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Proposal Project: Smart Navigation in Transport Interchanges: A Mobile App Case Study of Príncipe Pío

APP Name: A DÓNDE VAS?!

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Mayo, 2025.

Contents

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Project Background:

- Why is relevant to implemented this in an interchange?
- Characteristics of the case study and relevance in the Transport Network

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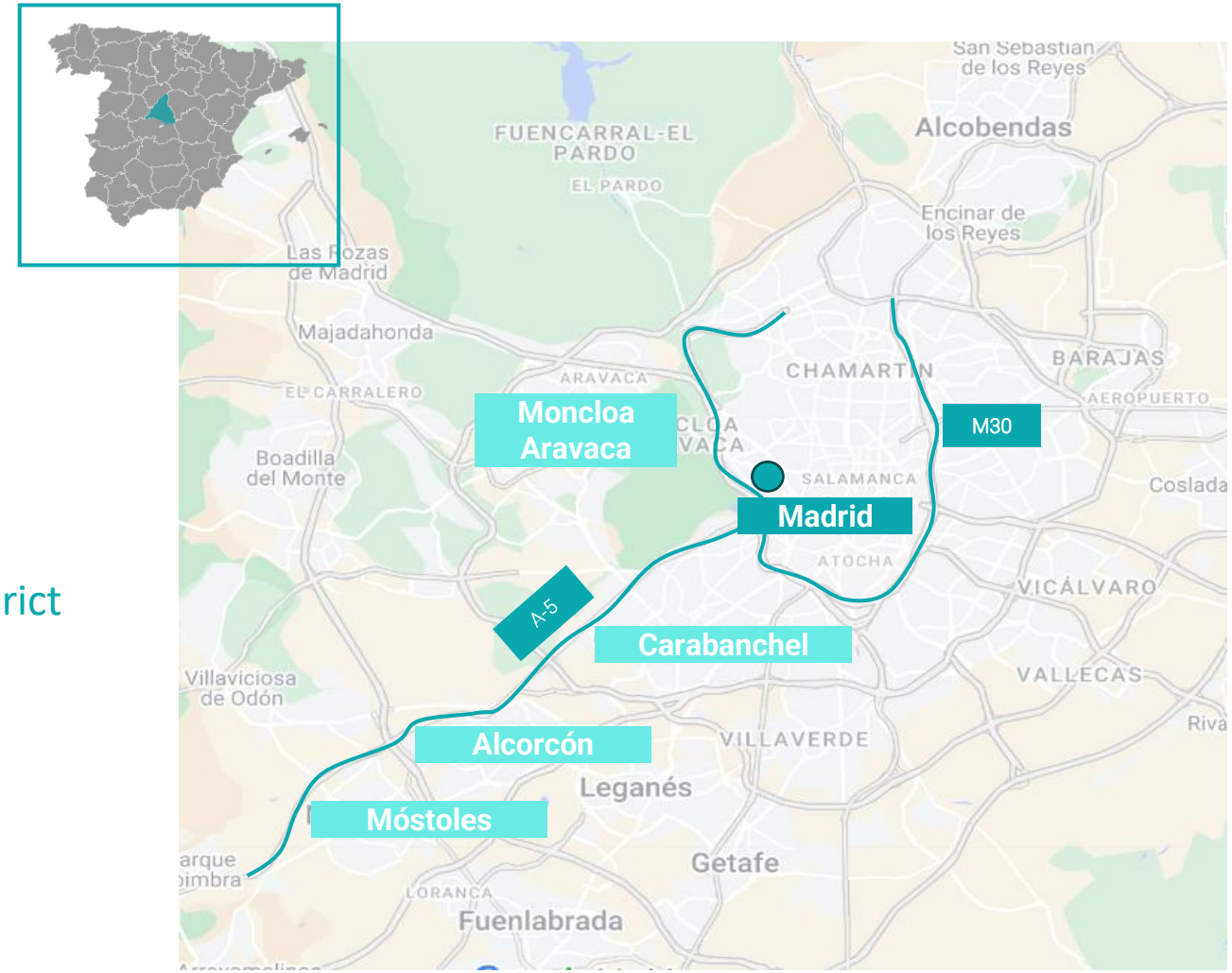
Principe Pio Interchange Station

Situated next to the River Manzanares, near the San Vicente roundabout, between the streets Cuesta de San Vicente, Paseo de la Florida, and Paseo del Rey in **Madrid's Moncloa-Aravaca District - Argüelles Neighborhood**



3.7M
Madrid City

270k
Moncloa-Aravaca District

The station also connects to major roadways, **including the A-5 (Carretera de Extremadura) and M-30**.

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Principe Pio Interchange: Services

3 Metro Lines

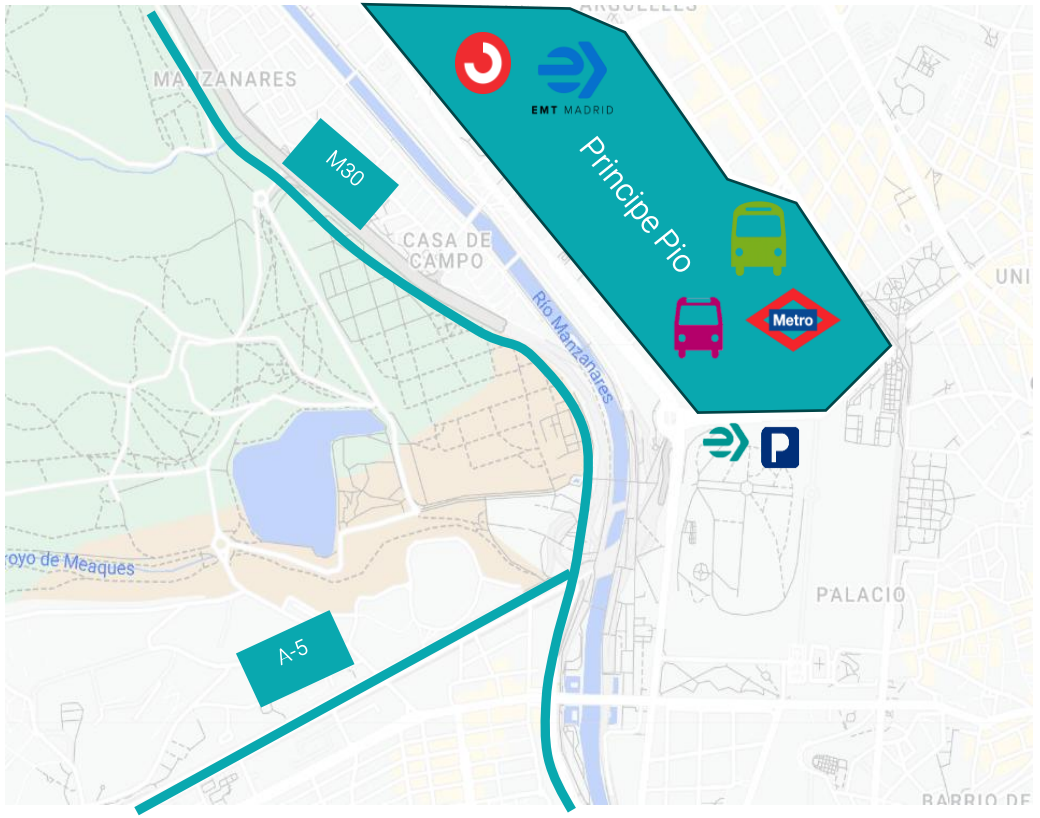
Lines 6, 10, and the Ramal branch Ópera - Príncipe Pío.

Line 6 is the busiest line in the system. Known as the "**Circular**" line. It connects with central Madrid, linking major neighborhoods, educational institutions, and transit hubs.

3 Cercanías Train Lines

Commuter rail lines C-1, C-7, and C-10 provide additional regional connectivity.

C-1 is the most used. It connects **Madrid-Chamartín** with **Príncipe Pío**, passing through stations such as **Sol**, **Atocha**, and **Argüelles**.



