# How to Evaluate an m-Health Project: Case of e-Ambulance in Japan

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*Abstract*— **This study aims at evaluating the economic effect of a e-ambulance project, or emergency telemedicine in the rural areas in Kouchi Prefecture in Japan. The focus is on ambulances equipped with ICT devices which transmit images of acute patients to remote hospitals. Kouchi Prefecture started the e-ambulance project in Aki and Muroto Cities in 2012. From two cities, it takes approximately one hour to reach emergency hospitals located in Kouchi City, the prefectural capital. One of the merits of e-ambulance with the image transmitting system is that doctors in accepting hospitals can monitor real time situation of a patient and prepare for necessary treatment prior to the time patient arrives. They thus save time and effort. In measuring benefit, this study employs different methodology; the e-ambulance project enhances wellness of residents since they perceive more secure. Thus the contingent valuation method (CVM) is applied and willingness to pay (WTP) is used as an index of benefit and estimated based on surveys to residents, which amounts to 1,747 yen per resident per year. Total cost calculated is 381,792,228 yen over three years, and accordingly, B/C ratio amounts 0.459.**

***Keywords- e-ambulance; WTP; Cost-benefit analysis; CVM; B/C ratio.***

## I. INTRODUCTION

e-Health has been implementing in many countries, and in order for the system to be diffused further, there are still lots of obstacles such as the legal framework, economic foundations of implementations, and other regulations. All medical systems were established in the age of face-to-face medicine fair prior to e-Health. To overcome these obstacles, it is required to demonstrate its effectiveness, that is, e-Health contributes to efficiency of medical services and enhances wellness of people [1]. Therefore, its cost-effectiveness must be proved by comparing its benefits and costs. The latter consists of equipment such as servers and peripheral devices, salaries and wages of doctors and nurses, and maintenance fees such as communication charges and other miscellaneous operating costs. On the other hand, to obtain its concrete benefits in monetary terms is analytically difficult, since the benefits mainly come from users' subjective satisfaction which is difficult to measure [2][3]. Without a firm basis of its cost-effectiveness, the future sustainability of the e-Health cannot be guaranteed.

The authors have been analyzing the benefits or merits of e-Heal in terms of the amounts of medical expenditures or treatment days saved by e-Health employing different methods, which are mainly statistical analyses [4]-[9]. These analyses became possible since the precise data of medical expenditures or treatment days were obtained. Based on the construction of the database, the effect of e-Health on these out comes were estimated for the various objectives or methods. The effect in the long-term effect such as 10 years is the example of the former [7], whereas the estimations without biases such as [5][8] are those of the latter. On the other hand, this study takes a different method other than statistical and focuses on the comparison of costs and benefits of e-Heath. In this sense, this paper examines e-Health in terms of cost effectiveness.

In order to measure the benefits of public services such as e-ambulance which are not traded on the market, the following methods are utilized in this field: (a) travel cost method: (b) replacement costs method; (c) hedonic approach; and (d) contingent valuation method (CVM). In what follows, this study employs CVM, which has been recently widely adopted in the fields of health economics and environmental economics [10][11][12]. CVM measures the benefits to users in terms of willingness to pay (WTP), which is the monetary amount that users want to pay for receiving the service. By asking WTP of each user, we can then construct the surrogate demand function for the e-Health service. It should be noted that this paper utilizes the results of economic evaluation of e-Health for the assessment of a project which aims to introduce the system. If the system is not introduced yet, it is impossible theoretically to evaluate a project by asking residents about WTP. CVM, however, can be applied even in this case, since it asks imaginary questions to people relating to benefits [13]. Although CVM and WTP have a strong theoretical basis, CVM tends to have a bias because it asks for concrete valuation and choice under fictitious circumstances. Care should be taken to clarify what kind of bias it possesses and to remove them.

