

Actual Proof Experiment of Electric Wheelchair “Monpal” for Enhancing Elderly QOL

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ABSTRACT

In August 2010, Honda and Kumamoto Prefecture concluded a comprehensive agreement concerning proof experiments of next-generation personal mobility. In accordance with that agreement, electric carts were provided on loan to elderly people and an evaluation was made of how the resulting augmentation of their mobility changed their quality of life.

Using the Medical Outcomes Study 36-Item Short-Form as an index for evaluating quality of life, changes in the subjective state of health of the experimental subjects were verified. Their life-space mobility was evaluated using the Life-Space Assessment. In order to reinforce those evaluations, the Activities Monitoring and Evaluation System was also used to carry out evaluation of everyday bodily activity.

The results indicated a tendency for the use of electric carts to expand life-space mobility and contribute to enhancement of overall sense of health, activity, and other such aspects of quality of life.

The following will report on these proof experiment results.

1. Introduction

In August 2010, Honda concluded the “Comprehensive Agreement Regarding the Electric Vehicle Testing Program for Next-Generation Personal Mobility Products” with Kumamoto Prefecture with a view to realizing the joy and freedom of mobility as well as a sustainable society where people can enjoy life. Honda then conducted proof experiments until March 2014.

The purpose of the experiments was to contribute to examination of concepts of future personal mobility that would enhance the quality of life (QOL) of elderly people by means of personal mobility utilizing electrical energy, and that by extension would contribute to enhancement of community QOL⁽¹⁾ (Fig. 1).

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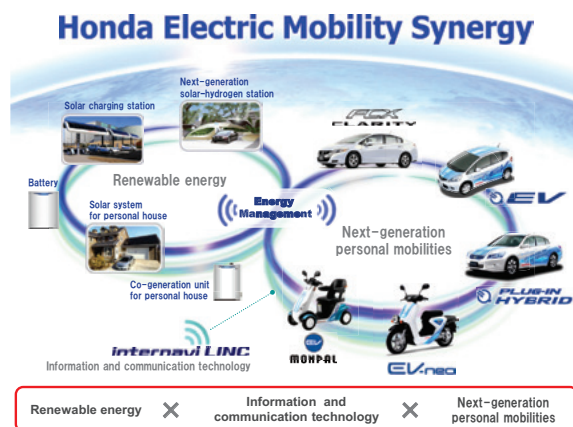


Fig. 1 Honda electric mobility synergy

2. Purpose of Social Proof Experiments Using Electric Carts

Honda has been marketing the Monpal electric cart as a device to assist elderly people when they go outside their homes. However, the Nursing Care Insurance Law that came into effect in 2000 requires the certification of need for nursing care for people to be eligible to use these on a rental basis, and shipments have been trending downward for this and other reasons (Fig. 2). As things stand at present, the fact that dependence on devices of this kind can result in further deterioration of bodily functions, and the scarcity of environments where people can feel at ease using such devices, are among the factors that have perhaps kept the recognition and active use of electric carts from becoming fully accepted in society.

Meanwhile, Kumamoto Prefecture aims to realize a society whose members can enjoy long life, and was interested in clarifying the impact of electric cart use on elderly people on the basis of QOL indicators. Concluding this comprehensive agreement concerning proof experiments of the next generation of personal mobility, therefore, the prefecture took the opportunity to form an Electric Cart Working Group centered primarily at the Japanese Red Cross Society's Kumamoto Health Care Center and involving collaboration by government, industry, and academia. This group has been a forum for active and extended discussion of new ways of using electric carts in order for elderly people to maintain as high a QOL as possible in their lives in local communities (Fig. 3).

