Economic Evaluation of Japanese e-Health Systems: A Cost-Benefit Analysis

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Abstract

The e-health system is a type of telecare that transmits health-related data of its users such as blood pressure, ECG, and blood oxygen to a remote medical institution via a telecommunications network. 100 Japanese local governments are already implementing such systems, utilizing a total of more than 12,000 devices (as of March 2005). This paper analyzes the economic benefits of the e-health system in the following four regions in Japan: Kamaishi City, Iwate Prefecture; Nishiaizu Town and Katsurao Village, Fukushima Prefecture; and Sangawa Town, Kagawa Prefecture. The Contingent Valuation Method (CVM), which has been recently widely adopted in the fields of Environmental Economics and Health Economics to measure the benefits of services not traded in the market, is used. We conducted a survey of 348 users in Kamaishi City regarding their Willingness to pay (WTP) to use the service. Using their WTP, we estimate the demand function of the system, which is assumed to be a logistic curve. The average WTP calculated is 4,519 yen (approximately US$37). We then compare the benefits with the costs of the system, which consist of equipment, salaries of doctors and nurses, and other operations. The ratio of benefits over costs (B/C ratio) is about 1.07, which implies that the system of Kamaishi City yields more benefits than costs. This result is rather surprising when compared with the systems of other regions. The paper also analyzes how the benefits expressed in terms of WTP are attributed in exact monetary terms to factors such as (a) reduced anxiety in day-to-day life, (b) stabilization of illness, (c) enhancement of health consciousness, and (d) decrease in medical expenditures. The costs borne by each of the involved parties are identified; namely, the respective amounts paid by individual users and public funds such as tax and medical insurance. This paper suggests reimbursing the e-health system through medical insurance.

1. Introduction

The e-health system transmits health-related data of its users, such as blood pressure, ECG, and blood oxygen, to a remote medical institution via a telecommunications network. To date, eighty Japanese local governments are currently implementing such systems, utilizing a total of more than 12,000 devices -- the largest number of any country. Several household electric appliance manufacturers such as Panasonic, NEC, Fujitsu, Sanyo, and Hitachi, produce and sell remote monitors at prices of US$2,000 to US$4,000 per set (see [1] for details). This system is equipped with a simple device which, when used continuously, records an elderly person's condition or a patient's illness in graphs, which are then used for diagnosis and consultation. Reports sent by the medical institution also help users to enhance their daily health consciousness and maintain good health. These positive effects have been identified through field surveys.

The e-health system in Japan has already passed the experimental stage, and is entering the diffusion stage. In order for the system to be diffused further, it is necessary to prove its cost-effectiveness by comparing its benefits and costs. The latter consist of equipment such as servers and peripheral devices, salaries and wages of doctors and nurses, and maintenance fees such as telephone charges and other miscellaneous operating costs. On the other hand, to indicate its concrete benefits in monetary terms is analytically difficult, since the benefits mainly come from users' subjective satisfaction which is difficult to measure. Without a definite confirmation of the e-heath system's cost-effectiveness, the system's future sustainability cannot be guaranteed.

This paper aims to carry out a Cost-Benefit Analysis of the e-health system in the following regions: Kamaishi City, Iwate Prefecture; Nishiaizu Town and Katsurao Village, Fukushima Prefecture; and Sangawa Town (currently part of Sanuki City), Kagawa Prefecture. Benefits are expressed in terms of WTP (willingness to pay), based on the CVM (Contingent Valuation Method), and costs are calculated as the sum of equipment, salaries of doctors and nurses, and other operations. The benefits and costs are compared with a B/C ratio. We also discuss policy measures to increase this ratio by means of reimbursement through medical insurance, as well as direct subsidies from tax revenue. For other economic evaluations of telemedicine, refer to [2], [3] and [4.]

