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Robotic Bicycle Parking with Autonomous Electric Power System

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The research is devoted to the development of an automatic complex that is being transformed with an autonomous power system. . This problem is now the most urgent one because the bicycle has become one of the ultra-high-speed vehicles in a big city.

In this work, the experimental design of an automated bicycle parking is considered: a gripping device that must capture the bicycle and hold it during transportation to the storage place inside the parking lot; a device for lifting and transporting, provides lifting and moving the vehicle during operation; place of direct storage of vehicles. Moving element - the automated operator's boom is equipped with a surveillance camera so that so that the user has the opportunity to monitor the operation of the system personally on the screen of the control panel. To ensure ease of construction, the main part of the operator is made of aluminum, which gives a preference for lightness by 40%, in contrast to the Steel counterpart, while maintaining the same strength. It also makes it possible to use engines of lower power and lower weight, as a result of which the design is cheaper. During the development of automated bicycle parking, a module of the solar power station was added, this made it possible to ensure autonomous operation of the system. The developed design has several sizes, starting from the basic one level and ending with the maximum possible five levels, so the system capacity changes, from 120 to 600 seats. In addition to various types of bicycles, automated bicycle parking may include different variety of electric scooters of the proposed design and weight.

The resulting design of an automated modular bicycle parking is higher than existing analogues, automated bicycle parking is higher by two times, and in saving space by three and a half times. Also, the modularity of the design is unique and has no analogues now. The use of alternative technologies allowed us to make the system autonomous and ecological, which allows us to place it both in the city center and in the forest conservation area or Ecopark.

Keywords: bicycle transport; electric scooter; automated bicycle park; autonomous power supply system; transportation; environmental policy.

Introduction

Bicycle development policy is considered in many countries as a necessary part of economic, transport, territorial planning, environmental, health and tourism policies. The problem of parking spaces is increasing every year, so with the growth of cities and metropolitan areas, the problem is only exacerbated. In today's environment, there is an acute shortage of parking space in cities, not only for cars but also for bicycles.

This problem is now the most urgent one because the bicycle has become one of the ultra-high-speed vehicles in a big city.

The indisputable advantages of a bicycle as a transport are: high mobility in traffic jams and narrow driveways, the absence of taxes and fuel costs, unlike cars. And also, the most urgent problem of modern cities is environmental friendliness and the absence of harmful emissions into the atmosphere, which makes the bike the most rational transport for short and medium distances in the city. According to many researchers, a bicycle in a metropolis is the best means of transportation. However, there is an acute problem of theft, vandalism and lack of parking spaces due to lack of space in the city. Another important factor is the cost of land, in the centers of megacities, the cost per square meter of land can reach several tens of thousands of dollars, which makes a classic bicycle parking extremely disadvantageous. In view of these problems, classic bicycle parking is not rational, and is not very effective on account of the small number of bicycles that can accommodate. Considering this, there is a need for a radical revision of the concepts of storing bicycles in the conditions of a shortage of city space.

1. Analysis of recent research and publications

Robotic parking for cars has already been fixed in some American cities, in China and Europe for many years. But bicycles are a relatively new addition to the market. The most impressive example of a solution to this problem is Tokyo's automatic parking. To solve the problem, back in 2010, the Japanese company Giken Seisakusho, specializing in flood protection systems, created 5 underground bicycle storage centers [1]. The construction, called the Eco-Cycle, was developed according to the concept of “Culture Above Ground, Function Under Ground”. Having a compact entrance cabin, it requires a minimum of space above the ground and provides more than 200 parking spaces underground. In 2013, the Czech bicycle importer Wheeler installed a tower automatic parking that uses a modified robotic stacker that hangs bikes vertically along internal supports for 117 seats [2]. The German company E-Bike Mobility builds robotic storage systems for solar-powered bicycles and has 112 bike seats [3]. In 2018, an automated bicycle parking, which works on the same principle as the Japanese one, appeared in Singapore and in the city of Utrecht, the Netherlands. In addition, the Hague and Amsterdam announced the construction of an underground bicycle parking.

There are several varieties of bicycle parking designs [4, 5]. Each type of design has its own advantages and features. The following types of bike parking are considered common: multi-tier parking, elevator parking and carousel (automatic tower-type parking) [6, 7]. An optimal design in the limited space of large cities is a parking lot such as automobile towers, now there is a Japanese analogue of such an ECO-Cycle design. However, the design has several disadvantages such as: a relatively small capacity (118 bicycles), an underground location increases the complexity of the installation and significantly increases the cost of the project [8]. So, none of the constructions considered is ideal, therefore, the design of the developed one will be devoid of the disadvantages of its predecessors and substantially redesigned.

