A Concept Compact City Vehicle Design for the Disabled Aging People

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Abstract: The degeneration of physical function of the aging often causes physical disability. The aging people have difficulties in getting in and out of the compact car, decreasing their chance to go outdoors. The present study is based on observation of six disabled aged users of light to moderate physical disability in moving inside and getting in and out of a car. From the video and interviews, problems the disabled aged people encountered in using compact cars were addressed. To solve the inconvenience and difficulty elderly disabled passengers have in a compact car, a concept design of a welfare vehicle was developed. In the concept welfare vehicle, a big hand bar on the side of the car door that can be controlled with the operation of car door was proposed to help the aging people support their body. Moreover, special enlarged chair, hand grip, and lighting under the rear seat were offered to help the aging people get in and out of the car. In addition, a hand grip hidden on the ceiling can help the elderly disabled passengers move around inside a compact car.

Key words: Aging people, disabled, welfare vehicle design.

1. Introduction

In recent years, the development of medical care has pushed almost all of the countries in the world into the era of advanced age [1]. Aging causes the degeneration of physical functions of human beings. The behaviors of aging people change with the increase of age and the degeneration of physical and psychological abilities cause some degree of limitations. Particularly, the degeneration of motor function will dramatically affect people’s activity and living habitual behavior. The aging people are not willing to go outdoors because of the inconvenience in activity and travel by transportation vehicles. As a result, they might easily lose contact with society and be unable to interact with the public [1].¹

Currently, the mass transportation tools or individual sedans are majorly designed for users of normal motor function. Taking Taiwan as an example, the government has concerned to provide the Fu-Kang Handicap Bus for the disabled to rent but the number of buses is too small for the disabled population. People still use their own sedans to pick up their aging disabled family members. In Japan where the advanced aging problem is more serious, many car manufacturers have made efforts in the design and development of new welfare cars. Furthermore, the Japanese government adopts some supporting measures to reduce the price of welfare cars, so that they have the most welfare vehicles in the world. However, because most people consider regular cars, a compact city car suitable for leisure activities for local families and for picking up the disabled aging people is chosen as the target. In the study, problems of the aging disabled subjects encountered while getting in and out of a compact car were analyzed for the development of a concept welfare vehicle for the disabled aging people. Based upon the problem

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observed, a concept design for welfare vehicle was proposed.

2. Literature Review

Mobile challenge refers to the status of some people that cannot fully utilize their ability of physical function due to the body injury. According to the grades and standard of physical and psychological handicap by the Department of Health, Executive Yuan, ROC, in 1999 and 2000, physical disability is defined as any impairment that limits the physical function of one or more limbs or fine or gross motor ability [2]. In the present study, the aging people with light to moderate degrees of physical disability are majorly concerned. The serious handicap aging people that cannot move by themselves and need mobile assistant equipment are excluded.

Due to the high gasoline price and economic depression, the engine capacity and fuel consumption are important factors to consider in car purchase. In Taiwan, most car manufacturers cooperate with international car manufacturers and produce models similar to those in Japan. In the definition of compact cars, the Japanese specification will be adopted. In Japan, a vehicle under 3,400 mm long, 1,480 mm wide, 2,000 mm high, and under an engine capacity of 660 cc is referred to as a compact car. And a small-sized car is a vehicle under 4,700 mm long, 1,700 mm wide, 2,000 mm high, and under an engine capacity of 2,000 cc.

A welfare car is a special vehicle designed for the elderly, weak, and handicap in the era of advanced age. It features convenience in getting in and out of the car. The development of welfare cars started after the mid 1960s and has not been emphasized until after 1990s. Since then, the number of welfare cars has increased and so has the assistant facility. After 2000, a compact welfare vehicle was introduced by a Japanese car manufacturer. Though space-limited, it brings great convenience to the users who have aged elders, making welfare cars popular in public [3]. Currently, there is no specific definition of a welfare car in the world but any vehicle that has assistant equipment belongs to a welfare car. According to JAMA [4], welfare cars can be divided into delivery and self-operation types. For the self-operation type, there are assistant devices for drivers of hand or foot-handicap. For the delivery type of welfare vehicles, there are rotary seats, lifting assistant seat, lifting back seat, move-in wheeler, and lifting wheeler. Most welfare vehicles are equipped with the rotary seat. Because the assistant devices need a lot of space, the price goes with the complexity of the device.

