CAM services
2025 – National vehicle approval scheme in place
NOW
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Automated Driving System
Common standards
Low complexity design domain
Medium complexity design domain
High complexity design domain
Connectivity
Safety data standards
Cooperative data sharing
Legacy fleet connectivity
Ubiquitous cooperative communication
Ergonomics and Design
Human interaction research
Common HMI guidance
Intuitive HMI and CAM vehicle design
High utilisation vehicle design
Sensors
Low cost high precision sensor development
Deliver initial sensor validation methodology
Deliver full sensor validation methodology
Enhanced sensor development
Major Milestones
2021 – Data sharing agreements in place
2027 – Safety vehicle connectivity
NOW
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Communications
Agree communications approach at a national level
Plan coverage and rollout
Deploy CAM road safety infrastructure
High connectivity across the road network
Digital
Define data governance and ownership
Develop virtual road environments for CAM
Deploy virtual road environments for CAM
National operational data hub
Virtual road environments for operational management
Roads
New planning and investment guidance
Digitisation of signage assets
Digitisation of road rules
Repurpose infrastructure
Intelligent Network Management
Understand new travel demands through trials
Define new operational models
Deploy new operational models
Increase network efficiency
Test and Development
Cyber centre of excellence
Deploy virtual test environments
Develop automated validation
Refresh Testbed UK
Major Milestones
2020 – Testbed UK live
2024 – UK-wide virtual environments for test and development
2027 – Roadside signage no longer needed
NOW
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Personal Mobility
Demonstrator trials
Small scale passenger deployments
Deployments plugging mobility gaps
CAM preferred in public service contracts
Integrated services
CAM more attractive than traditional services
Freight and Logistics
Low complexity trials
New freight policy developments
Small scale deployments
Last mile CAM delivers productivity benefits
Inclusive Transport
Understand how CAM can improve access to transport
Trials and pilots
Commercially viable service deployment
Sustainable and inclusive CAM services
Major Milestones
2021 – First commercial pilot deployment of CAM
2028 – CAM services are preferable in contracts

What does the roadmap tell me?

The roadmap is designed to provide insights into CAM for many different organisations. Within this there are three core user groups which have been considered; business, consumer and government. Each of these groups has a different set of needs and questions.

In engaging with different stakeholders during the creation process, questions for each user group have been discussed and a number of common ones arose. The following questions are just indicative of those critical areas in which the roadmap can help provide answers.

Business view

- **Should I invest?** By focussing on the investment landscape, the roadmap draws out a credible path to large scale adoption, where CAM is no longer a high risk venture. This will provide confidence in the growing market.
- **What relationships do I need to be successful?** The roadmap shows numerous stages of deployment which are potential routes-to-market. Whether you are delivering components, integration or services, the roadmap can bring to life the interdependencies from supply chain management to market exploitation.
- **How do I build desirable products?** Compelling services and products drive sustainable business models. Public dialogue is key to engage and understand public needs, and to ensure CAM services are desirable.

Consumer view

- **Will CAM be safe?** Safe and secure technology and services are the foundation of all trials and approvals. All development and deployments must pass through stringent testing processes.
- **What does CAM do for me?** CAM will unlock personal productivity through releasing lost driving hours and more efficient road networks. It will also unlock benefits and increase access to transport for all.
- **How will CAM make travelling easier?** CAM will deliver affordable mobility, increasing travel options and bringing together a more connected transport system.
- **Will CAM arrive all at once?** CAM will be introduced gradually, with initial deployments in 2021, increasing through to 2024. From there, deployments will scale up to significant numbers by 2030. Education programmes on interacting with varying levels of automation in vehicles is key to migrate to a highly-automated future.

Government view

- **How does this fit with the rest of transport policy?** Defining licencing frameworks that work nationally and locally is critical, they must fit with the wider future of mobility, promoting appropriate travel options.
- **When do we need legislation changes?** Legal changes must begin to be made now to enable safe and secure deployment, with clear responsibilities and liabilities in place, continuing to align at an international level.
- **How can government support CAM?** By drawing together a comprehensive view of the future, it becomes clearer where there are market failures and places where support is needed. This is particularly relevant in areas where collaboration is essential.

Roadmap structure

Themes within the roadmap

Society and People

page 20

Vehicles

page 24

Infrastructure

page 28

Services

page 32

Society and People

The Society and People Theme takes a people-centric approach, and is the primary driving force behind the roadmap. It covers Streams that deal with societal mechanisms such as Vehicle Approvals and Licencing and Use. Additionally, it includes the frameworks within which CAM must sit. Society and People also covers people-centric Streams such as Skills and Public Desirability. These focus on the impact CAM will have on people and the opportunities to enhance everyday life. Public dialogue will unlock many of the design and regulation choices that must be made.

The legal and regulatory considerations around vehicle approval and licencing must be established. National approaches and standards, within which technology and service development can occur, create a culture where innovation can flourish.

Key enablers, such as insurance and investment, create an environment to unlock deployment at scale. Providing investment platforms that are globally competitive ensures the UK is positioned at the forefront of the global market.

It is well recognised there are economy-wide skills shortages across emerging technology sectors. This roadmap highlights that cross-industry collaboration is absolutely critical to creating and filling a skills pipeline. This starts with encouraging STEM subjects in school, through to PhD level mastery, including complex capabilities in niche areas such non-deterministic AI ethics. The need to re-train and upskill is core to supporting today's workforce and sustaining the future of CAM.

Front and centre in this roadmap is the need to ensure the path to 2030 is one we take together – government, industry, academia and public in unison.

Vehicle Approvals

A key factor in progressing CAM is to ensure self-driving vehicles of all types meet a minimum safety standard to operate and function on public roads.

This Stream, along with Licencing and Use, explores how the UK is building on existing foundations, including the updated Code of Practice: Automated vehicle trialling (CCAV, 2019a) and ongoing work by the Law Commission to enable vehicles to be safely developed on UK roads.

The Vehicle Approvals Stream is multi-faceted, driven by the need to establish a mature approvals process for connected and self-driving vehicles. In the near future, the emphasis will be on developing an initial framework for advanced trial approvals that will support international processes and regulations. For example, it is expected that a national approval scheme will need to be in place by the end of 2027, with international approval harmonisation in place by 2030.

During the roadmap workshop series, legislation and regulation was consistently voted as the most critical aspect in enabling the connected and automated future.

The UK is widely acknowledged to already be a world-leader in terms of legislation and regulation.
(SMMT, 2019)

Licencing and Use

Regulations, standards and legislation are often cited as both 'enablers' and 'blockers' for the development, trialling and deployment of CAM technologies and services. Defining a robust standards framework for CAM and its services is crucial.

In the near future, the emphasis will be on developing the necessary legislation and regulation to enable the continual trialling, licencing and use of connected and self-driving vehicles. The progression of licencing regulation enables testing of CAM services in the early 2020s and the deployment of vehicles and services from 2024.

The objectives and goals of CAM are defined by the end of 2021, to help clarify the legislation and regulation required for vehicles to be licenced and used on the road for CAM services. Similarly, the safety protocols for CAM services will be in place by the end of 2022, in addition to a service based framework being in place by the end of the same year.

Legislation and Insurance

One industry where the adoption of connected and self-driving vehicles is likely to have a profound impact is that of insurance. Within this, the emphasis shifts away from the insurance of an individual to the insurance and liability of a vehicle or service (Burges Salmon, 2019).

As with legislation and regulation, insurance is another area where the UK is seen as a world leader, having well-defined liabilities (AEVA, 2018 and SMMT, 2019).

To enable the shift in insurance business models, greater collaboration is needed to ensure appropriate data sharing. Safety critical data requires particular focus in order to reach the eventual goal of a reduction in premiums for connected and self-driving vehicles and services. However, the frameworks that allow these to exist must first be developed. A mature and robust regulatory and legal framework for insurance will be in place by the end of 2028.

Society and People

Continued improvements in actuarial models will lead to connected and self-driving vehicles being cheaper to insure than human drivers by 2027.

Public Desirability

The roadmap sets a 2030 Vision for CAM to be widely accepted in the UK. In order to achieve this ambitious goal, a focussed and defined effort to understand how the UK public feels about connected and self-driving vehicles is key, including current perceptions and concerns.

In order to reach a position where the majority of the UK public truly accepts and understands the benefits of CAM, activities are needed to educate the UK public on connected and self-driving vehicles. Increasing exposure to CAM will allow them to be ready for commercial vehicle deployment by 2022. At the heart of this will be investment in and the creation of a UK-wide PR from 2020 and education plan by 2021, aiming to encourage changes in mobility choices (ERTRAC, 2019).

The plan will serve as a conduit for companies to engage and showcase their capabilities through wider public dialogue. Education on why CAM is being invested in, what the benefits are in terms of safety, productivity and access to transport will be key. On the other hand, removing stigma, stereotypes and misconceptions around CAM will also help to engage the public. Ongoing PR activities will be needed to maintain public interest as new CAM services are developed.

Investment

To deliver the entirety of the roadmap Milestones, it is clear that significant investment is required. Funding from various sources is expected, including but not limited to government, venture capitalists and private equity. However the question remains, what is needed to attract further investment?

Enabling the right conditions for growth in the UK is driven through investing in a world-class small and medium-sized enterprise (SME) environment. This starts now and grows to maturity over the next five years, promoting UK skills and capabilities as a strong CAM value chain is built by 2024. This must be complemented by addressing the structural changes needed to support scale-up businesses being globally competitive.

For any investment to be committed, there must be compelling business cases. The roadmap shows the definition and agreement of new benefit metrics in 2022 and new approaches to mobility and infrastructure business cases in 2023 are both fundamental in creating business cases. These are dependencies for many other Milestones within the roadmap.

The roadmap shows how the culmination of these tasks delivers significant investment through a mature and collaborative ecosystem. This ranges from low-risk private equity backing in stable CAM services from 2028, to foreign direct investment (FDI) as early as 2025.

Skills

The roadmap sets a 2030 Vision for the UK CAM ecosystem to be supported by high-value jobs with a rich skills pipeline in place. To achieve this, it is vital to focus attention on skills reform and gain a thorough understanding of the skills gap.

The automated vehicle industry is projected to create 10,000 net additional jobs in the UK by 2035, however, the number of enrolments onto relevant UK degree courses are growing by just 2% annually and apprenticeships by 3.9% (CEBR, 2018).

To tackle this challenge a CAM skills centre of excellence should be established. A comprehensive review of current skills capability will inform and help to establish the necessary skills pipeline from 2023 onwards.

The pipeline will serve to provide the necessary education and upskilling across schools, universities, industry and government, beginning in 2025. Central to its maturity is the development of new courses and training programmes to equip the next generation of leaders for CAM, as well as inform policy makers, investors and decision makers. The UK is in a strong position to deliver this upskilling, with three universities placed in the top ten global rankings (The Times, 2019).

Retraining and preparing vehicle mechanics to support fleets of connected and self-driving vehicles is crucial. Ongoing improvement and upkeep of this pipeline will be essential in responding to fluctuations in skills demand, as well and bolstering the UK's capability to deliver world-leading technologies, products and services.

395

The average driver in England currently takes 395 trips as a driver per year, covering 3253 miles per year. The future of CAM will change this

(DfT, 2018b)

Vehicles

Vehicles is the first of two technology-focussed Themes. It looks at the technology required to enable connected and self-driving vehicles, covering aspects such as the automated driving system (ADS) and sensors, as well as the components of vehicle design that are impacted by changes in use.

Much focus is given to the emergence of self-driving technology and there is a danger it could be seen as the end goal itself. The roadmap does not underplay the significance of vehicle technology to delivering the 2030 Vision, but places it in the context of the other three Themes.

Central to the Vehicles Theme is the Automated Driving System Stream, which is the heart of any self-driving vehicle. Much research and development is required to move from small-scale controlled trials into broad deployment.

Connectivity unlocks many of the 2030 Vision core deliverables – particularly when considering desirable mobility services and integration into towns and cities to enhance efficiency and productivity. Decision paralysis of technology choice can be avoided by considering data and information at the beginning. Finally, vehicles of the future will not look the same as they do today, therefore many nuanced changes to the ergonomics and design of passenger vehicles are needed.

Automated Driving Systems

Enabling the scalability of new self-driving service models is the technological maturity of the ADS. The ADS is at the heart of the driving task, handling the complexities of the road network through sensor-based perceptual models. The development of these systems aims to retract the need for a driver whilst drastically increasing the safety of our roads.

> The Institution of Engineering and Technology predicts by 2029 for every 10,000 errors made by human drivers, an automated vehicle will commit just one.
> (IET, Undated)

Significant UK investment has been made in research and development to gradually automate the driving task. Most notably, the Centre for Connected and Autonomous Vehicles (CCAV) has pledged £200 million to invest over 5 years (CCAV, 2017). This has resulted in many multi-sector, collaborative projects, focussed on heightening the automation capability of the ADS. From 2023, freight, buses and passenger vehicles will begin to be highly automated, at which point the driver relinquishes control of the driving task to the vehicle. Full automation will begin to be developed as early as 2026. Alongside automation development, work is already underway on the standardisation of Operational Design Domains (ODDs) (OICA, 2019). Establishing a mature software update process from 2023 will also be essential in a successful deployment of emerging technologies, products and services.

The intelligence of self-driving vehicles is driven by advanced features such as artificial intelligence (AI) or machine learning (ML) techniques. AI has implications for radically changing the way vehicles are treated in every aspect such as approval, certification, training, interaction and trust.

This Stream deals with both the development of new and improved AI and ML techniques, along with the ability to bound and contain them in frameworks for approval. Ensuring that AI algorithms can be externally understood or interrogated is a complex matter, it starts in 2022 but does not fully integrate into certification until 2030. However, and perhaps more importantly, is the need to understand the impacts of AI decisions on safety cases or, should the worst happen, root cause analysis of an incident. The roadmap shows the steps required to define standards, certifiable tools, algorithms and techniques from 2022.

Advances in AI will be primary in maturing the ADS capability. Ensuring that AI algorithms can be externally understood or interrogated, to the point it is needed, starts in 2024, but is not fully integrated into certification until

2030. However, potentially more important is the need to be able to understand the impacts of decisions on safety cases or, should the worst happen, root cause analysis in the event of an incident. The roadmap shows that the steps to define standards and certifiable tools, algorithms and techniques is required in 2021, with early standards adopted in 2023.

Connectivity

It is predicted that by 2026, all cars produced in the UK will be connected.

(SMMT, 2019)

Connectivity is a key element that will provide the foundations for the delivery of the economic and societal benefits of CAM – largely as it will enable new data services, driving efficiency, productivity and mobility. Significant uptake of connected and self-driving vehicles could improve reliability and reduce delays.

Connectivity also has the potential to deliver important safety benefits. These are highly dependent on standardisation and high-bandwidth low-latency communications.

Standards will be created from 2022, informed by collaborative trials of vehicle-to-everything (V2X) technology. This will lead to effective

Vehicles

planning for investment and deployment of supporting CAM road safety infrastructure from 2024, maximising the benefits of shared vehicle data. This will help to realise the advantages of smoother and more convenient journeys from 2026 and connectivity-enabled safety by 2028,

As high-bandwidth connectivity is rolled out and higher-quality sensor data is shared more easily, innovative data services will begin to support new mobility services. Research suggests connected and self-driving vehicles could generate in excess of 4TB per day (5GAA, 2017). These richer data sets could be consumed by digital twins to allow new information for people, cities and vehicles, in turn supporting more integrated journey scheduling in cities by 2027.

As higher levels of connectivity and self-driving technologies are deployed, the safety cases based on V2X will mature quickly. In 2022, this could lead to vehicles without advanced connectivity features beginning to be outfitted with onboard units or mobile device based connectivity – allowing safety-critical data to be shared with other vehicles.

It is predicted that if all vehicles use collision avoidance sensors as well as vehicle-to-vehicle (V2V) communication, the effective highway capacity could be increased by 273%.

(Tientrakool *et al.*, 2011)

Ergonomics and Design

One key aspect that underpins the Ergonomics and Design Stream, is encouraging passengers to engage with different uses of vehicles that CAM will enable.

Ride sharing and travelling in non-traditional positions, such as lying down, are prime instances that must be identified,triggering the need for safety considerations such as whiplash, rear-end and crash protection (Euro NCAP, 2017).

This Stream identifies the areas that must be considered to ensure design features keep passengers safe. Analysis shows that research is the first logical step in defining what needs to be considered, what concept decisions need to be made, what they will lead to and how they will be supported by the delivery of new standards.

Sensors

One of the essential building blocks for making the 2030 Vision a reality is the development of sensors. The fitting of vehicles with robust sensors is essential to build up an accurate perceptual model of the road environment. The ADS uses this model to make decisions, therefore understanding the capability bounds of the sensors involved is critical.

As the sensors mature in technological capability, alongside other communication advancements, sizeable network efficiency benefits can be realised.

Analysis shows the first major focus should be lowering the cost of sensor models and ensuring the availability of high-precision components (Automotive Council UK, 2017).

500

The roadmap is built up of over 500 milestones, connected through almost 600 unique relationships

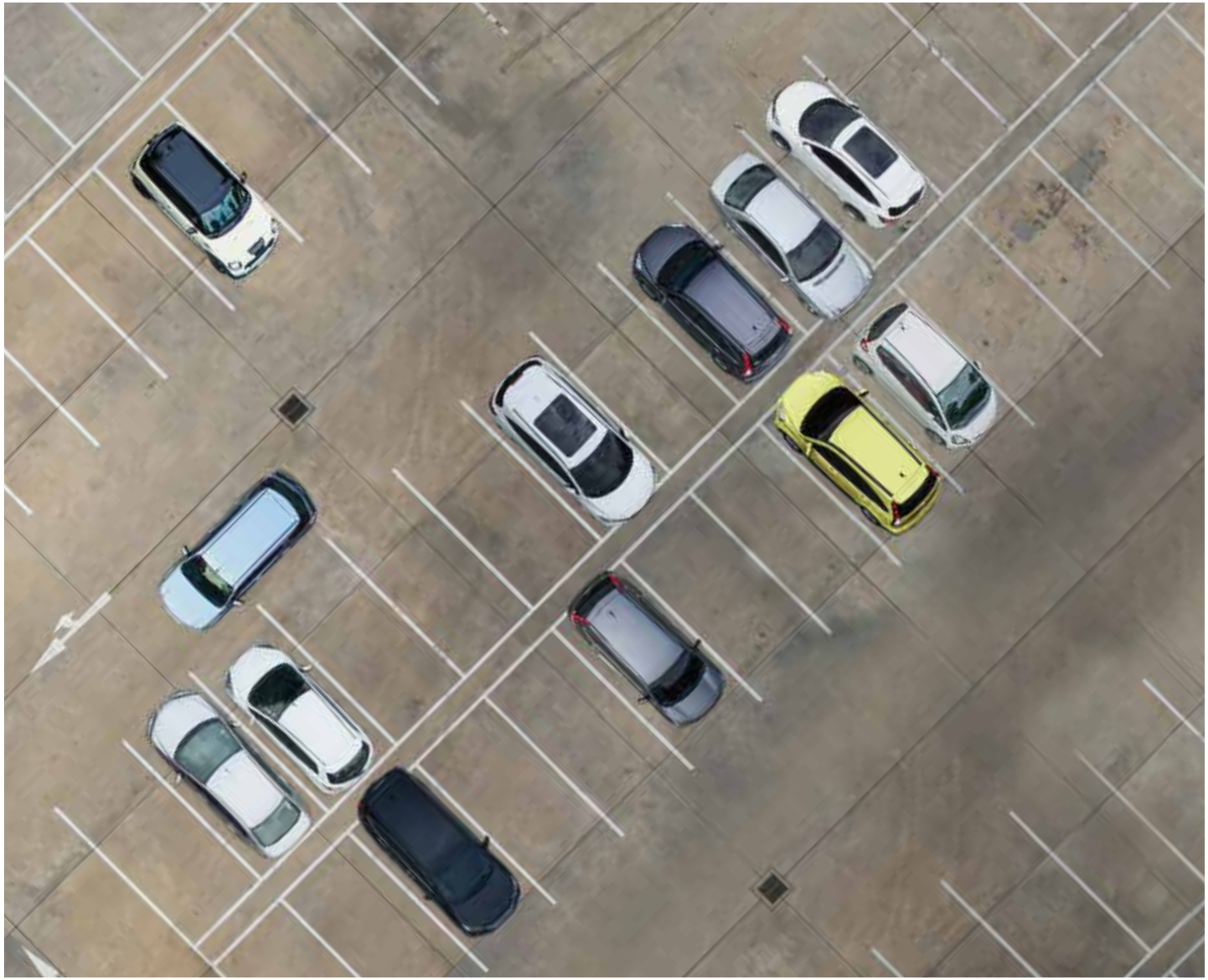
From now to 2025, the first stages will constitute the agreement of standardised sensor calibration methods, improving the data processing techniques involved with extracting accurate and reliable data as well as employing solid state electronics.

From 2024, new sensor technologies can be developed to deliver enhanced functionality. Subsequently, deeper research can be undertaken in recognition testing as well as establishing a comprehensive validation process for commercial deployment. Another key factor to address is the required redundant operational subsystems that activate upon failure of a component. These systems will be essential to ensure safe operation if there is a fault during operation.

Ultimately, sensor development serves to build an accurate picture of the road environment. As these models become more sophisticated, higher levels of automation, especially when considering relevant edge case conditions, can be tested and deployed safely for service operation.

"Connected and automated vehicles will help us build a healthier, happier and better connected West Midlands. The roadmap highlights current benefits and shapes conversation about the future of technology for society."

Chris Lane, Transport for West Midlands



Infrastructure

Infrastructure is the second of the technology Themes. It deals with the environment in which connected and self-driving vehicles will operate. It includes the enabling technologies that will enhance the utility and safety of the vehicle, and also fundamentally integrate the vehicle into society and the wider transport system. Infrastructure covers technology such as communications and intelligent network management, as well as traditional roads infrastructure and new digital infrastructure.

Communications networks are the most obvious of the digital technologies that CAM depends on. Much is spoken about the communications needs of connected and self-driving vehicles, and the most appropriate technology choice is widely debated. This roadmap does not define that choice but focuses on the data and information requirements that inform communication needs.

The road network itself, including management processes and procedures, has the opportunity to change radically. CAM presents a new paradigm for the integration of vehicles into cities and towns, no longer reactively, but collaboratively working together for optimum efficiency and productivity.

This Theme also recognises that having specific infrastructure in place to facilitate the development and testing of technologies and services is key to unlocking insights that inform regulation, service design and technology requirements.

Communications

The Communications Stream includes the preparation for increased deployment of CAM in areas with highly instrumented roads, supporting high levels of uptake.

These frameworks will underpin the relevant data transfers needed for low-latency safety

Communication frameworks will be essential to facilitate the scalable deployment of CAM services, as well as potentially reducing congestion.
(Bierstedt *et al.*, 2014)

80%

Analysis shows that by 2029, 80% of the strategic road network could have coverage with safety communications

cases and the coverage required for emerging new CAM business models.

Safety use cases are the priority for infrastructure development. Strong communication solutions for these critical elements of vehicle operation will need to be defined from 2020, to achieve deployment of the first service using safety messages in 2026. Further deployment rounds will need thorough business cases for emerging communications models.

Once safety-critical communications solutions have been developed, a nationwide coverage plan must be established in 2023, informed by nationally-agreed communication standards for CAM. This plan will aim to specify and execute the required coverage and network resilience roll out plans for robust infrastructural solutions across the UK.

As coverage roll-out progresses, areas of highly instrumented roads will expand as the proportion of strategic road network coverage increases.

Analysis also shows the areas with strongest business cases are more likely to lead to highly connected areas.

Digital

Data is foundational to emerging CAM technologies, products and services driving their safety, operation and connectivity.

To efficiently and securely handle this data, the development of sophisticated digital infrastructure solutions are required. These solutions will enable a rich, data-driven network across the various elements of CAM services, leading to intelligent awareness and optimisation of wider system operation.

The roadmap shows from 2021, enabling cross-organisational data sharing is a crucial first step. This includes agreeing what data must be shared between vehicles and infrastructure, specifying its accuracy and the mechanisms by which it will be transferred and stored. The establishment of cyber security data services by 2023 and commercial access to data hubs by 2026 will be crucial during this phase.

Governance of this data will be essential to define responsibility and ownership through driving standards and defining data-related use cases. The value of CAM services will become increasingly defined by the quality of data and the insights generated. As a result, governance over how this data is handled will become more important to ensure security and safety is at the centre of quality service provision.

Transport data is also fundamental to the CAM market, with potential financial benefits of £14 billion per year by 2025.
(TSC, 2017)

Analysis shows the publishing of open data standards and definitions of responsibility, ownership and maintenance in 2023 to be of utmost priority in this pursuit.

As digital infrastructure matures, the opportunities to develop operational management techniques will grow. One of the driving forces for digital infrastructure is an investment into national digital twins. By collating UK assets and geospatial data, digital twins can be used to optimise routing, manage

Infrastructure

assets, visualise real-time mapping information and display various traffic control layers. Agreements over ownership and operation of these twins will be essential in establishing trust for data security, providing a secure foundation for safe service provision with a rich, information-driven user experience.

Roads

The continued growth of vehicle connectivity and automation will naturally lead to questions around the functions and capabilities of the road network. Since a vehicle's ability to locally and collaboratively process information will increase, previous features of the road network may become redundant, evolve or be replaced entirely in order to best serve the emergence of new CAM services. As with the progressive shift of mapping data from static physical documents to interactive digital services, emerging CAM technologies will continue to affect the role of the road network in performing the driving task.

Analysis shows that defining new business models is a major factor in driving the evolution of road infrastructure from 2022. These models will dictate how investment should best serve the evolving road network and specify the reductions in spending on traditional infrastructure. New planning guidance and blueprints for CAM-ready cities, towns, highways and rural roads, from 2020, will look to accommodate CAM services for efficient operation. From 2022, detailing the elements of a 'naked highway', whereby gantries and signage will become entirely digitised for in-vehicle displays, will signify the shift to digital signalling.

The physical evolution and initial decommissioning of signs and signals in specific circumstances, beginning in 2027, will be the first visible indication that new road infrastructure has been deployed. This will follow the agreed models for digitisation of sign assets, as well as the specification of new safety services.

Alongside the deployment of new infrastructure, 2028 will see the replacement of physical signs and signals with in-car signalling.

The transition, development and widespread adoption of road infrastructure will be informed by new standards. They will specify how various connected services should be prioritised on the road network from 2023, as well as revise common approaches for safety and design standards from 2029. They will also describe the mapping requirements for different road infrastructure from 2024, performing the necessary revisions of existing road manuals for safe and secure operation of CAM from 2025.

Intelligent Network Management

As road network connectivity increases, rich, data-driven insights will allow for operational management techniques of previously unseen sophistication. These will be delivered through large-scale computing and data sharing, affording intelligent predictive capability of network performance, as well as demonstrable improvement of traffic flow metrics.

Deployment of discreet intelligent transport systems (ITS) use cases, such as the first national connected vehicle service going live in 2026, as well as nationally interconnected traffic management systems and green light optimal speed advisory (GLOSA) roll out in 2027, will contribute towards network intelligence. From 2026, the analysis of CAM travel patterns can be used to identify limiting factors in current city design. These will be instrumental in new city planning methods to increase the efficiency of CAM travel across the network from 2027.

Establishing new operational models will build upon travel pattern insights to improve network efficiency. These models will define the monitoring and compliance requirements from 2025 and routing protocols and their accompanying roles and responsibilities also from 2025.

Dynamic lane management systems and routing optimisation from digital twins are examples of the operational methods that will result in increased network efficiency.

Emerging CAM travel patterns can also be used to inform travel predictions from 2023, benefitting network efficiency and flexibility. As their supporting data diversifies and pervades more of the CAM network, predictions will further the intelligence of the network management techniques.

Test and Development

For the UK to be recognised as a world leader in CAM innovation, it is essential to have an enviable safety record and significant deployment of highly-automated mobility services – enabled by high quality test and development facilities and processes. Studies show that readiness to accept commercially deployed self-driving technology was driven by an assumption that regulators would require it to be rigorously tested (MERGE Greenwich, 2018).

This affects a large proportion of the roadmap – not just the technological elements of CAM. Already established are world-leading test sites in the UK known as Testbed UK – a global centre for innovation and development of connected and self-driving vehicle technologies and CAM services. These sites comprise a broad range of urban, rural and highway road types, in both controlled and public environments. The facilities also enable the testing of parking and data connectivity across virtual and physical environments, alongside many others.

"Effective planning and delivery of Infrastructure needs clarity of what is required and certainty of resource – the roadmap will help all involved to put both in place."

Andrew Hugill, Chartered Institution of Highways and Transportation

The roadmap highlights that mature testing procedures and standards, in addition to highly-automated validation capabilities across these sites should begin in 2025. These processes would see the agreement of test and validation methods as well as common standards for safety cases in 2025, moving through to 2026, at which point high complexity design domain capabilities are in the process of development.

