Financing a Large-Scale Picture Archival and Communication System[1]

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Rationale and Objectives. An attempt to finance a large-scale multi-hospital picture archival and communication system (PACS) solely based on cost savings from current film operations is reported.

Materials and Methods. A modified Request for Proposal described the technical requirements, PACS architecture, and performance targets. The Request for Proposal was complemented by a set of desired financial goals–the main one being the ability to use film savings to pay for the implementation and operation of the PACS.

Results. Financing of the enterprise-wide PACS was completed through an operating lease agreement including all PACS equipment, implementation, service, and support for an 8-year term, much like a complete outsourcing. Equipment refreshes, both hardware and software, are included. Our agreement also linked the management of the digital imaging operation (PACS) and the traditional film printing, shifting the operational risks of continued printing and costs related to implementation delays to the PACS vendor. An additional optimization step provided the elimination of the negative film budget variances in the beginning of the project when PACS costs tend to be higher than film and film-related expenses.

Conclusion. An enterprise-wide PACS has been adopted to achieve clinical workflow improvements and cost savings. PACS financing was solely based on film savings, which included the entire digital solution (PACS) and any residual film printing. These goals were achieved with simultaneous elimination of any over-budget scenarios providing a non-negative cash flow in each year of an 8-year term.

Key Words. Financing picture archival and communication system (PACS); film savings; cost savings; operational lease; workflow improvements.

In this work, we attempt to finance a large-scale multi-hospital picture archival and communication system (PACS) solely based on cost savings from current film operations. The task can be complex; one must plan and implement an information technology solution to improve clinical workflow while optimizing the financial aspects of the acquisition and operations. The task is also time-consuming. Many interactions with vendors, consultants, and internal staff may be needed. In our case, we leveraged on health system resources, in particular the expertise provided by the Information Systems, Legal and Finance Departments. These groups provided guidance and strength during business negotiations and contract drafting.

This is not our first time acquiring a large-scale PACS. The Hospital of the University of Pennsylvania (HUP; Philadelphia, PA) has been a pioneer in this field. A long-time developer and supporter of PACS technology (1–21), HUP has operated a PACS since 1991 and it has been filmless within the Department of Radiology for the last 3–4 years. It has operated a Radiology Information System (RIS) since 1979. HUP also represents about 40% of our enterprise-wide radiology workload. Three other hospitals (Pennsylvania Hospital, Phoenixville Hospital, and Presbyterian Medical Center) located within the greater

Acad Radiol 2004; 11:96–102

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doi:10.1016/S1076-6332(03)00544-0

Philadelphia area and five imaging centers in adjacent suburbs make up the Radiology Enterprise of the University of Pennsylvania Health System. Our plans are to expand the current RIS/PACS infrastructure into a fully integrated RIS-driven enterprise-wide PACS.

Our analysis indicated that it is viable to procure the desired PACS infrastructure and to finance it using the cost savings from current (and projected) film-based operations. The solution includes all PACS components (installed equipment) and related day-to-day operations (maintenance, management support, staffing, and training). We contracted this acquisition as an operational expenditure instead of a capital acquisition. An operational lease was crafted providing a non-negative cash flow in each year of an 8-year term. We used future savings (to be) provided by the PACS operation to pay for the digital conversion (from film to PACS) and to offset any initial negative variances in the film budget. The vendor of choice also agreed to take on the risk of continued use of film. The ultimate goal has been set at 80% filmless achievement across the health system. If greater savings are achieved, the upside is returned to the health system as credits. It is estimated that it will take 2 years to fully implement the integrated RIS-PACS solution at the multisite University of Pennsylvania Health System.

MATERIALS AND METHODS

The Picture Archival and Communication System Request for Proposal

The methodology used to evoke vendor response was a modified Request for Proposal (22). The Request for Proposal described our technical requirements. It contained detailed description of the desired PACS architecture and performance targets. The Request for Proposal was complemented by a set of desired financial goals, with the main goal being the ability to use film savings to pay for the implementation and operation of the PACS.

