HOW LONG IS THE ROAD TO DRIVERLESS VEHICLES?
Assessing how close the Nordics are to autonomous vehicles
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These days, Connected Autonomous Vehicles (CAVs) aren’t just part of an imagined future street scene. Driverless vehicles are on our roads, in a growing number of pilot and demonstration projects. Many of today’s vehicles already come with technologies that link vehicle control systems with manufacturers and the emergency services. To a limited extent, they let drivers ‘hand over’ control to their vehicle.

Experts in ‘exponential’ technologies – ones that double in power or speed each year - claim we’re nearing the point where the curve for driverless car technology goes vertical. The problem is us. We humans don’t (yet) have the capacity to actually understand what a driverless world will mean. The reality, and the possibilities, will hit us faster than we can adapt to them.

Think of the impact the internet has had on everyday life - and that development took nearly 50 years from the first email to the pervasive influence we see today. CAVs can potentially have an even bigger impact on our society - how we live, our infrastructure, our urban life and the way we interact with institutions. We don’t believe this technology will take 50 years to implement.

Accurately predicting how long it will take CAVs to become a common sight on our roads is extremely challenging and, looking at other industries, transportation will probably shift into a form of service, already labelled Mobility as a Service (MaaS). Besides the technology, many things will need to come together, including:

- **Regulation** – who oversees how the vehicles are used and what new laws will we need?
- **Insurance** – who’s liable if something goes wrong?
- **Compliance** – how do we enforce laws and regulations?
- **Roads** – will we need new ones? And how do authorities work with other bodies to cater for driverless vehicles?
- **Users** – will people think it’s worth switching to driverless vehicles?

Clearly, while the technology matters, it’s about much else besides. Nothing is solved until everything is solved.

To find out how close we are to the driverless revolution, we’ve created a framework of the capabilities behind it. It raises important questions from the many different perspectives involved in making driverless vehicles happen. This report shares what we’ve found so far by using the framework to get experts’ views. And it gives our view of what the results of our survey tell us about the future of driverless vehicles.

We expect the Nordics to adopt CAVs progressively over the next decade. So the question is not if, but when these vehicles will be able to pick us up and take us where we want to go.

Jan Tellefsen  
Nordic Lead - Roads & Regions  
PA Consulting Group

Frank Madsen  
Transport, Travel & Logistics Lead - Nordics  
PA Consulting Group

Leif Caspersen  
Nordic Lead - Rail  
PA Consulting Group
Communications and systems providers

Disruptive change to any industry creates effects that are hard, and sometimes impossible, to predict. Think about the advent of ‘text speak’ brought about by SMS messaging technology, or the growth of vlogging made possible by smartphone cameras and platforms like YouTube. Consumer trends like these are unpredictable, but significantly change ways of working and how future products and services develop.

Car makers have segmented their products based on driving experience and refinement. New mobility, with its new use cases and in-car functionality, means consumers will expect new choices and outcomes from their mobility providers.

For communication systems and connectivity providers, the challenge will be how to stay relevant in this new ecosystem. A key step to achieving that will be to segment customers by the outcomes they’re looking for.

Highways authorities

Because cars have evolved only gradually, the way we manage roads hasn’t had to change substantially or quickly. CAVs will change that. Highways authorities face challenges beyond operational ones like adapting road markings and traffic lights. The strategic challenges could take them by surprise if they don’t collaborate with manufacturers. If they work independently, it could hold up adoption or undermine safety. And managing a mixture of driverless and conventional cars will need them to join forces to create the right operational protocols.

Government and policy makers

CAVs could transform city landscapes and create many jobs for those with the right technology skills. But demand for commercial drivers will probably plummet.

So far, car builders and tech entrepreneurs, most of them overseas, have led on developing mobility technology and services. But national governments need a strategy to make sure they are part of shaping the implementation of connected and autonomous vehicles.

This will help make the most of the potential benefits, and minimise the negatives. Not doing this could see commercial driving jobs becoming hi-tech jobs in California.

