Helsingbotica – a prestudy

Date 2024-01-16

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A pre-study on data sharing for improved micromobility and an autonomous delivery robot pilot in Helsingborg

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Content

Summary

This project investigated new methods to enhance the use of micromobility vehicles, focusing on the growing use of bike and pedestrian road networks. It a preliminary study that utilized such vehicles for gathering images and applied machine learning to expand knowledge of infrastructure. The study successfully demonstrated the feasibility of collecting images of the road network, but also identified unique challenges such as varying angles and specific obstacles like gravel that need attention. Due to GDPR concerns, external cameras were preferred over built-in ones in vehicles like e-scooters.

The project also looked into how data could be shared back with users and stakeholders. It found established methods for handling static data but noted a lack of standards for dynamic obstacles. Efforts to participate in a U.S. Department of Transportation-led standardization initiative have begun. Additionally, the project crafted a preliminary policy for delivery robots. This policy includes geofencing, speed limits, and operating schedules, which Helsingborg has translated into machine-readable code using the Mobility Data Specification. Hugo Delivery have adjusted its platform to comply with these digital policies.

The final hypothesis of the project revolves around a pilot concept for autonomous delivery robots. This concept is grounded in on-site testing, workshops with municipal and commercial stakeholders, reviews of existing global delivery robot pilots, and Helsingborg's sustainability goals. It also takes into account the strengths and weaknesses of delivery robots. The idea is to pilot these robots as mobile delivery lockers in suburban areas, avoiding city centers with high traffic. This approach, termed 'community robots', envisions the robots operating within a specific area, with daily battery swaps. By shifting parcel deliveries from vans to these robots, a significant reduction in traffic accidents and emissions in residential areas is anticipated. Moreover, parcel delivery companies are expected to see a marked increase in transport efficiency. In a fully scaled system, this could lead to a reduction of about 40-50% in the last-mile fleet.

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Swedish Summary

Projektet har undersökt nya metoder för att förbättra användningen av mikromobilitetsfordon, med fokus på den ökande användningen av cykel- och gångvägsnät. Det innefattade en förstudie som använde sådana fordon för att samla bilder på det vägnätet och tillämpade maskininlärning för att bättre förstå tillståndet på anläggningen. Studien visade att det var möjligt att samla bilder av vägnätet, men identifierade också nya utmaningar som att olika fordon och specifika GC-nätshinder som grus som behöver ytterligare arbete. På grund av GDPR-förordningen har projektet kommit fram till externa kameror är att föredra framför inbyggda i fordon som elscootrar.

Projektet undersökte även hur data kunde delas tillbaka med användare och andra intressenter. Projketet fann etablerade metoder för hantering av statisk data men noterade en brist på standarder för mer dynamiska hinder. Ansträngningar för att delta i ett standardiseringsinitiativ ledd av USA:s transportdepartement har därför gjorts. Dessutom utformade projektet en preliminär policy för leveransrobotar. Denna policy innefattar geofencing, hastighetsbegränsningar och driftscheman, vilket Helsingborg har översatt till maskinläsbar kod med hjälp av Mobility Data Specification. Hugo Delivery har justerat sin plattform för att följa dessa digitala policyer.

Projektets slutliga och viktigaste hypotes kretsar kring ett pilotkoncept för autonoma leveransrobotar. Detta koncept är grundat på tester på plats, workshops med kommunala och kommersiella intressenter, granskningar av befintliga globala pilotprojekt för leveransrobotar samt Helsingborgs hållbarhetsmål. Det tar också hänsyn till styrkor och svagheter hos leveransrobotar. Tanken är att testa dessa robotar som mobila leveransskåp i förortsområden, och undvika stadskärnor med hög trafik. Denna strategi, kallad 'community robots', föreställer sig att robotarna opererar inom ett specifikt område med dagliga batteribyten. Genom att flytta paketleveranser från skåpbilar till dessa robotar förväntas en betydande minskning av trafikolyckor och utsläpp i bostadsområden. Dessutom förväntas paketleveransföretag se en markant ökning av transporteffektiviteten. I ett fullskaligt system kan detta leda till en minskning på ungefär 40-50 % för flottor som används för sista-kilometernleveranser.

Background

In recent years, we have seen a rapid development of micromobility vehicles and an increased use of pedestrian and bicycle networks with both new and already established types of vehicles. Despite this, most municpalities currently have a relatively limited understanding of how road space is used and how the physical infrastructure affects the operation of these vehicles. Therefore, there is a growing need to learn more about how these vehicles and pedestrians are affected by the physical infrastructure, and how it can contribute to an attractive city and a safer and continued increased use of the pedestrian and bicycle network (PB-network), where more and more actors must share the space. We have also seen how an unmanaged and extensive introduction of new types of traffic within micromobility generates both complaints and more accidents on the PB-network, but that a data-driven approach has been able to handle several of such challenges [3, 4].

Collecting data from the PB-network has so far been difficult, especially when it comes to more frequent data collection, but given connected vehicles equipped with various sensors, we can now get a better understanding of how they move and how the physical infrastructure affects their progress among other things. Therefore, this pilot study aims to make a first effort to understand potential needs for data collection and to look at the possibilities of managing and sharing collected data according to the Open Mobility Foundation's (OMF) data standard (Mobility Data Specification (MDS)). MDS is currently used in about 150 cities around the world, primarily to regulate electric scooters [1] but also to support pilot projects for delivery robots in the USA [2]."

The prestudy has investigated digital technology for sustainability, developing the use of micromobility through delivery robots in Helsingborg. The aim is to increase knowledge and there identify a pilot where acceptance of new digital solutions, reduced environmental impact, and enhanced efficiency is at the core. We also looked into functional digital regulations to enable shared, connected, and automated services. The project thus strengthens Sweden's position in the vehicle and ICT industry, and contributes to Drive Sweden's vision of a more sustainable transport system.

Project setup

Purpose

Why is this project important and what was the purpose of the project?

Objectives

The objective of the project has been to explore data sharing about the pedestrian and bicycle network for micromobility where the standard Mobility Data Specification (MDS) is central. The delivery is a substantiated application for pilot tests of delivery robots

Project period

The project ran from June 2023 throughout December 2023

Partners

Statens väg- och transportforskningsinstitut (VTI)
Helsingborgs stad
Univrses AB
Hugo Delivery AB

Method and activities

To achieve the objectives of the pre-study the project has used a variety of methods and activities, as explained below.

Explorative development and Proof of Concepts.

Here, the project partners have conducted necessary development to pilot delivery robots.

- **Hugo Delivery** has tested Hugo's capabilities in urban environments as a basis for finding a suitable pilot (including area). They have also explored the possibility of collecting bike and walk road data data through Hugo's delivery robots and how data can be shared between Hugo and Helsingborg using MDS.
- **Univrses** has Univrses has equipped bicycles and other vehicles moving on pedestrian and bike paths with a camera unit for collecting data about road damages and other objects in the road space. Based on the results, the advantages and disadvantages of different types of vehicle fleets have been identified. Univrses has also developed the solution for the project's purposes and examined additional functionalities that can contribute to a greater understanding and knowledge of the road space where micro-mobility vehicles move. Univrses has also worked with identifying opportunities and limitations regarding the data collection, e.g., how the type of road affects, or other factors relevant for future implementation."
- **The City of Helsingborg** has both developed a policy for autonomous delivery robots and implemented that policy digitally using MDS.

Internal project workshops

The project has conducted four internal interactive workshops during the project, on issues of high importance for meeting project objectives.

- **Data-sharing**: what data needs to be shared, to whom, why, when and using what standards
- **Scaling project solutions**: what is necessary to scale the solutions beyond the pilot setting.
- **Mobility Data Specification**: how should Helsingborg utilize the standard to express municipal policies for autonomous delivery robots.

External workshops and demonstrations.

The project has conducted

- **Start-up workshop**. The project's objective was introduced in a workshop discussing the potential benefits of autonomous delivery robots for the city. This was followed by a presentation from Andrew Glass Hastings of the Open Mobility Foundation, focusing on the vision and opportunities of MDS. Around 20 employees from the City of Helsingborg attended, all of whom could benefit from the use of autonomous delivery robots.
- **On-site demo and workshop**. On Oct 21, the project had an on-site demonstration of Hugo at Stadsparken in Helsingborg. The demo was followed by a joint workshop with employees from the City Helsingborg, Nowate Logistics, Ikea and Lund University.