To help senior citizens park their cars, Yasunobu and Kinoshita [5] developed an intelligent parking support system for welfare vehicles. Under the conditions of an already-known parking lot shape, low speed driving, and no dynamic obstacle, the welfare vehicle could enter the parking lot from the rear side by fuzzy control built in expert knowledge system. Shi et al. [1] developed a Turny-type power seat to help disabled people rise from a vehicle. The power seat system is equipped with swiveling, sliding, and extending functions primarily by DC motors, chains, and gears. After a series of tests, the power seat proved conformed to the ADA (American Disabilities Act) standards. The durability test ensured longer product life while the crash analysis showed a small rotational distortion not harmful to the passengers. Lee et al. studied the behavioral characteristics and inconvenience factors from viewpoints of disabled drivers and caregivers to develop adaptive vehicles [6]. Inconvenience factors in getting in and out of a vehicle were analyzed according to different types of disabilities. Based upon these inconvenience factors, improvements were proposed in which various types of adaptive driving controls and assistance devices from different countries were suggested. Lung and Sen proposed a model for integrating the resource of car welfare equipment providers, including taxi drivers and car rental services, to construct the transportation and care service system [7]. The result
of their survey showed that there was a significant scope for the promotion of a front welfare seat and transportation service system, particularly the installation of a welfare chair in a taxi. Demirbilek and Demirkan proposed a USAP (Usability, Safety, Attractiveness, Participatory) design model to develop safe and functionally appropriate products that would promote and maintain independent living of the elderly [8]. In their design model, there are five phases for the designer to transform a concept into a design description so that the artifact is able to produce the determined functions: concept development, concept refinement, prototype construction, user trial session, and production. Their study results demonstrated that involving the elderly in the design decision making process would enhance the design solutions and increase elderly people’s awareness of the consequences of the decisions. More importantly, the elderly people might gain satisfaction by having influenced the decisions. Yang et al. [9] integrated many innovated high-tech equipment such as safe action and biomedical supervisory control system, back care and anti-crash system, body temperature, pressure, and blood sugar measurement recall system, door and wheelchair remote control system to develop a welfare vehicle for elderly and action inconvenient people. Such a welfare vehicle enables the driver to drive the wheelchair up to the vehicle directly, to drive safely with the anti-crash censoring system, to measure their body status and report back information from local medical center.

In the present study, the goal of the design is to work out some assistance interior devices to reduce the difficulties of moderate handicap elders and give them more opportunities to go outdoors. Problems the aging subjects had in getting in and out of a Toyota Wish were observed. Based upon these problems, a concept design for welfare vehicle was proposed.

3. Methods

The experiment conducted in the present study helps to explore the difficulties and demands of the aging people have in taking current sedans so as to establish the key points for a compact welfare city car.

Subjects: Six subjects aged over 65 in different degrees of handicap took part in the experiment and survey. They could be divided into three groups according to their physical conditions and walking devices: crutch user, wheeler of lightly disabled, wheeler of seriously disabled (Table 1).

Experimental materials: To make it easy for the elderly handicap subjects to get in and out of the car, a Toyota Wish was chosen as the experimental material because of the bigger space in the rear seat.

Experimental procedure: The experiment was conducted in a participatory way. From observations, difficulties that the elderly people have in getting in and out of the cars and problems of the current car were obtained. The experimental vehicle was first taken to the elderly daycare center and the subjects were invited to get in, sit, and get out of the car. They were asked to do the following tasks (Table 2): (1) to open the rear door from the back; (2) to open the door and move their feet into the car; (3) to move in the car; (4) to open the door and move their feet out on the floor; (5) to step on the floor and leave the car. Their behaviors were taken down by video cameras.

To understand the situations the elderly subjects get in and out of the car, two video cameras were set for video shooting. Video 1 shot the way the subject got on the car and the action in the car and Video 2 shot how the subject opened the door and moved into the car. After the experiment, the content was analyzed for the key frames of pictures.

