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The impacts of smart cards on hospital information systems—An investigation of the first phase of the national health insurance smart card project in Taiwan

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KEYWORDS
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Summary
Purpose: To investigate the impacts of the first phase of Taiwan's Bureau of National Health Insurance (TBNHI) smart card project on existing hospital information systems.
Setting: TBNHI has launched a nationwide project for replacement of its paper-based health insurance cards by smart cards (or NHI-IC cards) since November 1999. The NHI-IC cards have been used since 1 July 2003, and they have fully replaced the paper-based cards since 1 January 2004. Hospitals must support the cards in order to provide medical services for insured patients.
Methods: We made a comprehensive study of the current phase of the NHI-IC card system, and conducted a questionnaire survey (from 1 October to 30 November, 2003) to investigate the impacts of NHI-IC cards on the existing hospital information systems. A questionnaire was distributed by mail to 479 hospitals, including 23 medical centers, 71 regional hospitals, and 355 district hospitals. The returned questionnaires were also collected by prepaid mail.
Results: The questionnaire return rates of the medical centers, regional hospitals and district hospitals were 39.1, 29.6 and 20.9%, respectively. In phase 1 of the project, the average number of card readers purchased per medical center, regional hospital, and district hospital were 202, 45 and 10, respectively. The average person-days for the enhancement of existing information systems of a medical center, regional hospital and district hospital were 175, 74 and 58, respectively. Three months after using the NHI-IC cards most hospitals (60.6%) experienced prolonged

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service time for their patients due to more interruptions caused mainly by: (1) impairment of the NHI-IC cards (31.2%), (2) failure in authentication of the SAMs (17.0%), (3) malfunction in card readers (15.3%) and (4) problems with interfaces between the card readers and hospital information systems (15.8%). The overall hospital satisfaction on the 5-point Likert scale was 2.86. Although most hospitals were OK with the project, there was about 22% dissatisfied and strongly dissatisfied, that is twice as many hospitals with satisfied (about 10%).

Conclusions: Our recommendations for those who are planning to implement similar projects are: (1) provide public-awareness programs or campaigns across the country for elucidating the smart card policy and educate the public on the proper usage and storage of the cards, (2) improve the quality of the NHI-IC cards, (3) conduct comprehensive tests in software and hardware components associated with NHI-IC cards before operating the systems and (4) perform further investigations in authentication approaches and develop tools that can quickly identify where and what the problems are.

1. Introduction

A smart card is a credit-card sized plastic card with an embedded computer chip that can be memory or also include a microprocessor [1,2]. A microprocessor chip can add, delete and otherwise manipulate information in its memory and hence offer complex data security schemes [3—6]. Smart cards have been in use as health cards for more than 10 years [7—11]. Several large-scale projects have demonstrated the practical use of smart cards in healthcare in Europe such as The Health Coverage's (Mutualités Belges) Social Identity System (SIS) cards in Belgium, versicherten-karte (Insurance cards) in Germany, carte vitale (vitale card) in France, health insurance cards in Slovenia [12], and so on. The European council of Barcelona of March 2002 decided to launch an European health insurance card on 1 June 2004. The card will replace all the current paper forms needed for health treatment in European union (EU) member state by 31 December 2005 [13,14].

Taiwan's bureau of national health insurance (TBNHI) has implemented National health insurance (NHI) program since 1 March 1995. All people in Taiwan must be enrolled in the NHI program. Based on the results of a survey on NHI program in terms of adequacy and accessibility of medical care, 75% of the insured persons were satisfied with the program [15]. However, in order to provide better quality of services and to improve the effective use of medical resources, TBNHI therefore launched a project for implementing smart cards as the health insurance cards since November 1999. The smart cards, known as ''NHI-IC'' cards in Taiwan, allow patients to access medical services electronically, and carry a certain amount of critical patient information. Because of its electronic nature, the NHI-IC cards also allow TBNHI to timely discover the inappropriate use of medical resources and to investigate medical frauds.

The NHI-IC cards have been used since 1 July 2003, and they have fully replaced the paper-based cards since 1 January 2004. Currently more than 22 millions NHI-IC cards have been issued, and more than 17,000 hospitals, primary care providers and health care institutions are involved in this project. Incorporation of NHI-IC cards into hospital medical services demands both information technology and financial support for building up the information infrastructure and enhancing the existing hospital information systems.

