Machine vision monitoring of loading sites

Location: Helsinki, Finland
Target groups: City traffic planners, delivery car drivers
Company: Ramboll Oy (sub-consultant Delicode Oy)

- **The objective of this project** was to test the functioning of a machine vision-based solution for monitoring the utilisation of loading zones.
- **The work was carried out** as a four-week period of monitoring, during which four different loading sites were observed in the Helsinki city centre.
- **As a result,** it was found that the tested solution is able to monitor the utilisation rate with certain marginal conditions as well as separate heavy goods vehicles from other vehicles.

Machine vision monitoring of loading zones

Ramboll Finland Oy

Delicode Oy

Funded by the European Union

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Contents

1. Background and objectives

As a whole, urban logistics is a critical area that affects the vitality and traffic management of cities, the well-being of their residents, and emissions. Well-designed and implemented logistics solutions improve sustainability and quality of life in cities, reduce costs and emissions, and ensure that products and services reach their destinations efficiently and safely.
There are several challenges in implementing logistics services in the urban environment, the most significant of which are the limited urban space and distribution emissions.

As part of the DISCO project, Forum Virium Helsinki is examining new kinds of possibilities for gaining an understanding of the loading sites in the Helsinki city centre and their usage, as this type of data is currently somewhat scarce.

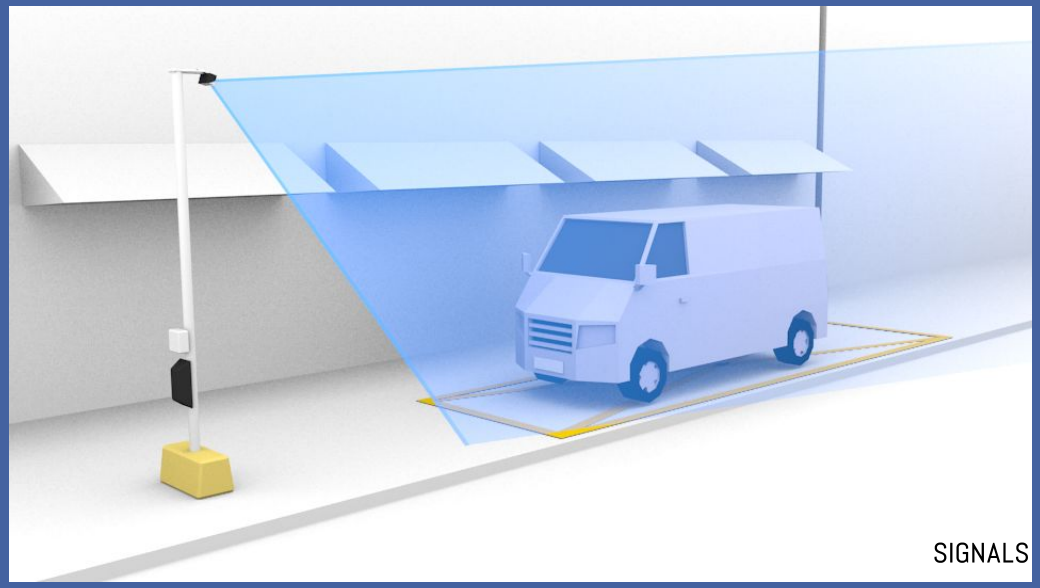
It is the aim of this work to provide answers to the following research questions:

- How well can a machine vision-based solution monitor the utilisation rate of loading sites?
- How precisely does the solution distinguish between types of vehicles?
- Is it possible to effectively communicate loading site status to drivers?

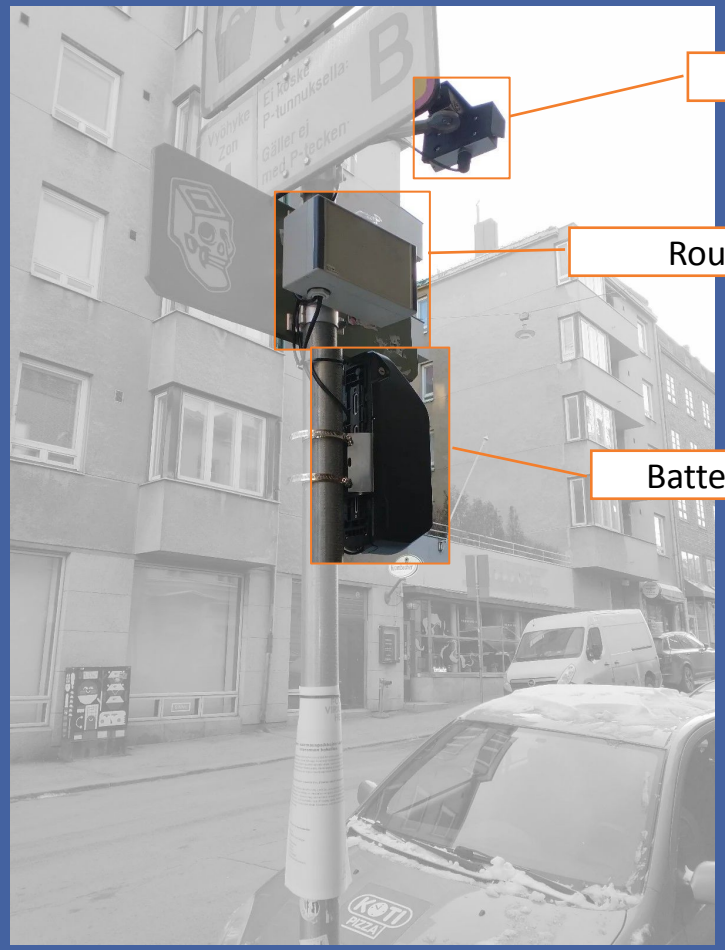
2. Description of the solution

The solution is based on camera monitoring with Luxonis cameras, which combine the features of machine vision stereo cameras and high resolution cameras.
Monitoring is based on identifying objects in the camera image. A specific area is defined in the camera's view in which the monitoring is targeted (loading site). Objects are separated into different categories, which means that different vehicle types can also be identified with certain restrictions.

The utilisation rate of loading sites is monitored in real time through a web portal (Signals user interface).



3. Equipment



Camera & CPU

Router

Battery pack

Luxonis Oak-D CM4 PoE

- The device uses Delicode's Signals software with the full feature set (including 24/7 readiness and remote management).
- Categories available for calculation: pedestrian count, bicycles, motorcycles, passenger cars and heavy goods vehicles.
- The device has an 80° diagonal field of vision. The device is installed approximately five metres from the monitoring site.
- The device is IP67 protected. Dimensions 130mm × 64mm × 30mm, weight 318 grams.

