Challenges and potential business applications of Automated Delivery Vehicles – a brief overview

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Preface

This report is part of the GLAD project (GLAD: *Goods deliveries under the last mile with automated delivery vehicles*). GLAD was a research and development project with the overall aim to gain knowledge about user needs as well as about the technical, societal, business and policy related challenges with automated delivery vehicles (ADV). The GLAD project was conducted during June 2020 and September 2022 and was coordinated by RISE Research Institutes of Sweden. The project was partly financed by the Swedish Transport Administration (ref. no. TRV 2020/26017). The partners in the GLAD project were RISE Research Institutes of Sweden, Aptiv AB, Combitech AB, Clean Motion AB and Halmstad university. The studies in the GLAD project are summarized in the following report:

- Söderman, M., (2022), *GLAD, Goods deliveries under the last mile with automated delivery vehicles - Summaries of the studies in the GLAD project*, ISBN 978-91-89757-24-0, RISE report 2022:135

The full reports from the GLAD project are:

- Andersson, K. (2022), *Autonoma leveransfordon – vad är de för sorts fordon och har det någon betydelse? (Eng. Automated delivery vehicles - what kind of vehicles are they and does it matter?),* ISBN 978-91-89711-44-0, RISE report 2022:100
- Söderman, M. (2022), *Typical and critical traffic situations with small electric delivery vehicles – indications for future automated delivery vehicles*, ISBN 978-91-89757-19-6, RISE report 2022:130
- Söderman, M., Andersson, J., Habibovic, A., (2022), *Use cases and high-level requirements for safe interactions between Automated Delivery Vehicles and human operators in a terminal,* ISBN 978-91-89757-20-2, RISE report 2022:131
- Andersson, J., Habibovic, A., *How to convey the intent of an automated vehicle with its longitudinal and lateral movements - evaluating four communication concepts in two traffic situations involving pedestrians* (Report under construction, 2022)
- Söderman, M., Clasen, R., Bergström, G., Collings, W., (2022) *Development of self-driving and control room functions and of external HMI for Automated Delivery Vehicles,* ISBN 978-91-89757-21-9, RISE report 2022:132
- Söderman, M., Clasen, R., Bergström, G., Collings, W., (2022) *People's understanding of external HMI and their experiences of interacting with an Automated Delivery Vehicle in a terminal context,* ISBN 978-91-89757-22-6, RISE report 2022:133
- Gonzales, S., Sveder, C., Oscarsson, E., Jönsson, S., (2022) *Challenges and potential business applications of Automated Delivery Vehicle initiatives - a brief overview,* ISBN 978-91-89757-23-3

Sammanfattning (Swedish)

Denna rapport tar bl.a. upp några av de drivkrafter som kan gynna utvecklingen av mindre självkörande leveransfordon (eng. *Automated Delivery Vehicle*, ADV), t.ex. ökad urbanisering, ökad e-handel, samt krav på effektiva transporter och krav på att möter de klimatmål som finns både nationellt och internationellt.

Det finns flera utmaningar för ADV:er för att de ska kunna operera i kommersiell skala. Dels är tekniken för självkörande fordon inte tillräckligt utvecklad för att köra i publika miljöer (vissa ADV:er kan köra i begränsade områden under övervakning av s.k. säkerhetsförare), dels är godsvolymerna relativt små, samt att logistikkedjan kräver en del manuellt arbete. Dessutom finns transportalternativ med manuella leveransfordon som kan leverera paket dörr-till-dörr, vilket ADV:er inte kan. Eftersom ADV:er är förarlösa finns potential att minska lönekostnader, men föraren har fler roller i transportkedjan än att köra fordonet, t.ex. leverera paketet ända fram till adressaten, attestera, föra dialog med kunderna m.m. För många leveransföretag är föraren är ansiktet utåt och viktig för relationerna med kunderna.

I rapporten finns en kortare genomgång av olika ADV-koncept och deras potentiella användningsområden, samt affärsmässiga utmaningar. Utgångspunkt har varit ett par workshops med intressenter kring ADV:er, samt intervjuer med företrädare av tre möjliga användningsområden för ADV:er i Sverige: flygplatser, matleveranser och leveranser och mindre paket. På flygplatser skulle ADV:er t.ex. kunna transportera bagage, men även gods från leverantörer av mat och material. För leverantörer av mindre paket skulle ADV:er kunna utföra vissa transporter och för matleveranser skulle ADV:er kunna bidra till fler och snabbare hemleveranser.

Transportbehovet i tätorter kommer att öka, vilket talar för att ADV:er kan fylla en viktig funktion i last mile/sista milen-leveranser. Företag som Google, Amazon, Nvidia och Apple investerar i utveckling av ADV:er, men flera tekniska, legala och marknadsmässiga utmaningar återstår.

Abstract

This report addresses some of the driving forces behind the development of Automated Delivery Vehicles, (ADV), e.g. increased urbanization, increased e-commerce, demands for efficient transport and the demands to meet climate goals, national as well as international.

There are also challenges for ADVs to operate on a commercial scale. On the one hand, the technology (sensors and software) is not ready to have driverless vehicles operating in public spaces (some ADVs can drive in limited areas under supervision by so-called safety drivers), and on the other hand, the freight volumes are relatively small. The logistics chain also requires manual work. In addition, manually operated transports can deliver packages door-to-door, which ADVs cannot. Since ADVs are driverless, there is the potential to reduce wage costs, but the drivers do more than just driving the vehicle. The drivers handle complex traffic situations, and deliver the packages all the way to the addressees, certifying, having the dialogue with customers, etc. For many companies, the drivers are key in maintaining the relations with their customers.