This paper aims to analyze the Cost/Benefit analysis of the e-ambulance project in two cities in the rural and depopulated areas in Japan: Aki City and Muroto City, Kochi Prefecture. Ambulances are equipped with ICT devices which transmit images of patient to remote hospitals. In the depopulated areas, the number of clinics and medical specialist is small and a patient with acute disease or wounded by accident must be transported to hospitals with full facilities. Traditional ambulances are equipped with the mobile communication system only for voice or facsimile, and accordingly information transmitted from the ambulance to hospitals is limited. Kouchi Prefecture started the e-

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ambulance project in Aki and Muroto Cities in 2012. From these two cities, it takes about approximately one hour to reach emergency hospitals located in Kouchi City, the prefectural capital. One of the merits of e-ambulance with the image transmitting system is that doctors in the accepting hospital can monitor real time situation of a patient and prepare for necessary treatment when patient arrives. They thus save time and effort.

The analysis in this study provides not only the firm theoretical basis of evaluating e-Health project but also practical guideline for regions which plan to implement e-Health. In particular, surveys to residents were conducted not only above two cities but also Ino Town, Kochi Prefecture, which plans to implement e-ambulance. In this context, we can compare how WTP is different between two types regions which are implementing or not, we can compare ex-post and ex-ante WTP. This study therefore leads to useful information to local governments which plan to implement e-Health.

The structure of the paper is as follows: In the next section, the surveys to residents and their results are briefly summarized and explained. Section III estimates WTP based on the data. The content of various costs and the comparison with benefits are analyzed in Section IV. The brief conclusion and further analysis are presented the final section.

## II. SURVEYS CONDUCTED

### A. Aki and Kuroto Cities

In this section, let us briefly describe Aki and Muroto cities. These neighboring cities are located in east Kochi Prefecture. They are mountainous and face the Pacific Ocean. Their primary industries are agriculture and fishery. Their population is declining, while the percentage of the elderly is increasing. Aki City with the area of 317.37km² has 18,657 residents and 8,055 households, and the elderly ratio is 29.14%, while Muroto with the area of 248.25 km² has population 17,490 and 7,598 households, and its elderly ratio is 32.94%. There are 42 in Aki City and 23 clinics in Muroto City, but no tertiary emergency medical facility in two cities and therefore patients who emergency services need have to be transferred to Kochi City. This is the background of the e-ambulance project.

### B. Surveys to residents

The surveys were conducted to residents in Ino Town on November 5, Aki City on November 18 and Muroto City on November 19, 2013. We interviewed 62 in Ino Town, 55 Aki City, and 47 Muroto City, totaling 164, and asked questions pertaining to the following: (a) WTP; (b) effectiveness; (c) frequency of usage; and (d) user properties such as age, gender, income, education, and health condition. These are supposed to affect WTP of residents.

Let us examine characteristics of residents who replied to our questionnaires. 76 are males, while 85 are females (TABLE I). The average age is 42.7 (TABLE II) and regarding education, high school, junior college, and university and higher are equally distributed (TABLE III). 153 are still working, while 8 not working (TABLE IV). The average family size is 2.9 (TABLE V), and people living alone and living with wife or husband share more than half. The number of children and grandchildren living in the same city is shown in TABLE VI. Regarding health condition, more than two-thirds replied either good, fair or all right (TABLE VII). Accordingly, the average frequency of visiting medical institutions per month is 1.6, and more than 90% reported no necessity for outside medical help, and these are due to their average ages (TABLE VIII). Even though two cities located depopulated areas, they are enough neighboring clinics, and the most of them live close to clinics (TABLE IX).

TABLE I. GENDER

| | Freq. | % |
|---|---|---|
| 1 Male | 76 | 47.2 |
| 2 Female | 85 | 52.8 |
| Total | 161 | 100 |

TABLE II. AGE DISTRIBUTION

| Age | Freq. | % |
|---|---|---|
| 20-24 | 12 | 7.5 |
| 25-29 | 13 | 8.1 |
| 30-34 | 6 | 3.8 |
| 35-39 | 16 | 10.0 |
| 40-44 | 17 | 10.6 |
| 45-49 | 24 | 15.0 |
| 50-54 | 29 | 18.1 |
| 55-59 | 22 | 13.8 |
| 60-64 | 10 | 6.3 |
| 65-69 | 6 | 3.8 |
| 70-74 | 4 | 2.5 |
| 75-79 | 1 | 0.6 |
| total | 160 | 100.0 |

