

Cost-Benefit Analysis of Electronic Medical Record System at a Tertiary Care Hospital

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Objectives: Although Electronic Medical Record (EMR) systems provide various benefits, there are both advantages and disadvantages regarding its cost-effectiveness. This study analyzed the economic effects of EMR systems using a cost-benefit analysis based on the differential costs of managerial accounting. **Methods:** Samsung Medical Center (SMC) is a general hospital in Korea that developed an EMR system for outpatients from 2006 to 2008. This study measured the total costs and benefits during an 8-year period after EMR adoption. The costs include the system costs of building the EMR and the costs incurred in smoothing its adoption. The benefits included cost reductions after its adoption and additional revenues from both remodeling of paper-chart storage areas and medical transcriptionists' contribution. The measured amounts were discounted by SMC's expected interest rate to calculate the net present value (NPV), benefit-cost ratio (BCR), and discounted payback period (DPP). **Results:** During the analysis period, the cumulative NPV and the BCR were US\$3,617 thousand and 1.23, respectively. The DPP was about 6.18 years. **Conclusions:** Although the adoption of an EMR resulted in overall growth in administrative costs, it is cost-effective since the cumulative NPV was positive. The positive NPV was attributed to both cost reductions and additional revenues. EMR adoption is not so attractive to management in that the DPP is longer than 5 years at 6.18 and the BCR is near 1 at 1.23. However, an EMR is a worthwhile investment, seeing that this study did not include any qualitative benefits and that the paper-chart system was cost-centric.

Keywords: Electronic Medical Record, Cost-Benefit Analysis, Benefit-Cost Ratio, Net Present Value, Payback Period

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I. Introduction

Electronic Medical Record (EMR) systems have numerous benefits, such as improvement in the quality of care, medical error prevention, and reduction of unnecessary care costs. However, one major barrier to the adoption of EMR systems is the cost issue [1-11]. As a result of searching on PubMed, 5 papers related to the economic evaluation of the EMR were identified (Table 1). Wang et al. [5] performed a cost-benefit analysis (CBA) of EMR with a computerized physician order entry system (CPOE). The result was a positive return on investment (ROI), and the benefits were mainly from savings in drug expenditures, radiology tests, billing errors, etc. Barlow et al. [7] assessed the effects of EMR assuming 5 years based on 1 year experience. The maintenance of paper-charts

Table 1. Previous studies on the economic evaluation of EMR systems

Author	System	Description of study	Result
Wang et al. [5]	EMR with CPOE	The cost-benefit analysis for 5 years was based on data from studies at the institution and the published literature. The benefits were from savings in drug expenditures, radiology tests, billing errors and etc. They were compared with the traditional paper-based medical record.	Positive financial ROI
Barlow et al. [7]	EMR	Assumption of 5 years savings was based on 1-year experience. The expenses for transcription of physicians' dictated notes and maintenance of paper-charts were decreased. The reimbursement process was improved after EMR's implementation.	Improvement in revenue
Hillestad et al. [6]	EMR	After the adoption of EMR, the potential safety benefits were based on the secondary data like MEPS 1999 Inpatient File, AHA 2000 Hospital Survey, and HCUP 2000 National Inpatient Sample. The potential savings and costs were based on a broad literature survey.	More than \$81 billion saving annually
Kaushal et al. [8]	CPOE	The published studies of the CPOE system, interviews with experts, and internal documents were used for the analysis. The major cumulative savings were from renal dosing guidance, nursing time utilization, specific drug guidance, and adverse drug event prevention.	Cost savings
Himmelstein et al. [4]	Hospital computing	An annual survey of computerization about 4,000 hospitals from 2003 to 2007 were used for the analysis. Cost and quality data were estimated from Medicare Cost Reports and 2008 Dartmouth Health Atlas.	No reduction of overall costs

These are papers related to "cost-benefit analysis" of "EMR", "CPOE", or "hospital computing" at PubMed Website.

