Report: Urban Mobility Startups For Livable Cities

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1 Introduction

Highly urbanized cities often face challenges such as high greenhouse gas emissions, increased pollution, and poor air quality, as well as a superficial sense of community and greater health issues among the residents. All of these concerns could be addressed with the implementation of the 15-minute city concept. It is an urban plan where each neighborhood offers access to its wide range of amenities within a 15-minute walk for all its residents.

The city of Eindhoven already greatly implements this concept. However, the remaining issue is the connection between such zones. To uphold the overall goal of sustainability that the 15-minute city notion introduces, we have to consider zero-emission mobility solutions. From the vast options of satisfactory modes of transport, such as electric bikes or cargo e-vans, our team decided to focus on the utilization of drones. They prove to have a lower environmental impact than most modes of transport, and only slightly higher energy consumption than cargo e-bikes, however also offering reduced human labor costs [1].

Drones are increasingly used for the distribution of various goods, ranging from groceries and consumer electronics to urgent documents and medicine, with our start-up specifically targeting the medical delivery sector. Access to medicine can be considered of great public interest, which makes its distribution have a high social impact. It is crucial that the medicine arrives on time, in an unscathed condition. Fast delivery, precision, lightweight payload, and minimal room for error make drones the ideal solution over traditional transport.

Our idea is not only unique, but even more importantly, it is feasible. Many medicines are lightweight and compact, fitting well within drone payload limits. Using air-zones for transportation eliminates the need for congestion avoidance implementations designed for ground traffic. Moreover, short charging times and autonomous routing make hourly dispatches possible. Last but not least, examples of successful deployment by other companies already exist [2].

In the following sections, we present the reader with a more detailed objective of our project, its business plan, the scientific rationale behind our design decisions, and the evaluation and validation of the obtained results.

2 Goal of the Project

With our start-up, we hope to contribute to the safe distribution of medicine while ensuring an entirely green approach by utilizing a zero-emission mode of transport. We strive to show how feasible it is to start implementing more sustainable solutions, which not only help to reduce the negative environmental impact but also generate positive revenue.

3 Methodology

In order to successfully develop the business and financial model of the pharmaceutical logistics system, both quantitative and qualitative sources were used. The average number of dispensations each day per pharmacy was provided with quantitative data by Stichting Farmaceutische Kengetallen, which is 341, and was critical in determining the requirement for daily deliveries [3]. AlleCijfers.nl offered demographic and geographical statistics, which enabled for an assessment of the city's population levels and needs [4]. Furthermore, Apotheek.nl's qualitative data helped to define the geographical distribution and contextual character of local pharmacies, which was useful for decision-making in terms of optimal delivery locations and practical deployment techniques [5]. The mixed-methods approach provides a balanced foundation for modeling logistical feasibility and system requirements.

We started the project's code development by extracting information about amenities in the city of Eindhoven, including their name, category, and exact geographical location. We obtained the data from the OpenStreetMap database, which uses a unique data model to represent geographic information that can be exported into different GIS (Geographic Information System) formats [6]. Afterwards, we were able to map the amenities onto the city's network and calculate precise walkable distances between them by using tools such as the OSMnx Python library and a custom Pandana network for faster spatial queries and computations. The results were subsequently input into an agglomerative clustering algorithm, through which the final clusters were successfully obtained. After deciding on the focus of our start-up, we chose the suitable zones for medicine distribution and simulated the deliveries. For the simulation, we first generated a request log for each pharmacy. The simulation then attempted to fulfill these requests while enforcing various constraints related to drone capabilities and the operational model of pharmacies. In essence, the program was implementing the Capacitated Vehicle Routing Problem (CVRP), which, with the use of tools such as Google OR-Tools, became feasible to solve. The results were used to assess the feasibility of our business concept. We generated the delivery schedule based on the previously computed routes, incorporating the battery limitations of a single drone. This approach successfully minimized the total time required to fulfill all requests and confirmed that a single drone could complete its deliveries within the pharmacies' operating hours.

The above description mainly outlines the general approach we adopted during our project. However, in the sections "Design Process and Scientific Investigation" and "Simulation Study", we go more in depth about the methods, tools, and sources used during the code development.

4 Business Plan

4.1 Business Canvas Model

4.1.1 Key Partnerships

Our drone-based logistics system within the pharmaceutical industry is based on the success of effective cross-sector partnerships. Salveo Pharma in central Eindhoven is a major medical provider, as well as a logistics center, which allows contacting our target pharmacies efficiently in such neighborhoods of Eindhoven as Vaartbroek, Nieuwe Erven and Vlokhoven. We would serve them closely as partners and pioneer users of their goods and this has enabled us to confirm planning of delivery, route efficiency and customer satisfaction. Technology wise, we operate with UAV suppliers /other suppliers and software developers, who give us the necessary critical systems in drone management, IoT and real time tracking. The Municipality of Eindhoven and other organizations, like EIT Urban Mobility and the MIT Innovation Subsidy (RVO), can provide guidance and even potential funding in the public sector in connection with the vision of a 15-minute city and sustainability in Eindhoven. These alliances, combined, define the support of the operations, regulatory compliance and scalability of the service in the long-term.

4.1.2 Key Activities

The drone-based pharmaceutical logistics system's key operations include the establishment of an efficient, dependable, and scalable delivery network to Eindhoven's community pharmacies. With a population of around 246,417 and a demand for more than 246 million Defined Daily Doses (DDDs) per year, pharmaceutical logistics necessitates the implementation of simplified and high frequency delivery systems throughout the city [4]. Salveo Pharma's model seeks to cover an initial service area of ten pharmacies out of 70 in the city, with each pharmacy receiving an average of 341 prescriptions every day [5]. That corresponds to a total daily volume of 3,410 prescriptions, or approximately 85.25 kilograms of medical payload per day, assuming an average unit weight of 25 grams by calculation.

To meet such demand, the delivery system is built so that each pharmacy receives three dispatches each week (Monday, Wednesday, and Friday), with each drone delivery containing a two-day prescription load (about 170.5 kg). A drone, the DJI FlyCart 30, with a cargo capacity of 30 kg, will require at least six trips per day of delivery. The operational activities include drone flight scheduling, real-time route optimization, monitoring, fleet maintenance, and payload batching. Other key infrastructure jobs include implementing and running intelligent charging infrastructure, secure mounting pads, and strong flight planning and pharmacy integration software.

4.1.3 Key Resources

A diverse set of physical, technological, and human resources is critical to the success of the drone-based healthcare logistics platform. These assets make it easier to transport pharmaceutical commodities between pharmacies and distribution facilities in a predictable and efficient manner while adhering to safety and regulatory guidelines.

The primary physical resources will be DJI FlyCart 30 drones, which will be chosen for their large carrying capacity, weather resilience, and operational range. Other ancillary facilities, such as charging stations, battery swapping facilities, and landing pads, are also required to ensure the smooth flow of activities and quick turnaround of drones.

A customized logistics platform will be required for route planning, fleet management, and delivery organization. This also includes pharmacy software, such as mobile or web-based apps for scheduling deliveries and tracking the status of those supplies in real time. It has automatic route optimization techniques, which help to improve efficiency and shorten delivery times.

The business will require a team of individuals with expertise in aviation logistics, software development, and regulatory compliance. They require professionals to fly drones, execute maintenance, and build and maintain software systems, as well as ensure compliance with aviation and pharmaceutical delivery regulations.

Finally, monetary assets are required to pay one-time capital expenses, such as drone procurement and digital infrastructure development. This funding will be provided through a combination of grants, sponsorships, and potential institutional partners.

In short, the platform's primary assets are its drone park, infrastructure, unique software, qualified technical team, and financial resources all of which are required to supply pharmacies with a stable, secure, and scalable logistical solution.

4.1.4 Value Propositions

The drone-based logistic system proposed transforms the old model of high-frequency, on-demand delivery, tailored to the needs of urban healthcare facilities. Through the avoidance of road congestion and reducing the lead time in delivery, the platform is essential to provide timely and safe access to the essential medication, which greatly affects clinical continuity, optimal inventory, and patient safety. It helps move temperature-controlled healthcare products with an optional cold chain service and ensures complete traceability via inline real-time tracking and IoT telemetry systems.

Besides the logistic performance, the platform also ensures a perceivable fixed-cost subscription model that enhances cost management and operational scheduling of the pharmacies. It has minimal carbon footprint and dependence on manual labor thus helping it to achieve long-term environmental sustainability and urban resilience. Moreover, the solution corresponds to the 15-minute city vision developed by the Municipality of Eindhoven and the zero-emission transport strategies, which will be implemented in the near future, therefore, making the service technologically feasible and politically acceptable. In this regard, the platform provides definite value in the essence of both efficiency, sustainability, and accessibility of healthcare.

4.1.5 Customer Relationship

The platform's customer connection approach attempts to foster trust, dependability, and commercial efficiency in its relationships with pharmacies. Given the urgency of medical logistics activities, the emphasis is on professional, service-oriented, and responsive relationships with client organizations.