2. e-Health systems

First we briefly introduce e-health systems and describe an example. Kamaishi City, Iwate Prefecture, which started its e-health system in 1993, was chosen for the survey data, as it has one of the longest records of implementation. In addition, the city's system is operated by a private medical corporation named *Rakuzankai* at a monthly charge of 2,500 yen (approximately US$22.73) per family of up to four persons, and a users' association that conducts many events to promote usage. Since the system uses the CATV network, transmission charges are zero. The peripheral device used by Kamaishi City ,called "*Urara*," is manufactured by *Nasa* Corporation. The device is

equipped with memory, an electric sphygmomanometer, an electro-cardiograph, an electric signboard, and a button for answering questions. At the hospital, nurses check transmitted data and report to the doctor as well as to the device's users whenever they notice abnormal symptoms. The hospital sends monthly reports to all users with comments, which are used for their health management. There are 211 devices, and the total number of users is 409.

Nishi-aizu and Sangawa have almost identical systems based on "Urara," since they imitated Kamaishi's system. Katsurao Village has a different system, using NEC's "Sukoyaka-mate" device. Katsurao Village distributes terminals to all families who have person(s) older then sixty-five years old, and thus it has the largest number of users. In Table 1, we compare the systems of four regions. We will see that these four regions yield different results according to the differences in their systems.

Table 1. Comparison of systems

	No. of users	No. of devices	Terminal	Network	Charges
Kamaishi	348	211	Urara	CATV	2,500 yen
Nishi-aizu	518	400	Urara	CATV	none
Katsurao	926	325	NEC	Tele. (ISDN)	none
Sangawa	384	225	Urara	CATV	none

3. Methods

3.1. Contingent valuation method (CVM)

In order to measure the benefits of services not traded on the market, the following methods are often utilized: (a) travel cost method: (b) replacement costs method; (c) hedonic approach; and (d) CVM. In what follows, we use CVM, which has been recently widely adopted in the fields of Health Economics and Environmental Economics. In CVM, the benefits to users are measured in terms of WTP, which is the monetary amount users are willing to pay for receiving a service. By asking the WTP of each user, we can then construct the surrogate demand function for the e-health system. Although CVM and WTP have strong theoretical bases, CVM tends to introduce bias, because it asks for concrete valuation and choice under fictitious circumstances. Care should be taken to clarify what kind of bias is introduced, and to remove this bias (for further discussion on biases, see [5]). .

3.2. Questionnaire

For the surveys, we use questionnaires. Let us take the example of Kamaishi City. We interviewed 348 users of the e-health system questions pertaining to the following: (a) WTP; (b) effectiveness; (c) frequency of usage; and (d) user characteristics such as age, gender, income, education, and health condition. The portion of the questionnaire related to WTP is as follows. We begin by asking whether they would be willing to pay monthly charges of 5,500 yen (US$45) to use the system. If their answer is "yes," we then ask whether they would be willing to pay 7,500 yen (US$62.5). If they reply "yes" again to 7,500 yen, their WTP is 7,500 yen. If "no," then we lower the amount to 6,500 yen (US$54.17). If they reply "yes" to 6,500 yen, then that is their WTP. If again their answer is "no," we lower the amount further to 5,500 yen. We repeat this process until their WTP is determined. Out of a total of 348 replies, 291 had no missing value. The distribution of WTP from the survey is as follows: 10,000 yen (16 users), 8,000 yen (1), 7,500 yen (12), 6,500 yen (11), 5,500 yen (62), 4,500 yen (8), 3,500 yen (69), and 2,500 yen (112). The distribution of replies is shown in Table 2. Those of the other regions are shown in Tables 3, 4, and 5.

3.3. Estimation of demand function and WTP

Based on the above WTP of each user, we estimate the demand function of the system; more precisely, we estimate the probability of acceptance to amounts questioned and the number of users who will agree to pay. The functional form of demand to be estimated is assumed to be logistic, namely,

$$\text{Probability of acceptance} = 1 - 1/(1 + \exp(-\alpha - \beta \log WTP)).$$

The probability of acceptance is the ratio of the number of users who reply that they are willing to use the device at the amount of charges provided in the questions. The estimated coefficients α and β are summarized in Table 6, 7,8, and 9 for four regions.

