

# The Foretelling Subway: Environment and Situation

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## ABSTRACT

In this work we introduce the environment for passenger occupancy prediction

## 1. INTRODUCTION

Underground transportation systems have significant impacts on energy consumption at a regional scale. While the transportation systems, i.e. trains, has observed regarding energy efficiency, the subsystems of metro stations and surroundings, such as ventilation, escalator and lightning are mostly unexplored.

Although a nominally small percentage of energy can be saved with an efficient management of these subsystems, a large energy saving in absolute terms can be obtained. In other words, a 5% energy saving in non-traction electricity consumption in one year, is equivalent to the electricity consumed in more than 700 households.

The remainder of this paper is organized as follows. In Section 2 an overview of SEAM4US project is given. Followed by Section 3, the metro station. In section 4 the passenger density data extraction is described. Section 5 discusses the passenger density data. Last, Section 6, draws our conclusion.

## 2. SEAM4US PROJECT

To investigate on energy efficient subsystems (ventilation, escalator, lightning), the EU funded in the Seventh Framework Programme the project "Sustainable Energy mAnAgeMent for Underground Stations" (SEAM4US). The aim of SEAM4US "is to develop advanced technologies for optimal and scalable control of metro stations [...]" [1].

In cases where the SEAM4US system performs energy management tasks based on situations taking place in the future, a predictive control architecture is used [2]. The control architecture proactively controls the metro station subsystems under different passenger density and thermal conditions. To control in a foreseen manner, prediction models are used. Besides others, one prediction model is the user

model, which predicts the passengers density in a certain section, on a certain time in the future.

The SEAM4US consortium consists of nine partners from six different EU countries, namely Cofely, UniVPM, UPC, Fraunhofer FIT, VTT, Almende, UniKassel, CNET, and TMB. Each partner supports the consortium within its expertise:

**Cofely** Cofely Italia Spa (Italy):  
Energy-efficient system management.

**UniVPM** Universita Politecnica Delle Marche (Italy):  
Building and environmental physics and construction.

**UPC** Universitat Politecnica De Catalunya (Spain):  
Building and environmental physics and construction.

**Fraunhofer FIT** Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V (Germany):  
R+D experts in middleware.

**VTT** Teknologian Tutkimuskeskus VTT (Finland):  
R+D experts in middleware.

**UniKassel** University of Kassel (Germany):  
User and agent-based scheduling modeling.

**Almende** Almende B.V. (Netherlands):  
User and agent-based scheduling modeling.

**CNet** CNet Svenska AB (Sweden):  
System integrator.

**TMB** Transports Metropolitans De Barcelona Sa (Spain):  
Metro network operator.

The SEAM4US system is implemented in the underground station "Passeig de Gràcia". Section 3 gives more details about the station.

## 3. PILOT STATION "PASSEIG DE GRÀCIA - LINE 3"

The SEAM4US system is implemented in the line station Passeig de Gràcia - Line 3 (PdG-L3), which is a station within TMBs metro network in Barcelona. This section describes the station in detail, while the understanding of a "station" in the context of metro networks is defined first.

In general a metro network consists of one or more metro lines. Each line has a defined railway with a given number of stops to allow passengers to get on or off the trains. Each of

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these stops is called "line station". In contrast, a "metro station" represents the point in space through which passengers get underground and into a line station. Metro station and line station can be the same physical entity, but it is possible that a metro stations holds more than one line stations.

The metro station Passeig de Gràcia (PdG) lies in the iconic and touristic part of Barcelona. Some popular buildings designed by Antoni Gaudí (Casa Batlló, Casa Milà) as well as the city's most renown and exclusive boutiques are in the proximity. The metro station is one of the oldest of the Barcelona metro network. First opened in December 1924, as station for Line 3 (L3), nowadays PdG holds three different line stations: Line 2, Line 3, and Line 4. The line stations were built in three different periods, using different construction technologies. All line stations have been refurbished a few times since 1924, and new equipment has been added recently. Figure 1 depicts an entrance/exit of metro station Passeig de Gràcia.



