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HISTORIOGRAPHY OF THE DEVELOPMENT OF THE AUTOMOTIVE INDUSTRY DEDICATED TO DRIVERS WITH DISABILITIES

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Abstract

The article presents retrospections of technological solutions for the construction of vehicles and adaptive devices used by drivers with disabilities. The author explored the subject using the method of historiographic analysis to collect and report the research material indicated in this study, taking into account the perspective of the development of science in this field. The study contains a dozen or so examples of vehicles that were constructed in the years 1945–2000, adaptive devices, microcars and autonomous vehicles dedicated to people with disabilities. The main purpose of the work was to draw attention to the trend in the development of simple technical solutions based on motorcycle mechanics to more complex autonomous vehicles. The direction in which the development of the automotive industry is heading is optimistic, although it still requires attention to be payed to certain aspects that will affect the use of the technological potential hidden in its capabilities. The study does not describe adaptive devices on the scale that is used, but rather shows that these measures were not perfect and were not based on relevant mobility needs.

Keywords: drivers with disabilities; car designs for people with disabilities; history of the automotive industry; adaptation devices

1. Introduction

A car equipped with a special steering system is one of the most important elements of functional rehabilitation of people with special disabilities [7, 30]. The vehicle makes it easier to cover considerable distances between the place of residence and the place of work, thus increasing the activity and quality of life [17, 36]. This problem is especially true of people who live and work outside large urban centres, with many infrastructural barriers. The paper presents an overview of technological solutions concerning construction of vehicles and adaptive devices used for the needs of drivers with disabilities.

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In order to understand the development process, it is worth referring to the bibliographic information about the activities of Stephan Farfler, a paralyzed watchmaker who constructed and made a three-wheeled vehicle powered manually by levers, similar to today's wheelchairs (1655). The second Farfler's vehicle, already a four-wheeled one, was reported to be driving on its own without any assistance thanks to the use of a gear mechanism [24]. Thus, the need for a watchmaker became the forerunner of the invention. Most of the publications refer to this invention as one of the prototypes of wheelchairs (bicycles), and it can also be called one of the first mobility vehicles of the micro-vehicle type with manual drive and power drive.

Before the potential of people with disabilities was noticed in the automotive market, there were the first functional vehicle constructions, imperfect in terms of functionality, dedicated to people with special needs in moving about. There is nothing improbable about it, because after 1945 a very large group of people struggled with physical limitations caused by the war consequences. The development of many areas of life meant that in the population, more and more people with congenital defects or as a result of traffic accidents survived and required assistance in more functional moving about [16, 28]. The post-war period also saw the development of medicine and rehabilitation, so the population grew with the development of these fields of science. Earlier years, unfortunately, did not allow to save, for example, underdeveloped children, because there were no qualified specialists who would support their physical and psychosocial development. Therefore, people with various diseases or disabilities were not able to function, and in extreme cases, a large percentage of these people was subject to "natural selection" due to the lack of knowledge and experience, especially in the area of medical support for these people.

A microcar is a term used to describe vehicles with low weight, small dimensions, with limited power of the drive unit and limited speed. These vehicles have long been known as three- or four-wheeled structures, powered by human muscles, later by an internal combustion engine, and nowadays also by an electric motor. In the group of these vehicles, you can find some characteristic features and distinguish, among others, as:

- vehicles propelled by human power or pedals,
- vehicles placed between a motorcycle and a car,
- single-seat vehicles for people with disabilities, for people in wheelchairs,
- microcars,
- quadricycles or tricycles.

An example vehicle called a cyclecar was a type of small, lightweight car produced in Europe and the United States from 1910 to the early 1920s. These vehicles filled the gap between the motorcycle and the car on the market. Currently, micro cars are experiencing a renaissance and are beginning to enjoy recognition in highly developed countries. Micromobility is closely related to the need to move. Electromobility as a consequence of the dissemination of electric drives in transport has a particularly large impact on the evolution of micromobility and thus its means of transport [21].

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2. Vehicles manufactured

2.1. Oscar

In 1945, a vehicle was created under the name OSCAR, which was designed and manufactured by František and Mojmir Stránský. The components of DKW and Java were used to build it. The engine drove a single wheel, and the front axle was steered. The vehicle did not have a reverse gear. Instead, it was possible to reverse the rotation of the engine, which allowed driving in reverse [31]. The factory was nationalized in 1950 and incorporated into the state-owned VELO plant based in Hradec Kralowe. The name Velorex first appeared in 1953, while Mojmír Stránský [10, 40] designed a control system in 1955 that allowed people with disabilities to move around in a car. The device worked on a mechanical basis and was used in all types of cars. The design of the vehicle is proprietary and is commonly known as "Stránský" [39]. The last variant of the Velorex (Figure 1) was the 435-0, produced between 1971 and 1973.