The primary relationship arrangement is a subscription-based service model. This ensures ongoing connection with pharmacists due to projected service rates, personal services, and individual logistics. Client onboarding will be a methodical process that includes instructing clients on how to utilize the digital interface to schedule deliveries, track shipments, and manage preferences.

To assure service quality and high customer satisfaction rates, the platform will provide account assistance to pharmacy partners, including technical help, operational news, and performance statistics as needed. The automated system would incorporate feedback loops, allowing pharmacies to report service concerns or make suggestions for improvements.

The primary mode of communication will be digital and automated through the web and mobile interfaces, with human support available in the event of escalation or complex inquiries. This mixed model ensures scalability, dependability, and accountability while dealing with clients.

In general, the customer relationship model will be long-term, value-based, and efficiency-focused, with the goal of establishing the platform as a trusted logistical partner in the healthcare supply chain.

4.1.6 Channels

The platform delivers its value proposition to pharmacies through a combination of digital and operational channels, with the goal of achieving easy access, service reliability, and prompt communication.

The primary distribution channel is a specially designed digital interface that is accessible via a web platform and a mobile app. This interface will allow pharmacies to plan deliveries, observe drone locations in real time, confirm delivery, and access billing and support services. The digital platform is also a key tool for onboarding, training, and customer support.

Aside from the digital platform, direct sales and account management teams will serve as relationship facilitators, particularly during the early client acquisition and onboarding procedures. These employees will provide demonstrations, technical guidance, and personalized consultations to assist with the integration of the service into the pharmacy's everyday activities.

The operational delivery channel includes drone delivery infrastructure, such as real drones, launch stations, and drop-off locations at pharmacies. Such physical touchpoints are critical in providing the key service promise: dependable and timely medical logistics.

The key marketing and outreach channels will be B2B, industry events, healthcare logistics conferences, professional networks, and targeted digital marketing to drugstore chains and independent operators.

The mix of various channels ensures that service delivery runs well, that customers are interacted with, and that the logistics platform is accessible for an extended period of time.

4.1.7 Customer Segments

The main category of the customers will be the community pharmacies functioning within the urban areas and especially the one in the districts of Eindhoven like in Vaartbroek, Vlokhoven, and Nieuwe Erven. Such pharmacies experience growing pressure to have medication delivered to them on time and in a consistent manner while dealing with restricted storage space and a labor force. Some secondary segments venturing into last-mile logistics are medical clinics, veterinary practices, and healthcare distributors. Institutional clients like hospital networks and insurance providers would also be targeted on a long-term basis with increased services and procedural inclusion in the regional healthcare system.

4.1.8 Cost Structure

The long-term viability of the logistics platform in healthcare represented by drones will be determined by an equitable combination of both initial CapEx and ongoing OpEx. Taken together, these financial obligations form the structural basis that is necessary to guarantee safety, reliability and scalability of the system.

- **Capital Expenditure (CapEx):** Critical long-term assets of total investment of €100,970.20 that will facilitate the deployment of the logistics structure have been identified. The latter consists of two DJI FlyCart 30 drones (€39,470.20) due to their high payload and operational stability; four additional batteries (€4,000.00) to ensure continuous rotations; three intelligent charging stations (€39,000.00) to support efficient recharging circuits; exclusive drone launch pads (€1,500.00); remote tracking and connectivity system based on IoT (€7,500.00); and the custom cross-platform software for delivery scheduling (€9,500.00).

- **Operational Expenditure (OpEx):** It is estimated that the annual operational expense will total to €114,900, which includes the major elements necessary in continued service delivery. These involve operating costs of management of operations, technical assistance, and dispatch (€95,500); maintenance of digital infrastructure including maintenance of the API and software (€7,500); insurance of drones, cyber liability, and general operation (€4,500); marketing and customer relationship activities (€3,900), and cloud-hosting services (€3,500).

CapEx and OpEx structure combination finances a lean business with operations that are robust enough to make a successful launch. Such a solution will also be feasible in the short-term operation and scalable in the long-term, correlating with larger urban sustainability concepts, like a 15-minute city model.

4.1.9 Revenue Model

The revenue model of the platform operates through a combination of fixed-price subscriptions, variable pay-per-use charges, and optional premium services. The core stream is a flat-rate monthly subscription, which grants access to a defined number of drone deliveries and ensures predictable income. This model is designed to cover operational expenditures and facilitate the recovery of capital investments, particularly during the early deployment phase.

Additional income is generated through pay-per-delivery charges for pharmacies that exceed their monthly quota or operate without a subscription. These are distance-based, starting at €1.75 per kilometer per delivery, with an optional urgent delivery surcharge of €2.00.

The third revenue stream consists of premium add-on services, including cold chain handling (€1.00 per delivery), priority dispatch, and night-time deliveries. These are tailored to support the transport of temperature-sensitive or time-critical pharmaceutical goods.

- **Revenue projections for Year 1:**
  - Subscription Fees: €102,000
  - Pay-per-Delivery Charges: €12,000
  - Premium Add-ons: €6,000
  - External Funding: €30,000
- **Total Projected Revenue (Year 1): €150,000**

This multi-stream structure — blending fixed and variable income sources — ensures financial sustainability while enabling scalable growth.

4.2 Financial Model

4.2.1 Revenue Model

Source	Description	Revenue (€)
Monthly Subscriptions	€850/month × 10 pharmacies	102,000
Pay-per-Delivery Fees	€1.75 × extra deliveries	12,000
Premium Add-Ons	Cold chain, urgent/night delivery	6,000
	Total Estimated Revenue (Year 1)	**120,000**

Table 1: Estimated Revenue Streams

This table reflects a hybrid income model with a predictable base of monthly subscription fees, complemented by usage-based delivery charges and premium logistics services. The combined streams allow both financial stability and operational adaptability, especially important during scale-up.

4.2.2 External Funding – Year 1

Source	Type	Support (€)
MIT Innovation Subsidy (RVO)	National Public Grant	15,000
EIT Urban Mobility	EU Pilot Grant	5,000–7,500
Municipality of Eindhoven	Local Innovation Fund	2,500–5,000
Private Sponsorship	Corporate/Partner Support	5,000
	Total Estimated External Support	**20,000–30,000**

Table 2: Expected Non-Recurring External Support

This table outlines the primary sources of non-recurring financial support for Year 1. These external contributions are essential to fund initial setup, reduce burn rate, and support innovation-driven public-private partnerships aligned with Eindhoven's smart mobility goals.

4.2.3 Capital Expenditure

Category	Description	Cost (€)
Drones (2 × DJI FlyCart 30)	Delivery backbone	39,470.20
Battery System (4 units)	For daily drone rotations	4,000.00
Charging Stations (3)	Smart infrastructure	39,000.00
Landing Pads	Deployment pads for pharmacies	1,500.00
IoT Connectivity	Remote tracking and telemetry	7,500.00
Software Development	Routing & delivery app backend	9,500.00
	Total CapEx	**100,970.20**

Table 3: Initial Capital Investments

The capital expenditure table summarizes one-time investments in core delivery infrastructure, connectivity, and platform development. These fixed assets are essential to ensure operational reliability and scalability from day one.

4.2.4 Operational Expenditure – Year 1

Category	Description	Cost (€)
Personnel	Ops Manager, Support, Dispatcher	95,500
Tech & Infra Maintenance	Cloud, API, digital platform upkeep	7,500
Marketing & CRM	Onboarding, pharmacy campaigns	3,900
Insurance	Drone, liability, cyber-risk	4,500
Cloud Hosting	AWS/GCP services	3,500
	Total OpEx	**114,900**

Table 4: Yearly Operational Costs

Operating expenditures reflect the ongoing costs of maintaining the platform. The emphasis is on human resources and technical reliability, with modest spending on outreach and risk protection. These costs are lean but sufficient to ensure a high-quality service rollout.

4.2.5 Cash Flow Forecast

The table below presents a 3-year cash flow forecast. It assumes a 15% annual increase in revenue due to increased adoption, while operating expenses remain fixed at €114,900 per year. Taxes, depreciation, and financing are excluded to focus on pure operating performance. The initial capital expenditure of €100,970 is treated as a Year 0 outflow.

Year	Revenue (€)	OpEx (€)	Net Cash Flow (€)
0	—	—	−100,970
1	120,000	114,900	5,100
2	138,000	114,900	23,100
3	158,700	114,900	43,800

Table 5: Cash Flow Forecast for 3-Year Rollout

This forecast illustrates the startup's ability to generate positive net cash flows as revenue grows year over year, providing financial sustainability even in the early stages of scale-up.

