

Quantitative Measurement Scale for Effectiveness of Adapted Vehicle

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ABSTRACT

With a goal of contributing to the enrichment of customers' social lives through adapted vehicles, the authors studied a method for quantitatively expressing the effectiveness of the vehicles in order to understand their effect and communicate their value. Effectiveness was defined as the degree of each customer's engagement in their individual social activities after continued use of the adapted vehicle, with engagement determined using a scale based on customer responses to 17 5-point questions. The authors then used this scale to statistically verify a predictive value for the degree of involvement in social activities. The questionnaire was given to physically disabled drivers and drivers involved in caregiving services. The results indicated that highly accurate predictions could be made for both groups, with accuracy rates of 0.825 and 0.846, respectively. This confirmed that the scale developed for this study can quantitatively express the effectiveness of adapted vehicles.

1. Introduction

Under the slogan "Fun For Everyone. Honda - The Joy of Mobility for Everyone," Honda continues to provide adapted vehicles in order to help physically disabled drivers and drivers involved in caregiving services enjoy mobility and social activities⁽¹⁾.

Adapted vehicles can be broadly classified into driving aids vehicles and wheelchair accessible vehicles. Driving aids vehicles have driver assistance devices that enable drivers with lower limb disabilities to operate the gas pedal and brake with their hands, or drivers with upper limb disabilities to operate the steering wheel with their feet. Figure 1 shows an example of a driving aids vehicle. Wheelchair accessible vehicles are equipped with elevating seats and wheelchair ramps to reduce the labor required to assist wheelchair users in and out of the vehicle. An example is shown in Fig. 2.

Honda introduced their first driving aids vehicle in 1976, a sedan equipped with devices to assist people with upper limb disabilities in driving. It introduced a wheelchair accessible kei car in 1995.

Figure 3 shows sales volumes of adapted vehicles in Japan. The market for adapted vehicles grew more than tenfold between fiscal years 1994 and 2004, peaked in fiscal year 2014, and then began to shrink with each subsequent year. The market is currently less than 30,000 units.

Although the adapted vehicle market is small compared to the approximately 4 million passenger cars sold in Japan, automakers have brought many different models to market. This suggests that automakers value the social responsibility side of their businesses adapted vehicles represent and that they strive to emphasize the value of adapted vehicles, even though such value cannot be measured by sales volume or



Fig. 1 Adapted vehicle with hand control device



Fig. 2 Adapted vehicle with rear ramp

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sales revenue alone.

Driving aids vehicles are considered to provide value to customers with upper or lower limb disabilities by enabling them to act autonomously when they use these vehicles. Wheelchair accessible vehicles are also considered to give value to customers who provide care and transport to those they care for, and value to those receiving care by easing their mental and physical burden, providing increased freedom to carry out their daily activities and expanding opportunity in their lives.

Additional product enhancement and development is required for adapted vehicles to continue providing customers with the value. This requires information on the effect that adapted vehicles provide, but the scarcity of such information makes it challenging to understand the actual situation. For that reason, a suitable survey instrument needed to be developed.

To understand the effect adapted vehicles provide, qualitative perceptions of that effect need to be expressed in concrete terms so that there is no gap with the customer's perceptions. This is also desirable in that it could help to understand customer needs, enhance products and services, and communicate the value of adapted vehicles. This is due to growing interest in ESG management and the increasing importance of quantitatively disclosing the effectiveness of corporate activities for society⁽²⁾.

Therefore, the authors attempted to define and quantify the effectiveness of adapted vehicles and to verify their usefulness in conjunction with previously proposed scales for measuring life satisfaction.