EMR: Electronic Medical Record, CPOE: computerized physician order entry system, ROI: return on investment, MEPS: Medical Expenditure Panel Survey, AHA: American Hospital Association, HCUP: Healthcare Cost and Utilization Project.

decreased and the reimbursement process was improved. Hillestad et al. [6] reported more than \$81 billion in savings annually after the adoption of EMR. The potential savings and costs were based on a broad literature survey. Kaushal et al. [8] analyzed the effects of CPOE systems based on published studies, interviews with experts, and internal documents. The major cumulative savings were from renal dosing guidance, nursing time utilization, specific drug guidance, and adverse drug event prevention. Himmelstein et al. [4] reported no reduction of overall costs in hospital computing after an annual survey of computerization in about 4,000 hospitals from 2003 to 2007.

They demonstrated that the EMR could result in a positive financial ROI [5-8]. However, such financial benefits were reported to be still premature at best, and it would be difficult to realize direct economic benefits, as Himmelstein et al. [4] asserted [8-10].

These conflicting results likely came from hypothetical esti-

mation based on secondary data, such as the Medicare Cost Report, the Medical Expenditure Panel Survey, and other broad surveys [4-8]. Therefore, there are some limitations to reflect economic benefits in real-life clinical practice. Therefore, there is a real need for further analysis to determine whether EMR is financially cost-effective in real-life clinical settings.

II. Methods

This study analyzed the economic effects of an EMR system using a CBA, based on differential costs of managerial accounting. In this paper, we excluded any qualitative factors, such as improvements to patient safety. These factors are much more important issues in healthcare service, but are not easily converted into monetary values. This study focused on using tangible items which can be measured in managerial accounting. In conclusion, this study discussed

cost shifting after EMR adoption at a tertiary hospital and its implications.

1. Study Site

Samsung Medical Center (SMC), founded on November 9th, 1994, is an academic nonprofit tertiary hospital, with 2,000 beds and about 6,500 staff, including over 1,300 doctors and 2,000 nurses. In 2013, more than 8,500 outpatients visited SMC per day.

This study defines the EMR system as a system that allows physicians to generate patient records during outpatient encounters and to maintain them. Implementation of the EMR system for inpatient care started in 2001 and was completed in 2003. Paper-charts were completely removed from the wards during this process. The SMC began the development of an EMR system for outpatients in January 2006. Hospital-wide adoption was completed at the end of 2008 [11] (Figure 1). Even though the EMR system for inpatients is interfaced to EMR system for outpatients, the costs for developing the system and the benefits were completely independent; paper-charts were separately managed at the time of implementation, and the systems were too dissimilar. Thus, this study only considered costs and benefits of the EMR system for outpatients.

2. Cost-Benefit Analysis

In this study a CBA based on cash flows of SMC was carried out. The detailed items of costs and benefits were determined based on differential costing, which is mainly used for decision making in managerial accounting, after comparison of workflows between the paper-chart system and the EMR system [12] (Table 2). This was a conservative CBA in that this study excluded any potential or qualitative benefits [2,3,8,10]. The financial costs and benefits were obtained primarily through the SMC accounting records. The costs of EMR im-

plementation were the actual measured value. However, the benefits were calculated by using the difference between actual measured values and expected values without the EMR system. Therefore, when data were not available, capital amounts were determined by the opinions of experts, such as medical record administrators, care floor nurses, and IT engineers. The measured amounts were converted to present values (PV) using SMC's expected interest rate. Then, the net present value (NPV), the benefit-cost ratio (BCR), and the discounted payback period (DPP) were calculated.

The period was set to 8 years, 2006 to 2013, rather than the 5- or 10-year periods considered in previous studies [4,5,7]. The 8 years were divided into 2 subgroups: the first 3 years for the partial implementation of EMR and the second 5 years during which the EMR system was fully operational.