Connects to the Internet and transmits data in real time (4G connection).

Battery tray with replaceable battery (enables quick replacement).

The equipment was attached to traffic signs with pipe clamps / fasteners. The camera was installed using a specially designed camera mounting arm.

Definition of a loading site

A loading site is a marked area reserved for loading and unloading goods. Loading sites are intended for delivery vehicles and heavy goods vehicles to stop and deliver goods near commercial premises and stores.

A loading site is indicated with traffic sign C43. The sign prohibits stopping for any other purpose than loading and unloading on the side of the road the sign is installed. Stopping is also permitted for picking up or dropping off passengers. Stopping being only allowed for a specific vehicle group is indicated with an additional sign.

4. Implementation

The monitoring of loading sites was carried out at four different locations over a four-week period (17 March – 10 April). Each loading site was monitored with one camera. As the equipment was battery-powered, the monitoring period was restricted to Monday–Thursday. On Mondays, the team replaced the batteries and on Thursdays, they collected the batteries for recharging, which took place over the weekend.

The equipment was installed on traffic signs either five metres behind or ahead of each loading site. The battery was attached and locked to a carriage installed on the traffic sign, after which the equipment automatically connected to the server. After the connection was established, a technician defined the area to observe (loading site) on their mobile device through the calibration interface. This only had to be carried out once upon the installation of the equipment. After calibration, the equipment began to produce and send information to the server and to the interface. The device was set to anonymise the data collected immediately so that individuals are not identifiable in the data. Only data anonymised in this way was transferred to the server.

4. Implementation

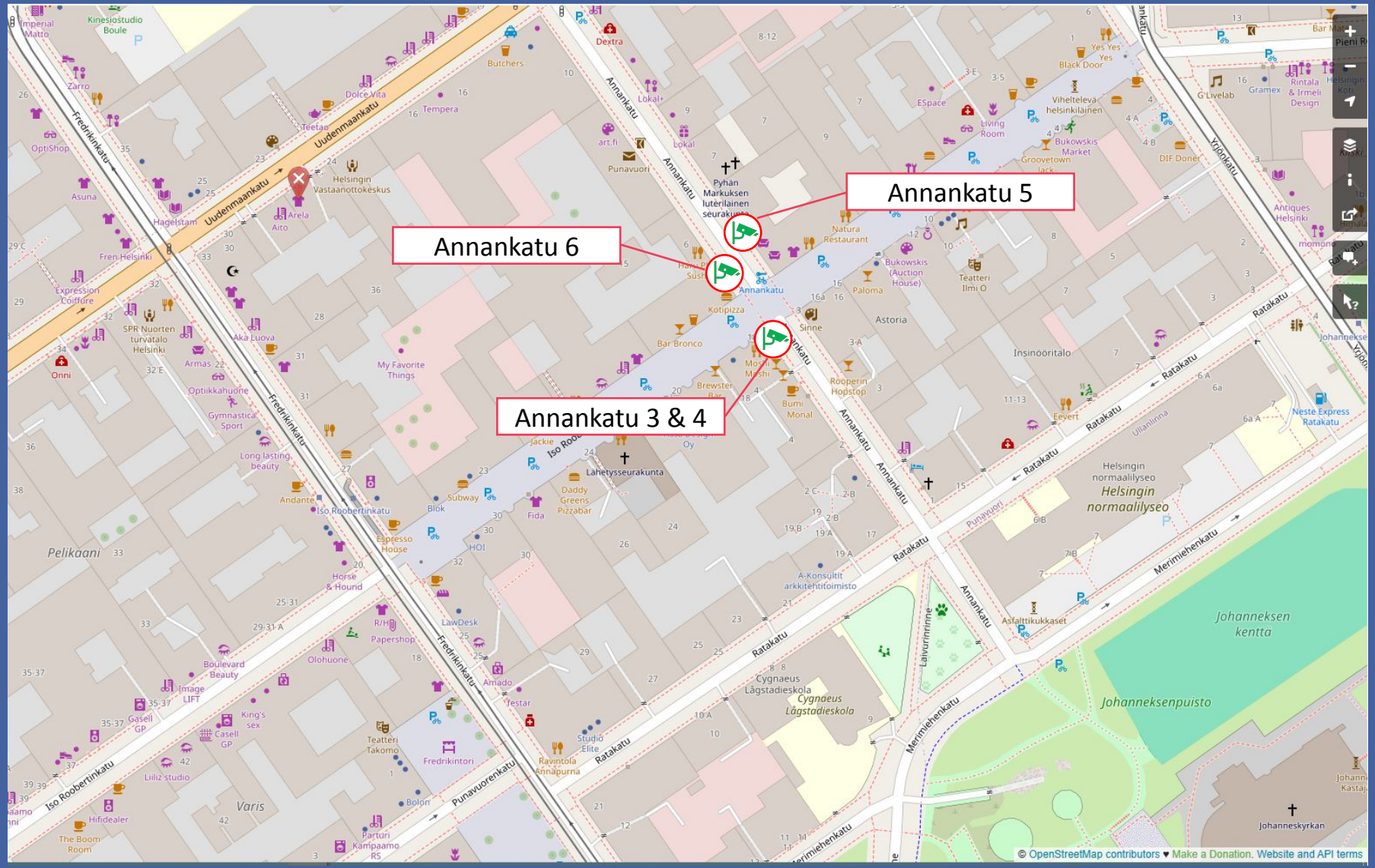
Week 0 (10 March – 16 March)

Final selection of the installation sites was carried out in connection with a location survey on 4 March. Choice of the installation sites was influenced by the possibility to install the equipment on traffic signs at the sites. The manager responsible for traffic signs at the City of Helsinki was notified of the installations. A bulletin was also attached to the equipment, explaining the purpose of the cameras and providing the details of the contact person of the client. The second factor that influenced the choice of installation sites was their proximity to each other. This made it easier to replace the batteries and provided gave a better picture of how loading sites in the area were utilised on a holistic level.

The first two cameras were installed on 10 March, but data was not collected until monitoring week 1 (from 17 March).

It was decided that the cameras would be installed at the intersection of Annankatu and Iso Roobertinkatu as shown in the following slide.

