The construction of an automated bicycle parking

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Abstract. Nowadays, the bike is so common and popular that with the development of technology, man began to create all kinds of facilities for this mode of transport. On the market you can find various modifications and special-purpose accessories created for the bike. One of these amenities are special parking spaces for bicycles. They were created in order to facilitate its detention by people who do not have such a possibility in homes or to provide a specially adapted place to temporarily leave it during the day. The paper presents a proposal for the construction of an automated bicycle parking based on the geometry of the circle.

1. Introduction

Three types of bicycle parking can be distinguished (Figure 1). The first of them are simple construction solutions, without any mechanisms or moving parts. They need full human participation and use physical work. Another type of bicycle parking has been more mechanized. These stands have simple mechanical solutions that increase its functionality and reduce the effort that a man must put in to handle it. The third type of bicycle parking is an automated parking lot, which significantly limits the human participation and physical work done by him. These are constructions controlled by logic circuits and driven by various types of electrical equipment.

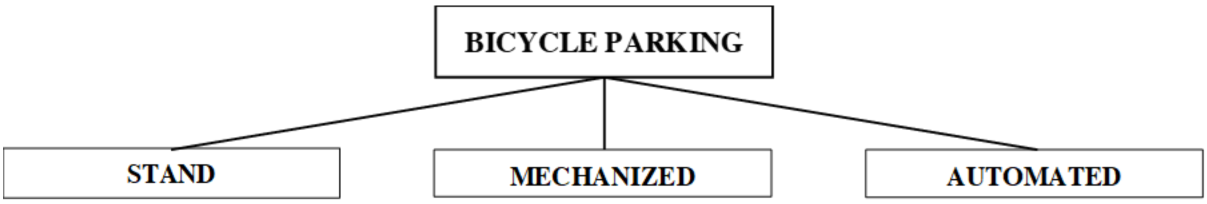

Figure 1. Types of bicycles parking

1.1. Stands

The most popular solution and available in every city (Figure 2). Elements of various shapes and sizes depending on the designated area for a bicycle parking and the number of parking spaces for bicycles. As a rule, they are anchored to the ground or attached to the wall. Their popularity came from their simplicity, low manufacturing costs and their maintenance. Their significant disadvantage is the lack of security. For this reason, bikes are exposed to theft or acts of vandalism. In order to protect against misappropriation, you can use various types of protection, such as chains or specially designed fasteners. To prevent the appearance of rust on bicycle parts, bicycle parking lots are often covered.

1.2. Mechanized
This solution is more elaborate and thoughtful compared to ordinary ones (Figure 3). The first mechanized bicycle parking lots were presented on the Dutch streets or at the main station in Graz (Austria), but we can also meet them in Poland, among others in Cracow. Its main advantage is the efficient use of space and the possibility of two-level parking of bicycles.

Figure 2. Most popular solution in the cities

Figure 3. Mechanized bicycle parking

In order for the user not to struggle with putting the bicycle in the upper parking space, it has been specially designed and supplemented with a drawer mechanism. Thanks to this, the parking rail can be pulled out and its end lowered, which facilitates parking.

1.3. Automated
A dozen years ago, the idea for automated bicycle parking was born. Thanks to the use of various types of mechanisms controlled by logic and electric devices, the bicycle parking process comes down to just a few buttons. One of the solutions (Figure 4) was presented in 1994 by the Spanish company ma-SISTEMAS. It presented a project called "Biceberg" which is a fully automated parking for two-wheelers. It consists of a terrestrial part, which in shape resembles a large ATM and is used to collect bicycles and an underground part for their storage. This design, depending on the model variant, can accommodate 23, 46, 69 or 92 bicycles and needs a cylindrical underground space with a diameter of 7.5 m and a height of 1.5 m, 2.75 m, 4 m and 5.25 m, respectively. Using the car park requires the use of a special card, which contains information about the occupied parking space by the user.