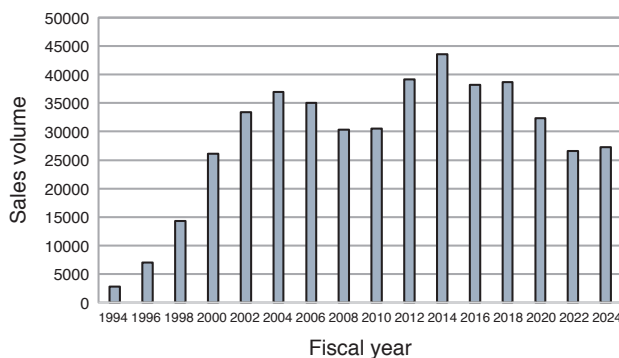


Fig. 3 Domestic sales volume of adapted vehicles

2. Study of Measuring Methods

2.1. Definition of Effectiveness of Adapted Vehicles

The effects of a company's business activities can be expressed over time using a logic model⁽³⁾. Additionally, individuals' life satisfaction and happiness have been found to be positively correlated with participation in social

activities and a person's willingness to participate in such activities, and with social capital at the individual level⁽⁴⁾⁻⁽⁹⁾. For that reason, the authors viewed the effectiveness of adapted vehicles as the impact on society and customers resulting from business activities. The authors then used the introduction of adapted vehicles to the market as a substitute for this business activity and laid out the impacts of adapted vehicles over time. The results are shown in Table 1 as a logic model.

The columns in Table 1 represent the initial, mid-term, and long-term outcomes over time after market launch. The rows represent the local community and beneficiaries impacted by adapted vehicles.

Beneficiary 1 represents drivers with upper or lower limb disabilities who use driving aids vehicles. The impact of the driving aids vehicle was assumed to be that using the vehicle would enable unassisted excursions, social participation, and independence.

Beneficiary 2 represents drivers of wheelchair accessible vehicles who transport individuals in their care, such as relatives. The impact of the wheelchair accessible vehicle was assumed to be that using the vehicle would reduce mental and physical burdens and enable both caregiving and social participation.

Beneficiary 3 represents individuals receiving care who are passengers in wheelchair accessible vehicles. The impact of the wheelchair accessible vehicle was assumed to be that its use would reduce mental and physical burdens and increase opportunities to interact with society.

The local community represents the area in which the beneficiary lives. The impact of providing adapted vehicles was assumed to be that it would foster social capital by increasing the number of people who find it easier to move around and get in and out of vehicles and by revitalizing individual action and society. It was considered that, beyond the positive changes in human behavior, the result would be a virtuous cycle of social revitalization and individual well-being.

After examining Table 1, the authors defined the effectiveness of adapted vehicles as "the degree of activation of the customer's individual social activities before and after the use of an adapted vehicle." This would enable surveys to be conducted at individual companies, with the potential for quantification through customers who purchased adapted vehicles.

2.2. Quantification of Effectiveness

The authors proposed the Vitality scale to quantify the degree of activation of the above-mentioned social activities of individuals.

Vitality can be measured using a questionnaire on changes in the behavior and awareness of individuals directly affected by adapted vehicles. Table 2 lists the items covered in the questionnaires.

Respondents answered each question on a 5-point scale. The meaning of each numbered response was as follows: 1.

Table 1 Outcome stages of logic model

Beneficiary classification	Initial outcomes	Mid-term outcomes	Long-term outcomes
Local community	(1) More people can move by car. (2) More people find getting in and out easier.	More people participate in social activities. People are revitalized.	Social capital is fostered. Society is revitalized.
Beneficiary 1	(1) Able to go out by oneself.	(1) Actions become voluntary	(1) Achieve social participation and independent living.
Beneficiary 2	(2) Reduced mental and physical burden.	(2) Balance personal activities and caregiving.	(2) Continue social participation to utilize individual abilities.
Beneficiary 3		(2) Able to move around for daily needs.	(2) Increased opportunities to interact with society.

