Autonomous Mobility Journal

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Arthur D. Little's semi-annual coverage of the latest developments in autonomous mobility worldwide

Arthur D Little

Contents

Foreword

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Dear Reader,

Transportation, as we speak, is going through unprecedented change. For decades we have seen continuous improvement: more sophisticated vehicles, better infrastructure, new business models.

Now we are at a junction that opens the door for a new quality of mobility: We will "go autonomous". The concept of autonomous mobility will become a contender to solve some of the key problems of today's congested and inefficient mobility systems. The potential is there to disrupt both current practices: passenger mobility and mobility of goods. We believe changes to autonomous transportation will be gradual, and exactly when we will experience a fully autonomous mobility-enabled world is anybody's guess. The question to ask ourselves, however, is what will drive this change?

Autonomous mobility is envisioned as a mass service for the future, which will foster new use cases related to transportation and complement the existing public transport system. It also will mandate modifications to the landscape of the urban city, as well as state-of-the-art infrastructure.

It is critical for mobility solution providers and governments alike to anticipate future trends, challenge the robustness of current business models, and question whether future evolutions are being correctly foreseen. To that end, we are continuously conducting projects and research around the world, as well as pushing the envelope with new thinking and drawing implications from the trends we see around us.

In this recurring publication, we will give our view of "state of the art" of "autonomous". What are the latest developments and breakthroughs, and what open questions need to be addressed? Which use cases stand out, and where are the world's hotspots? When does theoretical progress become tangible? We trust that you will enjoy the reading, and yes, we welcome your ideas, thoughts and opinions.

Best regards,

Ralf Baron

Partner, Global Head, Travel & Transportation

Industry dynamics

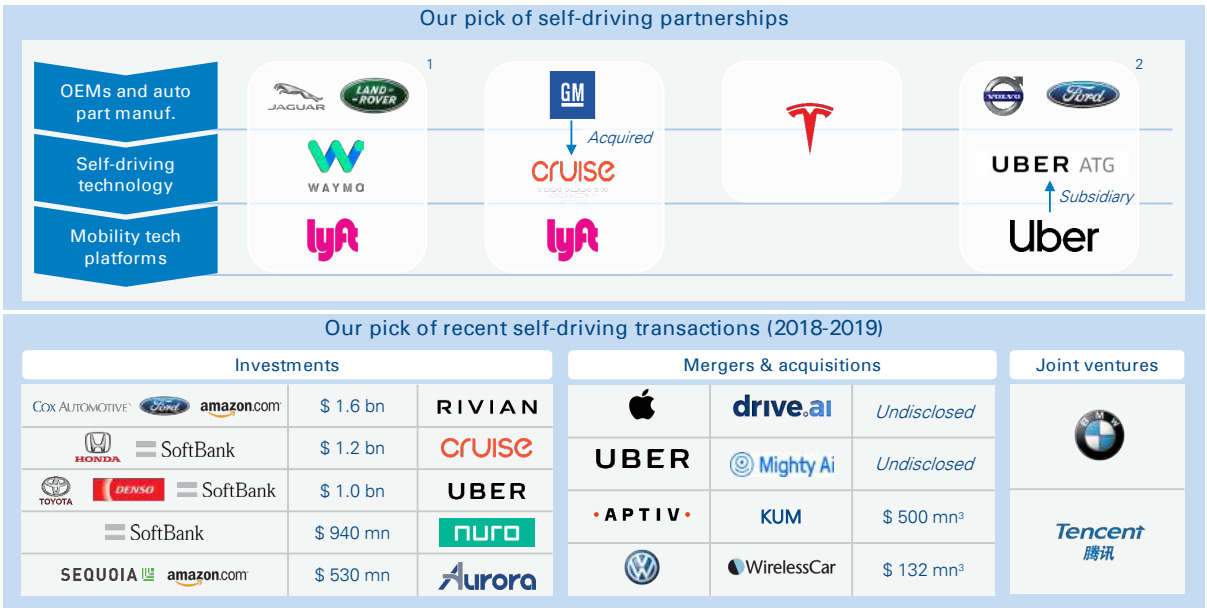
Self-driving transport players are battling to be the first to roll out an L4–L5 autonomous fleet

Self-driving transport players are battling to be the first to launch large level 4 and 5 autonomous fleets on the streets, with most designed for ride-hailing services. GM, through Cruise, was one of the first to announce a plan to launch a fleet by 2020 (originally aimed at the end of 2019). Waymo and JLR later announced their joint plan to launch a fleet of 20,000 autonomous I-PACEs, also by 2020. Tesla aims to beat both and place a fleet on the streets by the beginning of 2020. Players are already testing their fleets within geofenced areas. However, many question the real technological advancement, and it is yet to be demonstrated on a large commercial scale. Will cars achieve true autonomy within the promised timelines?