Overall Goals

The main goals of any enterprise-wide PACS are to achieve clinical workflow improvements and cost savings. An enterprise PACS goes beyond the Department of Radiology and serves the entire health system and its multiple clinical departments. It is designed to meet imaging and reporting needs of radiologists, referring physicians, patients, and administrators.

Beyond the clinical goals (many of them discussed in articles in this issue and other peer-reviewed publications) other objectives of a PACS implementation include: (A) streamlining all distribution and management of images and reports, (B) controlling costs related to film printing and film library activities, (C) elimination of lost films, (D) better data visualization (eg, 3-dimensional, cine, color) and manipulation (eg, quantitative image processing), (E) dissociation between acquisition and interpretation sites, and (F) reduction (or elimination) of the financial risks involved in the operation of the digital imaging technology (PACS) and residual film (analog) printing. This last item may lead to a risk sharing agreement between the health system and vendor, with penalties imposed in case of greater residual expenses and with the upside returned to the health system in case filmless targets are surpassed.

An additional goal that helps in the internal adoption of a PACS proposal is the elimination of any negative film/film-related budget variances, ie, PACS costs for any given period of time must not exceed projected film/film-related expenses. The entire project must be financed by savings provided from the conversion of analog (film) into digital (PACS) media. Secondary financial goals often include use of operational funds, instead of capital, to finance radiology's digital conversion and expansion.

Picture Archival and Communication System Architecture

Regarding the prerequisite infrastructure (23), we were able to use existing assets such as a high-speed corporate network interconnecting the multi-site health system and an enterprise-wide electronic master patient index, which is equivalent to a medical record number for the health system. Another necessary prerequisite, preceding the PACS roll-out, is the implementation and operation of an enterprise-wide RIS. With the network infrastructure, electronic master patient index, and RIS activities well under way, we moved forward with procurement of an enterprise-wide PACS.

Once fully implemented and integrated, the enterprise PACS embraces almost 200 imaging modalities. Projected workload is around 25–30 terabytes (TB) of new imaging data per year (uncompressed). The PACS architecture is hybrid, has a central, high-volume (275 TB), high-throughput DICOM archive, and distributed RAID servers (or Storage Area Networks–SAN) for immediate delivery of recently acquired images and associated priors. In areas of the health system where the workflow is non-deterministic, we adopt an on-demand image distribution method (23). Bandwidth requirements are high because all data must travel over the network at the time of request. A minimum of 100 Mbps to the desktop with gigabit backbone/backplane processing speeds are required. In addition to the on-demand operation, we take full advantage of the current corporate network architecture and the routing capabilities of the PACS to optimize flow of images to selected locations. This is especially useful within areas of the health system where the image flow is predictable or known a priori.

The typical imaging workflow starts with images being sent from the imaging modalities to a (redundant) central database server and distributed short-term storage system. The data are also copied into a digital linear tape library for long-term archival. An extra copy of the data is also electronically transferred to an offsite e-backup vault to be used for disaster recovery. Users located at any workstation within the health system can query the database server to immediately retrieve (typically, 2–10 seconds per study) and view any new or prior imaging studies. Users can also issue ad-hoc Digital Imaging and Communications in Medicine (DICOM) queries for data stored in the long-term archive (where typical retrieval times are between 5–10 minutes system-wide).

The scope of our implementation also includes the migration of all legacy data into the new PACS. The legacy PACS contains approximately 20 TB of DICOM data. Although highly automated, the migration process is still time-consuming. It does, however, provide the needed prior imaging data to our new PACS. Alternatively, to bypass the physical migration process, one could maintain the legacy equipment on "read only" mode, ie, serving data out of the archive on-demand. Unfortunately, this solution may create bigger issues related to maintenance and support of the legacy system for a period of time longer than expected. This is an important decision, especially when the legacy and new systems are manufactured and serviced by different vendors, as in our case.

