Carbon Circle

Shared electric scooters can be found all over the city - unfortunately, some people abondon these vehicles in inappropiate places or positions. It can result in scooters' damage or traffic disturbance - especially for visually impaired citizens. Our project aims to present a whole scooter system, which would:

provide an eco-friendly charging procedure

contribute to scientific research in artificial intelligence

reduce the number of unnecessary scooter repairs

encourage more people to choose alternative ways of transportation than cars

prevent the incidents with improperly situated vehicles (e.g. disturbed traffic)

provide a flexible and dynamic scooter infrastructure

We propose to reduce the emission of carbon dioxide through **Carbon Circle Scooter Infrastructure**. It offers four types of products:

- modernised **CC Scooters**,
- repairing and charging mobile **CC Docks**,
- **CC Logistics Centre**,
- software architecture, including logistics algorithms, artificial intelligence environment analysis in real-time and mobile application **CC App**.

Apart from the products, there are several campaigns planned to encourage people to start using alternative vehicles to cars. Such campaigns include seasonal special edition scooters (in terms of design), temprary increase of the number of CC Docks in areas with social events (e.g. juwenalia) or special fares within specific hours.

Renting a scooter is - in term of price - comparable to other companies' offer (estimated at 3 PLN as a entry fare plus 0,5 PLN per minute). However, we provide a subscription system - a user can choose between different monthly subscription options:

- daily usage to a maximum od one hour in total - 300 PLN,
- daily usage to a maximum of one hour in total within commuting hours (6:00-10:00 and 14:00-18:00) - 250 PLN.

Creating a subscription results in making scooters popular, therefore less people will be unfamiliar with the vehicles operation and fewer repairs will be needed.

Ideas behind the products

CC Scooters

- foldable, highly modular vehicles which allow for personal transportation with the speed up to 20 km/h
- easily replaceable scooter's parts helpful in case of damage or malfunction
- when left outside and people are detected nearby, they produce sound signal to prevent contact, especially with visually impaired citizens
- contains an air-bag to reduce harmful consequences of an accident

CC Docks

- their software based on autonomous vehicles' systems
- all are mobile
- have the automatic repairing and charging system for scooters
- serve as well as scooter lockers - users can rent a scooter from the dock
- solar panels at the top for charging scooter batteries
- some are located in predefined areas (scooters can aproach these docks on their own), but the majority of docks travel overnight locating the *nests* (specially formed groups of scooters) and repairing/charging the scooters there

CC Logistics Centre

- repair centre for docks and scooters which cannot be fixed autonomously
- solar power plant
- located on the outskirts

CC App

- showing available scooters nearby and allowing their rent
- helps gathering statistical data on the interest in scooters usage in specific areas

Software

As mentioned above, the application allows for renting scooters. There are three possibles ways of doing that:

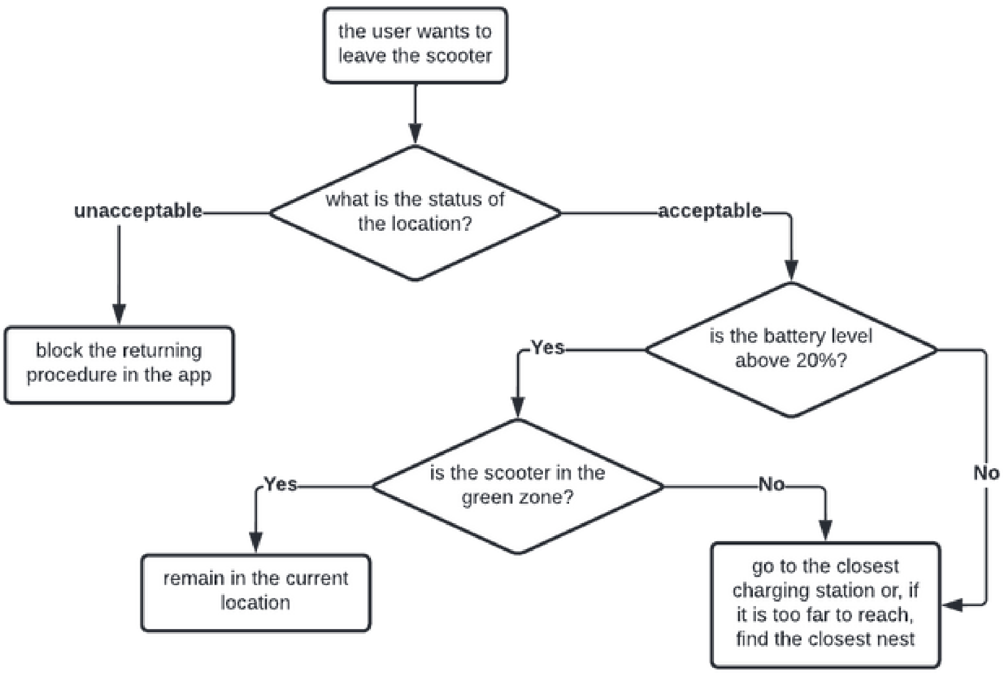
- ordering a scooter remotely in advance to approach your localisation and be ready to be used,
- scanning a QR code of the scooter found with the map available in the app,
- approaching a CC Dock and use the app-dock connection to collect a scooter directly from the dock.

