

## **Manufacturing of the Portable Electric Scooter Prototype According to Variation of Wheel Number**

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### ***Abstract***

*With the emergence of the words Personal Mobility (P.M.) or Smart Mobility (S.M.), which are terms for personal transportation, the activities of related technologies are increasing with the research. Personal transportation is basically used as a short distance transportation method using electrical energy. As personal mobility became more popular, the resulting products and studies are spreading throughout the country. Most of the electric scooters, which are personal vehicles, are mostly imported from China. This is due to the fact that the price competitiveness of major components of electric scooters is owned in China. At this point, the domestic research direction is considered to be desirable in terms of composition and design of the electric scooter body. In this study, the models of portable electric scooters according to the number of wheels mounted on portable electric scooters were presented and the prototypes were produced accordingly. The number of wheels applied to the electric scooter was 2 and 3 and 4; the contents and advantages and disadvantages of the proposed portable electric scooter models were reviewed.*

**Keywords:** *Wheel Number, Electric Scooter, Prototype, Personal Mobility,*

### **1. Introduction**

Recently, the term P.M.(Personal Mobility) or S.M.(Smart Mobility), which is a term for personal transportation, has emerged, and the activities of related technology applications are increasing vigorously along with research on this [1]. Personal transportation is basically used as a short-range transportation means while using electric energy. Korea lacks resources to convert energy into energy, but it has an industrial structure that uses a lot of energy. In this situation, the government is trying to transform the industrial structure using eco-friendly energy, and Korea is ranked first in the world in the aging population. In the method to cope with such environmental factors, it is judged that it is the right direction to use energy as electricity in personal transportation [2, 3].

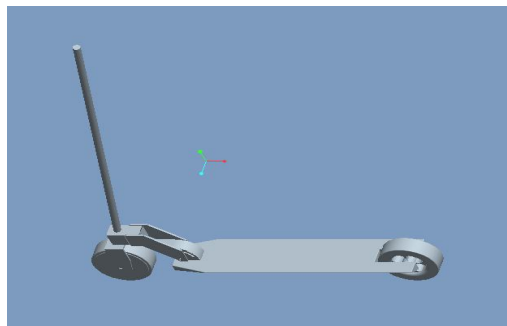
As personal transportation is popularized, related products are spreading in Korea, and electric scooter is the product with the largest market share in the personal transportation market. Most of the electric scooters are imported from China, which is due to China's competitiveness in major components of electric scooters [4, 5,

6]. In this situation, it is judged that the domestic research direction is desirable to construct and design the electric scooter body rather than cost reduction for the electric scooter components [7, 8, 9, 10].

In this study, the models of portable electric scooters according to the number of wheels mounted on portable electric scooters were presented and the prototypes were produced accordingly. The number of wheels applied to the electric scooter were 2 and 3 and 4; the contents and advantages and disadvantages of the proposed portable electric scooter models were reviewed.

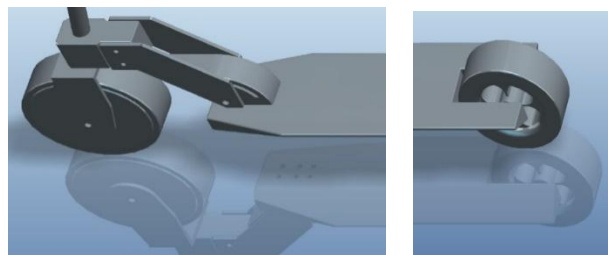
## 2. 2-Wheel Electric Scooter

When the number of wheels in the entire body of an electric scooter is set to two, it consists of one front wheel and one rear wheel in the layout structure of the wheel; this form is sometimes called an electric board; the basic model is Figure 1.



**Figure 1. The model of a 2-wheel electric scooter**

When the electric scooter is manufactured, the driving wheel selection is important. If the rear wheel is selected as the driving wheel, the front wheel can be lifted at the start, which may embarrass the driver. The folding structure of the car body is advantageous in consideration of the portability of the electric scooter, and the keeping and movement. If the foothold and steering column are comprised the hinge structure in order to make the folding structure possible in consideration of this the folding is possible the folding is possible. If the front-wheel drive system is applied to the two-wheel electric scooter, the rear wheel has the structure of passively following. The front and rear wheel structure design of the two-wheel portable electric scooter is the same as Figure 2.



**(a) Front wheel**

**(b) Rear wheel**

**Figure 2. Basic structure of front wheel and rear wheel for 2-wheel portable electric scooter**

In this study, the driving wheel was used as the front wheel in the production of the 2-wheel electric scooter, and the in-wheel motor was inserted into the front wheel. The front wheel drive, the steering shaft and the foothold are folded hinge structure is applied, and the rear wheel is manufactured in a passive form to follow

the front wheel. In the process of manufacturing, the battery and controller could be placed on the steering axis of the front wheel by installing the in-wheel motor on the front wheel. The prototype of the 2-wheel electric scooter is Figure 3.