Installation of cameras (original plan)



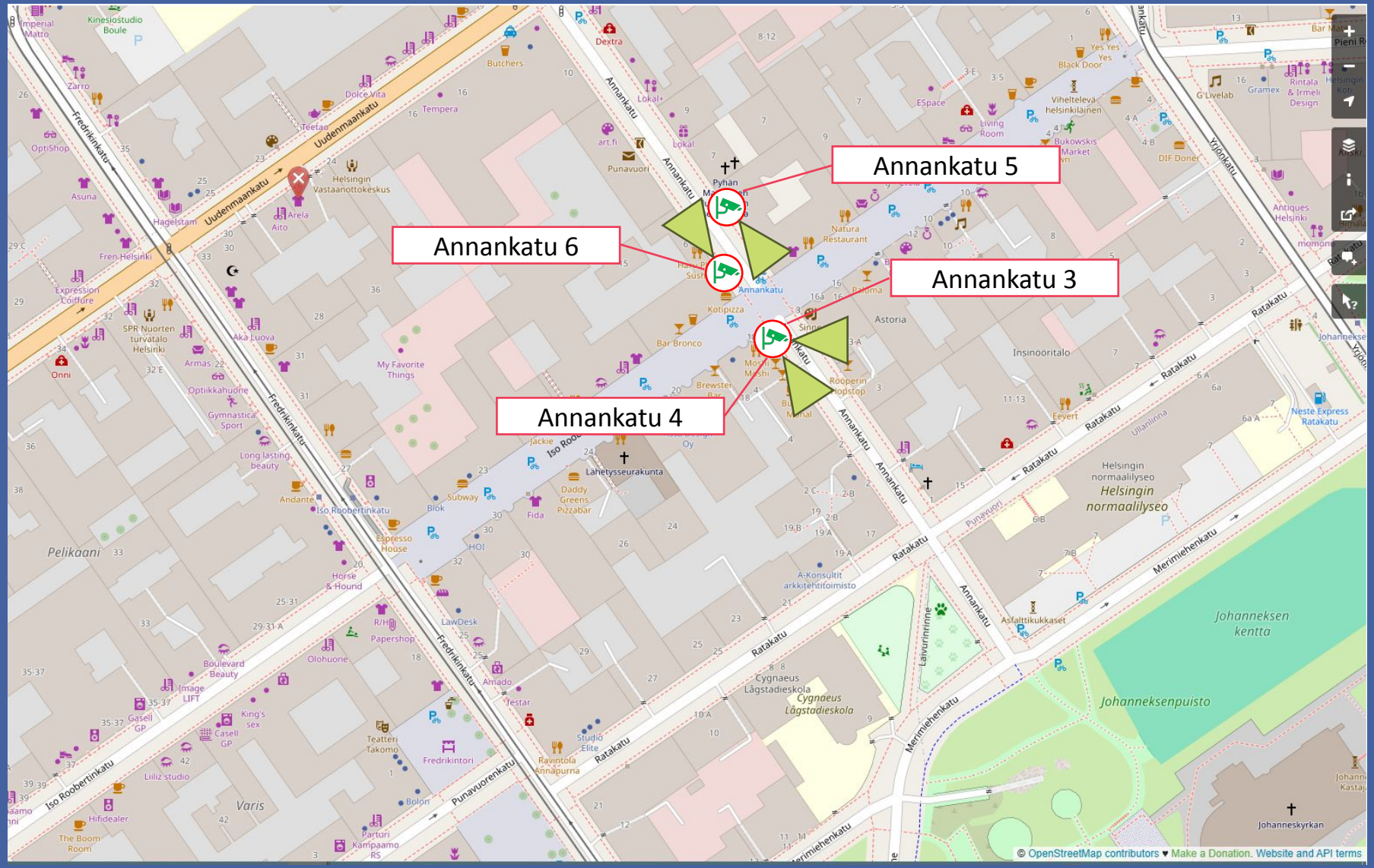
4. Implementation

Week 1 (17 March – 20 March)

The other two cameras were installed on 17 March, at which point all the cameras used for the project were installed and started producing data. The cameras were installed and oriented as shown in the following slides.

When the cameras were positioned towards the loading sites, we discovered a problem with the identification of heavy goods vehicles. When the tailgate was open, the object was no longer recognised as the heavy good vehicle model that had been taught to the neural network, which meant that the camera lost the vehicle / no longer identified it as a heavy goods vehicle. The solution to this problem was to install the cameras diagonally so that they observed the loading site from across the street, i.e. from the side of the vehicle. This allowed the image to better correspond to the model trained to the neural network even if the tailgate is open, making it easier to identify the vehicles. The to reorient the cameras was made during week 2 of monitoring.

Camera orientation (week 1)



Camera installation (week 1)

Annankatu 6

Annankatu 4

Annankatu 5

Annankatu 3

Bulletin

Installation of the cameras attracted considerable interest in the residents, and there were many questions about the cameras while they were being installed. For this reason, it was important to prepare a bulletin to describe the purpose and principles of the project to the residents. The bulletins were attached to the traffic signs with the cameras.

It was emphasised in the bulletin that these cameras are not used for parking control and that the camera image is not viewable.

FORUM VIRIUM HELSINKI

Suoritamme kuormauspaikkojen käyttöasteen seurannan kokeilua.

Suoritamme kuormauspaikkojen käyttöasteen seurantaa konenäön avulla. Kyseessä on Helsingin kaupungin innovaatioyhtiön Forum Virium Helsingin tilaama ja Rambollin sekä Delicoden toteuttama kokeiluhanke. Seurantatietoja ei käytetä pysäköinninvalvontaan, vaan kyseessä on kokeilu, jolla seurataan ainoastaan kuormauspaikkojen käyttöastetta. Kameravaa ei myöskään lähetetä eteenpäin, vaan tiedot käsitellään laitteessa ja ainoastaan käyttöasteeseen liittyvä tieto välitetään eteenpäin.

We are conducting a pilot project to monitor the utilization rate of loading zones.

We are monitoring the utilization rates of loading zones by using machine vision. This pilot project is commissioned by Forum Virium Helsinki, an innovation company of the City of Helsinki, and carried out by Ramboll and Delicode. The monitoring data will not be used for parking enforcement; rather, it is an experiment solely to track the utilization rate of loading zones. Camera footage is not transmitted elsewhere; instead, the data is processed within the device, and only information related to the utilization rate is forwarded.