4. Results and Discussions

4.1 Study Results

Key frames of the video data were taken for analysis. There are six types of problems frequently seen in the experiment. The elderly handicap subjects had many difficulties in getting in and out of the car.
Table 1  Physical conditions of the subjects.

<table>
<thead>
<tr>
<th>Subject code</th>
<th>Physical conditions of the subjects and their walking devices</th>
<th>Physical conditions of the subjects</th>
<th>Walking assistance tools</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Group 1: Crutch user weak coordination due to brain surgery</td>
<td>weakening joints and poor eye sight</td>
<td>Crutch</td>
<td>65-70</td>
</tr>
<tr>
<td>2</td>
<td>Group 2: Lightly disabled, move by the wheeler</td>
<td>seated in the wheeler most of the time</td>
<td>Crutch</td>
<td>76-80</td>
</tr>
<tr>
<td>3</td>
<td>Group 3: Seriously disabled, move by the wheeler</td>
<td>weak in the right leg due to the surgery</td>
<td>Wheeler</td>
<td>71-75</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>weak and seated in the wheeler most of the time</td>
<td>Wheeler</td>
<td>71-75</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>weak in the limbs and unable to exercise</td>
<td>Wheeler</td>
<td>76-80</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>Wheeler</td>
<td>81-85</td>
</tr>
</tbody>
</table>

Table 2  The experimental procedure.

<table>
<thead>
<tr>
<th>序号</th>
<th>步骤</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>打开车门</td>
</tr>
<tr>
<td>2</td>
<td>上车</td>
</tr>
<tr>
<td>3</td>
<td>坐在车内</td>
</tr>
<tr>
<td>4</td>
<td>下车</td>
</tr>
<tr>
<td>5</td>
<td>关上车门离开</td>
</tr>
</tbody>
</table>

Problem 1: Subjects need to hold the side handle bar to get in and out of the car.

From pictures in Table 3, all six subjects needed to hold the side handle bar to get in and off the car. In getting in the car, the side handle was the only support for them. In getting off the car, they had difficulties in standing. Therefore, they would hold the side handle bar to leave the car.

Problem 2: Subjects need to hold the front seat to get in and off the car.

From the pictures in Table 4, five subjects held the front seat to help them get in and off the car. It is clear that the front seat is the biggest support for the people seated in the back seat. When there is no assistant device in the car, the front seat is the major choice for the subjects to hold on for getting in and out of the car.

Problem 3: Subjects need to hold the seat back to move in the car.

From the experiment, six subjects needed to hold the seat to move in the car (Table 5). In getting in the car, there was no hand grip to the left. Therefore, they would hold the seat to move inside. When they prepare to get off the car, they would hold the seat with one hand to step out of the car because they did not have strong legs and stability.

To solve the above three problems, Japanese car manufacturers adopt hand bars on the back of the front seat (Table 6) for the elderly disabled passengers to hold or support their body to get in and out of the car.

In Table 6, Nissan Serena, a 7-passenger vehicle, there is a reversed L-shaped handle bar on the back of the first row of seats and a regular size of hand grip on the door side. And on the back of the second row of
Table 4  Subjects hold the front seat to get in and off the car.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

Table 5  Subjects hold the seat back to move in the car.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
</table>

Table 6  Current solutions of Japanese car manufacturers.

<table>
<thead>
<tr>
<th>Nissan Serena</th>
<th>Nissan NV200</th>
<th>Daihatsu Tanto</th>
<th>Toyota Raum</th>
<th>Toyota Sienta</th>
</tr>
</thead>
</table>

Source: Nissan, Toyota, and Daihatsu websites.

seats, smaller hand bars are provided. Because of the bigger space, Nissan NV200 uses bigger horizontal hand bars and hand grips to help passengers get in and out of the car. Toyota Sienta is a small-sized car and has no space for the bigger hand bars, so the hand bar is integrated with the seat. Daihatsu Tanto and Toyota Raum are also small-sized cars. Though they have big hand bars, they do not occupy the passenger space.