Returning the scooter is also possible via app (if the sensoric system decides it is safe, not in the middle of the street or right next to the lake/river). However, the scooter's behaviour, after it is returned, varies depending on the situation. Cities are divided into three zones specified on the basis of busyness, traffic disturbance:

- **green zone** - high probability of being rented, safe location in terms of being left there,
- **orange zone** - medium or low probability of being rented, or safe location, but might disturb pedestrians,
- **red zone** - location is predicted to be unsafe e.g. the middle of the street, being too close to a river/lake etc.

If the battery level is above the thershold and if the scooter is in the area that is defined as green zone, it can remain in its location to await a random user to approach. If the scooter was left in the orange zone or if the battery level is below threshold, the scooter will return on its own to a CC dock or, if it is too far away, to the closest nest (a location where scooters gather to be later charged by a mobile overnight CC Dock).

Users will be awarded in the app for placing the vehicles in the green zone and an additional charge of 1 PLN will be taken from the user for leaving a scooter in an orange zone.



Software

Autonomous operation

There are several aspects that contribute to the general intelligence of the system [1,4,5].
Scooters are equipped with a vision system (consiting of depth cameras), integral measurement units and GPS. Due to a sensor fusion, the information on the surrounding is obtained and a scooter behaves accordingly. Utilising a lidar was considered, however it is too expenisve and it is not necessary to assure basic functionalities - it can be added in the future generations after a success in the first phase of the busniess plan.
Supervised machine learning approach will be applied to train artificial neural networks to analyse images from the cameras. In parallel, classical image processing algorithms will be explored in the research part of the implementations. Moreover, the busyness (the number of people [and their smartphones]) of the area will be determined on the basis of the data received by Bluetooth and WiFi modules in the scooters. Setting wireless interfaces into monitored mode will allow for monitoring wireless packets activity on the physical layer.
The software will be implemented with **Python** programming language, with **PyTorch** for neural network implementation and **OpenCV** for classical image processing exploration. It is hoped that **YOLOv5** object detection architectures [7] will prevent our software engineers from reeinventing the wheel in their implementations. Similar solutions will be applied in CC Dock, to detect and classify scooter's modules to later repair the vehicle.
The logistics is a separate aspect of the software. The location of the organically created nests, navigating vehicles, defining routes for mobile overnight CC Docks, making decisions on the scooters' distribution over the city are to be solved with classical algorithms e.g. **Dijkstra algorithm** or **A***, **Travelling Salesman Problem** solutions etc. [8, 9]

Contribution to the worldwide AI research

Sharing is caring, so we would like our data about scooter use patterns, and real-time people density to be open-source. It would help other companies, organizations and local authorities for to predict what are the society requirements to the transportation system. Although a scooter's firmware is highly protected and cannot be changed by a third party, Carbon Circle aims to contribute to the worldwide AI research by providing statistical data and open datasets of images registered by scooters' cameras (after an initial anonymisation). It is hoped that the research centres at technical universities (with an example of AGH University of Science and Technology) will be interested in collaboration in terms of software improvement or explorations of such research aspects as **Hidden Markov Models** [6], **object detection**, **image classification** or maybe even **reinforcement learning** approach for autonomous vehicles.

