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PLANNING OF URBAN TRANSPORT DELIVERY ACCORDING TO DATA FROM THE NON-VOLATILE INFORMATION-MEASUREMENT NETWORK OF THE SMART CITY

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Abstract. *This study focuses on the organization of monitoring and planning of urban transport provision by processing data obtained from IP cameras. With the help of this system, it is possible to obtain statistical information about the number of passengers at stops. The relevance of the topic lies in the fact that the development of modern technologies and infrastructure of the Smart City creates a unique opportunity to improve the planning of urban transport delivery and reduce energy consumption. The idea of building non-volatile information and measuring networks with the organization of power supply of IP cameras at stops from solar panels, compact wind generators or the city power grid is also being developed. The developed software provides backup of data from IP cameras to cloud storage with subsequent transfer to the Smart City dispatch center, where transport supply planning is created on a visualized map with the drawing of urban transport routes and their stops. Using the results of the study will allow to improve the quality of service to citizens and optimize the movement of urban passenger transport.*

Keywords: *video surveillance, IP camera, information-measurement network, non-volatile network, computer system, data processing, software, urban transport, Smart City.*

Introduction.

The topic of obtaining and processing data on public transport stops based on computer vision is becoming increasingly researched as Smart City technologies develop and expand around the world [1; 2]. The relevance of this topic lies in the fact that the development of modern technologies and infrastructure of the Smart City creates a unique opportunity to improve urban transport delivery planning and pay specific attention to reducing energy consumption. Internet and high-tech solutions have already become a part of the daily life of citizens, and this allows for the implementation of new approaches to optimize transport movement and improve passenger service.

The aim of this work is to develop a computer system that will automate the monitoring and planning of urban transport provision by processing data obtained from IP cameras. Using this system, it will be possible to obtain statistical information about the number of passengers at various stops, which will improve the quality of service for citizens and optimize transport movement. To achieve this goal, the following tasks must be solved: analyze the state of the art in the subject area ; develop a database (DB) to store information about the number of passengers at a stop ; create a script that will determine the number of people in an image ; develop a user interface for working with data ; and develop and test the software to evaluate its performance.

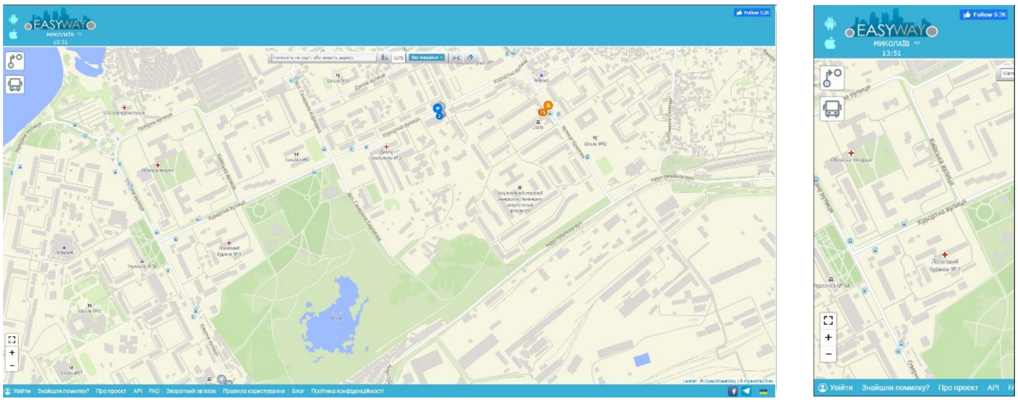
The State of the Art analysis. An analysis of existing applications with similar uses was conducted to evaluate the current state of the subject area.

• **Azure AI Vision** is one of the services of the Microsoft Azure computational cloud service, aimed at using artificial intelligence (AI) to work with image processing and computer vision [4]. Its advantages include the use of powerful algorithms for working with images, including their analysis, face recognition and identification, object detection, and other operations. It also uses visual search to find images that have similar content or specific objects. It offers developers the ability to use an API to integrate face recognition and image processing functionality into their applications. However, its disadvantages include the need for an active Internet connection for correct operation, which may not be feasible in some cases , and questions regarding the security and processing of personal data, as with any cloud computing service. The butt of the AZURE AI Computer Vision Model robot is shown in Figure 1.

