VAL_09: Improving the efficiency of the bus service and comfort of PT users

Description of the measure and main outcomes expected

This measure aims to introduce a system that allows for accurate passenger counting within buses and tracks boarding and disembarking stops for each passenger, facilitating the calculation of transport Origin/Destination matrices. The measure involves developing and deploying an advanced camera-based passenger counting system with artificial intelligence on buses. The objectives of this measure include providing real-time bus occupancy data to EMT for responsive service adjustments and to third-party applications to enhance the overall passenger experience. Furthermore, the system will analyse patterns of passenger entry and exit to enhance the precision of detailed origin-destination matrices.

Preparation of the measure

Definition of technical requirements and architecture

The solution developed should be capable of accurately counting passengers inside a vehicle and identifying boarding and disembarking stops to complement the transport Origin/Destination matrices.

Figure 1: Overview of bus where the system will be installed.

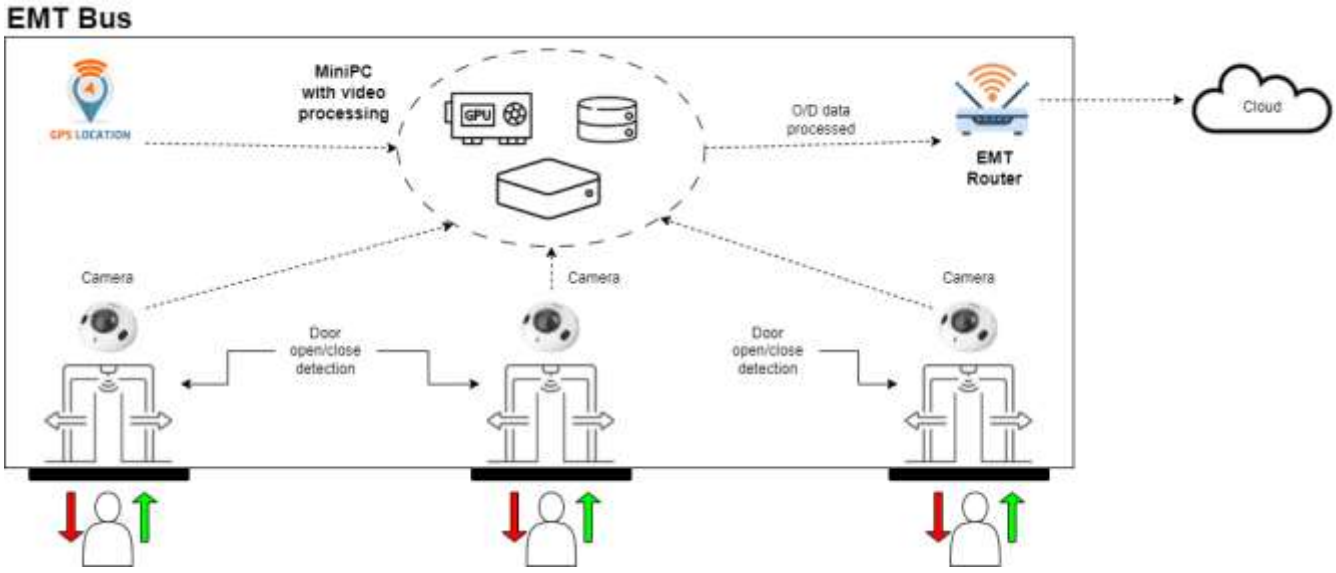

Figure 2: System Architecture Overview

Technically, the system requires installation of cameras and processing units on the vehicle. The system shall be composed of a camera for every boarding and disembarking gate of the vehicle and a processing unit.

These cameras will track identified individuals to re-identify them and detect when they exit the vehicle, thereby subtracting them from the total passenger count. Identification will not rely on facial recognition but on techniques to extract individual characteristics. The identification of the users will be carried out in the system itself by means of the hardware component designed for this function.

In addition to image recognition, the system will detect the bus location to link boarding and disembarking actions at specific stops, enabling accurate formation of Origin/Destination matrices. This linkage will utilize location data obtained from the bus itself or an integrated GPS device within the system.