2. Purpose of the study

The research is devoted to the development of an automatic complex that is being transformed with an autonomous power system. The developed design should have several sizes, starting from the basic one level and ending with the maximum possible five levels, so the system capacity changes, from 120 to 600 seats. In addition to various types of bicycles, automated bicycle parking may include different variety of electric scooters of the proposed design and weight.

3. Construction and principle of operation

In this work, the experimental design of an automated bicycle parking is considered the design of the automatic bicycle parking is hexagonal modules (Fig. 1), which are mounted on top of each other, with transparent walls with a protective transparent material covering the steel spatial power frame, inside which there is an auto operator and five drive towers rotating around its axis.

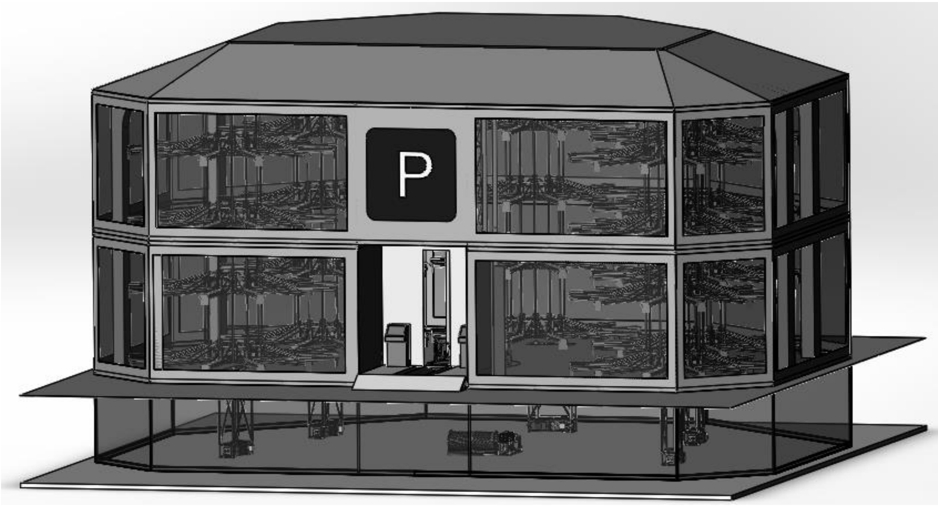

Fig. 1. General view of automated bicycle parking

The main storage location for bicycles is five rotating two-section towers. The lodging tower consists of two tiers in each section (Fig. 2).

Each of the sections is a welded twelve-sided steel frame fixed on a rotating base. The stand is actuated by a rotary actuator. Twelve boxes are mounted on each of the two tiers on each of the two tiers, which are a steel frame with rotating rollers. The gripping device is mounted on the lodge. Below the frame is a movable carriage with cable drive, as well as plates with a centering hole at the end of the frame.