The report lists eight different ADV concepts around the world. The report also addresses some potential use cases for ADVs, as well as the business challenges with ADVs. The basis has been a couple of workshops with stakeholders of ADVs, as well as interviews with representatives of three possible application areas for ADVs in Sweden: airports, food deliveries and deliveries and smaller packages. At airports, for example, ADVs could transport luggage, but also goods from suppliers of food and materials. For suppliers of smaller packages, ADVs could carry out certain transports, and for food deliveries, ADVs could contribute to more and faster home deliveries.

The need for transports in urban areas will increase, which suggests that ADVs could play an important role in last-mile/last-mile deliveries. Companies such as Google, Amazon, Nvidia and Apple are investing in the development of ADVs, but there are still technical, legal and market related challenges be handled.

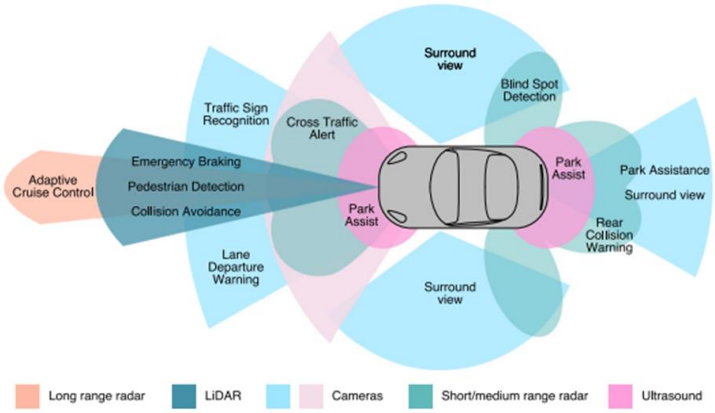
Key words: Automated delivery vehicles, potential business applications, driving forces

1 Background

1.1 What is an automated delivery vehicle (ADV)

Automated delivery vehicles (ADV) are delivery vehicles that use technology applications, such as sensors, actuators, machine learning systems, processors, and algorithms to operate[1]. Examples of sensors used to detect and scan the surrounding environment:

- Radar sensors monitor the position of nearby vehicles.
- Video cameras detect traffic lights, read road signs, track other vehicles, and look for pedestrians.
- Lidar (light detection and ranging) sensors bounce pulses of light off the car's surroundings to measure distances, detect road edges, and identify lane markings.
- Ultrasonic sensors in the wheels detect curbs and other vehicles when parking.



ADV's are controlled by computers supported by software that processes sensory input, plots paths, and sends instructions to the vehicle actuators, which control acceleration, braking, and steering. Obstacle avoidance algorithms, predictive modelling, and object recognition are also parts of the ADV's system[2].

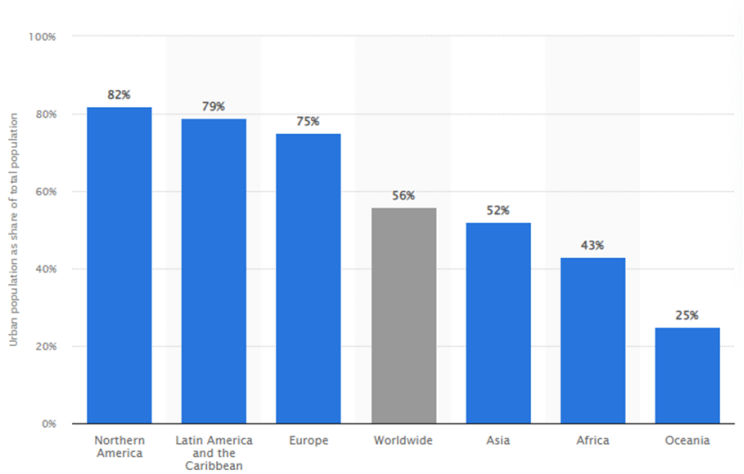
[1] https://www.synopsys.com/automotive/what-is-autonomous-car.html#:~:text=Autonomous%20cars%20rely%20on%20sensors,different%20parts%20of%20the%20vehicle

[2] https://www.synopsys.com/automotive/what-is-autonomous-car.html#:~:text=Autonomous%20cars%20rely%20on%20sensors,different%20parts%20of%20the%20vehicle

1.2 Driving forces for ADV

1.2.1 Urbanisation

The UN has predicted that by 2050[3], 68% of the global population will live in urban areas [4]. At the end of December in 2020 SCB, Swedish statistical bureau [5], reported that 88 % of Sweden's population lived in urban areas, slightly higher than the average European country. Globally this number varies depending on continent and country, but the overall urban population in 2020 is approximately 56% according to data from the World Bank[6] and the chart from Statista[7]. Urbanization drives the need for transports, which highlights the need for efficient logistics including safe and efficient means for transportation of goods. In this context ADV could play an important role.



1.2.2 E-commerce

According to Postnord[8] E-commerce revenue in Sweden has grown with 16 % during the second quarter of 2021. The reason why e-commerce had such a growth spurt is because of the Covid 19 pandemic, consumer trends and more user-friendly e-commerce platforms. The

3 https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/undes_pd_2020_popfacts_urbanization_policies.pdf

4 https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

5 https://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/land-use/localities-and-urban-areas/#:~:text=At%20the%20end%20of%20December,more%20than%20100%20000%20inhabitants.