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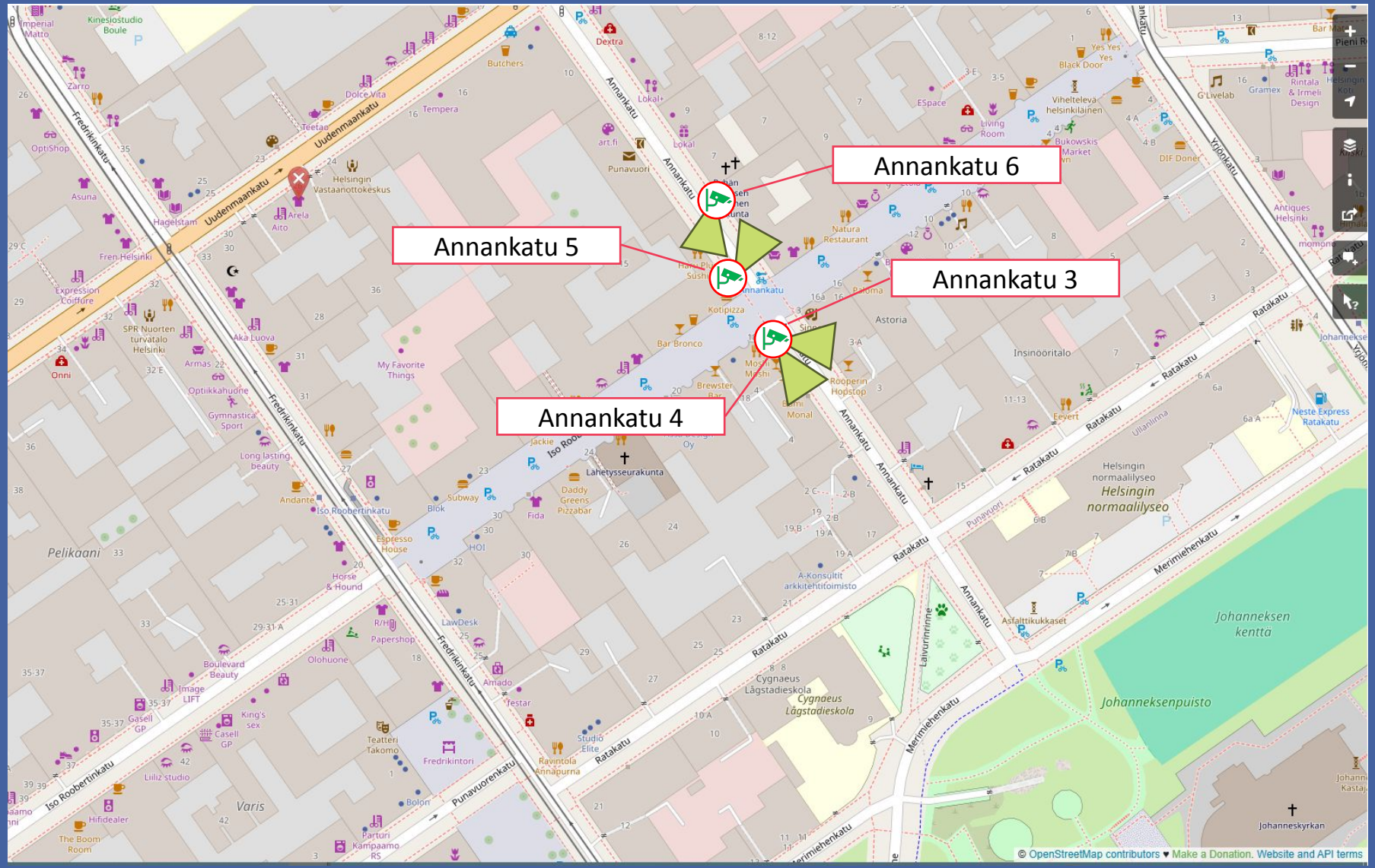
4. Implementation

Week 2 (24 March – 27 March)

On Monday morning, the camera batteries were replaced, and the cameras were turned diagonally as shown in the following slide. This improved the detection of high goods vehicles compared to the first week of monitoring. However, the cameras were installed fairly low on the traffic signs, which made visual contact with the loading site easily disrupted by an obstacle, such as a large vehicle, between the camera and the loading site. There had been a precaution to take this into account in the equipment: to only register a vehicle as identified after 20 seconds of continuous identification and to only register it as having left after 60 seconds of not being observed. Due to this identification method, it became possible to identify the same vehicle as two separate vehicles, if the visual reference was lost for the set 60 seconds. The re-alignment of the cameras is illustrated on the following slide.

Camera orientation (week 2)