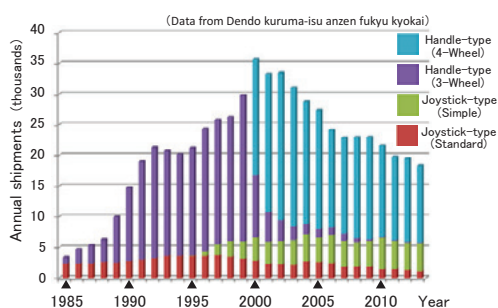


Fig. 2 Annual shipments of electric wheelchair

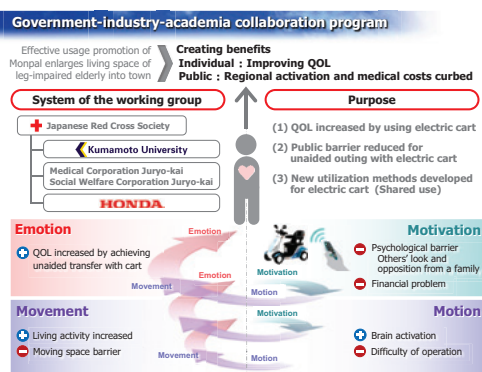


Fig. 3 Objectives of working group with government-industry-academia collaboration program

3. Overview of Proof Experiment

Proof experiments were held in which elderly people who have no experience in using electric carts were given the loan of a Monpal to assist in their everyday movements. This was done for the purpose of verifying the changes that such use brings to those elderly people's lives. A number of elder care facilities with differing lifestyle patterns were chosen as demonstration fields for the proof experiment, and surveys and analysis were conducted regarding changes in users' lives, range of mobility, and QOL before and after using an electric cart, as well as the circumstances of their electric cart use^{(2), (3)}. The experiments described below were conducted with the approval of Honda's Bioethics Committee.

3.1. Demonstration Field

Elder care facilities were selected as demonstration fields according to these two levels of criteria for bodily function and capacity for activity:

- (1) Nursing care facilities that are residences for people who require nursing care on an everyday basis
- (2) Assisted-living facilities with services for elderly residents capable of living independently

3.1.1. Demonstration field A (model of nursing care facility)

The elderly people who reside in nursing care facilities are either people whose care condition requires nursing care services under the Nursing Care Insurance Law or those certified as requiring nursing care because their condition requires assistance for daily living. Many of the people who receive this certification have diminished bodily function and in most cases they require the wheelchairs, walkers, or other such devices owned by nursing care facilities even for their everyday movement. These people have a more restricted range of mobility than most normally healthy people, and their opportunities for mobility are also more limited.

It appears likely, however, that even these people certified as requiring nursing care may be able to expand the range of their mobility and increase the frequency of their movement if they have electric carts that assist safe movement. Proof experiments were therefore conducted in the shared use of electric carts at nursing care facilities for the elderly, such as special nursing homes for the elderly located in the western part of Kumamoto City. This was done for the purpose of verifying a variety of changes in QOL before and after the use of electric carts by elderly people who receive the services of nursing care facilities.

3.1.2. Demonstration field B (model of assisted-living facility for the elderly)

Society is aging rapidly, the shift to nuclear families is progressing, and there are growing numbers of elderly people living alone or in households consisting only of

husband and wife. The national government has therefore been promoting the supply of residences for elderly people that have barrier-free construction and that provide services coordinated with nursing care services and healthcare services as measures to assure stable residences for the elderly. The elderly people who use these assisted-living facilities for the elderly have a greater degree of independence than those who reside in nursing care facilities, and most of them are able to carry on their daily living without assistance from others.

With advancing age, however, their physical abilities gradually deteriorate, and as they find it increasingly challenging to walk for extended periods of time or over long distances, they come to require aid in going outside their residences, assistance in traveling to healthcare appointments, and other such services. Even if they come to require these services, and even if they are able to make use of them, the elderly people who live in facilities with services for elderly residents may still be able to continue their independent lives if electric carts that support their safe mobility are available. As a result, they may also be able to shorten the period when they require aid in going outside their residences and assistance in traveling to healthcare appointments. Proof experiments were therefore conducted in assisted-living facilities for the elderly located in the eastern part of Kumamoto City for the purpose of verifying a variety of changes in QOL before and after the use of electric carts by residents of assisted-living facilities for the elderly (Table 1).

3.2. QOL Evaluation Tools

The following evaluation tools were used in the two fields of the proof experiment for the purpose of verifying changes in electric cart users' lives (daily activities), range of mobility, QOL, and other such factors before and after use.