32 Urban and Interurban Buses Lines

8 City Lines
22 Intercity Lines
2 Long-distances Lines

Park-and-Ride

1.5k Parking spaces

BiciMad

Station 2081

~ 15 Bikes

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Principe Pio Interchange: Demand

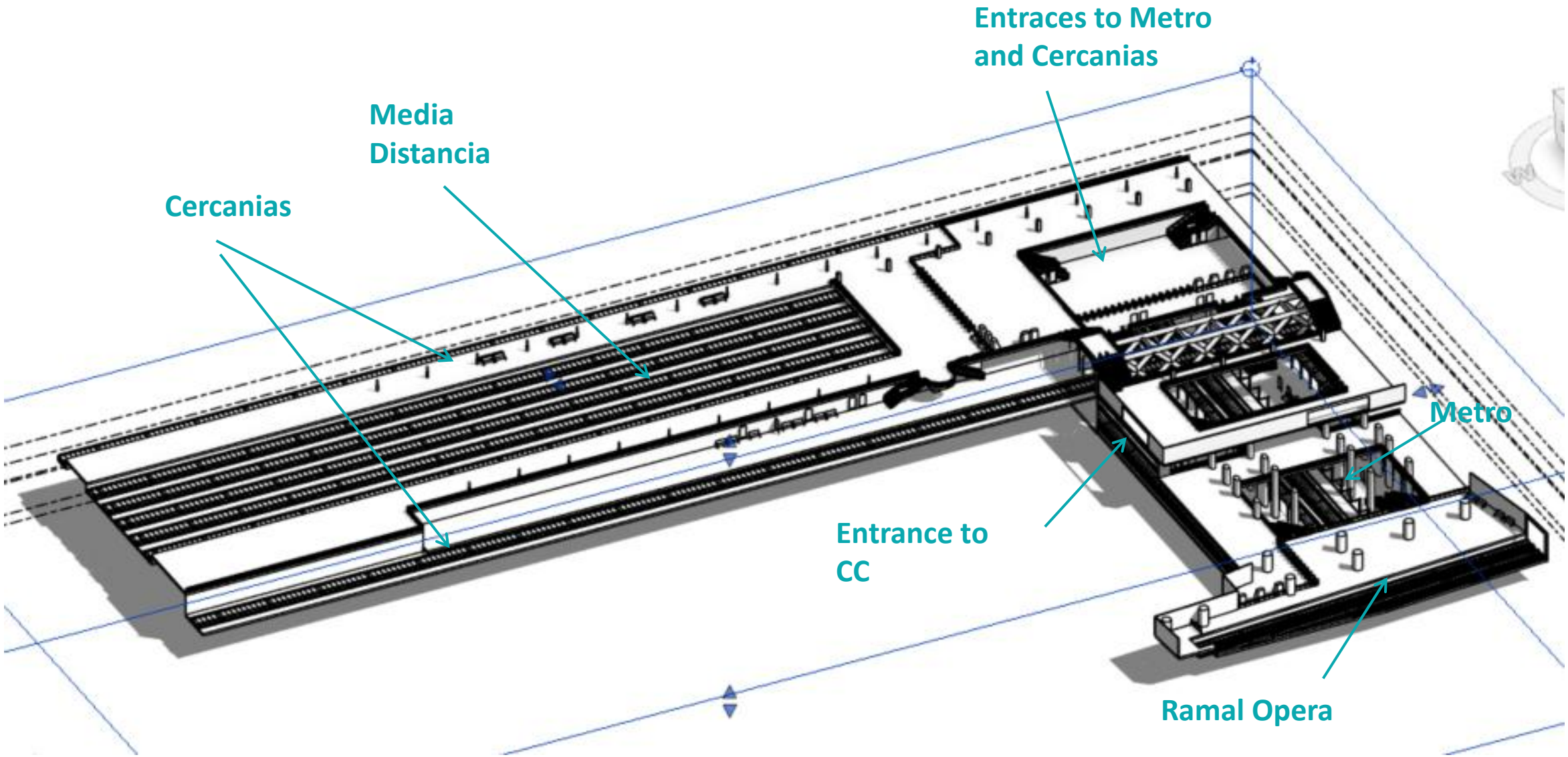
- Príncipe Pío features the Centro Commercial Príncipe Pío, a shopping center located within the station complex, creating a convenient stop for shopping and dining.

- The station is located close to Madrid's historic and cultural sites, such as the Gran Teatro CaixaBank and Madrid Río park, the station is ideally situated for both daily commuters and visitors seeking to explore Madrid's vibrant cityscape.

+385.5K
Passengers
per day

9.7M
Passengers
January-June 2024

3D Model


Entraces to Metro and Cercanias
Media Distancia
Cercanias
Metro
Entrance to CC
Ramal Opera

Identified Issues & Objectives

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Identified Issues

Lack of schedule and frequency coordination between services: Challenges in ensuring smooth flow across modes, both in daily operations and during special events.

Passenger organization issues in waiting areas and commercial zones: Improved crowd management is needed in these areas.

Enhanced monitoring and maintenance practices: maintenance needs should be detected early to minimize disruptions and reduce rehabilitation costs.

Interaction with nearby infrastructure (A5 and M30) and impact on the Low Emission Zone (LEZ): Better integration with surrounding road networks is needed to manage environmental impacts and traffic flow.

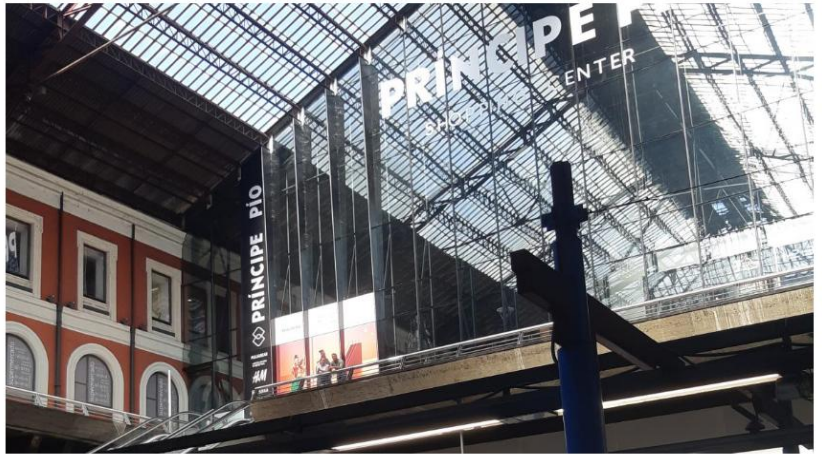
Environmental management: Addressing noise, air quality, and temperature control within the interchange, to create a more comfortable environment.

Real-time information for operators and users can be improved: timely communication across different transit providers is needed.

Inadequate signage within the interchange: makes navigation difficult for users. Clearer directional signage would enhance user navigation.

La Comunidad de Madrid aumentó un 8% los usuarios de los intercambiadores de transporte público de enero a junio

La Comunidad de Madrid ha superado en los primeros seis meses del año los 47 millones de usuarios de los cinco grandes intercambiadores de transporte público que existen en la actualidad en la región. Esta cifra supone un incremento del 8% comparado con el mismo periodo de 2023.



24 agosto 2024

El área intermodal más utilizada ha sido Moncloa con 17 millones de pasajeros de enero a junio de 2024. En segunda posición se sitúa el de Príncipe Pío con 9,7 seguido del intercambiador de Plaza de Castilla con 8,6. Por último, la cuarta y quinta posición las ocupan Avenida de América con 7,8 y Plaza Elíptica con 4 millones, respectivamente.

MADRID

Indignación por las largas colas en el intercambiador de Moncloa para subir a la sierra

— Decenas de madrileños que optaron por el transporte público se queda sin poder subir a los puertos ante la afluencia masiva de gente

General Objective

To enhance user experience and improve wayfinding, signposting, and information accessibility within transport hubs, ensuring seamless and efficient navigation for all users, particularly those unfamiliar with the system.

Specific Objectives

Implement a dynamic, interactive mobile app that uses geolocation and real-time data to guide users from their current location to desired destinations within the transport hub, reducing confusion and frustration

Display real-time, accurate transport schedules, delays, and incidents across various transport modes (bus, metro, train) on the mobile app and digital screens located within the hub to ensure users have the most up-to-date information.

Integrate sensors or cameras to detect congestion levels in real time, allowing users to avoid overcrowded areas and optimize their route for a smoother, quicker experience.

Develop a platform that ensures data security and can be scaled to different transport hubs while maintaining consistent user-centric services. Ensure that the app incorporates robust cybersecurity protocols to protect user data.

Project Roadmap

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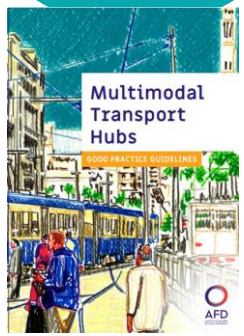
Project Road Map

NODES
New tOols for Design and OpEration of Urban Transport InterchangeS

Review international guidelines and standards and analyze worldwide case studies.



Identify and mapping structure and facilities characteristics, data sources, flows, general operation.

Define architecture of IoT sensors and data sources, and standardization of key areas and general Interchange structure.

Process data and analyze information demand across all transportation modes and passenger flow.

Apply and integrate different technologies and models for developing an infrastructure management system.

Develop an optimization and integrated model for Interchange management.