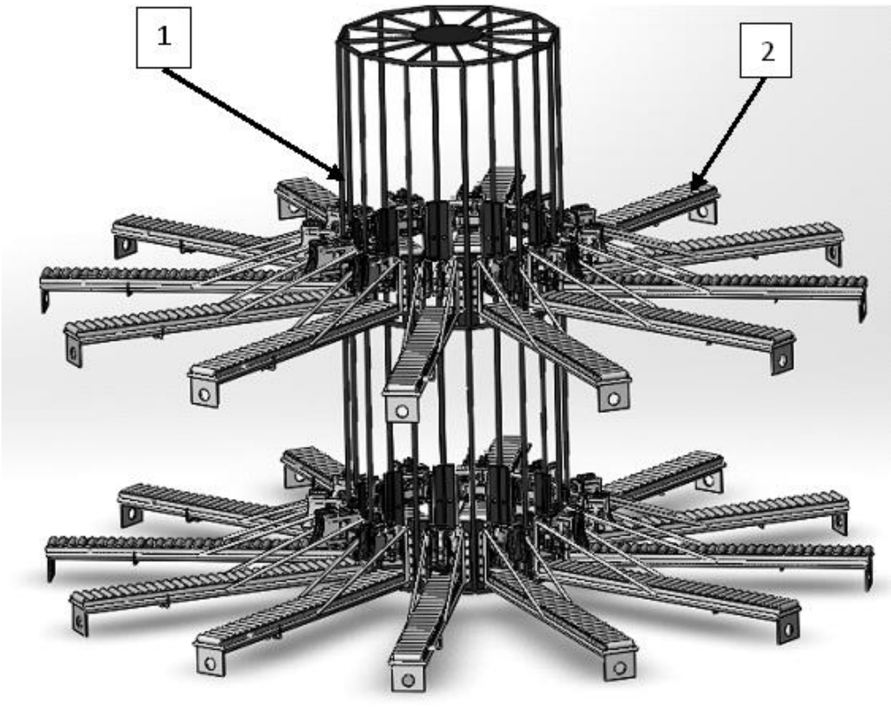

Fig. 2. General layout of the lodging tower section:
1 - steel twelve-sided frame; 2 - lodgment

The general layout of the lodgment is presented in Fig. 3

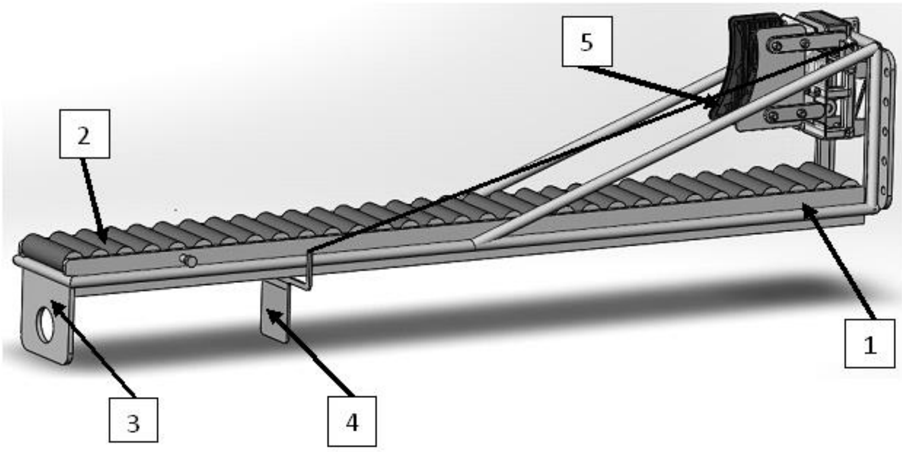

Fig. 3. General layout of the lodgment:
1 - lodgment frame; 2 - rollers; 3 - plate with a centering hole; 4 - carriage with cable drive; 5 - delight

The main working body of the design is the auto operator with a cylindrical working area, consisting of a lower and an upper movable platform. The lower movable platform, which is connected by a cable to the main occasion of the auto operator in the engine compartment, performs movements in a vertical plane. The upper platform using a rotary mechanism provides rotation around the vertical axis of the operator. An arrow with movable rollers installed in it is mounted on the opposite turning side of the side for free movement of the bicycle along it during loading and unloading. In fig. 4 shows the general layout of the auto operator.