Problem 4: It is not easy for subjects to open the door.

In the experiment, four out of six subjects had difficulties in opening the door (Table 7) because they were weak in the hands. Because of the degeneration of muscle force in fingers or arms, it was not easy for them to open the door.

Problem 5: It is not easy to push open the door because of the resistance force.

From the experiment, it had been found that four subjects had difficulties in pushing open the door (Table 8) due to the resistance force of the door. Because they were weak in muscle of their arms, it is not easy for them to push the door in one trial.

Problem 6: It is not easy to get in the car because the car and lower access of the entrance are too tall.

From pictures of Table 9, three subjects had difficulties in getting on the car because the car and lower access of the entrance are too tall. The reason is that the elderly subjects are weak on the knee and joints, so they do not work well in extension and supporting functions, leading a problem in getting in the car. Japanese car manufacturers have solutions to problems 4 to 6 listed in Table 10.

To cope with the problem in opening the car door, Japan car manufacturers enlarge the hand bar and add the width or thickness to reduce the pushing force so that it will be easy for the elderly passengers to open the door. For the problem of resistance force, a sliding
### Table 7 Subjects had difficulties opening the door.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

![Image of subjects having difficulty opening the door.]

### Table 8 It is not easy to push open the door because of the resistance force.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

![Image of subjects pushing the door with difficulty.]

### Table 9 It is not easy to get on the car because the car and lower access of the entrance are too tall.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
</table>

![Image of subjects having difficulty getting on the car.]

### Table 10 Solutions in current Japanese car manufacturers.

<table>
<thead>
<tr>
<th>Honda Freed</th>
<th>Mitsubishi ek</th>
<th>Back seat can move back and forth</th>
<th>Lower the height of the car floor</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Honda Freed Interior" /></td>
<td><img src="image" alt="Mitsubishi ek Interior" /></td>
<td><img src="image" alt="Back seat movement" /></td>
<td><img src="image" alt="Height reduction" /></td>
</tr>
</tbody>
</table>

Source: Honda, Mitsubishi, Daihatsu, and Suzuki websites.

### Table 11 Problems elderly subjects have in taking the car and their redesign and solutions.

<table>
<thead>
<tr>
<th>Problems in taking the car</th>
<th>Solutions and redesign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Elderly disabled subjects need to hold the side handle bar to get in and off the car.</td>
<td>Improve or add the hand bar to help get in and out of the car; the hand bar can be stored or hidden.</td>
</tr>
<tr>
<td>2 Elderly disabled subjects need to hold the front seat to get in and off the car.</td>
<td>Add a hidden hand bar on the ceiling to help elderly disabled people move their bodies.</td>
</tr>
<tr>
<td>3 Elderly disabled subjects need to hold the seat back to move in the car.</td>
<td>Adopt the sliding way to open the door (available in many current cars).</td>
</tr>
<tr>
<td>4 It is not easy for elderly subjects to open the door.</td>
<td>Reduce the height of the lower access of the car door (available in many current cars).</td>
</tr>
<tr>
<td>5 It is not easy for elderly disabled subjects to push open the door because of the resistance force.</td>
<td></td>
</tr>
<tr>
<td>6 It is not easy for elderly disabled subjects to get on the car because the car and lower access of the entrance are too tall.</td>
<td></td>
</tr>
</tbody>
</table>
style is used to replace the regular door opening way. For problem 6, car manufacturers lower the car height or car floor to 330-370 mm.

4.2 Design and Development of a Concept Welfare Vehicle for the Disabled Aging People

4.2.1 Problems Disable Aging People Have in Getting in and out of the Car

From the experiment, six kinds of problems were identified from the elderly subjects and their redesign and solutions are listed in Table 10. Problems 1 and 2 happen in getting in and out of the car. Currently, Japanese car manufacturers have offered hand bars for the elderly passengers to hold and get in and out of the car. A hidden hand bar is proposed in the present study on the door side and upper part of the door. They will lower or arise when the car door is opened and will be hidden when car door is closed.