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The Solution

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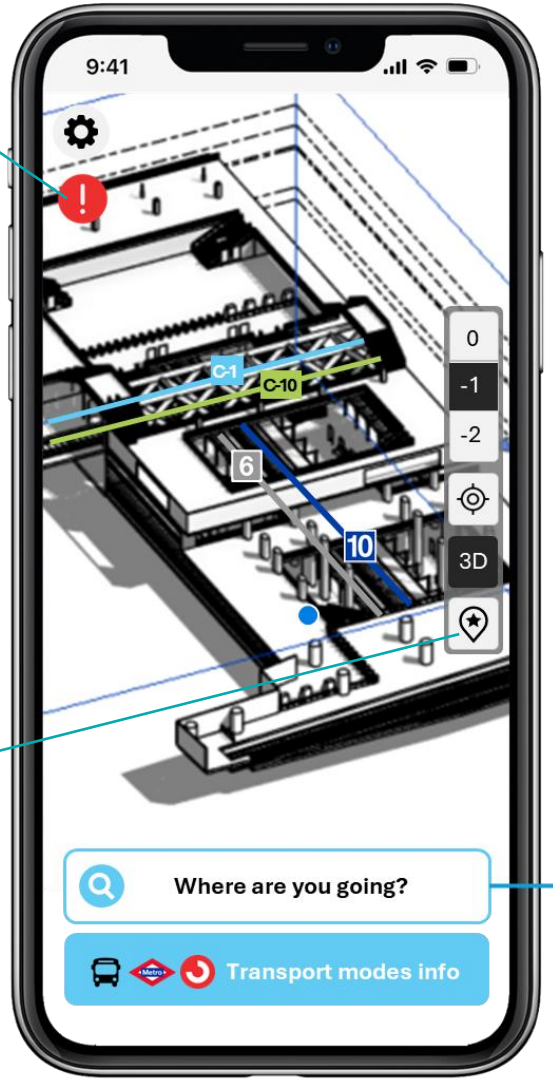
Frontend: A DÓNDE VAS?!

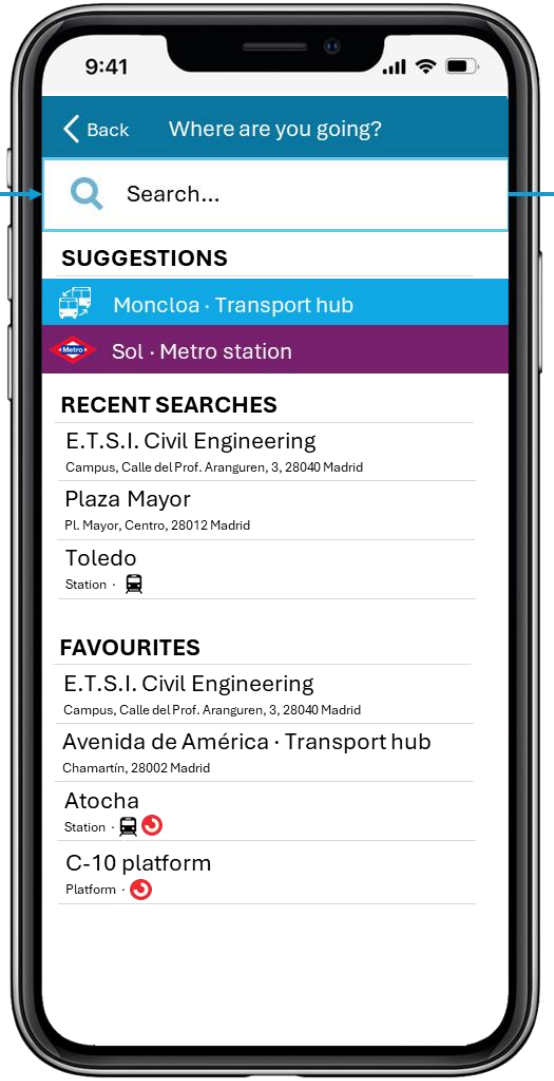
Real-time alerts:
Notifications about route changes, delays, closed access points, or high congestion.

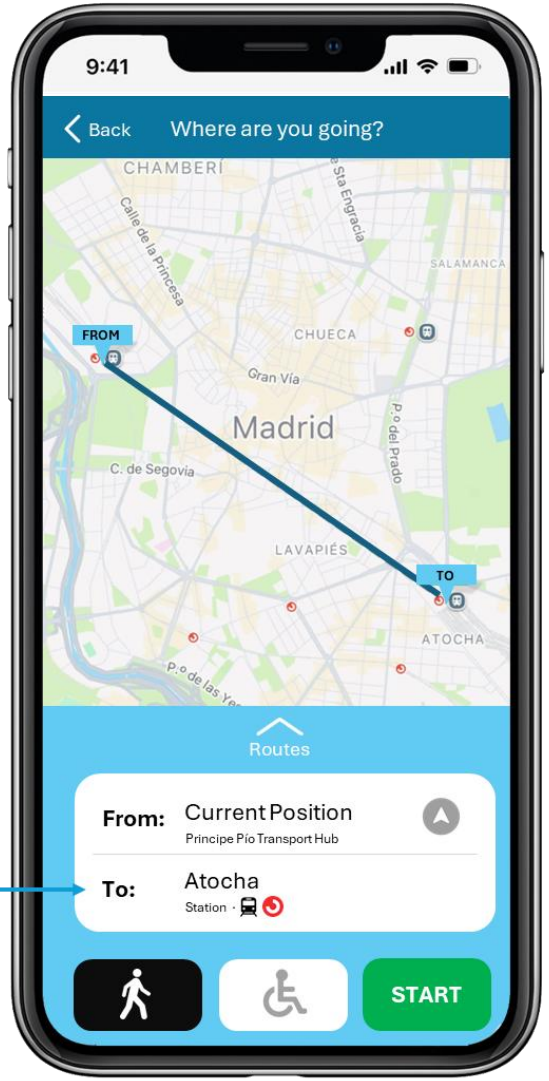
No alerts New alert

Interactive 2D/3D map:
Detailed representation of the transit hub with real-time routes.

Points of interest:
Location of restrooms, ticket booths, ATMs, rest areas, and commercial establishments.







USER-CENTERED designed tool for new and concurrent users

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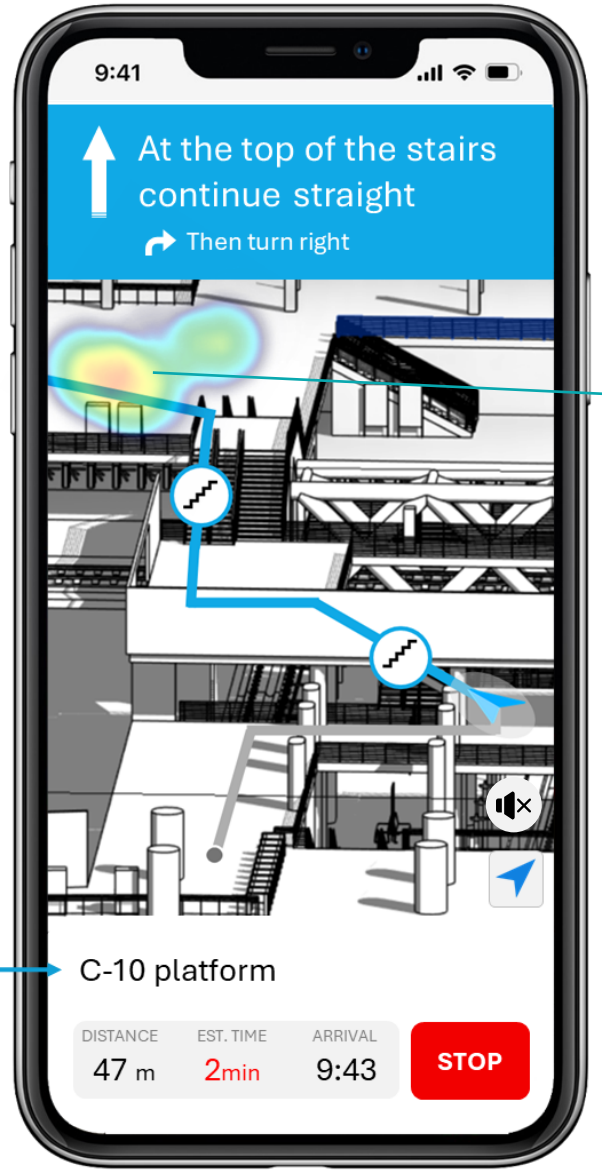
Plan the route and follow directions inside the interchange station

04

Toggle for accessible routes:
Options for people with reduced mobility, indicating elevators, ramps, and escalators.

Transport mode selector:
Allows the user to choose the preferred mode of transport.

Routes organized by transport modes and sorted by shortest travel time to the destination.



Step-by-step directions:
Visual and voice guidance to reach the nearest platform, station, or exit.