Law enforcement

The law today centres on control of the vehicle. Defining that becomes harder when the car is the driver. Enforcers need new skills to analyse software as evidence. They’ll need to discern which vehicles are autonomous and judge how non-CAVs interact with them.
Insurers

Liability is the big question. Can a driver who isn’t driving be liable for an accident? As well as that, insurers have to figure out how to:

- price risk for events that haven’t been tested – with no historical data to draw on, the usual method won’t be an option early on
- investigate claims – insurers will need to identify mechanical faults or software glitches in cases where manufacturers are liable
- insure driverless car manufacturers – they’ll need extra cover because insurers will be able to claim against them for software problems.

Regulators and Legislators

Regulators and law makers can enable driverless cars or block them. Attitudes will vary. Some will be cautious, others liberal. Legislators and regulators could see a chance to create an environment that puts their country ahead; encouraging investment and driverless car trials.

Already manufacturers and technology developers are moving, stopping and starting trials based on signals from regulators. Technology developers, are watching for signs like:

- recognition that driverless cars are different to existing cars
- a stable, consistent and forward looking regime
- scope for innovation in elements that hold competitive advantage, but rigid standards for elements that don’t.

Automotive Manufacturers

All car builders are investing heavily in driverless cars. They’ll have to decide how the driverless revolution will affect their business model. Will they be selling cars or smartphone-like entertainment platforms? Will they be selling cars at all, or leasing them as ‘mobility as a service’ (MaaS) providers? All manufacturers are placing bets on how the ecosystem will develop. The speed of that development will decide who comes out on top.
WHAT DO WE NEED TO ENABLE DRIVERLESS VEHICLES?

What do we mean by ‘driverless’?

In the last 10 years, vehicles have become significantly more autonomous. Technology helps us park, overtake, stay in lane, brake and control cruising speed. But this technology supports the driver, who stays in full control.

There’s no single definition of autonomy in vehicles. But there is an emerging international standard, which we’ve used as the backbone of our analysis. It starts at Level 0 - drivers in complete control with no help from vehicle systems. And it progresses to Level 5 - vehicle systems in complete control, with no need for a driver. In between are levels where the driver acts with help from the car or gives up control in certain situations.

The Tesla S is often talked about as ‘self-driving’. Its ‘autopilot’ capability is an ‘advanced driver assistance system that provides a hands-on experience [for drivers]… by augmenting their perception, improving their decision making, and assisting in their control of the vehicle’. But it’s still only on Level 2 of the scale below.

![Defined levels of automation (for road vehicles)](image)

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1 Figure 1: Society of Motor Manufacturers & Traders (SMMT), Connected and Autonomous Vehicles: The UK Economic Opportunity, March, 2015
Getting to Level 5 poses significant technology and systems challenges – and so far, what industry and the media have largely focused on is a technology solution. We used this maturity scale as guidance and asked our respondents to answer questions ranging from ‘nothing has happened’ to ‘full maturity’.

Widespread use of fully driverless vehicles means solving a host of other inter-related challenges:

- **Regulation and laws**
  What standards define when autonomous vehicles are fit to be on the road, and how they make decisions?

- **Compliance**
  How do we enforce laws and regulations?

- **Insurance**
  Where does liability lie if something goes wrong?

- **Consumers**
  Why should consumers want driverless vehicles? What do other road users want?

- **Roads**
  How will roads need to adapt for the Nordics to make the most of driverless vehicles?

- **Policy**
  What policies will we need to support driverless vehicles

These challenges overlap. Delays in one area could affect progress in others. Even if some technology challenges are close to being resolved, widespread use of driverless vehicles won’t happen if the social and legal challenges haven’t been tackled.

**Asking the experts**

We gathered the views of over 75 people currently involved in CAV development projects in the Nordics. They included people working for car builders, government, insurers, law firms, enforcement organisations, highways authorities, technology providers and representative bodies.