Fig. 1. Velorex [40]

Compared to previous constructions, these were already four-wheeled cars, available only to people with disabilities. Demand for Czechoslovak tricycles quickly turned out to be higher than the production capacity, and the "disabled people" waited a long time to pick up their dream vehicle. The production of this model was discontinued in 1973 [31, 32]. In 1951, it was decided to establish in Sierpuchów plants producing microcars for the internal market of the Soviet Union, for the needs of war invalids, for whom the vehicles of SMZ production were specially adapted. The production of vehicles for the "disabled" began in 1952. The first model was the S-1Ł with a 125cc engine. In the years 1958–1971, SMZ/SeAZ produced vehicles of the S-3A make, and in the years 1970–1997 – S-3D, commonly known as Inwalidka [42]. In 1988, in connection with the plans to produce the city car Oka, the SMZ plant was transformed into Sierpuchowska Car Plant (SeAZ).

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Fig. 2. WAZ-1111 [42]

This was accompanied by a considerable expansion of the plant, carried out in 1988. Oka cars were produced in 1989–2008 under the designation WAZ-1111 (Figure 2) for the base versions and SeAZ-1111 for the version for people with disabilities [41].

2.2. Messerschmitt

In the 1950s, Messerschmitt (Figure 3) KR 200 tricycles were leaving factory known for the production of the most famous Nazi German airplanes. The Germans could not produce combat aircraft, so they started designing and producing mini-cars with the same names. These vehicles were subsidized by the state as vehicles for "disabled people" [25]. Road tests of the Messerschmitt KR-200 scooter with a cabin were carried out at the Vehicle Testing Department of the Motor Transport Institute. The study was performed in connection with the production or import of small-engine cars to Poland. Despite positive opinions from the research conducted at ITS, it was not decided to distribute this vehicle [43, 5].

Fig. 3. Messerschmitt [25]

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2.3. Invacar model 70

The British Ministry, on the other hand, distributed micro-vehicles free of charge to disabled people from 1948 to 1970. More than 50 models were produced (Figure 4).

Fig. 4. Invacar model 70 – Wikimedia Commons, 2020e

On March 31, 2003, all these British government vehicles were recalled and scrapped for safety reasons. These vehicles did not comply with modern EU type-approval regulations [21].

2.4. Gacek

The first Polish "invalid" car W65.S65.N65 – WSK Gacek (Figure 5) was created in the Transport Equipment Factory, designed by engineers of the Krakow University of Technology, the Central Construction and Research Centre of the Automotive Industry in Warsaw. The body was co-designed by Eng. Cezary Nawrot, Polish industrial designer, mechanical engineer, car constructor, pioneer of innovative automotive design in Poland [29]. Professor and lecturer at the Academy of Fine Arts in Warsaw and the Academy of Fine Arts. named after Władysław Strzemiński in Łódź. Prof. Nawrot designed, among the others, the bodies of Syrena Sport and Ogar. During the design work, the factory in Świdnik decided that the plant would build a car dedicated to "disabled people" . Built with an internal combustion engine or electric drive, the "invalid" version of the vehicle was adapted to the transport of two people. The vehicle received a positive opinion of specialized rehabilitation centres in Konstancin and Warsaw and the Central Construction and Research Centre of the Automotive Industry. Gacek's good grades, expressed in the years 1968–1969, were not sufficient to start commercial production [26].

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Fig. 5. Gacek [12, 13]

The group of designers of this vehicle received in 1970 the award of the Minister of Culture and Art for achievements, and in 1971 the NOT award for outstanding achievements in the field of technology. Plans for the development of Gacek's design were prepared [6, 44]. After many years, the only example went to the Faculty of Mechanical Engineering of the Cracow University of Technology, where, under the supervision of professors, a group of pupils from vocational schools in Krakow dealt with its reconstruction for 2 years. The only one in the world Gacek is currently operational, and is located at the above-mentioned Faculty [13, 44, 45].