Congested area:
Visualization of areas with high congestion in real-time. Congestion affects estimated time.

Estimated travel time:
Calculation based on distance, crowd congestion, and user mobility.

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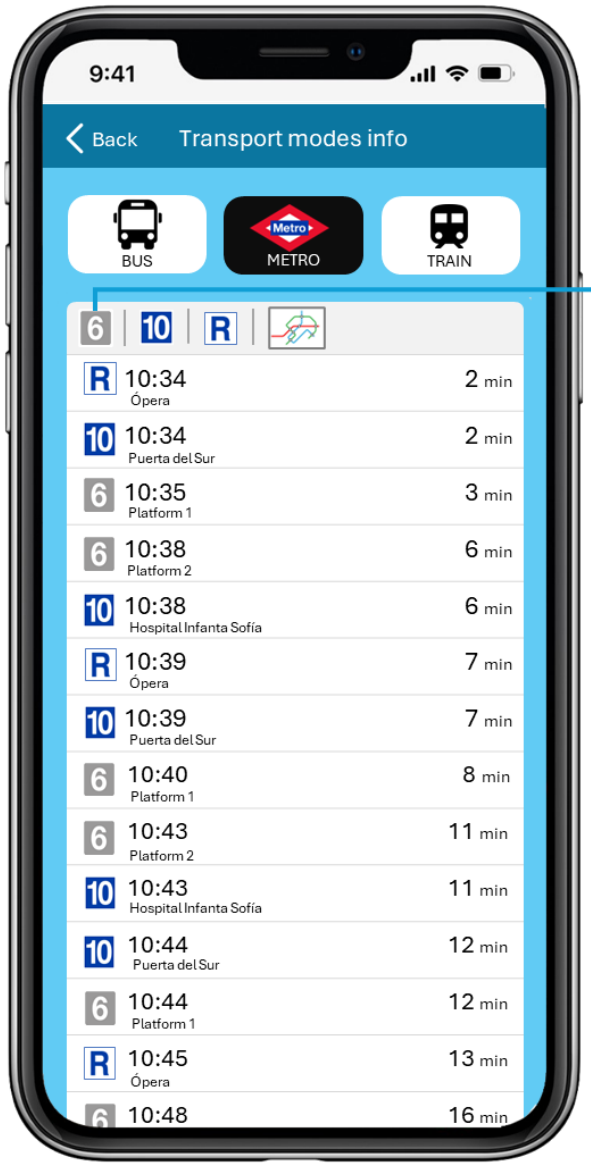
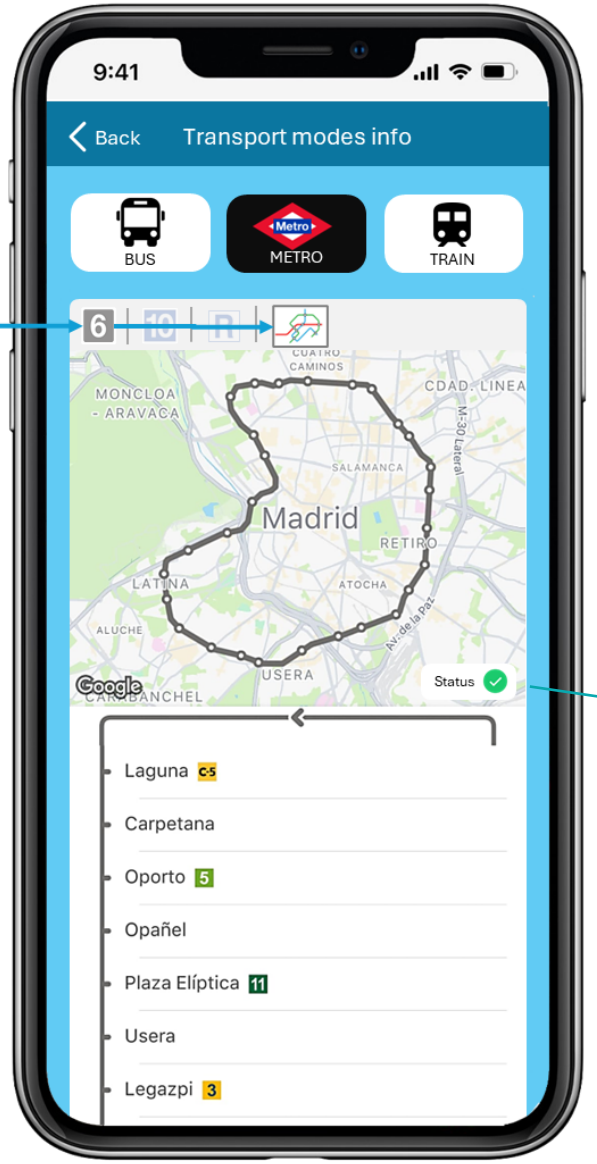
Transport modes information in real-time

Filter by transport mode and line.

Transport modes information menu:
Real-time information on transport schedules and route maps in a single menu.





Route maps:
Real-time information on transport schedules and route maps in a single menu.

Service status:
Real-time information about route changes or delays.

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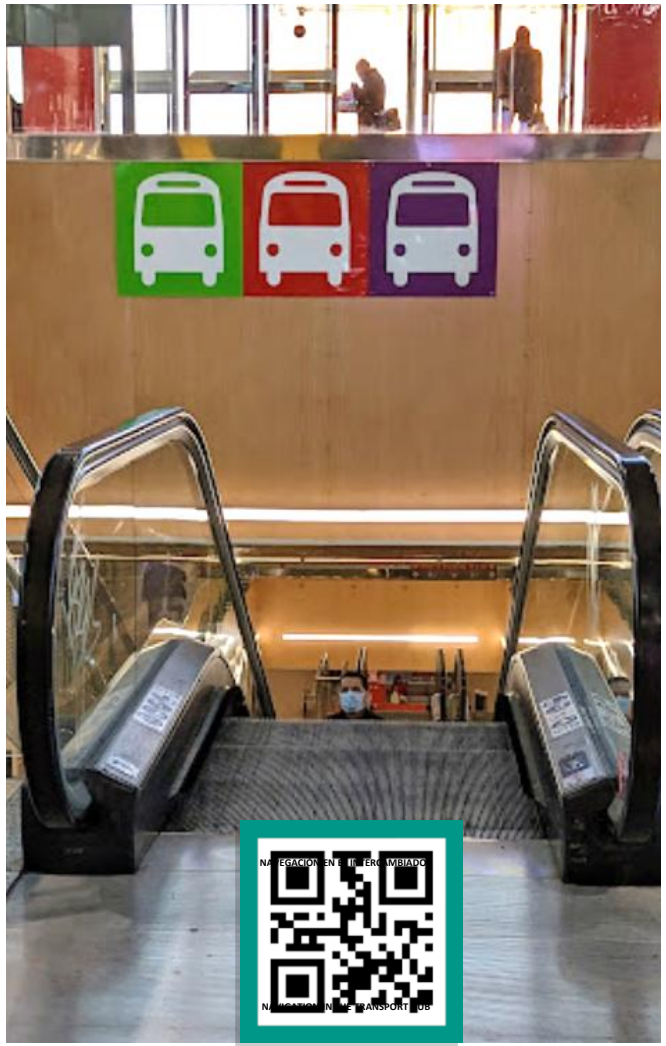
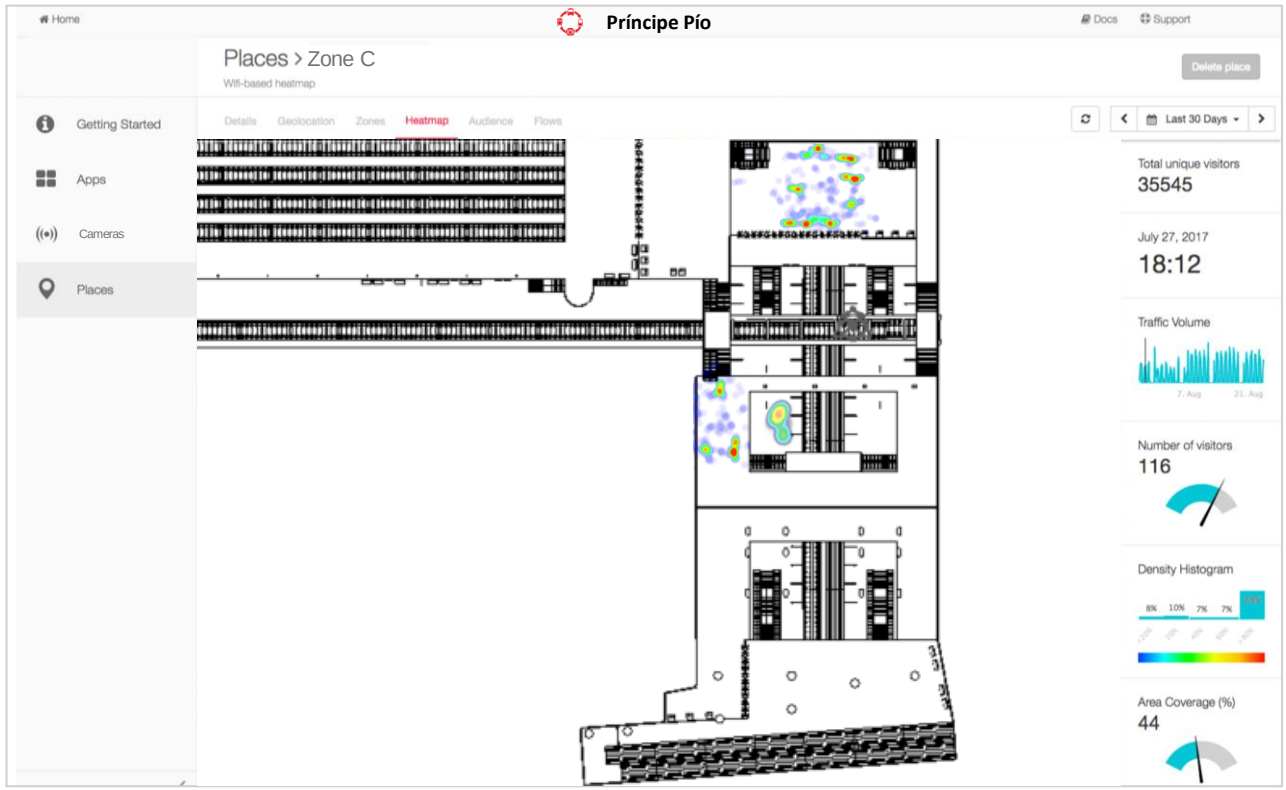
QR access



