

# The Construction and Inspection of General wheelchair design evaluation criteria

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**Abstract:** To provide the elderly with a suitable wheelchair, this study aims to construct general wheelchair design evaluation criteria covering development, production, supply, use, care service, which everyone concerned with a wheelchair can understand and share. In the 1st phase, in order to extract elements required to construct the criteria, we administered a questionnaire containing 37 items to 61 interim wheelchair users in Japan. In the 2nd phase, seven items, 17 sub items, and 120 sub-sub-items were drawn, based on demand from interim users obtained from the questionnaire, design/development, production, and from medical/rehabilitation services, and from a healthy social formation. In the 3rd phase, with three types of domestically marketed wheelchairs with different functions as examples, two evaluators with wheelchair knowledge performed an evaluation simulation for 120 items. From result of the 1st, the 2nd and 3rd phase we verified the validity of evaluation criteria.

**Key words:** *wheelchair, elderly, design evaluation criteria*

## 1. Introduction

In Japan, the processes where wheelchair users including aged people have begun to use wheelchairs are diverse and complicated. The reasons are different from how people use common consumer products. Such processes are diverse according to the situation where people need wheelchairs, the structure of those who are involved in the use of wheelchairs, how they are involved in it, the differences in their roles, the differences in legal implications, etc. As a result there are cases where wheelchairs suitable for the users are not provided or used. It is a matter of course that a wheelchair most suitable for a particular user is easy to use and attractive should be developed, produced, supplied, used, and serviced for every wheelchair user. However, specific adequate measures for this are not in place in Japan. One of the main reasons is that the idea of a wheelchair that is related closely to medical care and directly with the physical functions has not yet been clarified, i.e., what a wheelchair should be, and different from common consumer products. Matters on wheelchairs have been empirically handled, and if there are problems about them arising, information on them is not stored but left untouched. There are no indexes that can be used for the total evaluation of design of wheelchair, i.e., no such indexes that cover the development, production, supply, use, and care service, and can be understood and shared by everyone. Therefore, there are no moves to understand one another based on a common language or common indexes in this field. In this study, we started from understanding the current use status of wheelchairs, and understanding what is now required for wheelchairs by collecting voices of interim users to the users, i.e., those who engage in medical/care service and are capable of speaking for the users, to find the requirements about wheelchairs that might be different according to their positions or experience. The final aim is to set comprehensive items for a total evaluation of wheelchair design that cover development, production, supply, use, maintenance, and care service, and can be understood and shared by everyone involved in using wheelchairs, by adding the requirements in terms of design, development, production, and supply, to the requirements presented by the interim users. For that purpose, in this study, we analyzed the requirements presented by the interim users to the users in the first stage, the items for total design evaluation based on the analysis results in the second stage, and conducted an evaluation of commercially available wheelchair products based on the design evaluation items as a simulation to test the validation of those evaluation items in the third stage.

## 2. Analysis of Requirements Presented by Interim Users

### 2.1 Introduction

We collected opinions of interim users between the users (including aged people) and the wheelchair manufacturers, i.e., medical service staff, institutional administration staff, advisors, and home helpers, who see

wheelchair users and hear from them on a daily basis, by means of a questionnaire survey.

## **2.2 Questionnaire Survey**

### **(1) Participants of Survey**

The participants of the questionnaire survey were interim users working in institutional welfare service and in domiciliary welfare service according to the place of living for aged people. Those working in the former service were 61 members of the staff of four special nursing homes for the elderly and one geriatric health care facility for the elderly in Miyagi Prefecture, Japan. Those working in the latter service were 55 members of the staff of three home help offices in that prefecture.

### **(2) Questionnaire Sheet**

We prepared a questionnaire sheet of 37 question items in total to evaluate wheelchairs about traveling performance, user-friendliness, maintenance, care service, living environment maintenance, quality/material, production technology, design, and delivery on a five-point scale with 30 questions, and also three questions about the prices and trends in the market for wheelchairs, and four questions about the interim users' attributes (sex, age, job, and experience in using wheelchair).

## **2.3 Consciousness Structure of Interim Users by Cluster Analysis**

It was assumed that institutional welfare service staff and domiciliary welfare service staff had different consciousness structures of the requirements on wheelchairs according to their position, situation, and role. We studied their consciousness structures on wheelchairs, and evaluated and compared them, by cluster analysis, with seven clusters set. As a result, we found the following.