1) Costs

The newly implemented EMR system created additional costs that were not incurred with the paper-chart system. There are 2 cost categories: the system costs and the induced costs [5,10,13]. The system costs include the direct costs to build the system infrastructure, to develop the EMR applications, and to purchase office supplies [5,13]. The induced costs were required to smooth the EMR adoption. The first cost was to scan the existing paper-charts into the EMR system. The second cost was to provide assistance to doctors through medical transcriptionists (MTs). MTs are typists who enter medical records into the EMR system instead of the physicians at the point of care.

2) Benefits

The benefits include cost reductions and additional revenues. The cost reductions originated from cost savings due to elimination of the paper-chart system. There were 5 types of cost reductions: 1) the reduction of supplies for paper-charts, 2) the disposal of storage facilities, 3) the reduction of full-time equivalent (FTE) employees for paper-chart management, 4) laying off of clerks from the outpatient clinic setting, and 5) the reduction of supplies for medical devices [5-7,11]. These cost reductions fundamentally come from elimination of the paper-chart system operation costs. These operation costs were reduced or eliminated after adoption of the EMR system. This study estimated the reduced amounts based on SMC's accounting practices of 2006. The cost reductions were influenced by the number of daily outpatients, yearly new outpatients and interfaced medical devices. To ensure greater financial accuracy, the benefit was adjusted using the consumer price index (CPI), rental expense, and personnel expenses.

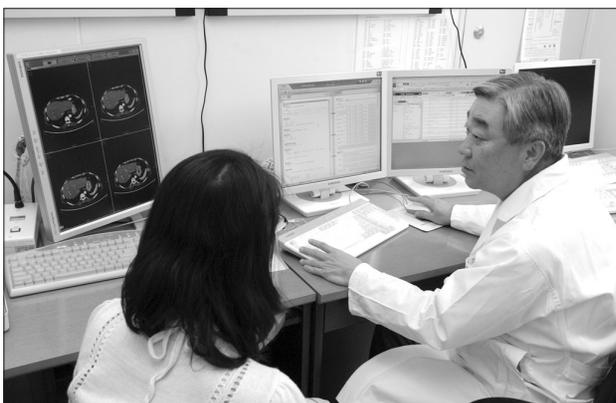


Figure 1. An outpatient encounter in the clinic room.

Table 2. Costs and benefits based on the differential costs

Item	Paper-chart system	EMR system
Cost		
System cost (A)		
System infrastructure (a1)	Not applicable	The managing costs of the system infrastructure such as SW and HW; the purchase and maintenance costs
System applications (a2)	Not applicable	The managing costs of the EMR viewer and the MDIS; the development and maintenance costs
Office supplies (a3)	Not applicable	The managing costs of office supplies, such as PC, monitors, printers, scanners; the purchase and maintenance costs
Induced cost (B)		
Paper-chart scan (b1)	Not applicable	The costs of scanning existing paper-charts into the EMR
MTs support (b2)	Not applicable	The managing costs of the MTs who enter the medical records into the EMR system instead of physicians at the point of care
Benefit		
Cost reduction (C)		
Supplies for paper-chart (c1)	The costs of supplies; chart holders, labels, cover papers, inner papers, gloves, and etc.	The reduced costs of supplies for paper-charts. The amounts were regressed by the number of daily outpatients. Both the transport costs from hospital to outside storage and the purchasing cost for chart cabinets and carousels were saved.
Chart storage space (c2)	The rental costs of the outside storage	The reduced rental costs of chart storage. The saved storage space was also regressed by the number of new outpatients.
Chart management FTE (c3)	The personnel costs of delivering the paper-charts to the clinic rooms	The reduced costs of paper-chart management FTE. The saved numbers of FTEs were estimated by regression analysis with the number of daily outpatients.
Clerks decreased (c4)	The personnel costs of dispensing and collecting the charts to the clinic rooms	The reduced costs of clerks in the outpatient clinic setting. The EMR system decreased the workload of clerks. Some clerks were laid off.
Supplies for MDIS (c5)	The costs of supplies for medical devices; A4-size paper, photographic paper, roll-paper, etc.	The reduced costs of supplies for medical devices. The amounts of supplies' consumption were estimated by regression analysis with the number of the interfaced medical devices.
Additional revenue (D)		
From remodeled storage (d1)	The space used to store the paper-charts was remodeled to clinic rooms for outpatients.	The transformation of storage space has generated incremental revenue. The revenues were calculated by multiplying the number of outpatients examined at the remodeled clinic rooms with both the yearly revenue per room and the contribution of the space to revenue.
From temporary storage (d2)	The charts were temporarily kept in some clinic rooms, before being dispensed to physicians	Five rooms were converted into clinic rooms to examine outpatients. Additional revenues were also generated from these temporary storage spaces in clinic rooms.
From MT support (d3)	Not applicable	More patients were examined since the MTs improve care flow at the outpatient encounter. As a result, additional revenues were also generated from the MTs.