Figure 4. Biceberg solution

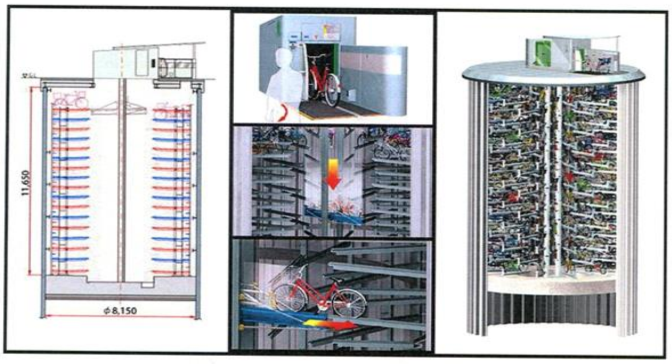

Figure 5. Eco Cycle solution

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After inserting the card and entering a personal code, the door opens and the user can enter the bike into a suitable box for this purpose. With the help of an elevator, it is transported to a designated place and waits there until it is picked up. Commands and additional instructions are displayed on the screen in written and graphic form, which facilitates and speeds up the process of learning how to use even to the point that it can be used by children. Activities related to parking or spending a bike last only 30 seconds. The second solution was presented by the Japanese company Gikenseisakushoco Ltd (Fig. 5). It created a project called "Eco Cycle". Its aim was to create an ecological underground bicycle parking, aimed at eliminating massive illegal bicycle trips on the streets, which disfigured urban landscapes and hindered traffic in the city. The structure has also been specially adapted and is resistant to seismic shocks. Its terrestrial part is a small and shapely house under which there is a cylindrical underground part with a depth of almost 12 meters and a diameter of over 8 meters. The bicycle parking, thanks to the effective layout of the parking rails, can accommodate up to 204 bicycles. To start the parking process, the user places the bike in the designated place and applies the card to the sensor. The bicycle is taken with a gripper and pulled onto the transport rail. Then, the elevator pulls to the appropriate level, is properly positioned and enters the parking rail. The process of downloading a two-wheeler is reversed. The activities related to parking or spending a bike last an average of 13 seconds.

2. Bicycle parking construction concept

Before starting the design work, a technical specification had to be created, input data determined and a preliminary construction scheme performed. It was necessary for the proper creation of the structure. The introduction and analysis of available bicycles on the market turned out to be necessary for this purpose. Their structure and dimensions constituted input data on the basis of which it was possible to start modeling a three-dimensional assembly. Initially, the creation of a polygonal structure was planned, with one parking space for each side. However, this solution would require the creation of a larger outer casing or a proper beveling of the polygonal edge, so that they do not cause a collision during rotation. Therefore, it was assumed that the created structure will have the shape of a circle (Figure 6), which will allow the most effective use of space and material [1-3]. The round platform on which the parking spaces will be mounted will rotate around its own axis until the desired place of the bicycle at the door is located. The door will be automatically controlled and when the platform's rotation is over, it will open. The parking process will start, and when it is finished the door will close and the bike will wait until it is pulled out by the user.

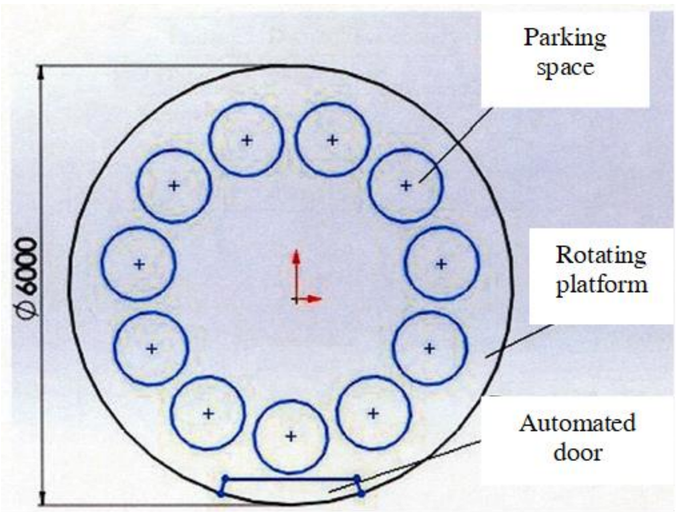

Figure 6. Structure of the construction

2.1. Technical specifications of the bicycle

A bicycle in comparison to a car is not a very complicated vehicle, but it exists in so many varieties, both visual and design, that the creation of a car park that all two-wheelers could use can be problematic. The reasons for the occurrence of these differences most often result from the adaptation of the vehicle to use in a specific environment or visual aesthetics and willingness to be different. Depending on the type of bike we can see different sizes, widths and asymmetries of the wheels. A different shape and frame construction results in a variable track width. Another important difference is the steering wheel. This is the widest element of the bike that should be taken into account when designing the structure and it may also change when comparing different types of two-wheelers. The next parameter necessary to include in the input data is the weight of the bicycle. Taking into consideration the most important features and the target location of the car park which is the city, the city bicycle is the main determinant for the input data when designing. This type of two-wheeler will most often be parked in a bicycle parking lot and therefore its design should be adapted to it. However, taking into account the wide range of bicycles on the market, the design of the car park should to some extent be versatile and allow parking also other types that will meet certain general requirements (Table 1).