Desk research and literature studies

- **Case studies on autonomous delivery robots**. To get an idea of other pilots, VTI undertook a search for relevant case studies.
- **Case studies on Light Electric Vehicles (LEV)**. VTI also looked into LEV, as these share many characteristics with ADRs and thus could serve as a learning subject.

Meetings with relevant stakeholders for a pilot study / beneficiaries of the pilot study.

- Various logistics companies, including both potential pilot participants and re-users of bike and walk road data.
- SKR on data standards for bike and walk road data.
- The Open Mobility Foundation regarding the use of MDS for ADR.
- US Department of Transportation regarding standardizing dynamic bike and walk road data.

Internal project coordination

- Every week the project met for status updates, discussions on moving forward, and planning joint activities. In total 17 such meetings were held.

Results and Deliverables

Collecting Data from the Bike and Road Network

As part of the Helsingbotica pilot Univrses is starting the journey to address the need for data on bike and pedestrian networks in the city. The previous focus of data collection in other projects has been from the carriageways but there is a growing interest in expanding the data collection to also include the bike and pedestrian network. This network is more difficult to monitor, and the consequences of potholes could be more severe.

Cities wish to attract more people to use bikes. However, many accidents with bikes are more severe than cars and are often caused by badly maintained bicycle paths. The condition of the network will be even more central when more different types of vehicle will also be using the same space. 3DAI™ City is transforming the management of these critical transportation corridors. Users can monitor bike path conditions, potential obstructions, usage, and safety. The data also can provide critical insight into how bike path design and investment can be adapted and optimized for safety.

Univrses is combating the decline of cycle and pedestrian paths by streamlining monitoring and maintenance, reducing response times and the potential for accidents or disruptions. Using the system, cities can allocate resources for path maintenance and repair based on real-time insights, reducing operational costs and enhancing experiences for users of the network.

How it works

Univrses' 3DAI™ City is a computer vision platform giving access to timely, relevant and actionable data about the roadside environment. It is made accessible by deploying a smartphone on any vehicle and processing image data from a smartphone. The images and other data are processed on the vehicle (at the "edge") using Univrses' proprietary perception software. Univrses' software, originally developed to give autonomous cars the ability to make sense of their surroundings, consists of computer vision and AI components that detect and map urban and roadside features. The processing extracts meaningful data relevant to the successful and smooth functioning of road management operations. In this way, vehicles are "mobilized" to become data harvesters.

Since data collection using 3DAI™ City is enabled using a regular smartphone the setup can be used on the new types of vehicles, there has been a need to mount the smartphone differently on for example bikes.

Adaptation in the Helsingbotica pilot

During the pilot Univrses has explored data collection methods using various vehicles, including bikes, the delivery robot Hugo, and explored the possibility of using maintenance vehicles that navigate pedestrian and bike networks. Each type of collection vehicle introduces distinct factors such as view angle, height, and speed, which influence the outcomes of data collection. These different factors are important in understanding the data collected in terms of for example the position, size and type of feature detected. The chosen vehicles are those already operational on the network, allowing Univrses to tap into existing mobility patterns. This approach aligns with scalability and futureproofing, particularly considering the potential integration of delivery robots into the infrastructure.

This data collection is central in understanding the detailed requirements when assessing different objects on this network. Based on the insights of the data and in understanding the different use cases Univrses has started the work of creating guidelines for image annotation. The data collected has been processed and to visualize the results a video was created.

The focus of object detection during the pilot includes identifying road damage, ongoing road works, and traffic signs within the pedestrian and bike lane network.

Standards and Formats

Actively engaging in the establishment of formats and standards, Univrses explores the Mobility Data Specification (MDS) for data exchange. This commitment ensures that data collected by the platform aligns with industry standards, promoting interoperability and seamless data exchange. In the context of HelsingBotica, adherence to standards like MDS is essential for effective collaboration and data sharing among stakeholders.

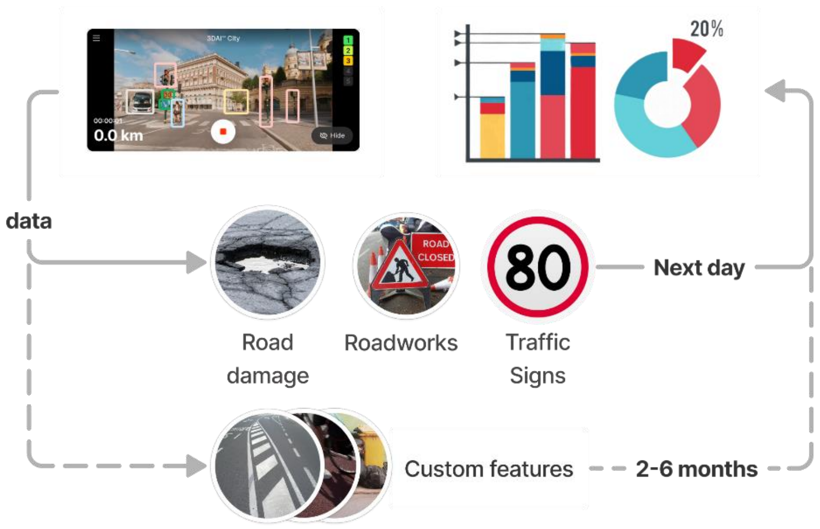
Collaborative Partnerships

In the HelsingBotica project, Univrses collaborates with entities like Helsingborgs stad, Univrses AB, and Hugo Delivery AB. This collaborative approach highlights the importance of engaging multiple stakeholders to address the complexities of micro-mobility, data sharing, and delivery robot deployment. The partnership brings together expertise from different domains to ensure a comprehensive and successful project outcome.

Next steps in developing the feature

Next steps will include to leverage deployed collection vehicles to collect training data using infrastructure in a range of environmental conditions. Collected data can be annotated and used to train Deep Learning networks in 3DAI City to detect road damage, road works and traffic signs on bike and pedestrian networks new features that are identified could be added as per Univrses' Feature Development Pipeline. The solution algorithms will need to be continuously refined.

Univrses is still in the exploration phase to determine objects of interest that can be detected within the pedestrian and bike lane infrastructure. To adapt and collect new types of features is something that has already been tested including street lighting, white lines, central reservation barriers and more.



Privacy

3DAI CIty has been developed with privacy as a core principle. By design, the operator of data collection does not have access to the images or the location data; the processing of Personal Data by the operator is fully automated by Univrses' software running on the smartphone or in-vehicle. Any images sent for viewing in the Dashboard are anonymized by using automated software developed by Univrses that, for example, heavily blurs faces and license plates. The information removal process is irreversible.

Data Collection and GDPR

When the city gathers information, it's essential to follow GDPR rules and ensure personal details don't fall into the wrong hands. Personal data includes both written information and images that identify individuals. It's important to establish during the buying process who is responsible for this data, and if there's an external party involved in collecting it. In our Helsingbotica project, we worked with Univrses, who manages the data, while the robot HUGO might be considered a data handler, though this isn't completely clear. The city needs to figure out its role too – are we managing the data or just processing it? This matters because the information we collect helps us make the city a better, easier place to live, work, and enjoy

Proposed solution

The potential personal data processed internally in 3DAI City consists of individual reference images taken as confirmation that the damage classification performed on the phone or camera in 3DAI City is accurate. When reference images are autonomously captured by 3DAI City, no person knows when an image is taken or when it is sent to the S3 Bucket server. Furthermore, no personal information is collected, and therefore, it is not possible to disclose any information.

1. The image is captured using a camera sensor in a mobile phone. As the vehicles with the phone or camera mounted are located in public spaces within the city, an autonomously taken image, captured for the purpose of verifying the accuracy of the damage classification, may include passersby or other vehicles. During the image capture and throughout the time it resides in the phone or camera, as well as during the entire process of transferring the image from the phone or camera to the server where it lands in an S3 bucket, the image is encrypted.
2. The image is decrypted only while it is in the secure S3 bucket, solely for the purpose of anonymization through the server's masking process. The information that is masked and anonymized includes all personal information, such as faces and vehicle license plates. The anonymization process occurs before the image progresses further into the system.
3. The original image in the phone or camera is not stored but disappears when the image, in encrypted format, is sent to the server. The original image that reaches the S3 Bucket server is immediately deleted upon decryption and completion of the anonymization process. It is not possible at any point to view or retrieve the image before it leaves the phone or camera, and it is also not possible to view or retrieve the image while it is in the S3 Bucket or before it has passed through the masking filter on the 3DAI City server.