Enhancing Testbed UK with digital capabilities will ensure a full test and validation offering. This will see the £1.7 million creation of virtual testing environments completed in 2025, a £20 million centre of excellence for cyber security in 2024, the establishment of a national threat database in 2025 and the adaption of an MOT procedure for cyber security considerations in 2028.

It is essential the testbeds receive the continual investment they need to test and develop emerging use cases and business models. A defined technology roadmap for testbeds, launched in 2028, is critical in anticipating these changes.

Services

Services is an outcome-focussed Theme. In some senses, it is the culmination of the three other Themes. Services articulates how vehicles (and infrastructure) contribute to achieving the vision to improve the mobility of people and goods, however it should not be seen as the final element of the roadmap to be delivered once all other aspects are complete.

There are strong links in the early parts of the roadmap where user needs inform service concepts. In turn, these dictate technology requirements and ultimately deliver trials, which inform regulation. The Cross Theme Dependencies are never stronger than when dealing with Services.

The Theme focusses on three key mobility areas: Personal Mobility, Freight and Logistics and Inclusive Transport.

The Personal Mobility Stream defines new solutions for the movement of people. Agnostic of the vehicle type or operating domain, it works towards supporting the future of mobility through multi-modal journeys.

Freight and logistics deals with the operational deployment of more efficient movement of goods, looking at both inter-hub transport and first-and last-mile solutions.

Inclusive mobility recognises that mobility solutions today do not equitably provide access to transport for all. Constraints on economic viability and appropriate solutions can be barriers to mobility. Leveraging new technology will plug existing gaps in mobility – each vitally important in the smooth running and inclusive future the 2030 Vision sets out to achieve.

Personal Mobility

The Personal Mobility Stream is one of the main culminations of many Cross Theme Dependencies. Bringing together regulation, vehicles, infrastructure and public acceptance is essential to enable large-scale deployment of desirable personal mobility services. Personal mobility is not constrained to any specific form of vehicle. Instead, it is focused on the movement of people rather than whether the vehicle is a bus, car or a pod.

This Stream relies on bringing together many pieces and there should be no surprise that many Milestone Groups deal with integration.

Key to the significant deployment of CAM is the genuine demand for new mobility offerings. Incentives for adoption must be clear – whether financial, convenience or time. Understanding future mobility needs and incorporating them into service design is prevalent in this Stream.

A recurring and fundamental enabler for this Stream is effective and transparent access to data. The integration of data sets from cities, road network operators and service providers unlocks the ability to collaborate and make system-side decisions. From operational planning to business model development, everything depends on open access to data.

This will lead to smoother journeys and CAM services being more desirable.

The future of mobility is linked to the shift away from modal transport choices to integrated and seamless journeys. The roadmap explores how we bring together CAM and traditional services into integrated Mobility-as-a-Service (MaaS) platforms.

Freight and Logistics

Freight and logistics are set to benefit from significant societal and economic advantages from connected and self-driving technology.

It has been estimated that up to three quarters of HGV operation costs are associated with the cost of a driver.
(Deloitte, 2017)

While the roadmap recognises new roles may be required to supervise self-driving freight services, the adoption of automated vehicles could serve to ease HGV driver skills shortages (Freightlink, 2018). By equipping 50% of HGVs for platooning, road capacity could be improved by 2% (Atkins, 2016).

The roadmap recommends government and industry invest in logistics test facility capabilities in 2019. This would support the

development of technologies and business models for first and last mile services. In the medium term, it will be necessary to explore how transport policy might be adapted to enable the benefits of connected and self-driving freight. By late 2024, issues such as allocation of curb space for self-driving logistics and licencing frameworks for last mile deliveries should be considered. The best practice in this instance would be understood through a call for evidence on improving freight efficiency in 2021.

"As Mobility is disrupted by new technology, we need to understand the new risks and opportunities it presents. The roadmap helps us to plan ahead, anticipate changes, and make sure we will be ready with the products needed by our customers in the future."

David Williams, AXA

By 2026, the first commercial freight platoons are predicted to begin appearing on UK highways, but widespread adoption could be slowed by legacy fleets without the necessary technology. The Government Office for Science has identified a risk, in which technology could potentially be a barrier to scaling adoption of platooning beyond motorways and dual carriageways. To avoid this, upgrades to infrastructure required to support

platooning should be developed from 2023 (GO-Science, 2019).

Self-driving road trains could also begin deployment. Initially these are likely to be implemented at off-peak times from 2028, but could be deployed at peak times by 2030. As data exchange, CAM business models and transport policy become more developed, we are likely to see new services appear, which could have a significant impact on efficiency and the environment. By 2027, this could include a national freight traffic control service to improve orchestration, eventually allowing consolidation of freight and people movements from 2028.

Inclusive Transport

Delivering affordable, predictable and desirable transport to society as a whole is an ambitious goal. However, CAM opens new opportunities to make this a reality. Early adopters of these services are likely to be the young and the elderly with 69% aged 17-20, not holding a driving license and 38% aged over 70, no longer driving themselves (DfT, 2017).

In 2017, the DfT reported 9% of people with disabilities had not undertaken a single journey in a year.

(DfT, 2017)

To deliver accessible transport for all, services and vehicles will need to be designed with the needs of vulnerable users and people with disabilities taken into serious consideration. Further investment is needed to define what accessible transport means in terms of CAM by 2024.

The Flourish project found that older adults engaged with self-driving vehicles more effectively when they received spoken, audio instructions

(Flourish, 2017)

From 2027, services will be deployed where a human is no longer required to drive and is instead more likely to deliver customer service.

In 2015, people with mobility difficulties made on average 86% fewer commuter or business journeys (SMMT, 2017). To ensure this trend improves with self-driving technology, services from 2022 onwards need to be trialled. These could include a degree of responsibility for the safety of vulnerable users, as well as offering additional new services on the journey – perhaps medical professionals for hospital services, or youth workers for school services.

From 2026, services will be deployed into not only large cities, but also major urban conurbations. In 2018, this accounted for 20.1 million people (36% of the population) in England alone. Just over 13 million people (23% of the population) live in rural areas with 35.9m (64%) of the population living outside major urban conurbations in England (ONS, 2019 and DEFRA, 2011). To prevent a disparity in services, or a situation of regional transport poverty, the policy and business models needed to support self-driving deployments at scale into smaller towns and rural settings will need to be defined using the data emerging from cities.

Services

40%

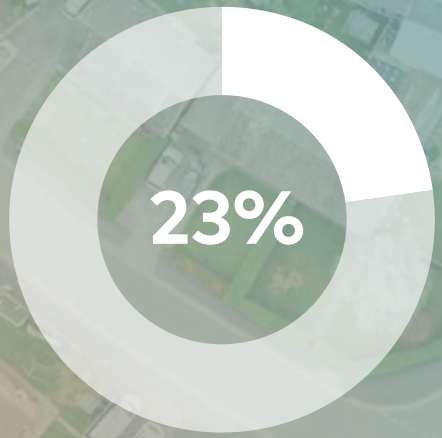
In 2018, adults with mobility difficulties made on average 40% fewer trips per year compared to those with no mobility difficulties

(DfT, 2017)

20.1m

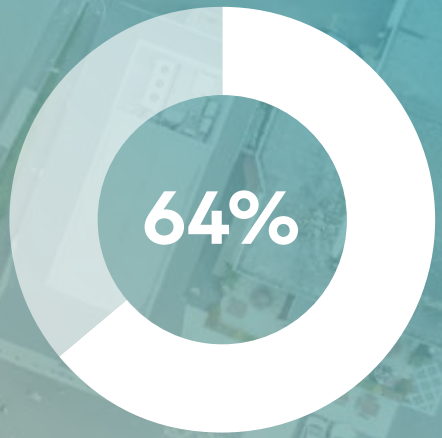
people (36% of the population) live in cities and major conurbations in England alone

(ONS, 2019 and DEFRA, 2011)



13.0m

people live in rural areas in England



35.9m

people live outside major conurbations in England

Golden Threads

What is a Golden Thread?

The nature of designing a roadmap for a complex ecosystem means a consistent, sensible structure is critical. It is inevitable that when considering the diverse range of readers and users of the roadmap, the structure may not be fit for purpose for everyone. To address this potential problem, the UK Connected and Automated Mobility Roadmap to 2030 takes advantage of the Interdependencies between Milestones. We utilise these Interdependencies to define threads of related Milestones. These threads can be grouped together around specific topics or Milestones to give a specific view across the roadmap, which is not restricted by the Theme and Stream structure.

Golden Threads are Interdependency-driven, rich insights that can be harnessed simply by selecting an orienting Milestone

Golden Threads allow any organisation to build a bespoke roadmap view tailored to their own needs. Therefore, the report uses this concept to demonstrate how the 2030 Vision can be achieved.

How can I use a Golden Thread?

Golden Threads allow the broad range of CAM stakeholders to visualise an interdependent journey through the roadmap, across its various Themes and Streams. This gives powerful insights as to how individual company objectives can be achieved, or how decisions should be made in the context of the wider CAM landscape.

Contained in this report is an exploration of six Golden Threads, which relate to the ten core deliverables, although the possibilities of different Golden Threads through the roadmap extends well beyond this.

As Golden Threads are Interdependency-driven, rich insights can be harnessed, simply by selecting an orienting Milestone. These Golden Threads can be used to inform company strategies and decisions underpinned by a wealth of insights created by experts across industries.

Homing in on a particular Milestone in the roadmap allows users to see the interdependent relationships around it, thereby understanding the associated enablers and deliverables that are linked to their point of interest.

This allows a roadmap user to understand the journey both forwards and backwards from a point of relevance to them in the roadmap.

The Golden Thread sections of this report include;

Contributing themes – articulate how many Milestones from each Theme contribute to the Golden Thread.

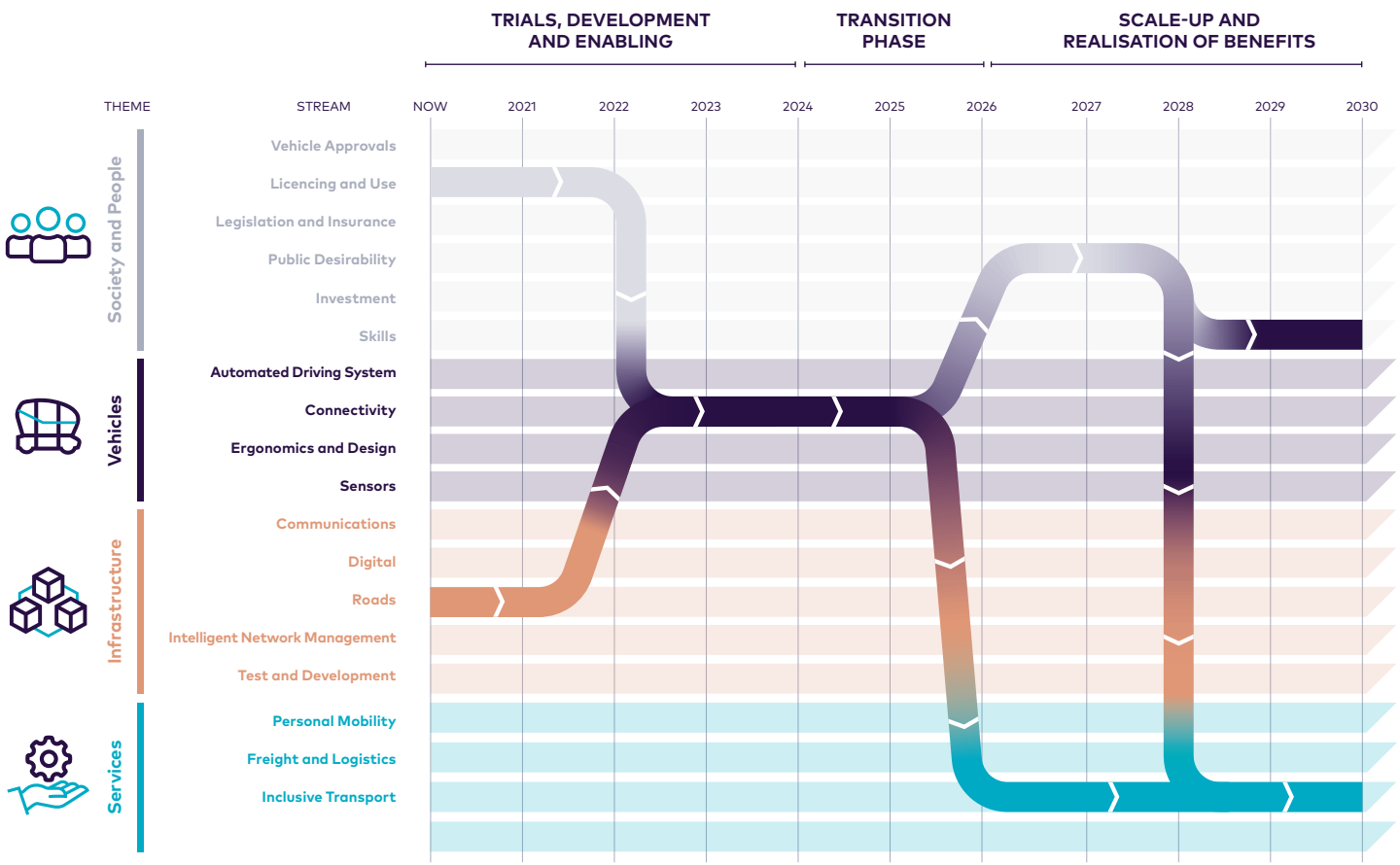
Major deliverables – the culmination of long strands of interdependent Milestones – typically important final deliverables.

Key enablers – the start of Strands that unlock many other Milestones. Typically they are the first step in achieving a significant number of other Milestones.

Critical waypoints – Milestones which sit in the middle of long Strands. Often they are pinch-points with many preceding Milestones enabling them and many deliverables unlocked by them.

These sections are supported by Golden Thread diagrams and deep dives. The diagrams and supporting keys help to visualise the Milestones and Interdependencies within each Golden Thread. The keys feature Milestone IDs which are unique to each Milestone. The deep dives explore the most important elements of each Golden Thread.

For more detail on Golden Threads or to gain further insight on how your project or organisation relates to the Milestones within the roadmap, you can access the interactive roadmap at zenzic.io/roadmap or contact the Zenzic team at info@zenzic.io.



Golden Thread 01

Legislation and Regulation

Introduction

The workshops that informed the creation of the UK Connected and Automated Mobility Roadmap to 2030 were fundamental in demonstrating that building a legislative and regulatory framework to allow the testing, development and deployment of connected and self-driving vehicles and services is crucial. Yet this Golden Thread takes the UK aspiration further – to ensure the UK has a world-class and mature legal and regulatory framework that enables CAM to be deployed at scale.

There are 104 Milestones within this Golden Thread. The majority of these are from the Licencing and Use and Vehicle Approvals Streams. Yet there are also key relationships with insurance, testing, development, infrastructure and different types of vehicles – reflecting the complexity and importance of the Golden Thread.

Contributing themes

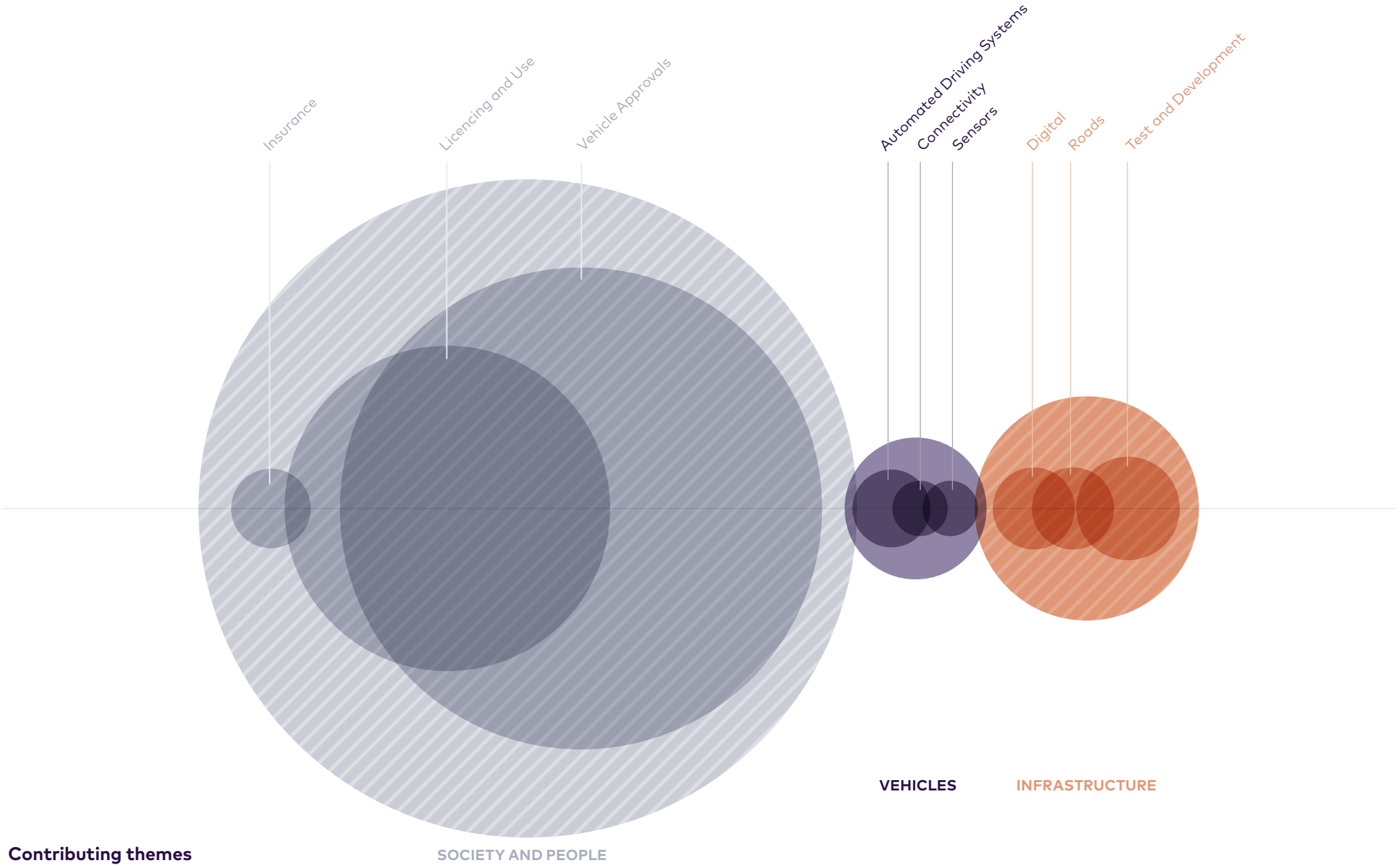
As expected, the majority of Milestones required for the delivery of this Golden Thread can be found within the Society and People Theme (78%), of that, the Licencing and Use, and Vehicle Approvals Streams account for 75%. The second largest Theme contributing to this Golden Thread is Infrastructure, which reflects the changes required to enable the deployment of connected and self-driving vehicles.

104

Key Milestones within Golden Thread 01

"Connected vehicles will bring a huge number of different companies together as CAV technology opens doors to advanced mobility solutions. The roadmap will allow us to see these connections outside our operating domains."

David Price, IDIADA



Contributing themes

Major deliverables

Within this Golden Thread there are several major deliverables, which will enable the UK to have a world-class legal and regulatory framework in place by 2030. In addition, there are Milestones that, although they do not have many Interdependencies, still play a critical role in the delivery of the 2030 Vision. These include clear *Common legal approach for insurance (IN10)*.

The key Strands related to this Golden Thread are:

- *Legislation for clearing road space for automated vehicles (HW17)*
- *Harmonised vehicle approval scheme established (LR57)*
- *Appropriate update cadence established (LR74)*
- *Highly-automated vehicles are more easily able to be on public roads legally (LR30)*
- *Partially-simulated certification in use (LR53)*

"Fast, reliable wireless connections will be at the heart of the future of transport. The roadmap is a vital tool for the UK on its journey towards a more connected transport system – helping bring together the many different players that will need to be involved."

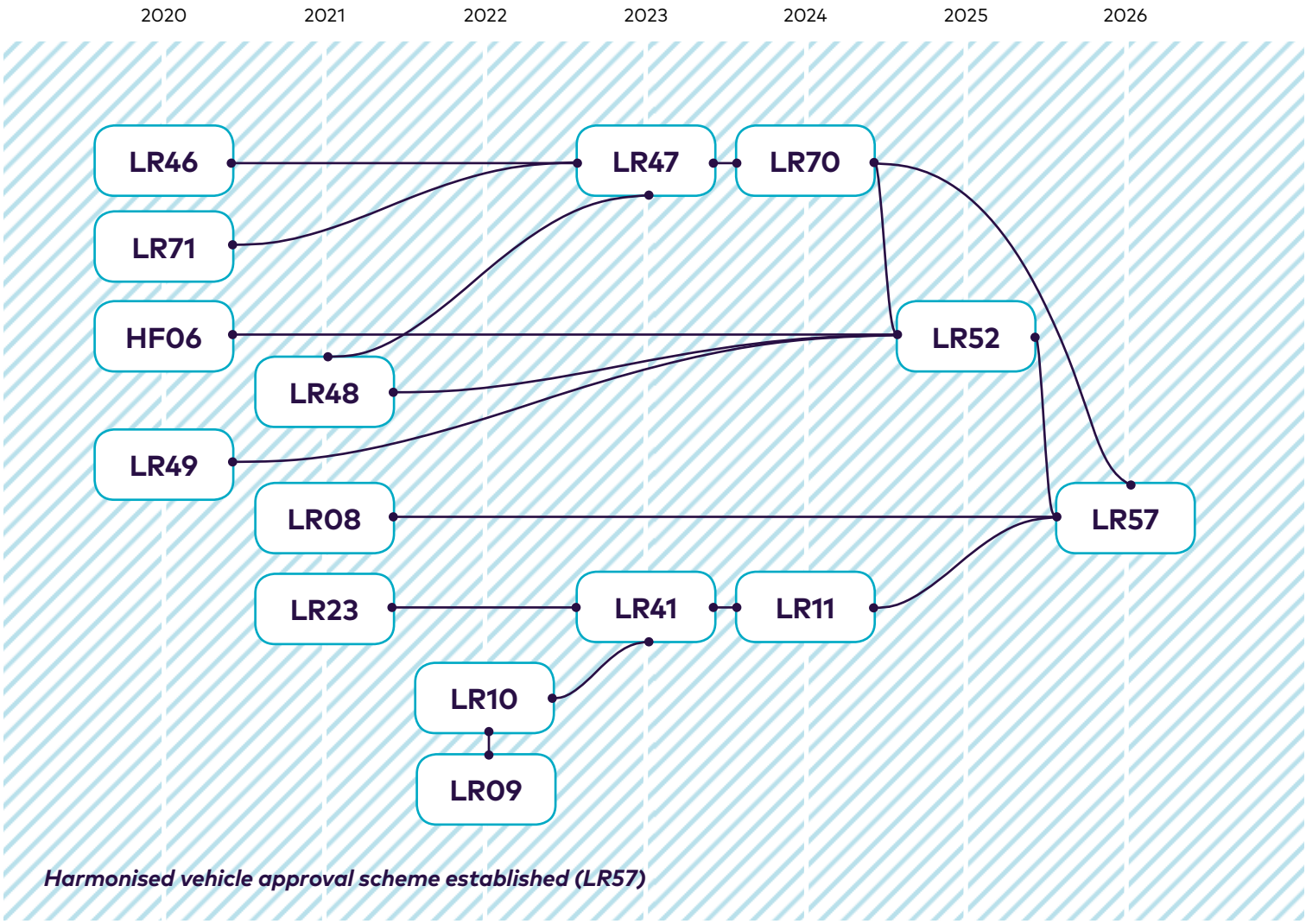
Mansoor Hanif, Ofcom

DEEP DIVE

Harmonised vehicle approval scheme established (LR57)

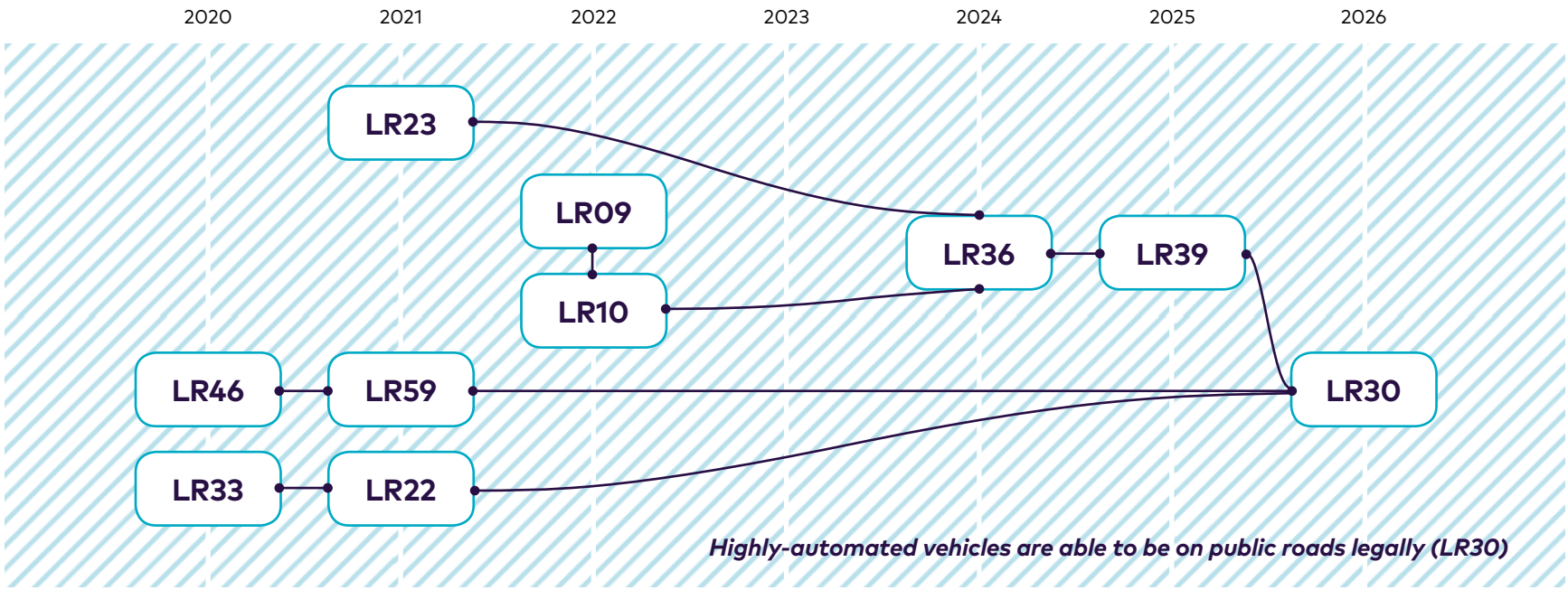
The establishment of a harmonised and holistic approval scheme for self-driving vehicles is a vital major deliverable. All but one Milestone in this Strand come from the Licencing and Use and Vehicle Approvals Streams. This Strand begins with the *Law Commission review into automated vehicles (LR09)*, and subsequent *Law Commission final report (LR10)* in 2022 (Law Commission, 2019). This, in line with the *United Nations Economic Commission for Europe (UNECE) cyber security regulations development (LR23)*, informs the creation of *Policies and legal frameworks in place to allow passenger transport trials (LR41)*, feeding into a wider *Process in place which speeds up new type approval from UNECE (LR11)*. A *Vehicle approval framework for self-driving vehicles (LR48)* leads to a *Small scale national type approval process (LR47), National vehicle approval scheme (LR70)* and ultimately a *Certification methodology in place for CAM (LR52)*.

The only Milestone that does not originate in the Licencing and Use or Vehicle Approvals Streams is *Human factors special interest group established (HF06)*. This Milestone highlights the importance of understanding the needs of special interest groups to enable appropriate type approval of different vehicles and services.



KEY

ID	Milestone	Date
HF06	Human factors special interest group established	2020
LR08	Defined ODD catalogue for type approvals	2021
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR11	Process in place which speeds up new type approval from UNECE	2024
LR23	UNECE cyber security regulations development	2021
LR41	Policies and legal frameworks in place to allow passenger transport trials	2023
LR46	Consistent framework for approval and licencing of self-driving vehicles	2020
LR47	Small scale national type approval process begins	2023
LR48	Vehicle approval framework for self-driving vehicles in place	2021
LR49	Simulation used as part of regulation and certification	2026
LR52	Certification methodology in place for CAM	2028
LR57	Harmonised vehicle approval scheme established	2030
LR70	National vehicle approval scheme	2027
LR71	Digitisation of rules of the road (The Highway Code)	2020



DEEP DIVE

Highly-automated vehicles are able to be on public roads legally (LR30)

This Strand is a contributor in achieving the key deliverable of a world-class legal and regulatory framework that promotes and enables CAM to be deployed at scale. The Law Commission review, and subsequent report (found in Milestones LR09 and LR10) and *UNECE cyber security regulations development (LR23)* are the cornerstone for enabling highly-automated vehicles to be deployed on UK roads. These Milestones feed into *Adapting regulation for highly and fully automated vehicles (LR36)*, which leads to further *Regulation change(s) to allow self-driving vehicles to be used for services (LR39)* by the end of 2024.