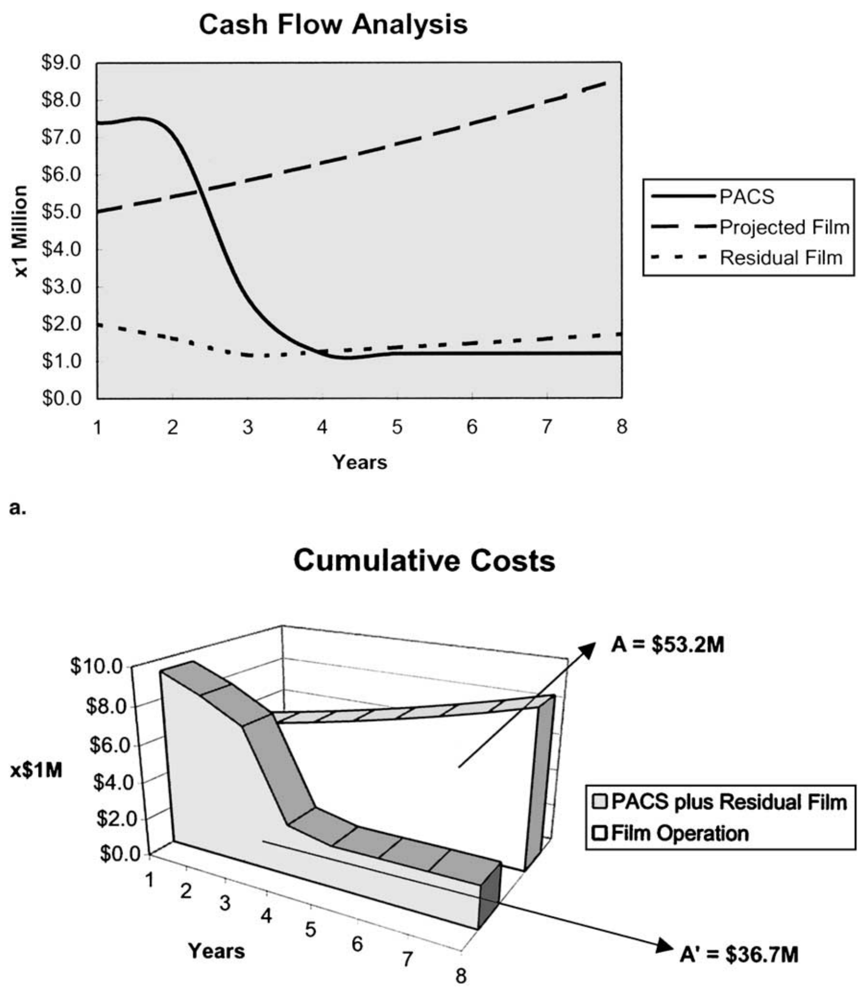
The PACS workstations have different functionality and serve different types of users. Typically, within radiology, high-resolution (between 1.5 k and 2.5 k) single, dual, or quad-monitor workstations are deployed. Within the different and numerous health system clinics, either a single or dual-monitor client-based clinical review workstation or single/dual-monitor web/thin clients are deployed. Within our health system, about 200–250 diagnostic and clinical review workstations are currently being deployed. In addition, more than 2,000 web access accounts are also being created, primarily for referring physician access within their offices and homes. Initially, to provide an alternate, redundant way to produce films, the printing infrastructure has been maintained. Most existing printers are still available for printing jobs sent directly from the imaging modalities or from PACS.

The multi-monitor Windows-based (Microsoft Corp, Redmond, WA) diagnostic workstations can be used to select images for review, to view the images, to manipulate the data presented, and to document findings. Image selection can be accomplished by sorting a study list, or worklist, using patient information, date of study, accession number, modality, or body part. The PACS is tightly integrated with the RIS and voice-recognition system. Linkage of patients across the different hospitals within the health system is provided by the electronic master patient index. As part of the integrated RIS-PACS solution, a RIS-driven engine controls the reading process at diagnostic workstations (via interpretation worklists), the technologist workflow (via modality worklists, study content notification), the referring physician workflow (results reporting) via the web, assists with the localization and management of exams throughout the network, and controls the scheduling workflow.