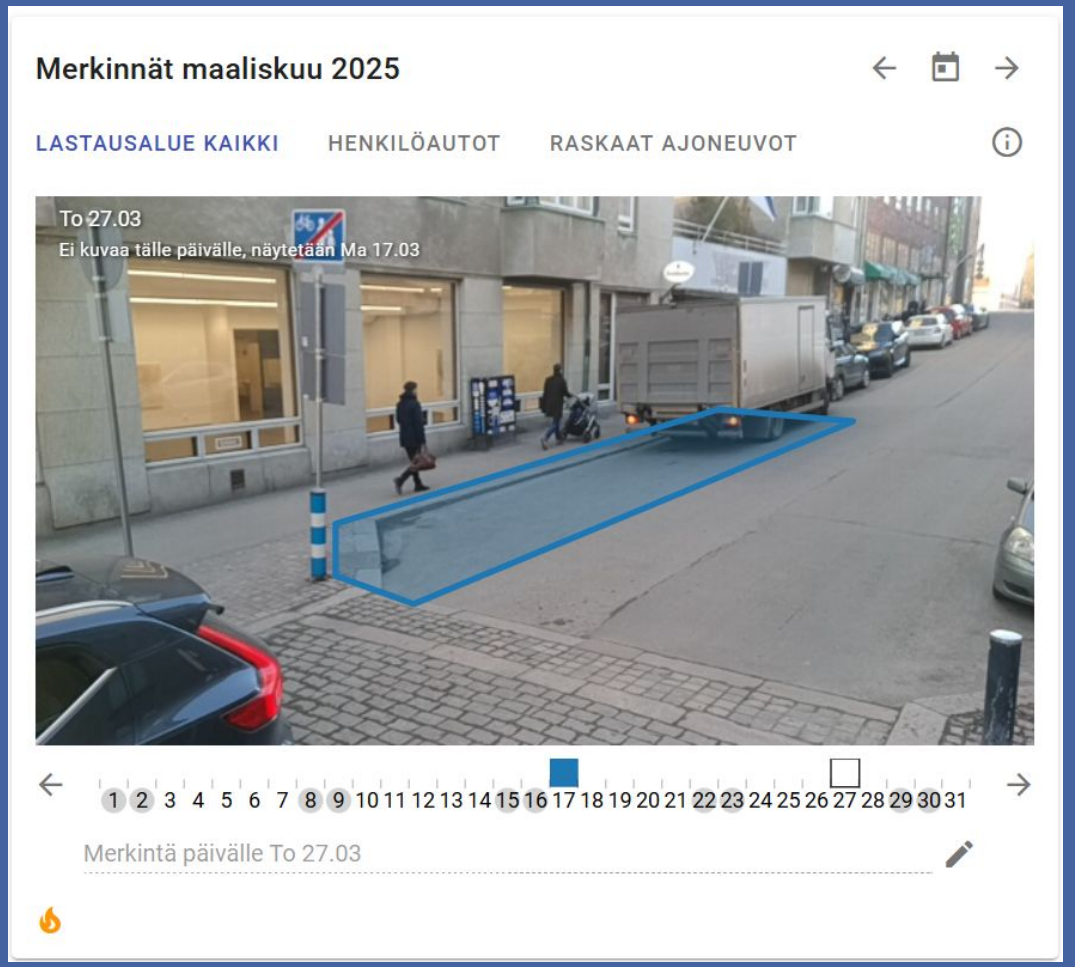


Compared to the first monitoring week, Annankatu 5 and 6 changed places, as the monitoring was now carried out from across the street. That is, the loading site of Annankatu 5 is now observed from the side of Annankatu 6. The orientation of the cameras and loading sites is illustrated on the following slides.