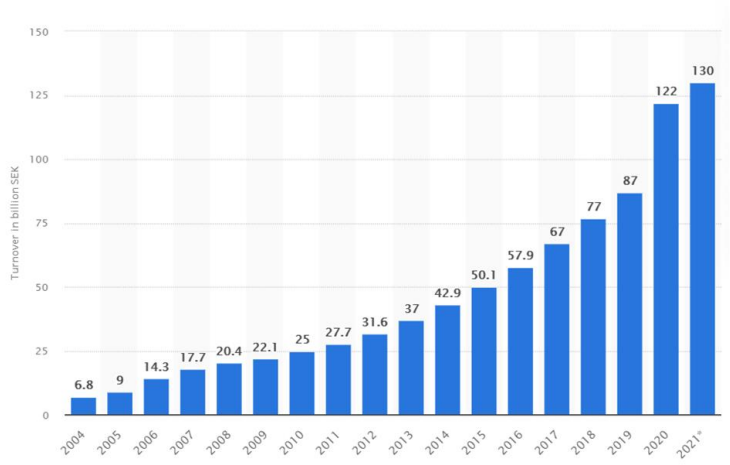
6 https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2020&start=1960

7 https://www.statista.com/statistics/270860/urbanization-by-continent/#:~:text=In%202021%2C%20the%20degree%20of,percent%20of%20the%20whole%20population.&text=The%20degree%20of%20urbanization%20basically,are%20defined%20as%20%22cities%22

8 https://www.postnord.se/vara-losningar/e-handel/e-handelsrapporter/e-barometern

chart by Statista[9] illustrates that the e-commerce turnover from e-commerce in Sweden increased from 6,8 billion SEK in 2004 to 130 billion SEK in 2021.

The steady growth of the e-commerce sector has contributed to logistical challenges in multiple parts of the supply chain, especially in the last mile. Where automation technology could be a part of the solution[10].



1.2.3 Global logistics market

According to Yahoo Finance[11]The Global Retail Logistics Market size was estimated at USD 205.44 billion in 2020, and is expected to reach USD 230.96 billion in 2021, and projected to grow at a CAGR of 12.75% reaching USD 422.27 billion by 2026. 'Research and Markets'[12] reported that the global logistics automation market size is projected to grow from USD 48.4 billion in 2020 to USD 88.9 billion by 2026, at a Compound Annual Growth Rate (CAGR) of 10.6% during the forecast period.

9 https://www.statista.com/statistics/643246/e-commerce-turnover-in-sweden/

10 https://www.researchgate.net/publication/343623144_The_Impact_of_E-Commerce-Related_Last-Mile_Logistics_on_Cities_A_Systematic_Literature_Review

11 https://finance.yahoo.com/news/global-retail-logistics-market-research-130400820.html

12 https://www.researchandmarkets.com/reports/5308209/logistics-automation-market-by-component?utm_source=GNOM&utm_medium=PressRelease&utm_code=k5fg6v&utm_campaign=1518219+-+Global+Logistics+Automation+Market+(2020+to+2026)+-+Adoption+of+Autonomous+Vehicles+and+Drones+Presents+Opportunities&utm_exec=jamu273prd

2 A view on the potential ADV market

The urbanisation and e-commerce trends have created a market where the logistics industry could potentially gain operational and financial benefits from implementing ADVs[13]. Logistic companies have therefore been testing different ADV prototypes in enclosed environments and under human supervision to handle parts of their supply chains[14]. According to Global data[15] forecasts from 2020 show that ADVs could appear in low volumes as early as 2024 with an equally slow ramp-up to around 500,000 ADVs produced in the year 2030. Optimists claim that by around 2030, autonomous vehicles will be reliable, affordable, and common to replace most human driving, providing significant savings and benefits. According to VTPI [16]

"*Optimists predict that shared autonomous taxis will soon displace most private vehicles (ITF 2014; Keeney 2017). For example, Kok, et al (2017), predicted that, "By 2030, within 10 years of regulatory approval of fully autonomous vehicles, 95% of all U.S. passenger miles will be served Autonomous Vehicle Implementation Predictions: Implications for Transport Planning Victoria Transport Policy Institute by transport-as-a-service (TaaS) providers who will own and operate fleets of autonomous electric vehicles providing passengers with higher levels of service, faster rides and vastly, increased safety at a cost up to 10 times cheaper than today's individually owned (IO) vehicles.*"[17]

Optimistic predictions like the example above, does not take in account the potential barriers that ADVs need to overcome before the can be considered as safe enough to be implemented on public roads. The forecasts differ a lot between, since the technological development of the autonomous industry is complex and is hard to predict. During the last few years, the optimistic views on automated vehicles has changed to a more restrained view about automated vehicles. There are several challenges that need to be solved, for example government legalisation, regulatory constraints, live safety tests and evaluation, social factors such as consumer confidence and trust and the status of the technological advancements[18].

13 https://www.futurebridge.com/industry/perspectives-mobility/future-outlook-of-autonomous-delivery-vehicles/

14 https://www.futurebridge.com/industry/perspectives-mobility/future-outlook-of-autonomous-delivery-vehicles/

15 https://www.globaldata.com/sobering-attitudes-towards-autonomous-vehicles-see-long-term-forecasts-cut-almost-half/

16 https://www.vtpi.org/avip.pdf

17 https://www.vtpi.org/avip.pdf

18 https://blogs.sw.siemens.com/thought-leadership/2020/04/16/autonomous-last-mile-delivery/

3 Potential pros and cons with ADV

3.1 Reduced accidents

According to WHO, majority of car crashes stem from human error[19]. Sophisticated software and hardware could through connectivity and automation potentially eliminate, or reduce, human errors and, therefore, also reduce the amount of traffic accidents. Since ADVs operate without human drivers the number of fatalities in case of accidents could be reduced as well. However, as a publication in Vox states[20], it could take decades to drive enough miles needed to prove the increased safety of ADVs.