4.2.6 SWOT Analysis

Strengths	**Weaknesses**
• Proven drone model in medical delivery • Predictable revenue via subscriptions	• High setup and compliance costs • Reliance on early pharmacy adoption
Opportunities	**Threats**
• Public-private funding mix lowers capital risk • Urban health funding in Eindhoven • Scalable to other Dutch cities with similar infrastructure • First mover advantage in EU medical drone logistics	• Limited delivery range under EU drone regulations • Delays in ILT/SORA regulatory approvals • Public resistance due to privacy, safety, or noise concerns • Risk of technology malfunction or cybersecurity breaches

Table 6: SWOT Analysis of the Drone-Based Logistics Model

5 Design Process and Scientific Investigation

5.1 Data Collection and Organization

5.1.1 Eindhoven Borders Definition

All the data used in this project were limited to the administrative borders of Eindhoven, depicted below. The border definition was taken from the OpenStreetMap source [7].

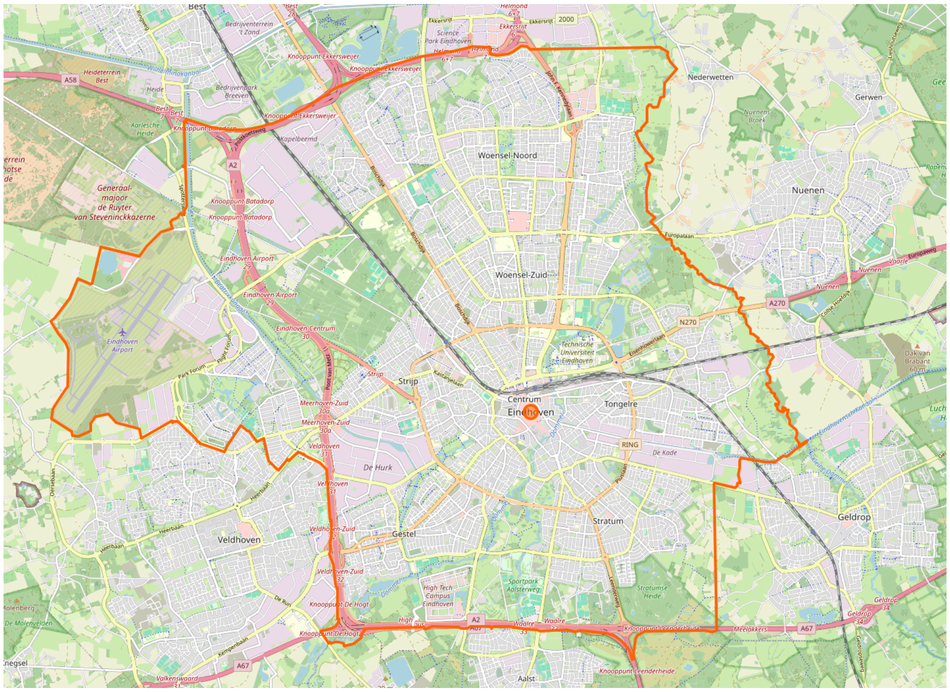

Figure 1: Administrative borders of Eindhoven.

5.1.2 Defining POIs

Throughout the report, we often refer to the so-called POIs. It is an acronym from Points Of Interest, in our case, these being the amenities located within the administrative borders of Eindhoven. We downloaded the amenities' data from the OpenStreetMap extract for the city of Eindhoven [8]. OpenStreetMap is a free and openly licensed map database maintained collaboratively by volunteers. It has its own data model for storing geographic information, which can be exported to various GIS (Geographic Information Systems) formats [6].

After having downloaded raw amenities' data, we used the tool OsmPoisPbf, which scans an OSM file to identify nodes, areas, and relations that are tagged as our POIs and exports them into a CSV file [9]. By default, it determines POIs based on tag combinations listed in the OSM Wiki Map Features, but it is also possible to supply a custom filter file to define the criteria. That is how data concerning only the following amenities (POIs) was extracted:

Table 7: Tags used by category in the dataset

Category	Tags
amenity	school, childcare, child_care, kindergarten, university, college, clinic, dentist, doctors, hospital, pharmacy, nursing_home, social_facility, veterinary, social_centre, community_centre, fountain, public_bookcase, library, townhall, cafe, restaurant, fast_food, food_court, pub, ice_cream, baking_oven, biergarten, bar, casino, nightclub, cinema, theatre, events_venue, arts_centre, fitness_centre, fitness_station, garden, park, playground, sports_centre, swimming_pool, gym, bicycle_rental, bus_station, car_sharing, bank, marketplace, place_of_worship
leisure	amusement_arcade, dance, dog_park, fitness_centre, fitness_station, garden, park, pitch, playground, sports_centre, swimming_area, swimming_pool, track
public_transport	stop_position, platform, station
railway	subway_entrance, tram_stop
landuse	allotments

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Category	Tags
office	coworking
shop	bakery, butcher, cheese, convenience, deli, dairy, farm, frozen_food, greengrocer, health_food, ice_cream, pasta, seafood, spices, supermarket, wholesale

The resulting data was saved in a CSV file *Eindhoven.csv* that contains the following columns:

poi_type_id Numeric code representing the amenity type according to OpenStreetMap (OSM).

amenity_id Unique identifier for the specific amenity.

lat Latitude coordinate of the amenity.

lon Longitude coordinate of the amenity.

name Name of the amenity.

amenity Descriptive type of the amenity corresponding to the `poi_type_id`.

Based on this file, a DataFrame resembling this data was created and further organized, such that each amenity was assigned one of the following seven categories: education, health and wellbeing, community space, food choice, nightlife, active living, and mobility.

	poi_type_id	amenity_id	lat	lon	name	amenity	category
0	10.0	CUSTOM	51.444199	5.473112	Salveo Pharma B.V., Medical Warehouse	pharmacy	health_wellbeing
1	64.0	N42452978	51.356153	5.305949	Kortkruisdijk,	platform	mobility
2	63.0	N42459812	51.359544	5.304001	Eersel, Postelseweg	stop_position	mobility
3	63.0	N42461335	51.359943	5.322896	Eersel, Monsigneur de Haasstraat	stop_position	mobility
4	63.0	N42464939	51.361349	5.466640	Valkenswaard, Merendreef	stop_position	mobility

Figure 2: Extract of POIs DataFrame.

The OSM extract for Eindhoven city contains data of a bounding-box-based region, hence it is not precisely aligned with the administrative borders and might include some information about amenities outside our project area. Thus, we had to further filter this data. We used the OSMnx[1] Python library to convert Eindhoven city into geographic coordinates and retrieve its official administrative borders as a polygon. We then refined the data to retain only those POIs located within this polygon, ensuring greater accuracy and geographic consistency.

	poi_type_id	amenity_id	lat	lon	name	amenity	category	geometry
0	10.0	CUSTOM	51.444199	5.473112	Salveo Pharma B.V., Medical Warehouse	pharmacy	health_wellbeing	POINT (5.47311 51.4442)
28	20.0	N36723712	51.447810	5.487505	Bibliotheek TU/e,	library	community_space	POINT (5.4875 51.44781)
51	64.0	N25294742	51.445874	5.492298	TU/e ingang De Wielen,	platform	mobility	POINT (5.4923 51.44587)
65	64.0	N31493215	51.482846	5.450862	Artoislaan,	platform	mobility	POINT (5.45086 51.48285)
66	64.0	N32575094	51.490576	5.451601	Castiliëlaan,	platform	mobility	POINT (5.4516 51.49058)

Figure 3: Extract of POIs within Eindhoven administrative borders.

[1] OSMnx is a Python library that allows for easy downloading, modeling, and analyzing street networks and geospatial data from OSM.