Annankatu 3

Installation

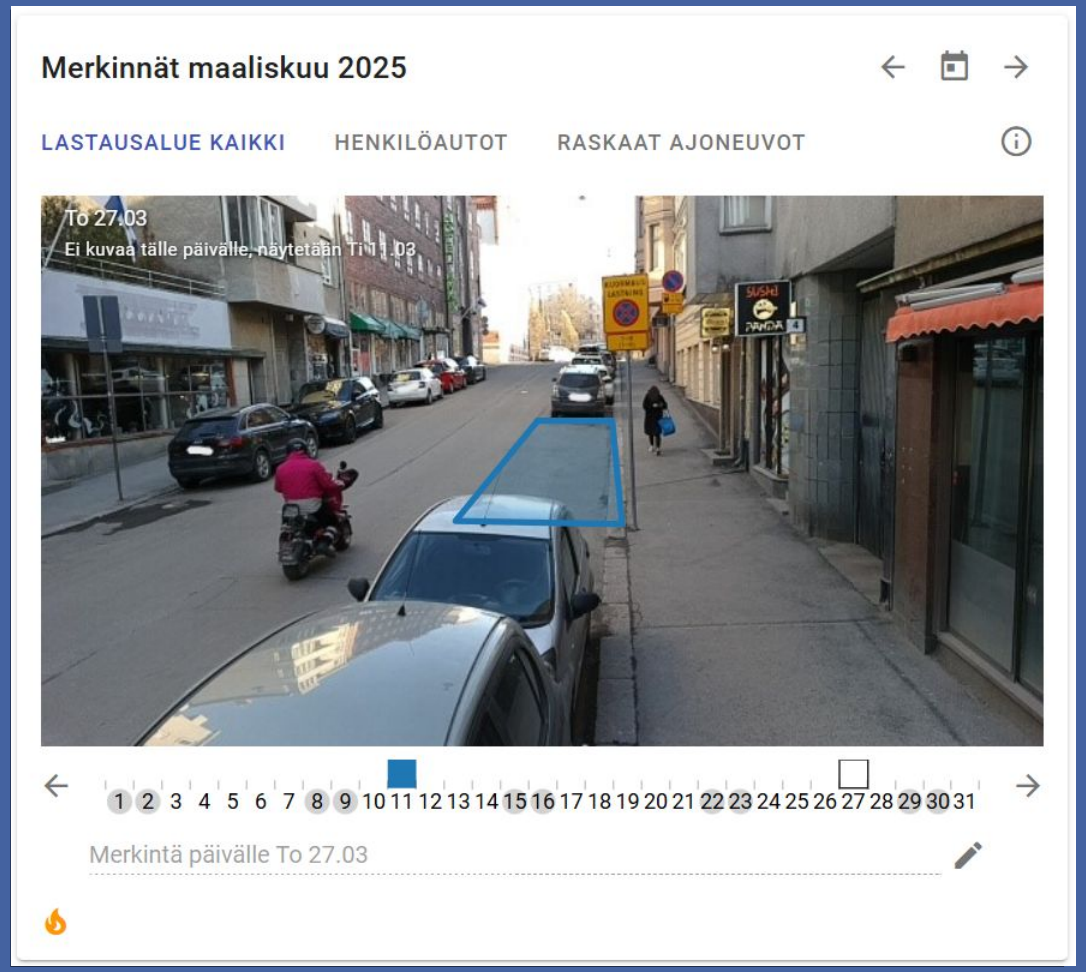
View



Annankatu 4

Installation

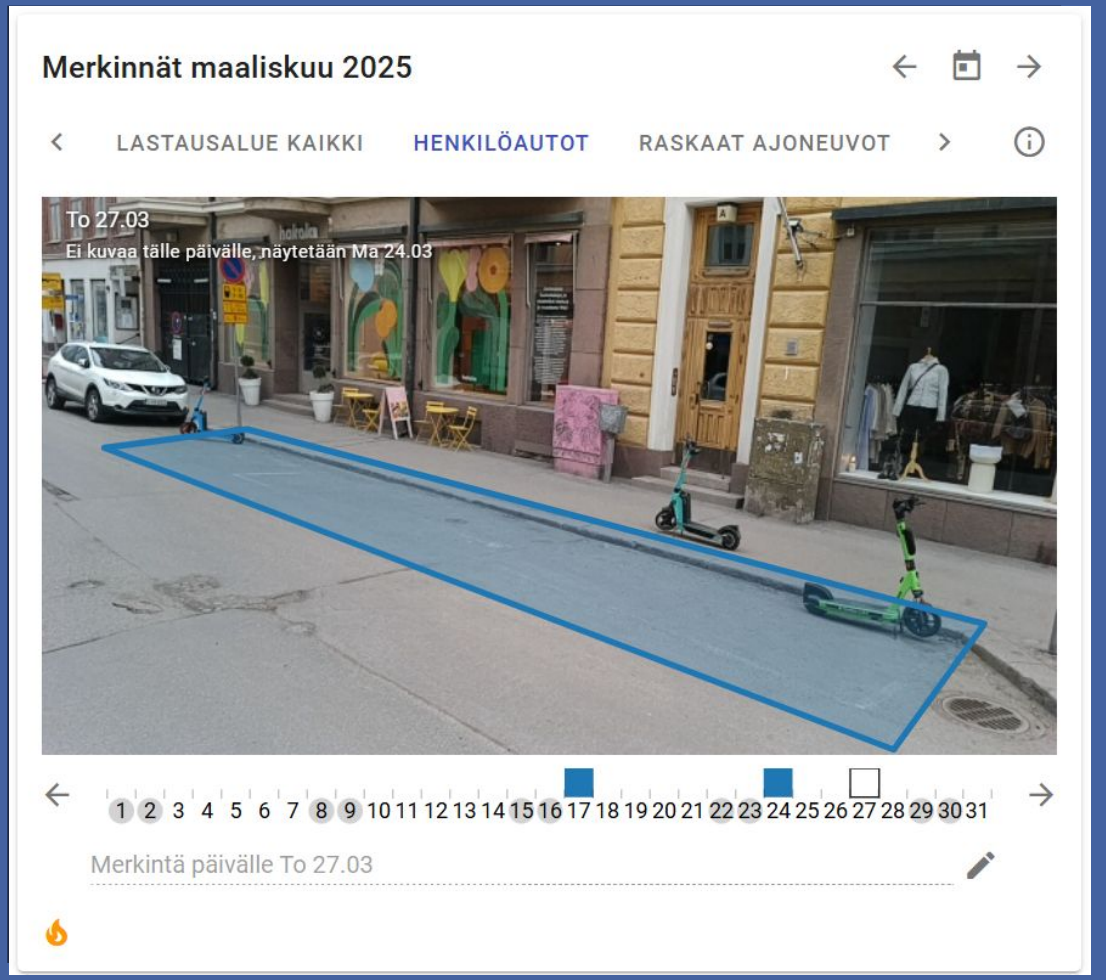
View



Annankatu 5

Installation

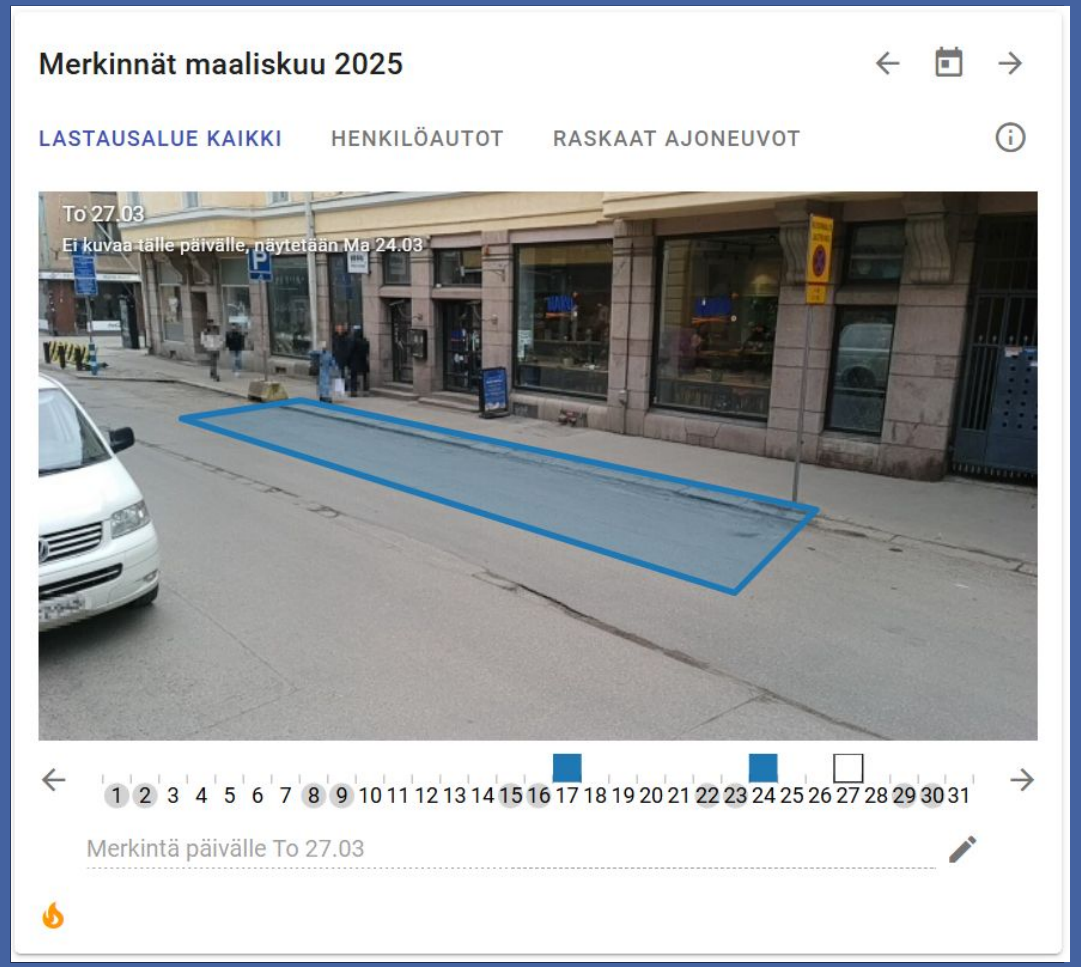
View



Annankatu 6

Installation

View



4. Implementation

Weeks 3 & 4 (31 March – 4 April & 7 April – 10 April)

Weeks 3 and 4 of the monitoring period were mostly free of issues. Recharged batteries were taken to the sites on Monday morning and collected on Thursday. On week 3, one of the cameras did not produce data, as there were problems with its router. However, the router was replaced the next day, which resolved the problem. Other malfunctions did not occur during the monitoring period.