3.2 Traffic efficiency

ADVs could create less congestion because connected vehicles can communicate with each other, and optimise the traffic flows and route planning. However, if the roads are populated by both manual vehicles and ADVs, it might not lead to improved traffic flows, but instead create new problems[21].

3.3 Cost efficiency

ADV are believed to be cost-efficient[22], because the salary cost for the drivers is a major cost item for transport companies. Moreover, the last mile is the most expensive part of the supply chain, accounting for approximately 53 % of total shipping cost on the US market.[23]

3.4 The supply chain and ADV

When it comes to implementing automation the supply chain needs to be adapted to the ADVs, for example the loading/unloading of goods and delivering the goods to apartment buildings or other multi-level structures where there are stairs and doors/gates[24].

19 https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

20 https://www.vox.com/2016/4/21/11447838/self-driving-cars-challenges-obstacles

21 https://www.researchgate.net/publication/329356042_Connected_and_Automated_Vehicles_on_a_freeway_scenario_Effect_on_traffic_congestion_and_network_capacity

22 https://roboticsbiz.com/autonomous-delivery-robots-benefits-and-drawbacks/

23 https://optimoroute.com/last-mile-delivery/

24 https://www.supplychain247.com/article/want_big_gains_automate_the_ins_and_outs_with_automated_trailer_loading_sys/agv

3.5 Connectivity and cyber security

For ADVs need fast and stable internet access 5G[25]. Malfunctioning network could have serious impact on the ADVs' abilities to operate. ADVs could also be vulnerable to cyber threats and malware, since connected devices are subject to threats such as data breaches, remote access, and sabotage.[26] Precautions being taken to reduce the cyber threats and severity of breaches when it comes to ADVs[27].

4 ADV pilots

4.1 General

Many companies have invested in projects to realise fully autonomous delivery vehicles. The types of ADVs that are being piloted around the world are side-walk vehicles and on-road vehicles, in sizes from mini vehicles, regular cars, vans to large trucks[28].

The most common type of ADVs are the smaller ADVs, or pods, which weigh around 15-45kg and have a loading capacity of 10-23kg. Examples are Scout, Yape and Starship robots. Bigger ADVs are, for example Nuro R2 and Neolix. These medium sized ADVs weigh between 850-1150kg with a loading capacity of 190-500kg. The biggest ADVs are, for example the Einride Pod that weights around 10 tons with a loading capacity of 16 tons.

There seems to be a race towards public approval between these companies. Everyone wants to be the first to have their ADV approved first. Some companies already claim to be the first in the world, which makes it even more confusing to understand how far the technology has advanced.

The outlook and future of ADVs have not only attracted start-ups. Large enterprises such as Amazon[29], Google[30] and Nvidia[31] are investing in ADVs. Even though there are ADVs involved in real pilots, it is still too early to say that ADVs are safe enough to operate on public roads on a regular basis. There is still a lot of development and testing to do before ADVs can operate without human monitoring.

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[25] https://www.automate.org/editorials/how-5g-standards-will-impact-driving-and-autonomous-vehicles

[26] https://ieeexplore.ieee.org/document/7872388

[27] https://carnegieeurope.eu/2022/03/24/computers-on-wheels-automated-vehicles-and-cybersecurity-risks-in-europe-pub-86678

[28] https://www.futurebridge.com/industry/perspectives-mobility/future-outlook-of-autonomous-delivery-vehicles/

[29] https://www.aboutamazon.com/news/transportation/meet-scout

[30] https://waymo.com/

[31] https://www.nvidia.com/en-us/self-driving-cars/#:~:text=NVIDIA%20DRIVE%20Hyperion%E2%84%A2%20is,with%20a%20complete%20sensor%20suite

4.2 Examples of ADV pilots

Below are examples of some ADVs prototypes. The information about the ADVs has not been examined or confirmed by any third-party. The information about ADV pilots is distributed by the companies themselves, their stakeholders, and sponsors. Therefore, it is difficult to get a picture of what the ADVs are capable of and under which circumstances.

4.2.1 R2 by Nuro

R2 by Nuro[32] is the second-generation self-driving vehicles. The previous model R1 was delivering groceries, food, and parcels to homes and businesses. The R2 is an upgraded version with extended loading capacity, customizable storage, and temperature-controlled compartments. Nuro R2 has been running trial deliveries in cities around the US since the first quarter of 2020 with retail brands such as Domino's, FedEx, Kroger, and Walmart to test their ADVs on public roads. Nuro R2 is planning to start commercial production in their facility in Nevada, expected to be completed in 2022. In January 2022 Nuro announced that they are developing their third generation.

Specifications[33]
Size: Length 274cm, width 110cm, height 186cm
Loading capacity: 190kg
Speed: 40km/h
Weight: 1150 Kg

[32] https://www.nuro.ai/technology
[33] https://www.dimensions.com/element/nuro-r2

4.2.2 Neolix

Neolix was founded in 2018 and is backed by Chinese electric vehicle start-up Li Auto. The company focuses on developing self-driving vehicles for retail, surveillance, and other city services. Neolix is categorised as “non-motor vehicle,” which suggests they are likely to be moving next to bicycles and electric scooters instead of faster-moving cars. During the second quarter of 2021 the company announced that they will initiate a trial with e-commerce companies JD.com, Meituan and FedEx[34] in Beijing[35].