We asked our respondents:

How far down the road are we to achieving each capability, on the five-level scale?

How long will it be before we achieve each capability, in years?

A similar survey was conducted in UK.
Our survey shows which areas need to make most progress for driverless vehicles to become a reality. It also highlights extremely challenging areas where it will be hard to find the right solutions. We believe the most interesting and important findings from this survey are:

**Technology and business models don’t go hand in hand**

While technology is developing quickly, and could be ready in around six years, according to our respondents, car builders and others in the emerging ecosystem need to focus more on business models.

**Regulation is challenging**

Regulation around vehicle testing may have progressed well, but other areas have a lot of catching up to do.

**Insurance faces fundamental change**

Not only will insurers have to solve the puzzle of accident liability, they’ll have to cover makers and operators of CAVs as well as users who haven’t been eligible to drive before.

**There’s no direction or vision for infrastructure**

Short-term investment risks impeding the progress of driverless vehicles. A combination of national and international strategies is needed to guide the work of engineers and infrastructure planners. Only then will we reap the full benefits of driverless vehicles.

**Optimism rules**

We also found the respondents are far more optimistic about the prospects for driverless vehicles than the official line. While the Danish Road Authority says 2 driverless vehicles will only be fully mature by 2065, our survey predicts we’ll reach that point by 2037 – almost three decades sooner.

We conducted a similar survey in UK to assess how stakeholders in UK perceive the maturity of CAV. The UK survey showed a general consensus in maturity to the Nordic results, with UK being slightly more mature, especially in regards to maturity of road networks and the regulatory environment. What the Nordic region lacks in maturity, they make up for in optimism; with a belief that full maturity will be reached before the UK average of 10 years.

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1. [https://ing.dk/artikel/forst-2065-eroberer-selvkorende-biler-danske-veje-193125](https://ing.dk/artikel/forst-2065-eroberer-selvkorende-biler-danske-veje-193125)
THE SURVEY FINDINGS IN DETAIL

Technology and business models don’t go hand in hand

Driverless vehicles depend on reliable and secure technology to be able to operate without drivers being involved. So a big part of our survey was about understanding how close the respondents thought we were to having the right systems and business models in place.

Technology is moving fast

The technology is developing quickly, driven mainly by new players like Tesla, Google etc. But established car builders also realising they have to get involved. Our survey suggests the technology is already well on the way to maturity: 57% of the respondents think the building blocks are in place or that implementation is underway.

Business models still need to be defined

Technology might be moving rapidly, but the final technical architecture is still years away from being at a solid state, and it’s still unclear how various companies will fit into a CAV value chain.

The lack of defined business models shows in our results, with 75% of respondents saying either that nothing has happened or that very little thinking has been done. The uncertainty comes across in areas like how to maintain CAVs or give them system upgrades.

It seems the consensus is that the technology is a race to develop a working driverless car, but that thinking around how the vehicles will be used isn’t anywhere near as developed.

This presents an opportunity for those not in the technology race to position themselves in the value chain as ‘owners’ of the customer relationship.

Timeline to reach full maturity

While there is consensus around the maturity of the elements of CAV technology and business models, there is a huge spread in perception of when full maturity is reached.

The most optimistic respondents claim that technology are ready within a year and the most pessimistic claims 20 years to full maturity. The average is six years. The huge spread could also be explained by that most optimistic apply a solely technology point of view. However, there is still big discrepancy to when national road authorities in Denmark believe, we will reach full maturity.

Our survey indicates this will happen almost 30 years sooner than their estimations of 2065.
Regulation is challenging

Having an appropriate regulatory and legislative framework is a key capability if we’re to make a success of driverless vehicles. A stable regulatory environment lets companies plan early and avoid risky investments in ideas that could face legal challenges later. It also builds organisations’ and citizens’ confidence in CAVs.

Regulation on testing is already making progress

Overall, the respondents thought regulation in the Nordics hadn’t made much progress. Only 7% said implementation was progressing or full maturity is already reached.