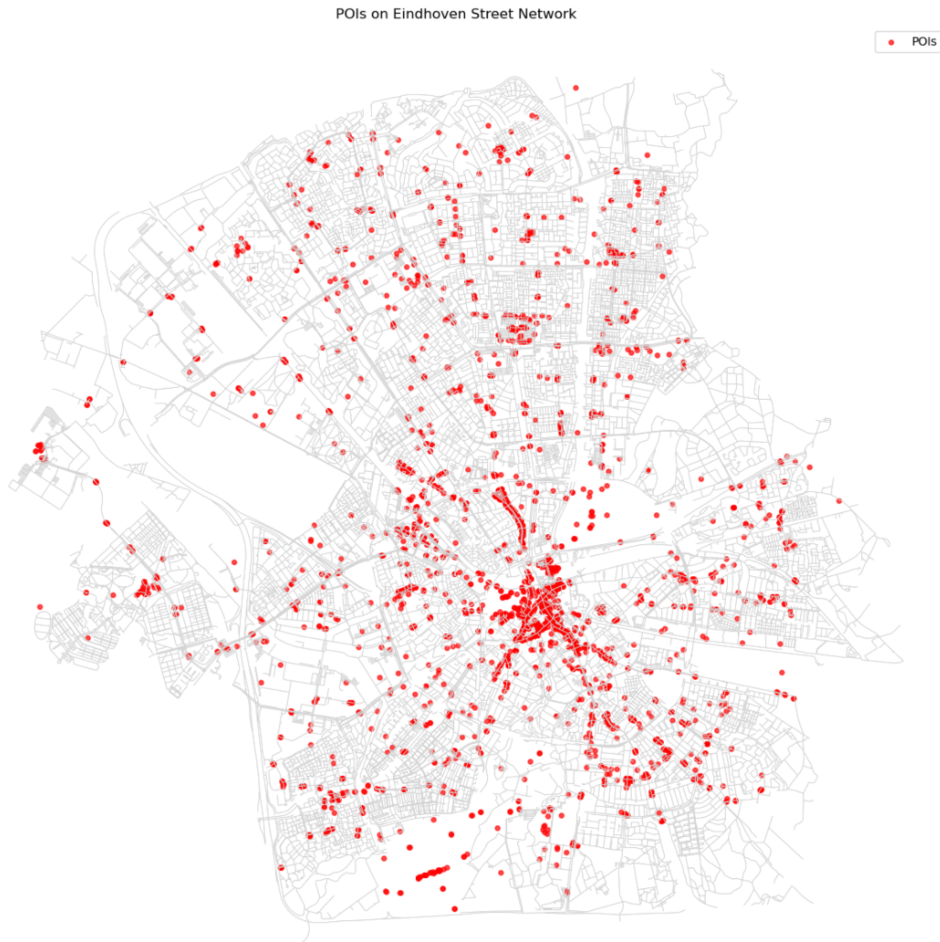

Figure 4: Visualization of the spatial distribution of points of interest (POIs).

5.1.3 Walkable Eindhoven Network

To visualize the distribution of the amenities and compute the walking distances between them, we first had to create a walkable network of the city. To ensure accuracy, we explicitly defined the network using nodes and edges extracted from a directed graph of Eindhoven generated with OSMnx. In this graph, nodes represent intersections or dead ends, and edges represent walkable paths. We then used these to construct a custom Pandana[2] network, which enables significantly faster spatial queries and computations than when using OSMnx alone.

5.1.4 Mapping Amenities Onto the Network

The distances between amenities are calculated using the walkable network. Since the network is based on nodes and paths between them, not the amenities themselves, each amenity had to be associated with its closest node (`node_ids`). Then, the actual distances were calculated between the nodes. The assignment procedure was done with the `get_node_ids()` methods of the Pandana network.

5.2 Clustering

To calculate the clusters representing the 15-minute neighborhoods, we used the agglomerative clustering method. It is a method performing a hierarchical clustering using a bottom-up approach: each point starts as its own cluster, and then clusters are successively merged together based on the

[2]Pandana is a Python library used for fast accessibility and routing analysis on large-scale transportation networks, particularly for walkability or travel time computations.

Figure 5: Pandana network of Eindhoven.

	poi_type_id	amenity_id	lat	lon	name	amenity	category	geometry	node_ids
0	10.0	CUSTOM	51.444199	5.473112	Salveo Pharma B.V., Medical Warehouse	pharmacy	health_wellbeing	POINT (671863.183 5702124.732)	11829067224
28	20.0	N36723712	51.447810	5.487505	Bibliotheek TU/e,	library	community_space	POINT (672849.575 5702560.144)	9999910010
51	64.0	N25294742	51.445874	5.492298	TU/e ingang De Wielen,	platform	mobility	POINT (673189.921 5702356.229)	9999909965
65	64.0	N31493215	51.482846	5.450862	Artoislaan,	platform	mobility	POINT (670173.277 5706369.94)	42751474
66	64.0	N32575094	51.490576	5.451601	Castiliëlaan,	platform	mobility	POINT (670195.781 5707231.148)	5504169717

Figure 6: DataFrame extract of POI-node assignment.

maximum (complete linkage) distance between their members. In our case, we are clustering network nodes together such that any further merging would result in a cluster with nodes more than 1500 meters apart. So, we set the maximum inter-cluster distance of 1500 meters, which approximates to a 15-minute walk. By the end of clustering, each node is assigned a cluster.

	node_ids	y	x	cluster
3	42642687	5.702180e+06	672279.974097	1
29	25547663	5.703035e+06	674554.623329	49
106	42580601	5.699474e+06	673349.091498	12
121	42580621	5.699479e+06	673441.983902	12
167	3882669677	5.699818e+06	673695.593141	12

Figure 7: DataFrame extract of node-cluster assignment.

Now, the POIs that are associated with a certain node get assigned to the cluster to which that node belongs.

	poi_type_id	amenity_id	lat	lon	name	amenity	category	geometry	node_ids	cluster
0	10.0	CUSTOM	51.444199	5.473112	Salveo Pharma B.V., Medical Warehouse	pharmacy	health_wellbeing	POINT (671863.183 5702124.732)	11829067224	31
1	20.0	N36723712	51.447810	5.487505	Bibliotheek TU/e,	library	community_space	POINT (672849.575 5702560.144)	9999910010	31
2	64.0	N25294742	51.445874	5.492298	TU/e ingang De Wielen,	platform	mobility	POINT (673189.921 5702356.229)	9999909965	22
3	64.0	N31493215	51.482846	5.450862	Artoislaan,	platform	mobility	POINT (670173.277 5706369.94)	42751474	15
4	64.0	N32575094	51.490576	5.451601	Castiliëlaan,	platform	mobility	POINT (670195.781 5707231.148)	5504169717	15

Figure 8: DataFrame extract of POI-cluster assignment.

Then, we calculate how many different categories of amenities each cluster contains, and we select those that have access to 6 or more. These clusters represent the existing 15-minute walkable neighborhoods or areas with a strong potential to develop into them.

After we created the clusters, we needed a way to name each cluster and connect them to an area in Eindhoven. The difficulty with this was that clusters did not necessarily follow strict administrative boundaries and were often spread across multiple neighborhoods. We used Google Maps as a tool to see which region the majority of POIs in a cluster were within, and used that neighborhood as the title of the cluster.

Table 8: Mapping of Cluster Numbers to Neighborhood Names

ID	Name	ID	Name
0	Irisbuurt	1	Centrum
3	Woensel Zuid	4	Vaartbroek
8	Evoluon	9	Putten
10	Strijp S	12	Nieuw Erven
13	Vlokhoven	15	Achtse Barrier
16	Gestel	17	Doornakkers
18	Limbeek	19	Schouwbroek
20	Tuindorp	21	Meerrijk
23	Eckart	25	Genderdal
28	Gijzenrooi	31	TU/E + North Centrum
33	Tempel	46	Rochusbuurt
49	t' Hofke		

5.3 Final Blueprint

With our map of all 15-minute neighborhoods in Eindhoven, we had to narrow down our focus to select a few clusters. In our search for the best-suited areas to focus on, there were a few criteria we were looking for in particular.

- One central area from which our start-up would provide logistics to the surrounding areas.
- Areas with a good availability of pharmacies or clinics.
- Demographics tending more toward elderly.
- One cluster containing a medical warehouse or distribution center, to be used as the central transport point.

With these priorities highlighted, the chosen neighborhoods were finalised as: TU/E + North Centrum, Vaartbroek, Vlokhoven and Nieuwe Erven. As for our justifications for selecting these clusters, the Centrum was chosen because it contains the company Salveo Pharma, which was found

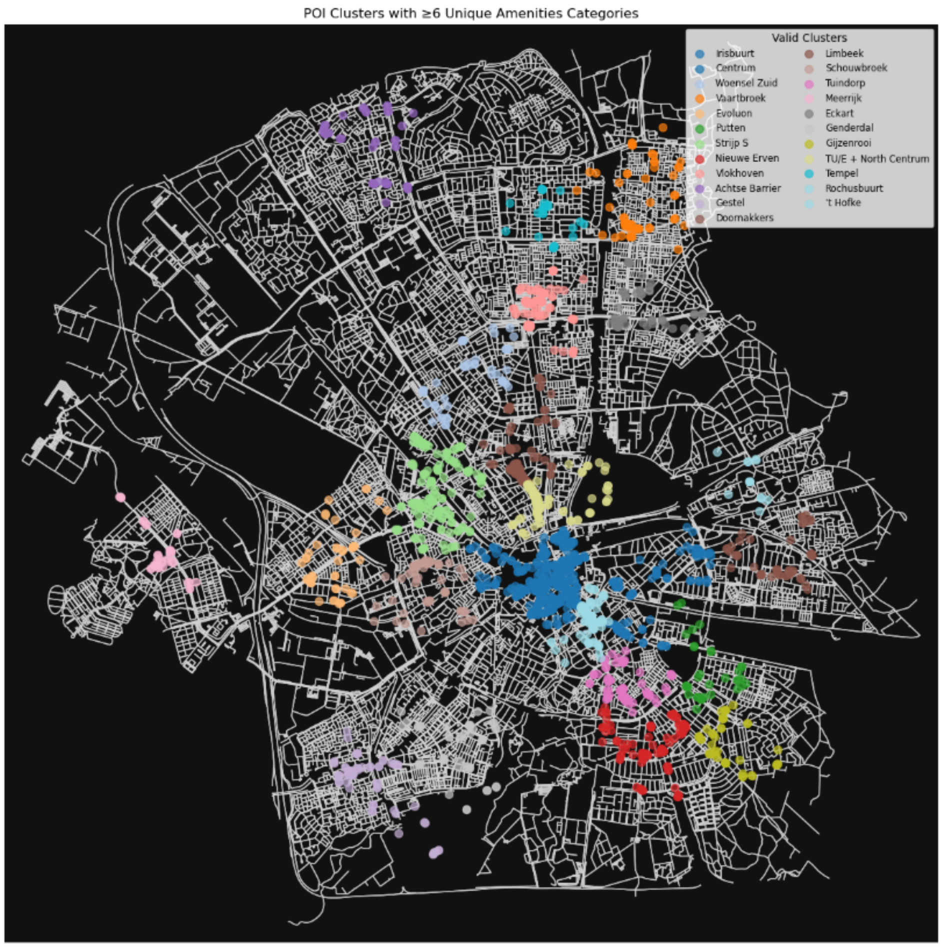

Figure 9: 15-minute zones in the city of Eindhoven.