A *Consistent framework for approval and licencing of self-driving vehicles (LR46)* and *Robust automated driving system licencing regime at scale (LR59)* need to be established. Whilst the regulations and legislation are being built to enable on-the-road use, the way vehicles interact and understand the *Rules of the road for shared spaces in urban areas (LR33)* needs to be determined. This will *Legalise the ability for pods to cross public roads at designated points (LR22)* by 2021. These Milestones culminate with highly-automated vehicles being legally able to drive on public roads in the UK by the mid-2020s.

KEY

ID	Milestone	Date
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR22	Legal ability for pods to cross public roads at designated points	2021
LR23	UNECE cyber security regulations development	2021
LR30	Highly-automated vehicles are more easily able to be on public roads legally	2026
LR33	Rules of road established for shared spaces in urban areas	2020
LR39	Adapting regulation for highly and fully automated vehicles	2025
LR36	Regulation change(s) to allow self-driving vehicles to be used for services	2024
LR46	Consistent framework for approval and licencing of self-driving vehicles	2020
LR59	Robust automated driving system licencing regime at scale	2021

"This roadmap complements Highways England's vision for the future. Providing better connected roads and vehicles, using new technologies, will help us make great improvements to everyone's journeys, improving safety and cutting congestion."

Joanna White, Highways England

Key enablers

Within this Golden Thread, several key enablers exist to facilitate the UK's aim of having a world-class legal and regulatory framework in place by 2030. These Milestones are catalysts; they unlock a further chain of Milestones. The key Strands related to this Golden Thread are:

- *First code of practice for CAM services (MS03)*
- *Baseline policy and standards established (LR05)*
- *UNECE cyber security regulations development (LR23)*
- *Vehicle approval framework for self-driving vehicles in place (LR48)*
- *Consistent framework for approval and licencing of self-driving vehicles (LR46)*
- *Agreed safety standards (LR17)*
- *Digitisation of rules of the road (The Highway Code) (LR71)*

"The roadmap is a tool that will ensure government and industry are aligned in the future planning around autonomous vehicles, ensuring all factors from a regulatory, legislative and social perspective are considered throughout the process."

Graeme Smith, Oxbotica

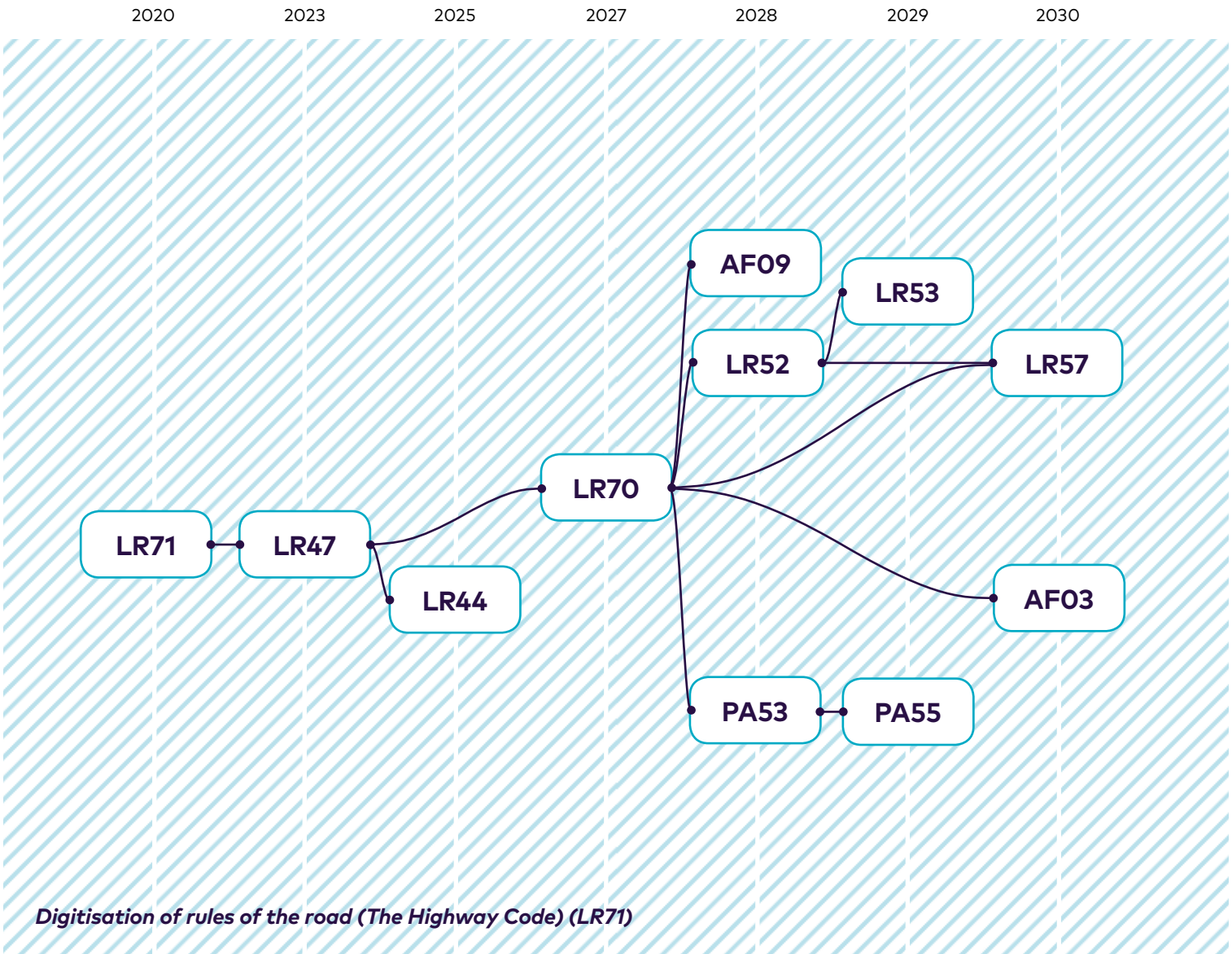
DEEP DIVE

Digitisation of rules of the road (The Highway Code) (LR71)

It is expected that connected and self-driving vehicles use a digital version of The Highway Code – the rules of the road. This would ensure vehicles obey traffic orders and follow restrictions placed upon them in certain locations and times. This plays an important role in enabling this Golden Thread, as a regulatory key that unlocks connected and self-driving vehicles to be deployed at scale.

Digitisation of rules of the road (LR71) enables *Small scale national type approval process (LR47)* to begin in 2021, as vehicles are able to understand (and in turn be tested on their knowledge of) the rules of the road. As this scales up to a *National vehicle approval scheme (LR70)* it further unlocks specific validation and certification capabilities (found in Milestones LR52 and AF03), as well as informing the wider international *Harmonised vehicle approval scheme (LR57)*.

Overall, the digitisation of the rules of the road is a key enabler to ensure the UK has a world-class, mature legal and regulatory framework that promotes and enables CAM to be deployed at scale.



KEY

ID	Milestone	Date
AF03	Verification that AI and sensor fusion algorithms are able to self-determine exceedance of ODD	2030
AF09	AI interprets and mimics human behaviour	2028
LR44	Independent validation methodology established	2025
LR47	Small scale national type approval process begins	2023
LR52	Certification methodology in place for CAM	2028
LR53	Part simulated certification in use	2029
LR57	Harmonised vehicle approval scheme established	2030
LR70	National vehicle approval scheme	2027
LR71	Digitisation of rules of the road (The Highway Code)	2020
PA53	Public gain exposure to self-driving vehicles and feel safe	2028
PA55	Evidence of safety record begins to show	2029

DEEP DIVE

Baseline policy and standards established (LR05)

The establishment of *Baseline policy and standards (LR05)*, realised towards the end of 2022, is a key enabler of this Golden Thread. Initially, *Baseline policy and standards (LR05)* enables four Milestones. Two of which are related to the establishment of stable standards *(Draft standards and regulation in place (LR24)* and *Wider international standards and governance established (LR12)*). A further two Milestones relate to the establishment of standards and test methods specifically for AI and ML *(Develop software standards for AI and ML code (AF11)*, *Develop methods for testing AI and ML systems (AF01)*.

In turn, particularly from *Wider international standards and governance established (LR12)*, the first set of *Stable standards and regulations now in place (LR66)* will be delivered by the end of 2029. This will ensure the UK has a world-class mature legal and regulatory framework that promotes and enables CAM to be deployed at scale. In addition, the significance of the stable standards leads to impacts on highway infrastructure design with *Revised highway safety and design standards (HW11)* and *Legislation for clearing road space for automated vehicles (HW17)* in place by 2030.

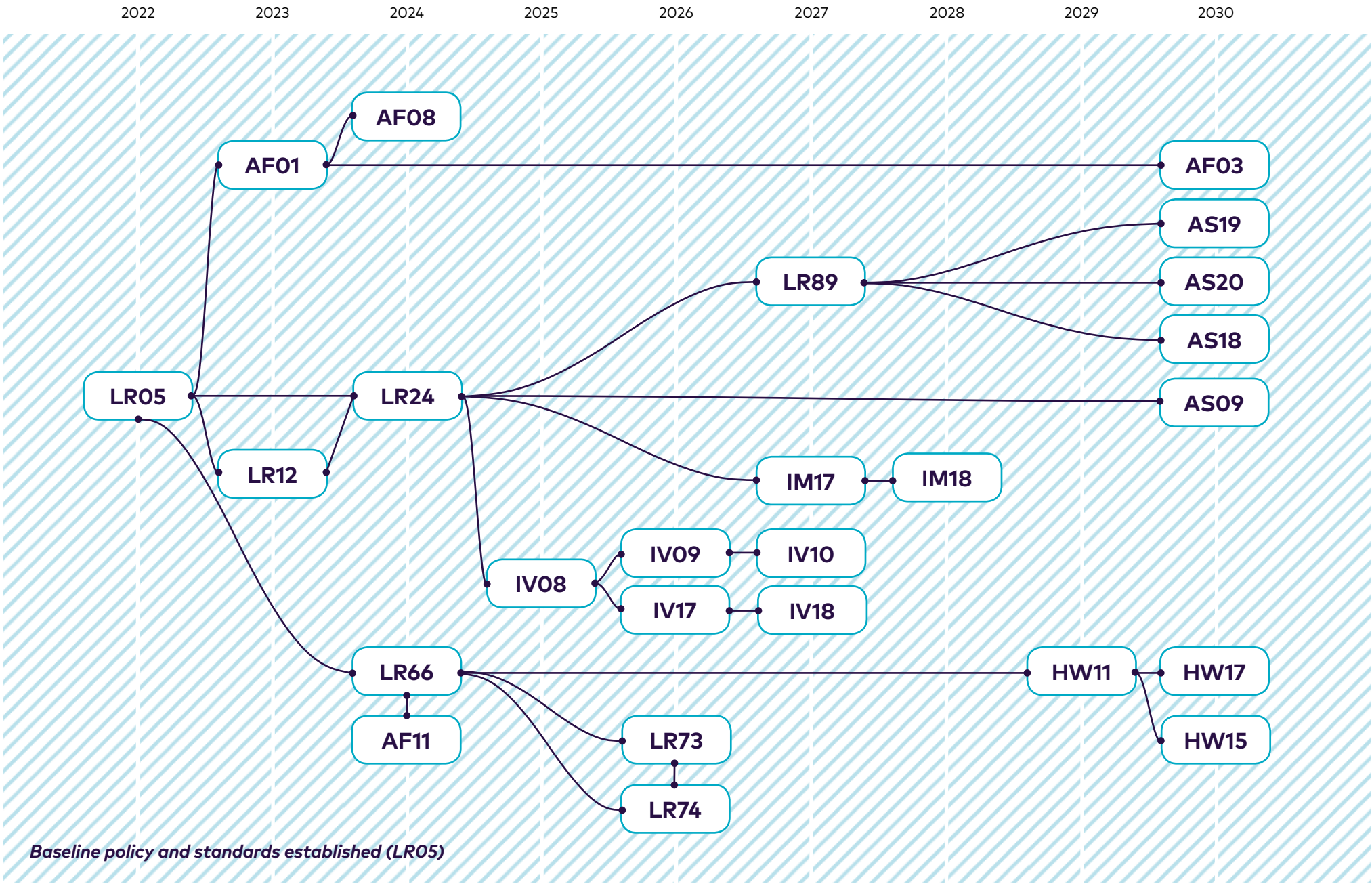
"CAVs will touch all of DVSA's services. This roadmap will help us to identify when to develop those services so they continue to support road safety in GB."

Bob Hannigan, DVSA

KEY

ID	Milestone	Date
AF01	Develop methods for testing AI and ML systems	2023
AF03	Verification that AI and sensor fusion algorithms are able to self-determine exceedance of ODD	2030
AF08	Non-deterministic AI trusted when balancing safety benefits	2024
AF11	Develop software standards for AI and ML code	2024
AS09	Passenger car assistive features for traffic congestion	2030
AS18	Develop fully automated passenger cars	2030
AS19	Develop fully automated buses and shuttles	2030
AS20	Develop fully automated freight vehicles	2030
HW11	Revised highway safety and design standards	2029
HW15	Reduced headway and width standards	2030
HW17	Legislation for clearing road space for automated vehicles	2030
IM17	CAM travel patterns identify limiting factors of current city design	2027
IM18	New city planning methods enable more efficient CAM travel	2028

ID	Milestone	Date
IV08	UK develops capabilities which are globally relevant	2025
IV09	UK provides core supply chain support to international customers	2026
IV10	Export in CAM increases	2027
IV17	UK provides international best practice capability	2026
IV18	UK delivers knowledge capability internationally	2027
LR05	Baseline policy and standards established	2022
LR12	Wider international standards and governance established	2023
LR24	Draft standards and regulation in place	2024
LR66	Stable standards and regulations now in place	2024
LR73	Framework in place to review legislation, regulation, standards and policies	2026
LR74	Appropriate update cadence established	2026
LR89	Self-driving vehicle are able to respond to emergency services	2027


2022
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AS09
LR12
IM17
IM18
IV09
IV10
IV08
IV17
IV18
LR66
HW11
HW17
AF11
LR73
HW15
LR74
Baseline policy and standards established (LR05)

Critical waypoints

This Golden Thread does not contain many critical waypoints. Most Strands within this Golden Thread are either key enablers or major deliverables. There are only three Milestones that could be considered critical waypoints:

- *Trials of CAM in multiple environments and differing economic models (LR37)*
- *CAM service licencing framework established (LR34)*
- *Development of MaaS regulations begins (LR13)*

"We believe autonomy will be an important part of the future mobility system for Cambridge. The UK CAM roadmap will support our planning processes and deployment of autonomous vehicles."

Dan Clarke, Cambridgeshire County Council

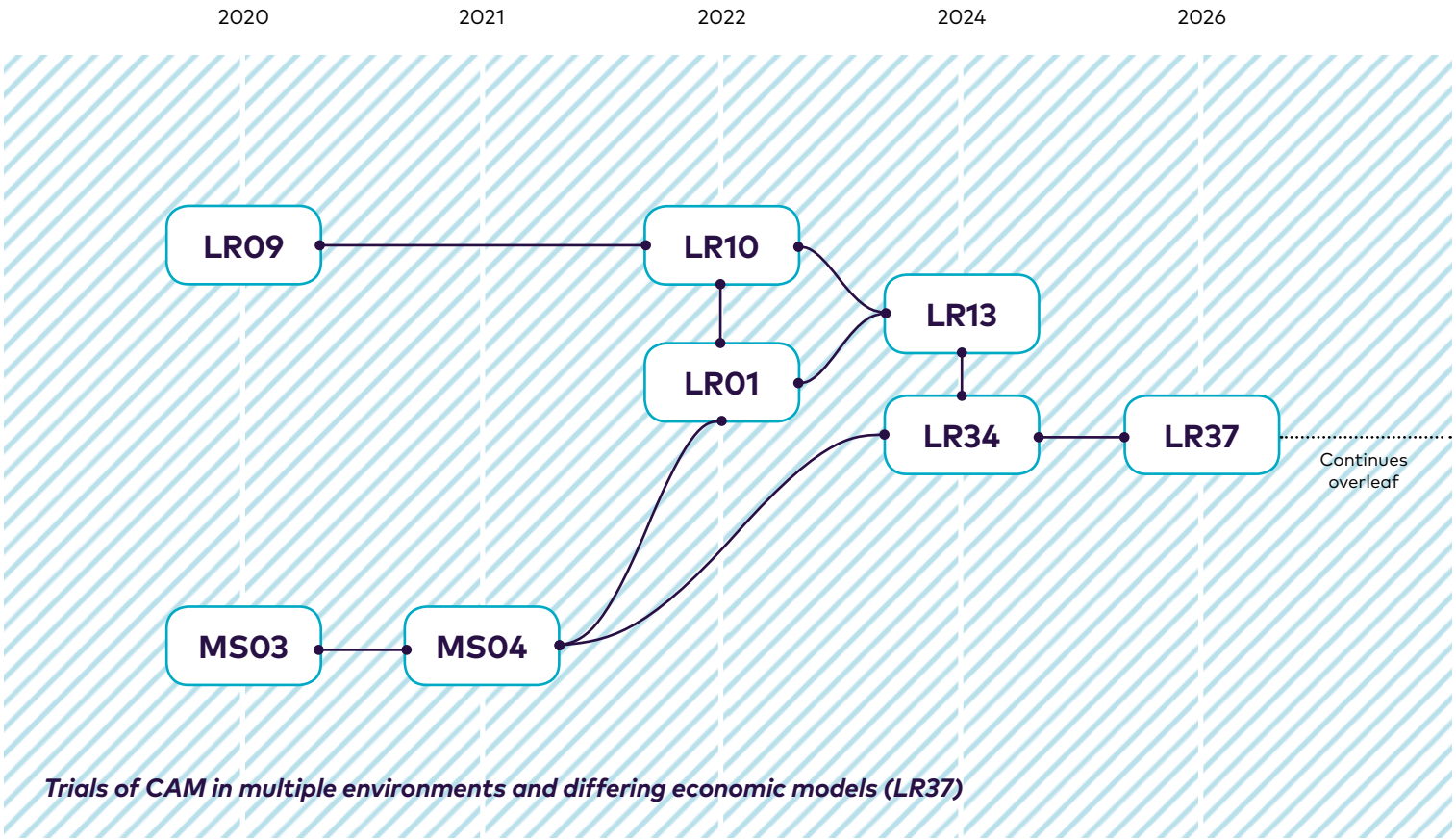
DEEP DIVE

Trials of CAM in multiple environments and differing economic models (LR37)

All the Interdependencies preceding this critical waypoint play a role in ensuring that the UK has a world-class legal and regulatory framework in place by 2030. This critical waypoint takes place in the mid-2020s once regulations have been established, to begin the trialling of such technologies and services. The first key Milestone is the *Law Commission final report (LR10)* which feeds into establishing MaaS regulations and governance by the end of 2024 (found in Milestones LR01, LR13 and LR34). The *Guidance issued by local authorities on adoption of MaaS (MS04)* is likely to be developed by the end of 2020, which would include the *First code of practice for CAM services (MS03)*. These Milestones enable *Trials of CAM in multiple environments and differing economic models (LR37)*.

On completion, it is expected that the learning and knowledge gained from these trials is likely to unlock seven individual Milestones – two of which contribute to this Golden Thread; *Revised highway safety and design standards (HW11)*, as well as *Legislation for clearing road space for automated vehicles (HW17)*.

It is clear from this analysis that trials are crucial both as a mechanism to test and evolve the enabling regulations, but also to unlock understanding which informs the operational environment within which CAM will be deployed.

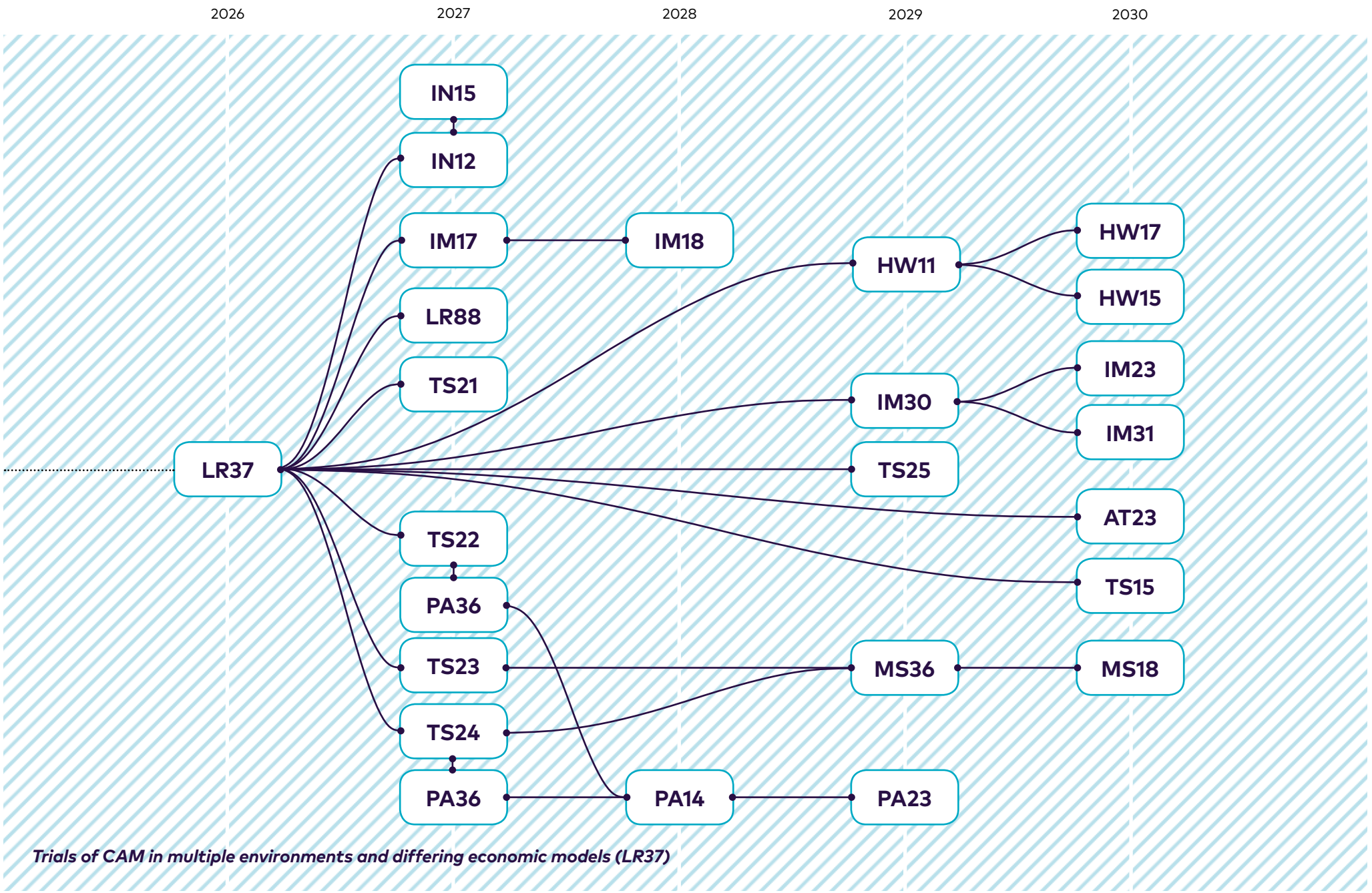


KEY

ID	Milestone	Date
LR01	MaaS regulation exploration	2022
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR13	Development of MaaS regulations begins	2024
LR34	CAM service licencing framework established	2024
LR37	Trials of CAM in multiple environments and differing economic models	2026
MS03	First code of practice for CAM services	2020
MS04	Guidance issued by local authorities on adoption of MaaS	2021

"CAM success requires incisive system thinking. Legislation & regulation are key; they must mesh with society's needs, technology and infrastructure. The roadmap gives us insight to those connections and unlocks decision making."

Chris Jackson, Burges Salmon


2026
2027
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2030
Golden Thread 01 – Legislation and Regulation
LR37
IN15
IN12
IM17
LR88
TS21
IM18
HW11
IM30
TS25
TS22
PA36
TS23
TS24
PA36
PA14
PA23
MS36
MS18
HW17
HW15
IM23
IM31
AT23
TS15
Trials of CAM in multiple environments and differing economic models (LR37)

KEY

ID	Milestone	Date
AT23	Trials and development of rural services	2030
HW11	Revised highway safety and design standards	2029
HW15	Reduced headway and width standards	2030
HW17	Legislation for clearing road space for automated vehicles	2030
IM17	CAM travel patterns identify limiting factors of current city design	2027
IM18	New city planning methods enable more efficient CAM travel	2028
IM23	Ongoing understanding of new travel patterns for CAM	2030
IM30	CAM deployments inform emerging travel patterns	2029
IM31	CAM integrated into travel demand management	2030
IN12	Continued development of actuarial models	2027
IN15	Self-driving insurance cheaper than human driven	2027
LR37	Trials of CAM in multiple environments and differing economic models	2026

ID	Milestone	Date
LR88	Definition of national-scale incident response plan	2027
MS18	Measurable growth of CAM services	2030
MS36	CAM is commercially viable and operationally preferable	2029
PA14	Start of public trust in CAM	2028
PA23	Public acceptance at 85%	2029
PA36	Determine if a clear, independent regulator is needed for trust	2027
TS15	Common CAM routing options established	2030
TS21	Outcome based service provision	2027
TS22	CAM cheaper option over traditional transport mode	2027
TS23	Proven superior safety record than traditional road services	2027
TS24	Smoother and more convenient journeys	2027
TS25	CAM services begin to scale due to decrease in implementation cost	2029

Summary

The UK is already widely acknowledged as a world-leader in legislation and regulation (SMMT, 2019). However, this Golden Thread explores the important and complex relationships required to ensure the UK maintains its leadership role, creating a world-class legal and regulatory framework that promotes and enables connected and self-driving vehicles to be deployed at scale.

The regulations, standards and legislation required to evolve self-driving vehicles and CAM services are often cited as key enablers for the development, trialling and deployment of these technologies and services. This Golden Thread confirms this view and it is vital the UK continues to develop strong legislation and regulation in this sector.

"BSI welcomes the launch of the UK Connected and Automated Mobility Roadmap which highlights the central role that standards play in realising the safe deployment of automated vehicles and mobility services for the benefit of industry and society."

Nick Fleming, BSI

Golden Thread 02
Safety

Introduction

Delivering inclusivity, underpinned by the core principle of safe and secure by design, is reliant on the success of interrelated initiatives identified within the roadmap. The core Themes of Society & People, Vehicles, Infrastructure and Services all contribute key deliverables to achieve an ecosystem that is both safe and secure. This Golden Thread explores these recurring Themes through a 'lens' of safety. By developing Golden Threads, the important outcomes, dependencies and critical waypoints are signposted.

The UK already has an enviable reputation throughout the world for its safety record and the associated frameworks. Despite this, on British roads alone, five people are killed and 75 seriously injured on a daily basis (DfT, 2018d).