In this paper, we will describe the current status of the project, the NHI-IC card system, and present the results of a questionnaire survey investigating the impact of the cards on hospital information systems. These results reveal the problems and potential issues that might be useful for those who are planning to implement similar projects.

2. The NHI-IC card system

The NHI-IC card system consists of the following major components: NHI-IC cards, the card readers for manipulation of the NHI-IC cards, the hospital information systems that controls the operations of the card readers and the communication networks that make the entire system work properly for medical services.

2.1. NHI-IC cards

Similar to a bank IC card, a NHI-IC card has an IC chip consisting of a CPU and 32 KB (10^3 bytes) of mem-

ory. The visible information on the NHI-IC card contains the cardholder's name, identification number, date of birth, photo (optional), and the card serial number (an unique number assigned to each NHI-IC card). The content inside a NHI-IC card can be divided into four segments: basic data, health insurance data, medical data and public health administration data [16].

The basic data segment stores the identification information for both the cardholder and the card itself. The health insurance data segment is comprised of the cardholder's insurance information and service data for insurance claims. The medical data segment contains 4 KB of memory, and is used to record important physician orders, prescriptions and drug allergies. The public health administration data segment contains 2 KB of memory, and is used for recording personal data pertaining to public health such as vaccination records and organ donation notes.

2.2. NHI-IC card readers

A NHI-IC card can be accessed and manipulated through a card reader. However, for access to sensitive data the cardholder's password may be required. The card reader can read/write the data from/into the NHI-IC card in accordance with the operations initiated by a host computer, which is usually a client of a hospital information system or a standalone computer. The host computer can invoke a set of predefined application programming interfaces (or so-called control software) to operate the reader and to manipulate the data in the NHI-IC cards. The control software is free, and can be downloaded from TBNHI website [17].

Each card reader is equipped with a unique security access module (SAM) distributed by TBNHI. When a card reader is powered on, it must perform an authentication test on its SAM against TBNHI database. Only after successfully passing the test, can the card reader work properly.

2.3. Hospital information systems

A hospital information system in general refers to a computer system that handles the workflows of daily medical services, facilitates the management of financial, administrative and clinical data, and processes healthcare insurance claims. Most hospitals in Taiwan have developed their hospital information systems. The changes to the workflows of medical services due to the introduction of NHI-IC cards will likely affect their information flows, and hence may result in changes to their information systems.

The hospitals are ranked based on their capacity and capability in providing the quality of health care [18]. They are, from the highest to the lowest, medical centers, regional hospitals, district hospitals and primary care clinics. Hospitals with higher rank usually have more sophisticated workflows of medical services, resulting in sophisticated information systems in those hospitals. The hospital information systems in primary care clinics are relatively simple since workflows there are straightforward. Thus, in this study we focused on medical centers, regional hospitals and district hospitals. We use ''hospital'' to refer to those three categories of the hospitals later in this paper.

The hospitals are characterized by the large volume of medical services and extensive use of computers [19]. It is crucial to integrate NHI-IC card readers into their hospital information systems so that the workflows of the medical services can be streamlined and the service time for a patient can be optimized. That is, the data required to be recorded in a NHI-IC card can be collected and made ready for transferral to TBNHI with as little human intervention as possible.

2.4. Interconnection networks

In order to facilitate the operation of the NHI-IC cards, TBNHI has established a NHI-IC card data center (IDC) to manage and maintain the card database and a high bandwidth health insurance service network (HISN) for connecting the card readers and data servers installed in hospitals or healthcare providers nationwide to the IDC. The hospitals must purchase NHI-IC card readers, and establish connections (e.g., leased lines or phone lines) to the IDC as shown in Fig. 1.

2.5. The current status of the NHI-IC project

There are three phases in the implementation of the NHI-IC card project. The information involved in phase 1 includes the basic data segment and the information essential for insurance reimbursement claims in the health insurance data segment. In phase 2, in addition to the information involved in phase 1, the information including the medical data segment would be included. In phase 3 all the information including health insurance data, medical data and public health administration data would be included. The ultimate goal is to record as much patient care information in the NHI-IC card as possible.