during our research and distributes medical products, making it a perfect fit for our logistics business. Vaartbroek and Vlokhoven are in the north of Eindhoven, within the Woensel district. They were chosen due to their numbers of available pharmacies for the business to work with, as well as consisting of a more elderly demographic, which is the type of people we would be targeting with our business model. The other location Nieuwe Erven is in the south of Eindhoven, which was chosen to create a good spread of covered regions across Eindhoven. It also has a good availability of pharmacies for us to work with.

5.4 Drone Utilization

5.4.1 City's Regulations

Placing the focus of our project on the city of Eindhoven, except for being guided by the overall goal of sustainability, we also had to ensure to adhere to any external policies imposed by the city. Our research revealed the zero-emission zone regulation in the city's inner ring, which has now been in effect since 2025 [10] (with an exception for trucks for which the regulation got postponed until 2028 [11]). Having already entered the project with an objective of utilizing zero-emission transport, we do not need to modify our approach. However, the policy itself acts as an external motivation for us.

5.4.2 Different Modes of Transportation

Before choosing a sustainable transport mode for our logistics start-up, it was important to research existing options and cases of their implementation in Eindhoven. We have looked into past attempts at zero-emission transport, including the Phileas Bus Rapid Transit system [12] (an electric, magneti-

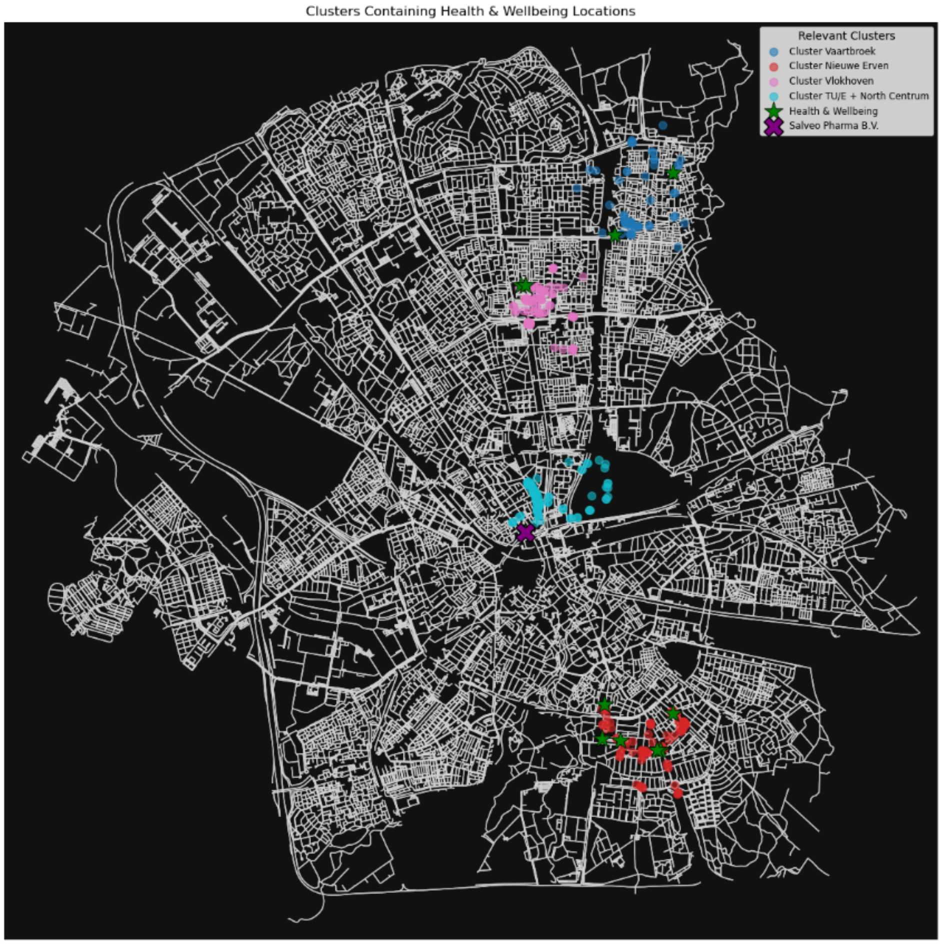

Figure 10: Final Blueprint of Eindhoven.

cally guided transport project) to understand where they were lacking. Moreover, we researched new sustainable modes of transportation such as: electric buses used by Hermes [13], electric cargo vans used by logistics companies such as DPD [14], and the upcoming infrastructure of assembling electric trucks fronted by DAF [15].

When comparing drones with other types of delivery vehicles, we found that they have one of the lowest energy consumptions and carbon emissions, which are only slightly higher than e-cargo bikes [1]. For example, according to Stolaroff et al. (2018) [16], the delivery of a small (0.5 kg) package with a small quadrotor drone has 54% lower greenhouse gas emissions than a diesel truck in California and 23% lower in Missouri. Although for larger drones to have a lower impact, they need to be charged with low-carbon electricity. Nevertheless, drones have other advantages that make them more appealing, these are:

- Ability to bypass road traffic, meaning faster deliveries. According to a case study in Rouen, France, [17] drone delivery of biomedical samples would take approximately 15 min, almost a third of 42 min estimated for e-vans.
- Option of on-demand delivery.
- Being cheaper than most other modes of transport. According to the same study, the cost per delivery for drones is estimated at EUR 1.92, while for e-vans it is at EUR 4.59.
- Reducing human labor.

5.4.3 Drones & Pharmaceutics

When looking specifically at the pharmaceutical logistics sector, we saw more promising applications of delivery drones. According to the "EGNSS4RPAS PROJECT" [18] biomedical samples delivery with UAVs is at least 20% faster and almost 70% cheaper than with e-van under normal traffic conditions.

Additionally, cargo drones have already been utilized in case studies to deliver pharmaceuticals to hospitals [19]. This study identified current technological and regulatory challenges, but also stated that especially the healthcare logistics sector could benefit from a drone delivery service, mentioning the benefit of increased hospital efficiency. In time-critical environments, like the medical sector, higher speed and lower price of delivery are essential. Therefore, drone deliveries would be advantageous for such an application.

5.4.4 Drones Requirements

For the successful implementation of a drone delivery service, several requirements must be met. Firstly, legal requirements regarding civil aviation regulations and air zone drone usage must be addressed. Eindhoven is situated within a Controlled Traffic Region (CTR) due to its proximity to Eindhoven Airport and nearby military airbases like Volkel and De Peel, which means drone flights are prohibited in the Open Category (A1, A2, A3). Flights are only permitted if the operator has obtained an exemption and explicit permission from air traffic control [20]. This requires a Specific Category, which can be assigned by applying for an operating permit (Operational Authorization - OA). In the Netherlands, we can apply for this permit at the Human Environment and Transport Inspectorate (ILT) [21]. This involves submitting a specific Operations Risk Assessment (SORA) detailing the safety measures and risk mitigation strategies for our drone operations [22]. Close coordination with air traffic control is also required, which involves obtaining clearance from the tower controller, submitting a detailed flight plan in advance, and maintaining two-way radio communication (RTF) throughout the operation [23]. Since medicine distribution can be considered an activity of significant public interest, we may consider applying for the establishment of a Temporary Restricted Area (TGB) for Beyond Visual Line of Sight (BVLOS) operations. Applications should be submitted to LIT with a lead time of at least 16 weeks. It could benefit us with a reduced airspace conflict, more operational flexibility, favorable consideration by LIT due to public interest justification, and simplified recurring operations [24].