But they thought progress on road worthiness was much better - 40% said it had gone beyond testing and thinking. Perhaps not surprisingly, testing is the most mature area when it comes to regulation. Testing is the key to fully understanding the opportunities and risks associated with autonomous vehicles on the roads.

Politicians have already green-lighted testing for fully autonomous buses in Denmark. With a new law coming into effect by 1st July 2017, operators can apply for approval to test fully autonomous buses. We expect the first request by autumn 2017.

More analysis needed before governments can access systems

More than eight out of ten of our respondents think regulations to let authorities interrogate CAV systems haven’t got beyond early thinking. These regulations are crucial because they let authorities investigate how CAV systems operate, and apportion blame for accidents. This area is certain to open up philosophical and ethical discussion on whether we can assign responsibility to objects.

Driver testing will need a major overhaul

The third major challenge our respondents raised is how to prepare drivers for the change to driverless vehicles. Users of CAVs will need to adapt to inevitable technical change in their vehicles. But 90% of the respondents say licensing CAV drivers hasn’t progressed beyond early thinking. The traditional approach of training and testing a driver as a one-off event won’t be fit for purpose. As the nature of driving changes, drivers will need to be retrained and retested and driving education will need a radical overhaul.

On average, our respondents think the regulatory framework to enable driverless vehicles is nine years away. So despite all the challenges and complexity, they’re still cautiously optimistic.
Insurance faces fundamental change

Driverless vehicles will give the insurance sector particularly complex problems to solve. Insurers will need to design products suitable for owners and operators of driverless vehicles. They’ll also have to cater for users of new mobility services. Given the array of possible new uses of CAVs, there will be new vehicle users who haven’t been considered eligible to drive before. Insurers will have to assess how to cover these risks.

**Insurers aren’t close to solving the liability puzzle**

Insurance is a key element to have in place before fully autonomous vehicles are roadworthy. But uncertainty about where liability will lie if accidents happen, plus statements from auto manufacturers, suggest insurance as we now know it might change have to change radically. That’s a view shared by 86% of our respondents, who say this capability hasn’t developed beyond early thinking.

Insurance companies face the same issue as government when it comes to assigning blame and liability. Does liability lie with the manufacturer, passenger or operator? Manufacturers have suggested they’ll will accept full liability whenever one of their vehicles is in autonomous mode[^3]. Their statements could indicate a shift for insurance from a traditional B2C model to B2B, with whole fleets insured.

**Immaturity in assessing risk**

It’s clear that CAVs will change the market for vehicle insurance, and fragmented approaches could emerge amid uncertainty about where insurance fits into the future value chain of CAVs. This uncertainty could explain by 85% of our respondents think insurers are only at the early thinking stage when it comes analysing the risks of driverless vehicles. One statement from the survey highlights this dilemma. As one respondents said, this is a chicken-and-egg situation: “Insurance policies have to be based on an assessment of costs and risks. CAV may reduce costs and risks. But there’s still very little data to act as a basis for writing policies.”

**Insurers are embracing technology**

While uncertainty marks this area, our respondents are still optimistic insurers can quickly develop enough capability to support driverless vehicles. On average, they think this could happen in 7 years.

Insurers are working closely with manufacturers to shape collision avoidance systems. Advanced driver assistance systems are helping to prevent many types of collisions, which is bringing down premiums. Short term benefits are present and still today a car cannot drive on the Nordic roads without a liability insurance.

There’s no direction or vision for infrastructure

Driverless vehicles could be implemented without the need for any changes to road infrastructure. Indeed some of the CAVs currently being tested on public roads require no adaptions to the road infrastructure to operate safely.

However, if the infrastructure are not optimised and managed properly the full benefits of CAV will be harder to reach. To reap the full benefits of CAV and enable a multimodal strategy, investment in intelligent traffic management, technology and infrastructure is required.