OEMs, self-driving tech players, and mobility platform companies are teaming up

Players from different parts of the value chain are teaming up to achieve the myriad technical capabilities required to get the autonomous car to the market. Most large OEMs have already secured technology capabilities by acquiring (e.g., GM with Cruise), investing in (e.g., Ford with Argo AI), and partnering with tech companies (e.g., JLR with Waymo). Tesla is one of the few trying to develop in-house capabilities organically. Additionally, OEMs are planning ahead and partnering with mobility platform companies to access their large customer bases and eventually use them to deploy fleets of autonomous cars. However, companies typically do not seem to be exclusive. For example, Uber is already working with both Ford and Volvo, and could

Figure 1: Self-driving partnerships



Source: Arthur D. Little analysis

1 Waymo has separate partnerships with both JLR and Lyft. JLR also has a separate partnership with Lyft
2 Uber Advanced Technologies Group (ATG) is a subsidiary of Uber and is working on self-driving technology. Ford also has a separate partnership with Lyft. Additionally, Ford and Volkswagen have invested around USD 7 bn in Argo AI, a self-driving tech company
3 Aptiv/KUM and VW/WirelessCar transactions were completed in 2018. All other transactions were completed in 2019

soon be doing the same with Toyota. (Toyota recently invested in Uber's Autonomous Technology Group). Ford is working with a large group of companies including Volkswagen, Uber, Lyft, and Argo AI to deploy future fleets.

As the automotive industry transforms, auto deals remain strong

Auto transactions remain strong in 2019, as traditional OEMs and auto-parts manufacturers are solidifying their future positioning through strategic deals. By the end of Q3 2019, the value of auto deals reached around USD 35 bn, versus USD 39 bn at the end of 2018 and USD 31 bn at the end of 2017. However, this does not account for some of the largest investments made in autonomous driving companies, such as the USD 1.2 bn invested in Cruise (May 2019) and USD 1 bn invested in Uber's Autonomous Technologies Group (April 2019). This trend is expected to continue as technology transforms the industry. Traditional players will use their strong investment capabilities as the primary weapon to access technology and build the necessary internal capabilities.

Big players use deals to access mobility technology and innovation to keep up with the rise of autonomy

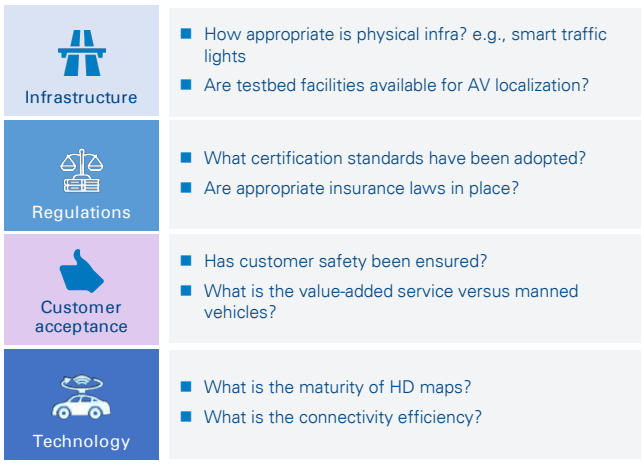
In a ground-breaking USD 500 mn deal in 2018, Aptiv acquired KUM, a South Korean provider of connectors and other equipment for harsh environment auto-applications. It aims to use KUM's tech to further develop the pilot autonomous fleet it launched with Lyft in Las Vegas. More recently, in June 2019, Apple acquired Drive.ai, an autonomous transportation start-up on the brink of shutting down, while Uber Advanced Technologies Group acquired Mighty AI to strengthen its autonomous transportation technology. BMW partnered with Tencent to launch a computing center to support autonomous vehicles. In addition to M&As and JVs, companies are still heavily investing in self-driving technology companies. For example, Rivian received a total of USD 1.6 bn during the whole of 2019, from Cox Automotive, Ford and Amazon. Second highest was GM's Cruise, which received USD 1.2 bn from Honda and SoftBank. Although deals are still being signed, large players seem to have gained most of the technology and expertise they need. They are now working in the background to accelerate the technology's challenging development path and meet their already-delayed timelines.