Specifications[36]

Loading capacity: 500kg (temperature-controlled compartment)
Range: 100km range, battery swap system
Size: 2.4 x 2.4 x 2.4 metre
Speed: Max speed of 50 Km/h (Operating speed of 20 Km/h)
Weight: Approximately 850 Kg

4.2.3 Cleveron 701

Cleveron is an Estonian company creating robotic-based terminals and developing last mile solutions.[37] The Cleveron 701 is an ADV that serves deliveries from micro-fulfilment centres or “dark stores” (distribution centres for online shopping) within 15-30 min radius. Cleveron 701 was the first ADV in Europe that got a pilot licence to operate on public streets[38]. In November 2021 it was announced that they had completed a 5-day trial in the Netherlands[39].

Specifications [40]

Loading capacity: 200 kg
Range: no data, rechargeable batteries
Size: No data
Speed: 50km/h
Weight: No data

[34] https://www.eseller365.com/fedex-neolix-test-autonomous-vehicle-china/

[35] https://techcrunch.com/2021/05/25/meituan-jd-com-and-neolix-begin-autonomous-deliveries-in-beijing/

[36] https://venturebeat.com/2020/03/11/neolix-raises-29-million-to-mass-produce-autonomous-delivery-shuttles/

[37] https://cleveron.com/about-us

[38] https://futuretransport-news.com/dpd-netherlands-trials-cleverons-autonomous-delivery-vehicle/

[39] https://www.parcelandpostaltechnologyinternational.com/news/automation/dpd-netherlands-trials-cleverons-701-autonomous-delivery-vehicle.html

[40] https://cleveron.com/news/cleveron-unveils-new-driverless-semi-autonomous-last-mile-delivery-vehicle

4.2.4 Starship robot

Starship technologies was founded in 2014 in Estonia. Their headquarters is in San Francisco with the main engineering office based in Estonia[41]. In January of 2017 the company started commercial delivery pilot programs in the US, UK, Germany, Switzerland, and Estonia with companies such as Just Eat, Hermes, Metro Group, Swiss Post, Wolt[42]. The ADV is designed to handle local deliveries of food and small packages by driving on sidewalks. The cargo box can be opened by the recipient with a smartphone app. In November 2021 Starship technologies claimed to have completed 1,500,000 deliveries[43].

Specifications [44]

Loading capacity: 10kg
Range: can carry items up to 6 km radius.
Size: length 67.8cm, width 56.9 cm, height 55.4 cm. Total height with flagpole 124.8 cm
Speed: 6 km/h
Weight: 23 kg

4.2.5 Kiwibot

Kiwibot started 2017 in Columbia and USA in cooperation with Segway. The Kiwibot 4.0 was developed to transport small packages using sidewalks[45]. One of the applications is the Kiwi Campus project in which Kiwibot delivers food in the campus in Berkeley, California[46].

Specifications [47]

Loading capacity: No data
Range: No data
Size: Height: 55,9cm, width: 43.2cm, length: 55.9cm.
Speed: 2,4 km/h
Weight: No data

[41] https://www.starship.xyz/company/
[42] https://www.starship.xyz/press_releases/starship-technologies-secures-172-e165-million-in-seed-funding/#:~:text=Starship%20Technologies%20is%20running%20commercial,food%2C%20grocery%20and%20parcel%20industries
[43] https://www.starship.xyz/company/
[44] https://www.dimensions.com/element/starship-robot#:~:text=It%20was%20designed%20to%20deliver,through%20the%20Starship%20Robot%20app
[45] https://www.robotics247.com/article/kiwibot_launches_version_4.0_of_its_food_delivery_robot
[46] https://www.financecolombia.com/kiwi-campus-colombian-californian-startup-is-rolling-out-autonomous-food-delivery-in-berkeley/
[47] https://www.dimensions.com/element/kiwibot

4.2.6 Yape by E-novia

Yape is developed by E-novia from Italy[48]. Yape is a small two wheeled self-driving delivery that is designed to drive on sidewalks and to deliver small packages and food. It is equipped with GPS, video cameras and range finding -lasers to navigate the streets and to avoid obstacles[49]. The Companies Foodora and Tele2 are using Yape in Sweden to launch a last mile delivery service using tele2´s 5G network.[50]

Specifications[51]

Loading capacity: Up to 20kg
Range: Up to 80 km
Size: Height: 80cm, width: 60cm, length: 70cm.
Speed: Up to 20 km/h on bicycle lanes / on sidewalks 6 km/h
Weight: 15kg

4.2.7 Scout by Amazon

In 2019 Amazon launched their ADV Scout. Amazon started testing Scout in their delivery operations with human monitors in January 2019. The tests took place in four areas in the United States: Snohomish County, Washington, Irvine, California, Franklin, Tennessee and Atlanta, Georgia[52].