Figure 1 – Butt of the Azure AI Vision robot

A source: [4]

• **EasyWay** is a widespread service that provides complete information about public transport routes and stops in 73 cities of Ukraine and other countries. Its main advantages include an intuitive interface that allows users to quickly find information and plan routes. It provides up-to-date information on public transport schedules in real time and offers a wide range of functions, including navigation and route updates. It has web and mobile interfaces for Android, IoS and WinPhone platforms (Figure 2), and also provides access to APIs [5]. Its disadvantages include the requirement for a stable Internet connection for some functions, privacy and confidentiality issues regarding the collection of user personal information, and the need for regular updates.



a. **b.**

Figure 2 – Interfaces of the desktop (a) and mobile (b) EasyWay application

A source: [5]

• **Amazon Rekognition** is a powerful service from Amazon Web Services (AWS) that offers face recognition, object analysis, text detection, and other image processing operations [6]. Its main advantage is its ability to scale easily depending on the size of the city and the number of stops, as well as a high level of reliability due to the AWS infrastructure. However, the problem of urban transport delivery planning does not require face recognition, which requires significant computational resources. Therefore, it can be concluded that AWS services are excessive for the purpose of this work. In addition, AWS services collect and process a large amount of data, including personal images, which raises questions of privacy and security.

• **All Aboard** is a free app that requires lower computational power and is gaining popularity in the US, Canada, UK, and Germany [7]. The deep neural network it uses can run in real time to recognize bus stop signs, identify bus signs, and a specific transit. Their project has been awarded a Microsoft AI for Accessibility grant.

A comparison of the reviewed systems is provided in Table 1.

Table 1 – Comparison of image object analysis systems

Indicators	Azure AI Vision	EasyWay	Amazon Rekognition	All Aboard
Functionality	+	+	+	+
Application	+	+	+	+
Ease of use	–	+	-	+
Scalability	+	–	+	–
Cost	–	+	–	+
Dependence on internet connection	+	+	+	+
Overall	**4**	**5**	**4**	**5**

Authoring

Organization of data processing from IP cameras at urban transport stops and their delivery to the Smart City Dispatch Center.

For decades, video surveillance cameras have been used by law enforcement and utilities in Smart Cities to monitor areas of interest. However, dispatchers must constantly monitor a video wall displaying video streams from multiple cameras (Figure 3).

Figure 3 – Viewing the video stream from the Smart City's IP cameras in Dispatcher's Centre

A source: compiled by the author

The burden of identifying critical situations and making decisions falls on the dispatcher, so automating this video surveillance data could significantly reduce the human workload and prevent errors due to overconcentration. Another problem is that processing large volumes of recorded video takes a long time. This limits the effectiveness and speed of decision-making to provide city residents with high-quality utility services, including urban transport.

Artificial intelligence and neural networks are the driving technology behind changes in the development of Smart Cities. Intelligent video analytics and the application of expert solutions can classify the normal and overloaded state of passenger transport stops [8]. This will help reduce hours of work to a few minutes, allowing staff to act faster and provide the necessary transport in a timely manner to clear stops.

One way to solve this problem is to develop a software-hardware information-measurement network that will collect and process data from IP cameras installed at public transport stops. The main requirements for such a system are low energy consumption and the possibility of autonomous power supply and energy independence (non-volatile) for a certain period. This network can also be used to analyze the occupancy of stops by passengers and, on this basis, plan the provision of transport with appropriate characteristics. Such software can be implemented as a web application consisting of two components. The first component is responsible for displaying data on surveillance cameras, while the second is responsible for displaying cartographic data and camera information on a map. The generalized structure of the interaction of the components of such a computer program is shown in Figure 4. In Figure 4:

- IP camera: this is the device that provides the video stream;
- Python script: a script written in Python that connects to the IP camera, uses the TensorFlow library with the RetinaNet model to analyze each frame every 15 seconds and stores the results in DB;
- Database: stores information about the number of people detected in each screenshot taken by the Python script;

– Dashboard (web interface): a web interface that provides the user with access to the DB data, displaying general information.