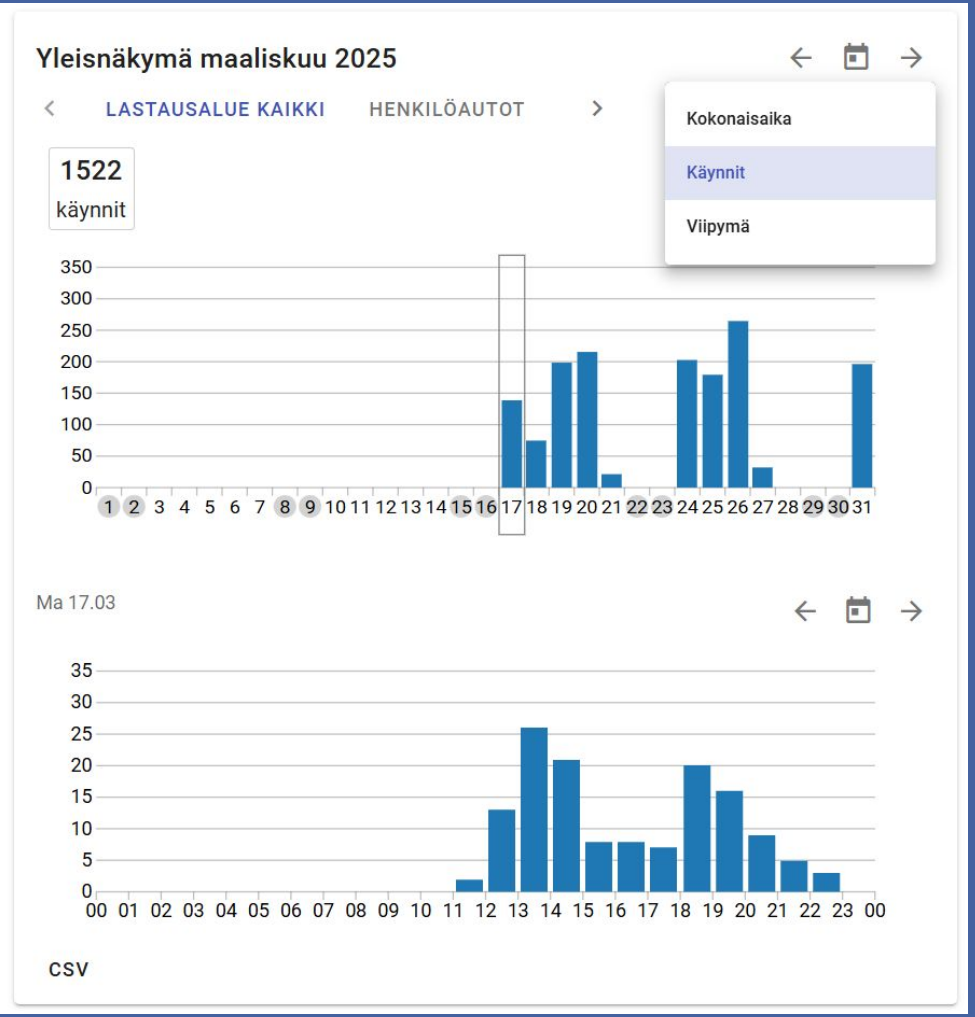
At the end of week 4, the equipment was collected as planned after the four-week monitoring period.

4. Implementation

Signals interface

Real-time monitoring of the utilisation of the loading sites was made possible through the browser-based Signals user interface. The interface made it possible to monitor daily and hourly utilisation. It was also possible to monitor the number of visits, total time spent and length of stay at each loading site. Separation of vehicles into passenger cars and heavy goods vehicles was also possible.

Access to the Signals user interface and user instructions were distributed to a group of personnel from the City of Helsinki and Forum Virium Helsinki.



4. Implementation

Tietorahti interface

One of the objectives of the project was to communicate the status of loading sites directly to distribution transport drivers. For this purpose, we chose to use Tietorahti's Kartta application, which includes a comprehensive set of information that is needed by professional drivers. It is an ArcGIS-based spatial data software that uses the REST API to transmit data. The POST method was used to communicate with the server. As a reference, it was decided that the reservation signal sent to Tietorahti was "1" (reservation) after 20 seconds of continuous identification and "0" (release) after 60 seconds of continuous non-identification. In the future, sensible status information could also be "2" (no information), to indicate that there are problems with communication. However, this was not included in this project.

During the implementation, driver experiences were collected through a separate survey in Tietorahti's application, but an analysis of these responses is not included in this report.

5. Results

During the project, all cameras produced data during the monitoring period (four-week monitoring period, with weekly monitoring from Monday to Thursday). There is a more detailed analysis of the loading sites data on the following slides, but generally, the loading sites are used by heavy traffic in the mornings and afternoons. In the evenings, passenger cars use the sites more as the loading site restriction is no longer in force. Loading points are reserved for distribution between 7:00 and 18:00, but maintenance parking on Iso Roobertinkatu is permitted between 19:00 and 11:00, and this can be seen as a lower utilisation rate in the mornings.

Of the indicators available in the user interface, the total time is the most reliable, and it is what the more detailed observations of the following slides are based on. The issue with visits and delays was related to the positioning of the cameras: when the cameras were positioned diagonally over the street (to avoid issues with vehicle identification while the tailgate is open), larger vehicles stopping momentarily in the line of sight of the camera to the loading site may cause the parked vehicle to be lost momentarily. In that case, several visits can be registered for the same vehicle and the vehicle-specific length-of-stay may reduce accordingly. The total hourly time shown in the results may also exceed 60 minutes if more than one vehicle is identified at the same time (the system presents the sum of these in the total hourly time).

The system is able to identify passenger cars and heavy goods vehicles. However, the neural network of this solution is not optimal for identifying vans and easily interprets them as passenger cars. In Helsinki, a significant part of distribution is carried out with vans, which means that this monitoring did make it possible to unambiguously identify and separate all distribution traffic.

The following slides show the daily and hourly averages at the loading sites during the monitoring period, but it is noteworthy that there were also large differences observed in daily utilisation rates.