Sharing Data from the Bike and Road Network

Another focus was on sharing data about the bike and pedestrian pathways after collection. This data was intended to be open to the public, as the project anticipated a wide range of users who could benefit, including delivery robot companies like Hugo, cargo bike couriers, e-scooter providers, and the citizens of Helsingborg.

The data aimed to highlight various obstacles that might temporarily exist on these paths. During a workshop, we identified several items worth sharing with a wider audience:

- Lighting conditions
- Images confirming damage (e.g., post-thaw road conditions)
- High curbs
- Vandalism
- Tree roots
- Use of public space
- Congestion, like that caused by roadworks

- Large clear areas, particularly around plants
- Overhanging vegetation
- Accumulation of snow or gravel
- Proper orientation of storm drains and pooling water
- Potholes
- General obstructions

Next, we explored how to best share this data. The bike delivery companies we spoke with used various mapping services like OpenStreetMap and Google Maps, depending on available data. Discussions with the Open Mobility Foundation (OMF) also highlighted the lack of a standardized approach for this kind of data sharing, and MDS didn't allow for describing neither the infrastructure nor time-sensitive obstacles. We also met with Swedish Association of Local Authorities and Regions (SKR), to inquire about what standards were currently being used by local road authorities in Sweden. We found that while the National Road Database (NVDB) does cater for static road properties (like bike lane width) it doesn't currently support more dynamic events and objects, like those in the list above.

As a result, the Open Mobility Foundation facilitated connections with a new initiative[1] focused on geospatial data for bike, pedestrian, and accessibility infrastructure. This initiative, which met online on December 1, discussed the lack of comprehensive, standardized data on infrastructure supporting walking, biking, and rolling, especially in terms of sidewalks, bike lanes, and curb ramps. Initiated by the Bureau of Transportation Statistics, the project aimed to bridge this data gap by creating detailed geospatial data layers. These layers were designed to provide in-depth information about the extent, connectivity, and condition of bicycle, pedestrian, and accessibility infrastructure. The goal was to enhance communication and collaboration among various organizations, including governmental, academic, nonprofit, and private sectors, to develop and standardize these data types. Through this collaborative effort, the organizations strived to unify their efforts and exchange knowledge to effectively develop this vital geospatial infrastructure data. While the outcome of this group remains uncertain, we see it as important to follow in order to share bike and walk road data for a wider audience.

Developing and Implementing Digital Policy for ADR

The project successfully developed and digitally implemented a policy for autonomous delivery robots using the Mobility Data Specification (MDS). This implementation involved Helsingborg creating and openly publishing the policy, as well as Hugo adopting and acting upon it.

After investigating the policy requirements for ADR, the project concluded that there are three key aspects to focus on (see Appendix 1).

- First, a geofenced area has been designated where ADRs are permitted to operate, ensuring that their operations are confined within this specific geography.
- Second, there are speed restrictions in place within this area to ensure safety.
- Lastly, an operating calendar has been established, which dictates the specific times and days when the ADR operations are allowed.

Experiences from the City of Helsingborg

The City of Helsingborg's journey with Hugo began with a straightforward requirement: to make Helsingborgs's policy accessible in MDS format. Helsingborg addressed this by sharing the policy and geodata file as a text file via its open data platform[2].

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[1] https://github.com/dotbts/BPA
[2] https://helsingborg.io/dataportal/datamangd/#esc_entry=494&esc_context=3

Initially, navigating the MDS policy framework, developed by the Open Mobility Foundation, had been daunting for Helsingborg. The extensive information and myriad use cases on the website offered an incredible amount of knowledge. However, without a clear grasp of Helsingborg's specific needs, applying this information practically was challenging. Nevertheless, Helsingborg soon learned that the key to mastering the MDS framework lay in understanding its structure and the specific scenarios it was designed for. By focusing on relevant information from the various shared use cases, Helsingborg gradually became more comfortable with the framework.

A significant hurdle for Helsingborg was figuring out how to make these files accessible to Hugo. The first version had been relatively straightforward, thanks to well-coordinated efforts. However, Helsingborg recognized potential challenges in updating these files for future projects.

Another vital aspect of Helsingborg's experience was learning how to prioritize and order policies. During the pilot phase, the structure of the policy had been simple, posing few challenges. But as Helsingborg moved towards full-scale operations, the complexity increased. This transition required close collaboration with the traffic planning team, whose expertise was invaluable in determining the priority and sequence of policies.

What stood out in Helsingborg's experience was the level of clarity and transparency that the MDS policy framework introduced. It fostered a clear line of communication between policymakers and service providers. By digitally sharing policies, Helsingborg saw how MDS facilitated interaction and cooperation among stakeholders in the project.

In conclusion, while the MDS policy framework might have seemed overwhelming initially, it is considered a powerful tool for managing and optimizing modern mobility solutions for Helsingborg with time, patience, and a willingness to learn. It was a path of continuous learning and adaptation, but the benefits in terms of clarity, transparency, and operational efficiency were substantial for the city.

Hugo's MDS Experience

In the current Helsingbotica project, Hugo has worked together with primarily the city of Helsingborg to create a digital ADR policy that uses the MDS (Mobility Data Specification) standard. This standard is designed to help different groups involved in mobility to communicate better with each other. Although operational real-world testing hasn't been implemented yet, the infrastructure is strategically set up to facilitate future trials, adhering to the MDS standard. The envisioned applications for this data exchange encompass both navigation and drive information, with the anticipation that Hugo will be able to leverage this system effectively in forthcoming tests. This collaborative effort, aligned with the MDS standard, underscores the commitment to establishing a shared technological framework for improved collaboration and streamlined information sharing within the Helsingbotica project.

Learnings from other ADR Pilots

The research and pilot programs reviewed (see Appendix 2 for details) have shown that autonomous robots are particularly useful, especially during emergencies like the COVID-19 pandemic and in the booming e-commerce sector in cities. They ensure deliveries are done quickly and safely. These robots not only make logistics smoother but can also help reduce CO_2 emissions, support sustainable delivery methods, and improve traffic safety in urban areas. Plus, they can gather data on their surroundings and customer habits, which is helpful for both government bodies and delivery companies.

However, there are challenges. For autonomous robots to work well, tech companies, logistics firms, city authorities, and other key players need to work together. Creating business models for these robots is complex and requires lots of research, new ideas, and teamwork. While these robots can deliver items at any time and potentially lower costs, there are worries about how customers will find the experience. For example, if people need to be home to receive deliveries, it limits the convenience of these services.

How the public sees these robots is very important. Early tests faced doubts and even damage, highlighting the need to educate the public and gain their acceptance. Also, setting up large-scale delivery systems with these robots is hard because of technological and physical limitations. Legal issues add another layer of difficulty, as laws can slow down their widespread use.

Beyond just delivering packages, these robots have uses in specialized areas like hospital logistics, where they can help with things like integrating with hospital systems, freeing up staff to focus more on patient care, and making sure deliveries are clean and safe. However, using them in sensitive places like hospitals means they must be very secure, protecting things like patient privacy and data. Also, getting these robots ready for use can be expensive as it might require changes to the environment.

In summary, while autonomous robots have proven their worth in various settings, from busy city streets in Belgium and Singapore to complex hospital environments in Sweden and the USA, there's still a lot to do to make them more widely used. Projects like ENDORSE are important because they work on improving these robots, making sure they are effective and affordable for different types of businesses.

Workshop on Scaling Data Collection and Delivery Robot Pilots

In order to identify how a future pilot can be scaled up beyond demonstration, the project held a workshop on that theme.

Light-Weight Electric Freight Vehicles (LEVs) and Last Mile Delivery

Since delivery robots can be seen as a type of Light-Weight Electric Freight Vehicle (LEV), it makes sense to derive learnings from such projects when designing a pilot for delivery robots.

LEVs are currently being studied and implemented in the Nordic countries. The 'last mile' of the logistics chain is notably the most costly, inefficient, and emission-intensive segment, especially for parcel delivery. For instance, light goods vehicles and vans are major contributors to CO_2 emissions, NO_x emissions, and particulate matters in urban areas (REF). In response, cargo bikes and electric vans are increasingly being adopted as alternatives to traditional vans for last-mile deliveries. Notably, cargo bikes, capable of taking shortcuts and faster than vans in certain contexts, offer closer access to customers and the convenience of parking directly outside destinations.