Virtuous cycle of well-being and social revitalization

Table 2 Vitality questionnaire

	Questions: Which of the following did you experience?
1	Increased shopping frequency.
2	Increased participation in lessons and clubs.
3	Increased participation in local festivals and events.
4	Increased participation in entertainment such as theater and sports events.
5	Increased opportunities to go out for a change of pace.
6	Increased frequency of meetings with friends and acquaintances.
7	Increased frequency of meetings with relatives and family.
8	Increased contact with neighbors.
9	Increased number of new acquaintances.
10	Income has become more stable.
11	More options to earn income.
12	More ability to be considerate of others.
13	Increased interest in new things.
14	Increased opportunities to feel moved with others (or to want to feel moved).
15	Increased motivation to take action.
16	Increased emotional ease and peace of mind.
17	Increased moments of joy (or wanting to feel joy).

Strongly agree; 2. Somewhat agree; 3. Neutral; 4. Somewhat disagree; and 5. Strongly disagree. A response of 1 or 2 was counted as an increase in opportunities to participate in social activities and was given a score of 1 point, while a response of 3 or more was counted as no change and was given a score of 0 points. The degree of activation towards social activities was then quantitatively evaluated based on the total score (out of 17).

2.3. Verification Method

2.3.1. Scale for comparative verification

Three scales were used for comparison against Vitality:

Table 3 Interpretation of correlation coefficient R

Correlation coefficient R	Level
$1.0 \geq R \geq 0.7$	Very high
$0.7 \geq R \geq 0.5$	High
$0.5 \geq R \geq 0.4$	Moderate
$0.4 \geq R \geq 0.3$	Fair
$0.3 \geq R \geq 0.2$	Low
$0.2 \geq R \geq 0.00$	Very low

the Philadelphia Geriatric Center Morale Scale (PGC)⁽¹⁰⁾⁻⁽¹²⁾, the Satisfaction With Life Scale (SWLS)^{(13), (14)}, and the Organisation for Economic Co-operation and Development Subjective Well-Being - Subjective Assessment of Life in General (OECD)⁽⁵⁾.

These are well-known scales to quantify subjective life satisfaction and happiness.

2.3.2. Correlation analysis

Four online questionnaires (PGC, SWLS, OECD, and Vitality) were administered to the Beneficiary 1 and Beneficiary 2 groups, who use adapted vehicles.

Since the PGC is a questionnaire for people 65 years of age and older, the PGC responses were used with Beneficiary 1 and 2 individuals aged 65 or older.

A total of 118 individuals responded. Of these, 23 of the Beneficiary 1 group were 65 or older and 23 of the Beneficiary 2 group were 65 years or older, while 36 of the Beneficiary 1 group were 64 or younger and 36 of the Beneficiary 2 group were 64 or younger.

The correlations between PGC, SWLS, and OECD against Vitality were determined from the score of each scale as found from the questionnaire results. The evaluation criteria for social surveys⁽¹⁵⁾ shown in Table 3 were used to determine the correlations.

2.3.3. Predictive value validation method

A total of five online questionnaires were administered: the PGC, SWLS, OECD, and Vitality questionnaires about changes in individual behavior and awareness, and a questionnaire about increased involvement in social activity. To ask about the facts concerning whether there was increased social activity, as a direct measure, the authors used a representative question on social activities, namely whether “participation in volunteering, NPOs, and civic activities has increased”⁽⁴⁾.

The target survey respondents were the same as in the correlation analysis. However, the questionnaire results described in the previous section were used for PGC, SWLS, OECD, and Vitality. The authors used logistic regression analysis to verify whether the scores from each scale derived from the online questionnaire results could predict responses regarding “whether there was increased participation in volunteering, NPOs, and civic activities.” based on the scores obtained by each scale.

The software R version 4.5.0⁽¹⁶⁾ was used to calculate and analyze scores from the scales, and a prediction model was developed using “whether they had opportunities to participate in volunteering, NPOs, and civic activities” as the dependent variable and scores for Vitality, etc. as explanatory variables. The logistic curve representing the prediction model is the standard sigmoid function shown in Eq. (1) and a typical curve is shown in Fig. 4.

$$q_i = \frac{1}{1 + e^{-z_i}} \quad (1)$$

Here, q_i is the incidence rate and e is the natural logarithm. The variable z_i is a linear predictor consisting of the sum of n explanatory variables x_n , partial regression coefficients β_n , and constant term β_0 , as shown in Eq. (2).

$$z_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_n x_n \quad (2)$$

A prediction model that forms a monomial in which each score value is substituted into x_1 in Eq. (2) was verified.