- (1) The consciousness structure of requirements on wheelchairs of interim users working in institutional welfare service consists of “consciousness of assuring and maintaining the functions and performance of wheelchairs themselves” and “consciousness of creating an environment where wheelchairs can be used in a proper way.”
- (2) The consciousness structure of requirements on wheelchairs of interim users working in domiciliary welfare service consists of “consciousness of the functions, performance, and user-friendliness of wheelchairs, considering care service,” “consciousness of maintenance for creating/improving an environmental condition to allow wheelchair users to go out,” and “consciousness of maintenance and repair, delivery, and appearance of wheelchairs.”
- (3) The difference between the two groups of interim users is that the institutional welfare service staff are more conscious of obtaining assurances of the functions and performance of wheelchairs, while the domiciliary welfare service staff are more conscious of user-friendliness of wheelchairs and creation of an environment to allow the users to go out, and the traveling function and performance to encourage them to do so.

## **2.4 Consciousness of Interim Users According to Their Attributes by Factor Analysis**

We studied the differences in consciousness of the institutional welfare service staff and the domiciliary welfare service staff according to their attributes (sex, job, age, and experience of use of wheelchair), with seven factors set for each group. The cumulative contribution ratio of the seven factors for the institutional welfare service staff was 55.8%, while the cumulative contribution ratio for the domiciliary welfare service staff was 60.1%. This study revealed the following.

- (1) Among the institutional welfare service staff, care managers are more conscious of wheelchairs in terms of the job factor, those who have an experience of using wheelchairs in advisory or medical jobs are more conscious of them in terms of the wheelchair experience factor, but younger people are less conscious of the functions and performance of wheelchairs in terms of the age factor.
- (2) Among the domiciliary welfare service staff, medical staff are more conscious of wheelchairs in terms of the job factor, those who have an experience of performing medical care or advisory work are strongly conscious of wheelchairs in terms of the wheelchair experience factor, but care managers, care staff, and those have an experience of care work are moderately conscious of them. Caring families are strongly conscious of the environment for use of wheelchairs. Women are more moderately conscious of wheelchairs than men.

## **2.5 Differences in Requirements between Institutional Welfare Service Staff and Domiciliary Welfare Service Staff by Factor Analysis**

We performed factor analysis on all the participants of interim users to find differences in requirements of those people between the institutional welfare service staff and the domiciliary welfare service staff. With seven factors set, the cumulative contribution ratio was 52.2%. This study revealed the following.

- (1) The institutional welfare service staff have higher requirements for the proper use and maintenance of wheelchairs, which represents their hope for proper management of wheelchairs.

- (2) The domiciliary welfare service staff have higher requirements for traveling performance, indoor/outdoor travel environment, ease to help, design, and deliveries. They have requirements from the users' perspective and from a wide range of other viewpoints.

## **2.6 Results of Analysis of a Questionnaire Survey in terms of Economy**

We clarified the consciousness structure of the interim users in an economic aspect of wheelchairs based on their answers to three questions concerning the purchase of wheelchairs on the questionnaire sheet. The study revealed the following.

- (1) Consciousness of purchasing wheelchairs

For the purchase of wheelchairs, a majority of both the institutional welfare service staff and the domiciliary welfare service staff are in favor of the idea of "Inexpensive and balance are important." None of the participants is in favor of the idea of "the cheaper, the better, even with poor quality." In addition, it was revealed that the institutional welfare service staff have a wide range of ideas about purchasing wheelchairs.

- (2) Price of wheelchair

A majority of the institutional welfare service staff answered "\50,000-100,000" for the main price zone but "Have not checked wheelchair products recently" or "Have checked wheelchair products recently but do not know the price." A majority of the domiciliary welfare service staff are in favor of the price zone of \10,000-100,000, so they are more conscious of the reduction of economic burden of households.

- (3) Sale of wheelchairs of poor quality

For the sale of wheelchairs of poor quality, more than 80% of each group answered "Not in favor at all" or "Little in favor." This indicates their uncompromising attitude about quality.