QR code to scan and navigate directly through the interchange station.

Add-on: Control panel for operators



Cameras information and location

People flow heatmap

Real-time statistics

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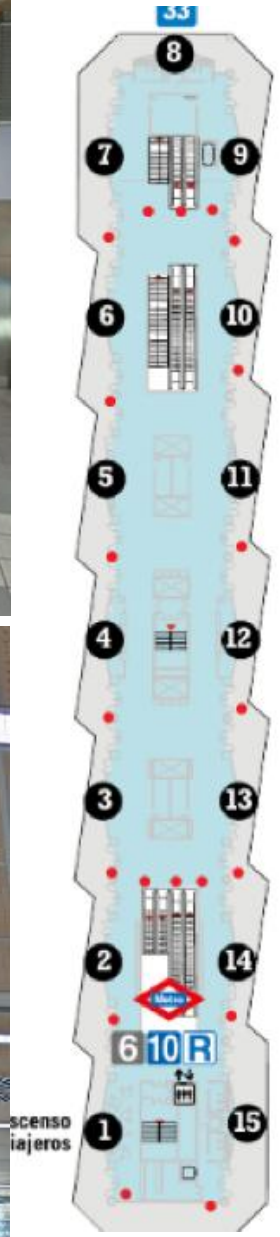
Sensors Analysis: Cameras

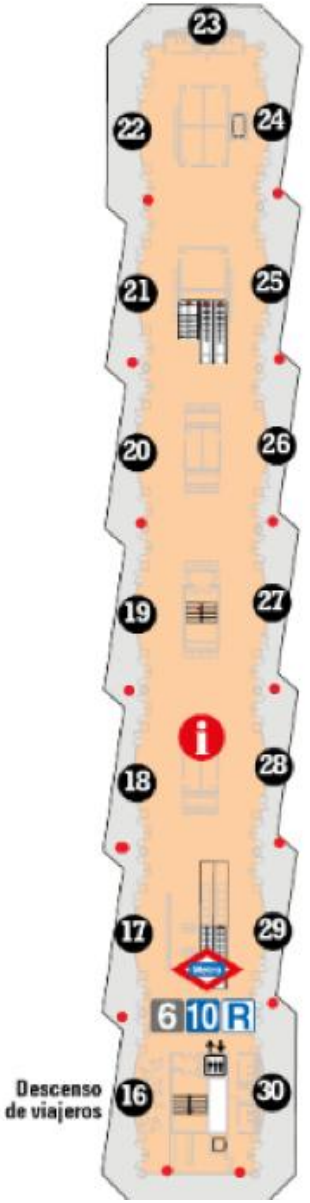
Domo Cameras:

- Integrated IA
- Yolo8-Detection

Bus station

AI video and audio analytics





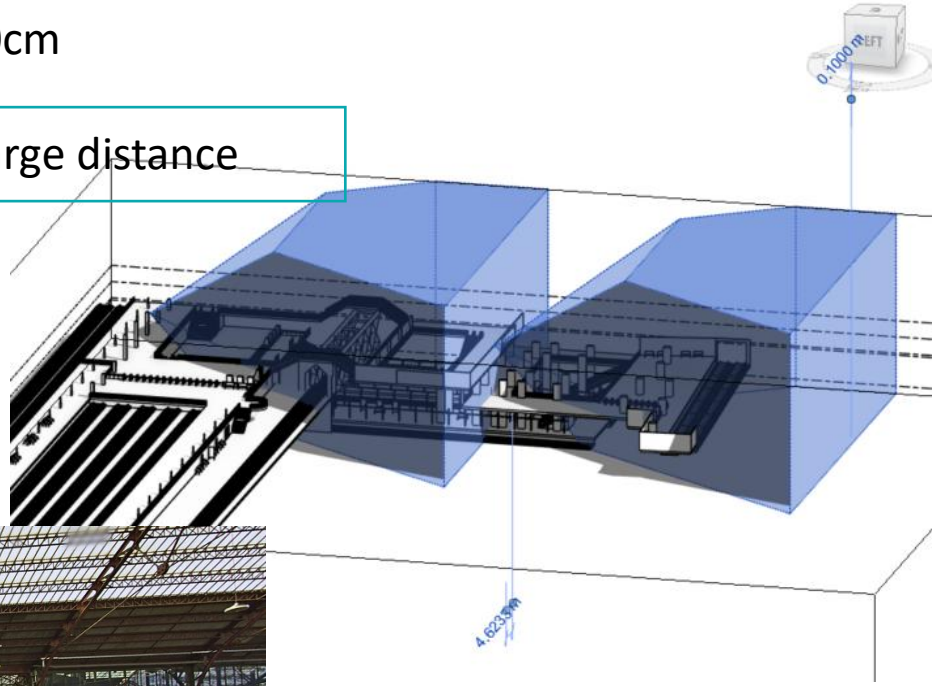
Metro station

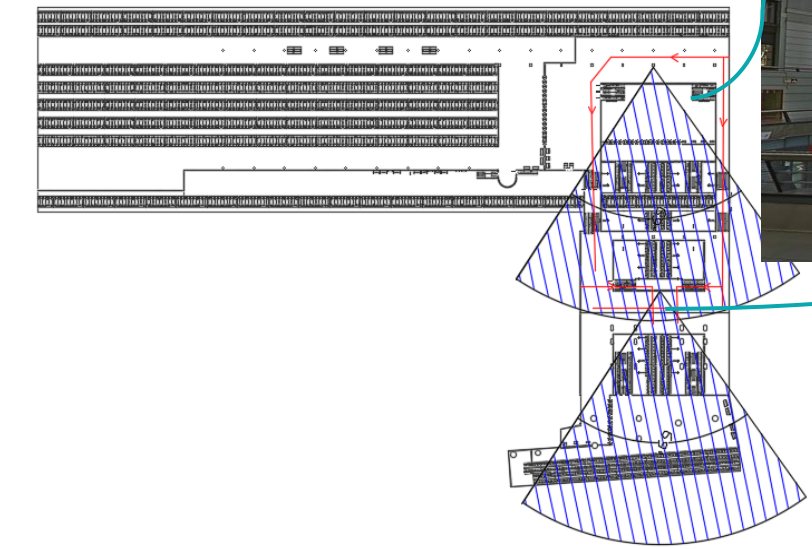
OAK-1 PoE:

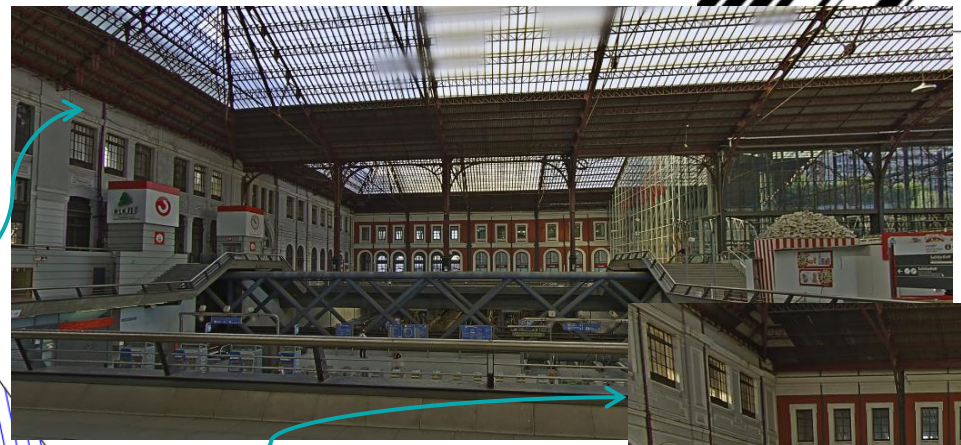
- Auto- Focus-8 to 50cm
- Fixed-Focus- very large distance

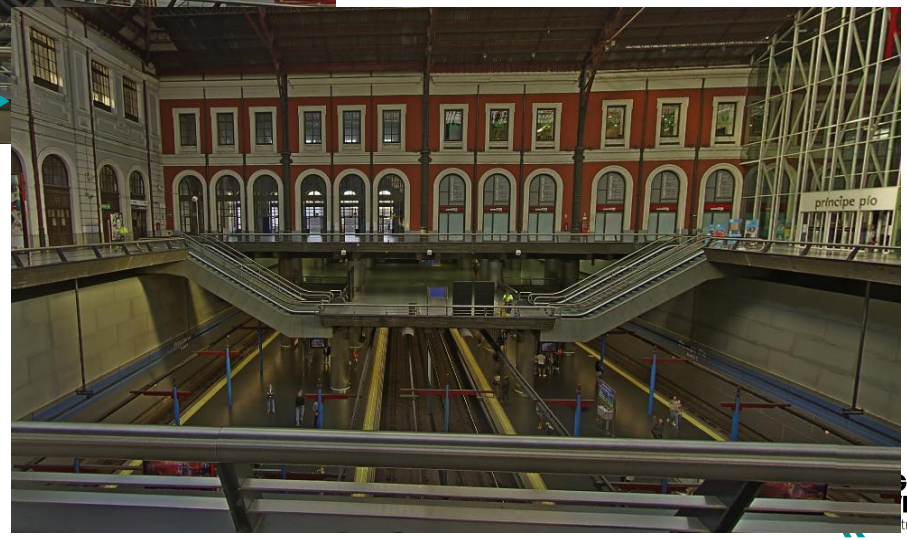
Camera specifications:

- Focus: FF: 50cm- inf
- FOV (Display/Horizontal/Vertical): 82° / 69° / 55°

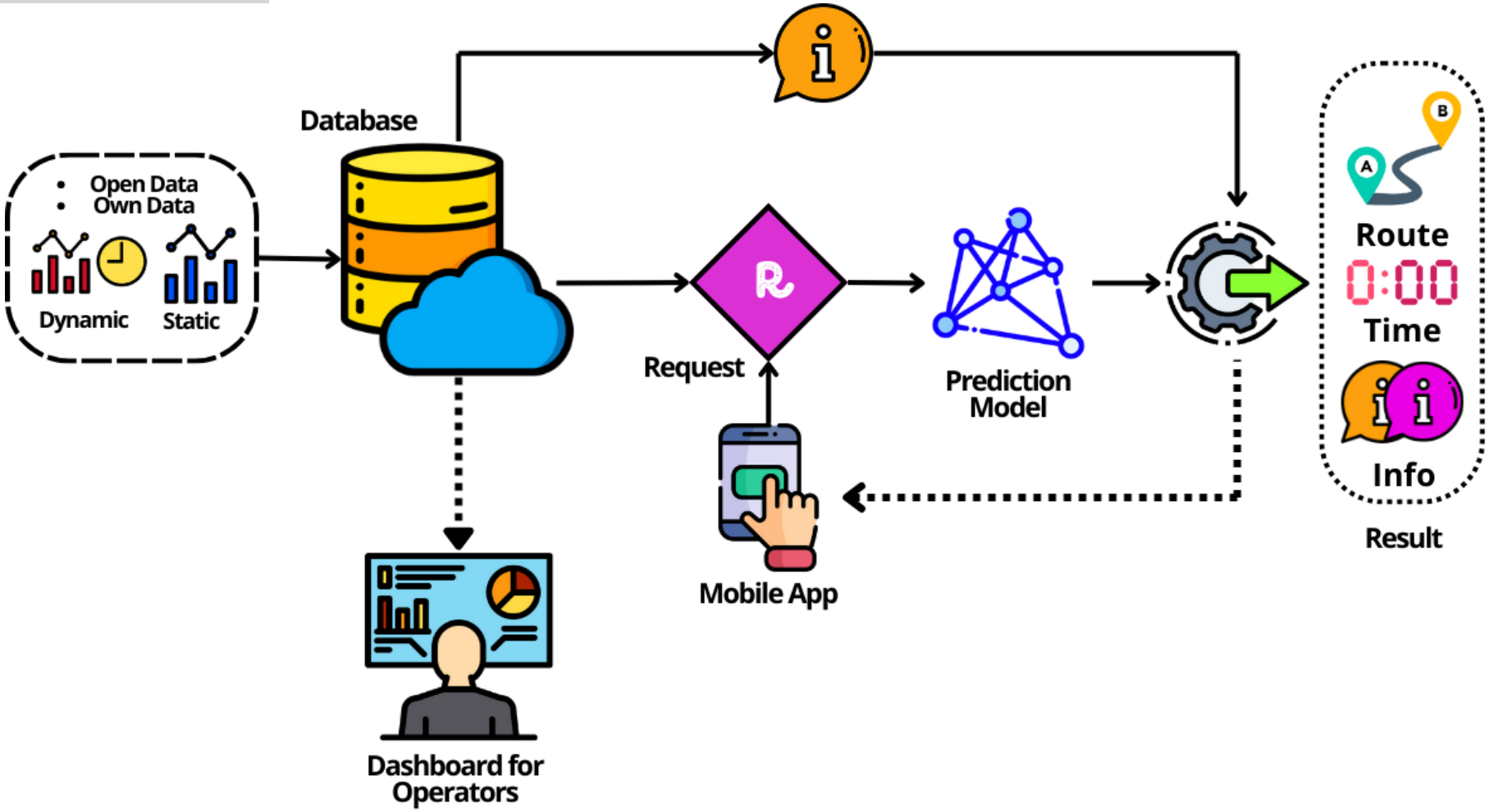








Backend



Information flow: Closed feedback loop, as the user's input (Request) is needed to execute the algorithm and generate the result.

Database
Scheme

3 Data sources:

1.Proprietary Data of the interchange operators.

2.Data Generated by the installed Cameras.

3.Open-source data available for the city.

Open-Source Data

City Council Information

Traffic_Data	
PK	UniqueID

Environmental_Data	
PK	UniqueID
	Weather Condition

Proprietary Data

Interchange Information

In_Out_Interchange	
PK	UniqueID
	Buses transit inside

Docks_Buses	
PK	UniqueID
	Boarding Desembarking

Internal_Envir_Conditions	
PK	UniqueID
	Temperature, humidity, noise...

Alerts	
PK	UniqueID
	Accidents, situations..

Transport_modes	
PK	UniqueID
	Reports: Metro, Bus, Cercacías

Cameras_Data	
PK	id INT NOT NULL
FK1	camera_id INT NOT NULL
	instant TIMESTAMP NOT NULL
	status INT NOT NULL
	data INT NOT NULL

Cameras_Facilities	
PK	id INT NOT NULL
FK1	camera_id INT NOT NULL
FK1	facility_id INT NOT NULL

Facilities	
PK	facility_id INT NOT NULL
FK1	classification_id INT NOT NULL
	cameras JSON NOT NULL

Facilities_classification	
PK	classification_id INT NOT NULL
	facility VARCHAR NOT NULL
	description VARCHAR NOT NULL
	width VARCHAR
	location POINT NOT NULL

Generated Data

Cameras	
PK	camera_id INT NOT NULL
	location POINT NOT NULL
	description VARCHAR NOT NULL

Incidents	
PK	id INT NOT NULL
FK1	camara_id INT NOT NULL
	instant TIMESTAMP NOT NULL
FK2	category_id NOT NULL

Incidents_categories	
PK	category_id INT NOT NULL
	facility VARCHAR NOT NULL
	description VARCHAR NOT NULL
	width VARCHAR

Dynamic (Real Time)

Static

Latent

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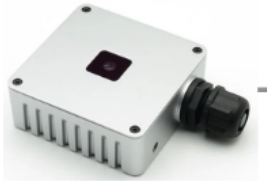
LOCAL AREA NETWORK (LAN)