C (cost reduction) is the operating costs of the paper-chart system, based on differential costs. However, after EMR adoption, the saved amounts are the benefits. A (system cost) is basically required to move the simple EMR system from the paper-chart system. However, B (induced costs) is also required to smooth the process of EMR adoption since there is some resistance. D (additional revenue) may be generated by EMR adoption.

SW: software, HW: hardware, EMR: Electronic Medical Record, MDIS: medical device interface system, PC: personal computers, MT: medical transcriptionist, FTE: full-time equivalent.

Table 3. The result of cost-benefit analysis (Unit: 1,000 US\$)

Item	2006 (0)	2007 (1)	2008 (2)	2009 (3)	2010 (4)	2011 (5)	2012 (6)	2013 (7)	Total
Cost									
System costs									
System infrastructure	1,241	-	-	-	98	93	88	84	1,604 (10.0)
System application	1,006	1,274	315	192	188	184	179	174	3,512 (21.9)
Office supply	306	286	-	105	102	98	95	91	1,084 (6.7)
Sub-total	2,554	1,560	315	296	388	375	363	348	6,199 (38.6)
Induced costs									
Paper-charts scan	-	-	724	519	-	-	-	-	1,243 (7.7)
MTs support	166	1,186	1,107	1,118	1,185	1,313	1,255	1,281	8,612 (53.6)
Sub-total	166	1,186	1,831	1,636	1,185	1,313	1,255	1,281	9,854 (61.4)
Total PV of annual costs	2,720	2,746	2,146	1,934	1,573	1,687	1,618	1,630	16,054 (100.0)
Benefit									
Cost reductions									
Supplies for paper-charts	11	52	258	100	248	91	231	3	1,076 (5.5)
Chart storage space	-	-	14	145	142	139	135	129	703 (3.6)
Chart management FTE	-	-	180	782	799	847	816	807	4,231 (21.5)
Clerks decreased	-	-	165	165	165	165	165	164	990 (5.0)
Supplies for MDIS	7	67	78	415	168	165	161	155	944 (4.8)
Sub-total	18	120	695	1,335	1,522	1,408	1,507	1,339	7,945 (40.4)
Additional revenues									
From remodeling storage	-	-	-	17	26	35	25	21	125 (0.6)
From temporary storage	-	-	261	300	280	275	269	262	1,646 (8.4)
From MT support	-	-	551	1,411	1,421	2,747	1,928	1,899	9,956 (50.6)
Sub-total	-	-	811	1,728	1,727	3,056	2,223	2,182	11,727 (59.6)
Total PV of annual benefits	18	120	1,506	3,063	3,249	4,465	3,731	3,521	19,672 (100.0)
Accumulated NPV	(2,702)	(5,329)	(5,969)	(4,839)	(3,163)	(385)	1,726	3,617	
Benefit-cost ratio									1.23
Discounted payback period									6.18

MT: medical transcriptionist, PV: present value, FTE: full-time equivalent, MDIS: medical device interface system, NPV: net present value.