The estimated demand function for Kamaishi's e-health system is shown in Fig. 1. The average WTP is calculated as the area under this demand function, which results in being 4,519 yen (approximately US$37) per user per month. The demand functions of other regions have the same form.

In sum, WTP of Kamaishi, Nishiaizu, Katsurao, and Sangawa are 4,519 yen, 3,177 yen, 1,640 yen, and 2,955 yen, respectively.

Table 2. Distributions of replies: Kamaishi

WTP (yen)	2,500	3,500	4,500	5,500	6,500	7,500	8,000	10,000
No. of users	112	69	8	62	11	12	1	16

Table 3. Distributions of replies: Nishi-aizu

WTP	0	500	750	800	1,000	1,500	2,000	
No. of users	141	4	2	1	54	7	3	
WTP	2,500	3,500	4,500	5,500	6,500	7,500	8,000	10,000
No. of users	67	38	1	69	6	13	9	5

Table 4. Distributions of replies: Katsurao

WTP (yen)	0	500	1,000	1,500	2,000	2,500	3,000	
No. of users	85	95	113	25	50	3	14	
WTP (yen)	3,500	4,000	4,500	5,000	5,500	6,500	8,000	10,000
No. of users	2	1	1	9	2	1	1	7

Table 5. Distributions of replies: Sangawa

WTP	0	500	1,000	1,500	2,000	2,500	3,000
No. of users	93	3	14	38	3	23	5
WTP	3,500	4,000	4,500	5,000	5,500	6,500	10,000
No. of users	6	0	17	1	2	2	2

Table 6. Results of estimation of demand function: Kamaishi

	Estimated	Standard error	t-value	p-value
α	27.441134	2.0739667	13.231	0.0000
β	3.3033572	0.2474318	13.351	0.0000

Table 7. Results of estimation of demand function: Nishi-aizu

	Estimated	Standard error	t-value	p-value
α	29.866890	1.9972607	14.954	0.0000
β	3.7547249	0.2382865	15.757	0.0000

Table 8. Results of estimation of demand function: Katsurao

	Estimated	Standard error	*t*-value	*p*-value
α	15.800151	1.8418040	11.775	0.0000
β	2.2491025	0.1794782	12.498	0.0000

Table 9. Results of estimation of demand function: Sangawa

	Estimated	Standard error	*t*-value	*p*-value
α	25.470392	2.5995525	9.798	0.0000
β	3.2403337	0.3281845	9.874	0.0000

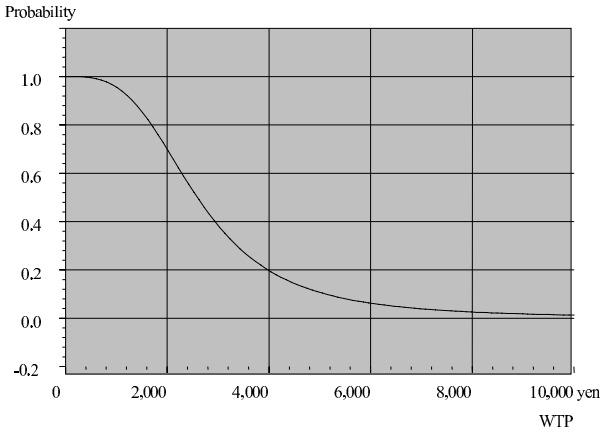

Figure 1. Estimation of demand function: Kamaishi

4. Cost-Benefit Analysis

4.1. Total Benefits

In our Cost-Benefit Analysis, total benefits and costs are compared over a period of several years. In this paper, the time span is set at six years because all device parts are held as inventory for six years. WTP obtained above is per user per month, and the total yearly value is obtained by multiplying by the number of users and by 12 months. At the time of the survey (October 2000), 348 users were registered. One-year benefits total approximately 18,871,344 yen (US$157,261). In order to obtain six years' worth of benefits, we calculate the present value of six years' benefits with a 4% discount rate, and we assume that the number of registered users remains constant for six years. This yields a six-year benefit total of 95,782,869 yen (US$798,182). In the same way, total benefits of the other three are also calculated, which are shown in Table 10.