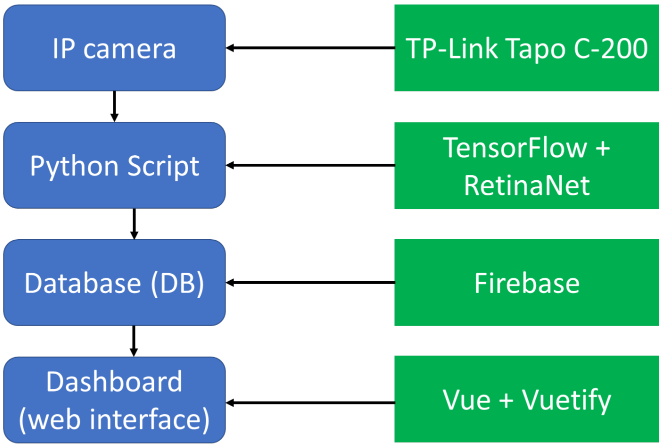


Figure 4 – Generalized structure of interaction of computer program components

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The main innovative trends in the development of the information-measurement network of a Smart City include providing non-volatile equipment for video surveillance (IP cameras, telecommunication equipment, etc.) installed at public transport stops. In this case, it is advisable to use, for example, outdoor Wi-Fi CCTV cameras such as Solar ABQ-Q1 Full HD [9] or iCAM-Solar365 [10]. The common requirements for such IP cameras are the availability of both a connection to the city's power grid and the ability to be powered by a solar panel and to store energy in external batteries. Most IP camera models have a night vision mode and infrared illumination within 30 to 150 meters, depending on the model, which corresponds to the size of urban passenger transport stops. The energy from a solar panel can be stored, for example, in two batteries with a capacity from 3000 mAh to 64 Ah, which power the IP camera. Professional all-year solar power systems for CCTV cameras provide energy for loads up to 50W throughout the year and 120W during the summer from March to September. The non-volatile time of these IP cameras is 10 days (energy reserve for a period without charging) (Figure 5).

Figure 5 – Professional all-year solar power system for CCTV cameras
A source: [11]

Figure 6 shows a functional diagram of a non-volatile information-measuring network. The data stream from an IP camera, which receives power from a solar battery, is transmitted to the Dispatch center of the Smart City through a router via the Internet channels of city providers. in the absence of an Internet connection, the data is pre-accumulated in a cloud DB. Energy from a solar battery can be accumulated in a Battery. Using a Hybrid Inverter, the Battery can accumulate energy both from the centralized city power Electricity network and from alternative power sources (solar batteries or a windmill).

The information-measurement network of a Smart City should be organized as a CCTV (Closed Circuit Television) system, where video signals are transmitted to a limited number of monitors or recording devices at a city dispatch center. The main characteristic of a CCTV system is that video signals are transmitted only within a closed system (in this case, the Smart City system) and are not broadcast on public networks [13]. Thus, the use of a CCTV system leads to an increased level of security and protection for the information-measurement network of the Smart City [14].

Information about DB object are accumulated with the characteristics shown in Figure 7, a. For example, each "IP camera" object includes: a unique ID for each IP camera *(*id*)*; latitude and longitude coordinates indicating the camera's location *(coordinates)*; a status indicating whether the camera is active (true) or not (false) *(status)*; the postal address where the IP camera is located *(address)*; the camera model *(model)*; and the ID of the district where the IP camera is located *(district)*.