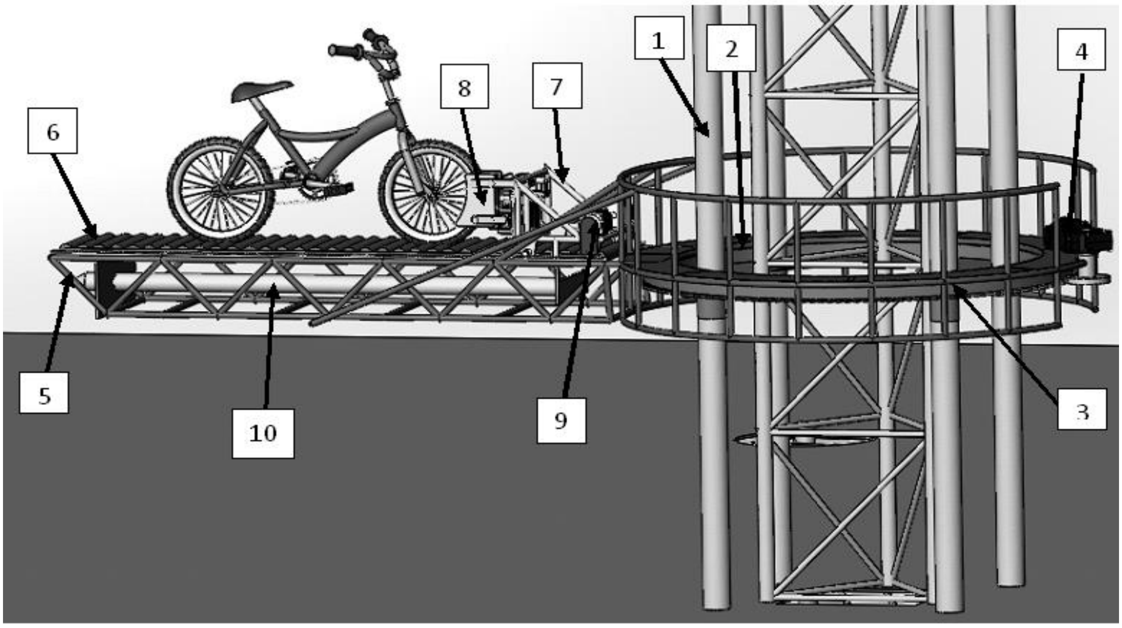

Fig. 4. Auto-operator general layout:
1 - power frame with guides; 2 - upper platform; 3 - lower platform; 4 - rotary mechanism; 5 - arrow; 6 - rollers;
7 - carriage; 8 - delight; 9 - carriage engines; 10 - piston with a conical tip

Moving element - the automated operator’s boom is equipped with a surveillance camera so that so that the user has the opportunity to monitor the operation of the system personally on the screen of the control panel. To ensure ease of construction, the main part of the operator is made of aluminum, which gives a preference for lightness by 40%, in contrast to the Steel counterpart, while maintaining the same strength It also makes it possible to use engines of lower power and lower weight, as a result of which the design is cheaper.

The gripping device is a specially designed bicycle gripper (Fig. 5). In general, the gripper is a welded aluminum frame with a stepper motor fixed to it, a gear rack assembly, a gear rack locking mechanism, a movable jaw guide roller bottom, a laser distance sensor, a damper and a protective Plexiglas shield. A strain gauge pressure sensor is fixed to the fixed sponge. The movable jaw is fixed on two rails, a gear rack and a lower supporting rail. Both sponges inside have rubber pads.

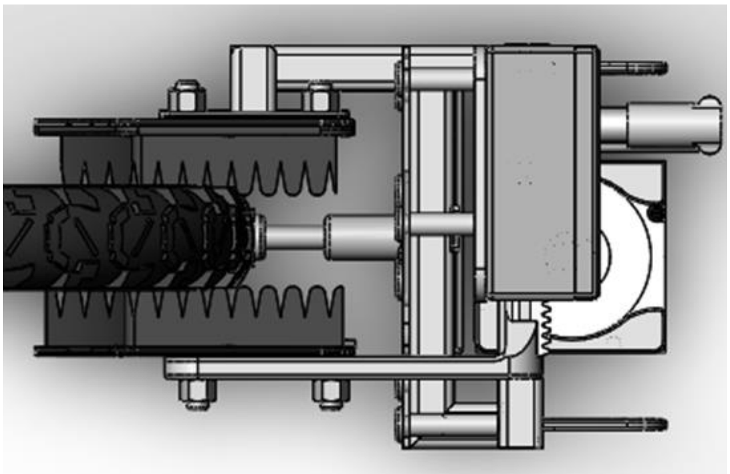

Fig. 5. Pressing the wheel all the way to the gripper

In addition to various types of bicycles, automated bicycle parking may include different variety of electric scooters of the proposed design and weight (Figure 6, 7).