Road infrastructure don’t fully understand how to enable CAVs

Our survey reflects pessimism about how far road operators are down the road to solving future infrastructure challenges.

92% of our respondents say only very limited thinking and testing have happened to try to understand how road operators can support CAVs and get the full benefits.

This lack of direction and vision for infrastructure is potentially costly, with investment going in to already mature technologies which could well be obsolete by the time they come into operation.

The success of driverless vehicles depends on national and European strategies to integrate CAVs into transport networks. Sets of principles like this would guide engineers on the technical questions. Some might be as straightforward as defining what CAVs will look like and what sort of safety-critical data they’d need to receive. These guidelines would also help cash-strapped local authorities to plan their infrastructure to fit the national plan, and cut the risk of fragmented approaches emerging.

Car builders’ needs are straightforward, but expensive

The need for more national multimodal infrastructure strategies is again highlighted when we asked the respondents to rate maturity of road operators’ ability to associate cost with the support for CAV.

98% indicated that no more than thinking have begun to get a full understanding the infrastructure cost associated with support CAV.

Vehicle manufacturers have two requirements in relation to the road and telecoms infrastructure to allow the rollout of fully autonomous vehicles.

• Firstly, better maintenance of road infrastructure so CAV technologies can read the road
• Secondly, full connectivity data services coverage across the road network is essential.

Meeting these requirements, however, will bring a need for a significant level of infrastructure investment across the Nordic countries.

It will take time. Even though a vision for infrastructure is critical, our respondents felt it would take an average of 11 years before the infrastructure and road operators are ready for driverless vehicles.
WHAT THE FUTURE LOOKS LIKE – AND WHAT IT MEANS

So what is next, and how do we progress from here?

Our key findings in this survey indicates that the answer to headline question is, that the road to completely autonomous vehicles remains long, but the first vital steps are taken. Fully connected autonomous vehicles will according to our survey findings be here in 15-20 years.

While, full autonomy is still a few years away, it is not the time to rest on the laurels, as many industries and organisations are yet to fully understand exactly how they become truly digital and ready for full autonomy. Lot of thinking and designing needs to be conducted to ensure business are enable to fully utilise and harness the power of connected autonomous vehicles. This is true for all organisations both public and private, we have highlight four themes that we think are key observations and will ensure that organisations are ready to find their role and value proposition in the future transportation ecosystem.

Mobility as a Service – from ownership to access

There’s plenty of evidence that a driverless future will mean an ecosystem made up of interconnected elements focused on customers, who buy transport as a service rather than a product. Subscription to mobility as a service (MaaS) will become a requirement as consumers demand the ability to use all modes of transport seamlessly.

Industries are already seeing the demise of products we own and the rise of services we use. Based on our survey, we’ve made a few observations that could help organisations and authorities fit in to this new ecosystem:

Digitise your business model

Businesses will need to be more adaptable to the digital future. Technology is pushing driverless vehicles closer to reality. Business models based on assets are under pressure to evolve into models more based on insights and services. This will mean seamlessly exchanging data with other players. Partnership opportunities will open up, letting businesses offer value to the ecosystem and open up new revenue streams.

Be progressive and learn from testing

To help develop regulations, it’s vital that CAVs are tested on the road, with results well documented. The first steps have been taken, and now need political momentum to sustain progress. Parliaments across the world must begin to draft legislation to move testing along.

What’s more, CAV technology is a chance to position the Nordic countries as innovators and a hub for the new technology. Given the relatively small population of the Nordic countries and the relatively advanced infrastructure, we have the prerequisites to become a pacesetter for driving this new ecosystem forward.
Insurance companies must manage the change

Car insurance is already in flux given the change in ownership models, the growth of short-term leasing and the arrival of FinTech. This trend will only continue and gather pace as CAVs develop. As CAVs mature, insurance will change from being business-to-consumer to business-to-business. The owners of vehicles, and so the buyers of insurance, will be businesses with major CAV fleets. This means even further disruption and adaptation is required from Insurance providers, to meet the reality of CAVs on Nordic roads.