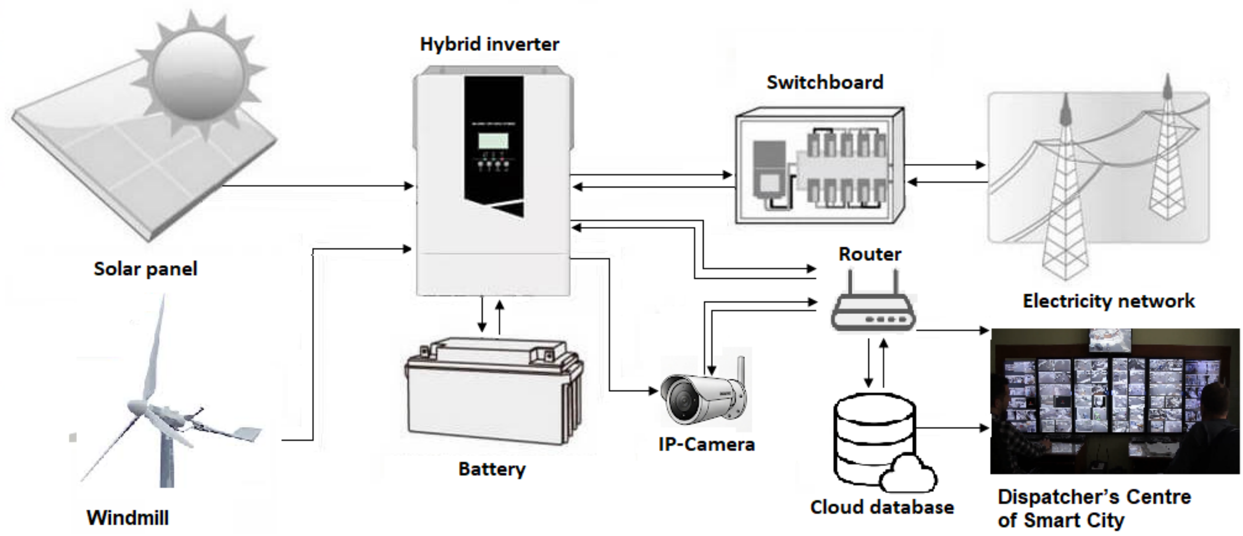
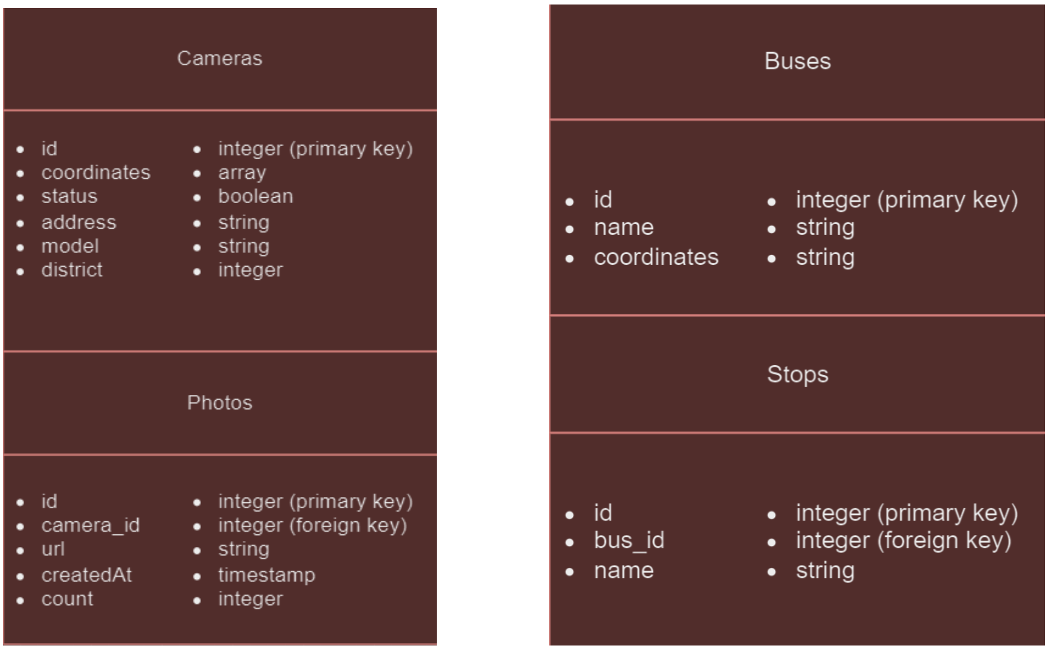


Figure 6 – Hybrid power system diagram

A source: compiled by the author

The Python script's main loop opens a web page, takes screenshots of the page, processes them to detect objects (in this case, people), uploads them to storage, and updates the document in the Firestore DB with data about the people in the image. After the program finishes, the browser is closed to free up resources.