Benefits and Challenges of Cargo Bikes and Robots for Delivery

Cargo bikes can utilize various forms of infrastructure, including bike lanes, car lanes, and pedestrian areas. Unlike other vehicles, they do not need to circulate to find parking and can take shortcuts. However, the cost of intermediate storage for cargo bikes is a significant issue, and finding a viable solution for this is crucial. Work domain analysis could help optimize the use of cargo bikes and robots in delivery processes.

While electric vans are typically the main focus for delivery companies, the use of light electric vehicles (LEVs) is on the decline. The delivery industry is traditionally slow to grow, facing challenges such as recruiting cargo bike drivers, especially in unfavorable weather conditions. The sector's maturity is also a concern, characterized by many small players and maintenance problems. There is a lack of standardization and sector maturity, with few major auto manufacturers involved.

City design and transport policies significantly impact the success of cargo bikes and robots. However, citizens often find themselves unsure of how to engage in the private sector domain of delivery. Implementing environmental zones and lower speed limits would be advantageous for cargo bikes and robots. Society desires emission-free transport with energy-efficient vehicles, but the costs are primarily borne by customers and transport companies, while the benefits are enjoyed by citizens and the city.

Cities and municipalities play a crucial role in promoting sustainable transportation solutions. By addressing these issues, they can drive the development and implementation of more environmentally friendly and efficient delivery systems.

Transshipment and last mile deliveries

Transshipment points, or hubs, pose significant challenges for cargo bikes and robots in terms of cost and complexity. Consequently, the feasibility of using parking lots, gas stations, or garages as transshipment point solutions is being explored. In New York, a major project focused on these hubs is underway, expected to last two to three years. Given the city's high population density and substantial demand for parcel delivery, alongside issues of truck traffic and pollution, there's a push for alternative delivery methods. New York has introduced a system that excludes trucks in certain areas, utilizing 25 different transloading locations with curbside access and cargo bikes. The aim is to complete the final delivery leg with emission-free vehicles.

This approach is also gaining traction in Sweden, where companies are collaborating with property developers to repurpose gas stations and parking lots. Property owners are finding value in this, both for marketing and monetizing unused spaces. Implementing transloading zones and restricting truck traffic are emerging as practical solutions.

The current economy harbors hidden costs, such as those for parking spaces, which are often unseen by consumers but nonetheless present. Redirecting existing budgets to support new enterprises is crucial. One proposal under consideration is establishing small, exclusive transloading zones. Additionally, the concept of a voluntary green zone, similar to the one in Gothenburg, is being discussed for implementation in cities like Stockholm, Gothenburg, Malmö, or Helsingborg.

Scaling up autonomous delivery robots

The city, as the primary beneficiary, should spearhead the scaling of solutions. Budget allocation is essential, potentially involving the reallocation of existing funds. Testing and validation of new delivery methods are necessary for implementing change. The leadership of the city is pivotal in promoting the adoption of innovative solutions. Confirming public preference for new delivery methods is important. The Helsingbotica project should focus on validating user preferences, achievable through testing and user feedback collection. However, hearing the perspectives of politicians in Helsingborg would also be valuable.

Helsingborg is recognized as an ideal testbed for emerging companies and technologies. The Helsingborg Declaration is a network aimed at establishing the city as the world's most sustainable logistics hub. Creating a compelling pilot test and testbed in Helsingborg is anticipated to be straightforward. Implementing lower speed limits and clarifying the need for emission zones could facilitate a landscape conducive to sustainable logistics. Politicians in Helsingborg, who are attentive to the city's corporate growth, are likely to respond positively to a strong case for sustainable logistics. The hidden costs of current delivery methods, such as parking space utilization, need to be transparent for informed decision-making. This transparency is crucial to shift public opinion towards sustainable choices. Discussions should acknowledge the current state and propose a positive, constructive approach towards transformation. The 2030 paper from Helsingborg has been inspirational, though initiating contact and collaboration was initially a challenge. The pilot project can incorporate design thinking exercises. The project should operate on multiple levels, both practical and political

Scaling up Data Collection

Currently, data is collected by retrofitting vehicles with cameras. The future plan involves integrating this technology directly into the vehicles, especially autonomous cars, to make the collected data more valuable and usable for cities. However, several scaling challenges arise in terms of policies, regulations, and data privacy.

Challenges and Opportunities of Data Collection in Vehicles

It is challenging to integrate a specific piece of hardware or technology into the large-scale production of vehicles for data collection. Car companies are beginning to recognize the potential of data collection, viewing it as an opportunity for further development. Beyond reducing CO2 emissions, data collection offers benefits like a better understanding of the environment and valuable insights. Understanding the needs of the city or organization is crucial in developing effective data collection implementations. However, there are policy and regulation challenges, especially at the EU level, regarding the use of data in vehicles. For Univrses, a particular struggle is avoiding the collection of personal data and differentiating themselves from companies that monetize privacy-sensitive data. Discussions with companies like Voi have shown an openness to sharing data for monetization and value creation

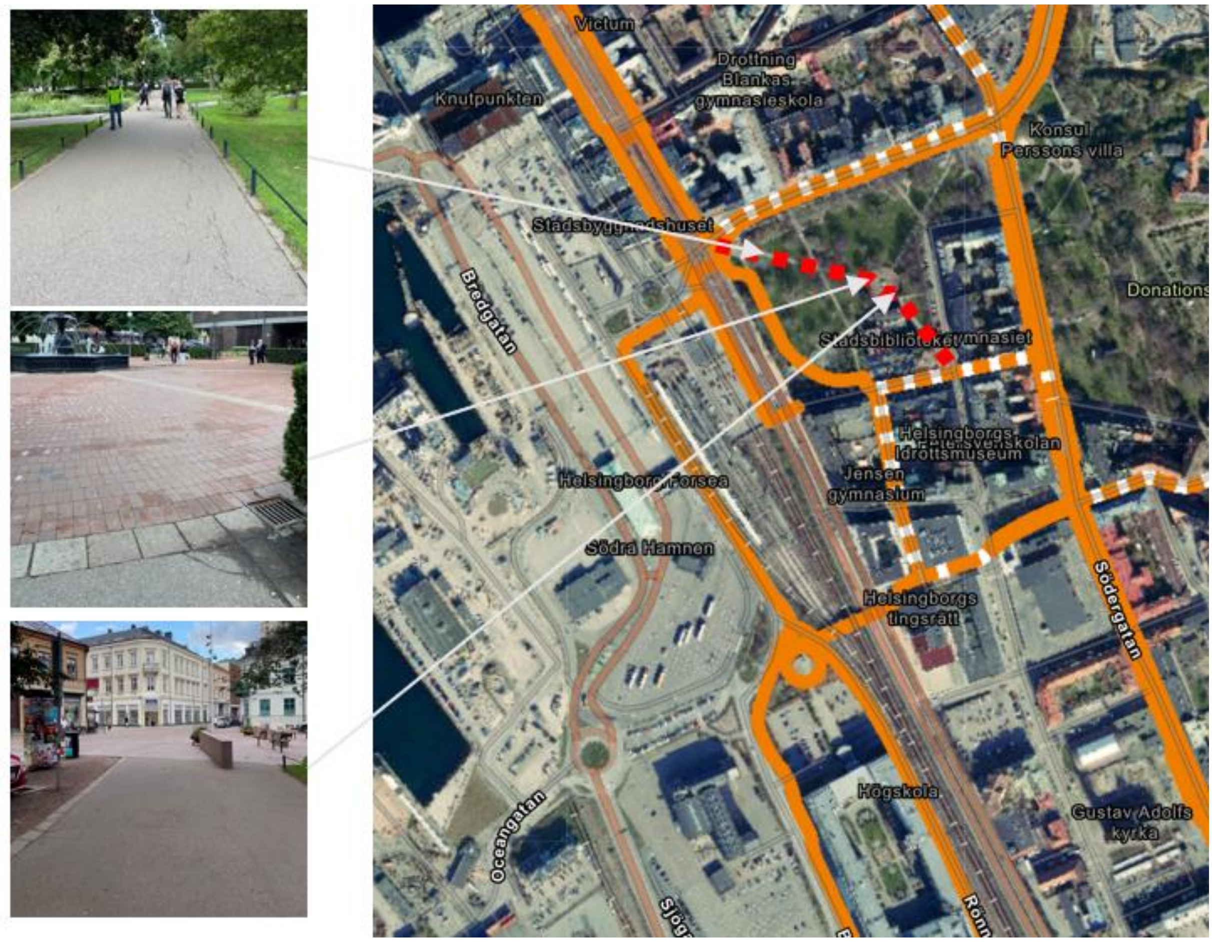
On-site demonstration and workshop in Helsingborg

On October 19, 2023, a workshop was conducted in collaboration with 20 individuals from various departments within the city of Helsingborg, including urban planning and technical services, school and recreation services, social services, city management, and the health and social care department. In addition to the project team members, participants included researchers from Lund University and representatives from two private companies: IKEA and Nowaste.