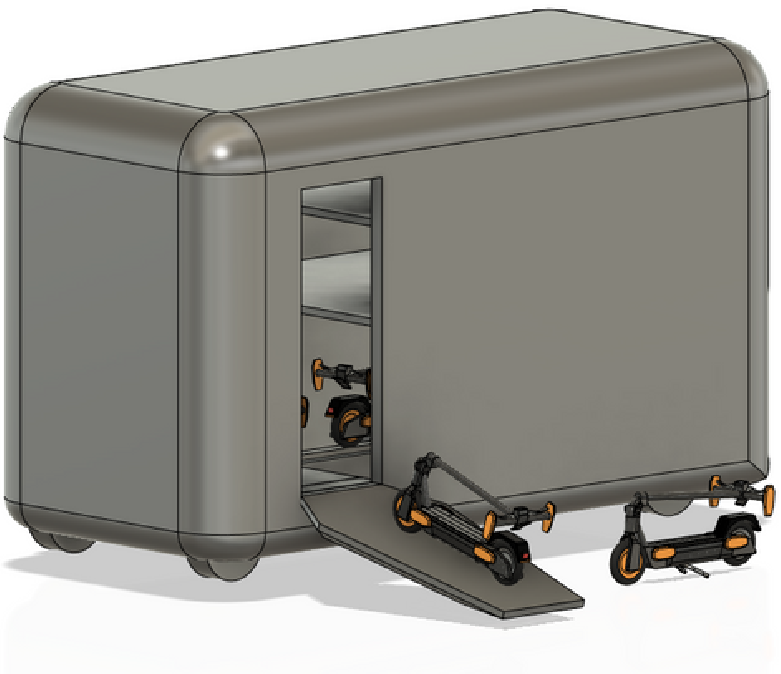
CC Scooter prototype

CC Scooter specification

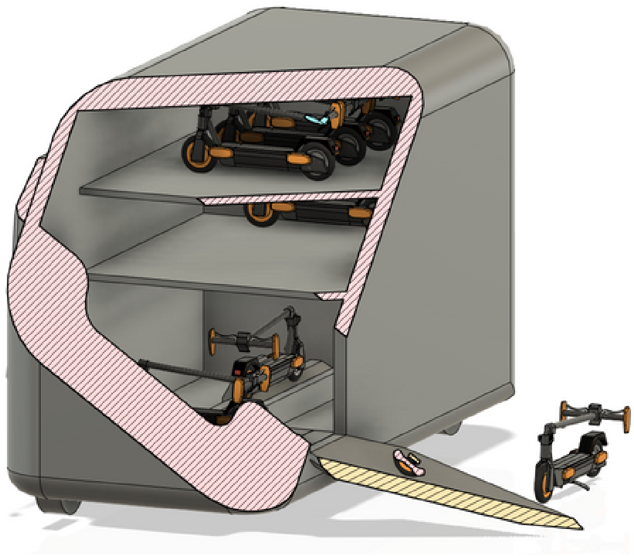
- 125 cm x 150 cm x 60 cm (folded: 125 cm x 60 cm x 60 cm)
- estimation of 14 kg
- made from carbon fiber, 3D printed PLA and PET-G, stainless steel
- **Modularity**
  - replacable modules which allow for easy repairs
- **WiFi & Bluetooth module**
  - ESP32 (~2$) [2]
- **GPS module**
  - Neo 6M (~2$)
- **Cellular**
  - SIM900 (~3$)
- **Computer Stereo Vision System**
  - Intel® RealSense™ D435 (~250$), in case of a need for cost reduction some cheaper, custom system will be created (~50$)
- **Battery pack**
  - Li-Ion 18650, 8s4p, 29.6V, 288Wh, with Battery Management System (180$)
- **9DoF IMU**
  - MPU-9250 (~10$)
- **Two BLDC motors integrated with wheels**
  - low KV (~20), high torque (25Nm), low speed (840rpm), around 350W (140$)
- **Electronic Speed Controller**
  - custom, 2 channel version of VESC (40$)
- **Small computer with some GPU and AI acceleration**
  - RPi + K210 AI Accelerator (80$)
- **Light system**
  - based on high power LED (4$)
- **Throttles**
  - for breaking and acceleration (5$)
- **Signal emitting module**
- **Airbag safety system** [3]