Alternatively, this linking of identification/stop can be achieved through the unequivocal detection of the vehicle and the mounted system, by cross-referencing detections with the timestamps used in identification.

The specific requirements established for the solution are listed below.

ID	Technical Requirements	Category
VAL09_TR01	The system should use high-resolution cameras capable of capturing clear images in various lighting conditions, including low light and nighttime	Hardware
VAL09_TR02	The system should use robust and weather-resistant cameras designed to withstand the vibrations and environmental conditions inside a bus	Hardware
VAL09_TR03	The system must incorporate a processing unit capable of running AI algorithms locally to reduce latency and bandwidth usage	Performance
VAL09_TR04	The system must have sufficient processing power to handle real-time image analysis and counting tasks	Performance
VAL09_TR05	The system must have reliable connectivity options (e.g., 4G/5G, Wi-Fi) for transmitting data to central servers or cloud platforms	Performance

VAL09_TR06	The AI algorithms used must have high accuracy in detecting and counting passengers, even in crowded conditions	Performance
VAL09_TR07	The system must have a secure and efficient storage of counting data	Performance
VAL09_TR08	The system must ensure that no personally identifiable information is captured or stored by the system	Security
VAL09_TR09	The system must adherence to relevant data protection regulations, such as GDPR	Security
VAL09_TR10	The system should use secure and vibration-resistant mounting solutions for cameras and processing units	Security
VAL09_TR11	The system must have reliable power supply options, possibly integrated with the vehicle's electrical system	Performance
VAL09_TR12	The system should be designed to be easily scalable to accommodate new routes	Performance
VAL09_TR13	The cameras should allow to use Power over Ethernet (PoE) technology to eliminate the need for separate power supplies	Performance

Table 1: The specific requirements established for the solution

The mounted hardware system shall initially consist of:

EDGECO

1 Jetson Orin NX 16GB VRAM

1 SD 128GB

GPS receptor module

DH-IPC-HDBW1430DE-SW

One camera connected to the EDGECO system for each of the vehicle's up and down doors.

Software development for AI-based passenger counting

To ensure a proper achievement of the measure VAL_09, an AI expert system has been developed, with the aim of being able to obtain a source-destination matrix in real time of all passengers that have used the current bus.

The system is composed by the following components:

Line Drawer: In charge of defining the line in each of the bus doors to properly detect insertions and deletions of passengers.

Persons Detector: In charge of detecting all persons in the bus using a neural network, assign an identifier to each detected person, with an own tracking algorithm, use the obtained id of each person to properly decide in which direction is crossing the line and discard the ones that are not in a crossing mode.

Embedding Extractor: In charge of extract a representation of each person that has crossed the line in a 1D vector shape using another convolutional neural network.

Manager: In charge of getting extracted embeddings and using another neural network based on re-identification to detect which persons have left the bus in each bus stop and send these results to the cloud in a source-destination matrix format (Format is pending to be defined in the future)

The software is ready to be able to accept disconnections in the hardware since it is always writing the results in the disk.

Finally, to be able to upload results in the cloud the system is connected to a MQTT queue which is receiving them and being read by another process to manage the results.

Software testing and validation

To test and enhance the accuracy of the recognition system, a preliminary pilot was conducted within ETRA's offices. The selected location for this pilot was a corridor and distribution area with dimensions (length and width) and pedestrian flow similar to that of a bus. This initial phase enabled fine-tuning of the detection system before progressing to the next stage – pilot test directly on a bus.

Challenges & Mitigations

No challenges were identified, the measure preparation went according to the plan.

Next steps towards implementation

The next steps towards implementation include:

Software testing and validation: ETRA will conduct a technical visit to the EMT bus depot to prepare for deploying the solution on buses. Prior to the technical visit, both entities will sign an NDA. Initially, the solution will undergo testing on a single bus to assess detection accuracy in a real-world scenario. Any necessary adjustments to the algorithm will be made to enhance accuracy.

Purchase of equipment: Following successful testing and validation, ETRA will proceed to purchase the necessary equipment for outfitting the remaining buses. Permits for installing the equipment on buses will be secured well in advance.