The workshop unfolded in three stages, each with distinct objectives. The first segment focused on exploring how the delivery robot, Hugo, navigates through different environments. The second part involved testing various methods for collecting data on the pedestrian and cycling network. The third phase aimed to invite other stakeholders to a demonstration of Hugo and a workshop discussing potential tasks for Hugo in an upcoming pilot test.

How the Delivery Robot Handles Different Environments

The test area where Hugo operated was the pedestrian and cycling path through the city park in central Helsingborg. The path is frequented by pedestrians and cyclists. Hugo's planned route was defined using GPS points.



Some challenges arose when individuals were present in the planned route. The robot successfully avoided obstacles but occasionally deviated from the cycling path. The test results indicated that the delivery robot could follow the planned route and that Hugo also needs to gather information about the area it operates in. This can be achieved by defining a geofence area.

Collecting Data on the Pedestrian and Cycling Network

To collect data on the pedestrian and cycling network, a mobile phone with Univrses' service was mounted on the delivery robot, Hugo. The installation was successful, and the data collection regarding the pedestrian and cycling network proceeded smoothly.

Workshop on the potential pilot tests

In the final segment, 20 individuals with diverse expertise witnessed a demonstration of Hugo and then brainstormed about the potential utility of a robot in the city. The following list summarizes the suggestions that were put forward:

- Efficient and eco-friendly E-commerce
- Retrieval of returns to a city hub, also serving as an intermediate storage facility
- Assistance with carrying heavy or cumbersome loads
- Deliveries within the city's departments and a method to consolidate storage facilities
- Indoor deliveries, such as assisting with carrying laundry in care facilities
- Support for care recipients who wish to go out more but require some assistance or extra security
- Handling and collection of packaging materials
- Collection of clothing, other reusable items, or collecting cans, old batteries, phones
- Food deliveries and repositioning food to reduce food waste
- Deliveries closer to home to enable more people to stay at home longer without needing assistance from the city.

ADR Capabilities in capabilities in urban environments: Hugo

Exploring Project Capabilities: Implementation, Rationale, and Workshop-Driven Developments

The on-site workshop held on September 21st was a pivotal moment that provided us with invaluable experiences. Initially, we anticipated challenges related to navigating around pedestrians and bicycles. However, the execution of what seemed like a simple task—ensuring the robot avoids collisions, stays on its designated path, and relies on its autonomous driving capabilities simultaneously—proved to be more complex than anticipated.

During the workshop, an unexpected issue surfaced: the impact of nearby Wi-Fi, mobile signals, and other electronic devices on the robot's connectivity. Remarkably, this challenge had not manifested itself in our previous tests leading up to the demo. Despite the multitude of tests conducted beforehand, the workshop shed light on aspects that had gone unnoticed or were not fully understood.

Post-workshop, we embarked on several noteworthy implementations aimed at enhancing our robot's capabilities. A significant addition was the installation of a lidar system. This cutting-edge technology plays a pivotal role by providing the robot with real-time surrounding information, constructing a dynamic picture of the environment for precise identification of obstacles and pedestrians.

The lidar system serves as a strategic upgrade, addressing the need for improved spatial awareness and obstacle detection. This not only fortifies the robot's navigational prowess but also elevates its overall operational efficiency. The integration of lidar technology aligns with our commitment to continuous improvement and innovation in our robotic systems.

In tandem with these efforts, our focus has persistently been on refining our waypoint follower system. This involves strategically positioning points on a map through a user-friendly web interface, allowing the robot to traverse designated points consistently and securely. The dynamic map we've crafted includes specific boundaries, restricting the robot from venturing into designated areas. These enhancements collectively contribute to fortifying the robot's operational safety within urban environments.

The implementation of the waypoint follower system is instrumental not only in ensuring a reliable and controlled navigation path but also in optimizing the efficiency of the robot's autonomous driving. Through judiciously plotting waypoints and defining no-go zones, our aim is to create an environment where the robot not only maneuvers safely but also adheres to predefined restrictions. This multifaceted approach not only enhances the overall safety of the robotic system in urban settings but also minimizes the data requirements for achieving a fully autonomous drive. Through this change, Hugo now align very well with MDS and how the standard assigns geofencing areas as part of the municipal policy on ADR.

Our commitment to these improvements reflects a strategic and holistic approach toward fostering both safety and efficiency in the deployment of our robotic technology. The integration of lidar technology and the refinement of the waypoint follower system are essential steps taken to address the challenges identified during the on-site workshop, ensuring that our robotic systems continue to evolve and adapt to real-world scenarios.

Unveiling the Project's Insights: ADR Capabilities in Urban Environments – Key Learning Outcomes

In the course of this project, it's essential to note that we have refrained from engaging with or incorporating ADR (Automatic Dependent Surveillance–Broadcast). Despite its potential relevance or applicability, we have deliberately chosen not to integrate ADR into our current initiatives. This strategic decision has been made based on our assessment of project requirements, technological considerations, and the specific objectives we aim to achieve.

While ADR may offer certain advantages in terms of surveillance and communication, we have opted for alternative approaches in order to align our project's development trajectory with specific goals and priorities. This deliberate exclusion doesn't discount the potential exploration of ADR in future phases, but it underscores our present focus on other avenues of innovation and technological integration. This nuanced decision-making process contributes to the comprehensive understanding of our project's strategic direction and the rationale behind technology selection.

Outcome: Autonomous Delivery Robot Pilot in Helsingborg

The literature review based on desk research (where a synthesis was presented in chapter 6) states the importance of the city, as the main beneficiary, to spearhead the scaling of ADR solutions. The literature also highlights the importance of careful selection of partners in the consortia for better results. Transloading points are also important in the sense that these add an extra node and therefore cost to the supply chain, so if possible, should be avoided. From the field test in Helsingborg, where the robot was demonstrated in a park, one learning outcome is that the competition of space for vehicles is especially prevalent in city centers and that test of new type of vehicles would benefit from being conducted in less populated areas such as suburbs and other residential areas just outside city centers. There are many examples where pilots do not succeed because the chosen test area does not adequately take into account the benefits as well as the drawbacks with robots. From a business model perspective, it is important that the proposal creates value for the customer/citizen/city. Based on these findings, we next present the proposal for a pilot study.

Robots for parcel deliveries the last (kilo)meter

Aurora CEO (USA Einride equivalent) on Netflix takes a longer socio-technical time perspective: (Netflix)

"A bunch of people drive cars a bunch of people drive trucks (vans), what happens to them? My expectation is that if you are a truck driver and you would like to drive a truck until you retire, then you will be able to do that. Because we have so much of a need for them. Um, but do I think you should probably go start becoming a truck driver today? Maybe not. There will be jobs that are going away. In the same way that there's way fewer saddle makers today than there was 100 years ago. But I think we will look back 50 years from now and say, that was a net win for safety. It was a huge win for efficiency. Accessibility. Those are values that matter in a company that aspires to transform something so important as transportation."

E-commerce offers the potential to enhance sustainability in freight transport, particularly for parcel delivery. Interestingly, an increase in truck movements can lead to a more sustainable transport system by extensively replacing private car trips. However, it's important to note that vans contribute significantly to emissions and vehicle kilometers, especially when compared to long-haul transportation, as shown in Figure 1 below.