5. Results

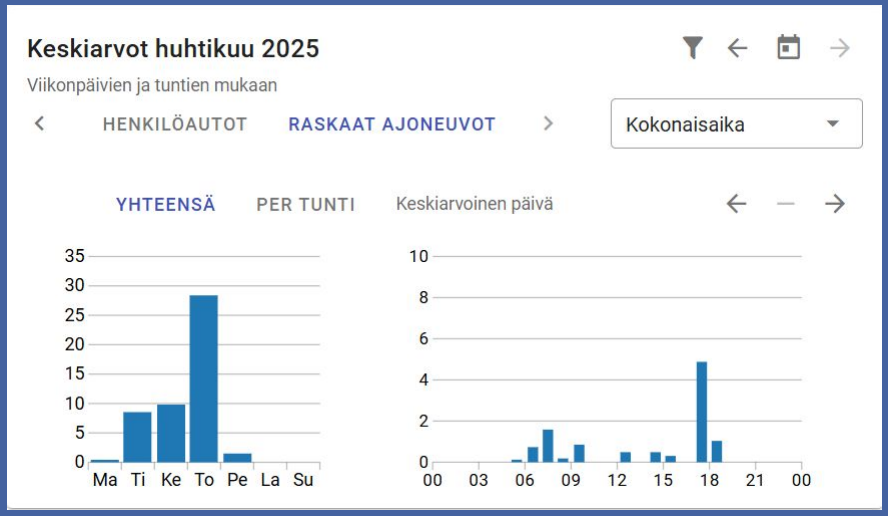
Annankatu 3

Based on the results of the monitoring period, this loading site was one of the busiest and most used by heavy goods vehicles.

5. Results

Annankatu 4

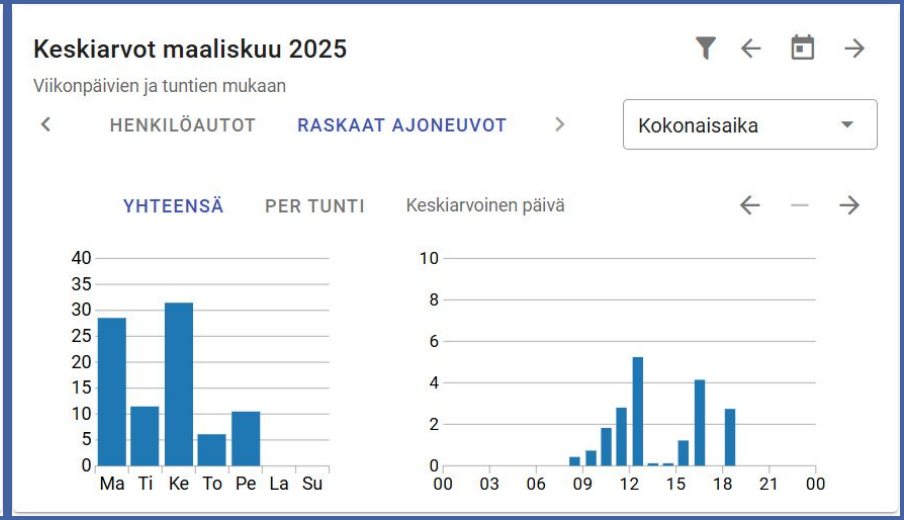
This loading site was the least used by heavy goods vehicles. This can be partly explained by the fact that the camera was positioned directly towards the loading site. As stated earlier in this report, this made it difficult to identify vehicles that had the tailgate open.



5. Results

Annankatu 5

In 2024, this loading site was a parking area for electric scooters. Although now marked as a loading site, a large amount of electric scooters continued to be parked here, which probably made it more difficult for heavy goods vehicles in particular to utilise the loading site. Based on the data, the use of the loading site (for heavy traffic) was smaller than in the other locations.



5. Results

Annankatu 6

Next to this loading site, there was a construction site that had reserved part of the street area. The loading site will probably also have served the needs of the construction site during the monitoring period.

6. Conclusions & reflections

Based on the monitoring period, we can conclude that the machine vision pilot is a suitable solution for monitoring the utilisation rate of loading sites under certain conditions. The positioning of cameras in relation to the loading site is the key issue. When positioned for the loading site, we found difficulties for the neural network to identify vehicles with the tailgate or rear doors open. On the other hand, when positioning the camera diagonally, temporary obstacles between the camera and the loading site (such as large vehicles) become a problem. This makes reliable monitoring of visits and lengths of stay challenging.

We were able to reliably classify vehicles into two categories: passenger cars and heavy vehicles. The latter included heavy goods vehicles and the first included both passenger cars and vans. This limitation makes it difficult to identify distribution traffic with full reliability, as urban distribution is carried out extensively with vans. However, it is possible to train the neural network to identify vans.

We were able to deliver the status of loading sites to an application, which also enabled drivers to utilise this information (Tietorahti's Kartta application). Difficulties in identifying vehicles and positioning of cameras resulted in data that was not as reliable as we might have wanted. Loading sites were reserved after 20 seconds of continuous identification and released after 60 seconds of continuous non-identification. In practice, this made it possible that the loading site was reserved, but an obstacle between the camera and the loading site made it impossible for the camera to identify a vehicle for 60 seconds, incorrectly indicating that the site was "available" for the application. Another company was responsible for the development and maintenance of the driver-facing application, which means that driver experiences of the usefulness of the status information are not included in this report.

7. Recommendations

Based on this project, the piloted machine vision solution is usable for monitoring the utilisation rate of loading sites. However, we recommend considering the detailed requirements of monitoring in terms of continuity. For example, communicating the status of a loading site to drivers requires a more continuous implementation, while it is possible to determine the utilisation rate with a shorter monitoring period. For a continuous implementation, a more effective way is to provide a power supply to the cameras, whereas monitoring of the utilisation rate can also be implemented with a battery-powered solution. In addition to the “free” and “reserved” statues, we also recommend the inclusion of an “unknown” status, which can be sent in case of a disruption, for example. This pilot did not include collecting the driver experience on the usefulness of status data, we do recommend doing so.

We recommend that special attention is paid to the positioning of cameras. In this project, we identified a number of problems with temporary installations on traffic signs. The installation method was also a compromise between cost and quality. The most functional and reliable solution would have been to place the cameras higher and aim them at an angle. This would ensure that the shape of the vehicle corresponds to the model taught to the neural network and eliminate obstacles between the camera and the loading site being monitored. However, such a solution is difficult and expensive to implement as a temporary solution, but if a longer-term implementation is planned, doing so definitely the best method.

In this report, the analysis of the data obtained from the monitoring of loading sites is very superficial. The raw data collected during the monitoring has also been delivered to the client, and we recommend a more detailed analysis of it. As a whole, the sample of this dataset is limited, as it only includes the loading sites at the crossroads of Annankatu and Iso Roobertinkatu. It is difficult to draw conclusions on the utilisation rate of loading sites for the whole region from this data. However, the project demonstrates a cost-effective way of collecting data on the utilisation rate, and we recommend more extensive utilisation of the data in the development programme of the city’s loading sites.

8. Contact information

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