The transportation industry stresses the importance of an ecosystem to achieve autonomous mobility

An ecosystem play is structured on four core elements: regulations, customer acceptance, infrastructure and technology.

The core questions to be addressed under each element are as follows:

Figure 2: Key ecosystem elements

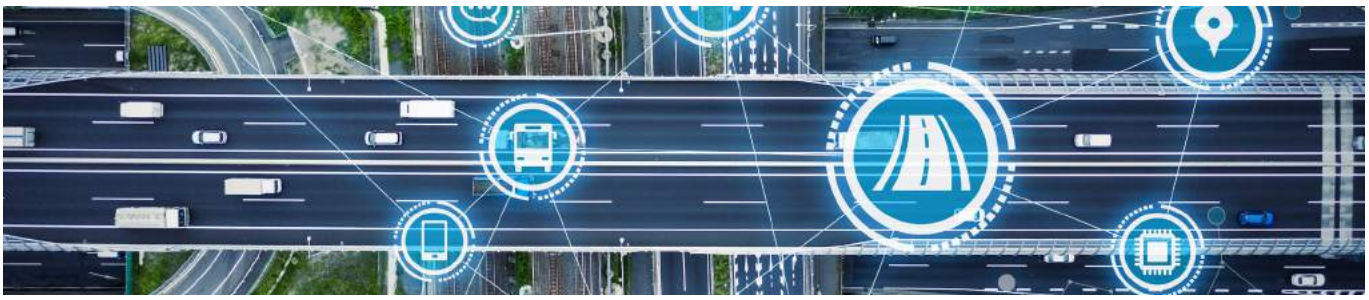


Source: Arthur D. Little analysis

For a properly functioning ecosystem, it is crucial that the above core elements are properly tackled so everything is seamlessly integrated. Different development speeds have been observed in different parts of the world. While Dubai is a hotspot at the forefront of this development, Singapore has exemplified one of the best uses of these enablers to push autonomous transportation. A full grip on these four elements will enable nations across the globe to fast-track progress in complementing their transportation systems with autonomous mobility.

Use case of the semester

Focus on last-mile delivery in logistic



Use cases of autonomous transportation

Autonomous transportation is being deployed in several industries across a range of applications. Examples include:

- **Automotive applications** such as autonomous parking assistant systems, autonomous valet parking, and highway pilots.
- **Public transportation** such as autonomous aerial taxis, on-demand robo-taxis, and autonomous shuttles/pods.
- **Logistics** such as warehousing operations, outdoor logistics operations, line-haul transportation and last-mile delivery.
- **Military and industrial applications** such as minesweeping, studying extra-terrestrial activity, and autonomous trucks in agriculture.
- **Consumer applications** such as autonomous vacuums.

In this section, we will focus on application of **autonomous transportation in logistics, particularly in last-mile delivery**.

With the growing popularity of e-commerce, parcel volumes for last-mile delivery have been rapidly increasing. Congestion on roads, tolls, etc., delays deliveries, making shipments more expensive. Last-mile delivery accounts for 25 percent of the total cost of shipping[4].

In order to improve the efficiency and cost of the delivery process, companies are testing autonomous technology for last-mile delivery.

Recent developments:

In January 2019, Starship Technologies, in partnership with Sodexo, launched its first batch of robots at George Mason University (US) to deliver food to 40,000 students, faculty, and staff on the campus[5].

In June 2019, BoxBot, a California-based start-up, announced a new last-mile delivery system that comprised an automated local hub and a fleet of street-based delivery vehicles. The local hub would store and sort parcels before automatically loading them for delivery.

In July 2019, Noon.com, a Dubai-based e-commerce platform, teamed up with Chinese technology company Neolix to test driverless vehicles for last-mile deliveries in the UAE and Saudi Arabia.

In August 2019, the US Postal Service and UPS launched driverless pilots with TuSimple, an autonomous trucking company.