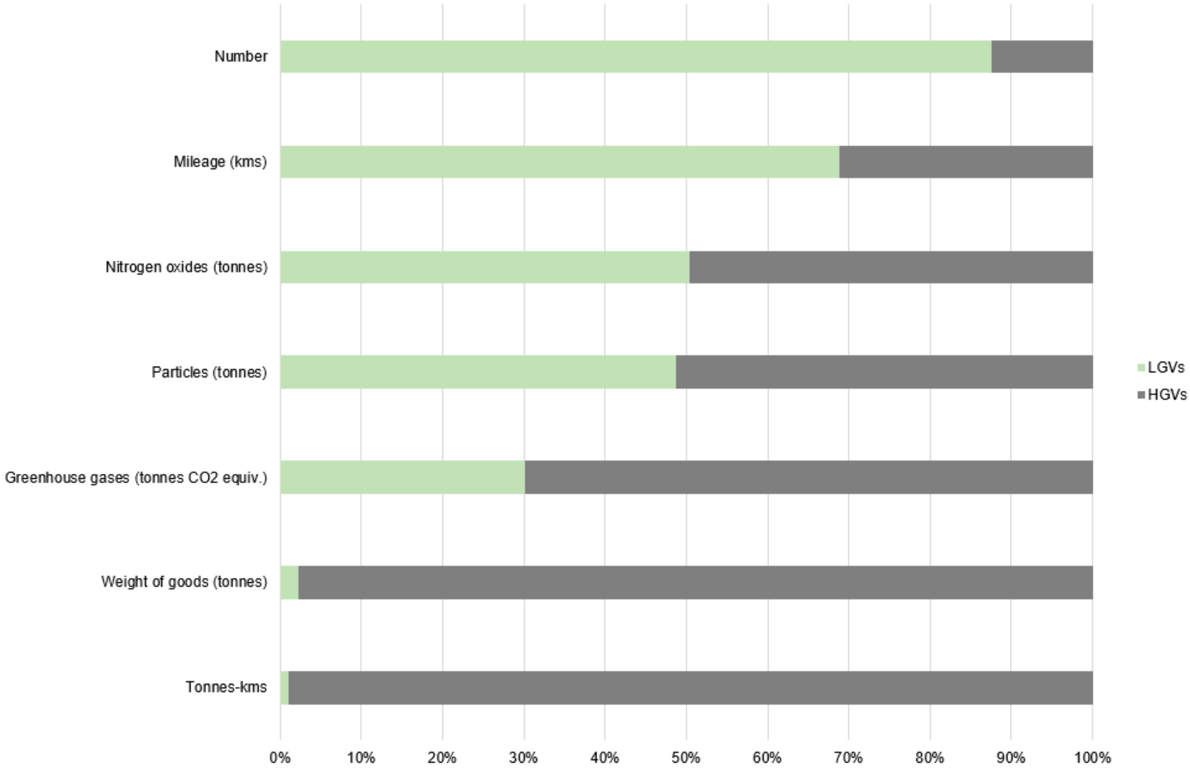


Figure 1- . Shares of light and heavy goods vehicles with respect to a range of variables. (https://www.trafa.se/en/road-traffic/light-goods-vehicles/)

Light goods vehicles, such as vans, carry relatively few kilos yet are responsible for a significant portion of emissions. In a recent study, the authority Trafikanalys examined the prevalence and traffic patterns of light trucks, defined as vehicles with a maximum total weight of 3.5 tons.

According to Trafikanalys, there are currently about 600,000 light goods vehicles in traffic, which is double the number from 20 years ago. These vehicles transport only 2 percent of all goods carried by road, while heavy trucks account for the remaining 98 percent.

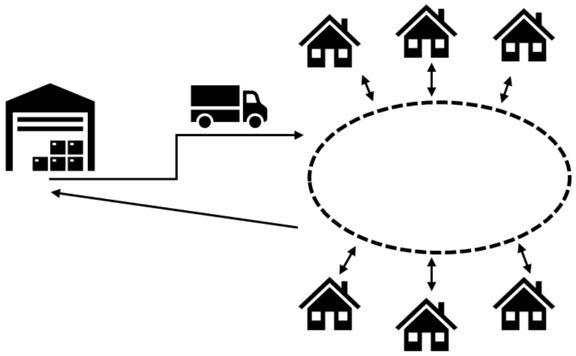
Predominantly operating in urban areas worldwide, these light vehicles may not be transporting substantial quantities of goods in terms of weight. This observation raises a question: could there be a potential for smaller vehicles in the last kilometer of delivery?

Pilot research question: What might a future system look like that leverages both the strengths and weaknesses of robots, and how could it seamlessly integrate into the existing distribution system? The overall goal of such a system would be reducing costs and environmental impact while enhancing the quality of urban living.

Current Parcel Distribution System

Figure 2 shows what today's system of "milk rounds" looks like, these are carried out all over the world millions of times every day, 30-40 stops are made.

Figure 2- Current parcel distribution system: the "milk round"



The primary factor affecting fill rate/utilization rate is not volume or weight, but rather a lack of time. Consequently, these vehicles are often not fully loaded. It's common to see dozens of vans entering each residential area daily. Beyond their environmental impact, these sizable vehicles often drive quickly in areas densely populated with children, leading to many serious traffic accidents involving goods vehicles.

To circumvent the chaos associated with electric scooters, as robots become more prevalent, it may therefore be worthwhile to focus on less crowded areas, like suburbs. In such settings, there is potential for utilizing street networks and deploying slightly larger robots. Additionally, it is important to mention that drivers spend 50 percent of their time per package outside the vehicle. This is particularly evident in the last stages of delivery, as shown by the double arrows in Figure 1, which represent the final meters.

Pilot suggestion: The Community Robot

We propose a novel idea involving "Community Robots" that help carry loads, as shown in Figure 3. These robots should ideally be trialed in residential areas instead of city centers. This approach avoids complications like traffic lights, stairs, elevators, and the chaos of electric scooters, especially as robots become more common.

The robots are designed to stay within a specific area, with battery replacements done daily by van drivers. While vans handle large deliveries, robots take care of smaller packages. As mentioned, drivers spend about 50% of their time per package on tasks like walking, ringing doorbells, and waiting. For instance, if each robot carries 10 packages, this could reduce the number of vans needed by two-thirds in a large-scale system. The details and calculations are outlined below.

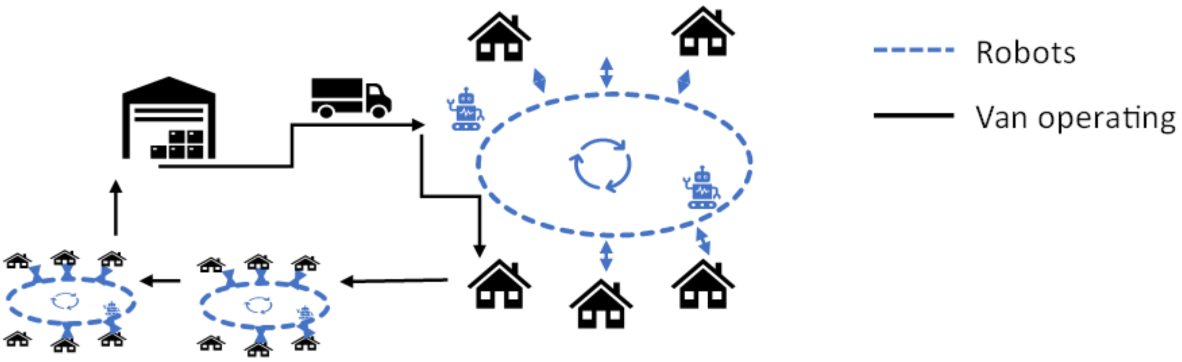


Figure 3 – A future parcel distribution system using community robots

This strategy offers logistical benefits similar to parcel lockers, where **larger vehicles deliver more parcels to fewer locations**. However, it eliminates the need for using significant space for these lockers. As well as unnecessary car trips to these lockers by customers. Suburban areas, often home to early adopters, are thus ideal for this system.

The process works like this: customers receive a text message when their package is nearby. They can choose to meet the robot or wait for it to arrive at their home. If a customer misses the delivery, they can locate the robot in the neighborhood using an app. If they miss the delivery window, typically 24 hours, they'll need to pick up their package from a local agent.

From a customer perspective, this system reduces congestion and emissions, and lowers costs. It's a flexible middle ground between home delivery and using parcel lockers. Plus, it doesn't require expensive robot arms for delivery cabinets. Public acceptance is likely to be high, especially in areas with many electric vehicles.

For operators, this means delivering more packages per vehicle and driver. The cost of the robots should be weighed against the increase in driver and vehicle efficiency. In the long run, this could mean fewer vans and less need for staff. How much would such a robot cost? 25000 SEK with increased production, life expectancy of 3 years with tire changes.

In the field of City logistics there is almost always someone who loses from new initiatives. We cannot think of any actor that loses from this except van manufacturers.

Impact calculation with assumption 10 parcel capacity per robot: Let us assume the driver can deliver 30 parcels, 30 stops. 1/3 is bulky, so 20 parcels into 2 robots, 10 parcels each. Makes for 12 stops (10 bulky and 2 robot), lets round down to 10 for simplicity. That means that the van can take 200 percent (10->30 stops) more packages (if not cubing and weighing out). Every van can do the work of 3 vans. 2/3 of vans are removed with the use of 2+2+2=6 robots in 3 communities.