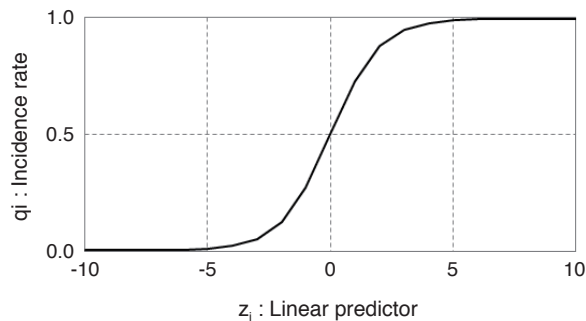


Fig. 4 Diagram of standard sigmoid function

2.3.4. Method of verifying proposed scale accuracy

To verify the accuracy of the Vitality model, 196 individuals from the Beneficiary 1 group and 319 individuals from the Beneficiary 2 group, for a total of 515 individuals, completed two online questionnaires on Vitality and “whether they had opportunities to participate in volunteering, NPOs, and civic activities.” Of the 515 individuals, the responses of 59 individuals in Beneficiary 1 group and 59 individuals in Beneficiary 2 group were based on the results of the online questionnaire described in the previous section.

First, between-group differences between those who had increased opportunities to participate in social activities and those who experienced no change were compared to see whether Vitality could be used to determine whether social activities had increased or not based on the results of this online questionnaire. Next, the authors verified the accuracy of the prediction model using the additional 397 individuals as training data.

3. Results and Discussion

3.1. Correlation Analysis

The correlation coefficients between Vitality and the three existing scales of PGC, SWLS, and OECD are shown in Table 4 for each Beneficiary group. The results show a weak correlation between Vitality and OECD, but little correlation with the other scale indicators. Therefore, the authors considered that Vitality can be treated as a scale independent of the existing scales.

3.2. Predictive Value Validation

Table 5 shows the data obtained from logistic regression analysis. p -values of less than 0.05 are considered statistically significant. No individuals in the Beneficiary 2 group aged 65 or older who responded to PGC had increased opportunities to participate in social activities, so these were excluded from the analysis.

The PGC p -value for the Beneficiary 1 group and the SWLS and OECD p -values for the Beneficiary 2 group exceeded 0.05 and thus were not statistically significant. This suggests that these scales are inadequate for distinguishing increased opportunities for social participation for the Beneficiary 1 and Beneficiary 2 groups overall.

On the other hand, Vitality was statistically significant for both the Beneficiary 1 and Beneficiary 2 groups, indicating that this scale can distinguish “whether there was an increase in opportunities to participate in volunteering, NPOs, and civic activities” and can quantify the degree of activation of an individuals’ social activities.

Figure 5 shows the logistic curves for each scale and the Beneficiary 1 group. The horizontal axis of the graph shows the score for each scale, and the vertical axis shows the results from the questionnaire on “whether there was an increase in opportunities to participate in volunteering,

Table 5 Logistic regression statistics

Items			Estimate (β_0, β_1)	Standard error	z value	p value
Beneficiary 1	PGC	(Intercept)	-7.924	5.810	-1.36	0.173
		PGC score	0.5718	0.5773	0.990	0.322
	SWLS	(Intercept)	-2.999	1.024	-2.93	0.003
		SWLS score	0.09952	0.05028	1.98	0.048
	OECD	(Intercept)	-3.290	1.020	-3.33	0.001
		Subjective happiness value	0.3208	0.1368	2.35	0.019
	Vitality	(Intercept)	-4.116	1.021	-4.03	$p < 0.001$
		Vitality	0.3430	0.09196	3.73	$p < 0.001$
Beneficiary 2	SWLS	(Intercept)	-1.337	1.114	-1.20	0.230
		SWLS score	-0.01302	0.05514	-0.236	0.813
	OECD	(Intercept)	-1.261	0.9454	-1.33	0.182
		Subjective happiness value	-0.05803	0.1383	-0.368	0.713
	Vitality	(Intercept)	-4.721	1.262	-3.74	$p < 0.001$
		Vitality	0.3591	0.1069	3.36	$p < 0.001$