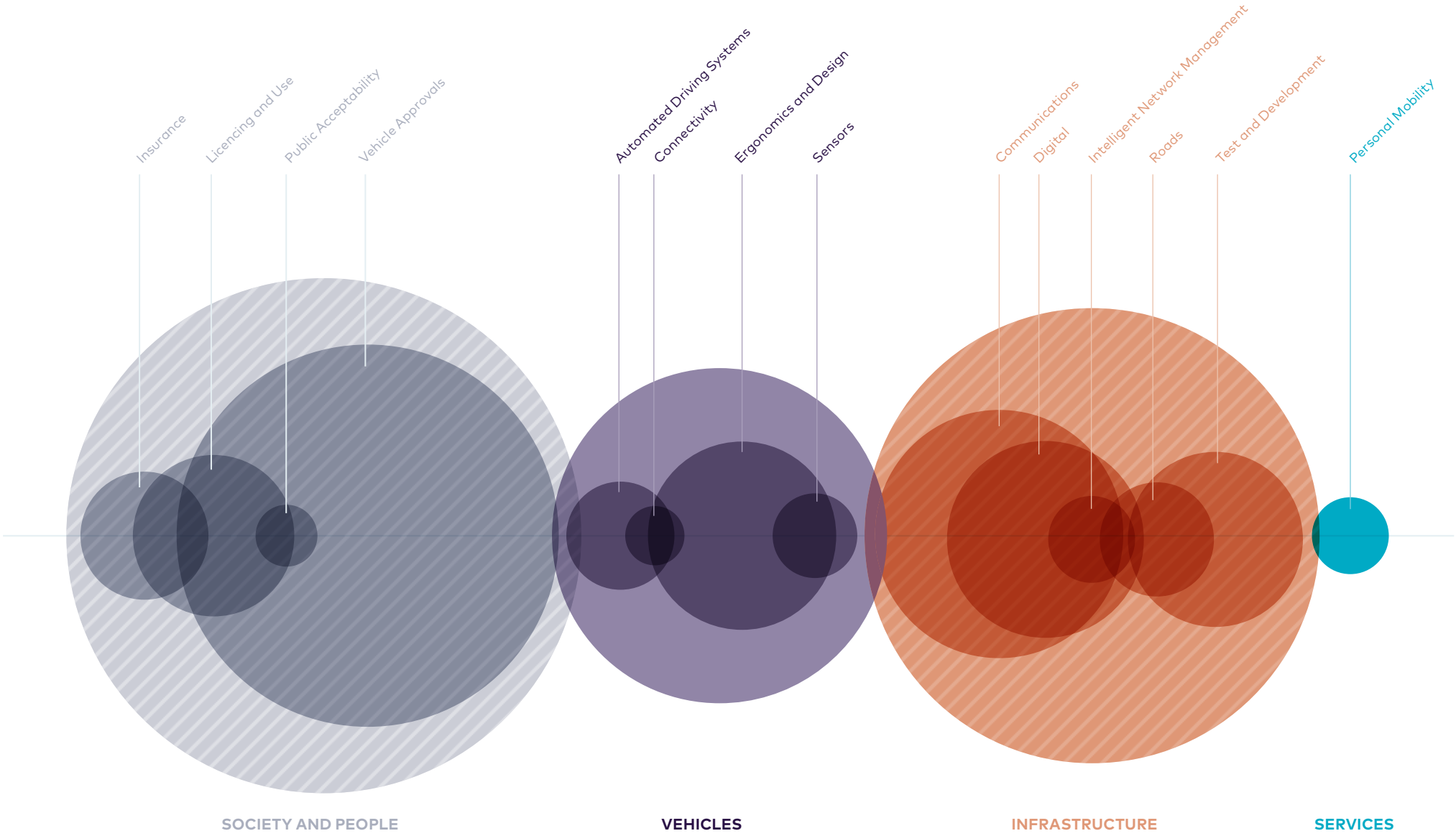
Research by the World Health Organisation (WHO, 2018) has found 85% of all road collisions resulting in personal injury involved human error, signposting the opportunity for automated mobility. Clearly, connected and self-driving vehicles represent an opportunity to significantly improve road safety by removing the opportunity for human error. Research has shown that evidence of a robust safety record and widespread belief in the safety benefits of connected and self-driving vehicles is antecedent to widespread public acceptance of self-driving vehicles. *Evidence of safety record begins to show (PA55)* will require not only a demonstrable record of improved safety, but also credible data security. This will demonstrate transparency to the public regarding the use of data, as well as a clear understanding of how it will be used.

Contributing themes

Society and people is the dominant Theme, but this Golden Thread also gains significant influence from the Infrastructure and Vehicle Themes. Whilst the Services Theme may contribute to building public acceptability of CAM, it will not directly contribute to the Safety Golden Thread, rather it is dependent on safety to deliver trusted and desirable services. The key challenge for players across the entire CAM ecosystem lies in achieving defined levels of safety, for example minimising residual risk to an acceptable level for consumers and regulators alike.

"The Zenzic roadmap complements our view that consistent, authoritative and trusted geospatial data and standards will underpin the framework for safe testing, operation and interoperability."

Simon Navin, Ordnance Survey



Contributing themes

Major deliverables

Major deliverables that will bring about the connected and self-driving benefits of safety and security are:

- *Legislation for clearing road space for automated vehicles (HW17)*
- *Revised highway safety and design standards (HW11)*
- *Harmonised vehicle approval scheme established (LR57)*
- *Evidence of safety record begins to show (PA55)*
- *Validation process highly automated (SN15)*

A public education programme may be required to secure acceptance through the gradual exposure to self-driving vehicles. Lessons learned from the introduction of Advanced driver-assistance systems (ADAS) suggest that consumer understanding of safety and security is one of the primary challenges impeding faster market acceptance (McKinsey, 2016).

Adoption of self-driving vehicles requires *Revised highway safety and design standards (HW11)*. The roadmap identifies outcomes such as vehicle community consensus on minimum safe highway infrastructure, baseline policy and standards supported by regulation.

The two deep dives illustrated below give examples of complex and interrelated factors that contribute to safe and secure connected and self-driving capabilities. Whilst by no means exhaustive, the intent of these examples is to demonstrate how the roadmap signposts key activities, and illustrate an approximate timescale of when these need to be delivered in order to achieve the 2030 Vision.

"The roadmap emphasises the need for many diverse spheres (technology, society and business models) to progress in parallel to meet the 2030 vision for connected and autonomous vehicles (CAVs), which requires collaboration across-sectors."

Paul Jennings, Warwick Manufacturing Group

"UK leadership in connected and self-driving vehicles has the potential to transform our transport network and attract billions of investment to the UK.

The UK is a global leader in the development and safe testing of this technology, thanks to collaboration between government, industry and academia.

Zenzic's roadmap is a fantastic example of the public and private sector working together to shape the future of connected and self-driving technologies – and demonstrate the UK as a world leading test-bed in 21stC Mobility."

Future of Transport Minister George Freeman

DEEP DIVE

Legislation for clearing road space for automated vehicles (HW17)

McKinsey, (2016) identifies regulatory reform and regulation, favourable to automated mobility, as a key enabler for developing vehicle safety assurance concepts. Rethinking vehicle safety assurance must deliver a *Certification methodology in place for CAM (LR52)*. Achieving this requires approval framework for self-driving vehicles as a precursor to a *National vehicle approval scheme (LR70)*.

The first step in this Strand is a comprehensive review of the legal landscape for connected and self-driving vehicles. CCAV has commissioned the far-reaching *Law Commission review into automated vehicles (LR09)*, including their use as part of public transport networks and on-demand passenger services. Launched in 2018, the Law Commission review has now delivered interim findings, arising from the analysis of 178 responses, noting that a connected and self-driving safety assurance scheme would need to go beyond the initial safety of the vehicle itself. Delivering *Baseline policy and standards (LR05)* will lead to wider standards and governance by 2022.

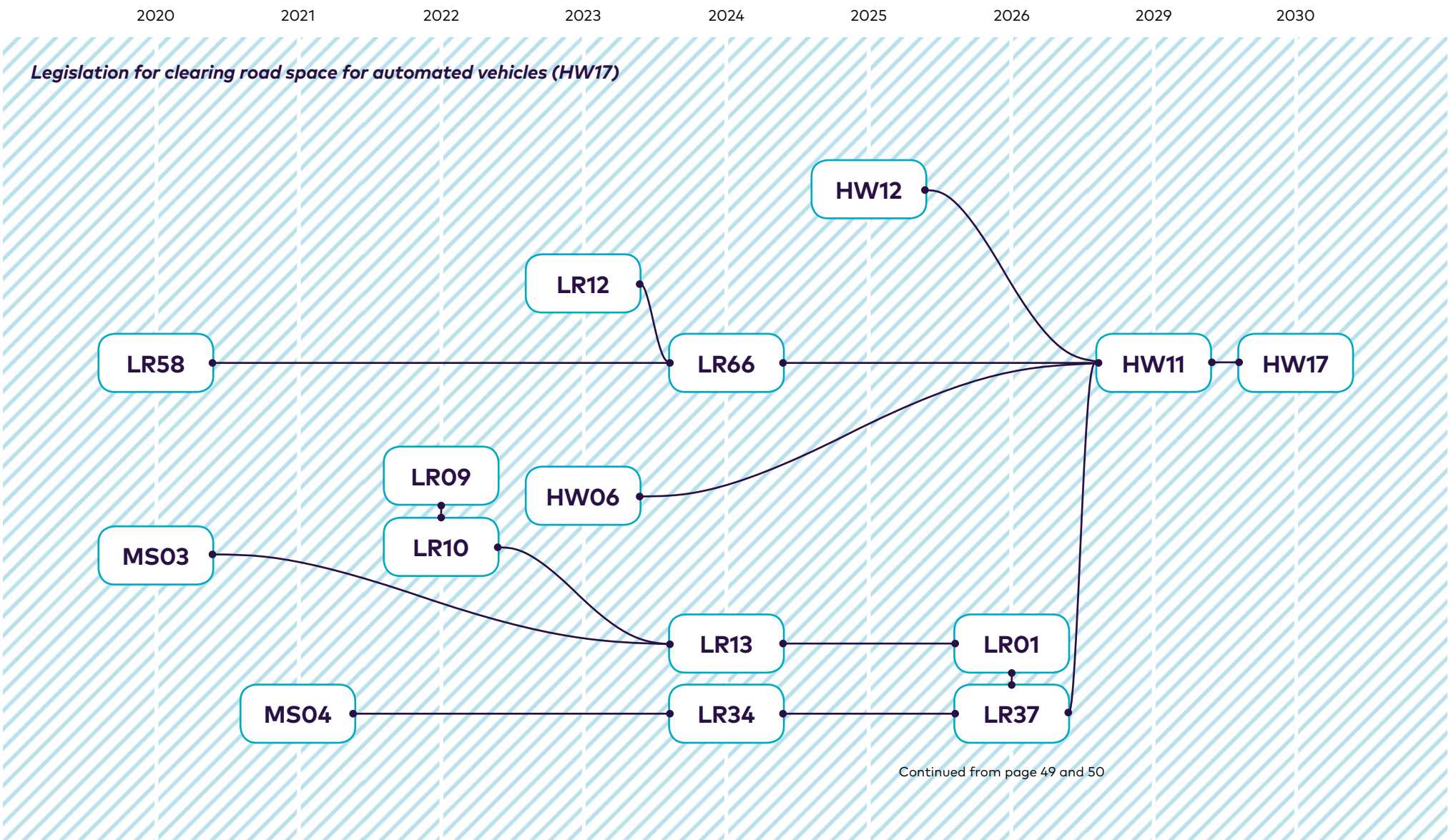
Developing the *First code of practice for CAM services (MS03)* in 2019 is critical to rethinking personal transport, and is arguably a key driver for connected and integrated mobility solutions. Building upon the experience of that local code of practice, it is expected that *Development of MaaS regulations (LR13)* begins in 2023, leading to a *CAM service licencing framework established (LR34)* by 2024. With a legal mandate for using connected and self-driving vehicles on the road comes the opportunity to explore *Trials of CAM in multiple environments and differing economic models (LR37)* by 2026. *Revised highway safety and design standards (HW11)* will be completed by 2029.

"Building on the vision of our 2017 Roadmap, this work now highlights how the UK can be amongst the first to benefit from connected and autonomous mobility, both safely and securely."

David Skipp, Automotive Council UK

KEY

ID	Milestone	Date
HW06	New minimum highway standards understood	2023
HW11	Revised highway safety and design standards	2029
HW12	Translate Traffic Signs Manual for CAM	2025
HW17	Legislation for clearing road space for automated vehicles	2030
LR01	MaaS regulation exploration	2026
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR12	Wider international standards and governance established	2023
LR13	Development of MaaS regulations begins	2024
LR34	CAM service licencing framework established	2024
LR37	Trials of CAM in multiple environments and differing economic models	2026
LR58	Version 2 of standards and regulations developed	2020
LR66	Stable standards and regulations now in place	2024
MS03	First code of practice for CAM services	2020
MS04	Guidance issued by local authorities on adoption of MaaS	2021



Continued from page 49 and 50

DEEP DIVE

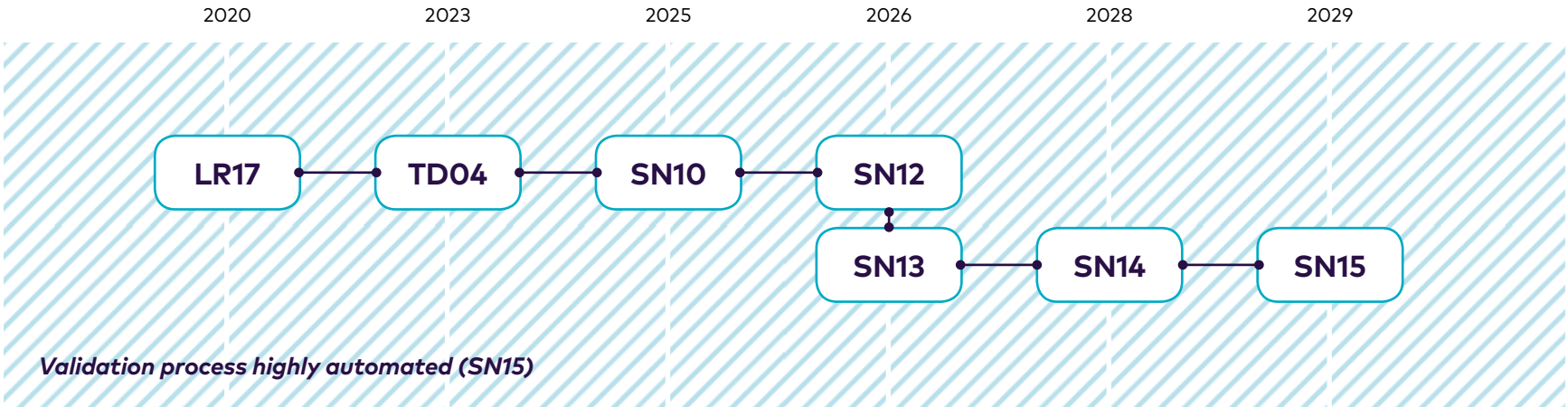
Validation process highly automated (SN15)

When examining the contributing Themes, it is evident the Vehicle Theme goes beyond consideration of vehicle architecture and technology design. Although achieving fully automated passenger cars is dependent, to some extent, on vehicle and sensor technology advancement, there is a greater reliance on creating an ecosystem that enables the safe operation of self-driving vehicles. Work is ongoing, to determine taxonomy, agreed defined terms and lexicon evident in (Milestone AS21). Once clarity of terms are agreed, the ecosystem can then develop a B*est practice and definitions report for different ODD elements (AS22)* by 2022.

This Strand is highly reliant on the convergence of vehicle architecture and sensor technology, with *Agreed safety standards (LR17)* and the need to *Establish a UK sensor test facility (TD04)* being clear examples of this. A process of agreement on relevant sensor technologies needed for ADS perception (lidar, radar, camera, ultrasonic), is ongoing, with direction expected by the end of 2020. Delivery of a sensor validation process requires *Sensor recognition testing (SN10)*. With a *Validation lifecycle process established (SN13)* by 2026 there is opportunity to refine and deploy a highly-automated validation process. Findings from these tests will inform the validation process, with this Strand expected to reach maturity in 2029.

KEY

ID	Milestone	Date
LR17	Agreed safety standards	2020
SN10	Sensor recognition testing	2025
SN12	Findings inform validation process	2026
SN13	Validation lifecycle process established	2026
SN14	Validation process deployed across UK	2028
SN15	Validation process highly automated	2029
TD04	Establish UK sensor test facility	2023



Key enablers

The roadmap shows there are several key enablers, these are early deliverables that enable significant follow-on initiatives to start, as illustrated below.

The key Strands related to this Golden Thread are:

- *Law Commission final report (LR10)*
- *UNECE cyber security regulations development (LR23)*
- *Agreed safety standards (LR17)*

"This useful tool will help us navigate the uncertainty of innovation in this complex environment. It looks across multiple pathways connecting diverse interests for the first time."

Peter Stoker, Millbrook

DEEP DIVE

Law Commission final report (LR10)

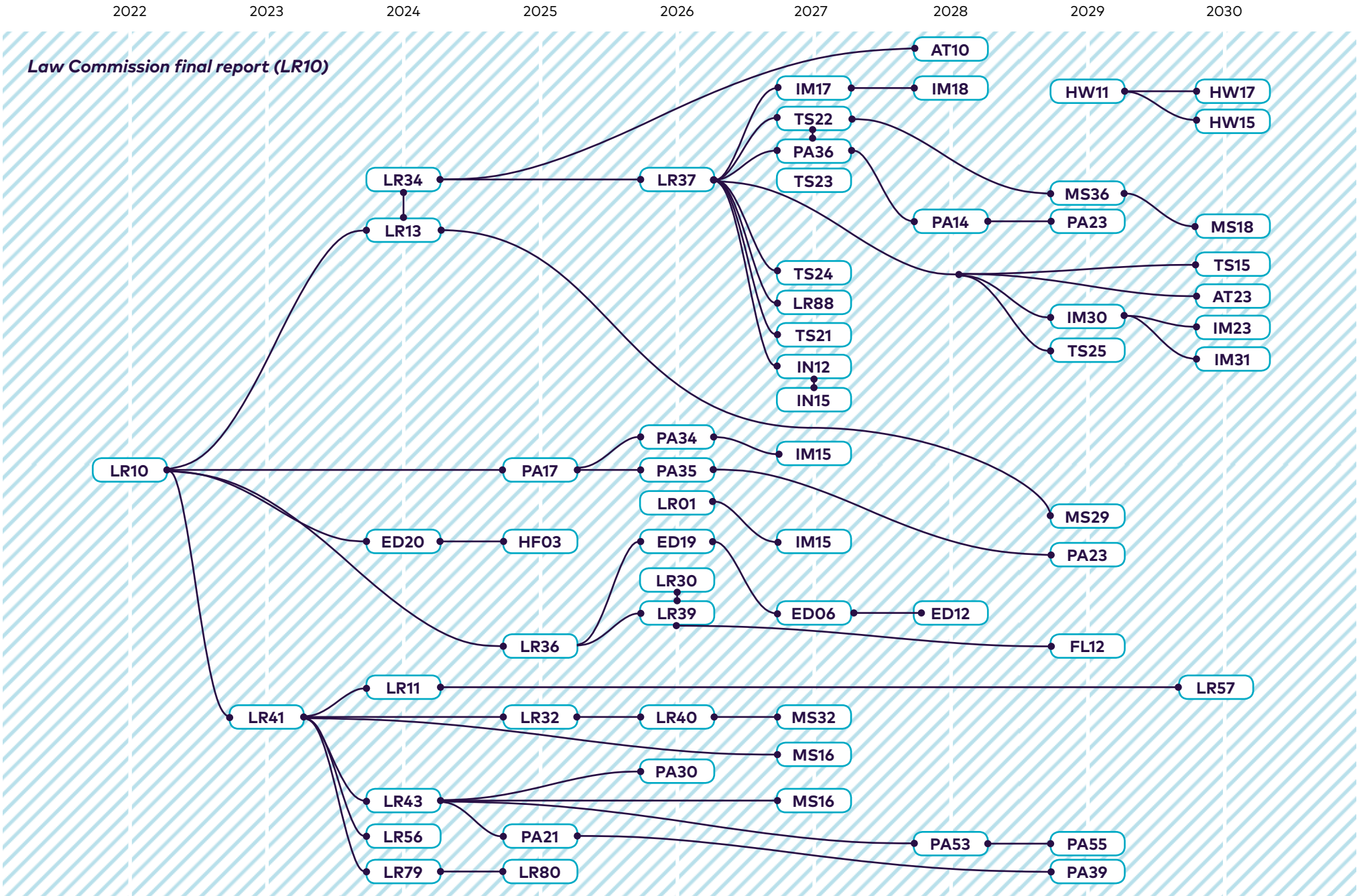
The *Law Commission review into automated vehicles (LR09)* is an important precursor to this Strand. It unlocks the thinking and preparation for connected and self-driving vehicles. Whilst the review process is ongoing, the final report is expected in quarter one of 2022. It is the single largest key enabler in the roadmap, unlocking 110 unique Milestones across many Themes and Streams. This Strand is too large to describe fully, but some key elements are covered below.

Having a *CAM service licencing framework established (LR34)* by early 2024, unlocks *Trials of CAM in multiple environments and differing economic models (LR37)*. These trials inform the design of future CAM services as part of MaaS (found within Milestones *TS21-25*). The certification framework *(LR34)* also unlocks *New city planning methods that enable more efficient CAM travel (IM18)*.

Pricing and policy that discourage private journeys (IM15), together with an insurance model that makes *Self-driving insurance cheaper than human driven (IN15)* will be rewarding drivers by 2030. Public acceptability is unlocked through the active participation of passengers who experience first hand the benefits of CAM, leading to *Public acceptance at 85% (PA23)* from 2028.

The roadmap conceptualises the potential future of mobility following the digitisation of our transport systems and highlights the societal benefits – safety, efficiency, health, environment and accessibility.

Richard Cuerden, TRL


2022
2023
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2025
2026
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2029
2030
Law Commission final report (LR10)
Golden Thread 02 – Safety
LR10
LR34
LR13
LR37
AT10
IM17
IM18
TS22
PA36
TS23
PA14
PA23
HW11
HW17
HW15
MS36
MS18
TS15
AT23
IM30
IM23
IM31
TS25
TS24
LR88
TS21
IN12
IN15
PA17
PA34
PA35
IM15
MS29
PA23
LR01
IM15
ED20
HF03
ED19
LR30
LR39
ED06
ED12
FL12
LR36
LR41
LR11
LR57
LR32
LR40
MS32
MS16
PA30
LR43
MS16
LR56
PA21
PA53
PA55
LR79
LR80
PA39

KEY

ID	Milestone	Date
AT10	New demand-responsive CAM services	2028
AT23	Trials and development of rural services	2030
ED06	Legal considerations for new seating positions and passenger design space	2027
ED12	Revise legislation on vehicle interior	2028
ED19	Highly-automated vehicles with no steering wheel start to appear on public roads	2026
ED20	Human behavioural models developed	2024
FL12	Consolidation of movement of freight and people	2029
HF03	Large scale trials completed to understand external human behaviour and interaction	2025
HW11	Revised highway safety and design standards	2029
HW15	Reduced headway and width standards	2030
HW17	Legislation for clearing road space for automated vehicles	2030
IM15	Pricing and policy discourage private journeys	2027
IM17	CAM travel patterns identify limiting factors of current city design	2027
IM18	New city planning methods enable more efficient CAM travel	2028
IM23	Ongoing understanding of new travel patterns for CAM	2030
IM30	CAM deployments inform emerging travel patterns	2029
IM31	CAM integrated into travel demand management	2030
IN12	Continued development of actuarial models	2027
IN15	Self-driving insurance cheaper than human driven	2027

ID	Milestone	Date
LR01	MaaS regulation exploration	2026
LR10	Law Commission final report	2022
LR11	Process in place which speeds up new type approval from UNECE	2024
LR13	Development of MaaS regulations begins	2024
LR30	Highly-automated vehicles are more easily able to be on public roads legally	2026
LR32	Alignment of future of mobility requirements around micro-mobility	2025
LR34	CAM service licencing framework established	2024
LR36	Adapting regulation for highly and fully automated vehicles	2025
LR37	Trials of CAM in multiple environments and differing economic models	2026
LR39	Regulation change(s) to allow self-driving vehicles to be used for services	2024
LR40	Mandatory coordination and integration of local authorities services	2026
LR41	Policies and legal frameworks in place to allow passenger transport trials	2023
LR43	Requirements for licencing captured from CAM trials	2024
LR56	Updated EU regulations for CAM	2024
LR57	Harmonised vehicle approval scheme established	2030
LR79	Best practice informs national standards	2024
LR80	UK safety case adoption feeds into global standards	2025
LR88	Definition of national-scale incident response plan	2027
MS16	Commercial trials findings inform regulation	2027

ID	Milestone	Date
MS18	Measurable growth of CAM services	2030
MS29	Seamless ticketing	2029
MS32	Highly demand-responsive transport services enabled	2027
MS36	CAM is commercially viable and operationally preferable	2029
PA14	Start of public trust in CAM	2028
PA17	The majority of society is bought into CAM	2025
PA21	Evidence lead discussion on safety benefits already being delivered	2025
PA23	Public acceptance at 85%	2029
PA30	Self-driving vehicles are no longer noteworthy	2026
PA34	More self-driving vehicles than traditional vehicles registered per year	2026
PA35	Approval rating above 65% for fully automated vehicles	2026
PA36	Determine if a clear, independent regulator is needed for trust	2027
PA39	Behaviours around CAM have changed to the positive	2029
PA53	Public gain exposure to self-driving vehicles and feel safe	2028
PA55	Evidence of safety record begins to show	2029
TS15	Common CAM routing options established	2030
TS21	Outcome based service provision	2027
TS22	CAM cheaper option over traditional transport mode	2027
TS23	Proven superior safety record than traditional road services	2027
TS24	Smoother and more convenient journeys	2027
TS25	CAM services begin to scale due to decrease in implementation cost	2029

Critical waypoints

The roadmap identifies three critical waypoints leading to a connected and self-driving ecosystem that is safe and secure by design. The waypoints identified support the notion that legislation and regulation are key enablers. The critical waypoints for safety are:

- *Development of safety protocols for CAM services (LR19)*
- *Stable standards and regulations now in place (LR66)*
- *Mandatory data sharing of safety critical data is legislated (LR26)*

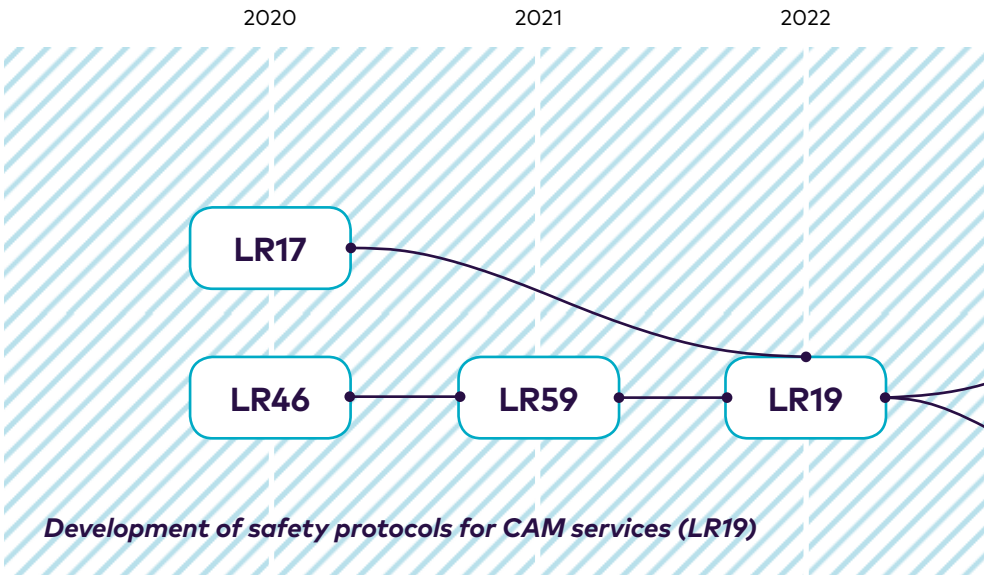
"Connected and automated mobility offers huge societal benefits, not least for road safety, but for these to be fully grasped delivery must be strategic and planned. The roadmap is key to this approach."

Joshua Harris, Brake

DEEP DIVE

Development of safety protocols for CAM services (LR19)

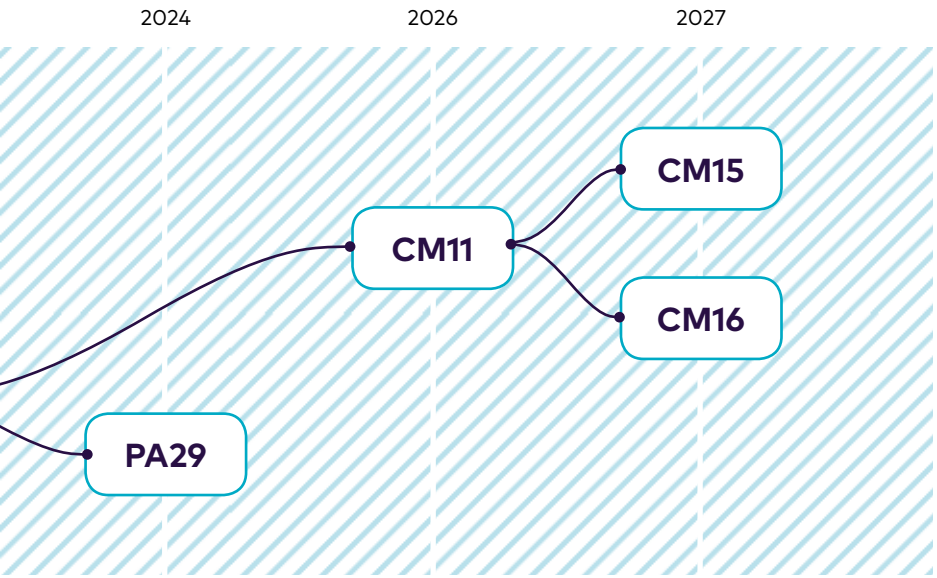
This Strand establishes safety management protocols, which are expected to be in place by 2022. Starting with *Agreed safety standards (LR17)* and building on top of *Consistent framework for approval and licencing of self-driving vehicles (LR46)*, safety management protocols can be established. This development unlocks the ability to provide safety messaging between vehicles and infrastructure (found in Milestones *CM11-16*), as well as ensuring *Legislation and standards for safety and security driving public acceptance (PA29)*.



Development of safety protocols for CAM services (LR19)

KEY

ID	Milestone	Date
CM11	First service deployed utilising safety messages	2026
CM15	Safety messages from all new vehicles and all new highway schemes	2027
CM16	Safety messages in all major urban areas	2027
LR17	Agreed safety standards	2020
LR19	Development of safety protocols for CAM services	2022
PA29	Legislation and standards for safety and security drive public acceptance	2024
LR46	Consistent framework for approval and licencing of self-driving vehicles	2020
LR59	Robust automated driving system licencing regime at scale	2021
PA29	Legislation and standards for safety and security drive public acceptance	2024



Summary

The roadmap shows that establishing the UK's robust and enviable safety record for connected and self-driving vehicles requires the conclusion of many diverse, yet highly-related pieces of work. Collaboration and initiatives from many sectors must be successful, resulting in the delivery of legislation, regulation, infrastructure and technology.