In October 2018, Kroger, the largest American supermarket chain, partnered with Nuro to test the concept of driverless home deliveries by distributing groceries to customers at a flat, affordable price of USD 5.95 per delivery. The pilot project was conducted on August 16, 2019, at the Fry's Food and Drug Store in Scottsdale, Arizona[2].

Another futuristic solution for last-mile delivery is autonomous shopping cars. Customers will be able to order goods online, and instead of collecting them themselves or arranging for home delivery, they will be able to book autonomous shopping cars. The car will pick up the parcels from the respective store and deliver them to the destination specified by the customer. The customer will receive a digital key to open the trunk of the car and collect their parcels.

4 wired.com
5 Markets and markets

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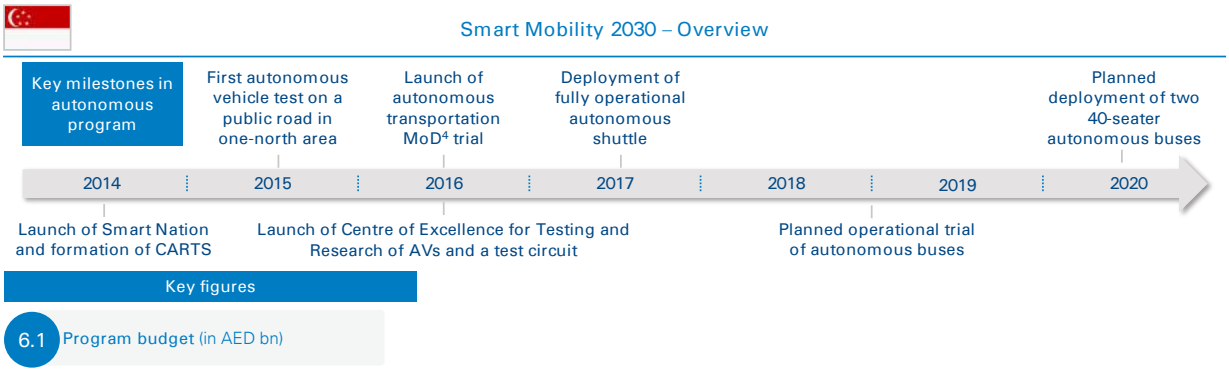
City of the semester

Focus on Singapore

Singapore is one of the leading nations in the world in the global race to achieve maturity in autonomous mobility

Figure 3: Self-driving partnerships

Case study: Singapore



Source: Smart Mobility 2030, Land Transport Authority, Arthur D. Little analysis

Singapore Smart Mobility 2030 Overview

Singapore Smart Mobility 2030 focuses on developing autonomous transport. It was launched in 2014 to enhance the accessibility and connectivity of Singapore public transport systems. The program, as part of Singapore's Smart Nation plan, is allotted a budget of c.US$1.7 bn, and primarily focuses on developing autonomous taxis, buses and shuttles. Singapore has initiated plans to venture into driverless trucks and aerial taxis as part of its long-term objective to include all transport modes under the autonomous transportation ambit. Singapore, which has a history of setting up precedents in automated transportation, pioneered the world's first automated rail rapid-transit line in 2003.

The Singapore government has been proactive in steadfast maturity of autonomous mobility since 2014. It established the separate Committee on Autonomous Road Transport for Singapore (CARTS) for charting and steering the direction of autonomous technology in Singapore; launched research centers and collaborated with academia to promote start-up activity and innovation; developed a regulatory framework for safe rollout of autonomous mobility; and led infrastructure funding for technology companies and OEM players to test readiness for commercial deployment globally.

Under the overall mobility goal, Singapore's Land Transport Authority (LTA) also plans to adopt ITS[6] standards, establish close partnerships, and co-create to complete 75 percent of all journeys in peak hours via public transportation by 2030. This is one of the key goals of Smart Mobility 2030.

Singapore has become a global testbed for autonomous vehicles

Singapore's strong road and telecom connectivity positions it at the forefront of autonomous vehicle infrastructure innovation. Although there is scope for improving charging infrastructure, the government has spearheaded the testbeds for technology and AV companies worldwide. These will perform trials and demonstrate readiness in limited operational design domains before graduating to more congested environments.