Specifications[53]

Loading capacity: 23kg
Range: No data
Size: Height: 73,7cm, width: 61cm, length: 76.2cm.
Speed: 24 km/h
Weight: 45 kg

[48] https://yapemobility.it/

[49] https://newatlas.com/yape-ground-delivery-drone/52751/

[50] https://tele2iot.com/case/doora-the-droid-how-tele2-5g-iot-is-enabling-robot-deliveries-with-foodora/

[51] https://bigsee.eu/yape-by-e-novia-design-team-italy/

[52] https://www.amazon.science/latest-news/how-amazon-scientists-are-helping-the-scout-delivery-device-find-a-path-to-success

[53] https://www.dimensions.com/element/amazon-scout

4.2.8 Einride Pod

Einride Pod is an electric and autonomous truck from the Swedish company Einride designed to operate on public roads and comes in five different versions depending on where to operate: *Fenced* - For closed facilities; *Nearby* - For short shipments on public roads and closed facilities; *Rural* - For operations on back road routes with limited traffic; *Highway* - For operations on major roads and highways; *City* - For operations on local roads in residential or commercial areas.

Specifications[54]

Loading capacity: 16 tons
Range: 200-300km
Size: Height: 7m, width: 2,5m, length: 7m.
Speed: 85 km/h (highway version)
Weight: 26 tons fully loaded

4.3 Automated vehicle pilots in Sweden

In October 2021 eight companies developing autonomous vehicles were registered at Transportstyrelsen, Sweden, three of which are developing ADVs.

	Ägare	Bolag
	Einride AB	Einride
✓	Självkörande, elektrisk transportfordon (Einrid Pod) i realistisk miljö	
	Keolis AB	Keolis
✓	Project S3 Lindholmen	
	Nobia Technology AB	Nobia
✓	Kollektivtrafik i Barkarbystaden	
	Nobia Technology AB	Nobina
✓	Utökad ansökan Barkarby	
	Nobia Technology AB	Nobina
✓	Utökat tillstånd EasyMile gen, 3 Barkarby	
	Scania CV AB	Scania
✓	Hub 2 Hub E4 fas 1	
	VTI*	Transdev Sverige AB
✓	Självkörande fordon	
	T-engineering	T-enginering
✓	Ombyggnad AD-bil i Trollhättan	
	Volvo Cars Corporation	Volvo Cars
✓	Motorvägsled i Göteborgstrakten	
	Zenseact	Zenzeact
✓	Automatiserade bilar i Göteborg och längs motorvägar	

*Statens Väg- och Transportforskningsinstitut

[54] https://www.einride.tech/pod

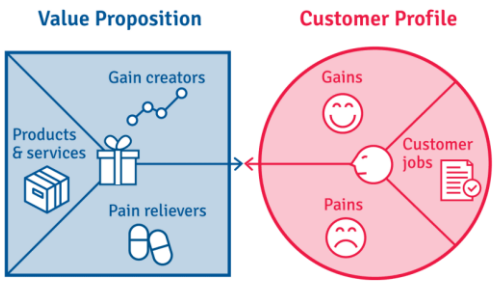
5 Method

5.1 Workshops

Two separate online workshops were held in October 2020, with members of the GLAD project group and members in the GLAD reference group. The workshops were held online, and the results were documented in a digital whiteboard. The goal was to identify potential use-cases and to select the three most interesting cases that could yield operational and financial benefits with ADVs. To define which business cases are suitable for ADV's in Sweden, the GLAD reference group discussed and gathered insights internally during the workshops. The analysis aimed to identify potential application areas for ADVs. Based on the value proposition canvases and the conclusions from the workshops three application areas were selected: airports, food deliveries and mail deliveries, and a number of interviews with representatives were carried out about the roles ADVs could serve in these application areas.

5.2 Value proposition canvas

The Value Proposition Canvas is a framework to analyse how a product can meet a market[55]. A grouping of the potential customer segments was done, and an analysis was performed by using the value propositions canvas. The Value Proposition Canvas can be used when there is a need to refine an existing product or service offering or where a new offering is being developed from scratch.



[55] https://www.b2binternational.com/research/methods/faq/what-is-the-value-proposition-canvas/

6 Results

6.1 Application areas för ADV

In the workshops the following potential application areas for ADVs in Sweden were identified:

- **Shops** - These businesses could benefit from ADVs by offering home deliveries to their customers without the need for additional staffing.
- **Services** - Businesses that pick up or deliver any kind of goods as a part of their service. For example, dry cleaners could benefit from ADVs by picking up the customer's laundry, driving it to the dry cleaner and delivering it back to the customer once it is finished.
- **Care and maintenance** - there is a variety of business areas that could benefit from ADVs. For example, the E-scooter require maintenance, charging and relocation which requires a driver to drive around town and service them. An ADV could in this case pick up all the vehicles in need of charging, maintenance or relocation and take it to the designated location.
- **Events** - During events that take place in a widespread area with multiple stages and locations, there is a need for shuttle services for both visitors and staff and deliveries of consumer goods to stalls or direct-to-consumer. ADVs could meet the needs of the visitors without the need to outsource or hire more staff to offer these services in events.
- **Retail** - Many physical stores are moving away from the traditional brick and mortar business and move towards an omnichannel approach to provide a more seamless customer experience. The number of retailers that offer home deliveries as a delivery alternative is expected to increase, which will require more drivers and last-mile delivery services. ADVs could be used by retailers for home deliveries in urban areas.
- **E-commerce** - E-commerce poses logistical challenges. ADVs could potentially create new innovative delivery services.
- **PRM Transport services** - In 2020, there were around seven million trips carried out with travel services in Sweden by people with reduced mobility[56]. This presents a feasible application area for ADVs if even only a portion of these trips could be done with ADVs

6.2 Selection of three potential application areas for ADV

Based on conclusions from the workshops three application areas were identified: Airports, postal services, and food delivery services. The selection was based on the operational and financial potentials to implement ADVs in the near-term in these kinds of businesses.