**Figure 1:** Passeig de Gràcia Entrance/Exit Gran Via. [3]

Depending on the weekday PdG is open 19 hours, 21 hours, or 24 hours. Between Monday and Thursday PdG service starts at 5:00 and ends at 24:00 (19 hours). Friday service starts at 5:00 and ends at 2:00 (21 hours). On Saturday service starts at 5:00 too but remain the entire night and day until Sunday midnight.

As pilot station for the SEAM4US system Passeig de Gràcia - Line 3 (PdG-L3) was selected since it turns out to be representative for many station within TMBs metro network [3]. The count of fans, escalators, and the platform schema is comparable to other stations. Moreover, PdG-L3 is a crowded station which have low-rate usage hours as well. Therefore a wide range of data are available, that allows to test with very busy peak hours as well as with off-peaks.

### 3.1 Spaces

The line station PdG-L3 consists of private (staff only) and public spaces. Private spaces such as technical rooms or staff dependencies are not part of the investigation of the SEAM4US project. Public spaces, such as halls, transit

areas, accesses to the platforms, and platforms are, however, in the focus.

Essential part of (every) line station are the platforms, which allow passengers to leave and enter trains. PdG-L3 laid out on a PRRP schema - Platform-Rail-Rail-Platform. The PdG-L3 platforms are depicted on Figure 2. To leave the platforms, several escalators are available. Figure 3 depicts exemplarily an escalator.



**Figure 2:** PdG-L3 Platforms. [3]

A schematic representation of PdG-L3 is drawn in Figure 4, where the platforms are highlighted in red. At the beginning and end of the platforms, the accesses to the platforms are visible.

### 3.2 CCTV System

Throughout the station a Closed Circuit Television (CCTV) surveillance system is installed. 20 CCTV cameras provide images for security reasons. Figure 5 show exemplary CCTV cameras on the platform (Figure 5(a)) as well as in the transit area (Figure 5(b)).

The CCTV System provides valuable information for the SEAM4US system, which is explained in the following section.

## 4. PASSENGER DENSITY DATA EXTRACTION

The SEAM4US system uses prediction model for proactively controlling the subsystems - as mentioned in Section 2. Besides others, the passenger density model is a part of the predictive controlling architecture. To predict passenger densities for a point in future, the model utilizes the output from the CCTV monitoring. In order to extract the passenger density within the station, the CCTV system is enhanced with image processing.

Whenever camera pictures are processed privacy issues are tackled. In order to ensure the passengers privacy several design constraints where defined:

1. All CCTV images are processed within the station.
2. All CCTV images are processed "on the fly". For the purpose of passenger density extraction, no CCTV image is saved.



(a) CCTV camera installed in a PdG transit area. [3]

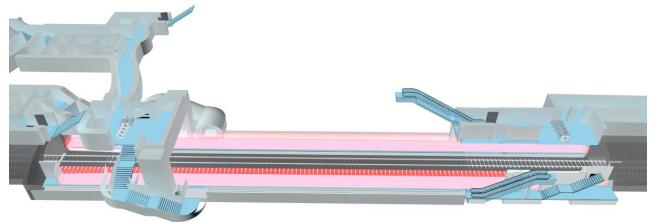


(b) CCTV camera installed in PdG-L3 platform. [3]

**Figure 5: Passenger density distribution of one CCTV camera in PdG-L3.**



**Figure 3: Escalator in PdG-L3 for leaving the platform. [3]**



**Figure 4: Schematic representation of PdG-L3. The platforms are highlighted in red. [3]**

3. The image processing is performed on a separate computer, which is not connected to other TMB Systems and is only accessible via a dedicated VPN connection.
4. The image processing works without human interaction.
5. The image data are filtered to avoid recognisability of individuals.
6. The image processing results are transmitting only in terms of integer numbers to the database.

With respect to these design constraints, the passenger density extraction was implemented. The workflow is described briefly in the following.