3.2.1. Methods for evaluating living activities

(1) Bodily Activity Evaluation

The Activities Monitoring and Evaluation System (A-MES), which monitors daily activities, was used for evaluation of bodily activity. The A-MES records data using two acceleration sensors affixed to the experimental subject's torso and thigh. Analysis of the data enables evaluation of the following activity states (Table 2, Fig. 4).

- Activity states over 24-hour period (reclining, sitting, standing, driving electric cart, walking)
- Reclining states (reclining on back, reclining on right side, reclining on left side, reclining on front)
- Number of times changed posture (stand up, sit up, number of times turned over while sleeping)
- Total time of each activity and maximum sustained time
- Percentage of time occupied by each activity state in one-hour period

A-MES is used in the medical and nursing care fields to track daily activities. The data is accumulated in a logger

Table 1 Forms of use in two different testing fields

	Ownership form	User	Utilization area
Field-A Nursing-care services	Care facility	Group	Living area
Field-B Assisted-living facility for elderly	Care facility	Personal	Living area

Table 2 General specification of A-MES

General specifications of the Data Logger	
Sampling period	0.2 sec constant
Recording time	≥ 24 hours
Power source	size AA battery x 1
Size	85 mm x 75 mm x 25 mm
Data	Sampling time, 6 sensor data items (12 bit/data), Measuring time

over an extended period of time, allowing monitoring of the everyday (24-hour) activity states of experimental subjects. In the proof experiments, bodily activity was tracked under the two patterns of days when electric carts were used and days when they were not used, and the differences in daily activities between the two were evaluated.

(2) Life-Space Assessment

The Life-Space Assessment (LSA) is defined as the product of the distance traveled in everyday life, the frequency of that travel, and the degree of independence of that travel. It is an index for evaluating mobility within the spatial expanse of people's lives. The distance traveled takes an individual's bedroom as the point of origin for movement used in evaluating life-space, and the life-space is represented in the following five stages from the bedroom to outside the town limits. The evaluation is made by assigning scores from zero to 120 points.

Life-Space 0: Bedroom

Life-Space 1: Home interior

Life-Space 2: Outside (very close to home)

Life-Space 3: Neighborhood

Life-Space 4: Town

Life-Space 5: Unlimited (outside town)

For the proof experiments, analysis was made of the LSA values from the one-month period before use of electric carts and the one-month period during use of electric carts.

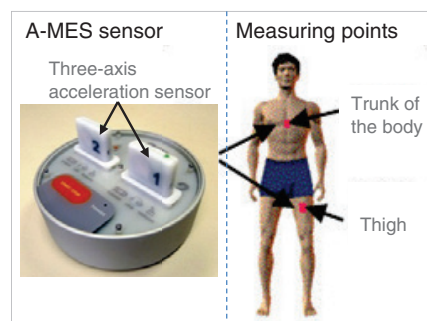


Fig. 4 Sensor and measuring points of A-MES

Table 3 General specification of GPS data logger unit

Size (LxWxH)	Communicator device	101.5 x 139.2 x 47.8
	Antenna	20.0 x 35.0 x 60.0
	GPS	φ 61.0 x 19.5
Total weight	1.8 kg	
Sampling time	1 sec (const.) 5 minutes of FOMA transmitting period	
Loading point	Under seat of MONPAL	
Sampling data	GPS NMEA0183 Velocity, Accelerator position Steering angle, Battery condition	

(3) Measurement of Range of Activity

A GPS data logger equipped with communications functionality was manufactured to record the Monpal operating state and driving operation status. These loggers were mounted on the Monpals.

The Monpal operating state and driving operation status together with GPS data were sampled at one-second intervals and recorded in a file. Distinguished by Monpal unit number and date, these files were transferred to the server over a mobile phone line at approximately one-minute intervals for accumulation and storage.