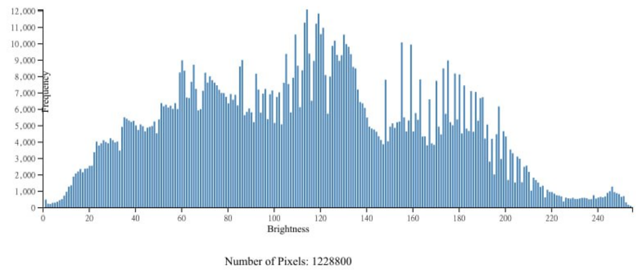
a. **b.**

Figure 7 – Database structure: a – with objects "IP camera" and "Photos", b – with objects "Buses" and "Stops"

A source: compiled by the author

A general overview of the structure and functionality of the Python script, which automates the process of detecting objects in images, uploading them to cloud storage, and updating information in the Firestore DB, has thus been provided. The script uses various Python modules and libraries, such as Selenium for interacting with a web browser, ImageAI for object detection in images, and Google Cloud modules for working with cloud services.

As a characteristic of the occupancy of a stop by passengers awaiting urban transport, the total number of pixels on the brightness histogram (Figure 8, b), into which the corresponding image (Figure 8, a) must be converted, can be used.



a. **b.**

Figure 8 – The result of the program for converting an image into a brightness histogram: a – input image; b – brightness histogram

A source: compiled by the author

In Figure 8, b, the ***x***-axis represents brightness values (from 0 to 255), and the ***y***-axis represents the number of pixels in the image that have that brightness value. The total number of pixels in the image, shown under the ***x***-axis, can be used as a characteristic of the occupancy of the stop by passengers awaiting urban transport [15].

The next step involves configuring the DB connection settings. A JavaScript-based user interface was developed for data interaction, where the configuration is set and a variable is output to the log to verify DB connectivity for subsequent use via the Dashboard interface. The completed first web page is shown in Figure 9.

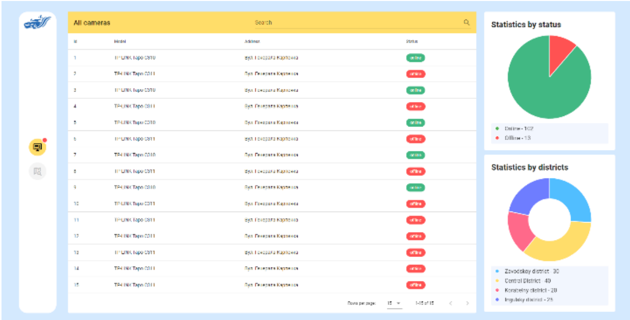


Figure 9 – Completed first dashboard page

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To view the maximum number of people at a bus stop recorded by a camera, a modal window was created (Figure 10), containing a chart that displays the maximum hourly occupancy. For example, if the maximum between 06:00 and 07:00 was 40 individuals, this value is reflected in the chart.