2.5. Dezamet

Another example of technical thought was the Motorydwan Norka – Dezamet (Figure 6), powered by the Romet Chart engine with a capacity of 50 cc, with automatic transmission. The vehicle was a two-person vehicle, the total weight was 335 kg, the load capacity was 190 kg, with an electric starter, the prototype was produced in 1996. The idea was based on the German model of Simson DUO. Simson Duo, on the other hand, is the colloquial name of the simple-in-design, two-seater DUO three-wheeler, produced in the years 1972–1991 in the German Democratic Republic, intended for people with mobility disabilities. From 1972 it was produced in FAB Brandis as DUO 4, and from 1973 as DUO 4/1.

Fig. 6. Desamet 755 [8]

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In 1981, the production of the tricycle was transferred to the VEB Robur–Werke plant in Zittau. In 1989, another DUO 4/2 model was developed there, equipped with a 4–speed M542E engine equipped with an electric starter, from the Simson SR 50 moped.

2.6. Simson DUO

In 1990, the production was transferred to the plants of FAB Brandis GmbH. In 1991, the production of the tricycle was terminated. Exported in the 1980s to socialist countries, DUO was a popular disability vehicle in Central and Eastern Europe. It was created as a successor and a development version of the Piccolo–DUO tricycle, produced in the 1960s at the Louis Krause factory in Leipzig. The Simson DUO (Figure 7) was fitted with a 50cc M53/11 AR motorcycle engine. Only one left rear wheel was powered, chain driven. The vehicle did not have a reverse gear. There was a double cabin; the driver sat on the left side of the vehicle. The roof of the tricycle was made of laminated fabric (dermatoid) based on a frame made of steel tubes, which also supported the windshield. The engine was started by a manual lever accessible from the outside or inside. The brake was activated by pressing the steering column, the movement of which was transmitted to all three wheels by a system of levers and cables. Gear shifting, starting with the DUO 4/1 model – with a hand lever; clutch – automatic, centrifugal.

Fig. 7. Simson Duo [37]

Wheel suspension on independent wishbones sprung by motorcycle shock absorbers with oil damping, rear wheels vertically stabilized with a reaction bar. The steering damper in the steering system is mounted as a Bowden cable in a closed system. The maximum speed was 55 km/h, in practice it did not exceed 60 km/h [37].

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2.8. Buzz

An example of a microcar is "Buzz" – an ultra–light car for the disabled, designed by students of the Faculty of Mechanical Engineering of the Cracow University of Technology: Jerzy Pajerski, Filip Przybylski, Dawid Żmuda and Jarosław Rusek, under the supervision of prof. Witold Grzegorz Ph.D., D.Sc. [14]. The car may only be controlled with the hands. The user drives inside the vehicle on a wheelchair, which is stably locked and acts as the driver's seat. The entrance is provided by the rear bottom flap, which – when lowered – acts as a driveway. The car's body is made of glued composite panels containing an aluminium honeycomb core. "Buzz" reaches a speed of approx. 40 km/h, with a range of approx. 50 km. The vehicle's batteries can be charged from a normal socket. Its small size makes it easy to park in a small space, and even drive into narrow doors and ramps for prams. Unfortunately, the vehicle remained solely in the field of engineering research [2].

2.9. ELBEE

The Czech ZLKL company in turn, with the participation of EU funds, designed and implemented (in 2013) a special vehicle for disabled people called ELBEE (Figure 8), which, thanks to its design, provides comfortable access for customers using a wheelchair. Modern design and excellent technical solutions place this vehicle among the world leaders in this category. Dimensions: 77 cm – interior width, 133 cm total length of the vehicle's interior, 248 cm total length of the vehicle.

Fig. 8. ELBEE [9]

The vehicle cannot be used by people with disabilities who do not use a wheelchair. The microcar can also be problematic over long distances due to the size and manner of seating in the vehicle [9].

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2.10. Kenguru

Designed specifically for wheelchair users, the "Kenguru" is an easy-to-operate, single-seat electric vehicle. The wheelchair is attached to the floor with special handles, providing the driver with stability during the journey.

Fig. 9. Kenguru [14]

The "Kenguru" (Figure 9) is equipped with an easy-to-use scooter steering wheel, and driving it does not require a driving license [15]. The vehicle is manufactured by an American company based in Texas, KLD Energy Technologies. At the beginning of 2016, it launched a new model of a motor vehicle for a person in a wheelchair. Compared to the previous version of Kenguru, the exterior of the vehicle has been changed, the performance and the power module have been improved.