Table 1. General requirements

Type	two-wheeled city bicycles
Length	140 – 190 cm
Width	to 65 cm
Height	to 125 cm
Weight	max 30 kg

2.2. Parking box for a bicycle

Special boxes made of polypropylene have been designed for storing bicycles (Figure 7). Their shape and dimensions have been selected in such a way as to ensure that users can use not only city bikes,

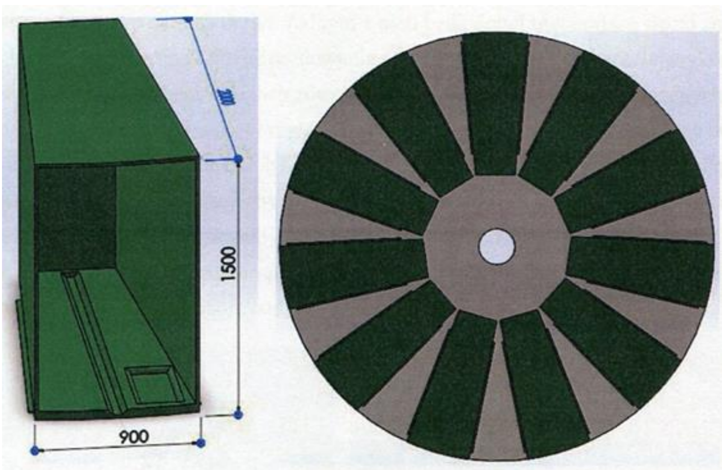

Figure 7. View of the parking box

but also other types of two-wheelers. Initially, a rectangular box was designed, but during modeling it was noticed that the shape is unfavorable during assembly. It occupied a lot of space on a round platform which limited the number of parking spaces. In order to better manage the place, the reduction of the width of the box along with its depth has been made. This operation allowed for the assembly of four additional boxes, but the bikes now have a imposed parking direction: the steering wheel must "be" on the wider side of the box to allow the bicycle to fit completely. At the base of the container there is a special recess for the wheels, which to some extent immobilize the single track and together with the steering wheel backrest against the side wall cause that it will not fall over in the box. In addition, a second rectangular recess has been designed for the user's needs. He can use them to leave a helmet, backpack, clothing or other personal items.

2.2.1. The mechanism of opening the door. When you look at the ready-made, automated mechanisms for opening the door, you can find many useful solutions. By analyzing the parameters and features of the mechanism, a variant that meets the most requirements needed for the created structure can be selected. A distinction can be made between the mechanism due to the number of elements forming the door, where their number depends on the space they occupy. The larger the area they have to cover, the more the parts make up. Another important aspect when creating the mechanism is the direction of opening. The door can open in almost any direction and it is up to the designer to decide which option he considers the most advantageous. Attention should also be paid to economic aspects, so that the mechanism fulfills its task in the most effective way.

2.2.2. Selecting the direction of movement. As already mentioned earlier, there are several possible variants when designing the mechanism for the door movement. One of them will be the door that opens outwards or inwards. This direction is by far the most popular and most frequently used, however, in mechanized and not automated constructions. In this work he will not find use due to its impracticality. At the door opening inwards, it would be necessary to remove the parking spaces so that there is no collision, which would significantly increase the diameter of the structure. In turn, in the direction of opening outside, this variant would interfere with the user's free use.

The customer, each time parking or picking up his bicycle, would have to move away and make room for the movement of the system, which is an unfavorable effect and can be considered even dangerous (Figure 8).

The second frequently used variant are mechanisms based on vertical movement. Usually, these are different types of blinds, which were used primarily for windows or shop windows. This solution can be easily automated by adding a drive to the drum or roller winding the curtain. This variant fits better from the previous one to the created structure, because it does not require development, so much space and is more user-friendly. However, the further development of the idea was abandoned due to the visual effects. As the whole construction takes the shape of a cylinder, the flat and protruding roller shutter along with the guides spoils the assumed geometry. What's more, the drive with the winding roller increases the height of the entire structure (Figure 9).