*Applied for the currency exchange rates: 1US\$ = 1,100K.

Additional revenues were generated from both remodeling of paper-chart storage rooms and the MTs' contribution. This study analyzed the number of outpatients examined in the remodeled clinic rooms. The incremental revenues were calculated by multiplying those numbers with both the yearly revenue per room and the contribution of the space to revenue. To calculate benefits of the MT support, we compared the average number of outpatients per examination session before and after EMR adoption. The differences were used to assess the additional revenue due to the MT support.

3) Present value and discount rate

All costs and benefits were converted to 2006, US currency

(US\$). The SMC's expected interest rate was calculated by adding the certificate of deposit (CD) rate to 1.7%. The CD class is non-guaranteed corporate, the time to maturity is 3 months, and the credit rating is A+ [14,15]. If the CD rate is 3.5%, the interest rate will be 5.2%. The starting point for analysis was set from 2006, when the SMC started the development of the EMR system. The PV is a financial amount discounted by the yearly interest rate on an accrued basis.

4) Outcomes of analysis

The primary outcome is the cumulative NPV which subtracts the PV of cost from the PV of benefit for the eight-year period. The second outcome is the BCR, which is the PV of

the benefit divided by the PV of the cost. The third outcome is the DPP, meaning the time to reach the breakeven point.

5) Case analysis

The SMC's expected payback period is 5-year. The SMC invested in a paper-chart scanning system to scan existing paper-charts to improve user convenience. It also provided MT assistance to alleviate the doctors' resistance to change. The combination of these conditions could facilitate another 3 case analyses.

III. Results

This study scrutinized the factors affecting both costs and benefits in order to calculate their financial value. These factors include outpatient numbers, rental fees, personnel expenses, CPI, CD rate, and the revenue per patient. Data from 2006 to 2012 were mainly obtained from SMC's accounting records, whereas data for 2013 were based on the SMC's management planning. The results are summarized in Table 3.

1. Costs

As described in the Methods section, costs were divided into 2 categories; the system costs and the induced costs. Among the system costs, the purchase cost of the system infrastructure in 2006 was US\$1,241 thousand with a 5-year warranty included. Maintenance costs have been incurred since 2010. The development costs of the EMR viewer and the medical device interface system (MDIS) were US\$1,006 thousand in 2006, US\$1,274 thousand in 2007, and US\$315 thousand in 2008. Maintenance costs for these applications have been incurred since 2009, and increased by 5.5% every year under Korean government guidelines. Office supplies, such as PCs, monitors, printers, etc., were purchased and the financial costs were US\$306 thousand in 2006 and US\$286 thousand in 2007. Maintaining these items costs 10% of the initial investment after the 1-year free warranty. Among the induced costs, the cost of investing in the existing paper-chart scanning system was US\$724 thousand in 2008 and US\$519 thousand in 2009. The personnel costs for MT support also have been incurred since September 2006. The cost for MT support was US\$166 thousand in 2006. The PV of all accrued costs was US\$16,054 thousand.

2. Benefits

To assess the benefits of cost reduction, we measured the supply consumption of September 2008 and compared it to the equivalent figures for 2006 and 2007. The supplies included paper-chart holders, labels, A4-size paper, gloves, etc., which were used to build and maintain the paper-charts. As

a result, about 1.3 million pieces of A4-size paper were saved in 2008. The transportation cost of the paper-charts to the outside storage facilities and the building costs related to the automated cabinets and carousel facility were also saved. The PV of the supply savings was US\$1,076 thousand.

Scanning existing paper-charts helped to eliminate 495 m² of indoor storage and 627 m² of outside warehouse space. According to our analysis, about 1 m² was needed to store the paper-charts of about 910 new outpatients, and an additional 150 m² per year were needed. Thus, the rental fees for the storage space were converted into a financial benefit. The PV saved from storage was US\$703 thousand.