Images selected are displayed in the workstation monitors and several tools are available for image manipulation, annotation, and magnification. Rule-based pre-retrieved priors used for comparison are also displayed according to user-selected hanging protocols. Basic image processing tools are also available including linear measurements, contrast and brightness adjustments, and simple segmentation (eg, thresholding) (21). Some new features include 3-dimensional views, maximum intensity projection, and registration of digital orthopedic templates to the corresponding digital anatomic images. At the end of the interpretation process, radiologic images and reports are sent to referring physicians and clinics, and also flow into the hospital information system and web-based electronic medical records system.

Financing Model

The investment model is primarily based on costs savings. In simple terms, we financed all PACS equipment, installation, service, and day-to-day operations using the existing and projected film budget. The cash flow analysis is presented in Figure 1**(a)**. In the initial years of a PACS implementation, the costs associated with PACS equipment and installation can be high, typically surpassing the existing expenses with film and film-related activities (printing, storage, distribution, and disposal). Over time, the PACS costs decrease and stay at a relatively lower



a.

b.

Figure 1. **(a)** Solid line represents the costs associated with PACS equipment and installation. After implementation, most of the PACS costs are associated with service, support, and system maintenance (including all current software version releases; four software refreshes, ie, four new software versions; and two hardware refreshes, ie, new components or new hardware for the 8-year agreement). Dotted line represents the residual film printing maintained within the PACS environment. Dashed line depicts the projected film expenses without a PACS. **(b)** Cumulative costs for PACS plus the residual film/film-related expenses compared against the cumulative costs for the film operation for a period of 8 years. For this specific project, the net present value is $10.9 million. The project's cost of capital is assumed constant for all periods and equal to 6.8% per year.

level through the contract term (solid line). That is, after the initial implementation period, the remaining PACS costs are primarily used to cover the service and support components of the PACS. Also represented in Figure 1**(a)** (dotted line) is the residual film printing maintained within the PACS environment. In this case, for each year, 20% of the projected printing needs will be kept to cover printing demands related to mammography, courtesy copies, and operating rooms. Maintaining some filming and printing capabilities can ease up the transition from analog to digital. However, if higher filmless achievement marks can be reached (ie, cost savings higher than originally targeted), then any additional savings generated will be returned to the health system as credits. Also depicted in Figure 1**(a)** is the projected film expenses without a PACS (dashed line).

In Figure 1**(b)**, we plotted the cumulative costs for PACS plus the residual film printing costs and compared with the cumulative costs for the film operation for a period of 8 years. The difference is staggering. This difference, however, is somewhat decreased if one accounts for the cost of money, ie, the financial costs associated with the use of future savings. The goal is to generate enough savings to cover for all financial costs and still return credits to the health system. For this specific project, the net present value is $10.9 million. The project's cost of capital is assumed constant for all periods and equal to 6.8% per year.

One of the reasons behind this substantial difference is that traditional film printing and film library expenses grow almost linearly with the growth in the number of exams. We have observed this behavior within HUP's operations over the past 10 years. This is illustrated in Figure 2. For HUP, between 1992 and 1998, we observed a strong positive correlation between number of exams and film/film library expenses. This relationship is plotted