TABLE III. EDUCATION

| | Freq. | % |
|---|---|---|
| 1. Junior high school | 5 | 3.1 |
| 2 High school | 56 | 34.8 |
| 3 Junior collage | 51 | 31.7 |
| 4 University and higher | 49 | 30.4 |
| total | 161 | 100.0 |

TABLE IV. EMPLOYMENT

| | Freq. | % |
|---|---|---|
| 1 Working | 153 | 95.0 |
| 2 Not working | 8 | 5.0 |
| total | 161 | 100.0 |

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TABLE V. NUMBER OF FAMILY

| | Freq. | % |
|---|---|---|
| 0 | 15 | 11.1 |
| 2 | 27 | 20.0 |
| 3 | 38 | 28.1 |
| 4 | 0 | 0.0 |
| 5 | 12 | 8.9 |
| 6 | 3 | 2.2 |
| total | 135 | 100.0 |

TABLE VI. NUMBER OF CHILDREN AND GRANDCHILDREN LIVING IN THE SAME CITY

| | Freq. | % |
|---|---|---|
| 0 | 123 | 76.4 |
| 1 | 14 | 8.7 |
| 2 | 9 | 5.6 |
| 3 | 9 | 5.6 |
| 4 | 3 | 1.9 |
| 5 | 2 | 1.2 |
| 6 | 1 | 0.6 |
| total | 161 | 100.0 |

TABLE VII. DISEASES TREATED

| Diseases | Freq. | % |
|---|---|---|
| 1 High blood pressure, Atherosclerosis | 11 | 27.5 |
| 2 Heart diseases | 1 | 2.5 |
| 3 Diabetes | 2 | 5.0 |
| 4 Stroke | 1 | 2.5 |
| 5 Chronic Gastritis, Gastric ulcer | 3 | 7.5 |
| 6 Assume | 1 | 2.5 |
| 7 Backache, arthritis, rheumatism | 6 | 15.0 |
| 8 Gglaucoma, cataract | 1 | 2.5 |
| 9 Rrenal disease, kidney failure | 3 | 7.5 |
| 10 Hemorrhoid | 0 | 0.0 |
| 11 Others | 11 | 27.5 |
| total | 40 | 100.0 |

TABLE VIII. FREQUENCY OF VISITING CLINIC

| Number | Freq. | % |
|---|---|---|
| 1 0 | 90 | 57.3 |
| 2 1-2 | 66 | 42.0 |
| 3 3-5 | 1 | 0.6 |
| 4 6-9 | 0 | 0.0 |
| 5 more than10 | 0 | 0.0 |
| total | 157 | 100.0 |

TABLE IX. MINUTES TO THE NEAREST CLINIC

| Time | Freq. | % |
|---|---|---|
| 1 less than 10 minutes | 79 | 50.6 |
| 2 10-less than 30 | 52 | 33.3 |
| 3 30-less than 60 | 16 | 10.3 |
| 4 60-less than 2 hours | 9 | 5.8 |
| total | 156 | 100.0 |

## III. ESTIMATION OF WTP

### A. CVM

In order to measure the benefits of services which are not traded on the market, the following methods are 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 [10][11][12]. CVM measures the benefits to residents or users of e-Health in terms of WTP, which is the monetary amount which users are willing to pay for receiving the service. By asking the WTP of each user, we can then construct the surrogate demand function for the e-ambulance system. Although CVM and WTP have a strong theoretical basis, CVM tends to have a bias because it asks for concrete valuation and choice under fictitious circumstances. Care should be taken to clarify what kind of bias it possesses and to remove them.