2.11. Micro vehicle

Recently, attention has been paid to the rapid development of urban, ecological and electric vehicles. However, none of these vehicles was commercially successful, mainly due to the cost of purchase, but they contributed to the development of vehicle body and chassis construction as well as drive and energy storage systems. Since 1997, the Faculty of Mechanical Engineering at the University of Brescia, Italy, has developed various plans for driving and transport systems for people with disabilities. The new philosophy behind this work was to develop a car that could be driven fully autonomously, regardless of the degree of disability of the driver. The aim of this work was to design a special car that could be driven fully autonomously while sitting in a wheelchair, and above all with the possibility of access without ramps and a robotic arm. The developed car belongs to the family of the so-called microcars, i.e. small city cars with 4 kW engines [14].

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2.12. Canta

The Dutch Canta (Figure 10) vehicle powered by an internal combustion engine is a vehicle dedicated to people with disabilities. The models available have an automatic gearbox. The Electro model is also produced – powered by an electric motor. It reaches a maximum of 45 km/h. It is not required to have a driving license to drive this car. A wheelchair user can drive the vehicle as a driver or be a passenger. The car can be accessed from the side, by moving into the seat, or from the back, by driving up a special ramp – it is possible to lower the floor pneumatically. Enabling people with disabilities to live without limitations in the Netherlands is not only about providing mobility, housing or education, but also taking care of spending free time, sports, recreation and fun [22]. In 2017, after almost 25 years of production, the last Canta manufactured in Veenendaal, left the assembly line.

Fig. 10. Canta [3]

It was developed in 1995 by Waaijenberg [41] together with the Delft University of Technology. In addition to the standard production models with a gasoline engine, the electric Canta was also designed for the German market, but it remained at the prototype stage [3].

2.13. ECO-car

The transport means used nowadays require individual adaptation to the needs of disabled people. As part of the research work carried out within the Eco-mobility Project co-financed by the European Regional Development Fund/Innovative Economy Operational Program, a car (ECO-car, Figure 11) was developed which was adapted for both able-bodied and disabled passengers.

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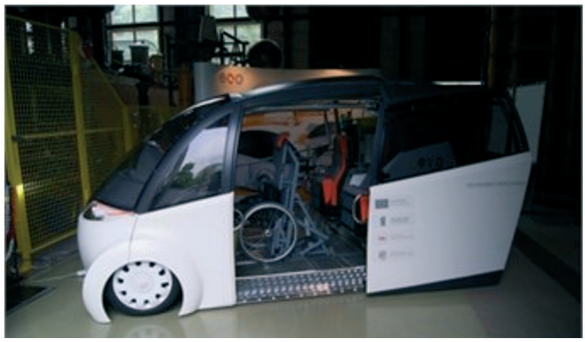

Fig. 11. Eco-car [4]

The car uses an integrated drive and brake-by-wire system, and is powered by lithium-ion batteries and a super-capacitor system. The design of the vehicle takes into account the assumptions in the ergonomic design process. The Eco-Mobility project was implemented at the Faculty of Transport of the Warsaw University of Technology.

2.14. Autonomous vehicles

The development of vehicles with an automatic driving system could be a milestone in the area of mobility of people with disabilities [1], as motor functions, which until now were only able to cover short routes and were associated with great effort, will now enable intercity driving.

It seems that the current state of development of autonomous cars is an excellent moment to use the potential of autonomous vehicles for people with disabilities, thus creating their characteristic application. It is worth emphasizing the fact that a person with disabilities driving a partially autonomous vehicle, regardless of the automatic driving function, must still be able to perform all operations related to driving the car. This does not mean, of course, that he must have a full motor fitness. The very use of an automatic transmission may allow a person with paresis in some limbs to drive a vehicle. Additionally, adaptive devices are able to prepare the vehicle for driving by a person with complete limb dysfunction. An autonomous vehicle does not change these requirements in any way, but it allows to reduce the intensity of handling activities by the driver while driving. This directly translates into reduced driver fatigue and, consequently, the possibility of driving the vehicle over longer distances. Driving comfort is also increased [38].

Table 1 presents the technical data of vehicles used by people with disabilities in the years 1945–2020, described in this publication in Chapter 2.