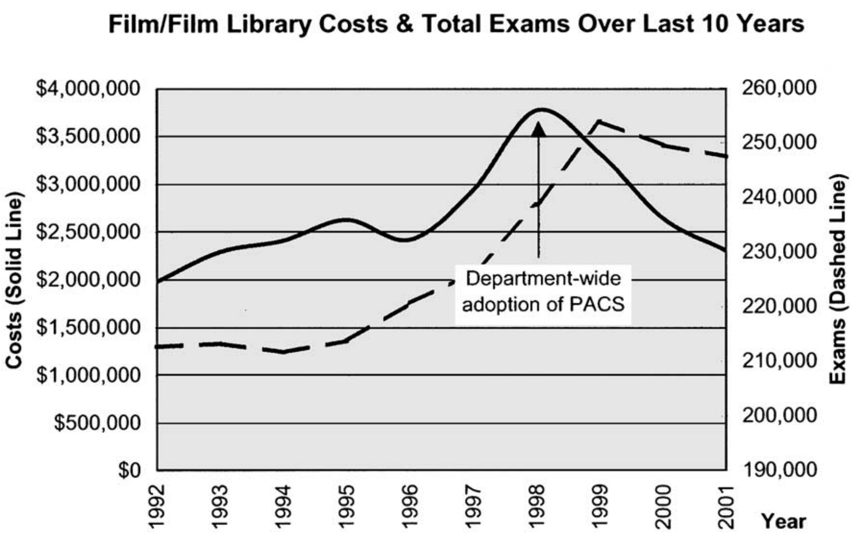


Figure 2. For HUP, between 1992 and 1998, we observed a strong positive correlation between number of exams and film/film-library expenses. The solid line represents the film and film-related expenses and the dashed line represents the number of exams. After 1998, with the full adoption of PACS within HUP's radiology operations, this trend was interrupted and film/film-related expenses actually began to decrease as more data was handled by the digital infrastructure.

in Figure 2 where the solid line represents the film and film-related expenses and the dashed line represents the number of exams. After 1998, with the full adoption of PACS within HUP's radiology operations, this trend was interrupted and film/film-related expenses actually began to decrease as more data was handled by the digital infrastructure. This decrease in film expenses eventually reaches a plateau once near 100% filmless operation has been achieved within radiology (except mammography). From this point forward, additional reduction in film expenses can only be achieved by going filmless throughout the hospital, so that film printing to referring physicians and other clinical departments can be replaced by digital access to images and reports (in general via a web-based application).

By examining the variables in our cash flow analysis, we derived the budget variance equation to be optimized:

$$\text{Budget } \Delta_t = \sum_t [\text{Projected Film} - (\text{PACS} + \text{Residual Film}) - \text{Interest}] \quad (1)$$

For any given year (t), the goal is to obtain either a positive or null variance in the image management budget. From the cash flow analysis plotted in Figure 1**(a)**, we can infer that for the first few years of a PACS project, the sum of the areas under the PACS and residual film curves are greater than the area under the projected film line, resulting in an undesirable negative budget variance. Conversely, for the later years in the project, the budget equation above will provide strong positive variances. One key ingredient for success is to find the right vendor that is willing to use these future savings (ie, future positive variances) to offset any negative budget variance during initial years of the project. If this is accomplished, for any given year (t), the PACS costs plus residual film costs plus interests will be below or at the projected film expenses, and $\Delta_t \geq 0$. In case $\Delta_t < 0$, the vendor assumes the downside or excess expenses. This model provided us with a solid financial proposal to gain approval and adoption of an enterprise-wide PACS solution.

RESULTS

To help our study, we performed a return on investment (ROI) analysis for the PACS project across the health system. For the purpose of this analysis, we assumed the PACS was being purchased using a straight cash outlay approach, staged over 3 years. The ROI measurements are depicted in the Table. We observed an overall ROI of 4.4 years for our multi-hospital health system when performing 600,000 radiologic exams per year and growing at approximately 5% a year. There was greater variability, however, in the ROI measurements at the level of each individual hospital within the health system. A closer analysis of the Table showed that some entities may have been either under-funding their film operations or under-reporting their actual film costs. This is particularly true for those film-based hospitals/clinics in which the average cost per exam is less than $10.00. An under-funded or under-reported film operation will neces-