Table 4 Correlation coefficient R between Vitality and existing indicators

Indicators	R for Vitality	
	Beneficiary 1	Beneficiary 2
PGC	0.11	-0.058
SWLS	0.16	-0.12
OECD	0.25	-0.098

NPOs, and civic activities.” An increase is scored as 1 and no change is scored as 0, with responses plotted using a circle mark. Equation (1), the logistic curve, is shown as a solid line, with the constant terms from Table 5 denoted as β_0 and the partial regression coefficient as β_1 for Eq. (2), substituting the score from each scale for x_i . Examining Fig. 5(a) with Vitality as the explanatory variable, the logistic curve shows an S-shape, and the incidence rate q_i exceeds 0.5 for scores between 10 and 15. Logistic regression analysis rounds the incidence rate to a binary classification, enabling the user to distinguish whether there was an increase in opportunities to participate. Such a distinction could be made in Fig. 5(c) SWLS and (d) OECD, but not in (b) PGC.

Next, Figure. 6 shows the results for the Beneficiary 2 group. The logistic curve shows that only Vitality in Fig. 6(a) could distinguish whether there was an increase in opportunities to participate, indicating that it is possible to quantify the degree of activation of individuals’ social activities.

3.3. Verifying Proposed Scale Accuracy

3.3.1. Beneficiary 1 group

The authors compared Cohen’s d with Cliff’s delta,

which can handle non-parametric data, to see if there is a between-group difference between those who had increased opportunities to participate in volunteering, NPOs, and civic activities because they had obtained an adapted vehicle and those who experienced no change in the Beneficiary 1 group. Table 6 shows that the between-group difference is large according to both indicators, enabling clear determinations of whether an increase in participation opportunities occurred.

Figure 7 shows a histogram of Beneficiary 1’s Vitality and whether there was an increase in opportunities for participation. A comparison of the two groups shows a large between-group difference, as indicated by the fact that the modes are on opposite sides, left and right.

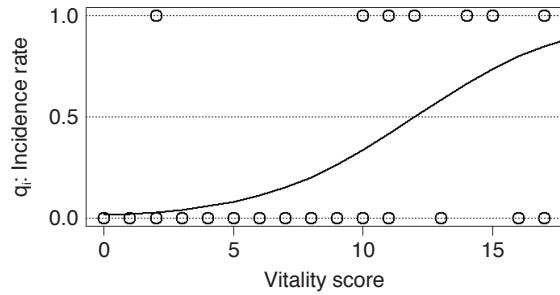
Next, Table 7 uses a confusion matrix to show the results of verification of Vitality prediction accuracy. The table shows actual data and predictions based on Vitality, treating an increase in participation opportunities as positive and no change as negative. The threshold to judge Vitality as positive is when the incidence rate q_i is at least 0.5 on the logistic curve shown in Fig. 5(a). The number of accurate answers for 137 questionnaire respondents was 113, so the model had an accuracy rate of 0.825 and a recall rate of 0.868.

The accuracy of Vitality predictions was also verified using the Area Under the Curve (AUC) indicator, which is used to evaluate the performance of classification models created by machine learning. The results are shown in Fig. 8. The AUC is the area bounded by the Receiver Operating Characteristic (ROC) curve consisting of the false positive and true positive rates, with a value between a minimum of 0.5 and a maximum of 1.0. Larger numbers indicate greater accuracy, and a value of 0.8 or higher is considered indicative of a good model. The fact that the AUC for Vitality is 0.848 means that the model was able to

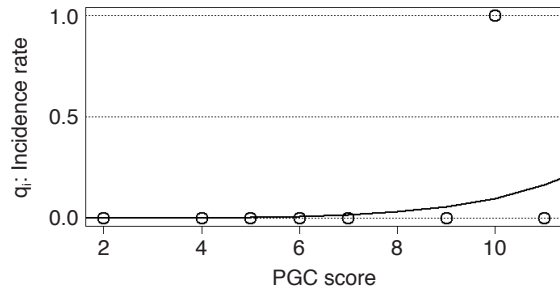
accurately quantify the effectiveness of adapted vehicles for Beneficiary 1 group.