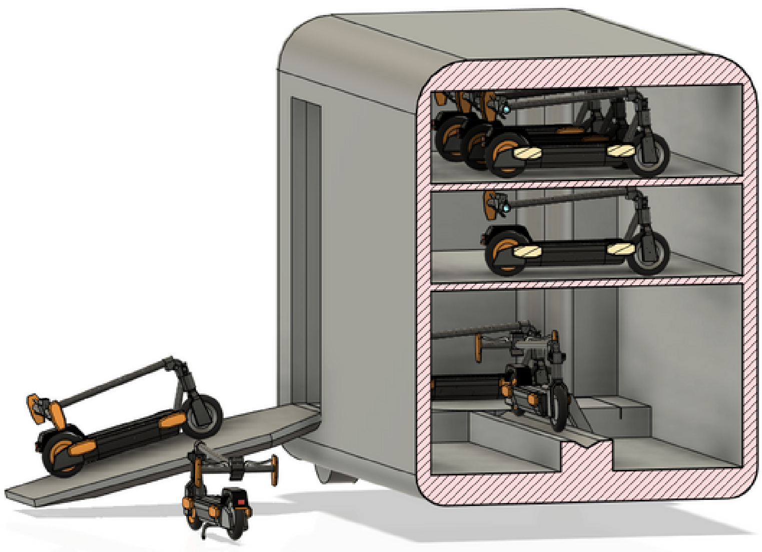
Total estimated cost: 899$ + VAT

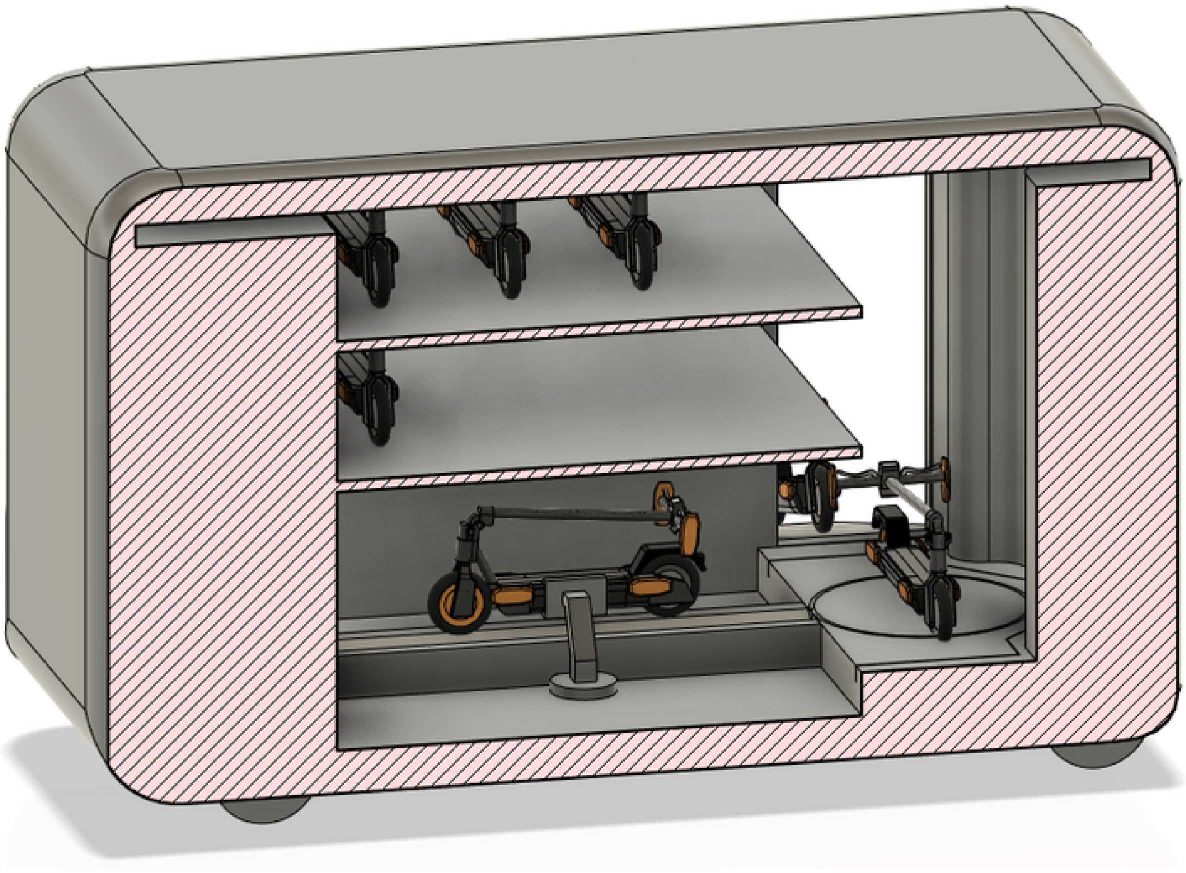
CC Dock prototype



CC Dock prototype







CC Dock specification

- 5.2 m x 2.3 m x 2.8 m
- ~15 t
- materials: glass fiber
- AGM batteries
- vision system composed of depth cameras
- GPS module
- 2 DoF robotic SCARA manipulator

