Chapter 6

Using of Electric Scooters in the Individual Electric Vehicle Category to Improve the Life Quality of Physically Disabled Person: A New Electric Wheelchair Design with Brushless DC Motor and Li-Ion Battery

Taner Çarkıt[1]

Anıl İbrahim Topçular[2]

Mehmet Yılmaz[3]

Türkan Ağır[4]

Gökhan Cumali[5]

Abstract

According to the information obtained from the World Health Organization, more than 1 billion individuals, which corresponds to approximately 15% of the world's population, have various disabilities. Dysfunction is seen in approximately 720 million people in this rate. Similarly, approximately 12.5% of Türkiye's population has various disabilities. Approximately 2.5 million people in this population have a physical disability that requires the use of manual and electric wheelchairs. In this study, it is aimed to realize a new engineering-based design for individuals who need the use of manual or battery powered chairs with motivation supported by technological development and change. The mobility of the prototype product is provided by the Li-Ion battery energy transferred to the brushless DC motor. SolidWorks computer program has been used during the design phase. As a result of research, development, modification and design studies on electric scooters and wheelchairs, which are in the category of individual electric vehicles, a new prototype product has been obtained. The advantages, disadvantages

1 Dr., Kırklareli University, tanercarkit@klu.edu.tr, 0000-0002-5511-8773

2 BSc., WattEnergy Ltd., Co., anilibrahimeem@gmail.com

3 BSc., Mert Döküm Inc., mehmetyilmaz092@gmail.com

4 BSc., turkanagir8@gmail.com

5 BSc., Teklas-Bulgaria EAD Inc., gokhancumali9@gmail.com

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and mobility features are emphasized by making comparisons with existing products.

1. Introduction

Depending on the changing disability definition and classification systems in the world, data collection criteria regarding the profile of the disabled in Turkey are also transforming. Questions and information on disability have been prepared by the "General Directorate of Services for the Disabled and Elderly" [1]. In the creation of these data, the disability question set, which has been created by considering the regional studies as well as the studies, censuses, researches and "Washington Group" recommendations made within the United Nations (UN) in related fields, has been useful. The question set in question has been also developed in accordance with the "International Classification of Functioning, Disability and Health (ICF)" developed by the World Health Organization (WHO).

The last current research that estimates the distribution of disabled people on a provincial basis throughout Turkey is the "2011 Population and Housing Survey" [2]. With the new approaches in the definition and classification of disability, in the research conducted in 2011, disability has been defined as follows: It focuses on limitations in functions rather than medical approach (organ loss, dysfunctions). In the research, disability is visual, hearing, speaking, learning for peers/performing simple four operations, remembering/concentration and mobility (walking, carrying, holding and going up and down stairs).

According to the information obtained from the WHO in 2021, more than 1 billion individuals, which corresponds to approximately 15% of the world's population, have various disabilities [3]. Dysfunction is seen in approximately 720 million people in this rate [4]. Similarly, approximately 12.5% of Türkiye's population has various disabilities. Approximately 2.5 million people in this population have a physical disability that requires the use of manual and power wheelchairs [5]. In addition, approximately 2500 people suffer from spinal cord paralysis every year in Turkey [6]. Almost all of these individuals who have had a stroke lose their ability to walk.

In the literature, the wheelchairs shown in Figure-1 have been developed to partially meet the living standards and expectations, ability and transportation needs of individuals with physical disabilities. There are two types of wheelchairs, which are seen as a tool and used to partially meet the needs of people who cannot walk or move easily due to a physical disorder

or disability, such as providing mobility and transportation, increasing their living standards and meeting their expectations [7]:

- Manual wheelchair,
- Powered (battery) wheelchair.

Figure-1: Wheelchair

Manual wheelchairs, which are based on mechanical mobility and developed as the first product, are based on human power. Transportation in the city is very difficult with manual wheelchairs. Manual wheelchairs are tools that give people the ability to move with muscle power. To look at the development of the manual wheelchair in the literature, although its history dates back to 4000 BC [8], it was turned into a product by the English inventor James Heath in 1750 AC. In 1933, Jennings & Everest added the foldable feature and turned it into a wheelchair. Choosing a wheelchair suitable for their physical condition and living standards is seen as a useful tool to improve the health, social and economic conditions of people with walking difficulties. The average weight of manual wheelchairs varies between 9 and 20 kg. The benefits of using a wheelchair for physically disabled people can be listed as follows:

- It increases the mobility of people to realize the things they cannot do freely and want to do,
- Users are provided access to social life by providing access to places such as schools, shopping, markets and homes,

- It can provide freedom in limited capacity by keeping their own lives under control with the mobility gained by the users' muscle power [9].