3.3.2. Beneficiary 2 group

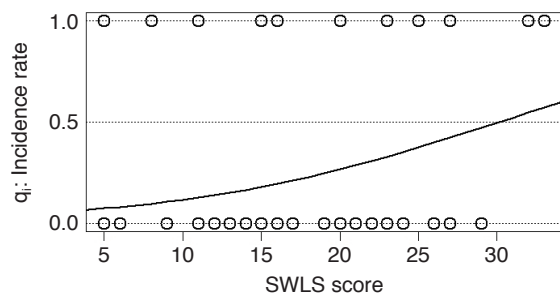
The accuracy of the Vitality model for the Beneficiary 2 group was verified in the same way as the Beneficiary 1 group in the previous section. The model's accuracy rate



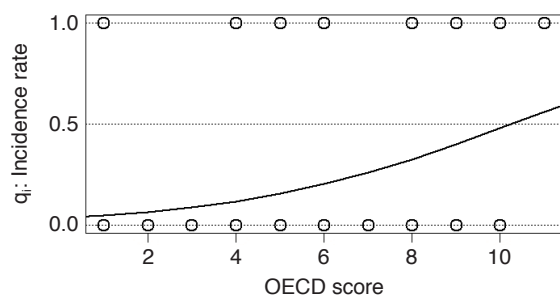
(a) Vitality logistic curve



(b) PGC logistic curve



(c) SWLS logistic curve



(d) OECD logistic curve

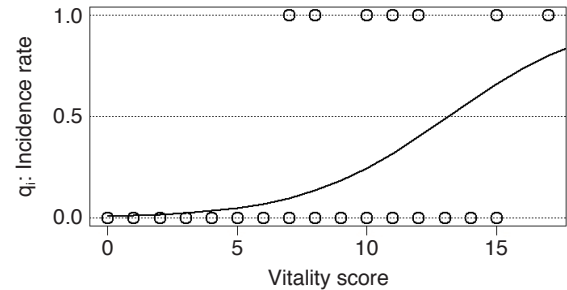
Fig. 5 Logistic curve for Beneficiary 1

Table 6 Calculation results of Cohen's d and Cliff's delta

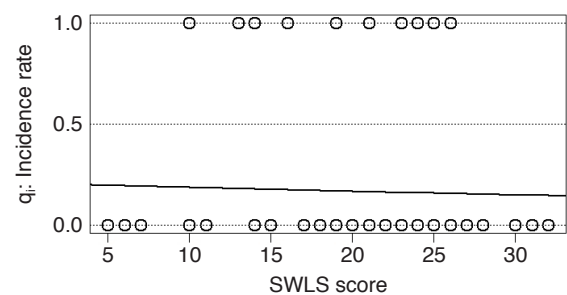
Index		Increase or no increase in participation opportunities in volunteering, NPOs, and civic activities	
Effect size		Cohen's d	Cliff's delta
Between-group difference		Large	Large
95% confidence interval	Lower limit	-2.60	-0.92
	Upper limit	-1.19	-0.55

was 0.846, the recall rate was 0.856, and the AUC was 0.925.