4.2. Total Costs

The total costs of the system include costs for equipment, salaries and wages of doctors and nurses, and other miscellaneous costs which include maintenance. The cost of host computers at the hospital is about 1,700,000 yen (US$14,166) which includes instalment fees of 250,000 yen (US$2,083) per device. The total costs for 200 devices are about 37,600,000 yen (US$313,333). Development of software prior to instalment costs 4,000,000 yen (US$33,333), which is also considered part of the initial costs. We

assume that 10% of the value of equipment can be considered its current value after six years of operation; therefore 90% of the value of equipment is included in the costs, which amounts to 38,970,000 yen (US$324,750). This is paid for with a one-time payment at the beginning.

Regarding salaries and wages, a part-time doctor is paid about 1,728,000 yen (US$14,400) per year, a full-time nurse is paid about 5,040,000 yen (US$42,000), and one part-time worker receives about 1,800,000 yen (US$15,000). The doctor and part-time worker spend half of their working hours on this system. Thus, total yearly salaries are 8,568,000 yen (US$71,400). Other maintenance costs, such as those for printer toner and postage, are about 1,851,600 yen (US$15,430). As mentioned earlier, there are no telecommunications charges. Thus, total annual operational costs are about 10,419,600 yen (US$86,830). According to this calculation of six years' operational costs, as well as those of equipment (with the 4% discount rate), the costs of the e-health system in Kamaishi City total 95,782,869 yen (US$789,190). The total costs of the other regions are summarized in Table 11.

4.3. B/C Ratio

From the above calculation, benefits total 95,782,869 yen (US$798,182), whereas costs total 95,782,869 yen (US$789,190) over the period of six years. Therefore, the B/C ratio is 1.07; that is, benefits exceed costs. This is a rather surprising result, because all other local governments where field research was conducted show ratios of less than 1. The B/C ratio being larger than 1 does not necessarily indicate that the medical corporation, *Rakuzankai*, earns a positive profit. Since its revenues consist of user charges of 2,500 yen, this amount is smaller than that of WTP; more precisely, 211 peripheral devices are being leased, and 2,500 yen is being charged per family. The monthly revenue from rental devices thus totals 527,500 yen (US$4,396), with annual revenue of 6,330,000 yen (US$52,750). On the other hand, annual operational costs as obtained in the previous subsection are approximately 10,419,600 yen (US$86,830). Thus, revenues are far less than operational costs. Though *Rakuzankai* is losing money through this operation, losses are covered by other hospital income. The B/C ratios of the other regions are shown in Table 11.

4.4. B/C Ratio for Local Governments

If the e-health system of Kamaishi City were considered as a private business, its profits would be negative; however, as a public project, it accrues more benefits to society than costs. For the other three local governments, the costs are larger than benefits. Why, one might ask, do these other regions implement such projects? This is a common question facing all local governments in Japan. For our answer, let us consider the matter from the viewpoint of the local governments themselves. Most e-health systems in Japan are supported by the central government, through subsidies to local governments that match the cost of equipment.

For all local governments other than Kamaishi City, the B/C ratio is smaller than 1. This difference is due to the costs of equipment; Katsurao Village purchased rather sophisticated and expensive devices capable of transmitting motion pictures. Nishiaizu and Sangawa received subsidies from different Ministries at different times, and since these devices cannot be utilized as one single system, it was necessary to install various kinds of equipment for each system. Kamaishi City purchased the lowest-cost devices; this is the primary reason that its B/C ratio is the highest. Due to central government subsidies, local governments must only cover operating costs such as salaries and wages, and maintenance costs. The B/C ratios recalculated in this manner are labelled as (B/C)* in Table 11. All (B/C)* values are larger than 1. This is the answer to the above question – for local governments with access to central-government subsidies, e-health projects accrue more benefits than costs.