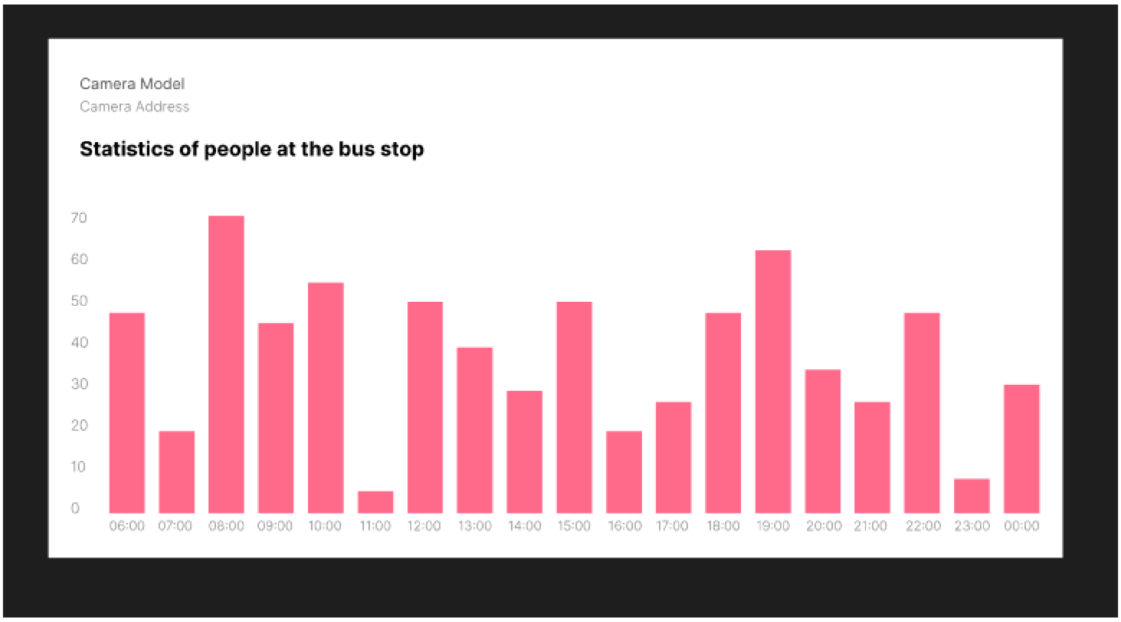

Figure 10 – Modal window

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The second page contains an interactive map that can be zoomed in and out at any desired location. Camera icons, positioned according to their addresses from the table, are displayed on the map. This page provides an auxiliary feature allowing users to visually locate each camera. Clicking on a camera icon opens the same modal window described above. To display bus routes on the map, relevant data must first be added to the DB.

When a number of bus route is selected and clicked, a green line is drawn on the map representing the entire route, and the list is replaced with a new one showing all stops for the selected route. The page design is shown in Figure 11.