Another type of mechanism are sliding doors. Properly made doors will allow you to move sideways without significantly changing the geometry of the structure or its dimensions. They will not interfere in any way or cause additional inconvenience when using the user's account. These complementary features and the fact that they fulfill the function they assume make this option the best solution for the developed bicycle parking structure and it has been developed more and presented in the further part of the work.

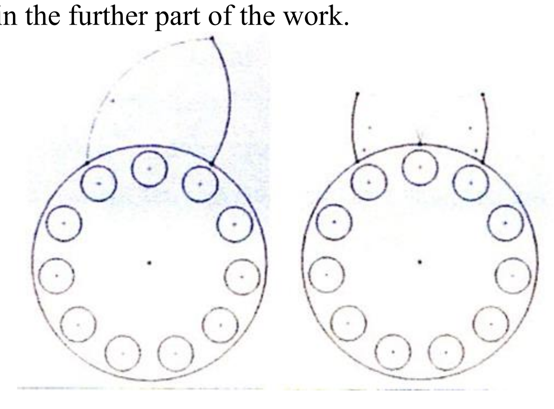

Figure 8. Conception horizontal door movement scheme: one-piece and two-part movement

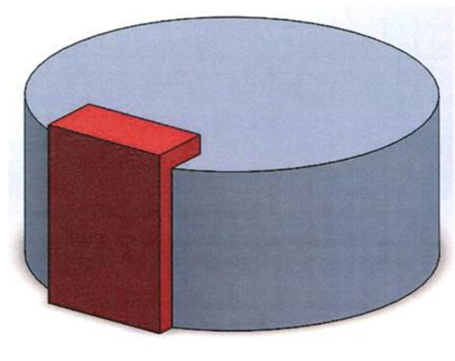

Figure 9. Geometric model with a blind

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2.2.3. Driving parts of the door. Selection of the drive had to start with the calculation of the force needed to move the door. For this purpose, doors made of aluminum alloy were designed, the weight of which was calculated in the Solidworks program. The total mass was almost 20 kg, and this value was accepted for further calculations. It was assumed that the door would be able to move thanks to four wheels on which the entire weight would be spread and which would move along the arched guide (Figure 10).

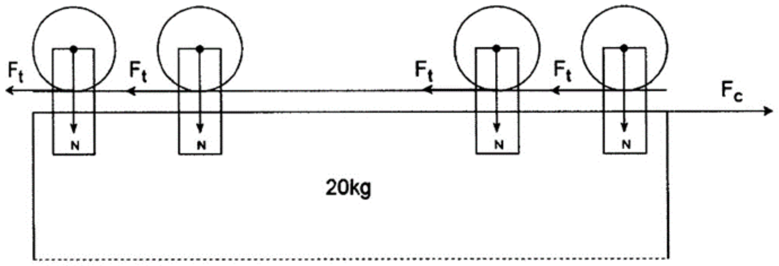

Figure 10. Diagram for calculations

After making the necessary calculations, the selection and design of subsequent elements included in the automated door were started. This mechanism will be driven by a linear system. The drive with a toothed belt was selected in the work. It allows for dynamic movements thanks to which they guarantee a short cycle time. The combination of the toothed belt and the toothed wheels prevents slippage, which was also considered important during the selection. Solidworks made assemblies of appropriate 3D models and checked the correctness of the mechanism. The round geometry of the structure turned out to be a major inconvenience because its distance from the door varied with the linear movement of the trolley. After a long analysis of the solution, it was decided to use a telescopic connection that would allow the free door with the trolley. Its task is to regulate its length depending on the position of the elements and extend accordingly at the greatest distance, and shorten at the shortest distance. The length of the propulsion equal to 0.996 m was chosen using the trial and error method. After the simulations carried out in the Solidworks program, it turned out that this value fits perfectly in the designed structure and the position of open doors and closed positions falls on the boundary sides of the linear drive (Figures 11, 12, 13).

