*Science, Engineering & Education, 7, (1), 2022, 56-66*

# The Past Future Bike – Bicycle with Additional Pneumatic Mechanism

Aleksandra Aleksandrova Umlenska

*HMS "Prof. Emmanuel Ivanov", Kyustendil, Bulgaria*

*Received 15 June 2022, Accepted 05 September 2022*

## ABSTRACT

*The Past Future Bike is a bicycle with an additional pneumatic mechanism. It is developed according to the characteristics of sustainable economic development in the cities of the future, among which the environmental, social and transport factors are forming. The project aims to use an innovative „fuel" that is economically and environmentally friendly and to promote safe cycling in urban areas. The inspiration for the development comes from urban transport over the past century and the active development of air used in the transport industry.*

*The prototype is made of a retro bicycle "Ukraine", which was repaired and tested. The mechanism uses a double-acting pneumatic cylinder, a bottle of compressed air, and an additional mechanism of gears and chains, which coverts reciprocating into rotating motion. The power of the developed pneumatic bicycle is estimated at 0.96 horsepower. The cost of refilling the bottle with compressed air is minimal, and BGN 0,014 are needed for a 1-kilometer distance. The personalization of The Past Future Bike is achieved through its technological and physical additions, including ARM-based system BBC Micro:bit, spy camera, alarm, solar battery, phone stand, reed ampoule-based mileage, and safety supplements.*

*Keywords: bicycle, recycling, pneumatics, compressed air.*

## INTRODUCTION

The cities of the future are a prosperous concept for sustainable development in various aspects of social development. The main focus is on transport, which has to be environmentally friendly and flexible in order to be successfully implemented in modern life, ecology, and all its aspects - from afforestation of garden areas to air and water quality control and others. Together they form the sustainable economy of these cities, some of which specialize more closely as garden cities, participatory cities, managed cities, sustainable cities, walkable cities, competitive cities, smart cities, eco-cities, integrated cities, productive cities, smart cities, resilient cities, and others or are included in hybrid combinations of two or more areas. Sustainable development ensures balance and high quality of life for the inhabitants of the innovative places.

"The environmental aspect is one of the leading components, which has been developed before the concept of the city of the future itself,

**Correspondence to: Aleksandra Aleksandrova Umlenska, HMS "Prof. Emmanuil Ivanov", Kyustendil, Bulgaria, E-mail: aleksandraumlenska@yahoo.com*

as higher levels of pollution began to be reported after the Industrial Revolution around the early 19th century, despite its significant contributions to everyday life. Historically, the development of industry began, but with the approach of the 21st century, machines are becoming more accessible to the mass consumer, which is a prerequisite not only for industrial pollution but also for that caused by consumers. In modern terms, various technology giants are working in the field of green energy and are trying to replace the resources we use in the form of fossil fuels, nuclear energy, and others to be replaced by renewable energy sources. This process requires not only the ultimate goal - the choice of energy source but also provides a stable and efficient system for its implementation.

The imprint that humanity leaves on nature is remarkably large, but due to the wide exchange, it also returns to the people themselves. The annual mortality, affected only by air pollution, in 2021 reached over 7 million people, while in 2017 the psychological limit of 5 million deaths per year is exceeded [1]. Of course, this is not the only influence that both internal and external air pollution has. It worsens the quality of life many times over, affecting mainly poorer countries, and shifts them further in the mortality rankings because they rely mainly on fossil fuels, which in most cases are of lower quality and higher volatility, or biomass and kerosene. This leads to more than a hundred times higher mortality due to this risk factor in Sub-Saharan Africa and South Asia compared to Europe and North America. Regarding the quality of life, the overall distribution of diseases caused or affected by air pollution in all age groups takes the form: over 27 % - pneumonia, 27 % ischemic heart disease, 20 % chronic obstructive pulmonary disease, 18 % stroke, and 8 % lung cancer, with the mortality rate caused by total air pollution reaching 11.65 % of the total according to WHO data [2].