Joined-up infrastructure needs joined up thinking

Infrastructure is a key foundation for developing driverless vehicles, and all transport. However, consumers’ changing behaviour will see different modes used in a much more integrated and seamless way. To get the full benefit, authorities need to gear infrastructure investment and mobility strategies to accommodate and encourage this shift.
As stated earlier in this report, and by many other experts, the future of transportation is most likely going to be an integrated and seamless ecosystem, where mobility is focused on convenience and ability to utilise your time better.

The benefits of connected autonomous vehicles are first truly realised when the various aspects of the connected are fully mature and the consumer behaviour have changed. A simple one-to-one replacement of traditional vehicles with driverless vehicles will not bring the series of benefits that only will be realised once the transportation paradigm have changed. PA Consulting believe that not only will connected autonomous vehicles be a fact, but a new ecosystem will also rise.

Imagine being in transport and you see your favourite show, you can finish your work; connect with friends or getting your health checked.

This will be the future and ecosystem where your everyday activities will be seamless integrated and not disrupted by hours in traffic.

Many aspects of our everyday lives have changed already due to technology enabling a more convenient world, where simple payment methods and a few clicks can give us access to an array of services from entertainment to grocery shopping.
As an example, long gone are the days of buying or renting physical movies. Netflix changed that by embracing technology and the changing consumer patterns. Transportation is one of the aspects of our everyday lives that potentially will be impacted in the same way, by the rise of technology and behavioural change of consumers. We will move away from transportation as means to get from A to B and a waste of time, but instead think of it as an opportunity to seamless use transport time to conduct your everyday activities.

We have conceptualised this ecosystem into the below diagram. The diagram illustrates that traditional vertical and modal thinking will be replaced with an ecosystem with a lot more flexibility and layers. Traditional players will need to rethink how they fit into this ecosystem and how to bring a sustainable value proposition to the ecosystem.

**PA Future of Transport Ecosystem**

The conceptual model overleaf tries to embed and build an understanding of the elements that together creates a future ecosystem for transport.

To provide a more pragmatic way forward, PA has developed this comprehensive CAV Capability model, designed to pinpoint when the autonomous vehicle revolution may occur, consider what is required to adopt autonomy effectively and benchmark when to invest in new technologies and systems.

This model is built around the key capabilities and end-states that are required for CAVs to operate effectively and with public confidence. Technology/solution-agnostic, these end states simply define what capability is needed to achieve.

For the first time, industry now has a comprehensive framework that can be used to systematically and robustly assess how close we are to having Level 5 CAVs operate effectively on our roads.
Figure 3. PA Future of Transport Ecosystem
PA CONTRIBUTORS

Jan Tellefsen  
Nordic Lead - Roads and Regions – Norway  
+47 41 56 46 80

Martin Torp Jensen  
Transport expert - Denmark  
+45 40 99 46 38

Leif Caspersen  
Nordic Lead - Rail - Denmark  
+45 40 90 46 31

Fredrik Enander  
Transport Lead - Sweden  
+46 760 87 53 80

Frank Madsen  
Transport, Travel and Logistics Lead - Nordics  
+45 40 99 46 23

For further information or an in depth conversation with one of our experts, please:

Call us: +44 (0) 207 333 6185  
or  
Email us: AutonomousVehicles@paconsulting.com
Make the Difference

An independent firm of over 2,600 people, we operate globally from offices across the Americas, Europe, the Nordics, the Gulf and Asia Pacific.

We are experts in consumer, defence and security, energy and utilities, financial services, government, healthcare, life sciences, manufacturing, and transport, travel and logistics.

Our deep industry knowledge together with skills in management consulting, technology and innovation allows us to challenge conventional thinking and deliver exceptional results that have a lasting impact on businesses, governments and communities worldwide.

Our clients choose us because we don’t just believe in making a difference. We believe in making the difference.