Figure 11. Guide type RSR25-400

Figure 12. Linear drive type LEZ9

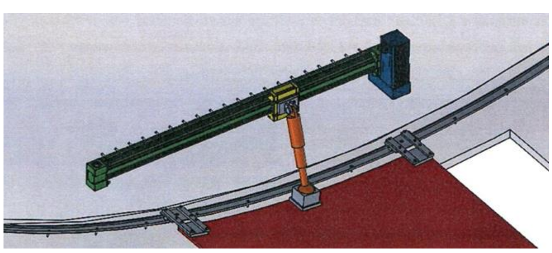

Figure 13. Model of the door control system

3. Rotating platform mechanism

In this work, the rotating platform was used to manage the position of parking spaces. This mechanism will allow you to change the place of parking boxes, so that users will be able to give and pick up bikes always from one point without having to walk around the garage structure [4], [5]. The implementation of the concept of construction began with drawing a model of a flat, round plate with a diameter of 6 meters to which parking spaces will be fixed. After analyzing similar constructions, it was found necessary to strengthen it. For this purpose, reinforcing elements made of closed rectangular profiles were used. The profiles with dimensions 50x20x1,5 made of general-purpose construction steel were selected. A complex platform model is shown in Figure 14. In addition, support wheels have been installed in the middle of the platform to improve stability and strength. This solution will serve as support supports and facilitate the movement of the platform. After making the appropriate calculations, 15 plastic wheels were selected (Figure 15).

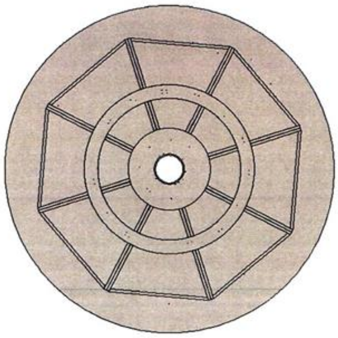

Figure 14. Rotary platform model

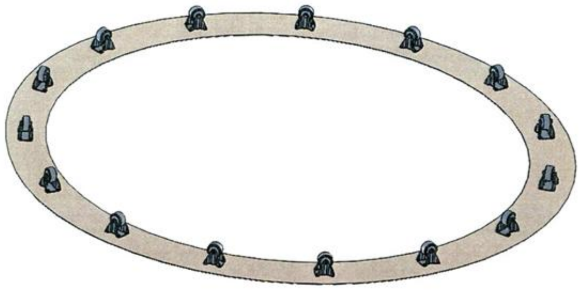

Figure 15. Model of the support wheels

3.1. Drive components

In order to put the platform in motion, a coronary bearing was used. This part is a large-size rolling bearing, which is characterized by specially shaped bearing rings. They allow direct fixing of two parts of load-bearing structures. One of them is rotating while the other one is fixed. It has been assumed that the design will preferably use coronary bearings with internal teeth. Due to the small rotations, the radial bearings are generally selected for static loads. Taking this into account and the data contained in the catalog of manufacturers, the static load capacity and the moment acting on the part were calculated.

Based on the calculated torque and static load capacity, the HS6-25N1Z ring bearing was selected from the Kaydon catalog (Figure 16).

Figure 16. Kaydon coronary bearing

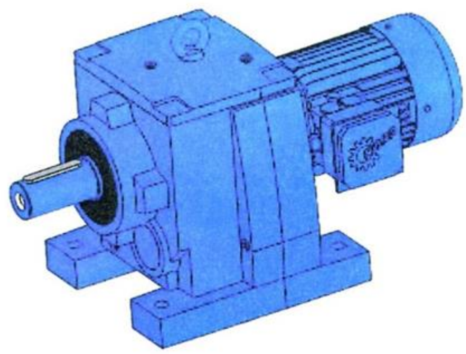

Figure 17. The NORD 1.5 kW geared motor

Due to the high engine speed, it will be necessary to use gears to reduce the rated values to the desired two rpm. In order to save space and not have to design a multi-stage gearbox, it was decided to use a gearmotor. Using the configurator available on Nord's website, an appropriate model was chosen (Figure 17). The biggest possible reduction in the speed by the gearmotor reduced the output speed from 1415 rpm to the speed of 14 rpm, therefore the remaining reduction was to be made at the connection of the gearmotor with the bearing. To achieve the desired speed of 2 rpm, a seven-fold speed reduction had to be made. For this purpose, calculations of the parameters of the toothed gear placed on the shaft of the gearmotor were made [6], [7]. For further considerations, a toothed wheel with a number of teeth equal to 13 was assumed. In turn, the pitch diameter of the sprocket was calculated, which amounted to 78 mm (Figure 18).