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Tab. 1. Technical data of the presented vehicles – own elaboration

Vehicle name	Years of production	Engine capacity	Speed max.	Engine power	Scales	Lengt	Width	Height
		m^3	km/h	RPM	kg	m	m	m
Oskar/Verolex, Czechoslovakia	1945–1973	250	80	4250	385	2.98	1.51	1.24
SeAZ-1111, USSR	1952–1997	649	120	5400	635	3.20		
Messerschmitt, GDR	1948–1952	191	92	5250	158	2.82	1.22	1.2
Invacar, GBR	1948–1970							
Gacek, Poland	1965–1970	350	72	3800	560	2.97	1.47	1.45
Dezamet, Poland	1992–1997	125		5000	140			
Simson DUO	1972–1991	50	55		147			
ELBE, The Czech Republic	since 2013	300	80		400	2,48	1.33	1.73
Canta, Italy	1995–2017		45			3.45	2.28	1,1
Chairiot, USA	since 2013					2.22	16.00	15.50

3. Adaptive devices

In the case of people with disabilities, functional deficits are substituted in the form of adaptive devices. A distinction can be made between the following driving aids and solutions:

- device for manual operation of gas (acceleration), brake and clutch;
- modification of the pedals;
- handle mounted on the steering wheel of the vehicle;
- remote control on the steering wheel of the vehicle;
- gas pedal lock (accelerator);
- pedalier (combined extension of the pedals);
- power steering and braking system;
- device for central control of the vehicle;
- moving the gas (accelerator) pedal to the left side.

The comfort of using the vehicle is achieved not only thanks to a modern technical solution, but also by taking into account the requirements set by the user. The possibility of using more and more expensive and more complex constructions of means of transport depends not only on their technical and operational properties, but above all on the way people interact with these means. Man, as a future user, modifies the device according to his capabilities and limitations [4].

In the second half of the 20th century, work began on the construction of devices for people with mobility problems. Eberhard Franz designed the first hands-free driving device. It was a groundbreaking event for people after amputations of hands. The prototype of the device was made in 1965 by ABB from Germany. A rotating pedal base was made for steering and

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accelerating the vehicle with the left foot, while the right leg operated the starter, gearbox, handbrake and direction indicators. A lot has changed in the mobility of people with disabilities since the last century. The devices assembled in Poland for these people are imported mainly from Italy, Germany, Sweden and the Netherlands.

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Table 2 presents the categories of adaptive devices for drivers with disabilities.

Tab. 2. Categories of adaptive devices intended for driving – own elaboration

Device categories	Mechanical	Electronic
The rim under the steering wheel, above the steering wheel		x
Wireless gas control devices		x
Other gas control devices (so-called pen)		x
Bar mounted in the floor of the vehicle "pull/push" L/R	x	x
Floor-mounted stick with accelerator lever	x	x
A rod mounted from the steering wheel	x	x
A rod mounted on the steering wheel with an accelerator lever	x	x
Brake rod mounted in the floor	x	
Brake rod mounted under the steering wheel	x	
Foot operated platform		x
Moving the gas pedal to the left side	x	
Joystick		x

Below, only examples of solutions are presented due to the complexity of the technical solutions presented on the market, both mechanical and electronic.

3.1. RGH – manufacturer Cebron

Fiat 126 with a control lever for people with disabilities is the first car adapted to be driven by people with motor disabilities in Poland. A device called RGH 1 – hand-throttle-brake was used in the vehicle (Figure 12). This type of device was the first designed and manufactured at the Research and Development Centre for Disabled People (currently Cebron Sp.z o.o.). Cebron was established as a result of the formal and legal transformation in 2013. The company is currently the legal successor and continuator of Cebron Spółdzielnia Pracy (2011) and the previously research and development unit of the Research and Development Centre for the Rehabilitation of Disabled Persons, operating under the supervision of the

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Minister of Labour and Social Policy, established over 50 years ago for research and implementation in the field of social and professional rehabilitation (1959).

Fig. 12. The adaptation device used in the Fiat 126, RGH I car [35]

Manual control lever RGH I – produced by CEBRON Warszawa. The levers operated the accelerator by turning the handle, with Bowden cable visible in the photo (Figure 13), while braking was performed by pushing the handle away. The device did not have a brake lock. This type of solution was the oldest model, currently not used [20, 27]. The Cebron company has produced versions II, III, IV and V Pantera. The first and only manufacturer that met the needs of the disabled community on a Polish market. The simple structure did not constitute an economic barrier in the acquisition costs.

Fig. 13. RGH I adaptive device [34]

However, it is worth adding that European producers went many steps further, constructing and producing adaptive devices, e.g. electronically assisted, which suited the needs of people with more difficult motor problems. Acceleration is obtained by turning the lever located at its base, while in order to brake, push the lever towards the dashboard of the car.