## **2.7 Comprehensive Discussion on Requirements of Interim Users for Wheelchairs**

Requirements of interim users about wheelchairs are formed from their internal factors. It is considered that their internal factors are reflected in diverse ways of use or selection of wheelchairs. Their internal factors are influenced by the differences in work environment, age, sex, and experience in using wheelchairs between the institutional welfare service staff and the domiciliary welfare service staff. Our study revealed that the institutional welfare service staff have more diverse requirements, while the domiciliary welfare service staff have more focused requirements. It can be considered to be the differences in requirements of wheelchairs between the two groups have occurred from the differences in the use environment and required positions.

There are many different ideas about a desirable wheelchair, such as medically or ergonomically desirable ones [Notes 1-5]. The interim users have not well indicated what a desirable wheelchair is. This is partially because they are not given sufficient knowledge about wheelchairs in their education.

This study clarified the requirements about wheelchairs from an interim user's point of view. We believe that this will provide a user's perspective for the evaluation of designs of wheelchairs.

## **3. Collection of Knowledge on Wheelchair Evaluation for Creating General Design Evaluation Criteria**

### **3.1 Introduction**

General design evaluation criteria were created by two people: one a care educator as the author and one with wheelchair designing experience. It was necessary to collect ideas and knowledge of people who engaged in a wide range of fields related to the evaluation of wheelchairs in order to cover comprehensive requirements about wheelchairs including development, production, supply, use, maintenance, and care service. We, therefore, collected such requirements from the positions of design/development, production, and medical rehabilitation through relevant papers and reports, in addition to the above-mentioned requirements of the interim users. The collected requirements, presented below, were used as referential knowledge in creating such criteria.

### **3.2 Requirements from an Interim User's Point of View**

It was considered that the requirements of the interim users discussed in Section 2 could be used in the creation of general design evaluation criteria as those of wheelchair users. They can be summarized into nine areas: "creation/improvement of proper environment," "improvement in traveling performance," "maintenance of good user-friendliness," "good quality/material," "improvement in production technologies/service," "improvement in care service," "improvement in design," "proper maintenance," and "proper delivery/receiving."

### **3.3 Requirements from Designers' and Design Developers' Perspective**

An example of requirements from a designer's/design developer's perspective is presented in Nashihara, et al., "Abstraction of Design Item and Construction of the Design Concept on Wooden Wheelchair" [Note 6]. This paper extracts and presents design factors as items and sub-items that are required for the development of wheelchairs for all uses, as set out below. The design factors presented there are used in the determination of

dimensions, shape, and configuration of a wooden wheelchair for production, supply, and use. It is considered that improvement in “sitting position for holding a good position,” “compatibility with environment,” “operability for traveling performance,” “light equipment for ease of control,” and “representation for better image” presented in the items, as set out below, can be well used as requirements from a viewpoint of those who design, and the creation of design evaluation criteria.

### **3.4 Requirements from Manufacturers’ Perspective**

Requirements from manufacturers’ perspective are based on ISO as an international standard and JIS as a domestic standard. In addition, there are local standards in overseas countries/areas such as EU and the United States, and wheelchair products in compliance with local standards are legitimately distributed/sold within the respective countries/areas. In this respect, requirements about wheelchairs from manufacturers’ perspective are considered to be “improvement in quality and performance,” “ensuring safety for users,” “improvement in cost return,” and “smoother deliveries,” and they can be used in the creation of design evaluation criteria.

### **3.5 Requirements in an Aspect of Rehabilitation**

In Japan wheelchairs are included in the category of welfare tools, but in major countries in the world, they are in the category of medical tools [Note 7]. Japan is rather exceptional in that wheelchairs are not treated as a medical instrument. In the United States, they cannot be sold without a license granted by the Food & Drug Administration (FDA). In Europe, they cannot be sold without a CE mark granted for a medical instrument. In other words, wheelchairs should be dealt with by experts.

In this respect, wheelchairs are generally evaluated in two aspects in the area of medical rehabilitation. One aspect is the functions, mechanism, and performance of a wheelchair as a vehicle, and the other aspect is the functions, mechanism, and performance of a wheelchair as a chair. From a perspective of rehabilitation engineering, Okigawa mentions that it is necessary that the functions, shape, and dimensions of each part of a wheelchair be further contrived from viewpoints of “drive,” “position,” “seating,” and “environment” [Note 8]. The Japan Association of Wheel-chairs and Seating developed Okigawa’s idea and compiled a collection of views/remarks of experts in the field of medicine, technology, prescription, supply, and management practice related to wheelchairs, titled “Kurumaisu Seating – sonorikai to zissen” [Note 9]. This book addresses the issue of “supply,” in addition to “drive,” “position,” “seating,” and “environment,” and provides useful knowledge.