A deep dive into the roadmap highlights that legislation and regulation is a precursor to developing, testing and using both infrastructure and vehicles safely, within a world where mobility is seen as a service enabled by connected and self-driving vehicles.

Regulation, establishing good practice and, ultimately, standardisation are the forerunners to building the framework for an ecosystem that allows interoperability whilst remaining safe and secure. A regulatory framework provides and clarifies the societal boundaries within which mobility and the connected and self-driving vehicle ecosystem can evolve. With this knowledge, infrastructure can develop to address the specific needs of connected and self-driving vehicles. Beyond the regulatory environment, the roadmap identifies the need to establish infrastructure to support testing, development and validation as critical deliverables. Specifically, the roadmap identifies the need to focus and standardise specific and relevant sensor technologies.

The UK's noteworthy, historical leadership in developing legislation, regulation and standardisation has in the past informed national standards, contributing to an enviable safety record. This historical strength will be pivotal in establishing a safety record that is readily replicated in connected and self-driving-enabled societies around the world.

Golden Thread 03
CAM Services

Introduction

The CAM Services Golden Thread is particularly complex as it is a culmination of many individual Strands, and in many senses is the end goal of the roadmap itself. There are many aspects of the roadmap, across all Streams, that must come together at the right time to deliver a significant number of CAM Services, including Personal Mobility and Freight and Logistics.

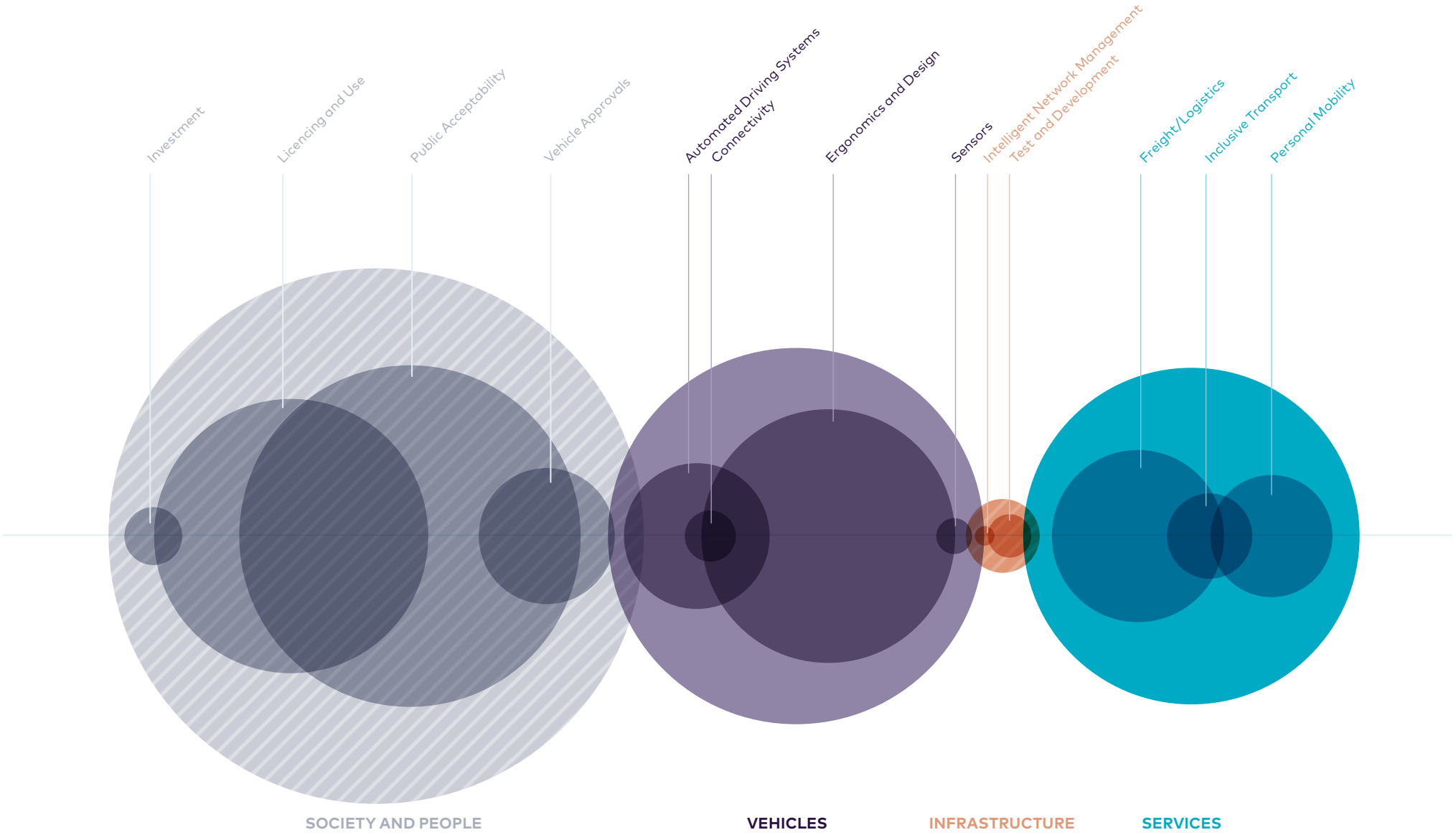
There are 151 Milestones which form the CAM Services Golden Thread. These Milestones are split across multiple Strands which clearly show there are many aspects that must come together. Without dedicated focus and collaboration in these key areas, we risk not fulfilling the 2030 vision.

Contributing themes

When looking at the delivery of significant CAM services, it is tempting to assume the Milestones required for delivery will only be within the Services Theme of the roadmap. However, when reviewing the roadmap it is clear this is far from the case. Bringing together all the Milestones needed to deliver significant CAM services, shows the delivery of CAM services is heavily reliant on items within Society and People, particularly Vehicle Approvals, Licencing and Use and Public Desirability.

"Engaging with the roadmap has enabled us to articulate the significance of the weather and the potential contribution of the Met Office within an industry-wide framework."

Dave Jones, Met Office



Contributing themes

Major deliverables

It is not remarkable to see the deployment of significant CAM services requires some major deliverables along the way. The roadmap allows us to quantify these and objectively understand where high levels of effort must be placed in order to deliver the 2030 Vision. There are major Milestones, which although they may not have many dependencies, are still critical. Examples include: legal frameworks, MaaS regulation in place and vehicle design for high utilisation. The key Strands related to this Golden Thread are:

- *Measurable growth of CAM services (MS18)*
- *Seamless ticketing (MS29)*
- *Highly demand-responsive transport services enabled (MS32)*
- *Develop fully-automated passenger cars (AS18)*
- *Consolidation of movement of freight and people (FL12)*

DEEP DIVE

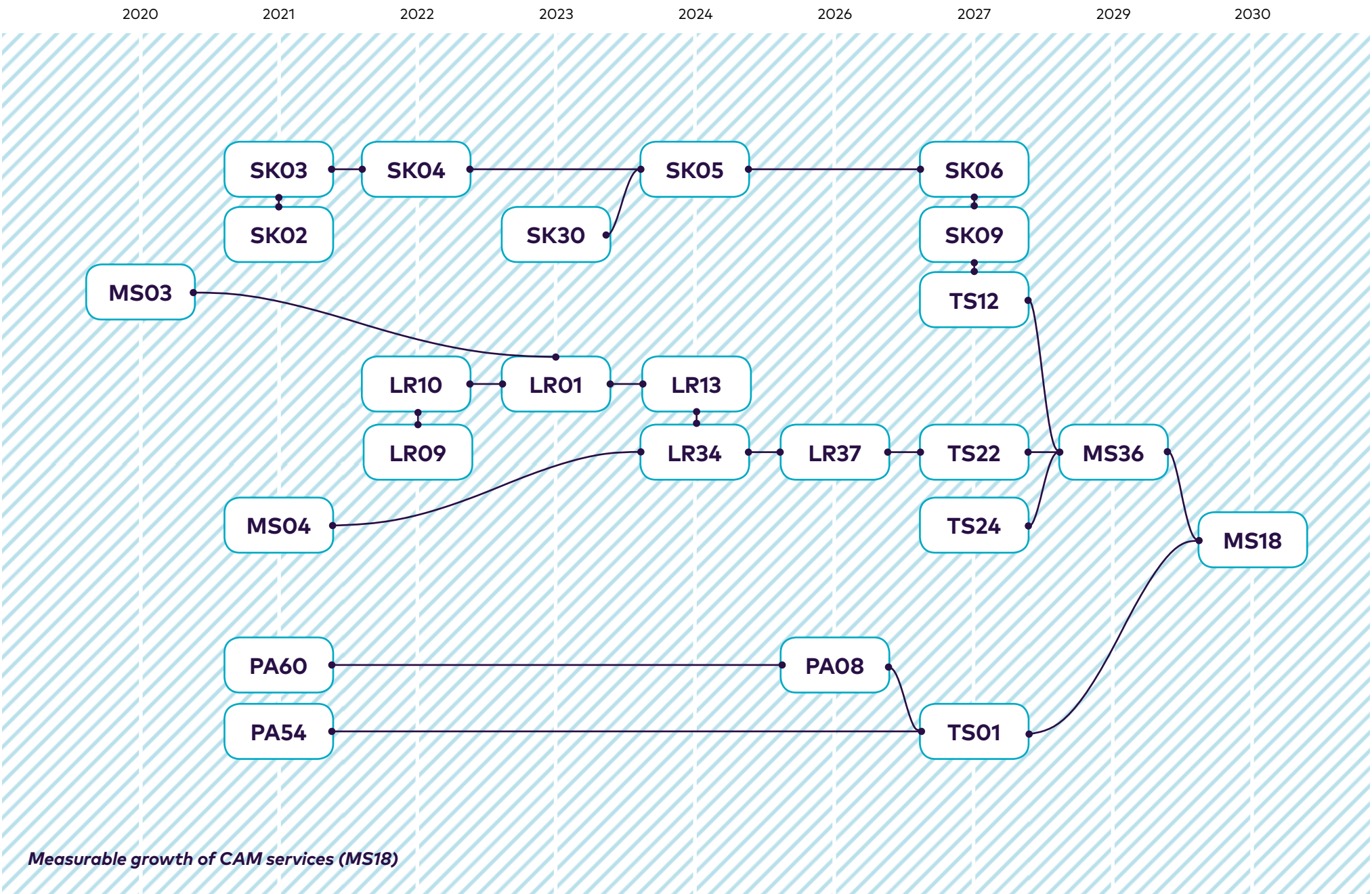
Measurable growth of CAM services (MS18)

This Strand shows that the development of appropriate skills, through a well-defined pipeline (Milestones *SK02-09*), leads to a solid foundation of specific operational skills and an outcome of *Operational skills in place (TS12)* that supports the ability to deliver CAM services sustainably. In turn, this contributes to *CAM being commercially viable and operationally preferable (MS36)* by ensuring that the ongoing maintenance and operational concerns are resolved. In parallel, the *Launch of a public education programme (PA54)*, raises understanding of vehicle capabilities and limitations, and is part of a wider *Public engagement programme (TS01)*, which brings the public more centrally into the design of CAM services. This drives public uptake, thus growing the market through increased demand. The importance of public dialogue during the service model definition phase ensures fit-for-purpose and readily acceptable CAM services.

The *Law Commission review into automated vehicles (LR09)* unlocks a regulatory regime, allowing at-scale pilots and *Trials of CAM in multiple environments and differing economic models (LR37)*. This in turn unlocks the economic benefits of lower operational costs leading to *CAM being a cheaper option over traditional transport modes (TS22)*.

KEY

ID	Milestone	Date
LR01	MaaS regulation exploration	2022
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR13	Development of MaaS regulations begins	2024
LR34	CAM service licencing framework established	2024
LR37	Trials of CAM in multiple environments and differing economic models	2026
MS03	First code of practice for CAM services	2020
MS04	Guidance issued by local authorities on adoption of MaaS	2021
MS18	Measurable growth of CAM services	2030
MS36	CAM is commercially viable and operationally preferable	2029
PA08	Core use cases defined	2026
PA54	Launch public education programme	2021
PA60	Establish open frameworks for public to contribute to scenario libraries and access test results	2021
SK02	Initial review of required CAM skills	2021
SK03	Gather evidence for existing skills provision	2021
SK04	Skills pipeline advisory consultation	2022
SK05	End-to-end skills pipeline established	2024
SK06	Development of courses for academia, decision makers and operations industries	2027
SK09	Academic courses and educational programmes deployed	2027
SK30	Establish cross sector promotion of common skillsets	2023
TS01	Launch public engagement programme	2027
TS12	Operational skills in place	2027
TS22	CAM cheaper option over traditional transport mode	2027
TS24	Smoother and more convenient journeys	2027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SK03
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MS03
TS12
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LR01
LR13
LR09
LR34
LR37
TS22
MS36
MS04
TS24
MS18
PA60
PA08
PA54
TS01
Measurable growth of CAM services (MS18)

Key enablers

To deliver significant numbers of CAM services it is vital to understanding what early deliverables are most critical to unlocking other pieces of work:

- *First code of practice for CAM services (MS03)*
- *UNECE cyber security regulations development (LR23)*
- *Independent body established to handle data (LR27)*
- *Large scale (50–100) public demos on different CAM solutions (PA07)*
- *Launch public education programme (PA54)*
- *Specify safety critical data use cases (CN06)*

"The roadmap provides an essential overview of the opportunities and challenges of CAM. I am particularly excited about the skills context, which should be a focal point for UK investment and attention."

Natasha Merat, Leeds University

Launch public education programme (PA54)

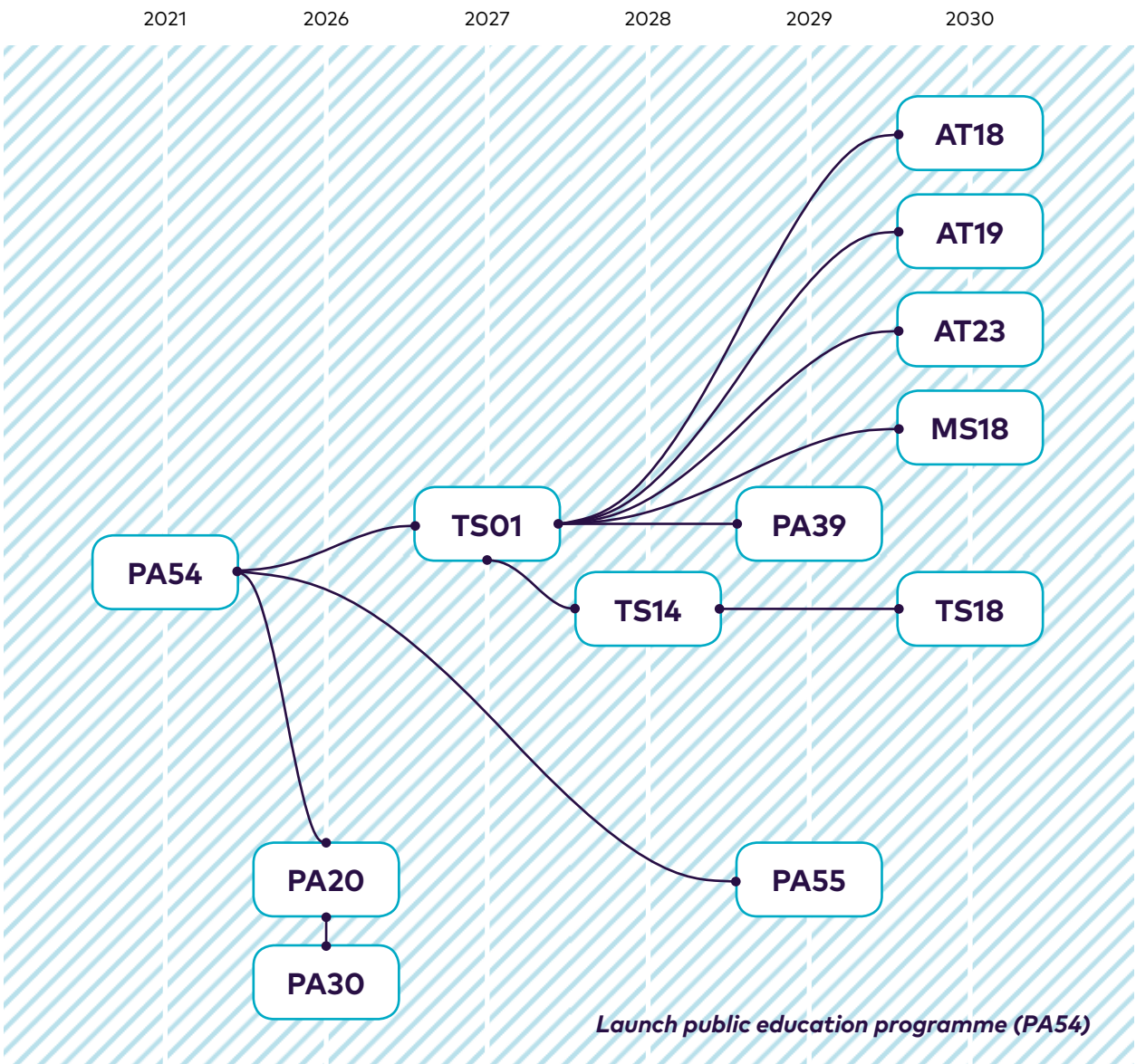
Although there are many major enablers for significant deployment of highly-automated CAM services that lie within the Vehicles and Infrastructure Themes, public education is also a crucial consideration.

Through a comprehensive *Launch of a public education programme (PA54)* and *Public engagement programme (TS01)*, multiple key Milestones can be unlocked. The first group of these constitute major progressions in inclusive transport across city, highway and rural environments (Milestones *AT18, AT19 and AT23*). These engagement and education Milestones support *Widespread awareness of CAM (TS14)* as the general public has a greater appreciation of CAM benefits and having their voices and concerns heard. The analysis shows all of the above can occur while *Measurable growth of CAM services (MS18)* is taking place.

KEY

ID	Milestone	Date
AT18	Trial and development of inclusive city services	2030
AT19	Trials and development of inclusive highway services	2030
AT23	Trials and development of rural services	2030
MS18	Measurable growth of CAM services	2030
PA20	Cultural and societal change to automation	2026
PA30	Self-driving vehicles are no longer noteworthy	2026

ID	Milestone	Date
PA39	Behaviours around CAM have changed to the positive	2029
PA54	Launch public education programme	2021
PA55	Evidence of safety record begins to show	2029
TS01	Launch public engagement programme	2027
TS14	Widespread awareness of CAM	2028
TS18	Solid uptake of CAM enabled Services	2030



Summary

Roadmap analysis shows the delivery of significant CAM services depends upon many contributing pieces of work, across technology sectors such as communications and road-side infrastructure. The need for early codes of practice for services to be complemented by local and regional licensing requirements, shows how service operators must work closely with city and regional authorities to deliver beneficial mobility for all.

The iterative processes for updating guidance, involving trials, pilot deployments and delivery of new regulation ultimately enables deployment at scale.

Golden Thread 04

Public Acceptability

Introduction

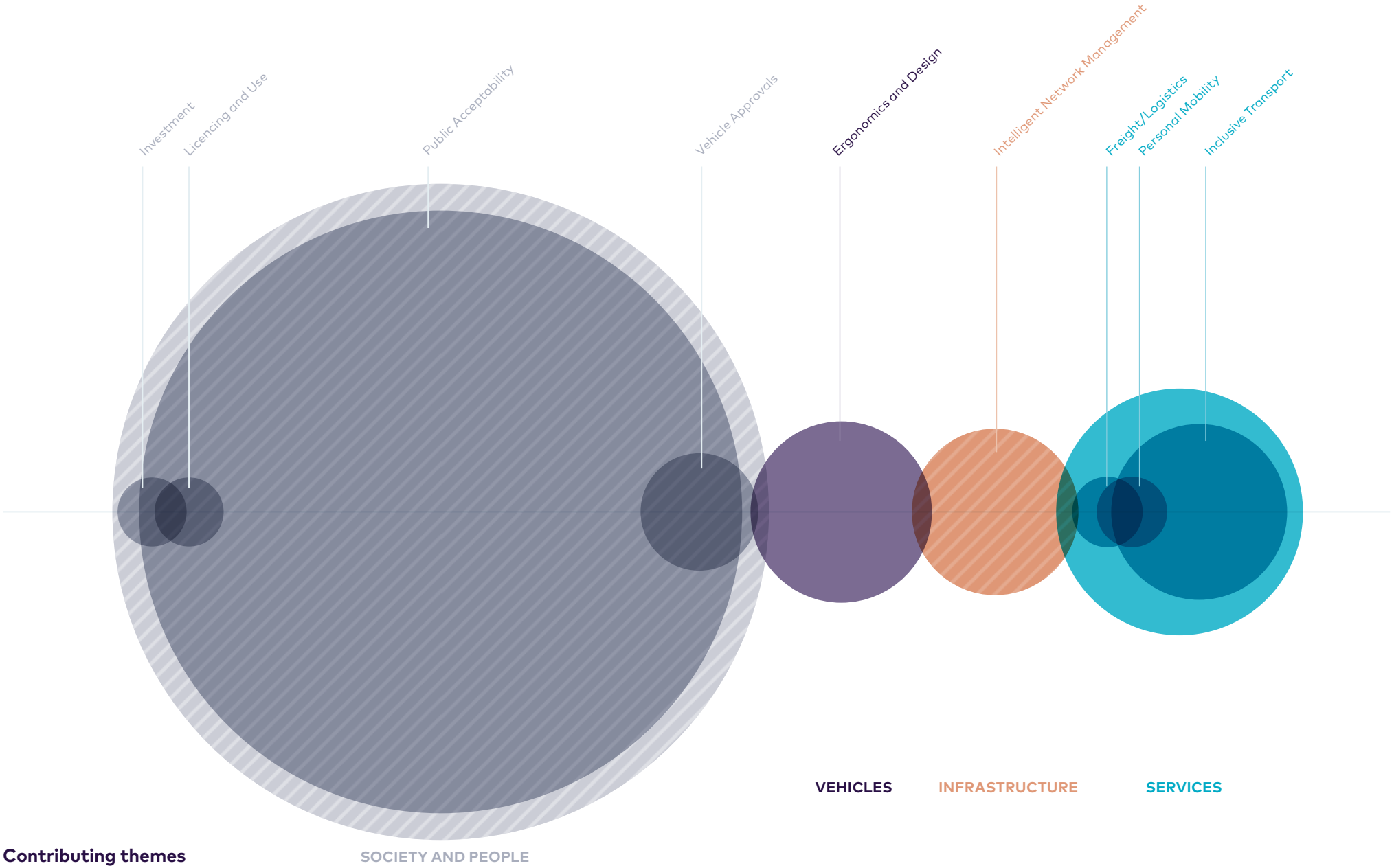
This Golden Thread relies heavily on several Strands which come together to inform the public so that ultimately there is understanding, acceptance and adoption of CAM. When exploring the Milestones that make up this Thread, there are 87 unique items. Although there are some standalone Milestones, almost half the items in this Golden Thread are significant Strands, and many of the connected Milestones either initiate or culminate in major deliverables.

Contributing themes

When looking at what leads to the delivery of significant Milestones a significant number come from the Public Desirability, Inclusive Transport and Personal Mobility Streams with additional input from Milestones in the Infrastructure and Vehicles Themes. When examined in greater detail, these Milestones depend heavily on delivery of the correct legislation and regulation.

"The arrival of autonomous vehciles represents a unique opportunity for a fundamental change in urban mobility. Testing on the public highway will help people understand its benefits and increase acceptability."

Rafael Cuesta, Transport for Greater Manchester



Contributing themes

Major deliverables

In order to reach a position where society understands, accepts and adopts CAM, there are a large number of deliverables that must be achieved – many of these rely on public acceptability. There are numerous deliverables that rely on public acceptability. The roadmap quantifies these deliverables to objectively identify and understand the levels of effort required to deliver the 2030 Vision.

There are several Milestones in this Thread that are not part of a chain, but are nonetheless critical, for example *Delivery of a cyber security centre of excellence (TD08)*, the *Trial and development of inclusive city services (AT18)*, and *Transport Service Providers collaborate (TS04)*. Additionally, there are numerous Strands made of multiple Milestones.

The key Strands related to this Golden Thread are:

- *Routing data from a digital twin available (DA26)*
- *Public gain exposure to self-driving vehicles and feel safe (PA53)*
- *The majority of society has bought into CAM (PA17)*
- *Evidence of safety record begins to show (PA55)*
- *Launch public education programme (PA54)*
- *Agreed safety standards (LR17)*
- *More self-driving vehicles than traditional vehicles registered per year (PA34)*

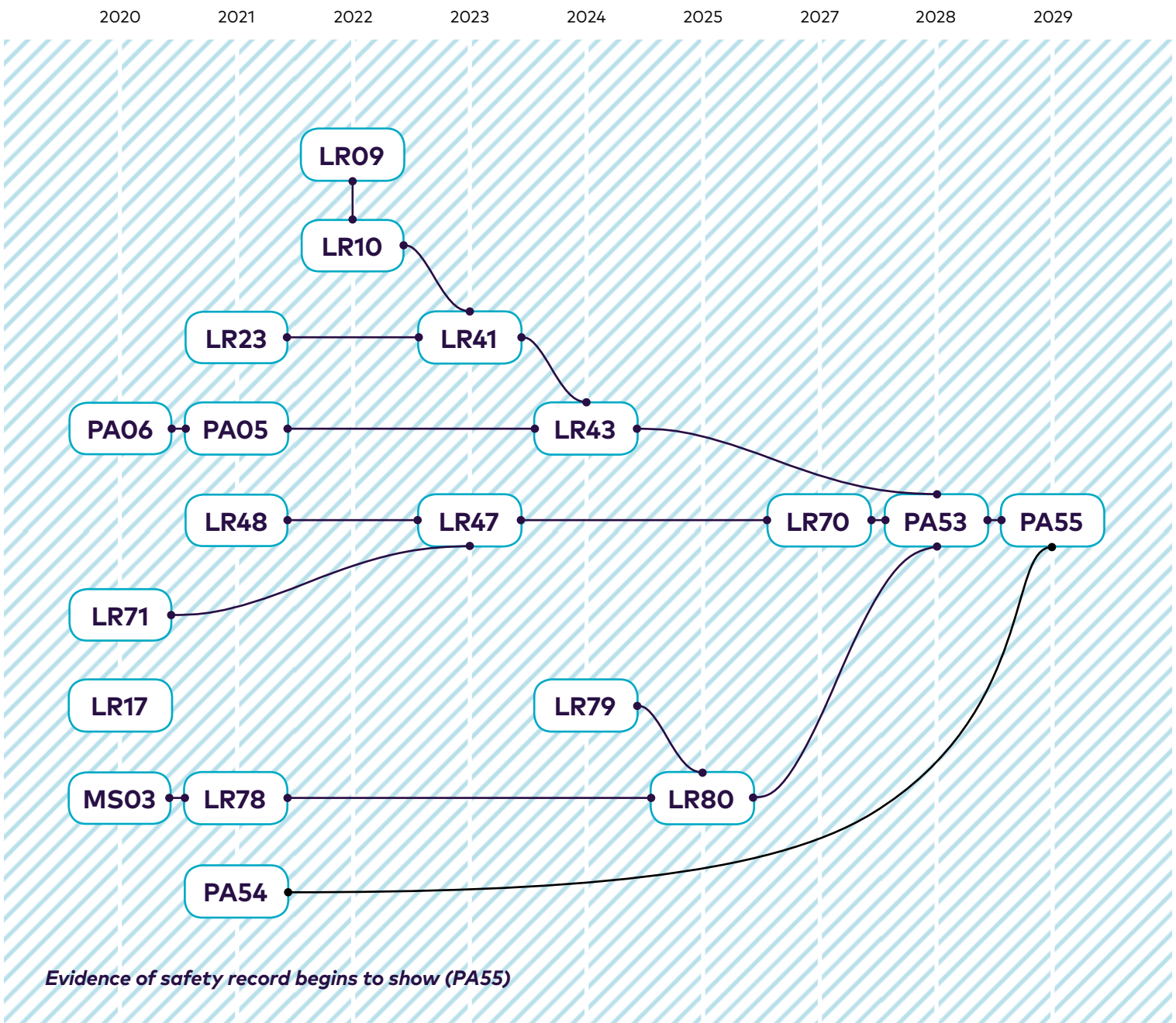
DEEP DIVE

Evidence of safety record begins to show (PA55)

It is fundamental that the safety benefits delivered by CAM are visible to the public. Legislation and regulation are huge components and need to be in place to enable this to happen. For example, the *Law Commission final report (LR10)* due in 2022 expands on the reviews that are currently underway, coupled with the *UNECE cyber security regulations development (LR23)*, that are key to enable the delivery of *Policies and legal frameworks to allow passenger transport trials (LR41)*. This will lead to delivery of the *National vehicle approval scheme (LR70)* by 2027. In addition, alongside the work on vehicle approval, there must be research and sharing of information on how personal data will be used, which drives the perception of personal safety, ultimately leading to a wide-scale *Launch (of a) public education programme (PA54)*, ensuring the *Public gain exposure to self-driving vehicles and feel safe (PA53)*. As a result, this will lead to *Evidence of a safety record beginning to show (PA55)* by 2030.