Several past and ongoing initiatives include:

- **Robo-taxi**
  - NuTonomy, an MIT/SMART[8] spin-off, is testing autonomous taxi services in the complex one-north region, equipped with 10 DSRC[9] units. It plans to deploy 75 autonomous taxis in selected areas by 2020.
- **Shuttle**
  - EasyMile, Robosoft and ST Engineering of Singapore introduced the first fully operational autonomous shuttle in Asia on a fixed route in Gardens by the Bay.
- **Bus**
  - NTU and Volvo have successfully tested the world's first autonomous electric bus at CETRAN[10]. The bus is 12 meters long and can fit about 80 people.
  - ST Engineering, SDC[11] and LTA introduced four autonomous mini-buses with technologies from SMART. They are undertaking a three-month trial of a 5.7 km route in Sentosa.
- **Logistics**
  - Kateon Natie collaborated with Singapore Management University and VDL Group to test Asia's first driverless trucks. The trucks transported products between ExxonMobil's packaging and intermediate storage facilities in Singapore, covering a round trip of about 6–8 kms and operating 24 hours a day.
  - The MOT[12] and PSA collaborated with Toyota and Scania to design, develop and test automation of docking and undocking cargo at ports. Initial trials took place in company research centers, followed by testing on a fixed 10 km route along the West Coast Highway.
- **Aerial taxis**
  - Volocopter, in collaboration with MOT[9], CAAS[13], and EDB[14], is expected to begin trials of aerial taxis above water in the southern part of Singapore. It will also build taxi-landing and -launch ports in collaboration with Skyports.

Singapore launched the world's first set of national guidelines for fully autonomous vehicles

Singapore's set of autonomous vehicle guidelines, famously known as "Technical Reference 68" (TR68), gives specifications for OEMs and other developers of autonomous technology. It sets clear targets for AV developers and eliminates the risk surrounding the technology. Created with a year-long effort involving representatives from four working groups – the AV industry, research institutions, academia, and government agencies – these guidelines are not rules. However, they lay a foundation stone and blueprint for future international standards.

TR68 covers a wide range of topics, mostly around basic behavior, safety, cybersecurity, and data types and formats. The document is aimed at companies expecting to roll out level 4 and level 5 autonomous vehicles in mixed-use traffic and on public roads.

The availability of clear standards and definitions positions Singapore as an attractive destination for AV companies across the globe. It also establishes Singapore as a hub for pilot programs and commercial deployment for AV technology.

6 Intelligent Transport Systems
7 Mobility-on-Demand
8 Singapore- Massachusetts Institute of Technology Alliance for Research and Technology
9 Dedicated Short-Range Communication
10 Centre of Excellence for Testing & Research of Autonomous Vehicles NTU
11 Sentosa Development Corporation
12 Ministry of Transport
13 Civil Aviation Authority of Singapore
14 Singapore Economic Development Board

Figure 4: Self-driving partnerships

	Liability & insurance	Registration & licensing	Data privacy & cybersecurity	Vehicle testing
Current status of legislation	■ Operators are required to have qualified safety drivers who will be able to take control of vehicles in emergencies ■ Operators must hold third-party liability insurance	■ LTA has defined specific tech. requirements for autonomous vehicles (sensors, cams, failure-alert systems, etc.) ■ System-level safety, applicable to ODD[15], mandates competent vehicle developer, system integrator and operator ■ Registration requires compliance with these specifications	■ TR68 requires storing the data gathered from the autonomous vehicle and providing it to LTA upon request ■ DSSAD[16] to record data ■ Extend existing cybersecurity standards and best practices for automotive applications to safeguard against security-threat potential present in L4/L5 AVs	■ Test vehicles are allowed on specified public roads with mixed traffic and at approved test sites ■ License/approval is granted by LTA and JTC[17] – it is valid for a maximum of 1 year ■ The Road Traffic Act enables the operation of the autonomous vehicle without active physical control or monitoring by a human operator

Source: Road Traffic (Amendment) Bill, Land Transport Authority, Arthur D. Little analysis

