A three-wheeled vehicle for the disabled people

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Abstract. This article presents the construction of a prototype three-wheeled vehicle for people with disabilities, approved in the L2e category. The vehicle is equipped with a special tilt mechanism that allows people with disabilities, who cannot balance their body, to return to an upright position after completing a driving maneuver on a curve of the road. The tilt angle of the vehicle depends on its speed and steering angle. When designing the vehicle, the availability and price of spare parts for scooters and motorcycles were taken into account to make the vehicle as cheap as possible.

Keywords: three-wheeled vehicle, disable people, tilt mechanism, electric drive, tilting frame, vehicle

1. Introduction
Currently, there are no systemic solutions and standardization of services in the area of mobility for people with disabilities. So far, support for people with disabilities in the area of mobility have been provided only by isolated activities of other people, driving schools or various non-governmental organizations, associations and foundations. The lack of a uniform, coordinated platform for activities in this area is the main problem and an obstacle in gaining a driving license by people with disabilities, and thus social and professional activation. The professional potential of people with disabilities, who often have higher education and great qualifications, is not used due to limited possibilities of commuting to work. One of the main reasons why people with physical disabilities are not engaging in social activities or have difficulties in finding employment and staying on the labor market is the limitation in individual mobility [1]. This problem is also magnified by insufficient urban infrastructure, especially in the field of public transport. Unadopted vehicles, bus stops, broken lifts or lack thereof significantly impede the ability of people with disabilities to move independently [2]. Currently, there are organized transports for people with disabilities, but even the best and most efficient transport systems will not fully meet the needs of independent travel at any time and over any distance. In most cases, three-wheeled vehicles are characterized by a low curb weight, and because of this they are often homologated in the L category [3]. Solutions for three-wheeled vehicles with a different Delta
1-2 arrangement, i.e. one front wheel and two rear wheels, have been known all over the world for a long time. Wheels at the rear and Tadpole 2-1, i.e. one rear wheel and two front wheels. The most famous example of tricycles today is the Piaggio MP3, where the tilt is achieved by push arms. The vehicle also has a tilt lock at a speed of 115 km/h.

2. Results
The structure of the vehicle in the Delta 1-2 system is a support structure in a form of a frame that is tilted together with the driver when driving along a curve of the road [4]. For the design of the frame, round tubes were used, which are normally used in production of scooter frames [4,5]. The maximum dimensions of the vehicle are 1700 mm high, 900 mm wide, and the center distance is 1500 mm. A particularly important parameter is the width of the vehicle, because the assumption is that the vehicle will fit in a door frame, which will allow it to move around closed facilities such as shopping centers, airports, etc. A concept of the vehicle is presented in Figure 1. Mostly readily available parts were used for the construction of the vehicle, especially spare parts for scooters and motorcycles, e.g. the front suspension has been completely adapted from the scooter and the braking system was adapted from a quad vehicle. Other ready-made elements are: wheel rims, tires, brake discs, steering wheel, gas shifters, display, as well as wipers, washers, etc.

The vehicle is driven by two electric motors located in its rear wheels. The use of an electric drive makes it a zero-emission vehicle, enabling it to move around landscape parks and city parks. The engine power is 3 kW. Thanks to bidirectional engines, reverse gear was obtained - required in wheelchair vehicles. Rear wheels are rigidly connected to each other, preventing them from moving relative to each other, thus creating a dependent rear suspension. Movement of rear suspension is possible by using a wishbone connection with the vehicle frame. An existing solution from a Honda Gyro tilting tricycle was used to design the swingarm. Appropriate modifications were made to ensure driving safety and for the vehicle to be allowed in land traffic. The rocker arm is an integral part of the tilt mechanism. The swivel arm allows the vehicle frame to tilt by a limited angle in relation to the rigid rear bogie [3].

![Figure 1. Three-wheeled vehicle – 3D CAD model.](image-url)
2.1. Tilt Forcing Mechanism

The purpose of the vehicle is to facilitate a return to a vertical position after taking a bend or other curve of the road. For this purpose, a special tilting mechanism was designed, that consists of suitably selected elements, based on analytical calculations, such as: DC electric motor, belt transmission, worm gear, the aforementioned pivoting rocker arm and a three-arm lever [6]. The tilt mechanism also features a simple belt tensioning mechanism that is pulled out during use. It is easy to use and therefore even the driver can do it independently. The detailed structure of the mechanism is shown in Figure 2. The mechanism is protected by patent no. 239880. The principle of operation of the mechanisms is shown in Figure 3.