For this knowledge to be used in the actual scene of life rehabilitation, the Welfare Tool Assessment Manual was developed for interim users in care management, etc., as a manual useful in the actual place of welfare service [Note 10]. This manual provides basic knowledge of how to use a wheelchair in an easy-to-understand way on the assumption that the use of a wheelchair helps social participation of the user. The contents are 1) the part names of a wheelchair, points to ponder and features of wheelchairs, 2) process to choose a wheelchair, and 3) basic knowledge for choosing a wheelchair (postures and wheelchairs, traveling and wheelchairs, transfer and wheelchairs, systems related to the acquisition of wheelchairs, representative commercially available wheelchairs, and cushions). These contents focus on how care managers, etc., should select wheelchairs and bring them to proper use by users, so this manual gives basic knowledge to those who select wheelchairs and cause the use of them.

From the above, the requirements about wheelchairs in terms of rehabilitation may be sorted out into “proper selection process,” “proper posture maintenance,” “proper transfer action,” “proper traveling operation,” “proper system for acquisition of wheelchair,” and “proper seating technology.” These can be used as requirements in medical terms for creating design evaluation criteria.

### **3.6 Requirements from a Perspective of Society**

Nashihara asserts that a wheelchair should be designed for society in the 21<sup>st</sup> century using the words “control with emotion and control with responsibility” in “Design based on Emotional Control and Responsible Control” [Note 11]. If his idea is adopted, a design solution is required to meet management with heart to help increase QOL without inhibiting the user’s way of life and also management with responsibility to give such functions, performance, and usability as to satisfy ergonomic requirements. The design principles for wheelchairs that he proposes involve the following sub-sub-items in the form of questions.

(1) Is a wheelchair long loved and used?, (2) Does a wheelchair have a good image?, (3) Does a wheelchair have simple functions, a simple structure, and a simple configuration?, (4) Is it easy to understand how to handle a wheelchair?, (5) Are the materials and production technology for a wheelchair friendly to the environment?, (6) Does the use of a wheelchair make a good human relationship?, (7) Is a wheelchair suitable for specific physical conditions?, (8) Does a wheelchair give a psychological burden?, and (9) Is the use of a wheelchair helpful in life in the local community?

These questions suggest indexes for wheelchair design for forming a better welfare environment from viewpoints of management with heart and management with responsibility about the supply and use of wheelchairs, and can be used for the creation of wheelchair design evaluation criteria.

## **4. Technologies to Create General Design Evaluation Criteria for Wheelchair**

### **4.1 Creating General Design Evaluation Criteria**

General design evaluation criteria for wheelchairs were created based on the knowledge and data obtained in Section 2. As mentioned, one care educator as the author and one former wheelchair designer created them. The two people discussed the criteria based on the requirements collected in Section 3. They created original criteria, and revised them in detail into the final ones, taking views/remarks of some care service leaders into consideration. The creation technologies are discussed below.

### **4.2 Process of General Design Evaluation Criteria Creation**

The process of the general design evaluation criteria creation is as follows.

- 1) Step 1: Random sampling of evaluation criteria  
Evaluation criteria for wheelchairs that occurred to the creators based on the requirements related to the evaluation of wheelchairs that were obtained in Section 2 were extracted in as broad a range as possible from perspectives of development, production, supply, use, and care service by means of the KJ method. They are described, including conceptual and concrete representations.
- 2) Step 2: Creation of a tree-diagram of evaluation criteria  
Extracted evaluation criteria were grouped and organized into a tree diagram with items, sub-items, and sub-sub-items.
- 3) Step 3: Addition/correction to the tree diagram  
Items/sub-items/sub-sub-items that were lacking or overlapped with each other in the tree diagram were added, deleted, or revised in the light of the aims of evaluation criteria. Then, the items/sub-items/sub-sub-items were checked for overlaps and contradictions.
- 4) Step 4: Extraction of evaluation elements for sub-sub-items  
To materialize sub-sub-items under each sub-item, as many evaluation elements, leading to specific measures, i.e., what should be satisfied or what should be noted, as possible were extracted on a sub-item by sub-item basis.
- 5) Step 5: Grouping of the evaluation elements  
All the obtained evaluation elements were rearranged within their respective sub-item because they overlapped and were lacking between sub-sub-items, and organized into small groups of evaluation elements. Lacking elements were added.
- 6) Step 6: Expression in writing for the small groups  
A sentence in the form of a question was made to represent each group of evaluation elements created. It is a design evaluation criterion to represent each group.