Key learnings from the Singapore autonomous transportation program

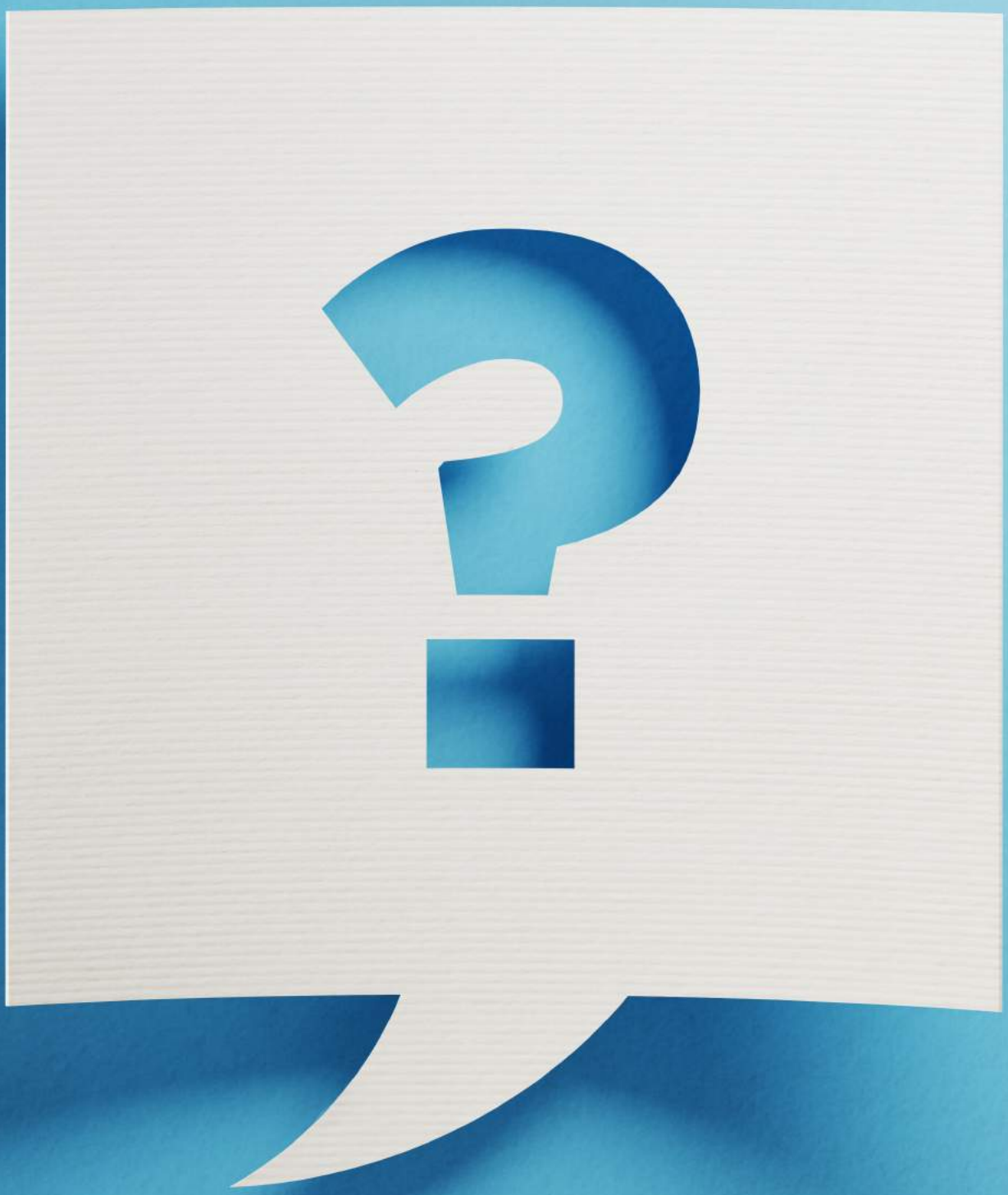
Singapore's case study provides valuable lessons for nations striving to take leaps in autonomous mobility. It highlights the importance of government initiatives for the ecosystem play in developing the autonomous mobility ecosystem.

Figure 5: Key learnings

Strategic vision	■ Clarity with a long-term strategic roadmap has helped the Singapore government focus on the right levers in the ecosystem
Ecosystem mind-set	■ The government's funding initiatives and partnerships with the private sector, academia, and research houses helped Singapore to create the right ecosystem for driving the sector
Execution agility	■ Proactiveness in defining regulatory guidelines and testing infrastructure for private players helped Singapore become a global benchmark for standards and testing in autonomous mobility

Source: Arthur D. Little analysis

15 ODD = Operational Design Domains
16 DSSAD = Data Storage Systems for Automated Driving
17 JTC = Jurong Town Corporation – State owned real estate company



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Interview of the semester

Interview with Navya's COO by Murali Krishna – RTA Marketing Chief Specialist

Navya is a pioneer and specialist in the autonomous vehicle market. It assists cities and private sites around the world in improving their transport offerings with its autonomous, driverless and electric solutions. At the cutting edge of technology, Navya revolutionizes trips by offering fluid mobility solutions.