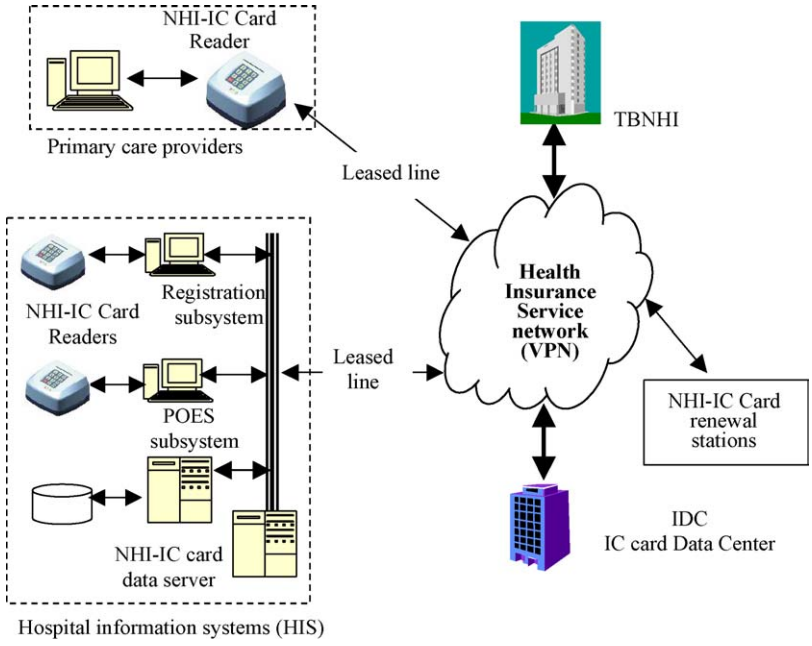

Fig. 1 The framework of the NHI-IC card system.

The current status of the project is in phase 1 now, with data involving identification information and insurance claims information. One of the key information for insurance claims is the service-sequence number, which is stored in each individual card. For each medical service, a healthcare provider must read the number from the card, and then update the number for next use. When the service number reaches a predefined number (now 6, reflecting the six blocks of time stamps in a paper-based card), the patient is responsible for renewal of his/her card at any public service terminal or at a card reader in a hospital.

TBNHI establishes and maintains the HISN network and the NHI-IC card database for hospitals and the public. As indicated above, the healthcare providers who provide medical services for their patients are responsible for updating the service-sequence number into the patients' NHI-IC card and transferring both the number and patient identification information to the IDC within 24 h, so that TBNHI can keep track of every insured's consumption of the medical resources.

A hospital is highly recommended to enhance the existing hospital information systems to support NHI-IC cards to facilitate patient services. However, there is great diversity in hospitals, stemming from the individual hospitals own financial and technical problems in adopting NHI-IC cards to their service workflows.

TBNHI realize that the NHI-IC card project influences not only the medical care providers but also the way ordinary people access medical facilities. Consequently, TBNHI conducted a series of public-awareness programs or seminars nationwide for educating people on the government NHI-IC card policy and explaining how to use the cards. BNHI also created technical teams to provide hospitals (healthcare providers) consultations on NHI-IC card related matters.

3. Methods for evaluating the impacts of NHI-IC cards

There are exceptions not related to NHI-IC cards such as patients seeking medical services without their NHI-IC cards or in case of power outage, which cannot be controlled by hospitals. TBNHI allows a hospital to make reimbursement claims for their medical services for the exceptions. The exception claims can be verified later as needed.

From this perspective, the impacts of NHI-IC cards on the existing hospital information systems can be divided into two components namely,

- the effect of changes to the existing workflow of the medical services, and
- the adoption capability of existing hospital information systems.

The impacts were evaluated by using a questionnaire survey consisting of three parts: the basic information of the hospitals and respondents who

answered the questionnaire, the financial burden of changes to the existing information systems, and the effects of the changes to medical services.

The questionnaire was reviewed by an expert committee. The reliability test, Cronbach's alpha (α) was 0.76. The survey was conducted from 1 October to 30 November 2003. A questionnaire was distributed by mail to all 479 hospitals, including 23 medical centers, 71 regional hospitals, and 355 district hospitals. The returned questionnaires were also collected by prepaid mail.