Developed as an alternative to manual wheelchairs, battery-powered wheelchairs are a technological product. Battery-powered chairs are produced with a mechanical-electrical-electronic design for the use of people who have walking difficulties, who cannot walk completely or partially, and who cannot turn the wheels with arm strength. Considering the development of battery-powered chairs in the literature, although the prototype product creation studies could date back to 1916 AC, it was turned into a commercial product by George Klein after the 2nd World War [10]. In the 2010s, R&D studies have been carried out on commercial products and battery-powered chairs that could be controlled by brain signals have been developed [11]. The weight of the electric chairs can start from 35 kg and go up to 85 kg. The load capacities they can carry vary between 100 kg and 200 kg. Battery-powered wheelchairs also have some disadvantages such as:

- Difficulty moving on uneven (rough) floors,
- Unable to fold,
- Covering a large area in the usage area,
- Difficult to transfer with one person due to their weight,
- Some models cannot brake on slopes due to low engine power, forcing the user to open the handbrake,
- Possible control lock failure,
- Difficulty in transportation with vehicles in daily use.

In this study, one of the basic building blocks of the prototype product designed by making technological contribution and difference is the electric scooter. Looking at the development of the electric scooter in the literature, a product that can be steered with an arm and a pedal was developed by Honda in 1974. In 1996, foldable scooters became available worldwide. After the 2000s, the use of electric scooters has spread more and more. They are mobility solutions in individual electric vehicles that are becoming more and more widespread in the transportation sector such as electric scooters and electric bicycles. It is foreseen that it will come to the fore in the formation of new mobility business models such as scooter rental, pick up from wherever you want / drop off wherever you want. Electric scooters are among the most popular transportation vehicles of recent times

in providing short distance transfers within the city. Especially in cities with a large population and in smart city works, the means of transportation offered by technology companies to reduce traffic are electric scooters. It is predicted that the market share of electric scooters will reach 38.6 billion USD by 2025 [12]. It is predicted that the market share will reach 42 billion USD by 2030 [13]. According to Mc Kinsey's global research report, it is predicted that worldwide "Micro Mobility (micro mobility)" companies will generate revenues between 150 billion USD and 500 billion USD by 2030. According to McKinsey's research report in 2019, 40% of car journeys are made for distances below 5 kilometers, while electric scooter technology, which provides short-distance transportation service, has achieved good success in a short time and reduced car usage [14-16].

It is thought that the advantageous features of the prototype product, which is expected to be obtained from the research, analysis and test stages in the study, such as being light, being easily foldable, and being easily portable, will be effective in the preference of the users. The aim of this study has been to obtain a multifunctional technological wheelchair by eliminating the disadvantages of manual and battery powered wheelchairs.

2. Method and Materials

Table-1 shows the number of individuals with at least one disability in the general population in Turkey by age group and gender. Similarly, the detailed version of the data in Table-1 according to the nature of the disability is presented in Table-2. In Table-2, the detailed distribution of the proportion of the disabled population in the general population is given [2]. Considering the walking disability category in the table that is directly related to this study, it seems essential to carry out such a study in this paper.

Table-1: Distribution of the population with at least one disability in the general population by age group and gender

Disabled Human	Population Ratio (%)	Male (%)	Female (%)
All Age Groups	**6.9**	**5.9**	**7.9**
3-9	2.3	2.5	2.1
10-14	2.1	2.4	1.8
15-19	2.3	2.6	2.0
20-24	2.7	3.4	2.0
25-29	2.6	3.0	2.3

Disabled Human	Population Ratio (%)	Male (%)	Female (%)
30-34	3.2	3.4	3.0
35-39	4.0	4.0	4.1
40-44	5.1	4.7	5.6
45-49	6.9	5.9	7.8
50-54	8.8	7.1	10.7
55-59	12.1	9.2	15.0
60-64	16.5	12.3	20.4
65-69	23.0	18.3	27.2
70-74	31.9	26.3	36.3
75 +	46.5	40.9	50.3