"The roadmap clarifies how CAV technologies, underpinned by data, should progress to ensure that our future mobility systems address both commercial and societal needs."

Nick Reed, Reed Mobility



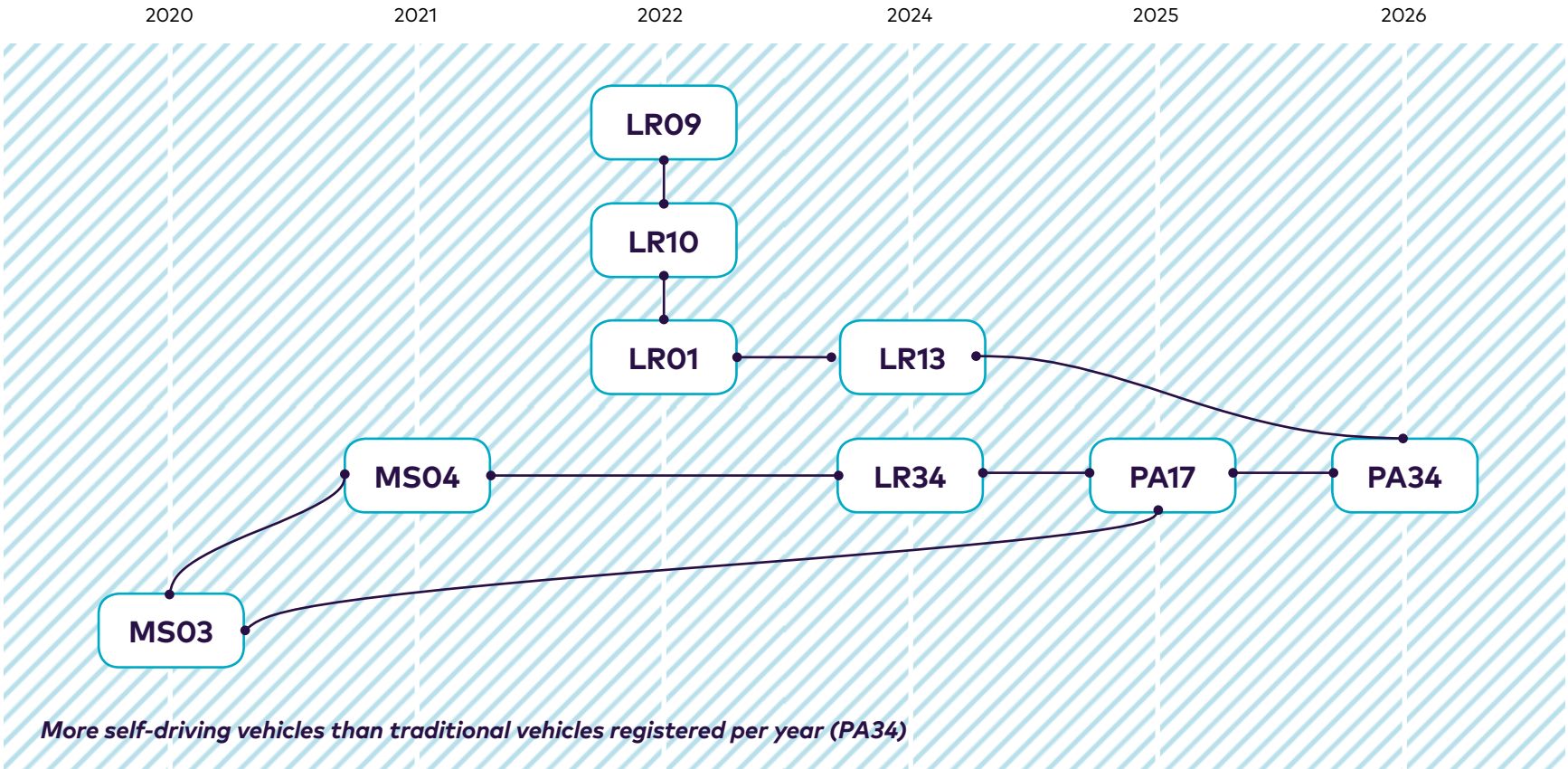
KEY

ID	Milestone	Date
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR17	Agreed safety standards	2020
LR23	UNECE cyber security regulations development	2021
LR41	Policies and legal frameworks in place to allow passenger transport trials	2023
LR43	Requirements for licencing captured from CAM trials	2024
LR47	Small scale national type approval process begins	2023
LR48	Vehicle approval framework for self-driving vehicles in place	2021
LR70	National vehicle approval scheme	2027
LR71	Digitisation of rules of the road (The Highway Code)	2020
LR78	Testing specialists define best practice	2021
LR79	Best practice informs national standards	2024
LR80	UK safety case adoption feeds into global standards	2025
MS03	First code of practice for CAM services	2020
PA05	Transparency on use of public data	2021
PA06	Public agrees with and understands how their data is going to be used	2020
PA53	Public gain exposure to self-driving vehicles and feel safe	2028
PA54	Launch public education programme	2021
PA55	Evidence of safety record begins to show	2029

DEEP DIVE

More self-driving vehicles than traditional vehicles registered per year (PA34)

More self-driving vehicles than traditional vehicles registered per year (PA34) will enable CAM to become increasingly widespread. In order to reach this target by 2030, a significant amount of related activities must take place in parallel. Achieving these objectives relies heavily on the development of MaaS. This includes *Guidance issued by local authorities on adoption of MaaS (MS04)*, a *CAM service licencing framework established (LR34)* and having a *CAM service licencing process in place (MS13)*, which should lead to *The majority of society bought into CAM (PA17)*. By 2026, this will ultimately enable *More self-driving vehicles than traditional vehicles registered per year (PA34)* as the demand increases.



"This cohesive roadmap will be used by industry to make critical investment decisions for the development and deployment of CAV technologies."

Chris Reeves, HORIBA MIRA

KEY

ID	Milestone	Date
LR01	MaaS regulation exploration	2026
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR13	Development of MaaS regulations begins	2024
LR34	CAM service licencing framework established	2024
MS03	First code of practice for CAM services	2020
MS04	Guidance issued by local authorities on adoption of MaaS	2021
PA17	The majority of society is bought into CAM	2025
PA34	More self-driving vehicles than traditional vehicles registered per year	2026

Critical waypoints

This Golden Thread has only one critical waypoint, with the majority of the Milestones coming either at the start or end of a chain of Milestones. This is to be expected as CAM services place so much reliance on other Milestones before they can become viable. This Golden Thread concentrates on those Milestones that are enabling the deployment of services.

The roadmap is a valuable tool in identifying key areas for collaboration in legislative and regulatory reform, as well as across different sectors. A monumental effort.

Jessica Uguccioni, Law Commission

DEEP DIVE

CAM service licencing framework established (LR34)

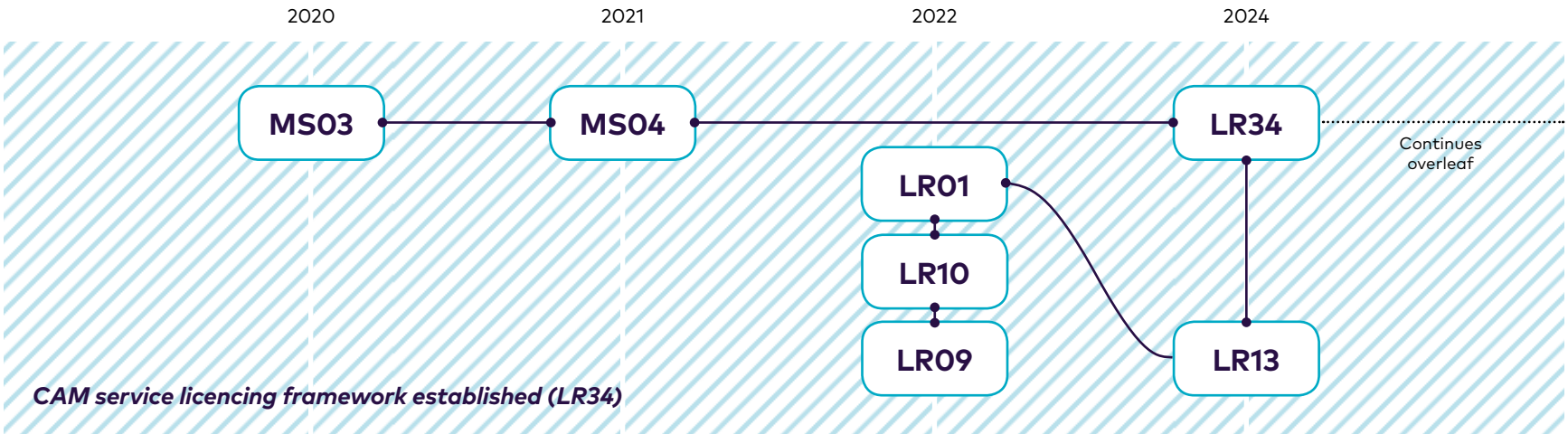
Beginning, as many Strands do, with the *Law Commission review into automated vehicles (LR09)* and subsequent report *(LR10)* as well as *First code of practice for CAM services (MS03)*, this critical waypoint establishes both *Guidance issued by local authorities on adoption of MaaS (MS04)* and *Development of MaaS regulations (LR13)*. In 2024 the *CAM licencing framework IS established (LR34)* and CAM services will have the legal and regulatory structures in place to begin deployment.

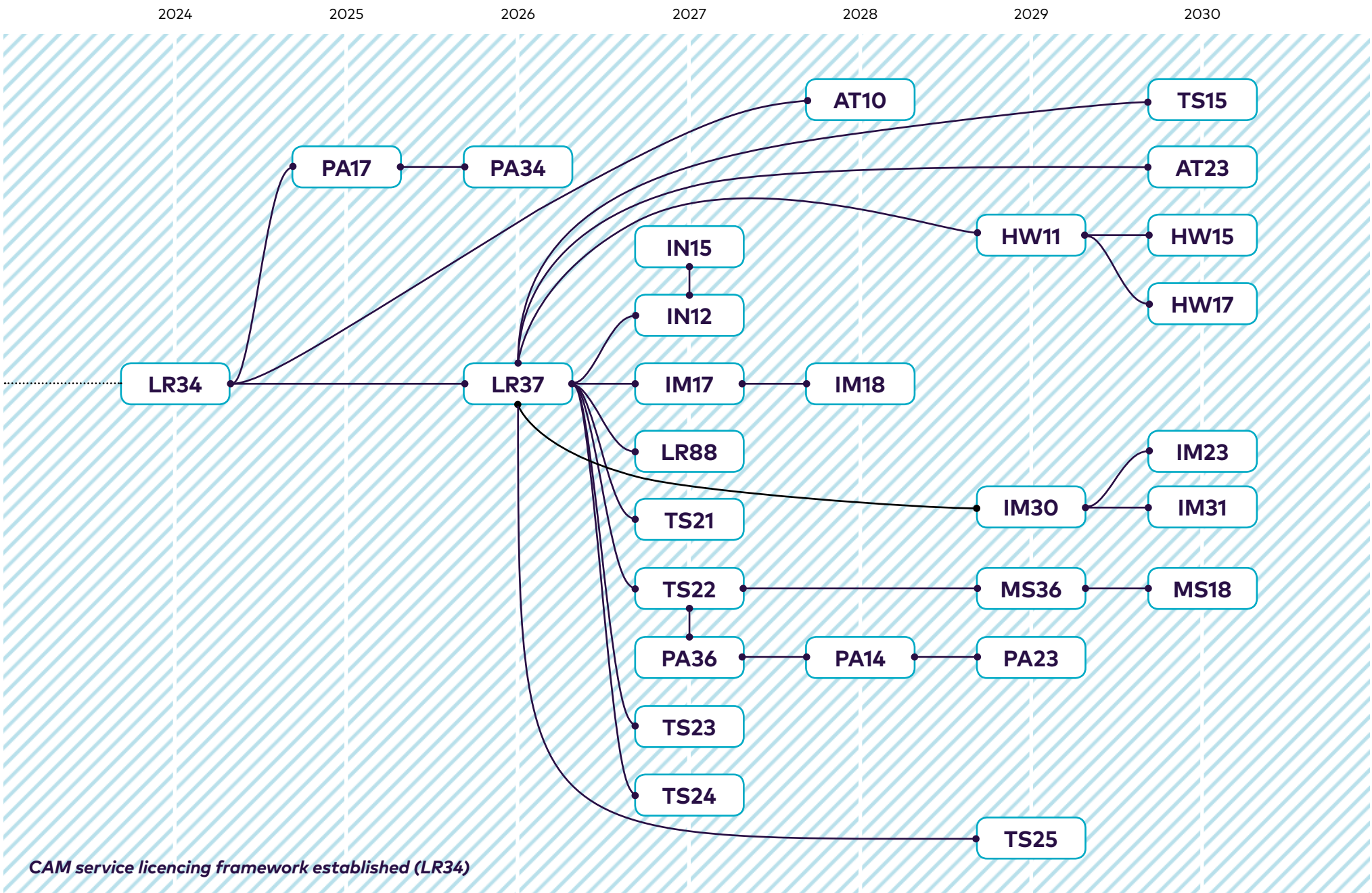
Emerging through the other side of the critical waypoint *Trials of CAM in multiple environments and differing economic models (LR37)* enables the *Continued development of actuarial models (IN12)* which in turn unlocks *Self-driving insurance cheaper than human driven (IN15)* by 2027. Public acceptance begins to increase as *The majority of society is bought into CAM (PA17)* and *More self-driving vehicles than traditional vehicles registered per year (PA34)* show the benefits for a robust licencing process.

As trials inform understanding, *CAM travel patterns identify limiting factors of current city design (IM17)*. This informs cities and regions who can then develop and use *New city planning methods to enable more efficient CAM travel (IM18)*.

KEY

ID	Milestone	Date
LR01	MaaS regulation exploration	2022
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR13	Process in place which speeds up new type approval from UNECE	2024
LR34	CAM service licencing framework established	2024
MS03	First code of practice for CAM services	2020
MS04	Guidance issued by local authorities on adoption of MaaS	2021

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Golden Thread 04 – Public Acceptability
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TS15
AT23
HW11
HW15
HW17
IN15
IN12
LR37
IM17
IM18
LR88
IM23
IM30
IM31
TS21
TS22
MS36
MS18
PA36
PA14
PA23
TS23
TS24
TS25
CAM service licencing framework established (LR34)

KEY

ID	Milestone	Date
AT10	New demand-responsive CAM services	2028
AT23	Trials and development of rural services	2030
HW11	Revised highway safety and design standards	2029
HW15	Reduced headway and width standards	2030
HW17	Legislation for clearing road space for automated vehicles	2030
IM17	CAM travel patterns identify limiting factors of current city design	2027
IM18	New city planning methods enable more efficient CAM travel	2028
IM23	Ongoing understanding of new travel patterns for CAM	2030
IM30	CAM deployments inform emerging travel patterns	2029
IM31	CAM integrated into travel demand management	2030
IN12	Continued development of actuarial models	2027
IN15	Self-driving insurance cheaper than human driven	2027
LR11	Process in place which speeds up new type approval from UNECE	2024
LR34	CAM service licencing framework established	2024

ID	Milestone	Date
LR88	Definition of national-scale incident response plan	2027
LR37	Trials of CAM in multiple environments and differing economic models	2026
MS18	Measurable growth of CAM services	2030
MS36	CAM is commercially viable and operationally preferable	2029
PA14	Start of public trust in CAM	2028
PA17	The majority of society is bought into CAM	2025
PA23	Public acceptance at 85%	2029
PA34	More self-driving vehicles than traditional vehicles registered per year	2026
PA36	Determine if a clear, independent regulator is needed for trust	2027
TS15	Common CAM routing options established	2030
TS21	Outcome based service provision	2027
TS22	CAM cheaper option over traditional transport mode	2027
TS23	Proven superior safety record than traditional road services	2027
TS24	Smoother and more convenient journeys	2027
TS25	CAM services begin to scale due to decrease in implementation cost	2029

Summary

It is clear from the roadmap analysis that in order for society to accept, understand and adopt CAM, there is much work to be done. The 2030 Vision relies heavily on having the correct legislation and regulation in place to enable the safe delivery of CAM, which can be seen by society.

In order to achieve the 2030 Vision, collaboration and synchronisation of multiple workStreams across different sectors is required. Engaging and involving the public along the journey through trials, pilots and deployments, as well as designing services which meet true customer needs, will ensure CAM services are acceptable to the travelling public long before 2030.

Golden Thread 05
Infrastructure

Introduction

The role of infrastructure in enabling CAM is self-evident, but often neglected. The UK road network is one of the world's oldest, yet it has suffered a chronic lack of funding over many years. The introduction of CAM unlocks the potential to radically change how we consider and invest in this infrastructure.

The 2030 Vision sets out the ambition of infrastructure that is ready for increased deployment of CAM, focussed on areas with highly-instrumented roads. This ambition is critical in enabling high levels of CAM uptake. This Golden Thread considers physical and digital infrastructure. The convergence of physical and virtual environments supports both the early stages of testing and development as well as operational deployment.

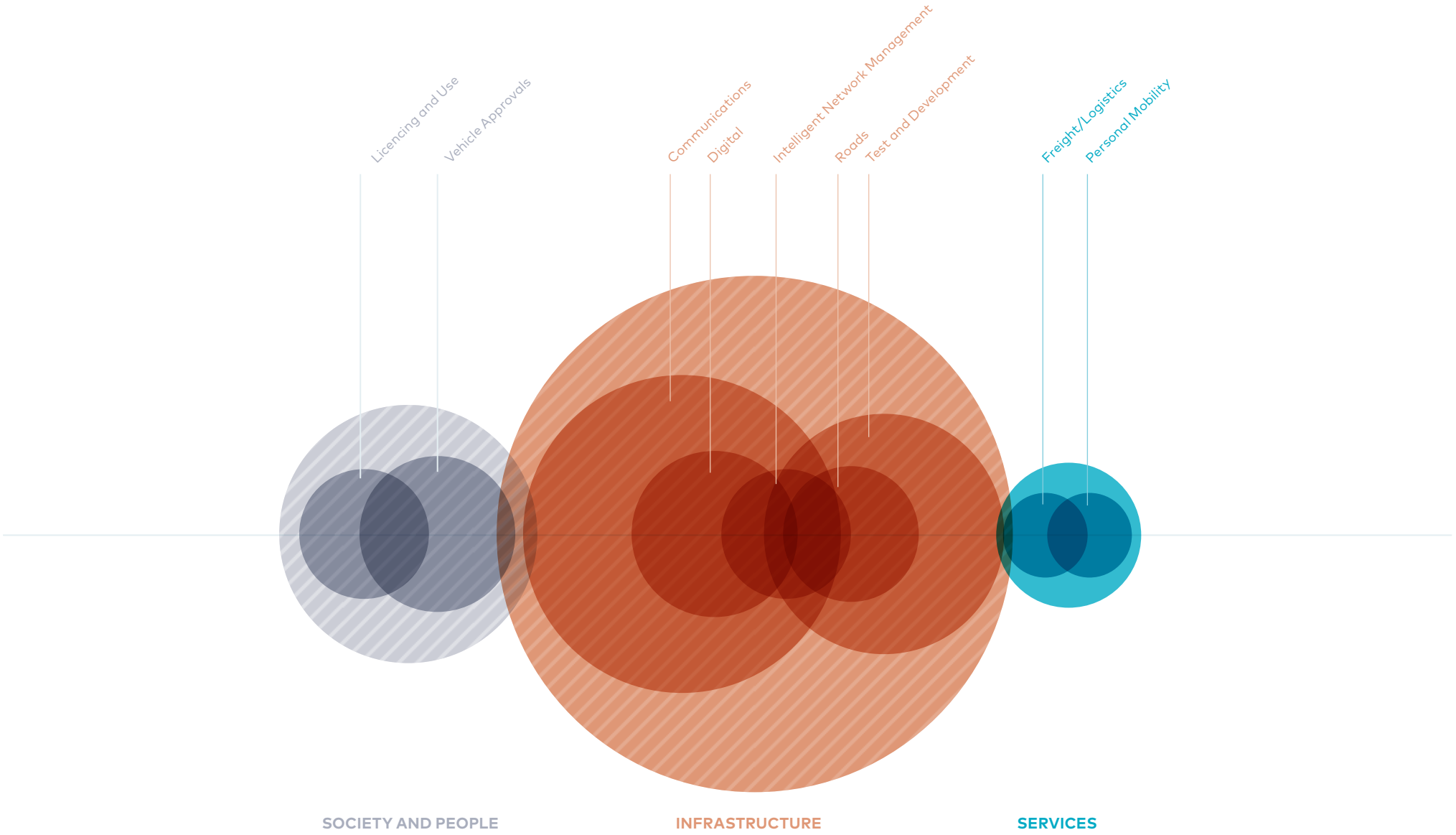
Contributing themes

As may be expected, the Milestones that contribute towards a CAM-ready infrastructure are dominated by those found within the Infrastructure Theme. However, there are strong dependencies on Milestones from the Vehicle Approvals and Licencing and Use Streams. This points to the need for early movements around standards and regulations across all Infrastructure Streams, from Communications to Test and Development.

Additionally, there is a clear contribution from Services in the delivery of infrastructure. The understanding of service requirements and business models must be used to inform requirements and deployment plans. It cannot be a one-way street when it comes to delivering appropriate CAM-ready infrastructure.

"The roadmap will help ensure the UK benefits from connected and automated mobility by reducing accidents, improving efficiency and increasing mobility for all. "

Laura Hughes, Association of British Insurers



Contributing themes

Major deliverables

The delivery and maintenance of new infrastructure is always a major undertaking, and the transition to CAM is no different. There are many major deliverables relating to the Infrastructure Theme in the roadmap.

The key Strands related to this Golden Thread are:

- *New city planning methods enable more efficient CAM travel (IM18)*
- *Safety messages from all new vehicles and all new highway schemes (CM15)*
- *Safety-related messages in all major urban areas (CM16)*
- *Safety messages protected by resilience (CM20)*
- *CAM improves travel metrics (IM19)*

"Creating appropriate research strategies and skills provision is vital for our success in this sector. Taking part in the Roadmap enables the right questions to be asked and decisions made to prepare for the future."

Kevin Vincent, Coventry University

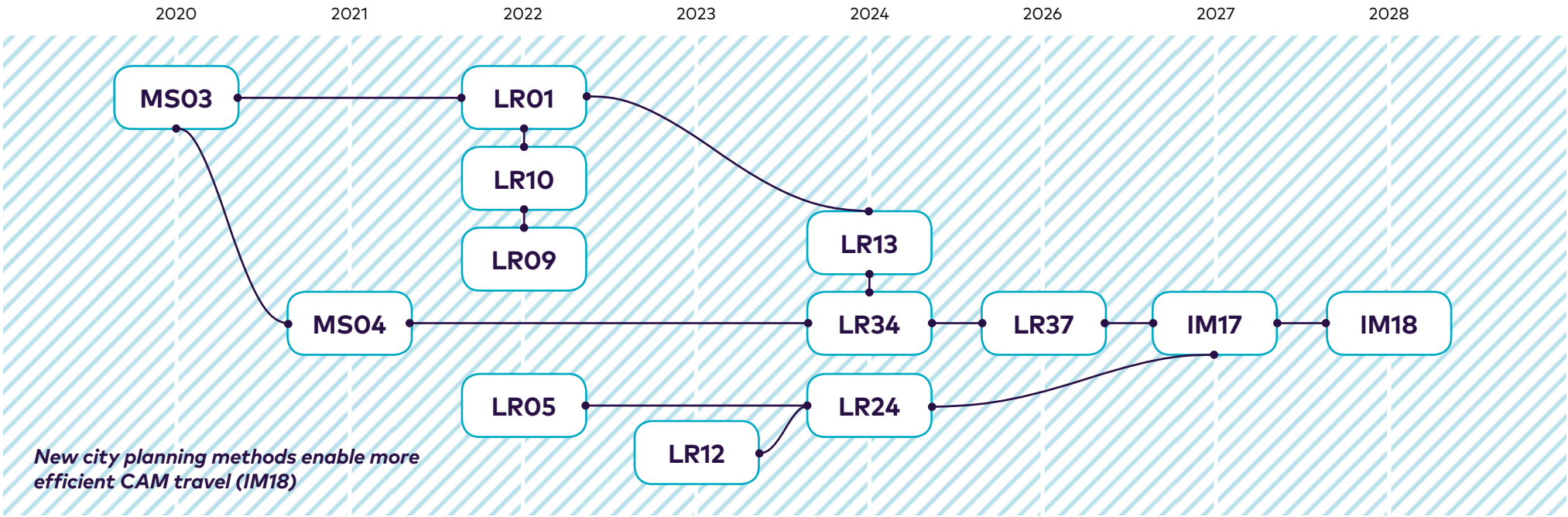
DEEP DIVE

New city planning methods enable more efficient CAM travel (IM18)

When considering that more efficient CAM journeys are delivered, in part, through new city planning methods, it is clear that efficient road networks are not just a matter for highways authorities. The path to delivering this Strand begins now, with the *Law Commission review into automated vehicles (LR09)* to set new legislative frameworks. As this work continues, *Guidance issued by local authorities on adoption of MaaS (MS04)* will begin to be produced for cities and regions from 2020.

The establishment of *Baseline policy and standards (LR05)* from 2019 start to form the backbone of collective understanding around both technology and critical outcomes such as safety and security. Carefully aligned with a strong international engagement plan, this work influences *Wider international standards and governance (LR12)* from 2022.

In 2023 the *Development of MaaS regulations (LR13)* begins, building local guidance and setting UK-wide requirements for MaaS operators. By 2024, the *CAM service licencing framework (LR34)* will allow both users and regulators to have confidence in the safety and security of proposed services. This unlocks large scale *Trials of CAM in multiple environments and differing economic models (LR37)* running through to 2026, which are used to refine and inform final regulation. With increasing numbers of CAM services running across the country, *CAM travel patterns identify limiting factors of current city design (IM17)* from 2026. Having identified limitations, new city planning methods build on and enhance initial CAM-ready blueprints – leading to more efficient journeys.



KEY

ID	Milestone	Date
IM17	CAM travel patterns identify limiting factors of current city design	2027
IM18	New city planning methods enable more efficient CAM travel	2028
LR01	MaaS regulation exploration	2022
LR05	Baseline policy and standards established	2022
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR12	Wider international standards and governance established	2023

ID	Milestone	Date
LR13	Development of MaaS regulations begins	2024
LR24	Draft standards and regulation in place	2024
LR34	CAM service licencing framework established	2024
LR37	Trials of CAM in multiple environments and differing economic models	2026
MS03	First code of practice for CAM services	2020
MS04	Guidance issued by local authorities on adoption of MaaS	2021

"The UK Connected and Automated Mobility Roadmap to 2030 is a great 'one-stop shop' for us to evaluate eco-system activities in delivering the future of connected and autonomous mobility."

Robin North, Immense

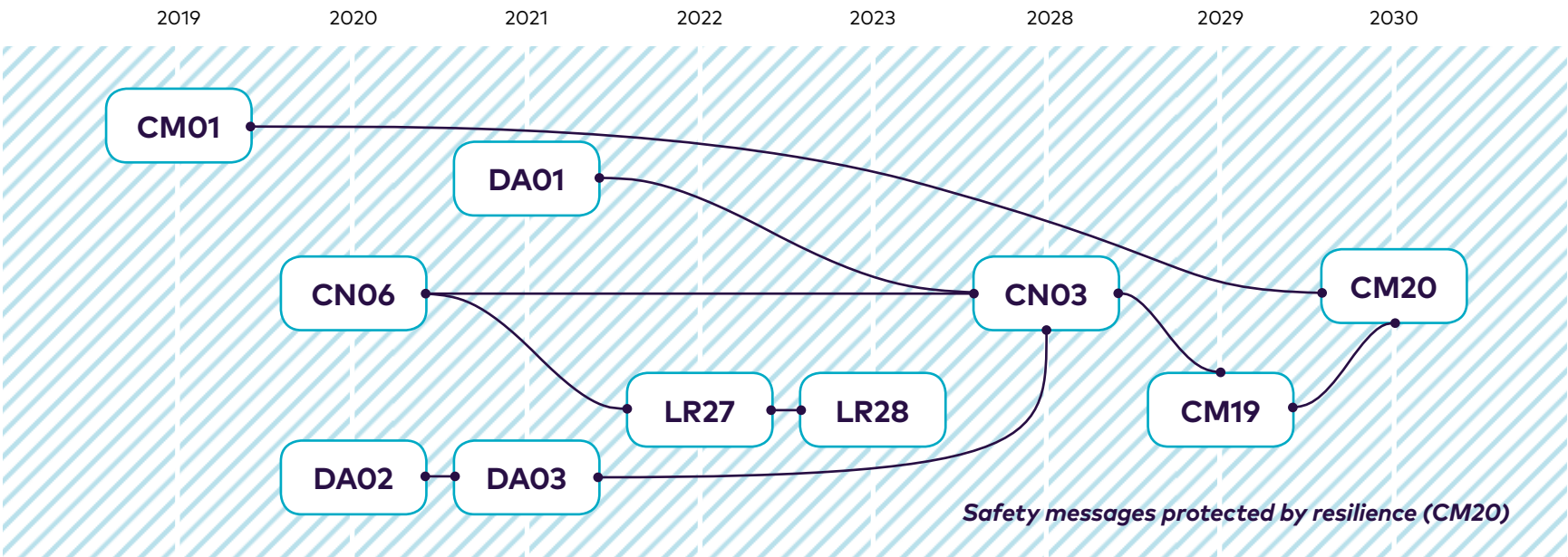
DEEP DIVE

Safety messages protected by resilience (CM20)

Focussing particularly on data resilience, this Strand starts with *Specifying safety critical data use cases (CN06)* in 2019 and *Defining the use case and data definitions (DA02)* in 2020 respectively. This understanding of data requirements, leads to *Publishing open data standards (DA01)* in 2021 to ensure widespread consensus and adoption. This means *Standards and common data formats for communications (CN03)* can be established, which evolve and are harmonised internationally through to 2028.