On the other hand, fossil fuels are unevenly distributed on Earth, which requires economic and trade dependence on importers, as well as the construction of additional transmission systems. One of the effective ways in which each citizen can contribute is to reduce the harmful emissions they accumulate with their daily motorized traveling. Minimal reduction, as well as reduction of traffic, can be achieved through the use of public transport. On the other hand, as an example, we can present the Netherlands - a country that is known for its cycling culture. At the same time, within a modern city, it is difficult to travel long distances on the basis of manpower with a non-motor vehicle. Many cycling enthusiasts are turning to battery-powered ones, but it has much more environmentally friendly alternatives such as compressed air.

Assumed by the environmental, technological, economic progress, and societal needs, The Past Future Bike has been designed in a way that responds to all the criteria set for flexible and efficient use in the cities of the future (Fig. 1). It presents a bicycle with an additional pneumatic mechanism, driven by air, with innovative additions. The goal of the prototype is to prioritize

Fig. 1. The Past Future Bike.

cycling and ecology. The original contribution to this type of bike is a complete change of the drive mechanism, the addition of a controller, and the possibility of use as an ordinary bicycle.

The inspiration for its development can be considered historically and practically. In relation to the above factors, we can summarize that humanity is looking for an environmentally friendly, efficient, and budget-friendly way to move in modern urban conditions. This is the reason why leading companies such as Tata Motors, Peugeot-Citroen, and others are developing effective prototypes of pneumatic cars, applying innovative methods to combine pneumatics in combined mechanisms, and it itself has long been widely used in practice due to its main features. Pneumatics is not a mechanism that belongs to the transport industry of the 21st century, its application began in the early 20th century in 1904 by the inventor Alfred Beach, who can be considered one of the founders of pneumatic transport. This year, he submitted the documents to his supervisor for the construction of a subway in New York, inspired by the public transport in Paris, although in Paris there were partial disruptions. This is the reason why the scientist's proposal was rejected, and then he decided to reduce the extent of his goals, by getting to the decision to build an underground transmission system for letters based on pneumatics, for which he received permission. In this way, he secretly began to carry out his original plan, reaching out to transport people over short distances in an underground tunnel with a luxurious interior [3].

## EXPERIMENTAL

The 1962 retro bicycle model "Ukraine" was used as a base frame for the construction of The Past Future Bike (Fig. 2). It was chosen after a long period of active use, and most of its main elements are preserved, including its pedals in their original form, so that the difference can be presented before and after the renovation. The preserved elements are the brake mechanism, the metal frame, which is characterized by high stability and greater mass, which is compensated by modern lightweight components and additional auxiliary drive, and others. The model itself is characterized by the absence of a gear mechanism. The purpose of using an old bicycle is to recycle and restore obsolete items, which helps to restore non-renewable mechanisms while preserving their nature. In order to be safe to use, the bike went through several steps, which included completely disassembling the bike and processing each of its parts. The paint was replaced with a new type of chameleon, which supports the modern look of the bike. It is made of different color combinations, which are treated with a special gloss that helps its rainbow bloom at different angles of view. The bicycle went through several stages of processing. Some of the components that have been replaced due to long use are drops, tires, handles, and a seat, which also contribute to the comfort of the cyclist when traveling long distances. After additional machining of the components, they were assembled to their original appearance, after which tests were conducted for their stability and ability to ride effectively.

For optimal use of the possibilities provided by the retro bicycle, AutoCAD drawings and hand sketches were made, including partial elements of the mechanism, the overall look of The Past

Fig. 2. Bicycle 'Ukraine'.

Future Bike, and calculations for the construction of the system.

The prototype is made of lightweight and sustainable materials, which help to lighten it, use it, and be easily implemented in the cities of the future, as well as a one-time investment in the product. The technological additions have a long warranty and high quality, which supports the possibilities for long-term personalization of the bike.

In order to preserve the authentic look of The Past Future Bike, no additional speed or brake mechanism has been added. The speed can be adjusted by the additional pneumatic mechanism and its properties. Part of the methods is the displacement of the metal plate from which the piston is repelled, or the adjustment of the throttle, which is part of the pneumatic cylinder. The brake mechanism of the wheels "Ukraine" is a type counter-pressure.