Additionally, requirements for drone specifications and parcel security must be met. The drones must support a payload capacity of up to 20 kg, with sufficient range and battery endurance to complete round trips reliably. High levels of navigation and autonomy are essential for efficient travel. This means including features such as automated flight paths and route optimization. Furthermore, to ensure the integrity of sensitive or fragile cargo, like biomedical samples or pharmaceuticals, temperature control and secure, tamper-evident, and shock/vibration resistant packaging are required. Finally, supporting infrastructure—such as landing pads and charging stations—must be established.

5.4.5 Types of Drones

Having identified drone delivery service as our desired transport mode for the logistics start-up, as well as its requirements, we then researched existing cargo drone models to find the most suitable option. Initially, 3 models were selected: DJI FlyCart 30, Wingcopter 198, and DJI Matrice 300. We then looked at the relevant specifications of each model.

- DJI FlyCart 30 [25]:
  - Hovering endurance, max weight, max battery capacity:
  - 18 mins (30 kg weight load, dual battery mode)
  - 8 mins (40 kg weight load, single battery mode)
  - Max flight distance, max weight, with max battery capacity:
  - 16 km (30 kg weight load, dual battery mode)
  - 8 km (40 kg weight load, single battery mode)
  - Max wind speed resistance – 12m/s

- Wingcopter 198 [26]:
  - Max range, with max payload - 75 km
  - Max speed – 14 m/s in multicopter mode, 40 m/s in fixed-wing mode
  - Payload – 4.7 kg
  - 15 m/s resistance against average wind
  - 20 m/s resistance against gusts
- DJI Matrice 300 [27]:
  - Max payload – 930 g
  - Max wind resistance – 12 m/s
  - Max flight time – 55 mins

Based on these specifications, we came to the conclusion that the DJI FlyCart 30 is the most suitable model for our delivery service, due to its capability to carry heavier payloads.

6 Simulation Study

To effectively evaluate the feasibility of our drone-based medicine distribution system, we developed a simulation that integrates main aspects of the business plan and operational constraints. This includes pharmacy demand, drone capabilities, and delivery scheduling. Below, we outline the logic behind these assumptions and the methods used, particularly the implementation of the Capacitated Vehicle Routing Problem (CVRP) using Google OR-Tools to optimize the delivery process while minimizing costs and ensuring time restriction conformance [28].

6.1 Key Variables

Throughout the simulation, we had to ensure that all used variables and constraints align well with the business plan, in order to ultimately validate or reject it. Based on the initial calculations included in the business plan, we know that:

- The average community pharmacy dispenses about 341 prescriptions per day. We assumed that the same number of medicines would need to be restocked.
- Average prescription weights 25g per unit.
- Our project concerns 10 pharmacies in the city of Eindhoven.

Having in mind the above results, we decided to shift the focus of the simulation from dynamic deliveries that handle requests as soon as they are ordered to a more structured approach, where the requests would accumulate over two days and then be delivered throughout one day. The deliveries would be carried out on Monday, Wednesday, and Friday (with Monday delivery having to cover only one day's demand, since the pharmacies are closed during the weekend).

It is crucial for our business that we establish a reliable delivery model. It needs to include the number of utilized drones, their specification, a precise delivery schedule, and define the designated routes for each drone. Moreover, it should be able to handle any medicine demand fluctuations. In essence, the simulation truly comes down to the famous Vehicle Routing Problem (VRP) [29]. VRP tries to compute an optimal routing schedule to visit specified locations with a limited number of vehicles, while optimizing the total covered distance. On top of that, we add the drones' capacity constraint and arrive at the Capacitated Vehicle Routing Problem (CVRP). We can further develop CVRP by imposing the condition of the maximum time the deliveries can take, to ensure they happen when the pharmacies operate between 8:30 AM and 6:00 PM. Moreover, for our business, limiting unnecessary costs is highly important. Hence, while optimizing the covered distance, we also want to minimize the number of vehicles (drones) used.

6.1.1 Request Log

As we have assumed above, each pharmacy requests approximately 341 prescription medicines per day. That is 682 medicines over the span of two days. In the simulation, we allowed each pharmacy to order up to 750 prescriptions, accounting for a safety margin of 68 units. Orders are not submitted all at once by each pharmacy; instead, they accumulate gradually over a two-day period to better reflect realistic demand patterns. Each filed request can be for medicines with the quantity ranging from 10 up to the remaining available stock (750 minus the total already ordered). This approach introduces a randomness factor contributing to the realism. Once all pharmacies reached their limit, the orders are grouped by the pharmacy and summed up to reveal the final 2-day demand request log.

Since we define the drone's capacity in weight units, in the generated request log, we convert the number of requested medicines to their total weight (25g per unit).

Table 9: Pharmacy Medicine Requests

Pharmacy	**Request [g]**
Apotheek SGE Woensel	18 975
Apotheek Lingmont	18 800
Dierenartsenpraktijk Heesterakker	18 950
Medisch Centrum Aalsterweg	18 950
Dental Clinics	18 975
Apotheek Arnouts	18 750
SGE Woensel	18 825
Apotheek de Roosten	18 750
Tandartsenpost	18 850
Tandartspraktijk van de Vondervoort	18 750

6.1.2 Distance Matrix

During the route calculation, it is crucial that the simulation considers all potential locations. It can only choose the most optimal one by being able to compare distances between different nodes. To allow the simulation to do so, we precompute a so-called distance matrix. Each row and column intersection describes the distance from the row's location to the column's location. Naturally, it is symmetric. All the distances are provided in meters.

Table 10: Distance Matrix Between Pharmacies and Salveo Pharma [m]

	Salveo	A. SGE Woensel	Lingmont	Heesterakker	Aalsterweg	Dental Clinics	Arnouts	SGE Woensel	de Roosten	Tandartsenpost	Vondervoort
Salveo	0	2984	3747	4694	2660	3088	2816	2979	3069	2291	2761
A. SGE Woensel	2984	0	1282	2285	5565	5855	5484	52	5844	5166	5626
Lingmont	3747	1282	0	1033	6088	6240	5820	1239	6237	5676	6105
Heesterakker	4694	2285	1033	0	6894	6971	6531	2246	6972	6482	6888
Aalsterweg	2660	5565	6088	6894	0	718	907	5553	681	412	220
Dental Clinics	3088	5855	6240	6971	718	0	462	5837	386	866	499
Arnouts	2816	5484	5820	6531	907	462	0	5463	475	830	713
SGE Woensel	2979	52	1239	2246	5553	5837	5463	0	5826	5153	5611
de Roosten	3069	5844	6237	6972	681	386	475	5826	0	837	463
Tandartsenpost	2291	5166	5676	6482	412	866	830	5153	837	0	470
Vondervoort	2761	5626	6105	6888	220	499	713	5611	463	470	0

6.1.3 Constraints Summary

Below, we give a summary of the considered constraints:

- Drone specification:
  - Average speed: 20 m/s
  - Maximum capacity: 30kg
  - Maximum range: 16km
- Number of drones: 2 (preferably just 1, and the other one as a backup)
- Requests made by the 10 pharmacies over 2 days: Request Log
- Precise distances between the different locations: Distance Matrix
- Time window for deliveries: 08:30 AM to 06:00 PM (570 minutes)
- Service time or halt time for the drone at the warehouse and each pharmacy: 15 minutes

6.2 Simulation Development

6.2.1 Tools

CVRP is an NP-hard problem, meaning its computational complexity exceeds polynomial time. However, using initial solution strategies and metaheuristics, solving CVRP becomes feasible. For our business, we were able to implement CVRP in the simulation by using Google-OR Tools.

OR-Tools is an open-source software suite for solving complex optimization problems like vehicle routing, scheduling, and bin packing using advanced algorithms. It includes solvers for constraint programming, linear and mixed-integer programming, and graph-based problems to efficiently find optimal or near-optimal solutions [30].

6.2.2 Implementation

In VRP, a limited number of vehicles depart from the same source, visit different locations, and then return to the depot. Each location is visited exactly once by a single vehicle, and each vehicle must visit at least one location. Once a vehicle returns to the depot, it cannot depart again. The objective of VRP is to minimize the total distance traveled by all the vehicles combined. However, by penalizing the use of vehicles, we can also make the algorithm reduce the number of vehicles utilized. That is, each time a new vehicle leaves the warehouse, a significant penalty is applied, influencing the solver to keep the overall costs as low as possible. After solving VRP, we obtain a route for each vehicle. Since the problem assumes that no vehicle can be reused, we can instead treat the returned number of vehicles as the number of routes that need to be completed. Then we can adjust the number of vehicles ourselves, allowing for their reuse, as long as routes are completed within the delivery time limit.

Except for the extra constraints imposed by us, there are also constraints directly related to the inner workings of CVRP that we need to respect.

- Every node is accessible either from the source node or from other location nodes.
- From each location node, we must proceed to another location node or reach the final destination.
- A specific number of vehicles depart from the source and reach the destination.
- When a route exists between two nodes, this constraint is set to 1, and 0 otherwise.
- The load on a vehicle does not surpass the vehicle's capacity.