Software for the verification of stored data was also developed (Table 3, Fig. 5, Fig. 6). It accumulates and

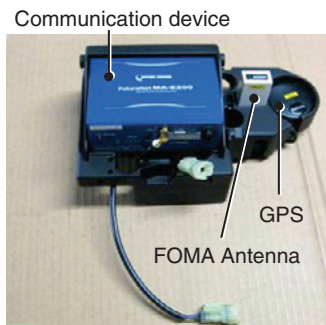
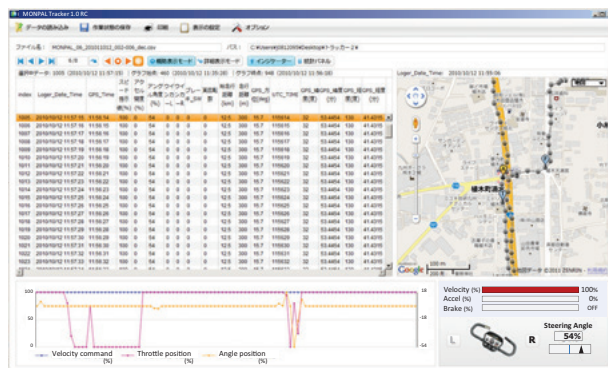


Fig. 5 External view of GPS data logger unit



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Fig. 6 View of Sampling data on PC screen

Table 4 Subscales defined in SF-36™

Subscale items	Abbr.	Scoring reference	
		Worst condition	Best condition
Physical functioning	PF	Impossible to take a bath or change clothes	All physical activity possible
Role physical	RP	Experience trouble with ordinary work	Experience no trouble with ordinary work
Bodily pain	BP	Ordinary work disturbed by severe physical pain	Ordinary work not disturbed at all without physical pain
General health	GH	Health condition getting worse	Good health condition sustained
Vitality	VT	Fully exhausted	Full of vigor
Social functioning	SF	Friendships with families, friends or acquaintance deadily disturbed by some physical or mental impairments	Friendship with families, friends or acquaintance not disturbed by any physical or mental impairments
Role emotional	RE	Problem with work or other activities due to mental reasons	No problem with work or other activities due to mental reasons
Mental health	MH	Always feel depressed with nervous temperament	Always feel calm and happy

(relating to a health condition in the past month)

analyzes Monpal data, including its movement track, the operating status of the accelerator, turn indicators, steering wheel angle, and so on, the vehicle speed, the battery state of charge and voltage, and the motor current.

3.2.3. Methods for evaluating QOL

The Medical Outcomes Study 36-Item Short-Form (SF-36™), which is an evaluation index for health-related quality of life (HRQOL), was used in evaluating changes in QOL due to the use of electric carts. Measures of HRQOL are generally classified under two types: generic measures and disease-specific measures^{(4), (5)}. The SF-36™ is classified as a generic measure, and has the advantage of being able to evaluate QOL without regard to an individual's illness or whether or not the individual has a health disorder. SF-36™ evaluation is made up of eight subscales. Table 4 shows explanations of the scoring for those measures. The survey used self-administrated response forms with questions on 36 items surveying state of health over the month preceding the time of the survey.

3.3. Proof Experiment Results and Discussion

Environments for Monpal use were developed in the proof experiment fields and the following results were obtained with regard to the daily activities of electric cart users before and after use, their range of mobility, changes in their QOL, and the circumstances of electric cart use.

3.3.1. Daily activities

Tables 5 and 6 show the results from monitoring two people wearing A-MES sensors who used electric carts at nursing care facilities. Their daily activities were monitored on days when an electric cart was used and days when one was not used. In order to rule out differences due to different time periods of daily activity on days when electric carts were used and days when they were not, those time periods on both days during

Table 5 Movement status of subject A in Field A

State/Posture	Without Monpal		With Monpal	
	Accumulated Time	Continuous Max. Time	Accumulated Time	Continuous Max. Time
Walking	02:44:57	00:03:03	04:06:04	00:05:50
Standing	00:46:22	00:04:24	01:11:38	00:02:04
Sitting	02:38:16	00:30:53	03:03:30	00:17:13
Recumbent	06:12:40	01:30:01	04:00:43	01:31:59
Total Time	12:22:16	-- : -- : --	12:21:56	-- : -- : --