Specialized details have been made for the assembly of the prototype. Some of them were created especially for The Past Future Bike, which required the production of specific schemes and sketches. They help to optimally innovate the bike, complementing the uniqueness of the prototype. They can be adjusted to the other components of the mechanism if the model of the bicycle used is changed. The non-specific elements are selected, as well as the technological additions from the field of the ICT industry, with a long warranty period, which also provides repairmen in an authorized service or replacement if necessary.

Technological and physical additions have been used to personalize the bike. They have a variety of options - solving everyday problems, helping the cyclist, increasing the safety of the cyclist and others, through which they support the integration of The Past Future Bike as a vehicle capable of moving in modern urban conditions. Part of the additions related to the technological aspect of the prototype is BBC Micro:bit (Fig. 3), [4], which is used for primary educational purposes. It features a small processor, which facilitates its implementation in the project, an open-source, ARM Cortex-M0 processor, and a combination of different sensors, including an accelerometer and magnetometer. It can make Bluetooth or USB connections with other devices. The display of the hardware device consists of 25 LEDs, lit in red, and two buttons that are further used to control the processes performed by the ARM-based system. It offers a variety of customization options and can be programmed via Micro Python, Microsoft MakeCode, and Scratch. In the case of The Past Future Bike, block programming was used to compile the code. The device has two modes of operation. One is used in everyday cycling and the other - in trick cycling. The daily actions it can perform to support the conditions for riding a bicycle are measuring the external parameters - temperature, lighting, noise level, and external pressure, as well as the cyclist's indicators such as heart rate. The trick cycling mode provides three levels of difficulty according to the capabilities of the cyclist. When the left button (button A) is pressed, an algorithm for the "beginner" level is executed, the right button (button B) corresponds to the "advanced" level, and when the two buttons are pressed simultaneously (combination A + B) - "professional". When BBC Micro:bit is shaken, original music begins to greet the user.

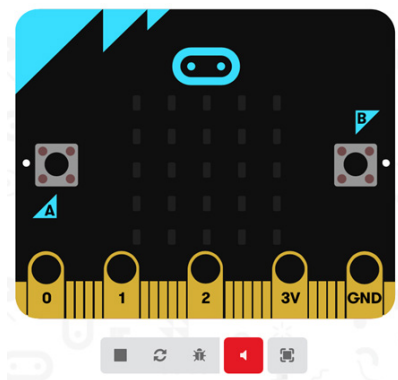


Fig. 3. BBC Micro:Bit [4].

Fig. 4. Additions to the Past future Bike.

Other physical additions (Fig. 4) are a solar battery that can serve as an additional headlight or power supply device, an alarm that ensures the safety of the bike in modern city conditions, a phone stand, and mileage, which has the function of a speedometer based on reed ampoule, located on the spokes of the wheel, a small spy camera that provides the ability to record video and reflective elements, including edging and valve caps which are shining when the wheels are moving.

The base components of the additional mechanism are a compressed air bottle (Fig. 5), a double-acting pneumatic cylinder, and an additional mechanism for changing the type of movement relative to the trajectory. Power influence and useful power are exerted, due to the gas that presses on the piston inside the cylinder. The pneumatic cylinder uses the energy of the compressed gas to reciprocate in both directions. Due to the additional mechanism consisting of gears and chains, it becomes rotational. According to tests, the pneumatic cylinder withstands over 40 000 000 cycles without change. The mechanism cannot be affected by adverse external conditions, which contributes to the sustainability of The Past Future Bike in modern cities. The type of bottle that was used to create the prototype went through several stages. The bottle originally used was a hydrophore pump to study the balance, the stability of the position of the bottle, and the aesthetic appearance of the project. Tests on the effectiveness of the system were conducted with a bottle of fire extinguisher, which has a pressure of 8 atm. With it, the maximum duration of work was reached within five minutes. The third stage of bottle replacement is calculated theoretically. The aim is to use a diving bottle with a pressure of 250 atm, which would be enough to power the mechanism for one hour. Thanks to the development of modern materials, their weight has reached less than 10 kilograms. It is remarkable for them that they have a high level of safety, as well as the other tested bottles. The only problem that can be encountered is in the valves, and they can be easily adjusted by inexperienced people, making them one of the safest methods that can be used in the field of transport to power bicycles. They are also much safer than batteries and accumulators used in electric bicycles and require special methods for recycling. On the other hand, steel bottles have a life of between 30 and 35 years with proper use, and then can be fully recycled, which supports the environmental aspect of the project. The goal of The Past Future Bike is to minimize the non-renewable energy sources used to power vehicles.