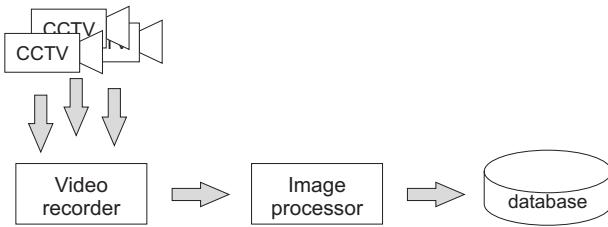
First, the video streams coming from all cameras are combined into one single video stream by a video recorder. This video recorder creates a carousel video composed of sections for the individual camera appearing in a predefined order. The duration of the camera sections is set to 3 seconds. With 20 cameras and 3 seconds hold on each, one turn of the carousel is completed in about one minute.

The video recorder is connected to the local computer and transfer the images subsequently. On the local computer,

the density estimator processes the transferred images and extracts the passenger density.

The density estimator algorithm uses a combination of edge detection and background subtraction. In the following, the algorithm is described briefly. First the algorithm separates background and foreground. Followed by creating the foreground mask. Through filtering the edges of the foreground only are extracted. The foreground edges are combined with the foreground mask. Finally, the result is refined by dilating (and then eroding) the segmented blobs. For different reasons, e.g. occluded or damaged camera, it is possible that the passenger density algorithm fails. In this cases, the algorithm returns the error value "-1".

The extracted passenger density as well as date, time and the camera-ID of the image are transmitted to the database. The general approach is depicted in Figure 6.



**Figure 6:** Gathering number of people out of the camera images.

The CCTV and image processing runs 24 hours, 7 days a week. Each day 28800 datasets are transmitted to the

database. Overall the database contains 90 days of data. The available data are discussed in the next section.

## 5. PASSENGER DENSITY DATA

In order to model the passenger density an understanding of the available data is necessary. In this section the data, visible pattern and other features are discussed.

Figure 7(a) illustrates exemplary the available values of a camera and week. At a more detailed view Figure 7(b) shows the passenger density level of a camera and (week)day. On both Figures, the PdG service times are visible due to the low passenger density level between 01:00 and 05:00 on weekdays.

## 6. CONCLUSION

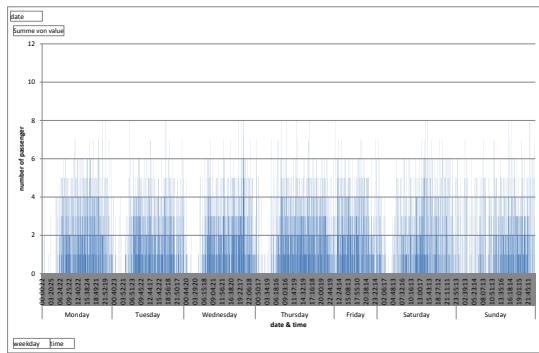
Conclusion

## Acknowledgements

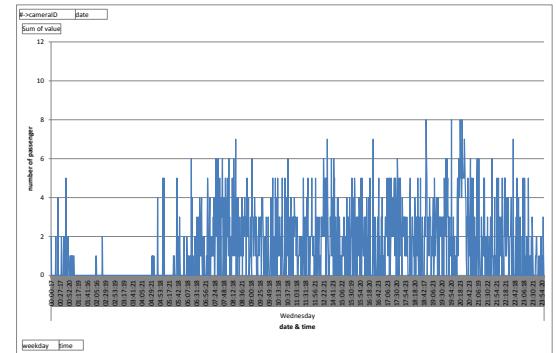
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## 7. REFERENCES

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- [2] Roberta Ansuini, Massimo Vaccarini, Alberto Giretti, and Sara Ruffini. Models for the real-time control of subway stations. Chambéry, France, August 2013.
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(a) Passenger density distribution of one camera during one week.



(b) Passenger density distribution of one camera during one day.

**Figure 7: Passenger density distribution of one CCTV camera in PdG-L3.**