Table 6 Movement status of subject B in Field A

State/Posture	Without Monpal		With Monpal	
	Accumulated Time	Continuous Max. Time	Accumulated Time	Continuous Max. Time
Walking	00:36:16	00:06:00	01:05:08	00:02:15
Standing	01:03:03	00:06:50	00:45:24	00:04:19
Sitting	03:04:28	00:13:14	02:55:36	00:24:37
Recumbent	02:32:43	00:32:52	02:30:07	00:31:14
Total Time	07:16:32	-- : -- : --	07:16:16	-- : -- : --

which accurate measurement of data had taken place were isolated for evaluation.

For experimental subject A, the periods of time evaluated on the day when an electric cart was used showed more time spent walking (by 1 hour and 21 minutes), standing (by 26 minutes), and sitting (by 25 minutes) than on the day when an electric cart was not used. On the other hand, time spent reclining was reduced (by 2 hours and 12 minutes). The number of times actions were performed per day showed an increase, with movements from sitting to standing and from standing to sitting nearly doubling from 32 times to 61 times.

For experimental subject B, daily activity times were concentrated in the afternoon, and the periods of time evaluated were shorter than for experimental subject A. Walking time had increased by 29 minutes. The number of times actions were performed per day also showed an increase, with sitting-standing movements nearly doubling from 16 times to 31 times.

Although the electric carts provide users with a convenient mobility, this also becomes a replacement for walking. Therefore some people expressed concern that this would reduce opportunities for walking and lead to diminished muscle strength in their legs. This concern was also found expressed here and there on the proof experiment questionnaires.

Because of the increased risk that diminished motor functions or disabilities will lead to the need for nursing care, efforts to prevent “locomotive syndrome” have been proposed. Consciousness-raising efforts are being made so that elderly people will maintain the habit of walking as much as possible and not lose their ability to walk. The possibility that easy availability of electric cart use may

Table 7 LSA scores and usage frequency of subjects

Subject No.	Life-Space Score <Before>	Life-Space Score <After>	Usage Frequency
1	120.0	102.0	B
2	84.0	24.0	B
3	49.5	63.0	S
4	102.0	120.0	A
5	66.0	84.0	S
6	120.0	—	—
7	84.0	84.0	S
8	120.0	63.0	A
9	120.0	63.0	B
10	22.5	54.0	S
11	120.0	120.0	A
12	18.0	—	—
13	19.5	—	—

go counter to such efforts is probably the reason for those expressed concerns.

The present proof experiments, however, indicate that electric cart use does not simply become a replacement for walking that reduces walking time, but rather that it increases opportunities for mobility. Apart from the two examples shown here, it was also found with all the experimental subjects that more time was spent walking and less time reclining on days when electric carts were used than on days when they were not used. This indicates that electric cart use tends to increase the activities of independent walking and sitting that accompany mobility.

3.3.2. LSA evaluation results

Table 7 shows the life-space scores and frequency of electric cart use in 13 cases among the experimental subjects who used electric carts in field A and were surveyed before and after use. The frequency of electric cart use is shown as S for use several times a week, A for use once a week, and B for use less than once a week.

People who had higher LSA scores before using electric carts tended to show a lower frequency of electric cart use. Conversely, people who had lower LSA scores tended to show a higher frequency of electric cart use. When changes in LSA scores were matched against frequency of electric cart use, it was found that four people had lower LSA scores after electric cart adoption than before, four people had higher scores, and two people showed no change. The four experimental subjects who showed greater frequency of electric cart use were found to have increases in their LSA scores.

3.3.3. Changes in QOL

The SF-36™ results for experimental subjects in field A before and after using electric carts were derived by norm-based scoring (NBS) based on national standard

values for Japan in each of the measures scored. Figure 7 shows the average values in the eight measures for before and after use.

In field A, scores for physical functioning and bodily pain were lower than national standard values by a large margin. Scores for general health, vitality, social functioning, and mental health were generally at national standard values.