[56] https://www.trafa.se/globalassets/statistik/kollektivtrafik/fardtjanst/2020/fardtjanst-och-riksfardtjanst_2020.pdf

6.3 Three application areas – gains and pains

6.3.1 Airports

Customer segment 1: Airports		
Jobs	**Pains**	**Gains**
Shared resources in big spaces.	Narrow spaces	Lower the delivery costs
Delivery to and from the airport	Delivery times	Send goods through security without the need for human interaction.
Deliver garbage from stores and restaurants	No one to ask	Flexibility in delivery
Need/capacity for customised kiosks	Small inventory space for shops and restaurants	Flexibility in the extraction of garbage
Delivery to the gate	Accessibility	Unmanned airports –helping personnel in a flexible way.

6.3.2 Postal services

Customer segment 2: Post package delivery		
Jobs	**Pains**	**Gains**
Send a vehicle	Sensitive packages	100% delivery
Receive order digital	Customer that not picking up	Cost/package
Notifications	Customer not responding or picking up	Sustainability and environment
Deliver packages	Right package to the right address	Increasing the delivered volume

6.3.3 Food deliveries

Customer segment 3: Food delivery service		
Jobs	**Pains**	**Gains**
Delivery when I'm home	Need to leave home	Convenient shopping without having to go outside.
Changes its mind in the last minute	Changes not possible	Never have to queue
Locally grown food sent to local customers	Not possible to get local grown food	Always the right groceries at home

Kommenterad [1]: Ska du fylla i Pains i kolumnen?

Bring home a single item missing at home	Can be expensive	Convenient if you can afford it
Regular orders on certain items delivered on a predefined schedule	Reluctant to make changes	Part of your “everyday” plan
Give back food that might expire if for example one is leaving for a vacation.	Efforts to package and deliver	Could get a refund

6.4 Interviews with representatives from selected application areas

6.4.1 General

The semi-structured interviews included the following topics:

- How do you look at Autonomous Delivery in the future?
- Opportunity with a variant that can hold 2-3 m^2?
- Challenges?
- Desirable functions?
- Short term view? (5 years)
- Long term view (10+ years)

6.4.2 Airports

Örebro Airport

Örebro Airport has a shuttle that carries containers from the aircraft to the loading dock. The vehicle has a large table on which a container (7-8 tons) is placed (High loader). This would require large and strong ADV to manage the same load. For transferring cargo in the airport, the interviewee believed that a larger ADV would be needed in order to provide any additional efficiency or operational benefits.

Snow clearing and road maintenance could be another application area for ADVs. There is for example a laser scanner that checks the 45m long surface at each take-off and landing. If that could be operated automatically and if an ADV could scan the entire runway - that could be beneficial for the Airport, provided that the ADV could operate also in extreme weather conditions.

For deliveries to and from the airport, there is a capacity challenge to overcome. At Örebro Airport there are about 6000-8000 boxes going in and out every day. For ADVs to be able to process these, you would need a fleet of ADVs ready to respond to the delivery calls. In order for the airport to receive operational and efficiency benefits from ADVs, they would

need to deliver all parcels from a central point in urban areas. Another application area could be deliveries of garbage from the shops and the restaurants.

Höga Kusten airport
There could be benefits with ADVs to improve the accessibility with wheelchairs and for those who require special assistance at the airport. ADVs could pick-up and drop-off passengers at the airport from the railway station. Also, transits between the cities of Kramfors and Sollefteå could be carried out by ADVs. Now, most passengers get to the airport by car, but they want to encourage travellers to leave the car at home and use public transports to get to the airport. ADVs that pick-up travellers could be an interesting application area, instead of a rail line (which is an expensive investment).

Skövde Airport
The airport has signed a contract with the company Droneamicks which offers driverless cargo delivery by drones, controlled from a tower. These delivery drones are intended for shipping of up to 300kg.This service is expected to be available in 35 airports in different countries in the years to come. ADVs may be used to transport the cargo from the drone to the delivery trucks or even the warehouses.

Göteborg Landvetter Airport
They are planning to test automated vehicles for snow removal vehicles. From the warehouses they transport goods over many short distances. In these cases, ADVs could be useful. ADVs could also be used to transport goods from the press office or from a retailer like Espresso House to the gate itself - or any other type of transport at the airport with predefined patterns and less cargo to load could be potential application areas for ADVs at Landvetter Airport.

Stockholm Arlanda Airport
For people with reduced mobility, ADVs could potentially replace or complement to on-site wheelchairs. In this case ADVs need to be custom designed to facilitate and provide the right conditions for people with various disabilities. There is also the need to transport both crew and passengers from one terminal to another terminal. Depending on the amount of people ADVs could offer a well-suited transit for both these segments.

Every day they receive deliveries from freight reception to different departments. ADVs could deliver these packages, as the routes are short and inside the terminal. Everything must be scanned and approved before it enters the receiving area. It is then delivered to different departments in the airport. Since it is the same route every day, this could be a good application for ADVs. Staff transport on the airside is another interesting application.