### B. Questionnaire

We conducted the surveys to residents in Ino Twon on 5, Aki City on 18 and Muroto City on 19, November 5, 2013, and asked questions pertaining to the following: (a) WTP; (b) whether they know the e-ambulance project, (c) desire to continue the project; and (d) user properties such as age, gender, income, education, and health condition. The questionnaire related to WTP is based on the three-stage double bound method: We begin by asking whether they would be willing to pay monthly charges of 1,500 yen (US$15). This initial value in CVM method is important, since WTP tends to depend on the initial value. If their answer is “yes,” we then ask whether they would be willing to pay 2,500 yen (US$25). If they reply “yes” again to 2,500 yen, their WTP is 2,500 yen. If “no”, then we lower the amount to 2,000 yen (US$20). If they reply “yes” to 2,000 yen, then that is their WTP. If again their answer is “no,” we lower the amount further to 1,500 yen. In the first question of 1,500, if the reply is “no” to 1,500 yen, then we lower the amount to 500 yen. If the reply to 500 yen is “yes,” then we ask whether 1,000 yen is acceptable. If the reply to 1,000 yen is “yes,” then his/her WTP is 1,000 yen. If not, it becomes 500 yen. On the other hand, the reply to 500 yen is “no,” then we ask how about 250 yen. If the reply is “yes,” then WTP becomes 250 yen. If it is “no,” then we ask how much he/she wants to pay. They reply their acceptable amounts. These series of questions are standard in the evaluation of issues in public services, environments, and so on.

The distribution of WTP from the survey shown in TABLE X is as follows: more than 3,000 yen (5), 2,500-2,999 yen (5), 2,000-2,499 yen (5), 1,500-1,999 yen (10), 1,000-1,499 yen (18), 500-999 yen (30), 250-499 yen (36), and 1-249 yen (11). It should be noted that there are 33 residents responded that their WTPs is zero. After checking their reasons, those are considered as “non-response,” and their replies are omitted from the analysis.

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TABLE X. DISTRIBUTION OF REPLIED WTP

| WTP (JPY) | 3,000> | 2,500-2,999 | 2,000-2,499 | 1,500-1,999 |
|---|---|---|---|---|
| Number | 5 | 5 | 5 | 10 |
| WTP (JPY) | 1,000-1,499 | 500-999 | 250～499 | 1～249 |
| Number | 18 | 30 | 36 | 11 |

### C. Estimation of demand function and WTP

Based on the above WTP of each respondent, the demand function of the e-ambulance service is estimated; more precisely, the probability of acceptance to amounts questioned is estimated and the number of residents who will agree to pay. The functional form of demand to be estimated is assumed to be logistic, namely,

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

The probability of acceptance is the ratio of the residents 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 XI. The average WTP is calculated as the area under this demand function, which results in being 1,747 yen (approximately US$175) per resident per year. The mean value For WTP, which is the amount that the probability of acceptance is 50%, is estimated at 1,379.45 yen. This paper uses the average value as WTP in the analysis in what follows.

TABLE XI. RESULTS OF ESTIMATION

| | Coefficients | S.D. | t-value | p-value | |
|---|---|---|---|---|---|
| $\alpha$ | 18.765 | 1.276 | 14.711 | 0.000 | *** |
| $\beta$ | 2.596 | 0.175 | 14.854 | 0.000 | *** |

Log likelihood function: -475.7578

## IV. COST BENEFIT ANALYSIS

### A. Total benefits

In the Cost/Benefit Analysis, total benefits and costs are compared over the period of several years. In this paper, two kinds of the time span are used: one is three years, which is the same as the project period, while that of five year is also considered, which is usual period of public projects like e-ambulance. WTP obtained above is for per resident per year, and it is multiplied by total number of residents, since all residents have a chance to use ambulance. The population of each city is 18,657 in Aki City and 17,490 in Muroto City as of January 1, 2014, and thus total population is 36,147. Since all residents have possibility of using ambulance, even if they are babies or 100 years old, the numbers of residents who receive benefit are total of two cities, we multiply WTP 1,747 yen by population of 36,147, which ends up with 63,148,089 (US$631,000). That is, one-year benefits of e-ambulance services total approximately 63,148,809 yen (US$631,000). In order to obtain three and five years' worth of benefits, the present values of three or five years' benefits are calculated with a 4% discount rate, and we assume that population of two cities remains at the level for six years. This results in three (five) years' benefits totaling 175,243,694 yen (281,127,278 yen)

### B. Total costs

The total cost of the system consists of two major categories; initial fixed and annual operating costs. The former is the items which have to pay at the first year of the project and covers that (i) ICT hardware equipment of the systems of transmitting and receiving images and related equipment, (ii) ambulance, (iii) costs related to software development and the purchase of software, (iv) installment, and (v) initial training cost. The latter, on the other hand, the latter is required annually and contains the followings: (vi) salary of ambulance crew; (vii) maintenance fees which consist of those related to hardware and software; (viii) gasoline mainly for ambulance; and (ix) communications charges for the wireless and wired devices. These cost items are summarized in TABLE XII for the annual basis.