The paper-chart management FTEs built, delivered, and collected the paper-charts. After adoption of the EMR system, the number of the FTEs was greatly decreased from 28 in 2007 to 1 in 2009, whereas the number of outpatients per day significantly increased. The actual decrease in 2009 was 27. However, this study applied 32 FTEs since this study had to consider the growth of outpatients, which would have affected the number of the paper-charts to be delivered. The figure for the 32 FTEs was not recorded in the accounting records, but it was a conservative estimate from the chief of the department of medical records, who had vast experience in administration of the paper-charts. She expressed that the number depended only on the linear relationship to the growth of outpatients, but it did not consider the expansion of the buildings and the distance between them. There were only 7 actual reduced FTEs in 2008, but it was estimated that up to 36 FTEs would have been reduced in 2013. The only job left is to scan the signed consent forms into the EMR system. The PV of the FTE reduction was US\$4,231 thousand.

Registered nurses in charge of the outpatient care floors showed that there were also 11 clerks fully dedicated to the management of the paper-charts, and they were laid off after the EMR adoption. It was very difficult to calculate the number of clerks on the outpatient care floors because the management of paper-charts on the floor was usually shared by all of the clerks. The registered nurses expressed that there were about 20 separate outpatient care areas, but only 11 clerks were moved to another department or did not have their contracts renewed. It is also conservative in that it did not consider the expansion of a building with about 10 outpatient care floors. The PV from the decreased clerk FTEs was US\$990 thousand.

In 2009, the number of medical devices interfaced with the EMR system through the MDIS was 352. The MDIS has saved supplies for medical devices such as A4-size paper, photographic paper, and roll-paper. The reduced cost for only 126 devices in 2006 was US\$7 thousand. The yearly cost

Table 4. The results of the case analyses (Unit: 1,000 US\$)

	This study	Case 1	Case 2	Case 3
Move from paper-chart to EMR	Applied	Applied	Applied	Applied
The existing paper-chart scan	Applied	Not applied	Applied	Not applied
MT support	Applied	Not applied	Not applied	Applied
Cumulative NPV				
8-yr	3,617	3,573	2,273	4,735
5-yr	(3,163)	(585)	(1,784)	(1,964)
Benefit-cost ratio (8-yr)	1.23	1.55	1.31	1.32
Discounted payback period (8-yr)	6.18	5.45	6.31	5.72

EMR: Electronic Medical Record, MT: medical transcriptionist, NPV: net present value.

*Applied for the currency exchange rates: 1US\$ = 1,100K.

reductions were proportional to the number of interfaced devices. The PV of the savings was US\$944 thousand.

Among the benefits, additional revenues have been recognized from the paper-chart storage areas. The indoor storage was remodeled into clinic rooms for outpatient examinations. The revenue from this clinic was US\$17 thousand in 2009, considering the contribution (4.15%) of the remodeled space to the revenue. The PV of the generated revenue was US\$125 thousand.

After adoption of the EMR system, 5 paper-chart temporary storage rooms on the outpatient care floors were also converted to clinic rooms. In this case, the contribution of the remodeled space to revenue was 4.02%. The PV from the clinic rooms was US\$1,646 thousand.

This study also found that the MT assistance also contributed to the growth of the number of outpatients per examination session. The contribution degree is counted as 25% of the growth; about 1.2 outpatients per the session they attended. The PV of additional revenue from the MT contribution was US\$9,956 thousand. The total PV of all accrued benefits was US\$19,672 thousand.

During the analysis period, the cumulative NPV and the BCR were US\$3,617 thousand and 1.23, respectively. The DPP was about 6.18 years (Table 3).

Total personnel costs for MT support were US\$8,612 thousand which was 53.6% of total accrued costs (US\$16,054 thousand). The direct costs for the EMR applications and the system infrastructure were 21.9% and 10.0%, respectively. These 3 items covered 85.5% of the total costs.