SENSORS



392-OAK-1-POE

SWITCH

Cisco Catalyst 2960X-48FPD-L

LOCAL SERVER

Dell PowerEdge R740

Real-time object detection algorithm based on CNN

occupancy: 20

HTTP POST /api/occupancy

```
{
  "camara_id": "Cam_Hall_1",
  "data": 20,
  "instant": "2025-02-13T12:34",
  "status":1
}
```

Endpoint

API RESTFul

CLOUD SERVICES: AWS

amazon RDS

PostgreSQL

Amazon SageMaker

anylogic

Simulation Model

AWS Amplify

FRONTEND

Revit

AUTHENTHICATION

AWS Cognito

Amazon API Gateway

AWS Lambda

Amazon CloudWatch

BACKEND AND SECURITY

FINAL USERS

Devices and Services

Agent-Based Simulation model (I)

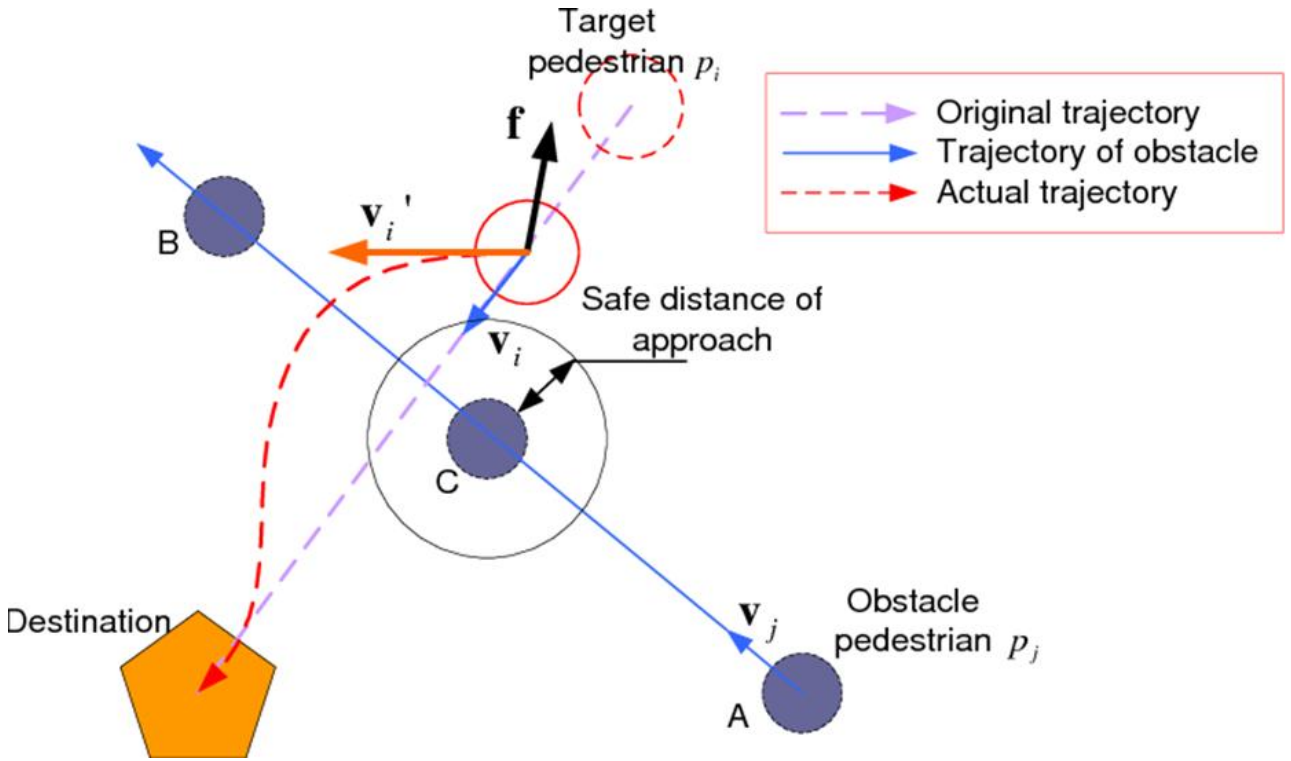
The model could integrate AnyLogic (pedestrian flow simulation) with Revit (BIM model) and use real-time data from OAK-1 cameras to continuously update passenger movement and calculate estimated travel times.

Agent-Based Model

Each agent (e.g., a passenger) behaves autonomously and responds dynamically to changes in the system (they walk at different speeds and take different routes)

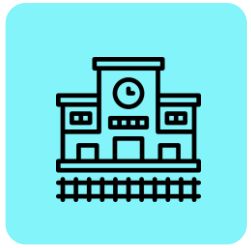
Social force model

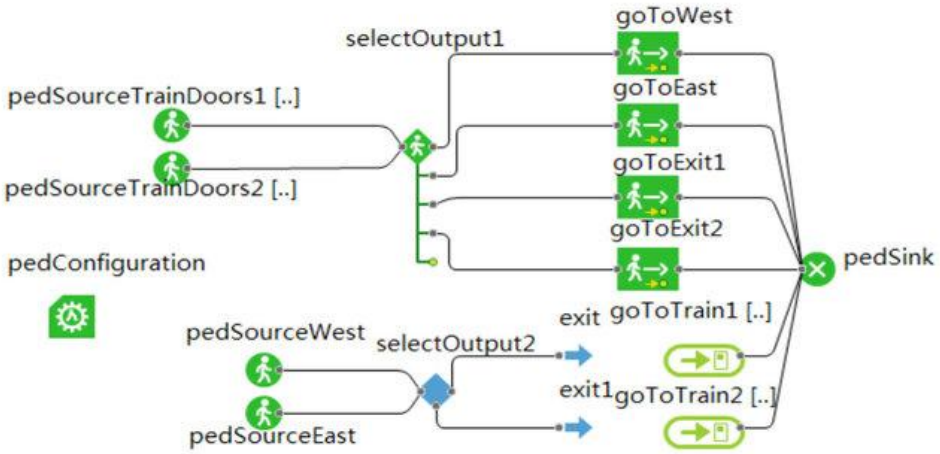
Pedestrians in AnyLogic move according to a social force model. They choose the shortest route, avoid collisions with other objects by analyzing the current environment, and make decisions on further movements.



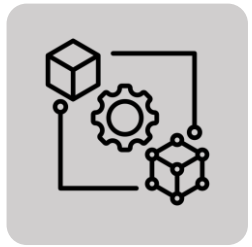
Agent-Based Simulation model (II)