TABLE XII. COSTS OF THE E-AMBULANCE PROJECT

| C. **Total Cost** (single year) | | JPY |
|---|---|---|
| **1. Initial cost** | | |
| Hardware (equipment) | | |
| | 1-A Equipment | 8,144,662 |
| Ambulance | | |
| | 1-B Ambulance | 36,000,000 |
| Software | | |
| | 1-C Software development | 19,341,000 |
| | 1-D Software | 4,114,803 |
| Installment | | |
| | 1-E Installment cost | 2,706,784 |
| Training | | |
| | 1-F Initial training | 1,680,000 |
| | subtotal | 71,987,249 |
| **2. Operational Cost** | | |
| Salary | | |
| | 2-A Salary of ambulance crew | 50,572,080 |
| Maintenance | | |
| | 2-B Software maintenance | 893,928 |
| | 2-C Hardware maintenance | 654,360 |
| Fuel | | |
| | 2-D Gasoline | 2,400,000 |
| Communication | | |
| | 2-E Communication fees | 1,200,000 |
| | subtotal | 55,720,368 |
| | Total | 127,707,617 |

In order to obtain total costs of three (five) year period, operational annual costs must be discounted at a 4% discount rate. As a result, the costs of salary in three (five) years are 140,342,126 yen (225,137,915 yen), respectively, while those of miscellaneous expense including maintenance,

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gasoline and communications are 9,990,328 yen (16,026,560 yen). Thus, total operating costs for three (five) years are 150,332,453 yen (241,164,475 yen), respectively.

### C. B/C ratio

From the above calculation, benefits total 175,243,694 yen (US$1,752,436) over the period of three years and 281,127,278 yen (US$2,811,272) over the period of five years, whereas costs total 381,792,228 yen (US$3,817,922) over the period of three years and 472,624,250 yen (US$4,726,242) over the period of five years. On the other hand, total costs amount to 381,792,228 yen (US$3,817,922) for three years and 472,624,250 (US$4,726,242) yen for five years. Therefore, the B/C ratio over the period of three years is 0.459 (see TABLE XIII), while 0.595 over the period of five years, that is, benefits are about half of costs for three year project, and about 60% for five year project (see TABLE XIV). It can be concluded that benefits are far smaller than costs.

Here the viewpoint is changed, that from the view of local governments which implementing the project, that is, Aki and Muroto Cities, they only bear the costs of operating costs, since initial costs are borne by subsidies from the central government, and they can bear only cost of operating costs. The B/C ratio calculated in this way is 1.166 over the both of periods indicating that for two local governments, benefits exceed its costs. Thus from the view of city, this project is favorable, and worthy to implement.

TABLE XIII. COST/BENEFIT: 3 YEARS

| | JPY |
|---|---|
| Total benefit B3 | 175,243,694 |
| Initial cist IC3 | 231,459,775 |
| Operating cost OC3 | 150,332,453 |
| Total Cost TC3 | 381,792,228 |
| B3/TC3 | 0.459 |
| B3/OC3 | 1.166 |

TABLE XIV. COST/BENEFIT: 5 YEARS

| | JPY |
|---|---|
| Total benefit B5 | 281,127,278 |
| Initial cist IC5 | 231,459,775 |
| Operating cost OC5 | 241,164,475 |
| Total Cost TC5 | 472,624,250 |
| B5/TC5 | 0.595 |
| B5/OC5 | 1.166 |

### D. Comparison with other e-Health projects

There is no economic evaluation of e-ambulance, but the results can be compared with other e-Health projects which are implementation of telecare. Telecare transmits health-related data of its users such as blood pressure, ECG, and blood oxygen to a remote medical institution via a telecommunications network. The system is equipped with a simple device which, when used continuously, records the condition of the elderly or a patient's illness in graphs, which are then used for diagnosis and consultation. Reports sent by the medical institution are also helpful for users to enhance their daily health consciousness and make an effort to maintain good health. Such positive effects have been identified through field surveys.