Among benefits, additional revenue from MT support was also the largest at 50.6% of the total accrued benefits (US\$19,672 thousand). The reduction of chart management FTEs contributed 21.5% to the benefits. The additional revenues incurred from remodeling of paper-chart storage areas

accounted for 9.0% of the benefits. These 3 items also covered 80.5% of the total benefits.

Both the costs and the benefits are largely influenced by the MT support, which was introduced to smooth EMR adoption. Scanning the existing paper-charts and storing them in the EMR system allowed the remodeling of the storage rooms into outpatient examination rooms. The benefits from this remodeling were also a large proportion of the total benefits. Looking at these results, the combination of the MT support and scanning the existing paper-charts could lead to different results. Therefore, this study attempted a case analysis with these 2 items.

3. Case Analysis

The SMC invested in both scanning the existing paper-charts and MT support with the EMR adoption. In other cases, one of these might be excluded or both might be excluded. Thus, 3 additional cases were used for the economic evaluation (Table 4).

If a 5-year analysis period would have been applied, the cumulative NPV would have been under 0. However, the cumulative NPV based on an 8-year analysis is greater than 0. Thus, the EMR system can be financially cost-effective, but only if it is used for at least 4 or 5 years after full implementation.

The most cost-effective choice would have been investing in a simple transition from the paper-charts to the EMR system. Without scanning the existing paper-charts and the MT assistance, the cost would have been much lower. The DPP in this simple transition would have been 5.45 years which is a little shorter than in other scenarios. Even though it would be the best choice among other scenarios, it still does not meet the SMC's expected ROI period.

IV. Discussion

It is a very meaningful economic evaluation in that this study performed a formal CBA using actual cash flows of tangible costs and benefits based on differential costs, which is useful for decision making in managerial accounting, in contrast to previous studies that have been based on potential factors.

As the previous studies mentioned, the biggest barriers to EMR adoption in hospitals are capital investment and high maintenance costs. Unfortunately, this study also revealed the same problem [7-11]. However, there is some comfort in that an analysis based on an 8-year study showed EMR to be financially cost-effective, because the cumulative NPV was greater than 0. Analysis covering a 5-year period after full deployment of the EMR system showed positive cash flow. Compared to other industries, it takes much longer to deploy IT systems in the health care industry. The health care industry also tends to use systems for longer periods of time, usually more than 5 years. The SMC, like other hospitals, still continues to use the EMR system actively, even though the SMC has now been using the EMR system for just over 5 years after full implementation. At that point, the EMR in the SMC became financially cost-effective. It is also true that there are various hard-to-quantify benefits that the EMR system contributes. If future research discovers more detailed benefits, such as the elimination of additional FTEs, the economic justification for the EMR system will be more supported.

One interesting finding is that the overall costs were in-

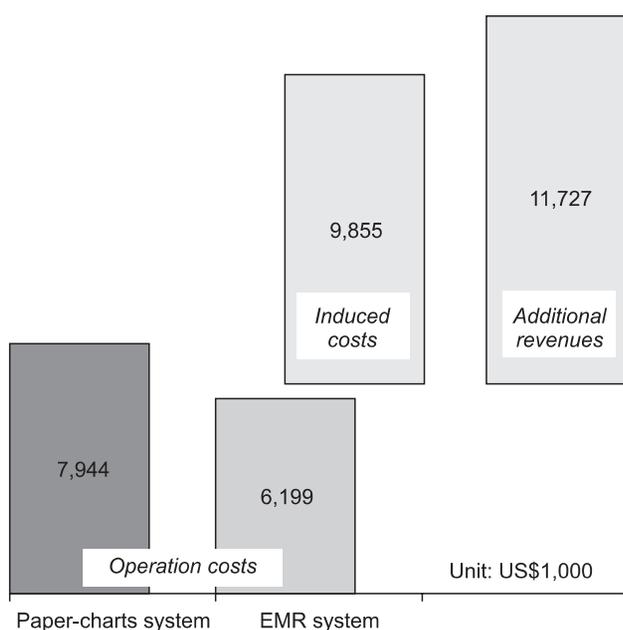


Figure 2. The cost shifting. EMR: Electronic Medical Record.

creased as the IT paradox, since the induced costs were included for a smooth EMR adoption [16]. However, with careful consideration, it was found that the costs for a simple transition from paper-charts to the EMR system decreased (Figure 2). Although induced costs were incurred, the cumulative NPV was positive as they contributed to additional revenues.