6.2.3 First Solution and Meta Heuristics

The approach to finding the final optimal result consists of two fundamental concepts. The first is a greedy heuristic that quickly produces a good-enough initial solution, while the second, known as metaheuristics, refines and improves upon that initial result. In our simulation, we used the `PATH_CHEAPEST_ARC` heuristic, which starts from the depot and repeatedly keeps adding the nearest node until it can no longer extend the route without breaking any of the constraints [31]. Then, we iteratively refined the initial solution with a metaheuristic `GUIDED_LOCAL_SEARCH (GLS)`. It penalizes frequently used arcs to diversify the search and find a better solution over time [31]. Whenever an improvement was found, it updated the solution accordingly.

7 Simulation Results & Reflections

After running the simulation, we obtained the following results describing the delivery routes.

Route for trip 1: **Path:** Salveo Pharma B.V. → Apotheek SGE Woensel → Salveo Pharma B.V.
Distance: 1005968 m
Load: 18975 g
Time: 35 min

Route for trip 2: **Path:** Salveo Pharma B.V. → Apotheek Lingmont → Salveo Pharma B.V.
Distance: 1007494 m
Load: 18800 g
Time: 36 min

Route for trip 3: **Path:** Salveo Pharma B.V. → Dierenartsenpraktijk Heesterakker → Salveo Pharma B.V.
Distance: 1009388 m
Load: 18950 g
Time: 38 min

Route for trip 4: **Path:** Salveo Pharma B.V. → Medisch Centrum Aalsterweg → Salveo Pharma B.V.
Distance: 1005320 m
Load: 18950 g
Time: 34 min

Route for trip 5: **Path:** Salveo Pharma B.V. → Dental Clinics → Salveo Pharma B.V.
Distance: 1006176 m
Load: 18975 g
Time: 35 min

Route for trip 6: **Path:** Salveo Pharma B.V. → Apotheek Arnouts → Salveo Pharma B.V.
Distance: 1005632 m
Load: 18750 g
Time: 35 min

Route for trip 7: **Path:** Salveo Pharma B.V. → SGE Woensel → Salveo Pharma B.V.
Distance: 1005958 m
Load: 18825 g
Time: 35 min

Route for trip 8: **Path:** Salveo Pharma B.V. → Apotheek de Roosten → Salveo Pharma B.V.
Distance: 1006138 m
Load: 18750 g
Time: 35 min

Route for trip 9: **Path:** Salveo Pharma B.V. → Tandartspost Load → Salveo Pharma B.V.
Distance: 1004582 m
Load: 18850 g
Time: 34 min

Route for trip 10: **Path:** Salveo Pharma B.V. → Tandartspraktijk van de Vondervoort → Salveo Pharma B.V.
Distance: 1005522 m
Load: 18750 g
Time: 35 min

- **Total distance of all routes:** 10062178 m
- **Total load of all routes:** 188575 g
- **Total time of all routes:** 352 min

7.0.1 Interpretation of the Results

The total distance of each route includes the 1,000,000 penalty (that is what helps reduce the number of vehicles - routes scheduled). Hence, to obtain the actual result, from each distance we have to subtract the penalty. We notice, that the distance remains within the limit of 16km for each route.

The load of each result represents the total weight of transported medicine, and it never exceeds 30kg as specified in the constraints.

The time variable accounts for the round-trip flight time, 15 minutes of loading the drone at the warehouse, and then 15 minutes of unloading it at the destination.

7.0.2 Evaluation of the Results

There are 10 trips that the drone would have to complete. Executing all of them with one drone takes 352 minutes, where 300 minutes accounts for the total loading and unloading time of all trips (15 minutes at the depot, 15 minutes at each location), so the drone would have to fly for about 53 minutes. Unfortunately, this exceeds the drone's battery limit, which is 18 minutes.

Hence, two solutions are possible. Either we swap the batteries once the drone reaches its limit, or we let it recharge. Swapping the batteries does not introduce any new time overhead, since it could be performed while loading the drone. However, it introduces new costs, as we would need at least three sets of dual batteries.

On the other hand, charging the drone takes around 26.5 minutes and would have to be completed three times to carry out all 10 deliveries [32]. Below I attach the delivery schedule including one drone, with the need of regular recharging (R).

Drone	**Trip ID**	**Delivered To**	**Start Time (min)**	**End Time (min)**
Drone 1	8	Apotheek de Roosten	15.0	33.0
Drone 1	4	Medisch Centrum Aalsterweg	48.0	67.0
Drone 1	9	Tandartsenpost	82.0	101.0
Drone 1	1	Apotheek SGE Woensel	116.0	136.0 R
Drone 1	5	Dental Clinics	177.5	197.5
Drone 1	6	Apotheek Arnouts	212.5	232.5
Drone 1	7	SGE Woensel	247.5	267.5 R
Drone 1	10	Tandartspraktijk van de Vondervoort	309.0	329.0
Drone 1	2	Apotheek Lingmont	344.0	365.0 R
Drone 1	3	Dierenartsenpraktijk Heesterakker	406.5	429.5

Table 11: Delivery schedule for Drone 1 including trip ID, destination, and time stamps. 'R' indicates the need to recharge.

Hence, it would take 429.5 minutes to complete all the deliveries, while the pharmacies are open for 570 minutes (from 08:30 AM to 06:00 PM). Thus, we successfully validated the idea of using just one drone with the assumed constraints to carry out all the requests. Naturally, increasing the number of drones greatly reduces the needed time, but it is not necessary, and it introduces very high additional costs.

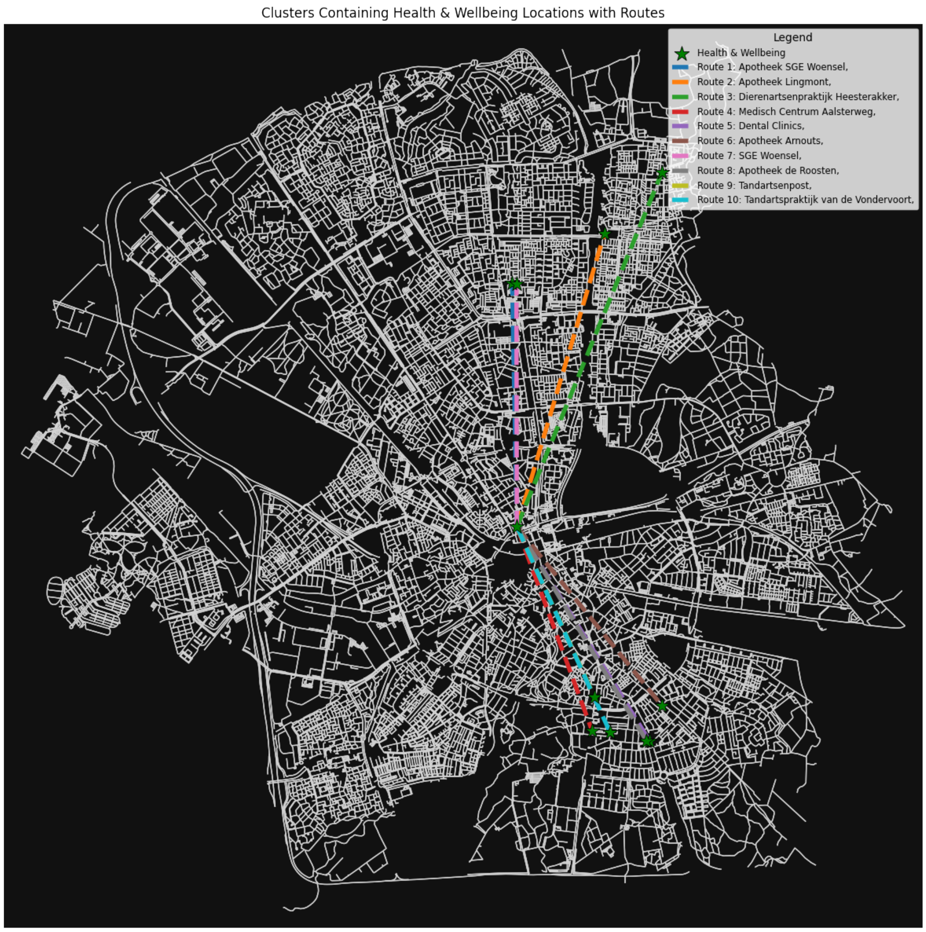

Figure 11: Visualisation of the routes the drone will take.

8 Future Directions

While the previous sections show that the simulation aligns well with the business logistics, ultimately validating it, some limitations remain that we are not yet able to overcome. Naturally, we are strongly limited by the specifications of the drones. For now, their range remains quite small, as does the payload they can carry. We believe that in the near future, with the growing utilization of drones, more advanced and affordable options may be introduced to the market. Currently, we are able to manage with just one unit carrying out deliveries, without having to install charging pads or split requests due to their weight. This might, however, become an issue when we try to scale outside the small area of Eindhoven. It might then become a necessity to either invest in more advanced drones (whose options are limited either way) or install intermediate maintenance locations.