4. Evaluation results

4.1. Basic data of respondents and their hospitals

One hundred and four hospitals returned their questionnaires: 9 medical centers, 21 regional hospitals and 74 district hospitals. The questionnaire return rates of the medical centers, regional hospitals and district hospitals were 39.1, 29.6 and 20.9%, respectively. The average return rate was 21.7%. The hospital with higher rank was higher than those with lower rank.

The volume of medical services of the responding hospitals, measured by inpatient beds and outpatient visits, is shown in Table 1. The average number of beds for medical centers, regional hospitals and district hospitals were 1187, 560 and 103, respectively, and the average outpatient visit per day was 4950 for medical centers, 1536 for regional hospitals and 466 for district hospitals. The results reflected the fact that the service volume of a medical center is usually greater than a regional hospital, and in turn greater than a district hospital.

The respondents' roles, as shown in Table 2, were largely IT professionals (64.4%), the administration or medical record management professionals (31.5%), and nurses (3.7%). The results show that most hospital top-level managers considered the NHI-IC project mainly related to hospital information systems, and assigned IT professionals or the like to complete the survey questionnaires.

4.2. The financial impacts

The financial burden to enhance the existing hospital information systems is divided into three parts: the number of card readers purchased, the cost of communication bandwidth and the person-days for enhancement of hospital information systems. The total number of card readers purchased by medical centers, regional hospitals and district hospitals were 1817, 947 and 768, respectively, as shown in Table 3. On average a medical center, a regional hospital and a district hospital purchased 202, 45 and 10 card readers, respectively, during phase 1 of the project. It is reasonable that the higher ranked the hospital, the larger the service volume, and thus the more card readers needed.

The bandwidth of the communication lines connecting between a hospital and the IDC usually depends on the amount of data to be transferred and on the cost of communication bandwidth. As shown in Table 4, most hospitals (48.1%) sub-

Table 1 The number of outpatient visits and the number of beds on an average in fiscal year 2002

Hospital category	Number of hospitals	Number of average outpatients/per day	Number of beds
Medical center	9	4950	1187
Regional hospital	21	1536	560
District hospital	74	466	103
Total/average	104	874	289

Table 2 Which of the following best describes your role within your hospital

	Medical centers	Regional hospitals	District hospitals	Total
Physicians	0	0	0	0
Nurses	0	0	4	4 (3.9%)
IT professionals	9	20	38	67 (64.4%)
Administration or medical record professionals	0	1	32	33 (31.7%)
Others	0	0	0	0
Total	9	21	74	104

Table 3 The number of NHI-IC card readers your hospital purchased

	N	Mean	95% confidence interval
Medical center	9	201.89	110.23—293.55
Regional hospital	21	45.10	34.36—55.83
District hospital	74	10.38	6.62—14.14
Total	104	33.96	21.23—46.70

Table 4 What type of communication lines between your hospital and the IDC

	Medical center	Regional hospital	District hospital	Total
512K/64K ADSL	3	3	38	44 (42.3%)
768K/128K ADSL	0	0	0	0 (0.0%)
1.5M/384K ADSL	0	1	2	3 (2.9%)
512K/512K ADSL	4	17	29	50 (48.1%)
T1/E1 leased line	2	0	5	7 (6.7%)
56K dial-up	0	0	0	0 (0.0%)
Total	9	21	74	104

Table 5 The number of person-days took to enhance the information systems of your hospital (*N* = 104)

	Number of hospitals	Total person-days	Average person-days	95% confidence interval
Medical center	9	1579	175	9.95—340.93
Regional hospital	21	1560	74	41.30—107.32
District hospital	74	4295	58	38.33—77.76
Total	104	7434	71.5	51.25—91.72

scribed 512K (downstream rate)/512K (upstream rate) ADSL (asymmetric digital subscriber line) [20,21], and 42.3% subscribed the 512K/64K ADSL, and 6.7% subscribed T1/E1 leased lines [20,21]. There was little relationship between the ranks of hospitals and their leased communication lines because there was little data to be transferred in the phase 1 of the project.

The enhancement of existing information systems was measured in person-days. Table 5 shows that the average person-days for a medical center, regional hospital and district hospital to enhance its hospital information systems were 175, 74 and 58, respectively. The results reflect the complexity of hospital information systems in different rank of hospitals.