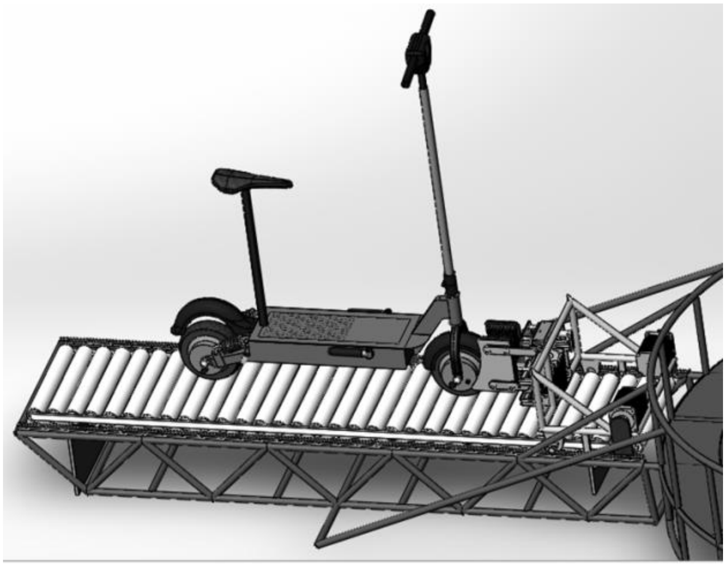

Fig. 6. Scheme of parking electric scooter

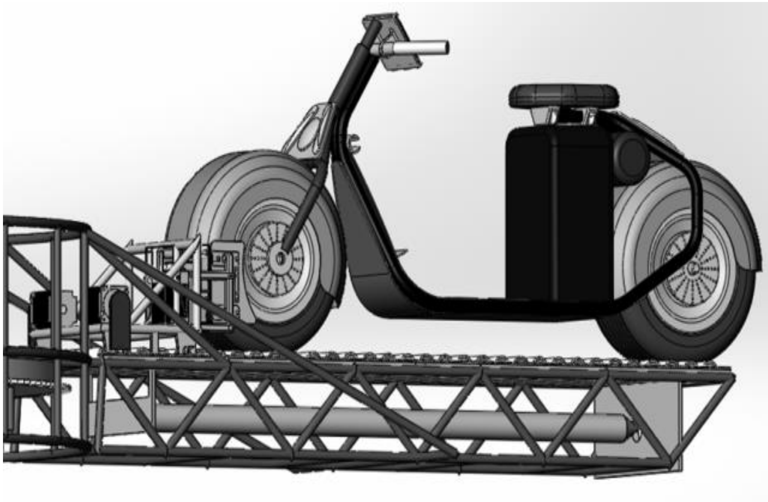

Fig. 7. Scheme of parking electric scooter

During the development of automated bicycle parking, a module of the solar power station was added, this made it possible to ensure autonomous operation of the system, allowing it to be used in power transmission and communications, as well as to increase the practicality of turning into a charging station for electric vehicles. Based on the results of which, the necessary power was calculated to power the system, the selected electronic components of the Solar Power Station.

4. Selection of electronic components and software

For a complete control system for the operation of automated bicycle parking, it is necessary to implement a system for calculating engine speed. For this we use Sendix encoders, paying attention to their high reliability and accuracy. We use the Sendix A020 encoder for large power drives, and the Sendix 5834 encoder for small motors.

The main requirement of modern engineering is the safety of the system. To increase security in the developed system, the user protection algorithm is applied at the user's contact point with the open mechatronic element (rolling platform). The user is obliged to drive the vehicle onto the trolley in the red trough exactly in the center, by feeding the front wheel into the receiving part of the gripper. After which the user is obliged to move to a secure white platform and start the boot algorithm by pressing the START button. The red trough is a control element that measures and controls the load to prevent vehicles that are too heavy, and also turns off the operation of mechanical drives while the user is in control zone. For the correct operation of the control element, the system needs an accurate measuring element capable of supporting the weight of the structure, as well as working in aggressive environmental conditions. This design uses a strain gauge model F2211 with an integrated microcircuit HX11, made on an elastic resistor and when the weight changes, its resistance changes, and, therefore, the voltage is removed from the bridge circuit. Since the resistors of the tensor sensor are connected in a bridge circuit, four wires depart from the device and have different color markings. The reference voltage is applied to the two shoulders of the bridge, and the output voltage supplied to the input of the operational amplifier of the HX711 chip is removed from the other two shoulders. Connection by wire colors is as follows: red – E +; black –

E -; white – A -; green – A +. For further processing and transmission of information, the HX711 is connected to the Arduino UNO. The HX711 load cell through the Arduino UNO controller can be connected to the LCD 1602 LCD or a computer using the USB port and standard libraries for Arduino.

As the output of the measuring bridge changes the voltage, so it is converted into binary code. The controlled voltage range depends on the selected gain. If the factor is 128, the range of measured voltages varies from - 20 mV to + 20 mV, the choice of gain 64 determines the limits of measurement from - 40 mV to + 40 mV and at a factor equal to 32 the limit of measurement is determined by values of - 80 mV to + 80 mV. These data will be correct only at a supply voltage of + 5 V. If the input voltage goes beyond the lower limit of the range, the ADC will issue a code 800000h, and if the upper one, the code will be 7FFFFFh.