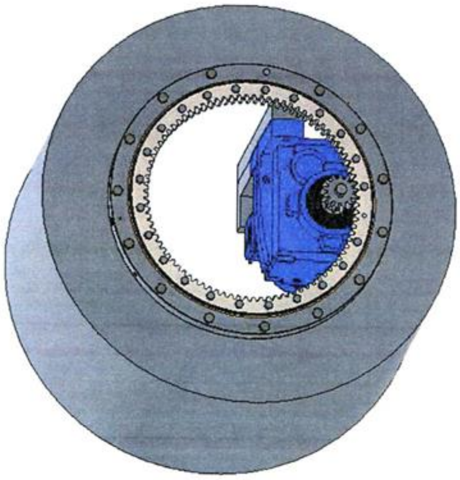

Figure 18. Model of the transmission driving the platform

3.2. Bicycle parking model

The ready bicycle parking model was made in the Solidworks program. The diameter of the structure is 6 meters, and its height is 1.67 meters (Figure 19).

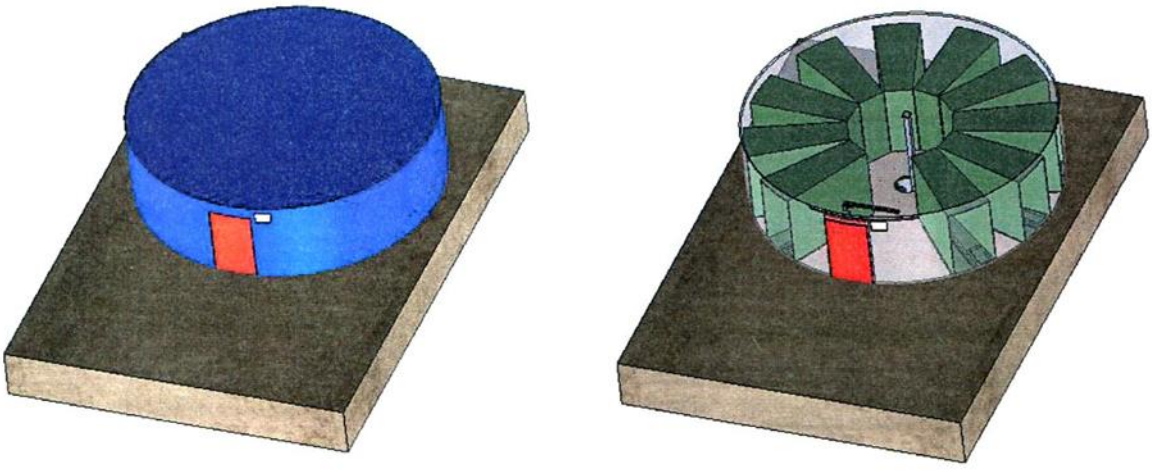

Figure 19. Model of bicycle parking, view 1 and 2

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4. Electronics and automation of bicycle parking

It was decided that the construction of the car park will be controlled by a PLC controller. To the inputs of the controller, measuring elements are connected to its output executive elements [8]. The measurement elements are photoelectric sensors that enable recognition of which parking spaces are in the position to perform the service. On the other hand, the executive elements were two electric motors, which were visible for the movement of the door and the rotation of the structure. The next step was the selection of elements creating the power system. To power the photoelectric sensors, the display necessary to operate the car park and the inputs and outputs of the PLC, a safe 24V power supply was used, while the controller itself was connected to a single-phase 230V voltage. Baumer: 0300.ER-PV1T.72N photoelectric sensors, 0300.TR-ZZZZ.72N transmitter were used to detect the position of parking spaces in relation to the door. The Mitsubishi FX5U-32MT / ESS PLC was used in the work (Figure 20). The GT2107 type H2 (Figure 21) panel was also selected from this company. The GUI project has been implemented in a special Mitsubishi GT computer program.