### **4.3 Creation Results**

#### **4.3.1 Extracted Item, Sub-item, and Sub-sub-item (Steps 1-3)**

As a result of creation work in Steps 1-3, eight items and 17 sub-items were obtained. (Figure.1)

It can be understood that the above items and sub-items appropriately reflect requirements from an interim user's point of view, those from designers' and design developer's points of view, those from the manufacturer's point of view, and those from a perspective of medical rehabilitation. In addition, they reflect requirements from a perspective of society, and it can be understood that the requirements for good human relationships and life in the local community are mainly reflected in reasons/aims for living.

#### **4.3.2 Extraction of Sub-sub-items (Steps 1-3)**

Some sub-sub-items corresponding to sub-items are presented below.

*Item:* Proper motion function

*Sub-item:* Support for traveling motion

*Sub-sub-item:* Light handling feeling; Residual functions are drawn; No hand slipping; Easy to turn wheels by hand; Easy to change directions; Easy to brake; Easy to travel on road

As mentioned above, the sub-sub-items are in the form of general questions about using wheelchairs, supplying wheelchairs, etc. However, evaluation elements that are helpful to materialize and lead such sub-sub-items to designs were not yet obtained. The following Step 4 was implemented.

#### **4.3.3 Extraction of Evaluation Elements to Materialize Sub-sub-items (Step 4)**

Evaluation elements for materializing the sub-sub steps obtained through Step 3 were extracted. Some of the evaluation elements under the sub-item: Support for this is presented below.

Under the above-mentioned sub-item, seven sub-sub-items including light handling feeling had been extracted.

Evaluation elements under one of those sub-sub-items are presented below.

Sub-item: Light handling feeling

- Extracted evaluation elements for providing a wheelchair with a light handling feeling  
Six evaluation elements: positions of body gravity and wheelchair; body size and wheelchair dimensions; setting of camber angle; wheel distance adjustment; proper hand rims; postural maintenance suitable for driving

As discussed above, evaluation elements were extracted for each sub-sub-item.

Item	sub-item
proper motion function	A: support for traveling action
	B: support for transfer action
	C: support for nursing-care action
proper sensitivity function	D: support for design
	E: adaptation to the senses
proper availability and use	F: proper procurement
	G: proper use and maintenance
proper seating	H: support for postural maintenance
	I: conformity to a physiological function
adaptation to environment	J: support for indoor environment
	K: support for outdoor environment
proper manufacturing technologies	L: rational production technologies
	M: support for quality control
safety and reliability	N: support for reliability
	O: support for safety
independence and definite aim in life	P: use method expansion
	Q: support for social participation

**Figure.1 Eight items and 17 sub-items of General Design Evaluation Criteria**

#### 4.3.4 Developing Design Evaluation Conditions (Steps 5 and 6)

The evaluation elements obtained in 4.3.3 included overlaps between them and lacking, and therefore, all of them were reorganized under their respective sub-item group into small groups of evaluation elements. Lacking elements were added. A sentence in the form of a question was made to represent each small group of evaluation elements. The above-mentioned sentence is a design evaluation criterion, and a total of 120 criteria were obtained. Fig. 2 shows an entire structure of evaluation criteria. The criterion: Support for traveling motion discussed in the following case is “A.”

Sub-item: Support for traveling motion: A

Eight small groups under this sub-item were newly documented. Some cases of them are presented below.