Depending on the type of bottle, different loading methods are required. The Past Future Bike prototype requires a simple reciprocating compressor, which is distributed at every gas station. If the bottle is diving, it is charged at a special station, and such can be found in larger cities. Their prevalence is increasing as air use is actively developing in all aspects of the industry and mechanical systems.

From a financial point of view, the energy required to fill the bottle is many times lower than that for the extraction of various types of fossil fuels. Due to a test with this type of compressor in 6 minutes 6 bar are reached in a cylinder with

Fig. 5. Pneumatic cylinder.

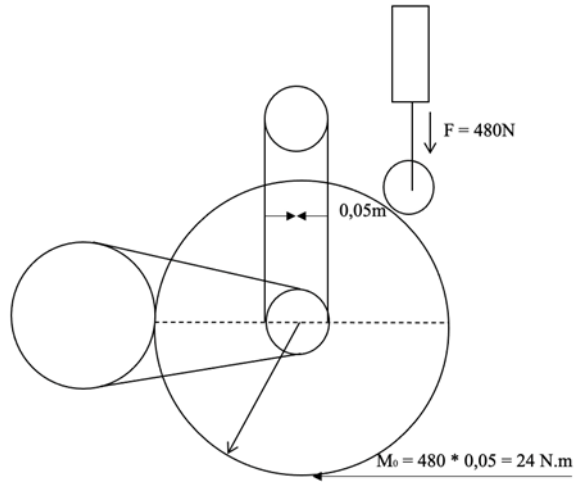


Fig. 6. Powertrain.

characteristics - volume 130 liters and an engine power of 2.2 kW. The demonstration bottle has a volume of 12 liters, which will be consumed 0.01 kW of energy. If we assume the average value of electricity for BGN 0.14 per kWh, the price for charging the compressed air bottle would be BGN 0.0014. With this amount of air, it is possible to be traveled due to tests between 100 and 150 meters, which makes the minimum value for one kilometer BGN 0.014.

Regarding the environmental aspect of filling the compressed air cylinder, a renewable energy source can be used to power the compressor such as a solar panel, wind power, and others. If one of these sources is not used, energy production will again have a much lower impact on the environment than fossil fuels, which are also a limited resource, which, together with their transportation, would increase their value in the future.

The power of The Past Future Bike is estimated at 0.96 horsepower. The tests that were conducted were a mathematical and physical study of the mechanism. The used pneumatic cylinder (Fig. 5) has a piston with a diameter of 3.2 cm and an area of 8 $cm^2$. The pushing force of the cylinder is equal to the product of the area of the piston of the cylinder and the pressure in bar. Its force is 480 N (Fig. 6), and the arm to which this force is applied is 0.05 meters. The torque to the axis of the bicycle is 24 N.m. The circumference of the wheel is 1.98 meters. The optimal speed that reaches The Past Future Bike is 25 km $h^{-1}$. At this speed, it performs 12.600 rotates, which is equivalent to 210 r $m^{-1}$. Horsepower is represented by the product of the moment and the r/m divided by the constant value 5252.

## RESULTS AND DISCUSSION

The leading motive for the development of The Past Future Bike is the research for innovative methods for the implementation of pneumatics that can be easily implemented in modern urban conditions, responding to the environmental, economic, budget, and social aspects.

Air as a “fuel” of the future has many advantages, among which the leading characteristics are affordability, financial and economic opportunity. It is an inexhaustible resource of energy that is used in its entirety, regardless of its composition. Its active develop-

ment and the interest of the automotive and machine-building industries predetermine its favorable economic development and its wider distribution. The energy for filling the bottle with compressed air is negligibly low, and at the same time, it is comparable to already known methods, over which we find many advantages.