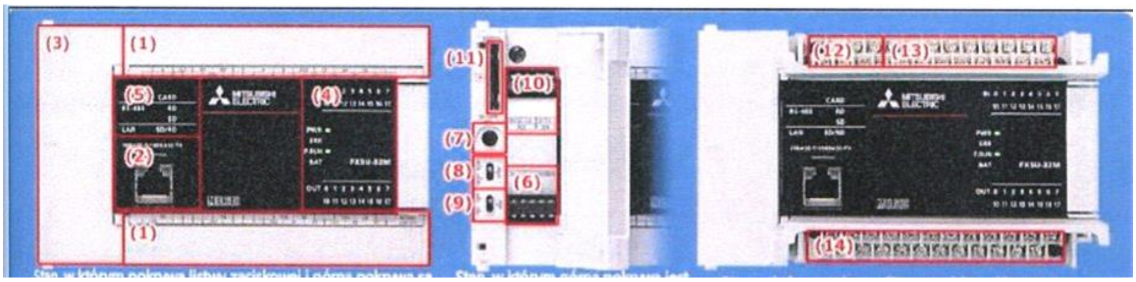

Figure 20. Construction of the PLC FX5U-32MT / ESS controller

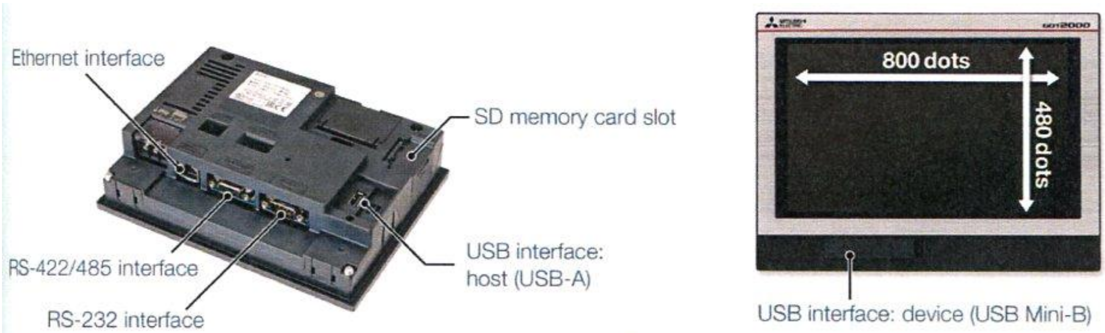

Figure 21. Mitsubishi HMI panel type GT2107

5. Machine control and programming

PLC controllers can be programmed using text and graphic languages [9]. At work, it was decided to program the controller using a graphic language, using ladder diagrams. This language is based on the use of standardized graphic symbols and putting instructions made on them line by line from left to right. To create the control program, the software provided by Mitsubishi called GX Works was used. Machine control was made possible by adding a touch panel to the construction. Thanks to cooperation and communication between the two programs, it was possible to carry out tests and perform simulations checking the correctness of the written instructions.

5.1. The course of the parking process

The program consists of blocks shown in the Figure 22 assigned to each parking space. The user, by accessing the device, sees the main screen displayed on the control panel. There are buttons on it corresponding to the assigned parking positions. The customer selects the correct number on the panel and the parking process begins. After selecting the parking position, the main screen changes into the waiting screen and the engine driving the platform starts. The engine is turned on until the proper box is placed next to the door. When the parking area is already in position, the engine driving the platform stops and the engine driving the door is started. The engine responsible for driving the door opening mechanism works until the signal is sent by one of the limit switches indicating the end of the process.

When the signal is sent, the screen changes and the message enter / lead out the bike is displayed. When this screen is displayed, the user has time to enter the bike into the car park. When the process is completed, he issues a command to close the door by pressing the button close the door. After issuing the order to close the door, the last panel screen is changed, the engine starts and the process of closing the door starts. After the signal is sent to the signal terminal, the engine stops and the user has the option to click the return button to the main screen. The whole process is in the same way for both leaving and picking up the bike.

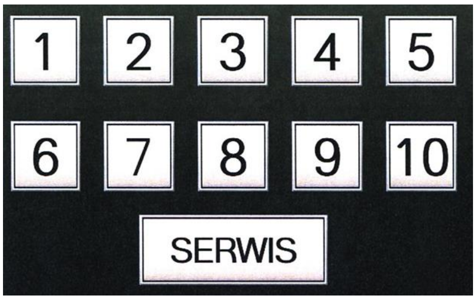

Figure 22. The main screen of the control panel

6. Conclusions

The purpose of this work, which was the design and software of an automated bicycle parking lot, was implemented. Most of the assumed aspects of the work were accomplished. A three-dimensional model was designed and constructed to show the construction of a structure in Solidworks. It allowed to simulate and check the correctness of the operation of the created mechanical connections. Electrical system diagrams have been created showing the connections of electrical components and the necessary parts that should be in the construction. A program was also written that could be checked thanks to the Mitsubishi GX Works and GT Designer software.

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