We had the pleasure of a quick tête-à-tête with Jérôme Rigaud, the COO of Navya, after the company won the Best Endurance & Reliability and Best Consumer Experience awards at the "Dubai World Challenge for Self-Driving Transport".

Mr. Jerome Rigaud is the COO of Navya, the first company in the world to sell fully autonomous shuttles, which currently has a footprint in more than 20 countries

Q: Could you give us a brief background on Navya?

A: Navya is a five-year-old company, established in late 2014. Today, we are around 300 people based in France and the US. We design and manufacture autonomous vehicles, as well as develop software and service fleets on first mile-last mile small buses and shuttles. We have developed and deployed our fleet in more than 20 countries, with 100+ shuttles in day-to-day operation. We cover a wide part of the globe, including Europe, North America, the Middle East, Australia, and Asia.

What is interesting for us is to not only test on a closed loop, but also to experience the day-to-day life of the passenger, pedestrian, driver or cyclist – plus face the industry, transportation service providers, and authorities. This helps us gain experience for deployment and operation of smart mobility service.

Q: Usually, entities produce either autonomous vehicles or related software. You have software elements such as Navya Lead, the Navya app, and Navya Cognitive, which are analogous to brain centers of autonomous transportation. You also have vehicles such as the Autonom shuttle, cab and tract. How do you balance this portfolio?

A: Right now, we do it all because there's no alternative in the market. You know how fast technology moves, and the only way to be in the market, to demonstrate the vehicle, and to get experience from it is to do it end to end, from head to toe. We know that the market is going to evolve, and when we reach a much larger goal – a bigger scale – we'll have to narrow our focus. Eventually, we will be more involved in software and services.

In fact, all the players in the market do everything in-house for the sake of agility, speed, learning, etc. You need to really understand how to make a vehicle with no steering wheel and no pedals. There was no one existing in the market when we came into the picture – no autonomous shuttle base at all. We had a choice of either transforming or adapting an existing line, or creating something new. We decided to create a new user and passenger experience in vehicles which had not been seen before. So we had to do everything ourselves.

Q: One of Navya's key products is the Autonom tract. What possibility do you see for that in the Middle East?

A: It's a product that is still at proof-of-concept stage, and we have prototypes right now – one at the airport and two at an industrial site with a carmaker in France. Its development is in partnership with French group Charlatte, which not only produces the automotive base, but also has all the connections and network needed. Charlatte has been in the business for 25 years with people who operate airports. There are many players in the market, and our partner is already in touch with many of them. This market will take off a lot faster since the regulations are more flexible, and the ecosystem is more controlled, than those of passenger transport.

Q: Where are you present in the Middle East, apart from Dubai?

A: Right now, we do not operate the fleet ourselves. We are in Abu Dhabi in Masdar, where we are deploying a fleet of seven vehicles on a long-term contract. We are also a partner with Dubai Electricity and Water Authority (DEWA). We are in the process of finding other partners in the UAE. The region is key for us because it's going to be at the forefront of new mobility and driverless services in the future.

Q: Coming back to one fundamental question that is being discussed all over the world – what are the key positive enablers for autonomous transit, and what are the key challenges?

A: Well, among the positives, one is the ability to create a tech ecosystem – to gather around the same table and speak with authorities, along with technology providers and external experts. They guide us, and we foster innovative solutions together. Financing is crucial because these are new solutions and there are experimenting costs involved. Financing is required to deploy solutions on a larger scale during operations.

It's all about gathering the right ingredients, crafting the secret sauce, and making it work. Just sitting around the table won't help; rather, it is important to talk, interact and learn from each other. This is the match to ignite the market. The other positive thing is the rapid evolution of technology – we know that level 4 is within reach.

What might be missing is that some standards need to emerge in the V2X and components sector, especially sensors. The right combination of components and sensors specifically, which will boost the market and enable providers and suppliers of technology to deliver goods and reliable products at affordable prices, is crucial. Every OEM needs support to avoid increases in prices. No OEM is going to produce an autonomous car from scratch to finish when you add up the costs of components, because the technology is expensive. The price of components will go down when volumes increase.