Table-2: Distribution of the disabled population in the general population by disability group

Disability Group	Total Population Ratio (%)	Male (%)	Female (%)	Total (Number of Persons)	Male (Number of Persons)	Female (Number of Persons)
Seeing	1.4	1.3	1.5	1 039 000	478 000	561 000
Hearing	1.1	1.1	1.2	836 000	406 000	429 000
Speaking	0.7	0.8	0.6	507 000	278 000	229 000
Walking	3.3	2.4	4.1	2 313 000	861 000	1 452 000
Holding, Carrying	4.1	3.2	5.1	2 923 000	1 136 000	1 787 000
Learning, Remembering	2.0	1.6	2.4	1 412 000	565 000	847 000

The mobility of the product, which is planned to be designed within the study, is provided by the DC (Hub) brushless motor in Figure-2, whose power can vary in the range of 250-350W [17, 18]. It is planned to use a ready-made intermediate product as a motor protection and driving circuit.

The advantages of the engine preferred in the design in this study can be stated as follows:

- Having high efficiency,
- Requiring less maintenance than other engines,
- Having a long service life,
- Low electrical noise ratio,
- Existence of mobile motor capability. In this study, the motor is placed in the front wheel (Alternatively, the engine can be placed in the rear wheel).

In addition to the advantages that affect its preference in the market, the engine also has some disadvantages:

- High installation cost,
- Confuse controls,
- High price,
- Requiring external power electronics circuit.

Figure-2: DC HUB motor

It is planned to use 18650 cylindrical type Li-Ion battery cells in 6-8 serial connection configuration during the transfer of energy to the electric motor [19]. The speed and range level of the motor in the product varies according to the connection configurations of the electrochemical Li-Ion battery cells used in the battery block. To give the product a multi-functional mobility feature, it is foreseen that the battery block should be in the front of the metal frame that forms the prototype skeleton in Figure-3. The importance of R&D activities in secondary electrochemical Li-Ion battery cells, called rechargeable cells, is increasing day by day. In addition to the

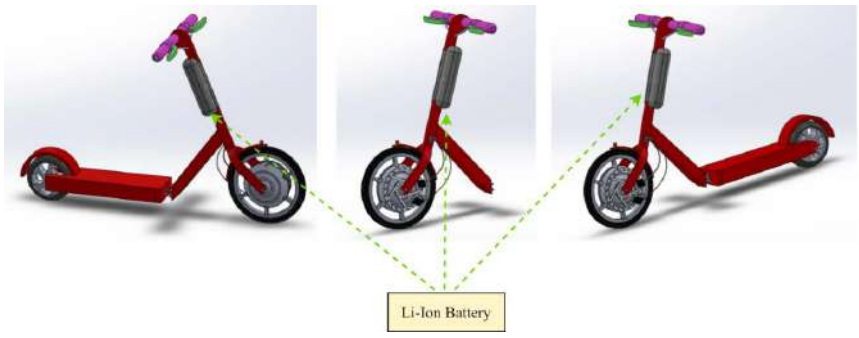
increasing demand for portable electronic devices, the increasing importance of individual/collective electric vehicles in the transportation sector increases the importance of Li-Ion batteries day by day [20, 21]. Some of the reasons why Li-Ion batteries are preferred as a power and energy unit in technological developments are as follows:

- Long life,
- No memory effect,
- Not require maintenance,
- Some types enable fast charging,
- Having high energy efficiency (≥ 90%),
- Having energy conversion efficiency,
- High energy-power density (270Wh/lt, 220 Wh/kg),
- Wide operating temperature range (-20, +60 C),
- High safety rates of some species by making different additives.

In addition to the advantages of Li-Ion batteries, there are naturally disadvantages that should be considered:

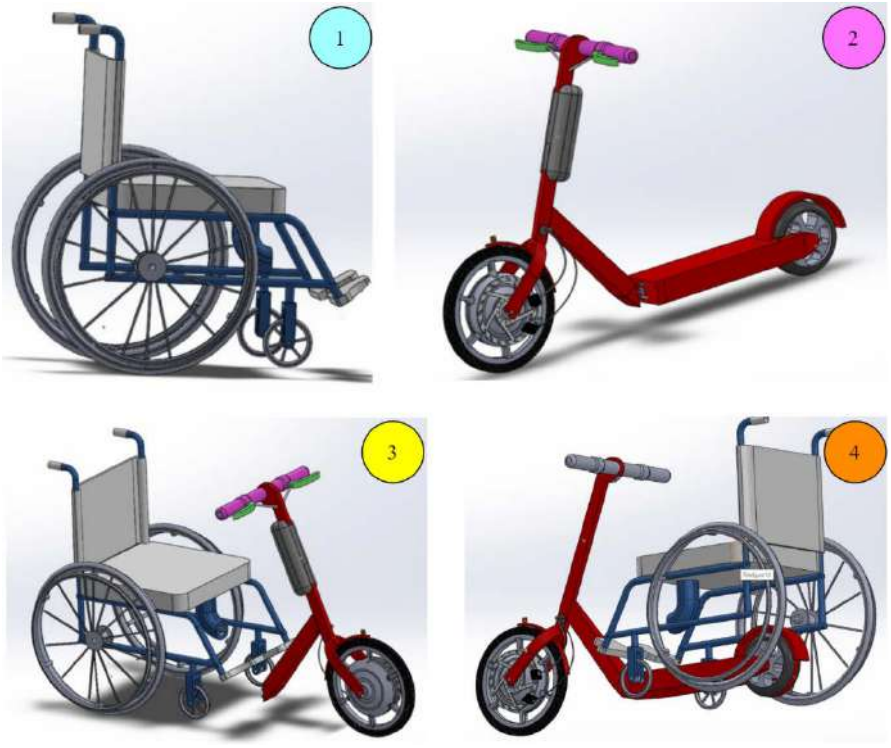
- Medium-high price ratio (Despite its high price, production costs are decreasing day by day),
- Requiring a protective electronic control circuit in order to take security measures (Battery management system (BMS) and charge control based protective electronic circuits).
- Loss of capacity that occurs normally due to long-term use,
- Loss of capacity as a result of overcharge-discharge.

Figure-3: Battery layout



The prototype product in Figure-4, designed in the study, can be put into the service of disabled individuals in the form of a wheelchair. Moreover, it can be offered to individuals without disabilities due to its ability to transform into an electric scooter and use it while standing. Another advantage of the design is that it can be used easily on uneven and sloping floors. The design is more convenient and practical for physically disabled individuals using wheelchairs compared to battery powered chairs. It also meets the expectations of individuals better by raising their living standards. While the design can be turned into an electric scooter by easily attaching to the wheelchair with mechanisms such as hooks or grippers, it can also be transformed into an electric scooter that can be used by a normal person without disabilities by attaching the other standing part of the scooter. On the other hand, optionally, a seat mechanism with plug-in feature can be added to use the scooter in a sitting position. It is planned to gradually control the speed parameter of the prototype in the design and increase it up to approximately 20-25 km/h. The weight of the power and steering part of the product is aimed to be approximately 12-14 kg. The carrying capacity of the product is expected to be in the range of 100-150 kg. It is foreseen that this weight will provide comfort and convenience in transportation and in case of being taken to desired places.

Figure-4: Designed product



3. Conclusion and Discussion

The design, which is seen as a single product, can transform into two different products and fulfill two different functions as both an electric scooter and a battery powered wheelchair. On the other hand, it can be used as four different products. As a result of the design, it is aimed to obtain a product for the physically handicapped and their families who use medical devices and apparatus such as wheelchairs, battery powered chairs and walking sticks. In the battery part, which is the power source of the product planned to be designed, it was deemed appropriate to use Li-Ion batteries, one of the components of clean energy and current technology.

An output that is more useful, practical, more efficient, more environmentally friendly and more suitable for the consumer, raising the living standards and meeting the expectations of the individuals better has been achieved for the physically disabled individuals using wheelchairs with the help of the designed product. While the design can be turned into an electric scooter by easily attaching to the wheelchair with mechanisms such as hooks or grippers, it can also be transformed into an electric scooter that

can be used by a normal person without disabilities by attaching the other standing part of the scooter. A prototype that is ready for the use of the user and their family at any time, which offers the opportunity to be transported by being folded in the trunks of cars in daily use, has been obtained. In the prototype, which is the subject of the study focused on R&D and innovation, the opportunity to offer two products (with four different usage options) to a wide market share has arisen as the biggest innovation element.

As a result, it is aimed to improve the mobility of physically disabled individuals and to present a common product prototype that can be used by their families and themselves.

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