**Figure 3. Manufactured prototype of a 2-wheel electric scooter**

The specification of the 2-wheel electric scooter prototype is the same as Table 1.

**Table 1. Specification of a manufactured 2-wheel electric scooter**

Items	Model or Specification
Motor	24V, 1.5kW
Controller	MINI 60S24
Battery	LG MF1, 24V 23A, Lithium Polymer
Driving method	In-wheel motor
Weight	12.5kg
Size	810mm*410mm(folding mode)
Minimum turning radius	130 cm
Max. velocity	25 km/hr
Over the Slope	10°
Caster wheel size	1 inch
Wheel diameter of front & rear	0.015m

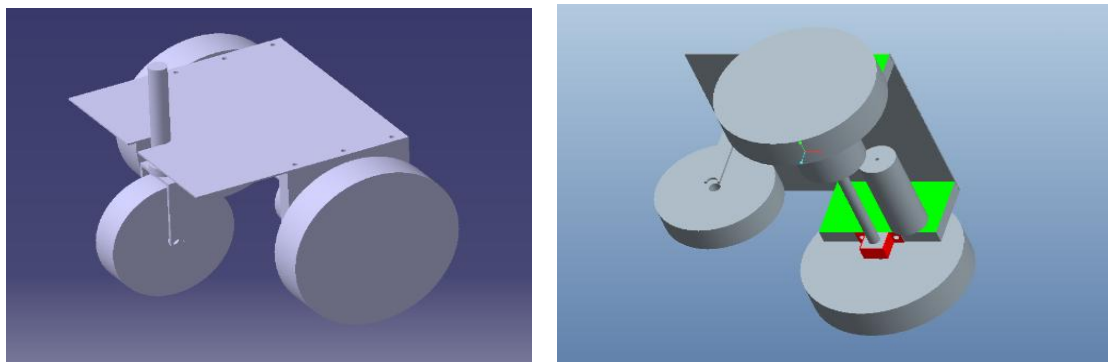
In order to widen the foothold area in the manufactured 2-wheel electric scooter, a folding-shaped auxiliary footboard was manufactured and attached to the car body. In order to secure stability during operation, a caster-shaped auxiliary wheel was installed to make it possible for the elderly to operate. The results of the modified and manufactured are as follows: Figure 4.



**Figure 4. Prototype of a 2-wheel electric scooter equipped assist foot plate and caster**

### 3. 3-Wheel Electric Scooter

The structure of the 3-wheel electric scooter is a structure that requires one front wheel or rear wheel, and the basic model of the 3-wheel electric scooter produced in this study is a structure with one front wheel, such as Figure 5. The structure with 2 front wheels is a form that can be seen on a quick board used by infants or motorcycle. The quick board used by infants is not electric driving, and the wheels of two front wheels are separated from the steering shaft. Two front wheels separated from the steering shaft are operated separately, allowing them to naturally differentially function. In addition, the two front-wheel motorcycles are in the form of rear-wheel drives, so there is no need for a separate differential device. In this study, two rear wheels were built and trans axles were introduced to perform differential roles.



**Figure 5. The model of a 3-wheel electric scooter**

The proposed 3-wheel electric scooter model is rear-wheel drive and the steering shaft is placed on the front wheel. In the production process, 24V and 270W motors were applied, and two wheels were connected using trans axles on the rear wheel, which has a differential gear. The rear wheel was applied with 9-inch tube tires, and the battery was applied with two 12V 12AH lead accumulator batteries, and the front wheel was adjusted to maintain the horizontality of the rear wheel and the foothold. The trans axles applied to the rear wheel was shown in Figure 6 and the starting product was the same as Figure 7.



Figure 6. Manufactured rear systems applied trans-accel of a 3-wheel electric scooter

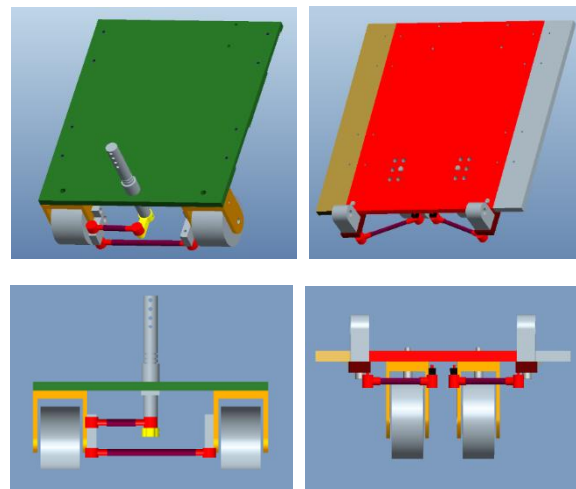


Figure 7. Prototype of 3-wheel electric scooter

As a result of the test run by producing the prototype of the proposed 3-wheel electric scooter model, the vehicle was pulled back when the throttle was pulled to start, and the rear wheel tire was large in size, so the overall level difference was high. To compensate for this, the size of the tire applied is reduced, and the front wheel drive is applied to prevent the body from being lift at the start. Also, it is advantageous to extend the wheelbase, which is the distance between the front and rear wheels, for the safety and convenience of the rider.