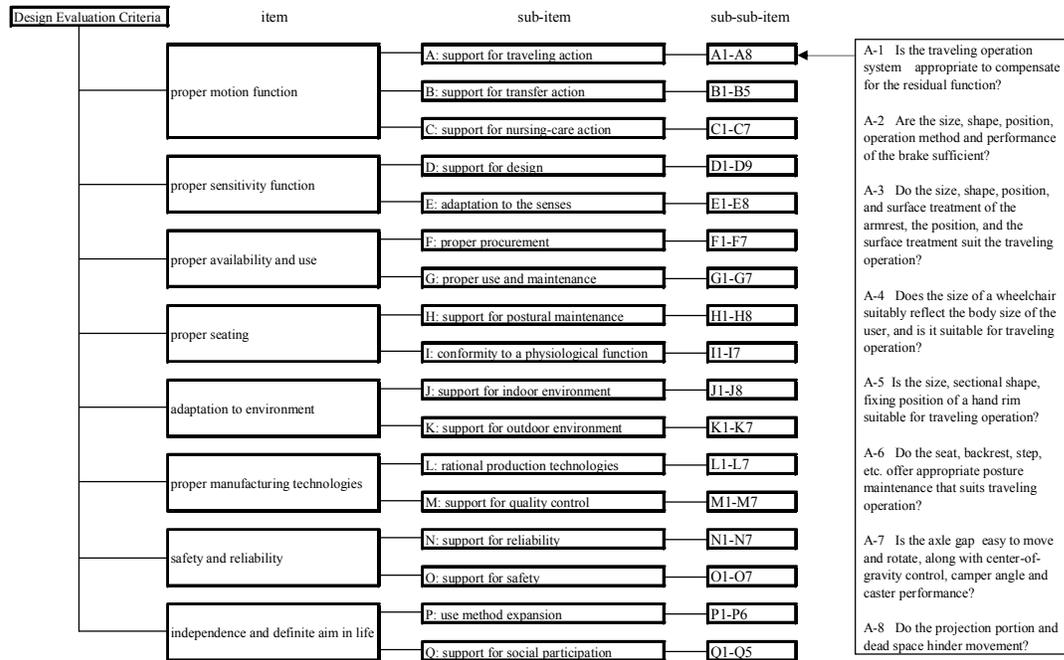
- One small group newly obtained

A sentence in the form of a question to represent { both-hand drive, one-hand drive, one-foot drive, sensor drive, helping drive } was created. As a result, it was made a design evaluation criterion as “Is the traveling operation system appropriate to compensate for the residual function?” Code A-1 was put to it.

In this manner, a total of 120 sub-sub-items corresponding to seventeen sub-items (A-Q) were developed.

#### 4.4 Characteristics of Design Evaluation Criteria

We analyzed which stage of development/design, production, supply, distribution, and use each of the extracted sub-items (17 sub-items) are mainly involved in. To simplify the issue, we set three stages for analysis: Optimal design of wheelchair, a stage of developing a structure, functions, and performance in drawings; Reasonable production technologies, a stage of manufacturing wheelchairs; and Service/support/laws, a stage of supplying, distributing, and using wheelchairs. The results are shown in Fig. 3. The figure shows that some criteria have only one stage with a color, and others have two or three stages with a color. It also shows that the stage of optimal design of wheelchair involves more evaluation criteria than any other stage; however, all the evaluation criteria should not be related to the same stage, but wheelchairs should be evaluated in different stages from different points of view, as necessary, for a good evaluation



**Figure.2 Structure of General Design Evaluation Criteria**

Design Evaluation Criteria	Optimal design of wheelchair	Reasonable production technologies	Service/support/laws
proper motion function	A: support for traveling action		
	B: support for transfer action		
	C: support for nursing-care action		
proper sensitivity function	D: support for design		
	E: adaptation to the senses		
proper availability and use	F: proper procurement		
	G: proper use and maintenance		
proper seating	H: support for postural maintenance		
	I: conformity to a physiological function		
adaptation to environment	J: support for indoor environment		
	K: support for outdoor environment		
proper manufacturing technologies	L: rational production technologies		
	M: support for quality control		
safety and reliability	N: support for reliability		
	O: support for safety		
independence and definite aim in life	P: use method expansion		
	Q: support for social participation		

**Figure.3 The relation 17 sub-items to stage of Optimal design of wheelchair, Reasonable production technologies and Service/support/laws**

## 5. Simulation of Design Evaluation Criteria

### 5.1 Aim of Simulation

Using the design evaluation criteria of 120 sub-sub-items obtained in Section 3, with the wheelchairs currently sold and used as examples, we examined the validity to apply the design evaluation criteria performing a simulation of design evaluation.