The environmental friendliness of the project is a key to the prototype and its subsequent development. The Past Future Bike is a demonstration of the combination of air use and pneumatic mechanism in the transportation industry as a potential accompaniment or replacement for internal combustion engine systems.

Pneumatic mechanisms in the transport industry have proven their effectiveness over time. The development of the inventor Alfred Beach is not the first with this point of view, but it has a key role in the implementation of pneumatics in everyday life. The stable beginning of this niche in the industry was laid by the design of trains before the development of internal combustion engines in the 80s of the 19th century. This mechanism was preferred because it was simple, safe, low value, and high efficiency for its creation time. In addition to their impressive parameters, they were characterized by rapid development and various forms and combinations, among which there were even hybrids. Among the key developments is Mekarski's system, that of Robert Hardy, who has created a two-step secondary heating scheme called the Hoadley-Knight system, which increases the distance traveled by the composition. For a more detailed example, we will use Mekarski's mechanism. The engineer heated the air with steam produced in a boiler called a bouillotte (Fig. 7) or used the option of heat exchange instead of mixing the gas with the air. To build the mechanism he uses a single-stage engine in which the air expands and then releases. The gas is heated again after leaving the system by placing it in a hot water tank, trapping the steam [5].

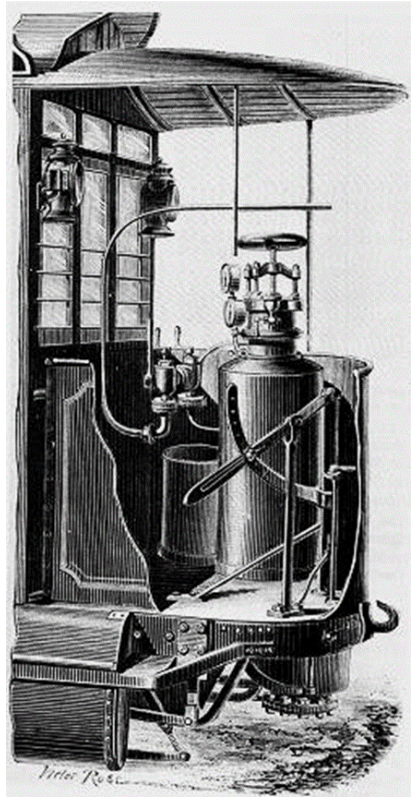

Fig. 7. Bouillotte [5].

Until the 1970s, apart from the development of railway transport, the focus was on other innovative transport systems, too. Inventors from the United States have been working actively, with significant discoveries made by Joseph Troyan, Terry Miller, Ray Starbard, Russell Brown, and Willard Truitt. The Italian Vittorio Sorgato has experimented within Europe. During this period, the first data about a pneumatic car was presented [6].

These days, with regard to the environmental aspect, compressed air engines, motorcycles, cars, and bicycles are being constructed. The development of this type of powertrain, despite its advantages, has some disadvantages, including significant energy loss during the process, and due to the low density of "fuel", higher pressure is required. The coefficient of converted energy also has lower levels than that of the other methods. Another drawback that Mekarski's system tries

Fig. 8. Pneumatic car by Peugeot-Citroen [8].


Fig. 9. AIRPod [9].

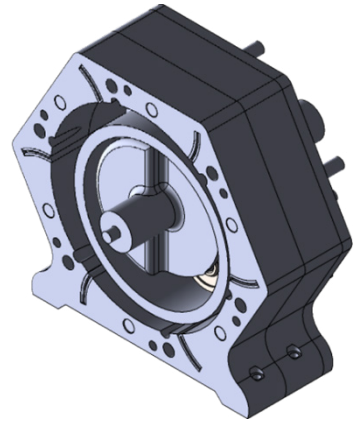

Fig. 10. Engine Di Pietro [10].

to avoid is that the process of throttling the air causes lower temperatures in certain parts of the system, which can cause problems in cold conditions. One of the alternatives is to use ethanol in the system or another type of alcohol to thaw the ice that blocks the flow of air [7]. These are some of the reasons why compressed air has so far had a better incorporation effect through hybrid combinations in transport systems. The most trivial would be the example of Peugeot-Citroen's development in 2013 (Fig. 8) through a combination of a conventional ICE engine and a compressed air system that operate separately, supporting the possibility of flexible regulation [8].