Table 10. Comparison of Benefits

Unit: yen

	No. of users	WTP	Benefit (6 years)	Fee
Kamaishi	405	4,519 (US$41.08)	102.9mil. (US$953.5 thousand)	2,500
Katsurao	926	1,640 ($14.91)	99.4 ($904.6)	none
Nishiaizu	518	3,177 ($28.88)	107.7 ($979.1)	none
Sangawa	484	2,955 ($26.86)	106.5 ($968.2)	none

Table 11. Comparison of costs and B/C ratio

	Kamaishi	Nishiaizu	Katsurao	Sangawa
No. of devices	211	400	325	225
Equipment	39.9 mil. yen	136.7 mil. yen	111.4 mil. yen	133.5 mil. yen
	($36.3 thou.)	($1,243thou.)	($1,012.7thou.)	($1,213.6 thou.)
Salaries	8.6 mil. yen	3.7 mil. yen	3.36 mil. yen	4.5 mil. yen
	($78.2 thou.)	($33.6 thou.)	($30.5 thou.)	($40.9 thou.)
Others	1.9 mil. yen	1.9 mil. yen	10.4 mil. yen	3.0 mil. yen
	($17.3 thou.)	($17.3 thou.)	($94.5 thou.)	($27.3 thou.)
Costs (6 years)	95.5 mil. yen	184.5 mil. yen	184.2 mil. yen	174.3 mil. yen
	($868.2 thou.)	($1,677.3 thou.)	($1,674.5 thou.)	($1,584.5 thou.)
B/C	1.07	0.58	0.54	0.61
(B/C)*	1.87	2.31	1.42	2.60

5. Cost-sharing among parties

5.1. Decomposition of WTP into effects

The previous result shows that WTP in Kamaishi is 4,519 yen. In this section, we decompose this WTP into the various discrete effects of the e-health system. We then calculate who bears the costs of the e-health system examined in the previous section, and to what extent.

In the survey of users, we asked whether the system led to four positive effects: (a) reduced anxiety in day-to-day life, (b) stabilization of illness, (c) enhancement of health consciousness, and (d) decrease in medical expenses. We regressed the users' stated WTP based on their replies to these questions. Thus, we estimated the following equation:

$$W = ax_1 + bx_2 + cx_3 + dx_4 + e,$$

where a, b, c, and d are coefficients to be estimated, x_1, x_2, x_3, and x_4 are dummy variables that each take a value of 1 if a reply is "yes" and 0 if it is "no," and e is an error term. The results are shown in Table 12, 13, 14, and 15 for four cases.

Based on the above estimation, the extent to which each effect had monetary value was calculated; that is, how the WTP is decomposed into these four components. The p-value of "decrease in medical expenses" was not significant, so this component was ignored. The results of the four cases are summarized in Table 16.

5.2. Exact Amount of Reimbursement

The effects of enhancement of health consciousness and reduced anxiety in day-to-day life offer benefits to the users themselves, since these users' personal lives are enriched. Stabilization of illness has an additional benefit to society, as it results in decreased medical expenditures, conservation of medical resources, etc. That is, this effect carries a positive externality. This argument leads us to suggest who should bear the cost of the e-health system. If an effect benefits individual users, then they are willing to pay that amount. On the other hand, if it benefits all of society, then society can collectively bear that fraction of the cost. According to the above figures, in Kamaishi City individual users bear 2,763 yen in cost, while society pays 349 yen as reimbursement. In Nishiaizu, reimbursement is 439 yen. Surprisingly, the amount of 2,763 yen obtained here is very close to the amount of 2,500 yen charged by Kamaishi City (for detailed discussion on reimbursement, see [6] and [7]).