The resilience of safety data is also dependent on appropriate ways of exchanging data between entities, whilst ensuring integrity and trust. There is a strong call for an *Independent body to be established to handle data (LR27)* from 2021 and for them to support the creation of a *Data exchange legal framework (LR28)*, in place by 2023.

To ensure the resilience of the transfer of safety data, suitable infrastructure must be in place, which is designed from the outset to be capable of delivering safety-critical data. The Definition of data requirements to and from 2021 is required to ensure *Safety messages are protected by resilience (CM20)* in 2030. By working across many Streams we can see how collaboration is the key to delivering resilient, trustworthy safety data.



KEY

ID	Milestone	Date
CM01	Define communications for new schemes	2019
CM19	Highways information over multiple communications paths	2029
CM20	Safety messages protected by resilience	2030
CN03	Establish standards and common data formats for communications	2028
CN06	Specify safety critical data use cases	2020
DA01	Open data standard published	2021
DA02	Use case and data definition defined	2020
DA03	Define data requirements to and from vehicles and infrastructure	2021
LR27	Independent body established to handle data	2022
LR28	Data exchange legal framework in place	2023

Key enablers

There are a number of key Milestones which are the foundation of delivering CAM-ready infrastructure. The key Strands related to this Golden Thread are:

- *Baseline policy and standards established (LR05)*
- *UNECE cyber security regulations development (LR23)*
- *CAM digital twin defined (DA19)*
- *Define communications for new schemes (CM01)*
- *Communications definitions in highways standards (CM05)*
- *Blueprint agreed for a CAM-ready town or city (HW01)*

"The roadmap demonstrates that a combination of technical, regulatory and societal steps are needed to ensure automated pods, cars and lorries are sufficiently safe for use on roads."

Pete Thomas, Loughborough University

DEEP DIVE

Blueprint agreed for a CAM-ready town or city (HW01)

One of the most significant key enablers is the agreement of a *Blueprint for a CAM-ready town or city (HW01)*. This blueprint, delivered by 2021 is critical to unlocking many Milestones within the Communications Stream and beyond.

The CAM-ready city blueprint also provides a foundation for the development of *New funding models for roads infrastructure (HW07)* from 2022. Thinking differently about how what has been often considered 'free' infrastructure is funded, is based on understanding what a future city can look like. These new business cases unlock a move to digital infrastructure and the *Digitisation of sign assets (HW10)* in 2024, along with in-car signalling being deployed. This in turn unlocks the implementation of the *First safety support services (HW05)* in 2025.

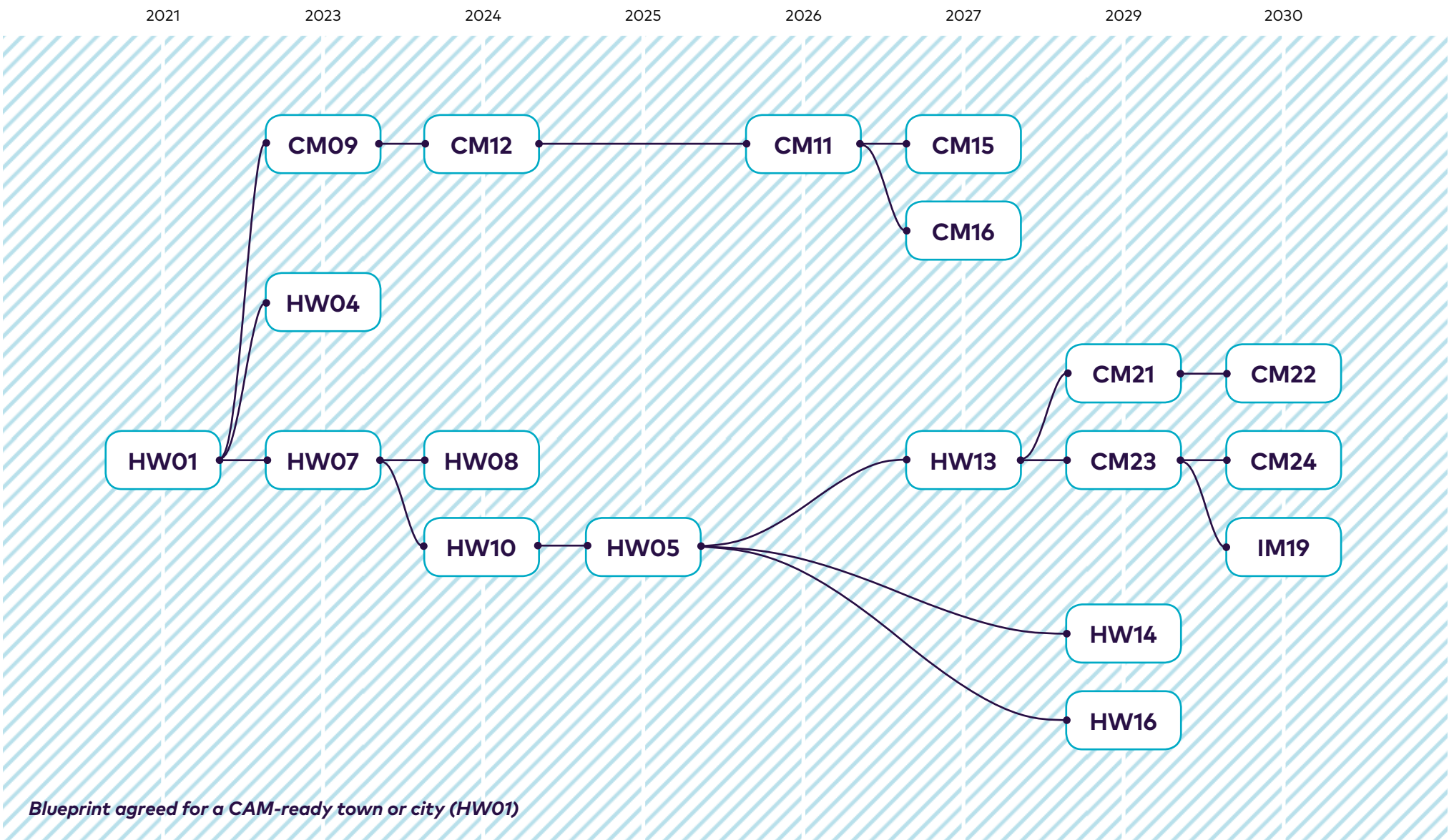
Demonstrating safe and secure use of digital messaging begins to reduce the reliance on road-side infrastructure. This will see new highway schemes move away from high cost (£10 million per km of smart motorway) assets in favour of digital infrastructure, swiftly followed by the *Decommissioning or repurposing of first signs and signals (HW13)* in 2027. As this progresses, *Highly connected roads in areas with the strongest business cases (CM23)* are seen, typically on the strategic road network (SRN) and within Future Mobility Zones in 2029. By 2030, the *Level of connectivity does not inhibit CAM usage (CM24)* and *CAM improves travel metrics (IM19)* – all driven from work on delivering a CAM-ready city blueprint.

"Costain will use the UK CAM roadmap to accelerate the development of integrated leading-edge smart infrastructure solutions for our clients that will improve people's lives."

Philip White, Costain

KEY

ID	Milestone	Date
CM09	Coverage plan in place	2023
CM11	First service deployed utilising safety messages	2026
CM12	Coverage roll out planning	2024
CM15	Safety messages from all new vehicles and all new highway schemes	2027
CM16	Safety messages in all major urban areas	2027
CM21	80% Strategic Road Network coverage with safety-capable communications	2029
CM22	70% of vehicles safety message compatible	2030
CM23	Highly connected roads in areas with the strongest business cases	2029
CM24	Level of connectivity does not inhibit CAM usage	2030
HW01	Blueprint agreed for a CAM-ready town/city	2021
HW04	Naked highway designed	2023
HW05	First safety support services implemented	2025
HW07	New funding models for roads infrastructure defined	2023
HW08	Reduce investment in new infrastructure	2024
HW10	Digitisation of sign assets	2024
HW13	Decommission or repurpose first signs and signals	2027
HW14	Begin repurposing redundant infrastructure	2029
HW16	Fixed signs and signals replaced by in-car connectivity	2029
IM19	CAM improves travel metrics	2030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CM24
IM19
HW14
HW16
Blueprint agreed for a CAM-ready town or city (HW01)

DEEP DIVE

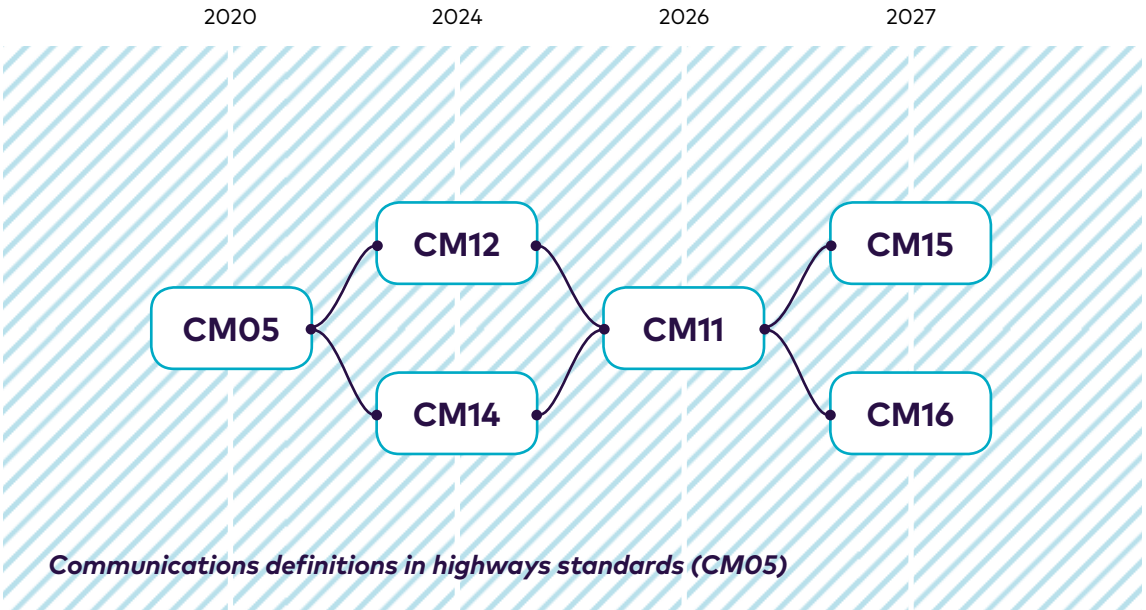
Communications definitions in highways standards (CM05)

When looking specifically at the delivery of communications infrastructure, the definition of requirements at a national level, specifically around early-adoption environments, is fundamental to genuine at-scale delivery.

Communications definitions in highways standards (CM05) must be established in 2020. This will enable planning coverage requirements and engagement with Ofcom and appropriate bodies for the *Necessary spectrum allocation (CM14)* through to 2024. This enables the *First service deployed utilising safety messages (CM11)* in 2026. This reduces the need for traditional infrastructure and *Decommissioning or repurposing of first signs and signals (HW13)* can take place from 2027.

"The roadmap is valuable to WSP as it provides excellent insight into how infrastructure connects to a far wider system of dependencies, critical to identifying links and solving problems for our clients."

James Bulleid, WSP



KEY

ID	Milestone	Date
CM05	Communications definitions in highways standards	2020
CM11	First service deployed utilising safety messages	2026
CM12	Coverage roll out planning	2024
CM14	Necessary spectrum is allocated	2024
CM15	Safety messages from all new vehicles and all new highway schemes	2027
CM16	Safety messages in all major urban areas	2027

Critical waypoints

The critical waypoints for Infrastructure outline points in time where preparatory work has taken place which enable the deployment and scale up of Infrastructure to occur.

The critical waypoint Milestones for this Golden Thread are:

- *CAM service licencing framework established (LR34)*
- *Coverage plan in place (CM09)*

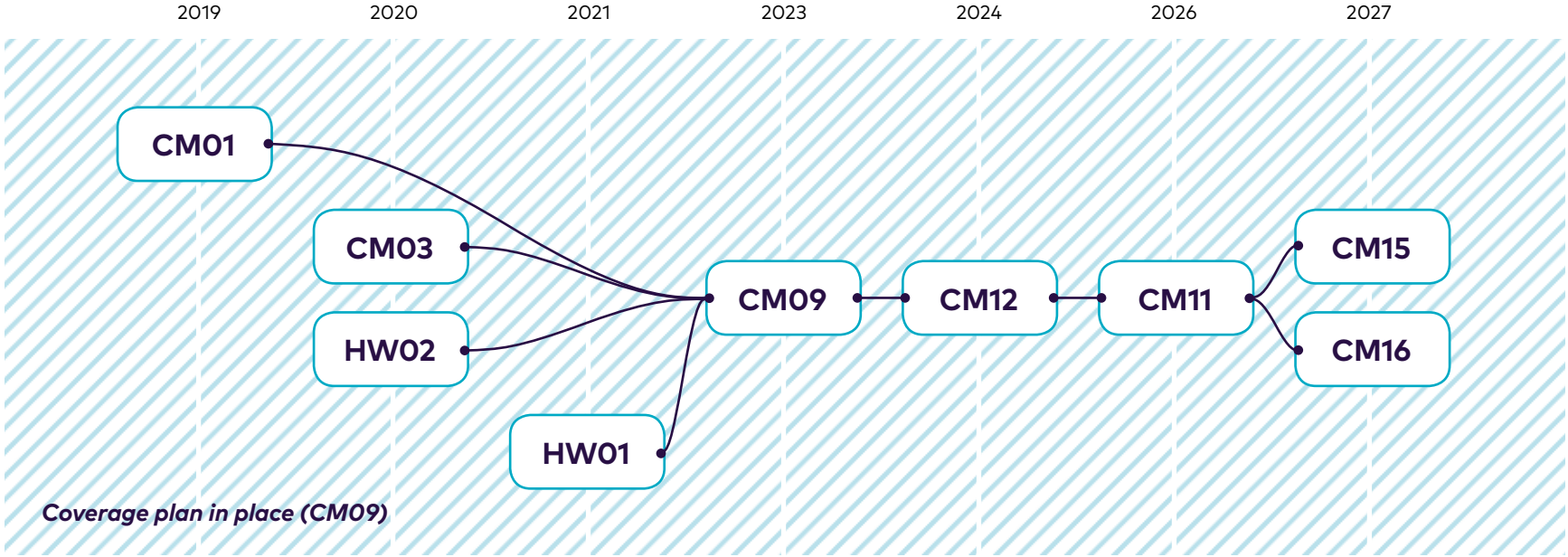
DEEP DIVE

Coverage plan in place (CM09)

A credible plan for appropriate communication coverage is both a major deliverable and a key enabler. This critical waypoint is a trio of Milestones that unlock benefits in infrastructure and all the services they enable. The period between 2022 and 2026 will be critical in having the *Coverage plan in place (CM09)*, *Coverage roll out planning (CM12)*, and the *First service deployed utilising safety messages (CM11)* for a critical, collective waypoint.

Four parallel Milestones enable these critical waypoints. This starts with *Defining communications for new schemes (CM01)* in 2019, followed by publishing a *Capacity requirement (CM03)* and a *Blueprint agreed for a CAM-ready highways and rural environments (HW02)* in 2020. The final enabler is agreeing a *Blueprint for a CAM-ready town or city (HW01)* in 2021.

The delivery of further major Milestones and benefits hinge upon these waypoints, warranting scrutiny and effort to ensure they happen when needed. These include *Safety messages from all new vehicles and all new highway schemes (CM15)* and *Safety messages in all major urban areas (CM16)* both in 2027. Similarly, early work to deliver the enablers which precede these waypoints must not be underestimated.



KEY

ID	Milestone	Date
CM01	Define communications for new schemes	2019
CM03	Capacity requirement published	2020
HW02	Blueprint agreed for a CAM-ready highways and rural environments	2020
HW01	Blueprint agreed for a CAM-ready town/city	2021
CM09	Coverage plan in place	2023
CM12	Coverage roll out planning	2024
CM11	First service deployed utilising safety messages	2026
CM15	Safety messages from all new vehicles and all new highway schemes	2027
CM16	Safety messages in all major urban areas	2027

Summary

It is clear from the roadmap analysis that data plays a fundamental role in achieving CAM-ready infrastructure. It shapes understanding of how data requirements can be defined, and the effect that has on the ability to deliver resilient communications technology. Although the impact on Intelligent Network Management has on Communications is not covered in great detail the impact Intelligent Network Management has on Communications, there are many strong dependencies between these Streams.

Infrastructure, like all other Themes, is not isolated. Whilst some Milestones can be delivered within traditional silos, CAM services require conversations between infrastructure providers and CAM operators – not neglecting the strategic objectives of highways authorities. The fundamental convergence of vehicle connectivity and infrastructure sits at the very heart of achieving the 2030 Vision. The roadmap highlights the need to bring many traditionally separate industries closer together.

"The UK CAM roadmap brings alignment to key themes across the delivery of mobility services. Perhaps most importantly it emphasises the need for early public engagement to ensure users understand and shape the services they will benefit from."

Andrew Wescott, Addison Lee Group

Golden Thread 06
Cyber Resilience

Introduction

Cyber security and resilience will add value across the economy and boost consumer confidence. The roadmap provides a set of dates over the coming decade, that unlock an effective and legally-sustainable system of engineering practice, regulations and insurance. This will support the growth of the ecosystem, enabling its development in directions that are currently unforeseen or misunderstood.

There are arguably no other topics in the roadmap as pervasive as cyber resilience. Cyber-secure, digitally-resilient services and systems cut across every Theme and Stream and influence a large number of Milestones – 249 in total. Cyber security can be defined as a subset of cyber resilience. Cyber resilience is not just about defending against malicious actors, it also considers how day-to-day operational problems like power or communications outages can affect the delivery of safe and efficient services.

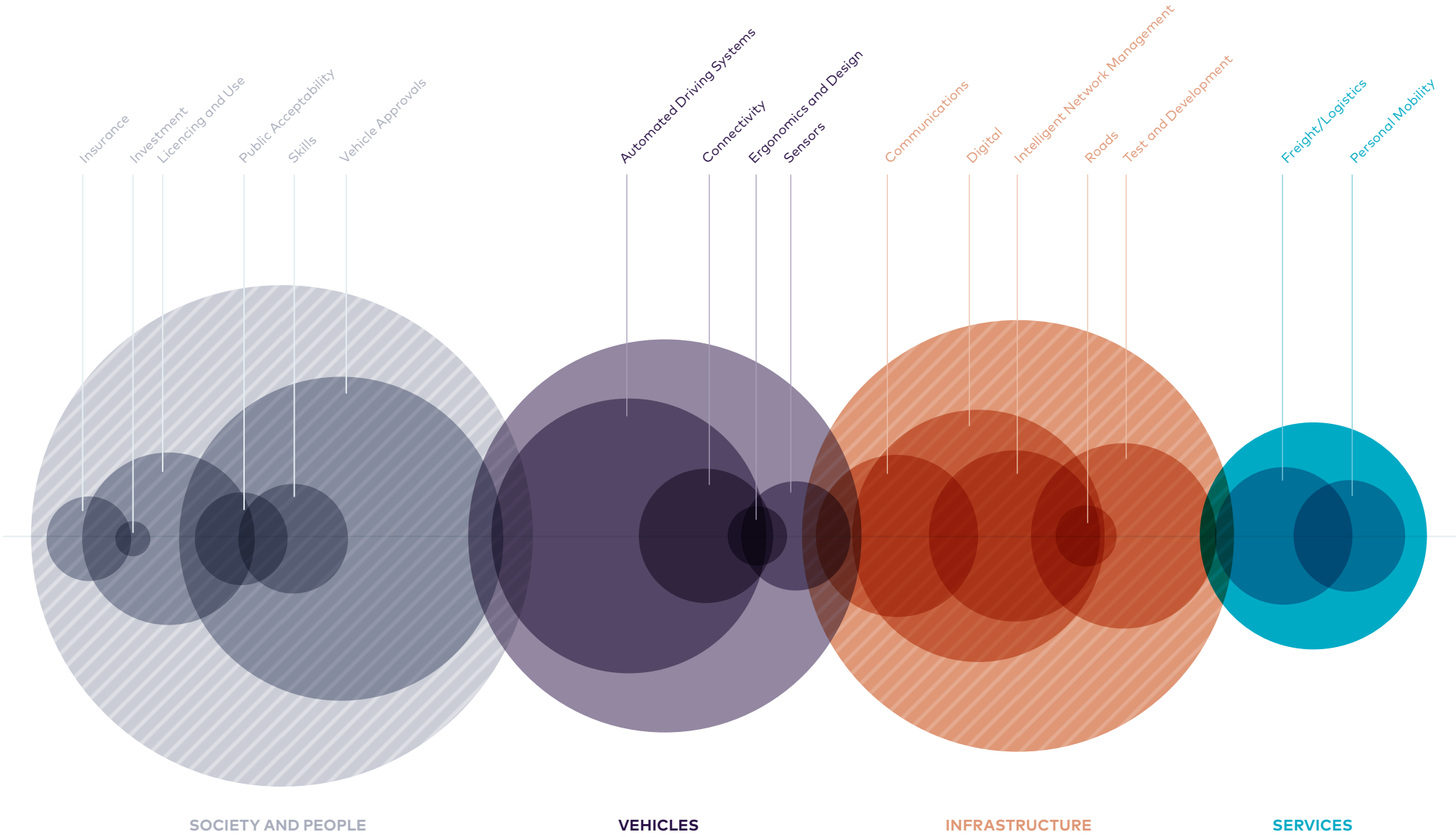
Connected vehicles are already with us, and all new vehicles will be connected by 2025 (SMMT, 2019). The interactions between vehicles, infrastructure and third-party services across rapidly-evolving applications and highly diverse uncontrolled supply chains could also make managing risk across this emerging critical national infrastructure very complex.

However, the UK is regularly ranked top three in global league tables for cyber security capabilities. Early investment from government and industry will not only ensure resilient and trusted services are built, but could also be a significant export strength for the UK in years to come.

Contributing themes

It is unsurprising that cyber security is pervasive across numerous Themes – not only within the technology-focussed Themes of Vehicles and Infrastructure, but also Society and People. In order to ensure a safe and secure CAM ecosystem, there is a necessity to regulate and set standards of best practice and guidance, as well as formal standards. Cyber security is seen as a fundamental part of public acceptance, which is vital for the uptake of CAM through the delivery of desirable services.

Technology areas such as digital infrastructure, connectivity and automated driving systems, rely heavily on cyber security. Testing and development infrastructure in these areas is needed to enable dedicated research for best practice of cyber security.



Contributing themes

Major deliverables

Cyber security is most often found as a key enabler within the roadmap. Consequently, there are not many major deliverables that result in a cyber security related outcome. *Cyber security becomes a core part of vehicle approval (LR82)*, is one example where a number of preceding steps exist. These steps allow cyber security to be truly integrated in the vehicle approval scheme.

"Robust cyber security practices will enable a safer CAM ecosystem. The roadmap of dependencies ensures the network can be secure by design."

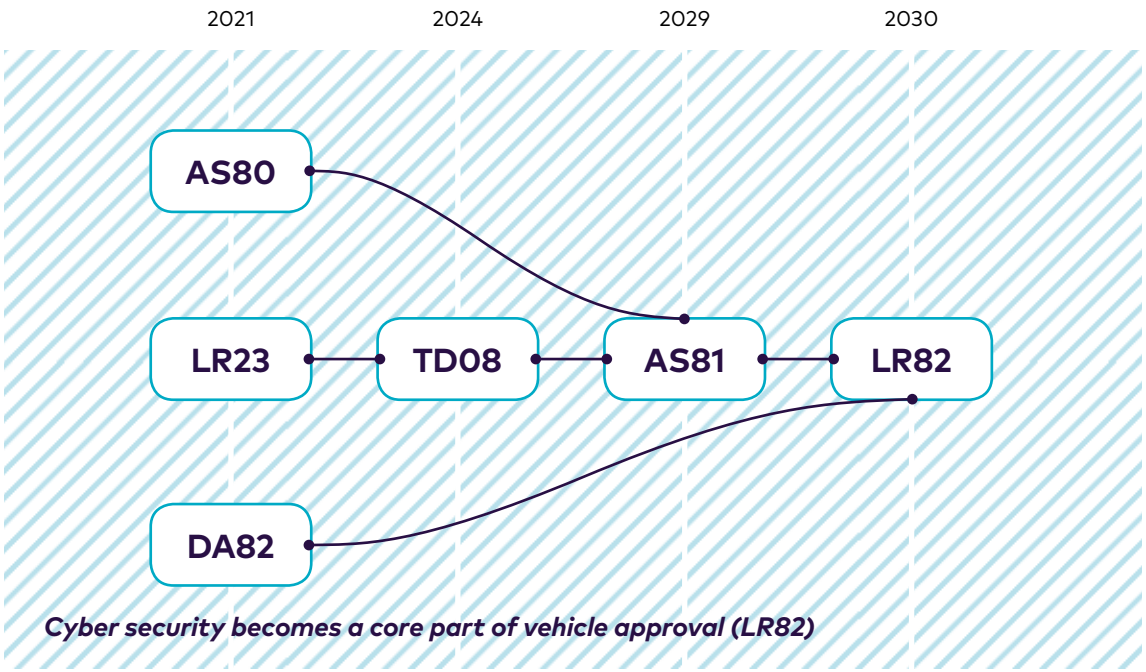
National Cyber Security Centre

DEEP DIVE

Cyber security becomes a core part of vehicle approval (LR82)

The establishment of a vehicle approval process that has cyber security at its core, is pre-dependent on subscribing to common regulations at a global scale in 2020, through the *UNECE cyber security regulations development (LR23)*. This is complemented by delivering, in parallel, a UK-centric *Definition of current best practice principles for cyber-secure vehicles and systems (AS80)*.

These activities allow a solid theoretical positioning of cyber security. The *Delivery of a cyber security centre of excellence (TS08)* in 2024 will provide a focal point for cross-organisational exchange of research and knowledge. Additionally, it will oversee and facilitate research and development into cyber reliance building upon the *Definition of best practice for cyber-secure road-side infrastructure development (DA82)*. The centre of excellence will be a strong voice, providing direction to government on the needs and best practice in placing security as central to safety in the vehicle approvals process from 2026.



KEY

ID	Milestone	Date
AS80	Definition of current best practice principles for cyber-secure vehicles and systems	2021
AS81	R&D into cyber resilience capability throughout the vehicle lifecycle	2029
DA82	Definition of best practice for cyber-secure road-side infrastructure development	2021
LR23	UNECE cyber security regulations development	2021
LR82	Cyber security becomes a core part of vehicle approval	2030
TD08	Delivery of a cyber security centre of excellence	2024

Key enablers

When looking for the early enablers in cyber security, there are a number of Milestones that stand out. Cyber security is part of 50 enabling Milestones, showing how key this topic is. The key Strands related to this Golden Thread are:

- *Delivery of a cyber security centre of excellence (TD08)*
- *UNECE cyber security regulations development (LR23)*
- *Specify safety critical data use cases (CN06)*

"The seamless link between physical and digital infrastructure is key for connected and self-driving vehicles to offer frictionless end-to-end journeys. The roadmap only validates our mission which is to Make Parking Forgettable."

Dan Hubert, Appy Parking

DEEP DIVE

Delivery of a cyber security centre of excellence (TD08)

There are few other critical enablers that unlock so many diverse aspects of the roadmap to the extent of which the cyber security centre of excellence does. The Milestone for the *Delivery of a cyber security centre of excellence (TD08)* supports trials, public acceptance, skills, legislation and regulation, services, vehicles, infrastructure and more.