Of course, there are also attempts to design fully pneumatic cars. One of the most successful was the Zhejiang University experiment in 2004, which is a vehicle, based entirely on compressed air. The prototype has a mass of 1820 kg and 4 air tanks are needed to actuate it. The engine of the experiment is a modified four-cylinder fuel engine. The average operating speed used by the research team was 30 km $h^{-1}$, and the average power was 2,673 kW, which means that the adiabatic thermal efficiency reached 24.15 %. The distance that can be traveled without recharging with these parameters is 1870 meters [6].

The interest in this type of car dates back to the end of the 20th century, with the first more famous realized prototype being the 'AIRPod', created in 1998 (Fig. 9). Later, MDI continued its work, as part of their finalized developments are 'OneFlowAir', 'CityFlowAir', 'MiniFlowAir', and 'MultiFlowAir'. The Indian company 'Tata Motors' is another company working in the field of pneumatic transport. In addition to their individual projects, it created a cooperative one with MDI called 'Tata Nano' [9].

The pilot project of the Australian company 'EngineAir' offers an opportunity for the successful implementation of compressed air. It presents its leading product - the rotary air compression engine 'Di Pietro' (Fig. 10). Its mechanism is a powertrain cylindrical shaft, which under the influence of the force of compressed air, is moved in an eccentric trajectory. In this way, the movement of the motor shaft is transmitted

by rolling elements and the bearings of the initial shaft. The time and duration of air release and intake are controlled by a timer located on the output shaft and rotating at the same speed as the rotor. The change of the magnitudes is controlled by a change in time - the longer duration of air intake provides greater torque and vice versa. One of the advantages of the 'Di Pietro' engine is that it provides instantaneous torque at zero speed and can be precisely controlled to ensure a gradual start and control of acceleration [10].

This engine has been successfully implemented in a two-wheeled vehicle - dirt bikes. The development is by Australian Dean Benstel and is called '$O_2$ Pursuit' (Fig. 11) and is a project of Australian Dean Benstead. The Yamaha WR250R enduro motor was used for its development. The compressed air drive mechanism has 'EngineAir' rotary air compression engine components, a diving bottle, and a rear wheel drive engine. Through this configuration, it manages to reach almost 100 km distance traveled, and the maximum speed of the engine after its processing is equal to the one, guaranteed by the manufacturers - 140 km $h^{-1}$. The advantage of dirt bikes is their lightweight compared to cars, and for Yamaha WR250R the wet weight is 134 kilograms. The time required for charging is remarkable - 2 minutes, which is significantly shorter than for powering motorcycles and cars [11].

Other two-wheeled vehicles that use a compressed air mechanism, as well as The Past Future Bike, are bicycles. Many of them have a common mechanism of operation - they use a pressurized air tank, which reaches the system through a 4-way 2-position pneumatic valve that controls the flow of compressed air. One of the positions allows the flow of compressed air to the system, and the other - is to the atmosphere. The piston of the cylinder performs a reciprocating movement, changing the position in which the valve is. It controls the crank via a connecting rod, belt, or chain drive. Exemplary parameters that are achieved with these system parameters

Fig. 11. $O_2$ Pursuit [11].

are the maximum pressure in the compressed air tank around 9.25 bar. At a speed of 40 km $h^{-1}$, the power of the bike is 10.96 kW and the torque is 209.41 N.m, achieve which requires an applied force of 6980 N [12].