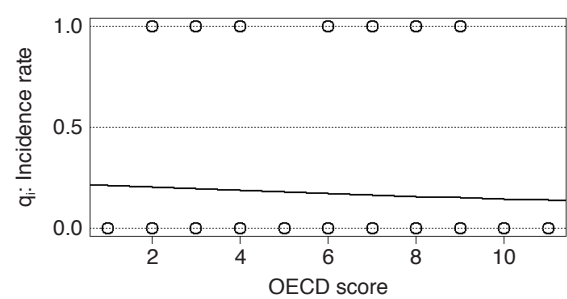
Therefore, the effectiveness of adapted vehicles for the Beneficiary 1 and Beneficiary 2 groups could be accurately quantified by Vitality.



(a) Vitality logistic curve



(b) SWLS logistic curve



(c) OECD logistic curve

Fig. 6 Logistic curve for Beneficiary 2

Table 7 Confusion matrix of Vitality in Beneficiary 1 with increased participation in volunteering, NPOs, and civic activities

		Prediction	
		Nonparticipation	Participation
Actual	Nonparticipation	92	10
	Participation	14	21

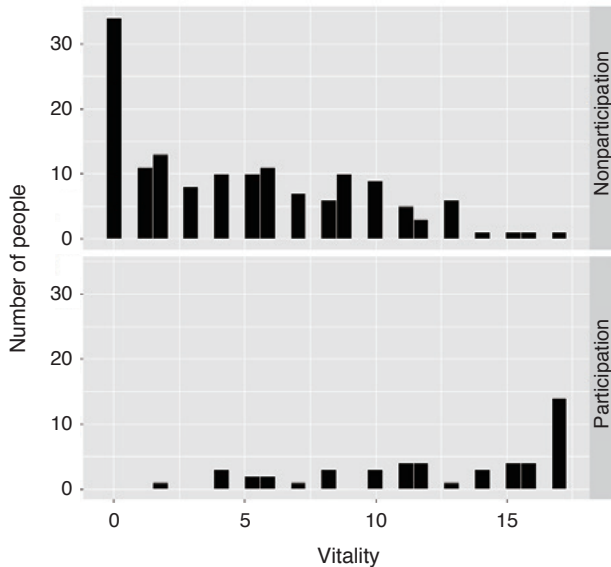


Fig. 7 Histogram of Vitality and increased participation opportunities in volunteer, NPOs, and civic activities in Beneficiary 1

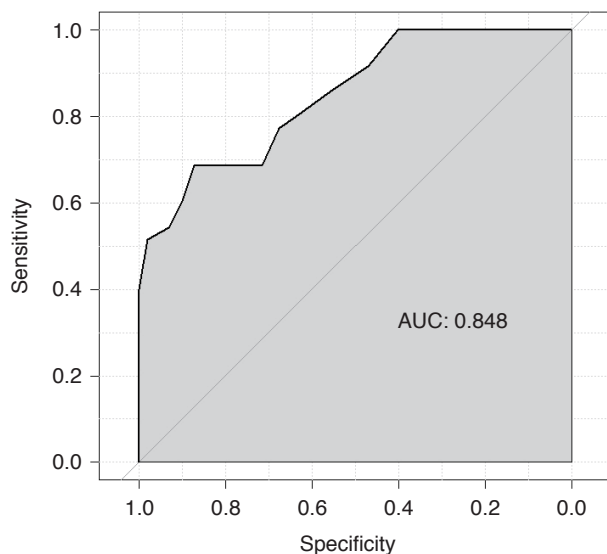


Fig. 8 ROC curve and AUC for Beneficiary 1

4. Conclusion

This paper has proposed a definition and a scale for the effectiveness of adapted vehicles in continually providing customers with the joy of mobility, and reached the following conclusions.

- (1) The authors defined the effectiveness of adapted vehicles as “the degree of activation of the customer's individual social activities before and after the use of an adapted vehicle.”
- (2) The degree of activation of social activities can be quantified by “Vitality,” which is obtained from the results of a 17-item questionnaire.
- (3) The proposed Vitality is a scale independent of existing scales.
- (4) This paper statistically verified that Vitality is an effective scale that can distinguish increases in opportunities to participate in social activities, and that it makes this distinction more easily than existing scales. Going forward, Vitality will be used to understand effect and develop products.

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