#### 4. 4-Wheel Electric Scooter

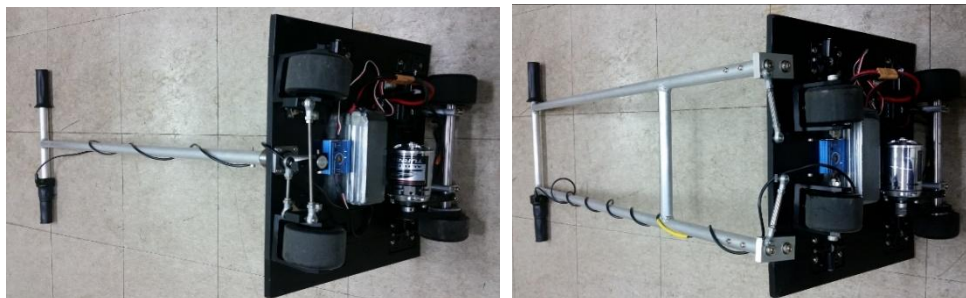
When the 4-wheel structure is introduced into the electric scooter, two wheels can be installed on the front and rear wheels, respectively. This structure has stability for the driver when driving and improves ride comfort. The proposed 4-wheel electric scooter model is divided into one and two steering shafts, and the link structure of the front wheel is the same as Figure 8 when the steering shaft is one or two, (a) of Figure 8 the form in which the steering column is 1, (b) the form in which the steering column is installed 2.



(a) 1-Shaft steering      (b) 2-Shaft steering  
**Figure 8. Steering structure of a 4-wheel electric scooter**

One of the methods of using one steering shaft with two wheels in front wheel is to connect two wheels with a link and to connect the steering shaft with another link. The structure designed for this is the same as that of Figure 8 (a). When the steering shaft is two, the steering shaft is connected to the steering shaft of two front wheels. However, the structure of rotation can be formed by the fixed reference point.

In the process of making the proposed 4-wheel electric scooter models, the throttle of the handle part connected to the steering shaft was used to control the speed for commercialization of the proposed models. In addition, the 4-wheel electric scooter models were designed to fold the foothold structure to expand the foothold as needed, considering portability. The 4-wheel electric scooter models are Figure 9.



(a) 1-Shaft steering      (b) 2-Shaft steering  
**Figure 9. Manufactured prototypes of a 4-wheel electric scooter**

In the process of manufacturing the steering system of the 4-wheel electric scooter, the link type is taken and the steering angle can be changed according to the location of the link connected. In the manufacturing process, a steering shaft is placed in the middle of the whole shaft connecting two front wheels, or two wheels are connected in a link form to enable steering. The specification of the 4-wheel electric scooter is the same as Table 2.

**Table 2. Specification of a 4-wheel electric scooter**

Items	Model or Specification
Motor	24V, 1650W, 3,000rpm
Controller	CCPM SERVO CONSISTENCY MASTER
Battery	14.8V, LiPo battery
Driving method	Trottle
Weight	11.5kg (1-Shaft steering) 12.4kg (2-Shaft steering)
Size	16×35×10(cm, folding mode)
Minimum turning radius	110cm(1-Shaft steering) 120cm(2-Shaft steering)
Max. velocity	20 m/s

As shown in the table above, the minimum radius of rotation of the one-axis steering system is smaller than that of the two-axis steering system.

## 5. Conclusion

This study is a study on electric scooters, which are representative personal transportation means, and suggests models of electric scooters according to changes in the number of wheels mounted on portable electric scooters. In addition, the number of wheels applied to the electric scooter that produced the starting product was changed to 2, 3, and 4 for commercialization of the proposed models. The following conclusions were drawn through the process of making the starting product for the proposed portable electric scooter models.

- (1) In order to increase the portability of the electric scooter, the folding type of the car body or the foothold structure is advantageous
- (2) In the design of the car body of electric scooter, the front part is lift if the rear wheel drive is applied, and the front wheel drive is advantageous.
- (3) If the wheel base is extended, the phenomenon that the front wheel part is lift can be suppressed.
- (4) In order to have a wide rotation angle of the steering wheel, it is advantageous to have one steering shaft.

## Acknowledgement

This paper was studied by the academic research fund of Seoil University in 2020.

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