Impact calculation with assumption 5 parcel capacity per robot: The driver can deliver 30 parcels, 30 stops. 1/3 is bulky, so 20 parcels into 4 robots. 5 parcels each. Makes for 14 stops lets round it up to 15 for simplicity. That means that the van can take 100 percent (15->30 stops) more packages (if not cubing and weighing out). Every van can do the work of 2 vans. ½ of vans are removed with the use of 4+4=8 robots in 2 communities.

A van has around 100 kWh capacity (Energy potential storage) whereas a robot of the size used today (rather small) has a capacity of 3 kWh. That means that if battery size is used as a proxy for emissions over the whole chain, up to 30 robots can be used instead of one van (100/3=33,3). **In our example we look at slightly bigger robots that can take 5-10 parcels and where 6-8 robots replace 1-2 vans. A pretty nice sustainability potential if the assumptions are correct.**

Table 4
ADR operation input parameters.

Input parameter	ADR 1	ADR 2	ADR 3	ADR 4	ADR 5	ADR 6
Volume capacity (m^3)	0.4	0.4	0.4	0.4	0.4	0.4
Expected stop time per delivery (min)	3	3	1.5	3	3	3
Powertrain efficiency	0.81	0.81	0.81	0.81	0.81	0.81
Vehicle mass (without battery) (ton)	0.23	0.23	0.23	0.23	0.23	0.23
Wheel/road friction coefficient	0.008	0.008	0.008	0.008	0.008	0.008
Air drag coefficient	0.65	0.65	0.65	0.65	0.65	0.65
Projected front surface (m^2)	1	1	1	1	1	1
Routing factor	0.7	0.7	0.7	0.7	0.7	0.7
Max. allowed speed (km/h)	25	25	25	10	25	25
Vehicle lifespan (km)	40,000	20,000	40,000	40,000	40,000	40,000
Battery mass (ton)	0.025	0.025	0.025	0.025	0.025	0.025
Battery capacity (kWh)	3.0	3.0	3.0	3	3	7.3
Battery cycle life (cycles)	2,000	2,000	2,000	2,000	2,000	714
Battery charging power (kW)	11	11	11	11	11	11
Electronics power (kW)	0.55	0.55	0.55	0.55	0.28	0.55

Lemardelé, C., Pinheiro Melo, S., Cerdas, F., Herrmann, C., & Estrada, M. (2023). Life-cycle analysis of last-mile parcel delivery using autonomous delivery robots. Transportation

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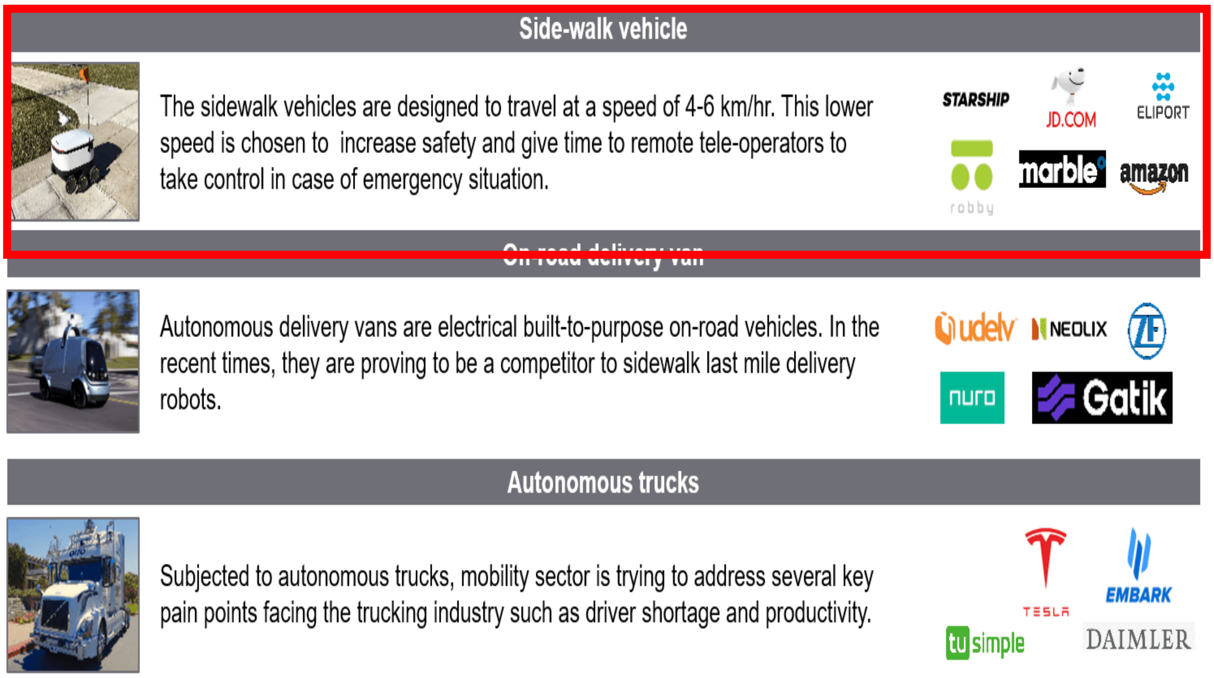

Dissemination and Publications

While the project has been a pre-study it's results and emergent findings will be presented at DriveSweden Forum and has also been disseminated in the following outlets

- ”Roboten Hugo lär sig hitta i Helsingborg”, Helsingborgs dagblad, 2023-10-23, https://www.hd.se/2023-10-21/roboten-hugo-lar-sig-hitta-i-helsingborg
- ” I framtiden kan robotar leverera mat och paket”, Lokaltidningen, 2023-11-11, https://etidning.lokaltidningen.se/p/helsingborg-sodra/2023-11-11/a/i-framtiden-kan-robotar-leverera-mat-och-paket/5053/1122361/44215007
- ”HelsingBotica prestudy”, IOT World, Barcelona, Spain, 2023-11-03

Appendix 1 Implemented Digital Policy for ADR

Requirement

- Geographical area (yellow marking - map)
- Speed max 5km/h
- Operating hours 08:30 – 11:00 and 13:00 – 16:00
- Operating days Mon,Tue,Wed,Thu,Fri

Appendix 2 ADR Projects/Trials

In the world of international autonomous robot testing, Starship Technologies has conducted extensive trials (Baker, 2022; Berthiaume, 2023; Bringuenti, 2023; Di Carlo, 2023; Grubhub, 2022; Westgarth, 2022) in collaboration with various entities since 2016, spanning 20 countries and 100 cities. While facing incidents of vandalism in the United States, their robots have contributed to cost-effective and secure deliveries, particularly during the COVID-19 pandemic. Moreover, data underscore the positive impact of these robots on environmental sustainability, reducing CO2 emissions, and enhancing overall last-mile deliveries for logistics companies.

Amazon's Scout the Robot, trialed in U.S. suburban areas from 2019 to 2022, aimed to improve delivery services for their customers (Patrao, 2022). Furthermore, Amazon collaborated with the World Institute on Disability to facilitate better delivery experiences for people with disabilities. Despite success in reducing emissions and congestion, Amazon scaled down the project due to limitations in fully meeting customer needs (Heater, 2022). DPD's collaboration with Cartken (developer of autonomous robots) in England since 2022 demonstrated positive outcomes in customer experience and cost-effective deliveries, albeit with the drawback of requiring recipients to be present which lowers the flexibility of a home delivery for the customer (Middleton, 2023; Mooney, 2023; Searles, 2022).

Robby Technologies (autonomous robot manufacturer), Doordash, Instacart, and Postmates (last-mile couriers) explored autonomous robot delivery from 2016, facing public skepticism and occasional vandalism (Bogue, 2019; Nichols, 2018). Beyond delivery, these robots were tested for providing directions, identifying risks for the robots from their surroundings, and data collection on infrastructure. Trials with autonomous robots in Knokke-Heist, Belgium, a collaboration with Carrefour (grocery store), Deliveroo (last-mile courier), and the municipalities, started in august 2023 (Pekic, 2023). Households close to the grocery store are offered free deliveries with the autonomous robots with the aim to investigate if large-scale usage is profitable. The city of Mechelen, Belgium, in collaboration with various private actors within the logistic and vehicle industries ran a project during 2016 to 2018 testing autonomous delivery robots in urban environments (VIL, 2023). The project found that the delivery robots can improve the efficiency of urban deliveries, offering more flexible route planning, a more environmentally sustainable delivery and increased traffic safety. Although the project highlighted the lack of sufficient infrastructure for the robots, both technological and physical.