The centre of excellence unites the expertise needed to support the reasoning and research that will build a sustainable digitally-enabled auto infrastructure, and its legally-sustainable justification. Without the ability to both develop new techniques for cyber resilient systems and to validate them, CAM services will not be delivered on a large scale and the public will not trust them.

In terms of delivering and maintaining CAM services, the cyber centre of excellence will allow *R&D into cyber resilience capability throughout the vehicle lifecycle (AS81)*.

This will include *Cyber security as part of the MOT test (TD10)* – in the future MOTs may not be annual, instead requiring continuous assessment. This has an immediate knock-on effect for *Training programmes deployed for maintenance (SK22)* to perform these services at scale for fleets across the country. Legal frameworks will need to be developed to govern risks as connected and self-driving vehicle services grow to become part of critical national infrastructure. The cyber security centre of excellence will provide a means to authoritatively identify, quantify and advise on mitigation strategies.

Providers of CAM services will be expected to adopt these best practices or potentially be unable to demonstrate that they have taken justifiable steps to mitigate cyber resilience risks, through a *Legal framework to deal with the consequences of cyber attacks (LR61)*. Failure to do this will have a negative impact not only on insurance premiums, but also defences in court if serious incidents do occur.

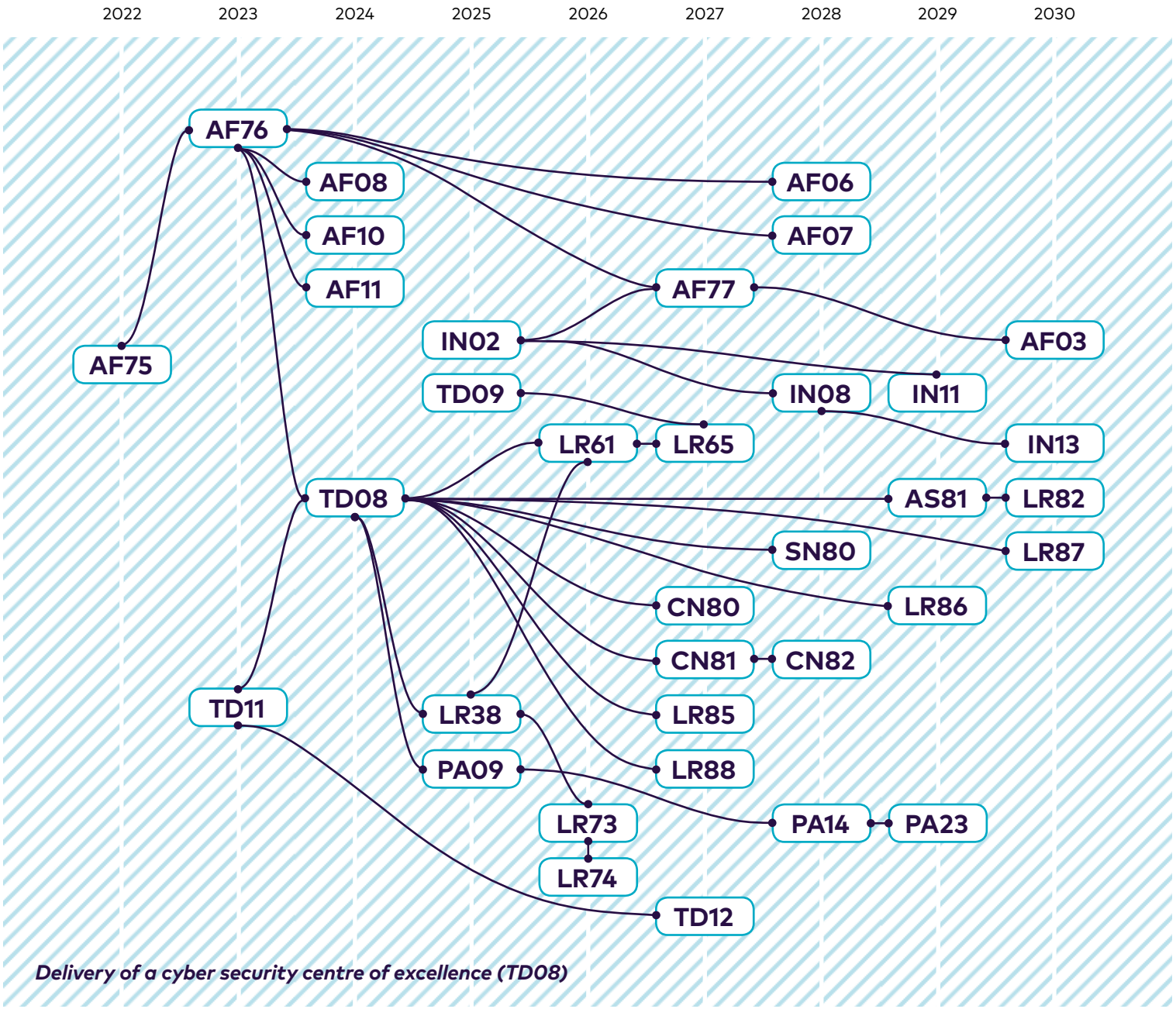
Research into security of AI (AF75) is a hot topic nationally and internationally, which will be *Defining guidance for security of AI (AF76)*. In particular, AI deep learning systems are only as effective as the data that is used to train them. Research into accredited data for training will unlock the means for creating validating data sets for the training and certification of AI systems. As a result, this will improve insurability and public acceptance.

Finally, early investment in a cyber security centre of excellence and appropriate supporting research programmes will have a significant positive impact in terms of being able to deliver the 2030 Vision. In particular, many current approaches and standards cannot be sustainably operated at scale and within budget, in the face of legal challenge.

KEY

ID	Milestone	Date
AF03	Verification that AI and sensor fusion algorithms are able to self-determine exceedance of ODD	2030
AF06	Develop methods for AI-generated bias mitigation	2028
AF07	Debugging process for AI decision making	2028
AF08	Non-deterministic AI trusted when balancing safety benefits	2024
AF10	Establish AI pedestrian reaction and behaviour simulation	2024
AF11	Develop software standards for AI and ML code	2024
AF75	Research into security of AI	2025
AF76	Defining guidance for security of AI	2023
AF77	Approved and trusted training data sets	2027
AS81	R&D into cyber resilience capability throughout the vehicle lifecycle	2029
CN80	Research into cryptography for safety data	2027
CN81	Development of suites of hardware and software crypt-for-safety capabilities	2027
CN82	Shift from Zero Trust Networks as default and towards fall back for connectivity	2028
IN02	Insurer access to required car data agreed	2025
IN08	New underwriting and insurance models developed	2028
IN11	Insurance and vehicle registration data is combined	2029
IN13	Shift from personal to service based insurance products	2030

ID	Milestone	Date
LR38	A legal framework that supports the creation and use of cyber-resilient ITS	2025
LR61	Legal framework to deal with consequence of cyber attack	2026
LR65	International standards on cyber security in place	2027
LR73	Framework in place to review legislation, regulation, standards and policies	2026
LR74	Appropriate update cadence established	2026
LR82	Cyber security becomes a core part of vehicle approval	2030
LR85	Assessment of CAM Ecosystem against Critical National Infrastructure definition	2027
LR86	Define supply chain security requirements	2029
LR87	Diversity and vulnerability to threat landscape is part of testing and approval process	2030
LR88	Definition of national-scale incident response plan	2027
PA09	Educate the public on the limitations of cyber security within CAM	2025
PA14	Start of public trust in CAM	2028
PA23	Public acceptance at 85%	2029
SN80	High integrity, resilient and redundant sensors deployed	2028
TD08	Delivery of a cyber security centre of excellence	2024
TD09	Establishment of national threat database	2025
TD11	Testing scenarios development	2023
TD12	Creation of a national test oracle	2027



DEEP DIVE

UNECE cyber security regulations development (LR23)

UNECE has begun to produce guidance to address all identified cyber threats and vulnerabilities (UNECE, 2019). Ultimately, this will ensure vehicle safety, should cyber attacks occur. The UNECE guidance published in 2018 details cyber security threats and suggests high level countermeasures. It also includes a draft UN regulation for the approval of in-vehicle cyber security.

The effectiveness of this first generation guidance, and its ability to be operationalised at cost, must first be understood. If the tools and techniques being chosen are not rigorously founded, they have the potential to destroy the value the UK hopes to achieve from CAM. Conversely, the effective application of a centre of excellence to this problem will enable the UK to take the lead in moving CAM and adjacent markets from demonstration systems to mass deployment.

Most significantly, the draft regulation lays the groundwork for a requirement to monitor cyber security post-production: "Organizations within the automotive industry shall have the capability to identify how threats and vulnerabilities to vehicles or systems change over time and to identify threats that were not identified or accounted for in the development stage" (UNECE, p.10, 2019). Given that hundreds of thousands of new threats are estimated, that could be identified over the average eight year life of a vehicle, this represents a formidable challenge for vehicle manufacturers.

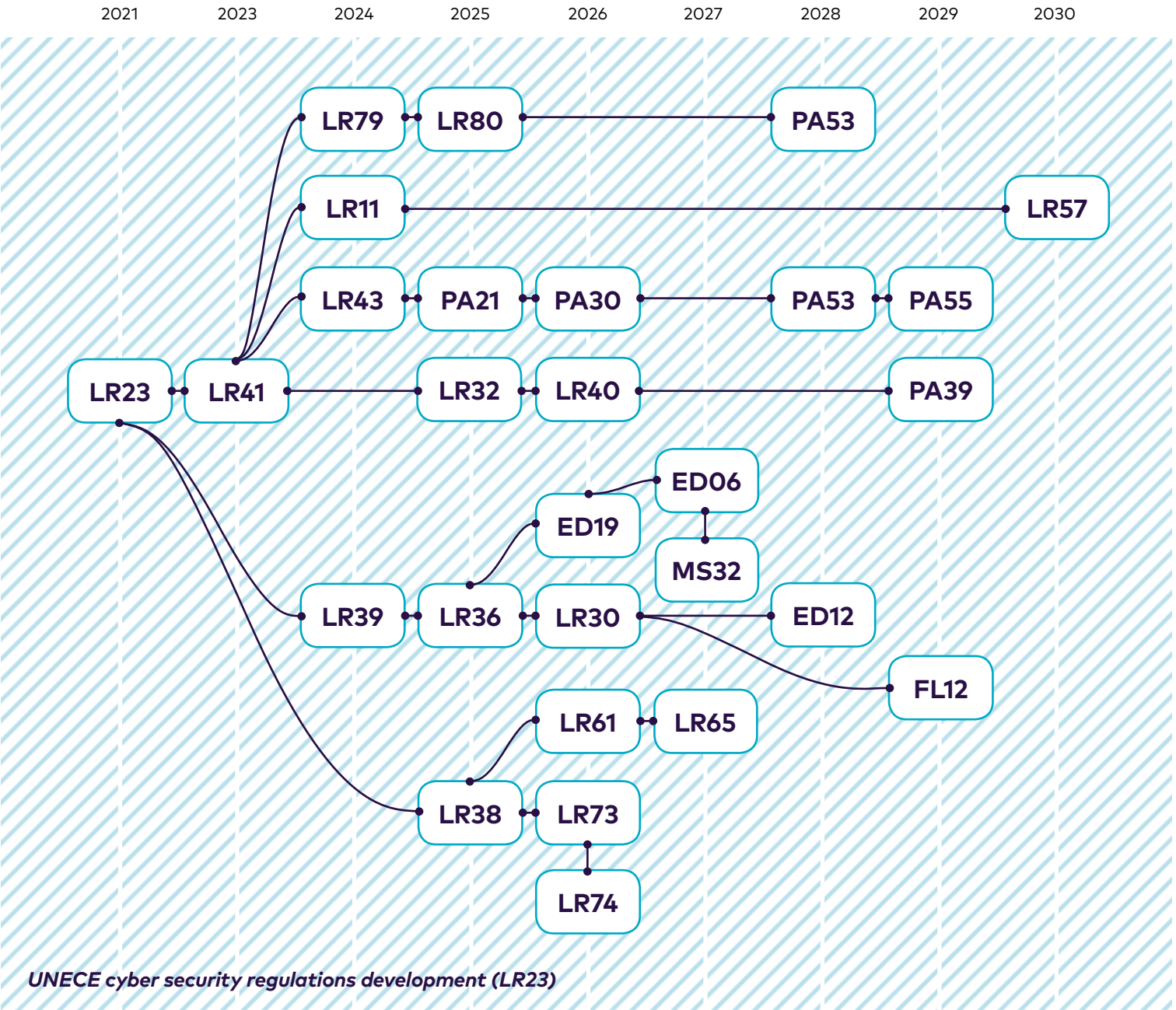
By 2024, building upon current UNECE cyber guidance and following a trend set by BSI PAS 1885 (BSI, 2018), *A legal framework that supports the creation and use of cyber-resilient ITS (LR38)* is expected. As highly-automated vehicles begin to be deployed, cyber security regulations will be incorporated into vehicle certification regimes and approval. Cyber security and resilience requirements derived from CAM trials will begin to be rolled into the licencing of services, ensuring automated fleets operate safely and effectively. In addition to regulation, projects like 5StarS (5StarS, 2019) are good, working examples that will allow more solid steps towards an effective, trustworthy and legally-sustainable regime for the assurance of automotive systems in the face of cyber attacks.

From 2026, the adoption of cyber security principles will support the delivery of new vehicle types at scale as *Cyber security becomes a core part of vehicle approval (LR82)*. The implementation of solid cyber security principles throughout the lifecycle of the vehicle and across CAM services will contribute to an excellent safety and reliability record for self-driving vehicles. This track record will contribute greatly to the public's positive perception of self-driving technology with *Public acceptance at 85% (PA23)* by 2028.

KEY

ID	Milestone	Date
ED06	Legal considerations for new seating positions and passenger design space	2027
ED12	Revise legislation on vehicle interior	2028
ED19	Highly-automated vehicles with no steering wheel start to appear on public roads	2026
FL12	Consolidation of movement of freight and people	2029
LR11	Process in place which speeds up new type approval from UNECE	2024
LR23	UNECE cyber security regulations development	2021
LR30	Highly-automated vehicles are more easily able to be on public roads legally	2026
LR32	Alignment of future of mobility requirements around micro-mobility	2025
LR36	Adapting regulation for highly and fully automated vehicles	2025
LR38	A legal framework that supports the creation and use of cyber-resilient ITS	2025
LR39	Regulation change(s) to allow self-driving vehicles to be used for services	2024
LR40	Mandatory coordination and integration of local authorities' services	2026

ID	Milestone	Date
LR41	Policies and legal frameworks in place to allow passenger transport trials	2023
LR43	Requirements for licencing captured from CAM trials	2024
LR57	Harmonised vehicle approval scheme established	2030
LR61	Legal framework to deal with consequence of cyber attack	2026
LR65	International standards on cyber security in place	2027
LR73	Framework in place to review legislation, regulation, standards and policies	2026
LR74	Appropriate update cadence established	2026
LR79	Best practice informs national standards	2024
LR80	UK safety case adoption feeds into global standards	2025
MS32	Highly demand-responsive transport services enabled	2027
PA21	Evidence-lead discussion on safety benefits already being delivered	2025
PA30	Self-driving vehicles are no longer noteworthy	2026
PA39	Behaviours around CAM have changed to the positive	2029
PA53	Public gain exposure to self-driving vehicles and feel safe	2028
PA55	Evidence of safety record begins to show	2029



Critical waypoints

Due to the foundational nature of cyber security, there are few critical waypoints that deal explicitly with it, but many of which rely on it for effective delivery. Of those critical waypoints, the one which most closely deals with the need for cyber security is widespread adoption of safety case standards, which feeds into the global influence of standards.

"Systemic resilience between users, vehicles, sensors, networks and infrastructure is crucial for a CAM network. This roadmap shows what to design, invest, deploy and operate, supporting CAM adoption and normalisation."

Nathan Marsh, Atkins

DEEP DIVE

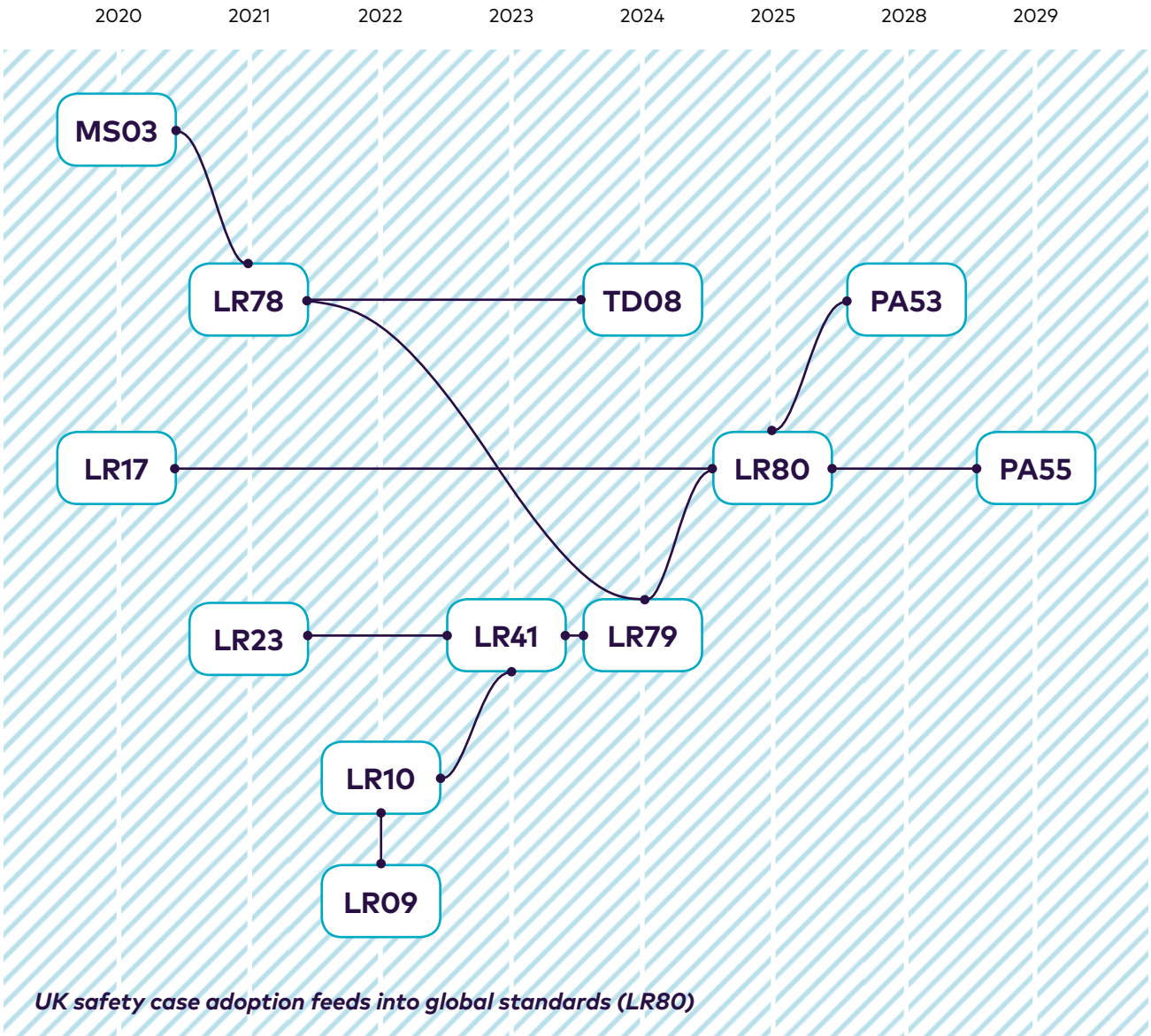
UK safety case adoption feeds into global standards (LR80)

Information and data on resilience and security from trials and testing enables *Best practice which informs national standards (LR79)* and unlocks the delivery of cyber resilience into vehicle approval schemes. This further ensures the *Public gain exposure to self-driving vehicles and feel safe (PA53)*, allowing services to become more prevalent, and in turn assists in adoption, because the public feels safe as the *Safety record begins to show (PA55)*.

Cyber security and cyber resilience are not a primary matter for the *Law Commission review into automated vehicles (LR09)* and *Law Commission final report (LR10)* on connected and self-driving vehicles. However the report will assist in establishing how assessment and certification regimes might operate, which should include cyber resilience. As a result, to unlock cyber resilience in vehicle approval schemes, several parallel activities are required both in terms of the delivery of testing technology, in addition to legal review. *Delivery of a cyber security centre of excellence (TD08)* enables rigorous development, testing and trials of cyber resilient CAM services.

KEY

ID	Milestone	Date
LR17	Agreed safety standards	2020
MS03	First code of practice for CAM services	2020
LR23	UNECE cyber security regulations development	2021
LR78	Testing specialists define best practice	2021
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR41	Policies and legal frameworks in place to allow passenger transport trials	2023
LR79	Best practice informs national standards	2024
TD08	Delivery of a cyber security centre of excellence	2024
LR80	UK safety case adoption feeds into global standards	2025
PA53	Public gain exposure to self-driving vehicles and feel safe	2028
PA55	Evidence of safety record begins to show	2029



UK safety case adoption feeds into global standards (LR80)

Summary

Analysis of the Cyber Security Golden Thread highlights the critical nature of defining, from the outset, how to design and deploy safe and secure systems. Cyber security is by far the largest Golden Thread, with over 249 related Milestones. It proves to be instrumental in unlocking core technology topics such as data, digital infrastructure, automated driving systems, as well as legislative areas such as vehicle approvals, and licencing and use. All of these lead to the conclusion there are immediate activities that must be undertaken, including significant input into the UNECE cyber programmes and the establishment of a CAM-focussed cyber security centre of excellence, which is the focal hub for research, guidance and testing within the UK.

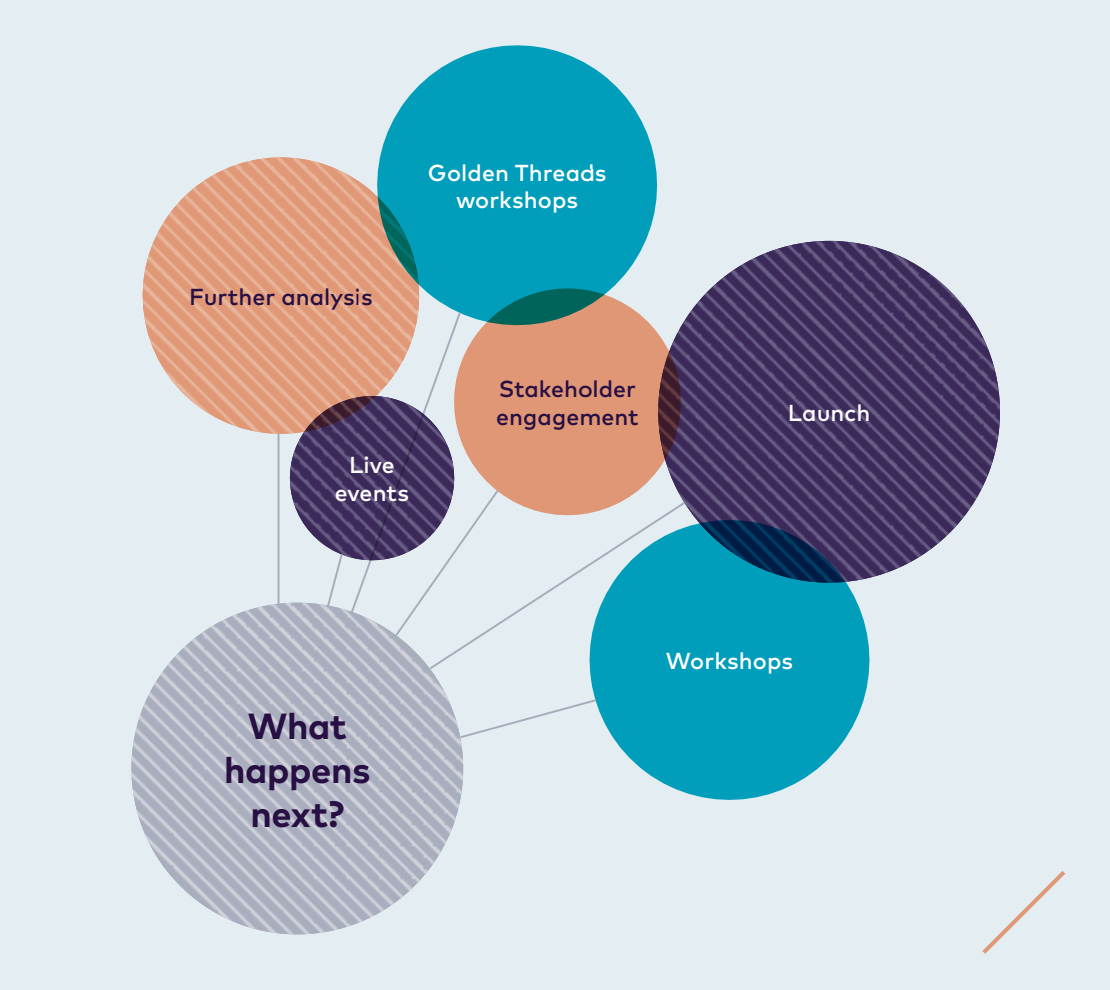
"NPL is helping to build confidence in the testing and modelling of CAV sensors, one of the components the roadmap identifies as required for the future successful deployment of CAM."

Andre Burgess, National Physical Laboratory

What's next for the roadmap?

Central to the continuing usefulness of the UK Connected and Automated Mobility Roadmap to 2030, is the update and refresh process. Because of the fast-moving nature of CAM, an accurate and pragmatic view of the future is essential for decision makers, investors and users across the ecosystem to reliably understand the CAM landscape. This is only achievable through ongoing stakeholder engagement and updates to the roadmap, accurately reflecting a consensus view across CAM's wide range of industries. It must be a living tool that is dynamically revised as the ecosystem evolves.

With this in mind, the next year is a rich opportunity for further stakeholder engagement, development of future features, deep dive roadmap studies through industry collaboration as well as a comprehensive programme of workshops and events. This will support the continual refresh and update cycle, constantly feeding the roadmap with updated information on the CAM landscape. Honing the tool will allow decision makers to further progress CAM capabilities in the UK.



The Chartered Institution of Highways and Transportation (CIHT) – Reflection

CIHT has been clear the continued development of connected and self-driving vehicles has the potential to significantly improve road safety, reduce congestion and enhance car users' and drivers' experiences. There are many challenges and hurdles to overcome for these technologies to be successfully implemented and effectively used by the wider population. As a Chartered professional body, and charity with a focus on developing the public benefit of all aspects of highways and transportation (H&T), the significant development of the sector offered by CAM is a key area for us.

The H&T sector currently has a limited understanding of the CAM ecosystem. This was highlighted in a 2018 survey of CIHT members, where 87% thought the sector had a limited level of understanding about CAM, and 13% reported a very limited level of understanding (CIHT, 2018). The roadmap pulls together all the activities around CAM in a way that has not been seen before and will enable wider understanding and, importantly, proper consideration of all the issues surrounding the topic.

CIHT will use the roadmap to inform members and the sector on the interactions between a wide range of activities, and to develop thinking around overcoming the challenges and hurdles the roadmap identifies. This will allow CIHT to work with government and others to develop guidance and solutions, across a wide range of areas. The roadmap will identify the changing skills requirements the sector will need to react to and allow decisions to be made in light of the UK's response to climate change.

The roadmap, as it develops, will provide clarity on timescales and resources required to successfully implement a fundamental change in transportation in the UK over a long period. It is a key component of a coherent, integrated national transport strategy that CIHT has consistently called for. CIHT has long argued of the benefits that come from strategic clarity, and continuity of funding and resources.

The roadmap will help develop a sustainable solution for a key part of our transport strategy but only if it has input from across all the parties involved in a collaborative manner.

Andrew Hugill
CIHT's Director, Policy and Technical Affairs

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- 5GAA's Roadmap of monetizable features and business models for LTE V2X – timeline for introduction of LTE V2X (V2V) (2017)
- Automotive council UK's ICV enabling environments communications roadmap (2018)
- Automotive council UK's ICV a roadmap for Connected & Autonomous Vehicles (2017)
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- US Department of Transportation's Automated Vehicles 3.0: preparing for the future of transportation (2018)
- SMMT's Connected and Autonomous Vehicles – the UK Economic Opportunity (2015)
- SMMT's Connected and Autonomous Vehicles – winning the global race to market (2015)
- WMG's CAV demonstrator roadmap (2019)

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"The UK has a world-leading automotive sector and, through our work with industry, we are building on this exceptional reputation, earning our position at the forefront of the design and development of future vehicle technologies.

"The Roadmap published today shows how we can work together to meet the generational challenge posed by climate change and define the future of mobility. Autonomous vehicle technologies will revolutionise how we travel – reducing congestion and emissions, increasing accessibility and reducing accidents on our roads."

Nadhim Zahawi MP, Minister for Business and Industry

Want to find out how the roadmap can benefit your organisation and CAM projects?

Access the interactive roadmap at **zenzic.io/roadmap**

Contact the team to book a meeting or workshop and find your route through the roadmap – info@zenzic.io

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