Table 12. Result of estimation: Kamaishi

	Co-efficient	Stand. Error	*t*-value	*p*-value
Stabilization of illness	979.0	298.6	3.3	< 0.001
Enhancement of health consciousness	2612.9	224.1	11.7	< 0.001
Reduced anxiety in day-to-day life	1535.7	264.3	5.8	< 0.001
Decrease in medical expenses	767.9	701.8	1.1	<0.28

Table 13. Result of estimation: Nishi-aizu

	Co-efficient	Stand. Error	*t*-value	*p*-value
Stabilization of illness	753.1	299.3	2.51	< 0.012
Enhancement of health consciousness	1340.5	340.4	3.93	< 0.000
Reduced anxiety in day-to-day life	909.6	366.7	3.48	< 0.014
Decrease in medical expenses	493.3	348.5	1.42	<0.158

Table 14. Result of estimation: Katsurao

	Co-efficient	Stand. Error	*t*-value	*p*-value
Stabilization of illness	329.5	463.5	0.71	< 0.478
Enhancement of health consciousness	446.0	256.4	1.74	< 0.083
Reduced anxiety in day-to-day life	1075.8	268.7	4.00	< 0.000
Decrease in medical expenses	887.2	1217.8	0.73	<0.487

Table 15. Result of estimation: Sangawa

	Co-efficient	Stand. Error	*t*-value	*p*-value
Stabilization of illness	402.0	409.9	0.98	< 0.329
Enhancement of health consciousness	302.6	380.5	0.80	< 0.428
Reduced anxiety in day-to-day life	2190.2	321.4	6.81	< 0.000
Decrease in medical expenses	-130.0	522.4	-0.24	<0.804

Table 16. Decomposition of WTP into effects

Value (yen)

Effect	Kamaishi	Nishi-aizu	Katsurao	Sangawa
Stabilization of illness	349	439	not significant	not significant
Enhancement of health consciousness	1,834	1,075	179	not significant
Reduced anxiety in day-to-day life	929	680	475	774
Decrease in medical expenses	not significant	not significant	not significant	not significant

6. Conclusion

So far, we have conducted surveys of four local governments. Except for Kamaishi City, their B/C ratios are approximately 0.5; that is, benefits cover only half of the costs. In addition, regarding the frequency of usage of the device, Kamaishi City has a much higher ratio than the other local governments. Thus, Kamaishi City demonstrates very distinctive characteristics. This is due to their efforts to promote usage, such as a users' association that organizes events to enhance health consciousness, and to the participation in the system of medical doctors, which increases the users' reliance on the system.

It is clear from our previous studies that the e-health system is useful for consultation and for maintaining the good health of the elderly and patients suffering from chronic diseases who are in stable condition, but that e-health is not effective for curing disease. E-health has psychological benefits, such as providing a sense of relief to its users by the knowledge of being monitored by a medical institution 24 hours a day. This makes it difficult to estimate its benefits in concrete terms. We are only able to provide estimates of these amounts in this paper.

To date, Japanese local governments implementing this system have not charged any fee, except for Kamaishi City, instead receiving all their money in subsidies from the central government. Kamaishi City itself receives subsidies from the Ministry of Welfare through collaboration in two of its projects – the Special Project for Promoting Regional Health, and the Pilot Project for Promoting Tele-Medicine. Katsurao Village receives subsidies from the Ministries of Welfare Agriculture, Nishiaizu from the Ministry of Welfare, the Land Planning Agency, and the Ministry of Agriculture, and Sangawa from the Ministries of Welfare and Agriculture. Due to the current severe fiscal situation in Japan, however, local governments can no longer rely on such subsidies. For sustainability of the e-health system from a financial point of view, a new framework is required. Reimbursement using medical insurance is one possibility. Analyses such as the Cost-Benefit Analysis carried out in this paper provides a theoretical foundation for such reimbursement to be realized.

In this paper we selected four regions, applied CVM to each e-health system, and made a comparison of the results. This, however, is not the most appropriate method for such an estimation. It is necessary to pool the data of the four regions, and then proceed with the analysis. This is our task for the future.

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