In Punggol, Singapore autonomous robots have been utilized in the local shopping mall and households in urban areas since 2021. NTUC FairPrice (grocery store) and OTSAW (tech developer) have collaborated with the city of Punggol and the trials showcased positive results on customer experience and more efficient last-mile delivery, especially for the retail employees which could use the robots for heavy and bulky packages from storage (Chua, 2022; IMDA, 2021). Furthermore, it provided significant data identifying the specific areas within the urban infrastructure that necessitate improvements to facilitate the widespread implementation of autonomous robotic systems.

JD Logistics, one of China’s largest logistics services providers (JDL, 2023), partnered with AutoCore.ai, an open-source community for autonomous driving, in 2023 to develop and increase the utilization of autonomous delivery robots in their supply chain (Wang, 2023). JD Logistics has conducted trials and operationalized autonomous robots since 2016, deploying 600 autonomous vehicles in 30 cities throughout China. The findings indicate that the utilization of autonomous robots enhances the timeliness reliability of last-mile deliveries and augments flexibility for customers.

In Sweden, the HUGO robot has undergone trials in various projects. Between 2018 and 2019, Hugo Delivery, the manufacturer of the HUGO robot (HUGO, 2023), conducted exploratory initiatives in collaboration with Foodora, Coop, University of Borås, and Ericsson to assess the viability of employing autonomous robots in last-mile deliveries. Subsequently, a collaborative effort involving Postnord, Hugo Delivery, and Tele2 demonstrated societal acceptance during testing phases conducted in Stockholm, Borås, and Gothenburg spanning from 2018 to 2023 (Drive Sweden, 2022; Kjellsson, 2022; Tele2, 2023; Postnord, 2022).

Hugo Delivery expanded their trials further in August 2023 to the municipality of Lund, Sweden in collaboration with the School of Business, Economics and Law at the University of Gothenburg. This expansion aimed to investigate the economic, environmental, and social value that an autonomous delivery robot like HUGO could potentially offer to the citizens in the area (Future by Lund, 2023; Lund, 2023). Despite strong indications of favorable perceptions in Sweden (Ekman et al., 2023), autonomous delivery robots' possibilities to streamline last-mile delivery, and the environmental benefits (Kjellsson, 2022), hindrances to widespread implementation persist (Berge, 2023). These challenges include legal constraints, a lack of necessary physical and technological infrastructure. Moreover, there are a lack of financially feasible business models for a large-scale autonomous delivery system, with a need for policy changes to facilitate this (Williamsson, 2023).

Similarly, Foodora and Tele2's Doora the Droid, tested in central Stockholm in 2021, showcased that the infrastructure of the city was prepared for autonomous delivery robots and that the customers are receptive of this change (Foodora, 2021; Hultén, 2021; Movaheddin, 2021). At the same time, constraints connected to the ability to have access to adequate internet connection and legislation concerning autonomous robots were identified as the biggest hinders for facilitating large-scale usage. More specifically were the classification of autonomous delivery robots identified as an area where more in-depth analysis is needed.

Helsingborg municipality in partnership with Robot Minds AB and NSR AB (regional waste management company) are trialing autonomous robots for garbage collection (Helsingborg, 2023; Vinnova, 2023). The first part of the trails, started in August 2023, are done in a test environment with the expectation to upscale real conditions. The anticipated outcomes of the trial encompass data from sensors on the robots, enabling them to discern the optimal times for waste collection. The city of Helsingborg perceives the project as a way ensures better environment for the citizens of the city and to streamline the garbage collection system of the city. Additionally, the trial will extend to evaluating the applicability of the robots for diverse purposes, including deliveries within the school and welfare system.

In Helsinki, Finland projects and trials with autonomous delivery robots in urban environments have been ongoing since 2018, a partnership between public and private organizations within the logistics and vehicle industries. The New Solutions in City Logistics project, 2018 – 2020, with the aim to pilot autonomous robots delivering groceries in a shopping center in Helsinki to investigate the possibility to replace traditional logistics vehicles and lower the environmental strain from the logistic industry and make last-mile deliveries more efficient (Forum Virium Helsinki, 2020). The project had positive results, with positive reception from the customers and the chance of new business opportunities.

Further on, the LMAD (Last Mile Autonomous Delivery) projected was carried out in 2019-2022 in Helsinki and Paris, France (Forum Virium Helsinki, 2022). In Paris the autonomous delivery robots were trialed in an office setting at the Nokia Paris-Saclay Campus, delivering small parcels (LMAD, 2022). In Helsinki the robots are tested in both University and household areas, delivering smaller parcels and groceries alike (Jokiniemi, 2021). Investigating not only the possibility to lower environmental impacts, increase flexibility for the customers, and reducing logistics costs, but also collecting data for furthering the development of the robot and its interaction with its surroundings, both the city infrastructure and the people, and information related to the national legislation of autonomous delivery robots (Forum Virium Helsinki, 2022).

Helsinki continues with developing and testing autonomous delivery robots, a new project, URBANE (2022-2026), is scaling up the testing in several different densely populated city districts (URBANE, 2022). With the aim to reduce vehicle traffic, making the city socially and environmentally better, and to explore different logistics solutions to streamline last-mile delivery in urban areas. There will also be pilots in Bolonga, Italy; Valladolid, Spain; and Thessaloniki, Greece (Kultanen, 2023).

Regarding hospital logistics, Fragapane, G. et al. 2022 explored the applications of autonomous robots, emphasizing benefits such as timesaving for hospital staff, integration with other technical systems, and sterile transportation of tools. One of the biggest risks identified was the risk of harming patients' integrity, that the systems can be hacked and access to the video feed, or other sensitive information, of patients could land in non-authorized hands. NHS in the UK, along with Milton Keynes University Hospital and the Academy of Robotics, is testing autonomous robots to address staffing issues and streamline material retrieval since 2023 (Min, 2023).

In 2022, Skåne University Hospital in Malmö, Sweden started to utilize autonomous delivery robots in the hospital area to help deliver food, medicine, laundry, garbage, and post to the different wards from a service unit, acting as a logistics center (Region Skåne, 2023). As of fall 2023, all the delivery flows in the hospital are done by the 36 robots. One of the biggest challenges the hospital had to work on was that the hospital buildings are not built for autonomous robots and thus, adjustments were required, it has been important that the robots have had access to all areas of the hospital. The main advantage has been that the staff have had more time for patient care, and less running between different wards of the hospital (SR, 2023).

In the U. S., hospitals in Texas collaborated with Texas Health and Diligent Robotics to test Moxi robots (Moxi, 2023) for diverse deliveries and assess their role in healthcare (Kyrarini, 2021). Positive outcomes included increased staff focus on patient care and substantial task efficiency. Notably, Moxi robots, equipped with LED faces and arms, demonstrated social acceptance among patients and family members. The Mercy TUG robot, an autonomous robot, is being employed by Mercy Healthcare (health system that owns and manage 44 hospitals in USA) in St. Louis, USA (Mercy, 2023), to streamline various tasks within hospitals (Larimore, 2022). The TUGs can pick up and deliver patient meals, linens, medications, and other supplies, reducing the workload on human staff and allowing them to focus more on patient care. After a successful pilot program at Mercy Jefferson (hospital outside of St. Louis), the TUGs are being deployed at Mercy's largest hospital in St. Louis and will be gradually introduced to other Mercy hospitals throughout the year. The robots operate autonomously, navigating around obstacles and people, reacting to emergencies, and even using elevators to move within the hospital.

Commercial indoor spaces like hospitals and offices offer great potential for logistics robotics due to structured navigation and reliable communication infrastructure. However, existing solutions face challenges, such as costly installations and limited integration with corporate systems. The ENDORSE project (part of EUs Horizon 2020) aims to address these issues with autonomous delivery robots in hospital and commercial environments (Endorse, 2020). The goal is to provide efficient, adaptable, and cost-effective robotics solutions for diverse tasks within commercial spaces.

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Drive Sweden is one of the Swedish government's seventeen Strategic Innovation Programs (SIPs) and consist of partners from academia, industry and society. Together we address the challenges connected to the next generation mobility system for people and goods. The SIPs are funded by the Swedish Innovation Agency, Vinnova, the Swedish Research Council Formas and the Swedish Energy Agency. Drive Sweden is hosted by Lindholmen Science Park AB.

Published by – Daniel Rudmark, VTI