Total estimated cost: 30 000$ + VAT

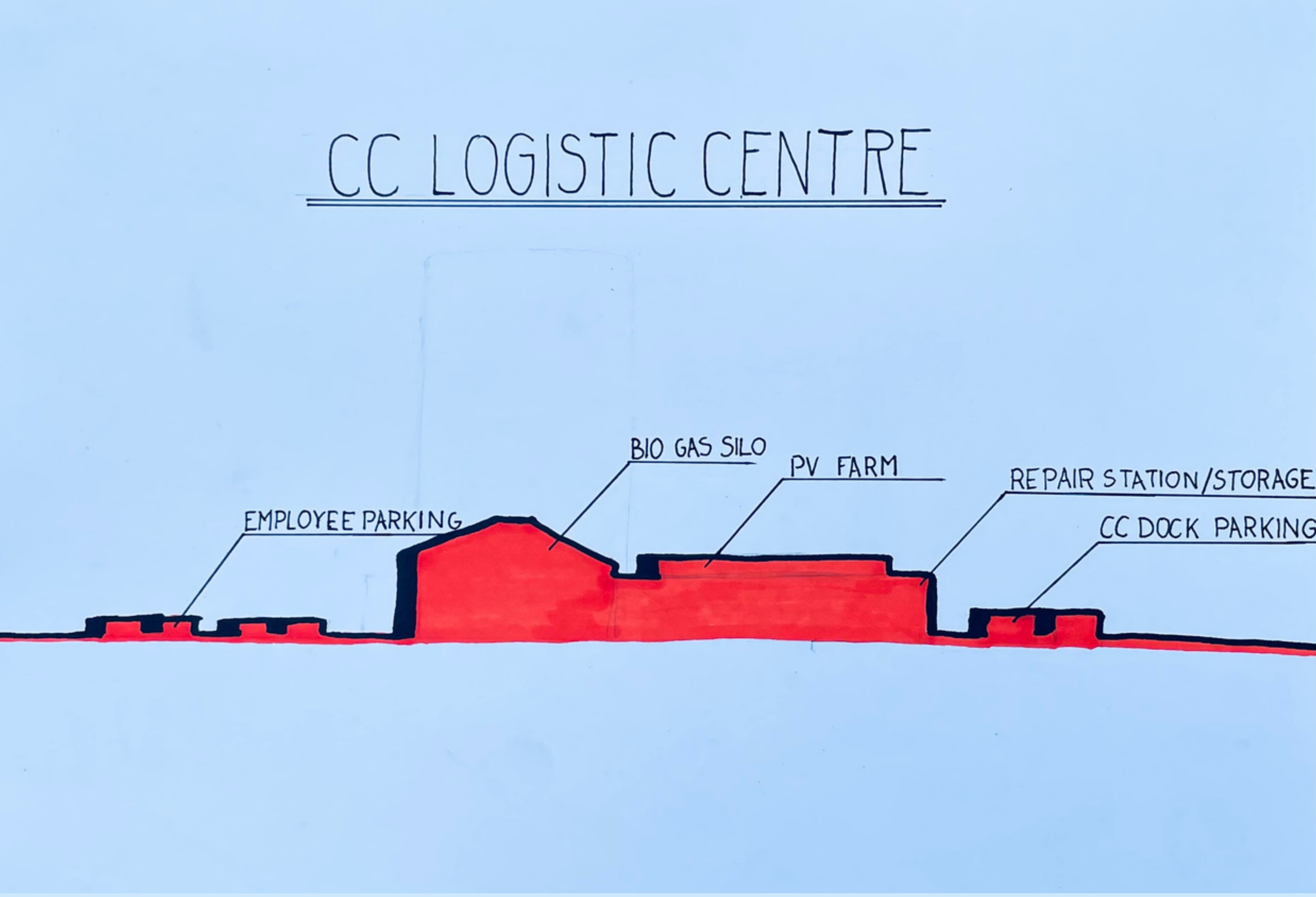
Way of operation

A scooter approaches the ramp and gets into the dock. An electric lift moves a scooter inside the Dock into a proper place. There are few storage areas inside, depending on what the current scooter state is. As a scooter knows what is broken, thanks to its internal sensor, it can be repaired in some cases. If it is needed, it goes to the automatic repair section inside the dock. 2DoF robotic scara manipulator can exchange some parts. If the damage is uncommon or very hard, the scooter will be put in deeply broken section, waiting for a visit in CC Logistic Center. If the scooter is not broken, it can be slightly cleaned up by an automatic brush set. Then, it is connected to power supply or the battery is changed: it depends on the battery condition. Scooters that are clean and fully charged are in a separate place inside the Dock and are waiting for people to be rented!

CC App

Available on both Android and iOS systems, allows for ordering and renting a scooter. A user can sign in with an email, use an Apple ID or a Google account. Tha map shows locations of scooters (pins) and docks (anchors).

Draft of the CC Logistics Centre



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