4.3. The impact on medical services

The impact on hospital medical services can be identified by observing whether the service time for a patient visit takes longer after inclusion of the NHI-IC cards into the workflows. As shown in Table 6, 60.6% of responding hospitals felt that the time for an outpatient service was prolonged, 34.6% remain unchanged and few (4.8%) became shorter. Thus, for most of hospitals, inclusion of NHI-IC cards into medical services tended to make the service time longer because the workflows become more complicated, and may even cause problems in their hospital information systems.

After inclusion of NHI-IC cards in medical services the problems that resulted in interruptions of the services were shown in Table 7. The major causes of the problems were (1) NHI-IC cards themselves (31.2%), (2) the failures in SAM authentication (17.0%), (3) the malfunctions in interfaces between the hospital information systems and card readers (15.8%), and (4) the failures in card readers (15.3%). It is noteworthy that about 5.6 and 2.9% of the problems were introduced by unfamiliarity with the operations of the NHI-IC card systems and others, respectively.

Most hospitals have been involved in the NHI-IC card project. Overall speaking, so far the hospitals have taken a passive stance to the NHI-IC card project. As indicated in Table 8, no hospital strongly agreed with it, 10.6% agreed and 67.3% had no comment. However, 19.2 and 2.9% disagreed and strongly disagreed with the project, respectively.

Table 6 The time for an outpatient service in your hospital after implementation of NHI-IC cards ($N = 104$)

	The time for an outpatient service in your hospital			Total
	Longer	Shorter	Remain unchanged	
Medical center	7	1	1	9
Regional hospital	11	1	9	21
District hospital	45	3	26	74
Total	63 (60.6%)	5 (4.8%)	36 (34.6%)	104

Table 7 What were the problems that interrupted medical services after inclusion of NHI-IC cards into the services (multiple choices)

	Medical center	Regional hospital	District hospital	Total
Failures in SAM authentication of card readers	8	13	36	57 (17.0%)
Failures in card readers	4	17	30	51 (15.2%)
Malfunctions in interfaces between the HIS and card readers	4	7	42	53 (15.8%)
Failures in hospital networks and host computer	4	7	28	39 (11.6%)
Failures in NHI-IC cards	8	23	74	105 (31.2%)
Unfamiliarity with operations	0	4	17	21 (6.3%)
Others	1	3	6	10 (2.9%)
Total	29	74	233	336 (100.0%)

Table 8 As a whole, from your hospital point of view, you are satisfied with the NHI-IC card project so far ($N = 104$)

	Strongly agree (5)	Agree (4)	OK (3)	Disagree (2)	Strongly disagree (1)	Average score
Medical centers	0	3	4	1	1	3
Regional hospitals	0	1	15	5	0	2.81
Distrcit hospitals	0	7	51	14	2	2.85
Total	0	11 (10.6%)	70 (67.3%)	20 (19.2%)	3(2.9%)	2.86

The results show that the lower ranked the hospital, the stronger the dissatisfaction with the project because their business scale would not allow them to allocate adequate resources to enhance their hospital information systems and reorganized their workflows as well.

5. Discussion

With the capability of portable and highly secured storage, smart cards have played a major role in the area of healthcare. Most of them provide visually readable information and carry identification data. Some may be used as access keys to the relevant databases, while some may carry patient health information for emergency use. Taiwan's NHI-IC cards carry not only identification data but also the data needed for health insurance, medical care and public health administration. Moreover, a healthcare provider is responsible for writing the specified data into a card and transferring the data to TBNHI within 24 h. Therefore, hospitals are likely to face more obstacles in adoption of the NHI-IC cards as an integral part of their hospital information systems.

As indicated in the survey results, 3 months after inclusion of NHI-IC cards into the medical services, most hospitals experienced longer service time due to more interruptions introduced by the problem in the NHI-IC cards themselves, the malfunctions in card readers, authentication of the SAMs and interfaces between the card readers and hospital information systems. It is noteworthy that about 30% of the interruptions were caused by NHI-IC cards. Improvement of the quality of the NHI-IC cards and provision of education on storage and usage of the

cards for the public at the beginning of the project would effectively help reduce the occurrences of the problem.

Another major problem was the failure in the online authentication of card readers. There are too many factors involved in authentication testing such as the HISN networking system, the IDC database system, hospital networking systems and the card readers [22]. The causes cannot be distinguished easily, and hence the problem tends to take longer to fix. Therefore, TBNHI should perform further investigation in alternative authentication approaches, or develop tools that can quickly identify where and what the problems are.