Compared to this model, The Past Future Bike has smaller characteristics due to the parameters of the demonstrative compressed air bottle used. However, it is a unique prototype, as it offers personalization through its technological capabilities. Its mechanism is non-locking and can be used both as a pneumatic bicycle and as an ordinary one. The bicycles "Ukraine" are constructed of heavier materials, but by renovating the bike and lightening the additional mechanism, the optimal weight has been reached. They rely on their sustainability, which is proven by the long-term use of the base bike used to make the prototype, without repair and maintenance. The stability of its additional elements is a prerequisite for long distances in urban and rural environments, and its mechanism can help move through challenging terrain. The Past Future Bike is also can be used in sports and trick cycling, which expands its possibilities for use. For the development of the prototype, observations were made and data were synthesized for the needs of the cities of the future. The results showed the need for additional physical components to support the safety and security of the bicycle and formed its goals - to pass longer distances without human effort, thanks to a renewable energy source that is suitable for integration in modern

urban conditions with innovative technological additions. Another goal was to be affordable. The budget which needs to be invested in a bike with features similar to The Past Future Bike can be adjusted to the user's needs regarding the type of compressed air bottle, the bike, and the technological additions to it. The value of the prototype amounts to BGN 730. The investment in the product is one-time, as the materials used are highly durable even under more unfavorable conditions of use, and the mechanism does not require additional maintenance. If The Past Future Bike is put into mass production, its value with the same components could reach BGN 600 per product. The safety aspect of the cyclists has been observed. The Past Future Bike has been tested many times in different conditions, on various terrains, and with several types of cycling, and the tests were conducted by people with unequal opportunities in the field of cycling. Safety is also supported by the sustainable mechanism, frame, and characteristics of the used bottle, storing the compressed air.

The project provides opportunities for further development, including the development of an additional mechanism through which the energy of turning the pedals provides an additional distance that can be passed without refilling the bottle or improving the combination used so far. In terms of technological additions, the bicycle provides space that can be used according to the wishes and needs of the user (Fig. 12). The bicycle can be supplemented with sensors, the most promising would be those to maintain balance and detect obstacles. Presenting the environmental aspect of the project in an accessible way to the public is important due to the presented data on air pollution.

## CONCLUSIONS

The Past Future Bike is an air-powered bicycle with innovative additions. A retro model bike was used for its assembly. The drive mechanism consists of a double-acting pneumatic cylinder and a bottle of compressed air under pressure in combination with an additional mechanism. The energy of compressed air is used to perform a reciprocating motion, which becomes rotational. Air is an inexhaustible environmentally friendly "fuel" with the active development of modern mechanisms for its implementation in the cities of the future. The power of the prototype is estimated at 0.96 horsepower and consumption is 0,14 BGN/km. It is supplemented with

Fig. 12. The Past Future Bike in use.

technological solutions, such as a controller programmed to examine important indicators, that help to personalize the product for the user. The goal of The Past Future Bike is to prioritize cycling and ecology.

**REFERENCES**


1. Hannah Ritchie, Max Roser, Air pollution, 2021, https://ourworldindata.org
2. Diseases caused by air pollution, 2021, https://www.who.int
3. Massachusetts Institute of Technology, Alfred Beach. Beach Pneumatic Transit System, https://lemelson.mit.edu
4. BBC Micro:bit V2, https://erelement.com/microbit/microbit-v2
5. Siemens Energy Global, Steam Turbines. Power Generation, https://www.siemens-energy.com
6. Y. Fang, Y. Lu, A.P. Roskilly, X. Yu, A review of compressed air energy systems in vehicle transport, 2021.
7. Pneumatics advantages and disadvantages, https://pneumatictips.com
8. Darren Quick, Peugeot Citroen to introduce compressed air hybrid by 2016, 2013, https://newatlas.com
9. Darren Quick, Peugeot Citroen to introduce compressed air hybrid by 2016, 2013, https://newatlas.com
10. Di Pietro engine, https://www.engineair.com.au
11. Alexander George, Air-Powered Motorcycle Runs on Scuba Tank, Rotary Engine, 2012, https://www.wired.com/
12. Hardik Mehta Mechanical Engineering department, Indus University, Rancharda, Ahmedabad, Gujarat, India, Gaurav Patel Mechanical Engineering department, Indus University, Rancharda, Ahmedabad, Gujarat, India, Air Powered Bike, International Journal of Engineering Research & Technology (IJERT), 2016.