The shift in the business model is also a challenge – we are still at an experimenting stage and should align ourselves with service providers. User experience also needs to be measured according to clear parameters.

Q: For the business model, how much of a role do you think the government should play in terms of funding? What can be the optimal mix of private and public capital?

A: Well, that's a tricky question and doesn't necessarily have a mathematical answer. For governments, not considering or promoting sustainable transportation services is not an option. Some level of government funding is certainly required. It's important to determine at what stage government support is crucial, e.g., early versus late stage. I haven't really thought through this in depth, but off the top of my head, I think government involvement should start at the time of the first fleet deployment. They can use selected parts of the city and make autonomous solutions work day-to-day with a per-ride fee.

I'm not talking about the magnitude of financing, but partial government funding is necessary to help this ecosystem come together, support tech going on field, and test at a certain scale – not just at an experimental scale or, for instance, a two-hour-ride or day scale.

We are involved in day-to-day services in Florida, Switzerland and France right now. By measuring the number of passengers that go in and out, we learn from passenger ramp-up. So everyone can test the business model – you add shuttles during the peak hours and retrieve them during off-peak hours. Tests and trials need be done to see how things work in real life. On establishing proof of concept, the government can pull back and merely worry about the regulations. This, I believe, will turn the market around.

Q: Regarding regulations, do you think companies such as Navya have a role to play in providing input to transport entities – for instance, the RTA in Dubai, which offers input towards developing and implementing proper regulation of autonomous vehicles?

A: The key success factor in formulating any regulation is to be able to talk, discuss, and keep an open book with no fear of push-back from the government, because with evolving technology, there could be incidents or even drawbacks. We

just had a roundtable where Suntech presented its vision, which was accurate and very helpful. We all share the ambition to have the right enablers in place for autonomous mobility. Today the regulator cannot expect a very high level of safety in an industry that is just 50 years old.

We need to find the right balance and make the regulator aware that if the standard is too high, autonomous transit is going to remain a closed-loop and private-site operation – there's no way we'll be on the open road. Just about everywhere, we need to collaborate openly and build trust at all levels. A regulator, typically, is risk averse and will want to put safety standards in place. We deal with regulators directly ourselves in 21 countries already, and have a full team of safety professionals that provide important information.

The beauty of Navya's technology is that you can track everything. So, of course, we can report any incident and provide the whole story in detail. In many countries, we share confidential information and maintain an open-book policy even with our processes, and this practice has been very helpful.

Q: Considering the regulatory constraints that exist today, and the time needed to amend them, would it be a good idea to think about parallel infrastructure systems such as dedicated parking and corridors, to speed up the adoption of autonomous transit modes?

A: Certainly, this is one of the possible options to explore: delivering real, day-to-day services to paying passengers in a protected or segregated environment. This would ensure that the safety that the technology cannot guarantee in mixed traffic, highways, four lanes, etc., was compensated for, and enable increased trialing of autonomous fleets. It would be a game changer.

Q: When do you think the autonomous vehicle industry will start moving at a faster pace in cities, assuming favorable conditions are in place?

A: I believe first- and last-mile solutions like ours will be part of the multimodal transportation network, and as natural as taxis and ride sharing. The pace of adoption depends on each country – on the ability to change regulations and adjust the environment accordingly. We believe the real massive market for us will start in two years. Then we will deploy our solutions, depending on the environment, in gradual steps. In two years, we will reach targeted areas where ecosystems and appetites for autonomous mobility exist. This is going to happen fast because there's a need for it. We must remember that our solutions are not going to replace anything – they are, rather, a missing part of today's transportation.

Q: If regulations were in place, do you think Navya could respond quickly to massive deployment requirements to fulfill prospective demand today?

A: We are getting prepared, and our current production capacity is 800–900 shuttles per year, overall. We have two production plants, two production lines in each plant, and two shifts. When the market reaches volumes, our capacity will reach thousands. Therefore, we are also collaborating with automotive suppliers that are primarily electric bus makers to design cutting-edge buses. We will still be suppliers and deliver turnkey solutions to transportation operators, but will also align ourselves with people in the business who have more expertise and have been present longer than we have been, with the ability to produce in volumes.

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Arthur D. Little's semi-annual coverage of the latest developments in autonomous mobility worldwide

Arthur D. Little

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