Tsuji et al. [14] applied the Cost/Benefit Analysis to the telehealth systems in the following four regions in Japan: Kamaishi City, Iwate Prefecture; Nishiaizu Town and Katsurao Village, Fukushima Prefecture; and Sangawa Town, Kagawa Prefecture. Benefits are expressed in terms of WTP based on CVM, whereas the costs are calculated as the sum of equipment, salaries of doctors and nurses, and other operations. Then, the benefits and costs are compared in terms of the B/C ratio, and the results obtained are shown in TABLE XV. Since the users receive and perceive benefit from telecare by using every day, while benefits of e-ambulance are less noticed by residents, WTP of e-ambulance tends to be larger than e-ambulance.

TABLE XV. COSTS AND BENEFITS OF TELECARE BY CVM
Unit: JPY

| | Kamaishi | Nishiaizu |
|---|---|---|
| Number of devices | 211 | 400 |
| WTP | 4,519 | 3,177 |
| Equipment | 39.9* | 136.7* |
| Salaries | 8.6* | 3.7* |
| Others | 1.9* | 1.9* |
| Total costs (6 years) | 95.5* | 184.5* |
| B/C | 1.07 | 0.58 |
| (B/C)** | 1.87 | 2.31 |
| | Katsurao | Sangawa |
| Number of devices | 325 | 225 |
| WTP | 1,640 | 2,955 |
| Equipment | 111.4* | 133.5* |
| Salaries | 3.36* | 4.5* |
| Others | 10.4* | 3.0* |
| Total costs (6 years) | 184.2* | 174.3* |
| B/C | 0.54 | 0.61 |
| (B/C)** | 1.42 | 2.60 |

Note 1: * indicates million yen
Note 2: (B/C)** indicates Benefit/Operating cost
Source: [14]

Thus the B/C ratios obtained for e-ambulance are similar to those of telecare, which were operated by local governments and received subsides for initial equipment from the central government. As a project, they are less than 1, that is, benefits are smaller than costs, while for local governments it is worthy to implement since benefits to the users are larger than costs which were borne by local governments. From the view of local governments which implementing the project, that is, Aki and Muroto Cities, they only bear the costs of operating costs, since initial costs are borne by subsidies from the central government, and they can bear only cost of operating costs. The B/C ratio calculated in this way is 1.166

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over the both of periods indicating that for two local governments, benefits exceed its costs. Thus from the view of city, this project is favorable, and worthy to implement.

## V. CONCLUSIONS

In this paper, WTP in Aki and Kuroto Cities and Ino Town is estimated by CVM and WTP obtained is 1,747 yen. According to our rigorous analysis, we found that this value is not different from the ex-post WTPs estimated in our previous research. The effects of the e-ambulance in Aki and Muroto Cities are also similar to realized ones in the other regions. These results indicate that WTP can be an indicator of potential effectiveness of regional health policy implemented by local governments.

So far, we have conducted surveys of four local governments as shown in TABLE XV. 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 also has a much higher ratio than the other local governments. This is due to charges, not free like other region, their efforts to promote usage such as a users' association which organizes events to enhance consciousness towards health, and the participation by medical doctors in this system, which increases the users' reliance on the system. It is clear from our previous studies that telecare is useful for consultation and maintaining the good health of the elderly and patients suffering from chronic diseases who are in stable condition, but it is not for curing disease. It therefore has a psychological effect 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.

On the other hand, benefits of e-ambulance are hardly perceived by residents, except transported by ambulance. But the residents feel wellness because of e-ambulance, since in case of acute diseases they would be treated better than the situation without it. These benefits are less perceived and it is difficult to measure. CVM seems to be the only suitable method to measure benefits.

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