Figure 2. Tilt mechanism. 1- DC motor; 2- worm gear; 3- toothed gear wheel; 4- toothed belt; 5a- internal guide rollers; 5b- external guide rollers; 6- three-arm lever; 7a- swing side rocker arm (connected with frame of vehicle); 7b- swing rocker arm (connected with rigid trolley of vehicle); 8- tensioner; 11- upper arm three-arm lever; 12- down arm three-arm lever; 13- adjusting screw; 14- tensioner handle.

Figure 3. Example of tilt operation to the left side with the tilt mechanism visible a) - rear view, b) - front view.

The method for controlling the tilt of the vehicle frame works as follows: based on the signals from the steering wheel angle sensor and the vehicle speed sensor, the controller transmits the tilt angle signal,
which is corrected by the value of the feedback signal from the vehicle frame angle sensor, and then
processed by the position controller, then corrected again for the current measured between the motor
control module and the electric motor. This signal is sent to the current regulator. Based on this
signal, the current regulator generates a control signal for the motor control system, which is converted into a
PWM signal in the PWM signal generator (Pulse Width Modulation) and the engine control system
powers the electric motor to drive the tilt function. A Hall effect sensor or a shunt connected to an
analog-to-digital converter is used to measure the current between the motor control module and the
electric motor [7]. The block diagram of the control system is shown in Figure 4. The tilt control method
is protected by patent No. 239393.

![Block diagram of the vehicle tilt control system](image1)

**Figure 4.** Schematic block diagram of the vehicle tilt control system: CV - vehicle speed sensor; CK -
steering angle sensor; CP - vehicle frame tilt angle sensor; M - electric motor; AC1, AC2, AC3 -
analog-to-digital converters; L1 - counter circuit (timer); R1 - position controller; R2 - current
regulator; FC1, FC2, FC3 - digital filters; PWM - PWM signal generator; SS - engine controller; S -
controller.

Value of the set angle of tilt of the vehicle’s frame with the driver inside is selected from the tilt angle
table, based on two data values - the steering angle and the vehicle’s speed. The set angle is therefore a
discrete-valued function. Vehicle’s speed is obtained from its speed sensor located in the propulsion
engine. Due to the presence of two identical motors, and the same two variable frequency signals, the
system uses a counter circuit, which enables a frequency proportional to the frequency of the signal to
be determined [6]. The arrangement of the sensors on the vehicle is shown in Figure 5.

![Location of sensors in the vehicle](image2)

**Figure 5.** Location of sensors in the vehicle. CV - speed sensor; Frame angle sensor; CK - steering angle sensor.
2.2. Facilities for disabled people
The vehicle has been designed so that it has an open body, thus making it easier to transfer from a wheelchair to the driver's seat and to mount the wheelchair on the rear luggage compartment on your own (Figure 7). An ergonomic, adjustable seat with five-point seat belts was also used. The chair is adjustable in height, it lowers to a height of 550 mm from the ground, i.e. the height of the standard wheelchair seat. It is also possible to adjust the seat's distance from the steering wheel. In addition, the seat is rotatable by 360° with the possibility of locking every 45°. Additional leg protection in the form of supports are also attached to the chair to prevent uncontrolled leg movement. The method of transfer is shown in Figure 6.

![Figure 6. The method of transferring the driver to the driver's seat](image)

![Figure 7. The way of loading a wheelchair on the trunk](image)

3. Conclusion
The article presents the concept, model and application of a three-wheeled vehicle for people with disabilities. Table 1 presents the most important vehicle parameters which, apart from the requirements for adaptation for people with disabilities, also meet the vehicle approval guidelines in L2e category, i.e. three-wheeled mopeds. This category was chosen due to the fact that it is not necessary to have a category B driving license to be able to drive such a vehicle. This is due to the fact that some people
with disabilities, for reasons such as claustrophobia, cannot drive ordinary cars adapted for them. In addition, the vehicle can be used by people without disabilities and minors over 16 years of age.

Table 1. Technical parameters of the vehicle

| Parameter                | Value         |
|--------------------------|---------------|
| Max. speed               | 45 km/h       |
| Vehicle weight           | 190 kg        |
| Engines power            | 3 kW          |
| Max tilt angle           | 10 °          |
| Range on one charging    | 100 km        |
| Height vehicle           | 1700 mm       |
| Axis distance            | 1500 mm       |
| Width vehicle            | 900 mm        |

The modular structure of the vehicle allows the removal of luggage compartment for a wheelchair and installation of a trunk, creating a small cargo space, which enables it to be used as a small delivery vehicle or in carsharing. The use of many ready-made elements in the form of spare parts for scooters or motorcycles means, that the target price of the vehicle will be much lower than other solutions currently available. It also makes the servicing of the vehicle much easier. Work is currently underway on the construction of a prototype. It is planned to conduct tests related to the safety, driveability and stability of the vehicle.

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