Another interesting finding is that the paper-charts management system was cost-centric (Figure 3). Year by year, the maintenance costs for the paper-charts were growing. However, the EMR system created new revenues according to this study based on differential costs. Thus, the adoption of an EMR system is not a matter of choice, but a necessity for management.

As described in the Methods section, the data for 2013 were based on the SMC’s management planning. According to the plan, the estimated number of outpatients per day is 8,368. The actual measured number during the 1st quarter was 8,806. The difference was 438 patients per day, or 5.2% more than planned. This will positively affect the benefits, which are based on the number of outpatients per day. However, there is uncertainty as to whether this positive trend will last for the rest of the year. Thus, this study decided to apply the planned number of outpatients in the analysis.

This is a considerably conservative CBA in that this study did not included any potential benefits, such as the reduction of adverse drug events, as stated by Kaushal and Bates [17]. The benefits are much too great to be ignored. There are many difficulties in measuring values. Sometimes, the accuracy of measurement may generate controversy [4,5,7,10]. It is a limitation that this study does not include such meaningful benefits.

In case of the SMC, the transition time from paper-charts to the EMR took longer than necessary. This helped to re-

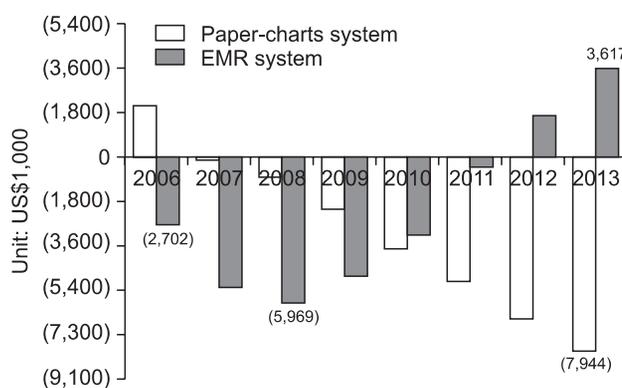


Figure 3. The cash flow of the paper-charts and the Electronic Medical Record (EMR) system.

lieve inconveniences to users and resistance to change from the doctors. It is really arbitrary to set an analysis period in this type of study. Since different results may be found if the analysis period is varied, the results must be interpreted with careful consideration.

Overall, our findings may not always be applicable in all clinical settings since our study was conducted in a single large academic hospital with a rich digital-based infrastructure. In the case of the SMC, all medical devices have been interfaced with the EMR system. All the existing paper-charts were also scanned into the EMR system. To meet user requirements or management strategies requires higher costs. However, it is difficult to say that the EMR system could not be adopted without such convenient services. Therefore, the results may vary with the hospital size, patient volume, and specific IT investment policies.

Although the adoption of an EMR system at a tertiary hospital resulted in overall growth in administrative costs as predicted by Himmelstein et al. [4], EMR adoption was financially cost-effective since the cumulative NPV was positive. The positive NPV, as Wang et al. [5] suggested, was attributed to both cost reduction and additional revenues. EMR adoption is not so attractive to management in that the DPP was longer than 5 years at 6.18, and the BCR is near to 1 at 1.23. However, the EMR is a worthwhile investment, seeing that this study did not include any qualitative effects, and the paper-chart system was cost-centric.

This study was a considerably conservative CBA in that any potential benefits were not considered. To support the economic justification of the EMR, more detailed benefits, such as the elimination of labor hours, which are not recorded on the accounting record, should be examined. Therefore, we recommend that more cases of tangible benefits of EMR should be reported to accelerate its adoption in the future.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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