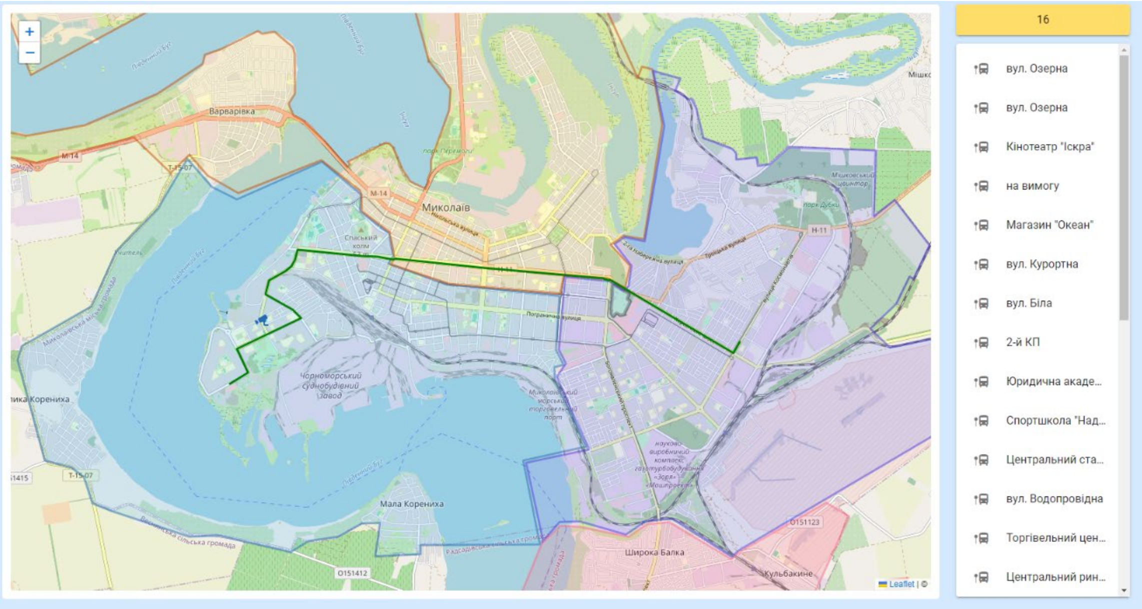

Figure 11 – Route of selected bus number displayed on the map

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To return to the full list of routes, the user clicks the yellow button containing the selected route number. For real-time tracking of public transport on the map, real-time data technologies can be employed. Attaching a GPS tracker to each vehicle enables continuous acquisition of location data, which can be transmitted to a server with a mapping system. Using JavaScript or other programming languages, this information can be rendered on the map in real time.

Results and Discussion. In the process of work, an image processing system from IP cameras installed at city passenger transport stops and connected to the Smart City computer system was configured and tested. Data is transmitted to the Smart City Dispatch Center via Internet channels of city providers. In the absence of communication, the data is accumulated in the Firebase cloud database with subsequent transmission to the Dispatch Center. The obtained images can be used to determine the number of people at a transport stop and plan the supply of transport of appropriate capacity to city transport stops.

Not only information flows in the specified system for planning the supply of city transport to stops were considered, but also ways to ensure energy independence of the information and measuring network based on smart city IP cameras. As an alternative to power supply from the city power grid, energy consumption from a solar panel and/or wind generator has been considered. The possibility of storing excess energy in a battery via a hybrid inverter was investigated.

During this study, two components of the web application were tested and analyzed. The first component (implemented as a Python script) is responsible for displaying data from surveillance cameras, and the second (in JavaScript) is responsible for displaying cartographic data and information from cameras on the map of city.

As a result of testing the Python script, its successful operation on various conditions, including normal and night modes, was confirmed. The obtained data were saved in the database for further use via the Dashboard interface.

The practical value of the work lies in the fact that it opens up new opportunities for improving the system for planning the delivery of urban transport of appropriate capacity and comfort to full stops.

Thanks to the implementation of high technologies and Smart City infrastructure, the system will provide effective monitoring and analysis of information at transport stops. This will allow optimizing transport traffic, ensuring accurate determination of passenger needs and timely response to changes in demand. In addition, the system is important for improving the quality of service to citizens.

Using IP cameras to collect data on the number of passengers at different stops will allow for adapting transport schedules and resources to where they are needed most, making travel more comfortable for citizens and helping to improve the Smart City services.

Summary and conclusions.

In the course of the work, a system for determining the number of people at a transport stop by processing images from IP cameras was configured and tested.

During this study, two components for a web application were tested and analyzed. The first component is responsible for displaying data on surveillance cameras, while the second is for displaying cartographic data and camera information on a map.

As a result of testing the script, its successful operation on different types of images, including normal and night mode, was confirmed. The received data were stored in the DB for later use through the Dashboard interface. In summary, the described components of the developed software successfully determine the number of individuals at public transport stops by processing images from IP cameras in the Smart City system, while providing users with a convenient and informative interface for working with IP camera data.

The practical value of the work lies in the fact that it opens up new opportunities for improving the urban transport delivery planning system. Thanks to the implementation of high technologies and the Smart City infrastructure, the system will provide effective monitoring and analysis of information at transport stops. This will allow for the optimization of transport movement, ensuring an accurate determination of passenger needs and a timely response to changes in demand. Thus, the proposed research is a relevant and sufficiently economical solution in terms of the electrical and computing power involved.

Moreover, the system is important for improving the quality of service for citizens. The use of IP cameras to collect data on the number of passengers at different stops will allow for the adaptation of transport schedules and resources, directing them where they are needed most. This makes travel more comfortable for citizens and contributes to improving their overall experience.

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