Summary of potential usage of ADV at airports:
- Snow removal
- Staff transport airside
- Deliveries between departments within the terminal
- Shuttles for PRM (people with reduced mobility)
- Smaller airport shuttles
- Deliveries from/to the airport
- Private flight cargo transport

- Deliveries from retailers to the gate
- Last mile deliveries from delivery trucks to the airport warehouses

6.4.3 Postal services

For PostNord, the mailman is important for the communication and relationship with the customers. These types of human interactions cannot be replaced with ADVs. Another matter is whether the customers want a quittance insurance or not. Quittance will affect the cost of the delivery, as it requires additional steps and procedures in the delivery process.

One way to go would be to use ADVs for letter services as it does not require quittance. Even though there is no need for quittance, there are challenges to hand out the letters in for example, apartments. For ADVs to be able to deliver letters it would need to be able to access the letter boxes from inside the complexes, which is not possible for an ADV without the help from a human or a supporting system. Therefore, a better solution would be if the letter boxes could be located outside the complexes. ADVs could also complement letterboxes in suburbs, where the delivery points are further from each other. For example, ADVs could be easier to use as they don't necessarily have to go from point A to B, but rather move in a loop and bring the pickup point closer to the customer, giving customers the possibility to pick up their parcels directly from the ADV from anywhere within the transit loop.

Another area for ADVs could be an environmentally friendly express delivery, where people could pay a premium to get a parcel delivered to the door. Night-time deliveries are also possible since an ADV could wait for customers to pick up their parcels in a location and at a time to their convenience. This could be offered through a service where you charged customers for a pre-determined time slot. The interviewee said that they don't know enough about ADVs and their strategy for ADV solutions would be to run trials in defined areas with partners in different scenarios to learn how and where ADVs could be useful.

Summary of the potential usages of ADV for PostNord:

- Letter services
- Mobile letter boxes
- Home deliveries
- Night-time deliveries

6.4.4 Food delivery services

Foodora is a restaurant delivery platform operating in Sweden, Finland and Norway[57]. Foodora started an ADV initiative called "Doora", which is a small, electric delivery robot they are testing together with Tele2 for home deliveries. A "safety-person" is required that walks along with it ready to intervene if needed.

The regulatory aspect of getting the permission to use ADVs is currently seen as a challenge. They would like to see authorities moving faster to classify and create regulations around these types of vehicles to run more real-life tests. Real-life testing is also important to

57 https://careers.foodora.se/departments/foodora-market

gain more knowledge how to communicate and to be transparent with their usage of ADVs to adjust the operations and technology until it works for the customers to choose ADVs as a shipping mode.

Deliveries to apartment buildings are challenging, since the ADV cannot access the buildings. However, according to Foodora the residents were positive to ADVs delivering their food and they had no trouble going down to pick up the food, provided that the deliveries are faster and cheaper.

ADVs may have the potentials to offer timely and convenient deliveries to their customers, as well as giving good customer experiences, but the implemented of ADVs in urban environments must also involve city architects and planners.

Summary of the potential usage for food deliveries:

- Home deliveries of both food bags and groceries
- Quick commerce deliveries
- Complimentary shopping

7 Discussion and conclusions

7.1 Market

Provided that urban deliveries and e-commerce purchases will keep increasing, ADVs could be the next “big thing” for urban transportation. Corporations such as Google[58], Amazon[59] [60], Nvidia[61] and Apple[62] are investing in development of ADVs, either by acquiring start-up companies or by developing these technologies themselves. This could be an indicator of the future of ADVs and why many believe that ADVs will be a business opportunity.

7.2 What benefits could ADV bring to society?

It is possible that there are economic and operational benefits with ADVs in the transportation and logistics sectors, but how ADVs will be used to create these benefits depends largely on the unique aspects of the business or service itself. For transportation and logistics companies ADVs could hypothetically help to reduce operation costs and increase the efficiency of deliveries, by reducing reliance on traditional transportation

[58] https://waymo.com/

[59] https://aws.amazon.com/automotive/autonomous-mobility/

[60] https://www.businessinsider.com/amazon-zoox-seattle-self-driving-cars-test-rain-weather-climate-2021-10?r=US&IR=T

[61] https://blogs.nvidia.com/blog/2022/06/30/faction-affordable-avs-drive/?fbclid=IwAR0HWaAdHzc0C-sUbRDsyP5qAjkx_AQdQkAasrRijbn-JGYbu9eXRUOKSbY

[62] https://appleinsider.com/inside/apple-car

methods. However, it is still unclear whether ADVs are capable of successfully reducing traffic congestion by improving coordination of transit routes.

Since ADVs are driverless, it is believed that ADVs can improve operational efficiency and eliminate costs for drivers. However, this might not be suitable for all businesses, as the driver still have carry our important tasks that ADV’s cannot.

ADVs also have problems delivering to apartment buildings or other multi-level structures. So, they would require a dedicated drop-off area, or an automatic system adapted for ADV deliveries, which may not be available in some locations. ADVs can't deal with traffic the same way as a human driver. They can have difficulty fitting into a traffic flow with human drivers and navigating around obstacles. And it is likely that ADVs won't be capable of accounting for all weather conditions. This could lead to more accidents in the short term, which brings us to whether special roads would be needed for autonomous transits. It is also believed that ADVs can improve traffic safety. Since ADVs are connected vehicles, they depend on receiving their instructions in a secure way. ADVs could be hacked, and sensitive information could be stolen or tampered.

The technologies for ADVs are still under development and businesses and governments need to make substantial investments before ADVs can operate on public roads or in environments that are adapted to transports with ADVs. When ADVs are available depends largely on solving the challenges associated with ADVs, the challenges that are known today and the ones that are unknown in the future.