Phase 1
Simulate Interchange Station

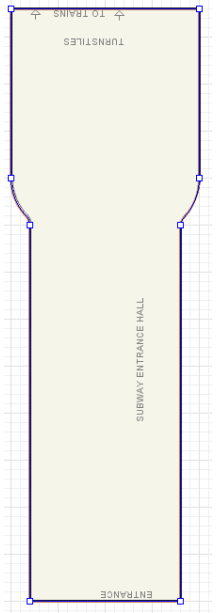




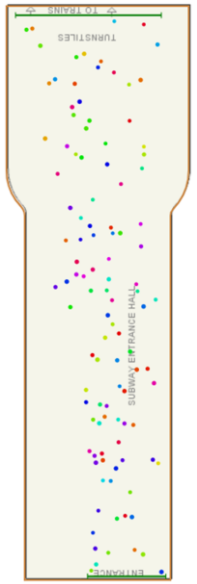
Phase 3
Run the simulation

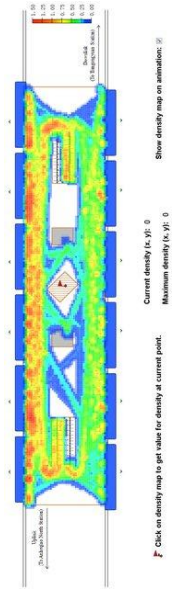


Time of arrival estimation



Phase 2
Creating a flowchart defining the passenger flow





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Project Cost Breakdown

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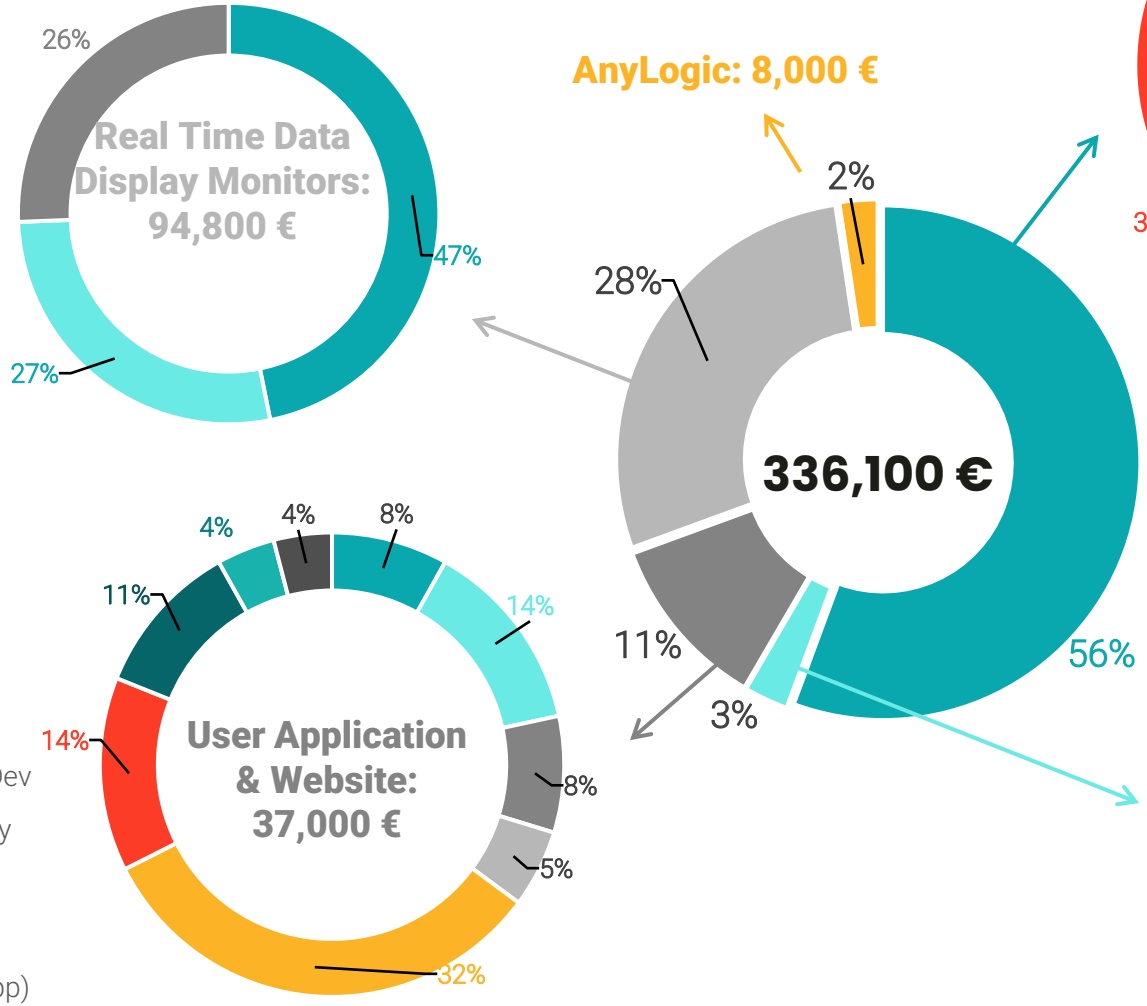
Investment



- Data Display Monitors
- Software Development for Integration
- Installation

- Strategy Analysis
- Asset & Documentation Analysis
- BIM Modeling
- Inventory & Data Ontology
- DT Platform Configuration
- DT Functionality Implementation
- Integration of Systems
- Results Monitoring & Evaluation

- Design & UX/UI
- Backend Dev
- Frontend Dev
- Real-Time Integration
- Native/Multiplatform Dev
- Real-Time Functionality
- UI/UX for Mobile
- Testing & Validation
- Deployment (Web & App)

- Cameras
- PoE Power
- Installation Accessories
- Medium Cabinet
- Switch
- Mounting Accessories
- DELL Server E5 32GB 1TB
- VMS Licenses
- Office Licenses
- Recorder
- Installation
- Analytics Setup
- Central Deployment
- Training
- Rental for Installation

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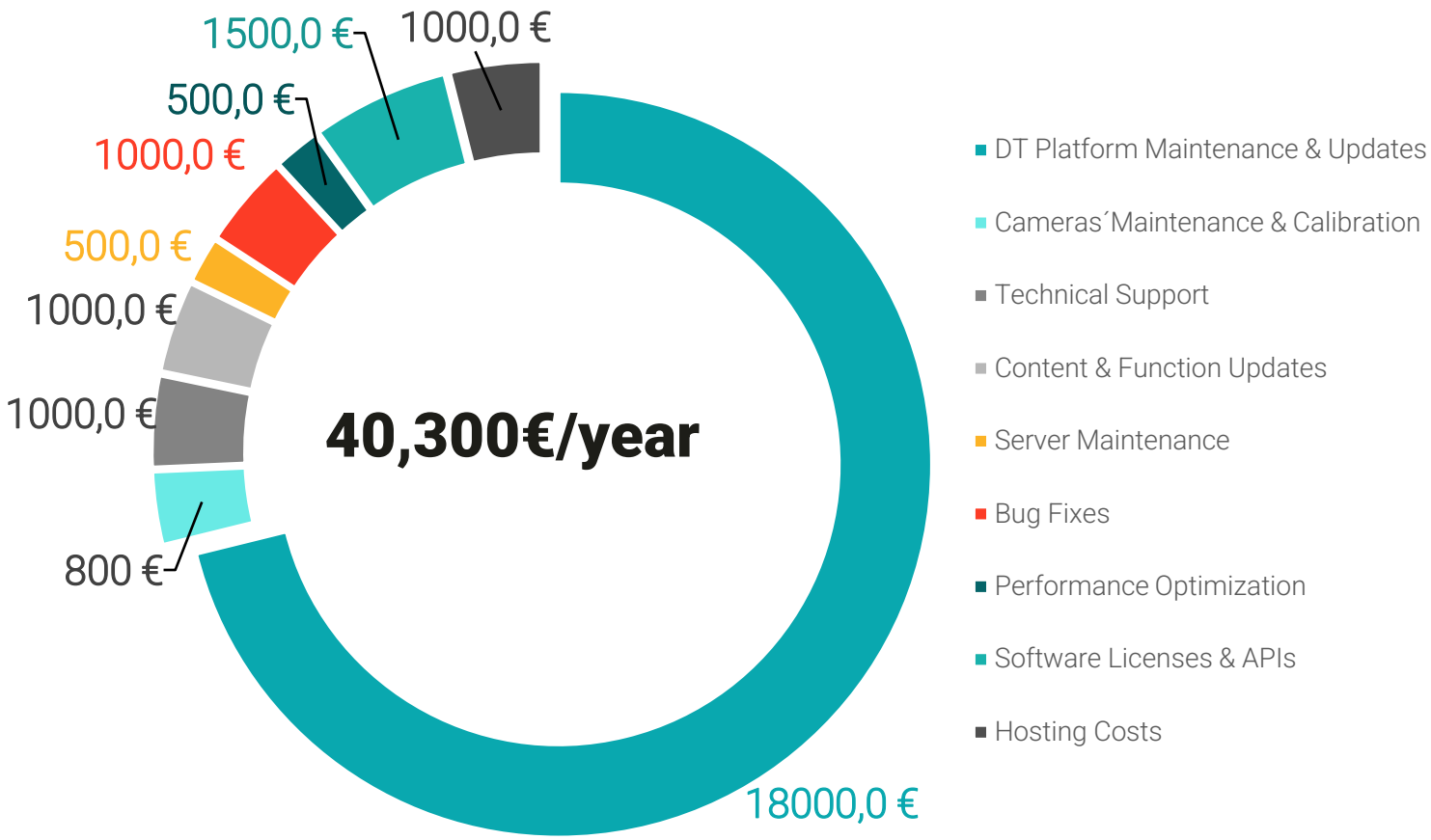
Maintenance



BUDGETING CONSIDERATIONS

- Benchmark analysis based on similar projects in the country.
- Consultation with key industry players to refine estimates.
- Potential for future scalability and growth.

Conclusions

Conclusions

After analyzing the key issues at Príncipe Pío, we decided to prioritize improving user wayfinding, addressing people distribution, movement, and flow throughout the hub. **Given the large volume of users, enhancing movement and reducing congestion became a critical focus**.

Focused on improving wayfinding and addressing people movement within Príncipe Pío, a hub with high traffic, to facilitate smoother navigation and reduce congestion

The solution enhances the user experience, especially for people with disabilities, ensuring greater accessibility.

The Digital Twin system can be extended to other transport hubs, including larger facilities like airports, offering a flexible, long-term solution.

The solution minimizes confusion, reduces reliance on physical signage, and increases user independence, ultimately improving the hub's usability.

The system will streamline and optimize daily tasks for staff by providing real-time data, reducing the need for manual interventions, and improving operational efficiency..

The system can integrate additional services, such as parking or bike availability, and can scale to accommodate more transport modes and data sources, enhancing operational efficiency across different hubs.

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Thank you!