In the beginning of 3 months of the first phase, most problems resulted mainly from ill-designed and incomplete tests in hardware and software components. After TBNHI distributed a new version of the control software, the professionals of the hospitals were familiar with the NHI-IC card system and learned the integration approaches, there have been fewer and fewer such problems reported as the project proceeded. Thus, well-integrated and robust hospital information systems could alleviate the prolonged service time.

Very few hospitals (2.9%) complained about the interruptions to medical services caused by the other problems (not listed in the question), which mainly refer to non-technical problems such as patients seeking medical services without their NHI-IC cards, in case of power outage, and so on. The outcome might be attributed to TBNHI's comprehensive public-awareness programs for the public and healthcare providers before starting use of NHI-IC cards. Likewise, we can reduce or remove 5.6% of problems due to unfamiliarity with the system operations by giving more comprehensive training programs to end users at the very beginning phase.

The success of the project is very much dependent on the cooperation and support from hospitals. The hospitals can hardly get direct benefits from early adoption of NHI-IC cards in the current phase. In addition, they have to invest their money in enhancement of their hospital information systems. As shown in Table 8, although most hospitals were OK with the project, there was about 22% dissatisfied or strongly dissatisfied, that is twice as many hospitals with satisfied (about 10%). The lower rank of a hospital, the less satisfaction with the project it had because its business scale is rather small and would not allow them to invest money in full computerization their medical services in a short time.

Even with the low satisfaction rate, there are two forces driving the NHI-IC card project ahead. Firstly, there is only one health insurance provider in Taiwan. The hospitals must make their information systems compliant with the NHI-IC card requirements in order to get reimbursement for their medical services. Secondly, most people consider the NHI-IC cards as simple and convenient for access to medical services and would expect hospitals provide such a convenience. Thus, although some hospitals disagreed with TBNHI, the NHI-IC card project has been now survived and continues to approach the initially designed goals.

The overall return rate of this questionnaire survey was low, and the hospitals with higher rank had higher return rate. There might be a sample bias. The results may be over estimated. Therefore, the problems revealed here would be less than as they were.

6. Conclusions

From the survey results, very few hospitals complained about the interruptions caused by non-technical problems; instead, the major problems that caused the interruptions of medical services were the impairment of NHI-IC cards and online authentication testing. Therefore, our recommendations for those who are planning to implement similar projects are: (1) provide public-awareness programs or campaigns across the country for elucidating the health smart card policy and educating how people can use and store the cards, (2) improve the quality of the NHI-IC cards, (3) conduct comprehensive tests in software and hardware components associated with NHI-IC card systems before operating the system, and (4) perform further investigations in authentication approaches and develop tools that can quickly identify where and what the problems are.

Although there was not enough direct incentive for hospitals to adopt NHI-IC cards into their medical services, the cards are simple and convenient for the public to access medical services. It is expected that the project will gradually move to phase 2 and phase 3. Hence, more and more patient health information can be stored in the cards as well as in the TBNHIs database. The healthcare providers can take the advantages of the availability of such data to provide better quality of care, while the TBNHI can keep track of the use of medical resources precisely to prevent the potential medical frauds timely.

What was known before the study:

- TBNHI has launched a nationwide project for replacement of its paper-based health insurance cards by NHI-IC cards since November 1999. Hos-

pitals must support the cards in order to provide medical services for insured patients.
- Incorporation of NHI-IC cards into medical services was critical, but little was known of the cost of building up the systems associated with NHI-IC cards and enhancing the existing information systems.
- Little information was attained on the major problems of the NHI-IC card system after it was in operation nationwide, and most of what was attained was indefinite.

What this study has added to the body of knowledge:

- The survey results reveal that the average cost for a hospital to build up the systems associated with NHI-IC cards and to enhance the existing information systems. The cost was proportional to its rank.
- The major problems after the NHI-IC card system was up and running nationwide were (1) impairment of the NHI-IC cards, (2) failure in authentication of the SAMs, (3) malfunction in card readers and (4) problems in interfaces between the card readers and hospital information systems.
- Most hospitals experienced prolonged service time for their patients in 3 months after starting to use the NHI-IC cards.
- We learned from the project, and made recommendations to those who are planning to implement similar projects.

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