### 5.2 Selection of Wheelchair

The following three types are selected as the candidates for evaluation from the wheelchairs currently sold in Japan. The first is an aluminum standard wheelchair (Fig. 4) sold from a domestic company A, which is commonly used in hospitals and welfare institutions and rented to individuals. The second is an aluminum multifunctional wheelchair (Fig. 5) from the same manufacturer with the equivalent basic structure, and the third is an aluminum modular wheelchair (Fig. 6) from a domestic company B.

### 5.3 Evaluation Method

All 120 sub-sub-items of A1-Q7 were graded on a five-point scale. We determined the average mark for every 17 sub-items of A-Q. We let a standard wheelchair be the evaluation standard and put it three points as the reference point.

There were two evaluators: a social worker who has wheelchair knowledge about a wheelchair and has the social welfare experience and a certified care worker who has sufficient experience for care working, and has detailed knowledge of a wheelchair.



**Figure.4**  
Standard wheelchair



**Figure.5**  
Multifunctional wheelchair



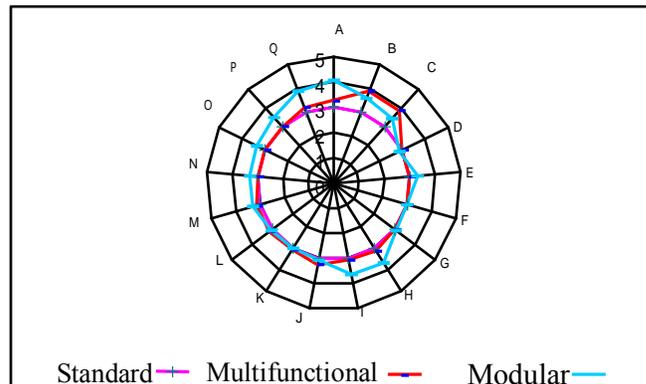
**Figure.6**  
Modular wheelchair

#### 5.4. Evaluation Results

The average of the two evaluators data was calculated. The result is shown in Fig. 7. As a result, the features of a multifunctional wheelchair and modular wheelchair are as follows, as compared with a standard wheelchair:

##### (1) Features of a multifunctional wheelchair

A multifunctional wheelchair is designed to facilitate to transfer between a wheelchair and a bed with additional functions. Reflecting the above, it especially excels in proper motion function, B: support for transfer action, C: support for nursing-care action. For other evaluation items, A: support for traveling action and J: support for indoor environment had slightly better evaluation, but there was no difference from a standard wheelchair. There was no significant difference from a standard wheelchair from mass production technologies for components, holding the stocks, and assembling them, to use and maintenance providing through the sales representatives.



- A: support for traveling action
- B: support for transfer action
- C: support for nursing-care action
- D: support for design
- E: adaptation to the senses
- F: proper procurement
- G: proper use and maintenance
- H: support for postural maintenance
- I: conformity to a physiological function
- J: support for indoor environment
- K: support for outdoor environment
- L: rational production technologies
- M: support for quality control
- N: support for reliability
- O: support for safety
- P: use method expansion
- Q: support for social participation

**Figure.7 The Evaluation Results of three Wheelchair**

##### (2) Features of a modular wheelchair

A modular wheelchair is assembled by modules and is developed putting emphasis on postural maintenance that is adjustable for each user, traveling function with good small turning radius, and quality. Reflecting this, it shows outstanding performance that is not available in other two types of wheelchairs; in proper motion function, A: support for traveling action, in proper seating, H: support for postural maintenance, I: conformity to a physiological function, and in independence and definite aim in life, Q: support for social participation, P: use method expansion. For other evaluation items, this provides slightly better performance in proper motion function, B: support for transfer action, C: support for nursing-care action, in safety and reliability, O: support for safety, proper sensitivity function, E: adaptation to the senses. Compared with the other two types, this wheelchair has many better evaluated items. Meanwhile, proper manufacturing technologies (L: rational production technologies, M: support for quality control), adaptation to environment (J: support for indoor environment, K: support for outdoor environment), proper availability and use (F: proper procurement, G: proper use and maintenance) were hardly different from the other two types. This indicates that there is no significant difference from a standard wheelchair in the development of producing components and holding the stocks, assembling them, distributing through sales representatives, use and maintenance. This indicates that a modular wheelchair is questionable how it can provide use and maintenance by the method beyond a standard wheelchair.