Problem 3 frequently occurs when the elderly disabled subjects move in the car. The elderly passengers are often unable to move to a proper place in the car, causing inconvenience in the action. Because of no assistant device, the elderly passengers need to rely on the front seat to move their body in the car. It is suggested to have a hidden hand bar on the ceiling above the rear seat. The hand bar will make it possible for the elderly passengers to support their body by directly holding the hand bar above. In addition, problems 4 and 5 are related to the door open problem. Currently, the best solution to this problem is the sliding style door opening system. It not only solves these two problems but also adds space in getting in and out of the car. At last, problem 6 happens when the car or car door is too tall. Doubtlessly, the decrease of the car height and the car door is the way current Japanese car manufacturers adopt to solve the problem.

4.2.2 The Concept Welfare Vehicle for the Disabled Aging People

In the present study, Daihatsu Tanto, 2,420 mm in wheelbase, 3,385 mm in length, 1,470 mm in width, and 1,710 mm in height, is used for the reference for a new concept welfare vehicle. It is an electric car for the middle age group users who are likely to take their aging elders to go outing, shopping, and see the doctor. The lower chassis for this concept car is convenient for the aging people to get in and get out of the welfare vehicle. Moreover, the higher interior space makes it easier and more comfortable for the aging people to move inside.

For the aging people to get in and out of the welfare vehicle, a sliding way is adopted for the rear car door and an extended pedal is set for the convenient access of the car interior. In addition, the rear seat is flat and the back rest is slightly tilted backward so that elderly people can get up easily. In the welfare car, the rear seat is composed of two seats; one is bigger and the other is smaller. For a bigger room for limb extension, the bigger seat is offered for the aging people. Refer to Fig. 1 for the rear seat design.

Extended bars are added on the back of the front seat so that the aging people who are weak on the leg can move their body with the support of their hands. Refer to Fig. 2.

To get in the car, the elderly people can first hold the vertical hand bar by the door with their right hand and hold the seat back with their left to take a seat in the car. Finally, they can move in their body by the support of left hand on the seat. Please refer to Fig. 3 for the procedure.

To get out of a welfare vehicle, the elderly people will first move their body to the rear door. There is a vertical hand bar on the upper corner of the door. After sliding open the rear door, they can step out their right foot and then move their body with the support of their hands pushing the seat. Please refer to Fig. 4. Special lighting is added under the rear seat (Fig. 5) to light up the aisle space, making it easier for the elderly people to get into the rear car space.

Features of the new concept welfare vehicle:

(1) A wider chair is equipped in the rear seat, offering a comfortable and spacious surrounding for the disabled aging person.
Fig. 1  A sliding back door is designed and higher interior space will be offered in the concept welfare vehicle.

Fig. 2  The interior of the concept welfare vehicle.

Fig. 3  Procedure for the aging people to get in the welfare vehicle.

Fig. 4  Procedure for the aging people to get out of the welfare vehicle.

(2) The lighting under the rear seat helps the passengers in the back seat see the aisle clearly.

(3) A special hand grip is offered between the wider chair and the smaller chair in the rear seat so that the aging person can have a support to move out of the car.

5. Conclusions and Suggestions

Physically disabled aging passengers have difficulties in getting in and out of the compact city vehicle. Another problem lies in the fact that they don’t have enough muscle force in opening or closing
the door. The height of lower access of the door entrance is still another problem. Currently, car manufacturers adopt hand bars in the rear seat and hand grips on the door side, sliding car door opening system, and reduce the lower access of the car door to help elderly passengers get in and out of the car. A hidden hand bar in a proper place that can be stored when it is not used is proposed in the present study to directly support the elderly passengers and make it easier for them to move inside the car and get in and out of the car. Though the authors also conducted a questionnaire survey in the observation, the subjects are aged and have difficulties in expressing their ideas, causing an improper validity. Based on the problems the authors observed, a concept welfare vehicle was proposed. Special back seat, hand grip, and lighting in the rear seat were offered to help the aging person get in and out of the car. In the future, a concise questionnaire survey should be designed so that it will be easy for the elderly subjects to answer the questions. In the study, only six subjects were recruited. More subjects may be invited to improve the validity in the future.

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