The measures of “role physical” everyday role functionality, “role emotional” everyday role functionality, and mental health were found to have risen from before the use of electric carts to after.

3.3.4. Verification in assisted-living facilities for the elderly

Results of proof experiments at nursing care facilities indicate that greater increases in QOL can be anticipated for people who are more capable of operating an electric cart on their own and who have an environment that allows for greater freedom of operation and mobility.

Elderly people who live in assisted-living facilities for the elderly were given Monpals on loan, the effects were verified, and the receptivity to use was confirmed. Figure 8⁽⁶⁾ shows the activity of an experimental subject in field B.

Before his Monpal use, this experimental subject had no choice but to use taxis for mobility within his living area, and he felt stress from being unable to go out immediately whenever he wanted, and from keeping taxis waiting. Once he started using a Monpal by himself, he felt a sense of satisfaction at being able to go out more or less every day, even at the height of summer or during a light rain. The facility manager felt that the way the experimental subject who cooperated as an experiment monitor had become emotionally and mentally more receptive was the most pleasing result of this proof experiment, and expressed gratitude for how the Monpal had motivated the experimental subject and brought about such a dramatic change in his life.

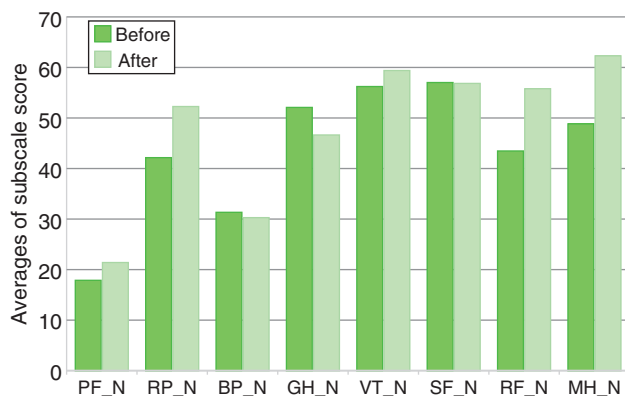


Fig. 7 QOL before-after difference using Monpal in Field A

Active use of the electric cart thus increased the LSA. That in turn was found to have a tendency to contribute to heightened QOL in terms of not only everyday convenience, but also the overall sense of health, vitality, and other such measures.

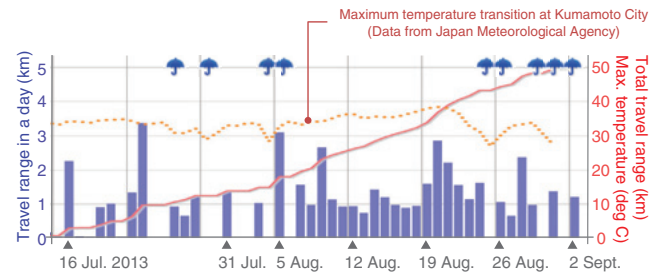
The October 2011 amendment of the Act on Stable Supply of Residences for the Elderly resulted in the establishment of assisted-living facilities for the elderly that offer residents a large degree of freedom in leading their lives, and the supply of such housing within people's living areas has increased. It was inferred, therefore, that such residences have greater need for electric carts.



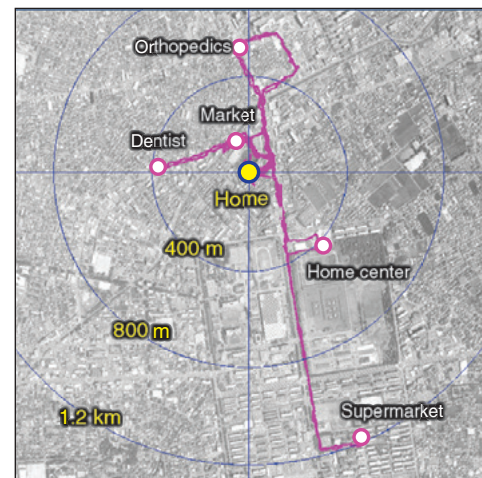
Subject: Mr. K

- Age 86
- Care need level 1: Legs impaired
- Occupancy date : Jun. 2013
- Method of moving around while outside the home: Taxi (almost every day, sometimes twice a day)

(a) Profile



(b) Monpal usage throughout the testing period



The recorded movement locus and circular polar coordinates are aligned with the corresponding section of geospatial photograph from the site (<http://maps.gsi.go.jp/maplibSearch.do>) provided by the Geospatial Information Authority of Japan.