### (3)Comprehensive evaluation

When the above is comprehensively examined, as compared with a standard wheelchair. A multi functional wheelchair excels in transfer function and nursing-care function. A modular wheelchair is superior to traveling function, postural maintenance, quality, safety, etc., and can contribute to use method expansion and social participation for users.

## 5.5 Discussion

As the evaluation simulation result in the above three type wheelchairs, it can be found that if our design evaluation criteria are used, wheelchairs with different forms and functions can be comprehensively evaluated. It becomes a heavy burden for the evaluator to evaluate 17 sub-items and 120 sub-sub-items. However, since all stages of development, design, production, supply, use, and nursing-care support service, from the standpoint of those who develop/design, manufacture, supply, offer service, use can be evaluated, and it can verify the evaluation results, which is supposed to be valuable data for each position. The evaluators were two welfare related experts. It is assumed that the evaluator may be unable to reply to all 120 items depending on his or her experience. In order to conduct this evaluation more effectively, it is judged to be better to step ahead while people in various positions participate in evaluation and having discussions.

We gave three points as the reference point to a standard wheelchair, and analyzed by relative evaluation. Although there are many things to be figured out from this method, it has a fault of not recognizing the actual condition of the main body. For example, a standard wheelchair should be improved in many aspects including postural maintenance. The reference point is appropriate to be less than three points. It seems to be required to scrutinize the evaluation method, including using an absolute evaluation. Although the average was calculated for 17 sub-items, the feature of evaluation is not highlighted, such as which evaluation in each sub-item is especially characteristic, etc. The features of evaluation are not made to emerge. It may be needed to examine each sub-item in detail.

## 6. Conclusion

This study elucidated the following.

### 6.1 Consciousness of Interim Users

Requirements of interim users about wheelchairs are formed from their internal factors. It is considered that their internal factors are reflected in diverse ways of use or selection of wheelchairs. Their internal factors are influenced by the differences in work environment, age, sex, and experience in using wheelchairs between the institutional welfare service staff and the domiciliary welfare service staff. Our study revealed that the institutional welfare service staff have more diverse requirements, while the domiciliary welfare service staff have more focused requirements. It can be considered to be the differences in requirements of wheelchairs between the two groups have occurred from the differences in the use environment and required positions.

### 6.2 Creation of General Design Evaluation Criteria

(1) We collected data/materials that can be helpful to evaluate wheelchairs, and used them as knowledge to create general design evaluation criteria for them. There are requirements from interim users' points of view, from designers' and design developers' points of view, from manufacturers' points of view, from a perspective of medical rehabilitation, and from a perspective of society.

(2) We created general design evaluation criteria by a process in Steps 1-6: 1) Random sampling of evaluation criteria → 2) Creation of a tree-diagram of evaluation criteria → 3) Addition/correction to the tree diagram → 4) Extraction of the evaluation elements for sub-sub-items → 5) Grouping of the evolution elements → 6) Expression in writing for the small group. As a result, we obtained seven items (Proper motion function, Proper feeling function, Proper availability/use, Proper seating, Compatibility with the environment, Proper manufacturing technologies, Safety/Security, and Reasons/aims for living), and seventeen sub-items corresponding to the seven items, and a total of 120 design evaluation criteria corresponding to those items and sub-items.

(3) It was discovered that the obtained general design evaluation criteria are related to one or more of three stages in the course from the development to the use of wheelchairs and care service: Optimal design of wheelchair; Reasonable production technologies; and Service/support/laws. Therefore, it is meaningful to evaluate wheelchairs from different points of view, as necessary.

### 6.3 Effectiveness of General Design Evaluation Criteria

(1) We evaluated commercially available wheelchairs with different shapes and functions of three types: Standard, Multifunctional, and Modular type on the 120 general design evaluation criteria as a simulation to check the validity of application of those criteria. As a result of assessment by two welfare experts who had enough knowledge of wheelchairs, the simulation clarified the differences among three types, and proved the

validity of application of these criteria.

#### **6.4 Further issues**

It is necessary that those who work in development/design, production, supply, use of wheelchairs, and care service engage in design evaluation, present their views/opinions in their positions, and discuss them, so that the evaluation will be further developed for more exact evaluation and scrutiny of the evaluation criteria.

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