5. Principle of operation

The system is aimed at the simplest management for the user and has a simple and understandable algorithm of use. The designed system is used according to the following principle:

- the first step: roll the front wheel into the passage, tightly pressing it to the stop inside the gripper and he will grab the wheel;
- the second step: we leave the red zone, press START. If everything is done correctly, the robot rolls the bicycle in and the doors close, in a few seconds the auto operator raises the bicycle to one of the levels and carefully parks it in one of the lodges inside the parking lot. The whole process is accompanied by instructions on the control panel, and then online translation from the display of the auto operator. At the end, the vending machine will say the floor and the parking space, and will also issue a parking ticket;
- the third step: getting a bicycle - the barcode of the parking ticket is read at the bottom of the machine, payment is made, the robot rolls out the bicycle (the parking algorithm works in the opposite direction).

Results

For the developed design, a 3D model was designed, tested structural rigidity, based on the findings of which weak points were strengthened and the stiffening element of the power frame of the drive towers, selected electronic components were added. Motion transmission methods were selected and calculated, calculated and matched drives. The main draft drive (carriage lift) and drive rotation drives of the drive towers are located in the engine room under the construction to save weight and facilitate the drives themselves. For the same purpose, the carriage moves thanks to a cable drive. A bicycle parking control system and an algorithm for its operation were developed, and a security system for the user and maintenance personnel was developed. The developed design is as safe and environmentally friendly as possible.

The resulting design of an automated modular bicycle parking is higher than existing analogues, automated bicycle parking is higher by two times, and in saving space by three and a half times. Also, the modularity of the design is unique and has no analogues now. The use of alternative technologies allowed us to make the system autonomous and ecological, which allows us to place it both in the city center and in the forest conservation area or Ecopark.

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Роботизована велопарковка модульного типу з системою автономного живлення

Дослідження присвячене розробці автоматичного комплексу, що трансформується, з системою автономного живлення. Ця проблема нині, є найбільш актуальною, оскільки, велосипед став одним з надшвидкісних транспортних засобів, в умовах великого міста.

У цій роботі розглядається експериментальна конструкція автоматизованої велосипедної парковки, а саме: захватний пристрій, що повинен виконувати захоплення велосипеда і утримувати його під час транспортування до місця його зберігання усередині парковки; пристрій підйому і транспортування, що забезпечує підйом і переміщення транспортного засобу під час роботи; місце безпосереднього зберігання транспортних засобів. Рухомий елемент стріла автооператора обладнана камерою спостереження за для того, щоб користувач мав змогу слідкувати за роботою системи особисто на екрані пульта керування. Для забезпечення легкості конструкції, основну частину автооператора виконано з алюмінію, що дає перевагу у легкості на 40%, на відміну від сталевого аналогу, при збереженні тієї самої міцності. Також це дає можливість використовувати двигуни меншої потужності, та меншої ваги, в слід чого конструкція є більш дешевшою.

В ході конструювання автоматизованої велопарковки був доданий модуль сонячної електростанції, що дозволило добитися автономності роботи системи,

дозволяючи розміщувати її поза зоною ліній енергопередач і комунікацій, а також підвищити практичність перетворюючи в зарядну станцію для електротранспорту. За підсумком якої була розрахована необхідна потужність для живлення системи, підібрані електронні компоненти сонячної електростанції.

Розроблена конструкція має декілька типорозмірів, починаючи з базового одного рівня і закінчуючи максимально можливими п'ятьма рівнями, через це змінюється місткість системи, від 120 і до 600 місць. Окрім різних типів велосипедів автоматизована велопарковка може вміщувати в себе електросамокати та електроскутери передбачуваної конструкції та ваги.

Отримана конструкція автоматизованої модульної велопарковки перевершує показники існуючих аналогів, автоматизованих велопарковок по місткості в два рази, а по економії простору в три з половиною рази. Так само модульність конструкції є унікальною і не має зараз аналогів. Застосування альтернативних технологій дозволило зробити систему автономною і екологічною, що дає можливість розміщувати її як в центрі міста так и в заповідній зоні лісів чи екопарків.

Ключові слова: велотранспорт, електросамокат, електроскутер, автоматизована велопаркова, система автономного живлення, транспортування, екологічна політика.

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