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Fig. 14. RGH – II, IV, V

Currently, Cebron (Figure 14) produces 3 versions of a mechanical device. The multi-function lever allows you to declutch when pressed, locking in any position and allowing you to change gear. Acceleration is obtained by turning the knob located at its base, while in order to brake, push the lever towards the dashboard of the car.

3.2. RGH – Kroepke Kontrols manufacturer

Figure 15 shows a mechanical device with Push-Pull control type. A simple system that does not require the removal or modification of the dashboard, manufactured by Kroepke Kontrols Inc of City Island, N.Y.

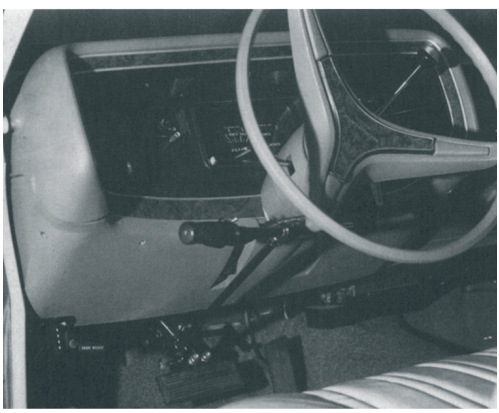

Fig. 15. Device installed in 1973 [11]

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After 2000, the development of vehicles for people on wheelchairs. However, many people still use traditional vehicles incorporating a large pool of adaptive devices from companies other than car manufacturers. Acceleration is obtained by turning the lever located at its base, while in order to brake, push the lever towards the dashboard of the car.

3.3. Ring GHOST

One of the basic driving aids is the rim (Figure 16), also known as the accelerator. It is an adaptation that fulfills the function of electronically assisted acceleration, enabling manual maneuvering of the vehicle, which allows people with partial or complete lack of motor functions to drive it. The adaptation can be installed on cars with automatic transmission, automatic transmission or automatic clutch. Thanks to this design, little space is needed to install the system, and its dimensions and alternative mounting method ensure the driver's convenience.

Fig. 16. Electronic acceleration controller (ITS)

Together with the device presented above, a brake is also used, which is mounted in the form of a rod on the steering wheel.

3.4. Pull–push bar

The device (Figure 17) is mounted to the floor of the car between the steering wheel and the automatic gearbox lever. Mechanical controller for gas (acceleration) and "pull/push" brakes in the form of a lever mounted vertically to the base of the station, on the right side of the steering wheel.

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Fig. 17. Pull-push bar (ITS)

The device is used in a vehicle for a person with lower limb dysfunction. The mechanical controller may cause problems in operation for people with hand disabilities (lack of grip and flaccidity of the hand). The base was made in accordance with the principles of ergonomics. There is a lock on the left side of the stick base, which makes it easier to control gear shifting.

3.5. Accelerator stick

The Veigel Classic device (Figure 18.) is operated according to the principle of rotation and pushing – to accelerate, the handle rotates clockwise, the brake is applied with minimal pressure towards the desktop.

Fig. 18. Accelerator stick (ITS)

Veigel is a world leader in the production of adaptive solutions, operating on the market for over 100 years. Innovative devices manufactured by Veigel ensure mobility despite disabilities.

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4. Summary

The direction in which the development of the automotive industry is heading is optimistic, although it still requires attention to be payed to certain aspects that will affect the use of the technological potential hidden in its capabilities [33]. The study does not describe adaptive devices on the scale that is used, but rather shows that these measures were not perfect and were not based on relevant mobility needs.

The descriptions of micro-vehicles dominate in the paper, because most likely in financial terms they did not require such large outlays for their production. Moreover, in the last century, the number of people with disabilities was much smaller than at present. The countries of the Eastern Bloc did not attach importance to using the potential of this social group. The changes that have taken place in the policies of European countries and meeting the demands to improve the functioning of people with disabilities have led to socio-political changes in this respect.

What one should pay attention to when exploring this area? It seems important to direct the researchers' attention to the psychomotor abilities of the users of vehicles and adaptive devices for people with disabilities as the basic determinants [18, 19]. The use of a given technical solution will depend on the possibilities, capabilities and predispositions that will allow the use of individual transport for a given person [23]. To solve this problem, one needs to know and understand the nature of the human being and his determination to be independent in the area of mobility. Preparation of standard vehicles, taking into account some elements supporting driving, e.g. cameras, sensors, elements necessary for adaptive devices to become fully compatible with the vehicle.

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