Another non-obvious constraint is the restriction of the air zone for aerial vehicle flights. Eindhoven is located within a Controlled Traffic Region (CTR), making it one of the most restricted areas for drone operations in the Netherlands. Since our business addresses an activity of significant public interest - medicine distribution - we expect to obtain a permit to carry out our project within the designated area. However, the license only applies in this particular region. Any expansion of the distribution range would likely require obtaining additional permits and meeting further regulatory requirements. It is not unlikely that we may have to consider an alternative zero-emission mode of transportation in zones disallowing drone usage.

Last but not least, as a small start-up, we are naturally limited by the financial side. A single drone costs approximately 20,000 EUR, which is a significant amount, highly restricting the number of units we can currently afford. Although our financial model indicates the potential for positive revenue, which might allow us to invest in more transportation drones in the future, this is not yet feasible.

9 Conclusions

We would like to conclude this report with an optimistic prediction on the real-world implementation of our drone-based medicine distribution project. The initiative seems to have a strong potential for generating positive revenue as well as supporting further expansion. Beyond economic viability, the project promises meaningful societal benefits: contributing to a healthier environment through reduced emissions and enhancing the safety and efficiency of medical deliveries.

However, this positive forecast does not imply that the project is free from limitations. Regulatory requirements, financial constraints, and uncontrollable drone limitations remain critical challenges that must be addressed. Despite these, we believe the long-term advantages strongly justify the continued development and refinement of our solution.

References

[1] Rodrigues, T. A., Patrikar, J., Oliveira, N. L., Matthews, H. S., Scherer, S., & Samaras, C. (2022). Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery. Patterns (New York, N.Y.), 3(8), 100569. https://doi.org/10.1016/j.patter.2022.100569

[2] Chi, Nguyen & Phong, Le & Hanh, Nguyen. (2023). The drone delivery services: An innovative application in an emerging economy. The Asian Journal of Shipping and Logistics. 39. 10.1016/j.ajsl.2023.01.002.

[3] Stichting Farmaceutische Kengetallen. (2017, December 7). *Per apotheek gemiddeld 341 verstrekkingen per dag*. Pharmaceutisch Weekblad. Retrieved June 19, 2025, from https://www.sfk.nl/publicatie/2017/pw-artikel/apotheek-gemiddeld-341-verstrekkingen-dag

[4] AlleCijfers.nl. (2025, June 16). *Gemeente Eindhoven in cijfers en grafieken*. AlleCijfers.nl. Retrieved June 19, 2025, from https://allecijfers.nl/gemeente/eindhoven/#googlevignette

[5] Apotheek.nl. (2025). *Vind een apotheek*. Retrieved June 19, 2025, from https://www.apotheek.nl/vind-een-apotheek?q=51.440928,5.4958807&usedSearch=true#stroomz-apotheek-meerhoven--marker

[6] Wikipedia contributors. *OpenStreetMap*. Wikipedia. Retrieved June 8, 2025, from https://en.wikipedia.org/wiki/OpenStreetMap

[7] OpenStreetMap contributors. (n.d.). *Relation: Netherlands (47504)* [Map]. OpenStreetMap. Retrieved June 19, 2025, from https://www.openstreetmap.org/relation/47504

[8] BBBike.org. (n.d.). *OpenStreetMap extract for Eindhoven*. Retrieved June 19, 2025, from https://download.bbbike.org/osm/bbbike/Eindhoven/

[9] MorbZ. (n.d.). *OsmPoisPbf* [Computer software]. GitHub. Retrieved June 19, 2025, from https://github.com/MorbZ/OsmPoisPbf

[10] Gemeente Eindhoven. (2025). *Zero-emissiezone en milieuzone*. Gemeente Eindhoven. Retrieved June 19, 2025, from https://www.eindhoven.nl/stad-en-wonen/verkeer/zero-emissiezone-en-milieuzone

[11] Arunraj, B. (2024, June 4). Combustion engine trucks allowed in the city centre until 2028. *Eindhoven News*. Retrieved June 19, 2025, from https://eindhovennews.com/news/2024/06/zero-emission-plan-for-trucks-postponed-to-2028/

[12] Wikipedia contributors. (2024, 3 maart). Phileas (public transport). Wikipedia. Retrieved June 19, 2025, from https://en.wikipedia.org/wiki/Phileas_(public_transport)

[13] The largest electric bus fleet in Europe operates in Brabant. (n.d.). Retrieved June 19, 2025, from https://brainporteindhoven.com/en/business-and-innovation/cases/the-largest-electric-bus-fleet-in-europe-operates-in-brabant

[14] DPD. (2021, November 3). Op weg naar elektrisch rijden. Retrieved June 19, 2025, from https://www.dpd.com/nl/nl/2021/11/03/on-our-way-to-electric-transport/

[15] NV, D. T. (n.d.). New DAF Electric Truck Assembly plant officially opened. DAF Trucks. Retrieved June 19, 2025, from https://www.daf.com/en/news-and-media/news-articles/global/2023/24-04-2023-new-daf-electric-truck-assembly-plant-officially-opened

[16] Stolaroff et al. (2018). Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery. Retrieved June 19, 2025, from https://www.nature.com/articles/s41467-017-02411-5

[17] Thiago Tavares, VVA Brussels (2019). Comparing the cost-effectiveness of drones v ground vehicles for medical, food and parcel deliveries. Retrieved June 19, 2025, from https://www.unmannedairspace.info/commentary/comparing-the-cost-effectiveness-of-drones-v-ground-vehicles-for-medical-food-and\protect\discretionary{\char\hyphenchar\font}{}{}parcel-deliveries/#_ftn2

[18] THE EGNSS4RPAS PROJECT. Retrieved June 19, 2025, from https://www.euspa.europa.eu/sites/default/files/uploads/galileo_egnos_for_drone_egnsrpas_leaflet.pdf

[19] De Silvestri et al. (2022). Design of a Service for Hospital Internal Transport of Urgent Pharmaceuticals via Drones. Retrieved June 19, 2025, from https://doi.org/10.3390/drones6030070

[20] AERET. (n.d.). *AERET kaartviewer* [Interactive map]. Retrieved June 19, 2025, from https://aeret.kaartviewer.nl/?@dpf_basic#Info

[21] Inspectie Leefomgeving en Transport. (n.d.). *Drones (UAS): Categorie specifiek* [Web page]. Retrieved June 19, 2025, from https://www.ilent.nl/onderwerpen/drones/categorie-specifiek

[22] Inspectie Leefomgeving en Transport. (n.d.). *Exploitatievergunning onbemand luchtvaartuig* [Web page]. Retrieved June 19, 2025, from https://www.ilent.nl/onderwerpen/drones/categorie-specifiek/exploitatievergunning-onbemand-luchtvaartuig

[23] Luchtverkeersleiding Nederland. (n.d.). *Drones* [Web page]. Retrieved June 19, 2025, from https://en.lvnl.nl/services/drones

[24] Inspectie Leefomgeving en Transport. (n.d.). *Nationale voorschriften categorie Specifiek* [Webpagina]. Geraadpleegd op 19 juni 2025, van https://www.ilent.nl/onderwerpen/drones/categorie-specifiek/nationale-voorschriften-categorie-specifiek

[25] DJI. (n.d.). *FlyCart 30 – Specificaties* [Webpagina]. Geraadpleegd op 19 juni 2025, van https://www.dji.com/nl/flycart-30/specs

[26] Wingcopter. (n.d.). *Wingcopter 198* [Productpagina]. Geraadpleegd op 19 juni 2025, van https://wingcopter.com/wingcopter-198

[27] DJI. (n.d.). *Matrice 300 RTK* [Ondersteuningspagina]. Geraadpleegd op 19 juni 2025, van https://www.dji.com/nl/support/product/matrice-300

[28] Chidarala, N. (2023, October 21). *Capacitated Vehicle Routing Problem (CVRP) optimization using Google OR-Tools and Python*. Medium. Retrieved June 19, 2025, from https://medium.com/@nag96.chidara/capacitated-vehicle-routing-problem-cvrp-optimization-using-google-or-tools-and\protect\discretionary{\char\hyphenchar\font}{}{}python-7848fb5ffd16

[29] Google. (2024, August 6). *Vehicle Routing Problem* [Web page]. Google Developers. Retrieved June 19, 2025, from https://developers.google.com/optimization/routing/vrp

[30] Google. (n.d.). *OR-Tools* [Software suite]. Retrieved June 19, 2025, from https://developers.google.com/optimization

[31] Google. (2024, August 28). *Routing options* [Web page]. Google Developers. Retrieved June 19, 2025, from https://developers.google.com/optimization/routing/routing_options

[32] DJI. (n.d.). *FlyCart 30 - Veelgestelde vragen* [Webpagina]. Geraadpleegd op 19 juni 2025, van https://www.dji.com/nl/flycart-30/faq