(C) Representative frequent routes of travel

Fig. 8 Survey of subject's travel in Field B

4. Development of Software to Assist People in Going Out Using Electric Carts

Requests were received from demonstration field managers and Monpal user family members for a way to check on the present whereabouts of Monpal users by means of location information obtained using mobile phones. A way was therefore found to do this using Inter Navi, a car navigation service intended for automobiles. This uses a remote monitoring app for smartphones to provide information that supports mobility activity over a wide area and with a high frequency⁽³⁾.

The system was configured to have data generated by the GPS logger used in the proof experiment in collaboration with the Inter Navi server. Figure 9 shows an overview of this system configuration.

The app being provided on this occasion is a Webapp developed using the HTML5 language. This app was adopted because the development man-hours were reduced, the app response speed was increased, and provision of feedback was made easier than before by placing the file with font size and other such settings on the server. The provided app has two functions as described below.

The first is a current position map that shows location information for the Monpal being managed from a base location defined by the facility or family (hereafter, managers). The second is an operation status display (Fig. 10) that allows the Monpal operation status, battery state of

charge, and driving history to be tracked.

The current position map has an additional function that, for example, allows managers to set a destination on the Inter Navi screen. Using that, managers can check the current position by acquiring it from the GPS logger by smartphone. They can register that location with the app so that it is there in advance when they need to go there to pick up the user, and they can use the Inter Navi service to get there.

Questionnaires were administered at facilities that were cooperating with the proof experiment after development of the app had been completed, as well as at the time of the in-town shared use field tests. Managers were asked about how it felt to use the remote monitoring app, and whether using the app gave them a sense of security from remotely monitoring the users. Out of 22 respondents, 19 answered in the affirmative. When asked whether an activity history could serve as an index for health management, nine out of 12 responded in the affirmative. When asked if, in the event that activity history was used as an index for health management, Monpal use could serve to stimulate an increase in frequency of going outside the home, eight out of 12 responded in the affirmative. A comprehensive look at the questionnaire results indicated that the remote monitoring app could serve as a tool to assist with mobility outside the home.

Meanwhile, there was another issue that emerged from the questionnaires. This was the need first of all for an enhanced user interface that would be easy to use even for people who do not, because of their age group, use smartphones on an everyday basis. Measures were also needed to enable people to master the essentially broad applications involved, even in courses on the use of smartphones and apps.

5. Conclusion

As indicated by these proof experiments, greater enhancement of QOL can be anticipated for people who have the capability to operate electric carts on their own and who have an environment that allows them to freely operate the electric carts and be mobile.

For elderly people who find their physical abilities deteriorating and their living area becoming constricted, developing social systems that utilize IT together with personal mobility that allows freedom in operation so as to encourage those elderly people to move outside their homes contributes not only to their individual QOL but also to the formation of a society with higher QOL.

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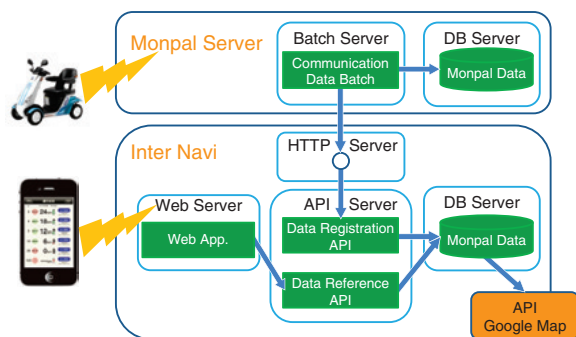


Fig. 9 General diagram of system configuration



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(a) Menu screen (b) Actual location (c) Operation status

Fig. 10 Display of tracking monitor on smart phone

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