Table
Picture Archival and Communication System Return On Investment

Entity	Exams/Year FY00	Costs/Exam (Film-Based Operations) FY00	Required Capital Expenditures To Go Filmless FY 02	FY 03	FY 04	Total	ROI (in years)
HUP	249,525	$10.26*	$5,236,000	$0	$0	$5,236,000	2.5
PMC	66,551	$11.25	$2,156,000	$0	$0	$2,156,000	4.2
PAH	122,122	$ 6.13	$0	$3,850,000	$0	$3,850,000	10.9
PHX	79,814	$ 9.46	$0	$2,464,000	$0	$2,464,000	4.6
Imaging centers	58,300	$ 6.96	$0	$0	$1,694,000	$1,694,000	10.7
Total UPHS	576,312	$ 9.05	$7,392,000	$6,314,000	$1,694,000	$15,400,000	4.4

Abbreviations: FY, fiscal year, from July to June.
*Partially filmless since 1998.

sarily create a negative bias toward the ROI calculation because less funds are available to finance the PACS operation.

After spending considerable amount of time and energy in the analysis of different propositions and negotiating the terms with vendors, we opted to finance the PACS through an operating lease agreement. It includes all PACS equipment, implementation, service, and support for an 8-year term, much like a complete outsourcing. The agreement complies with standard accounting principles for operating leases (generally accepted accounting principles [GAAP]). Among other requirements, there is no transfer of ownership or buyout at the end of lease. As an operating lease, equipment refreshes (both hardware and software) are included by definition. In our case, it includes all current software version releases; four software refreshes (ie, four new software versions); and two hardware refreshes (ie, new components or new hardware) for the 8-year agreement.

This financial mechanism can greatly facilitate funding the large costs associated with a turn-key PACS operation. Our agreement also linked the management of the digital imaging operation (PACS) and the traditional film printing. More importantly, it shifted to the PACS vendor the operational risk of continued printing (because of failure to deliver an adequate digital solution or resistance to change by referring clinicians) and costs related to implementation delays. An additional optimization step provided the elimination of the negative film budget variances in the beginning of the project when PACS costs are higher than film and film-related expenses. This step made the PACS proposal very attractive from an enterprise (internal) perspective. That is, solely relying on film savings to finance the entire digital solution (PACS) and any residual film printing and, simultaneously, eliminating any over-budget scenarios.

Our financing mechanism may not be appropriate for all hospitals and imaging centers. Institutions with higher exam and printing volumes, eg, more than 300,000 exams per year, may be in a better position to leverage on their size and successfully outsource the PACS equipment and operation solely on the basis of film savings. If there is not enough critical mass, then a PACS outsourcing using film savings may still be achievable, but the contract terms may have to be extended for a longer period of time.

DISCUSSION

Although ROI measurements may be good analytical tools, they may not be the most adequate method for measuring the payoffs yielded by an enterprise-wide PACS implementation. Return on investment is a simple concept that everyone understands, but it may be just too simplistic for analyzing the impact of a PACS on radiology's operations. The intangible value created to patients, radiologists, referring physicians, and administrators, is not directly measured by an ROI analysis that focus on cost avoidance and (to a lesser degree) on revenue growth.

In either case, an ROI analysis provides a good financial indicator vis-a-vis the required capital expenditures for a large-scale PACS. We observed an encouraging ROI using the cash outlay option; however, globally, the PACS ROI was still greater than the commonly adopted "3-year threshold" used for analyzing many information technology investments in health care. To strengthen our position, we focused on the total value of the proposition instead of solely relying on an ROI analysis for deciding on the feasibility of the PACS project. We researched payoffs in different dimensions. For instance, we carefully evaluated the value added to referring physicians due to reduction in the report turnaround time, timely and widely availability of images, and elimination of film loss; all of which contribute to improved quality of care while optimizing staff productivity.

Increased radiologist and technologist productivity may be one of the major contributions of a PACS to radiology's operations. It provides the ability to do more with the existing resources. A PACS can be quickly and efficiently reconfigured to fulfill the changing health system's demands. The imaging data can be accessed by any radiologist within the PACS network regardless of physical location. Demand for film interpretation can be quickly matched by the availability of radiologists across the health system, including access to subspecialists. Finally, the PACS can accommodate increases in volume, both increases in number of exams as well as increases in study size, with greater flexibility and at a lower incremental cost than film-based operations.

CONCLUSION

In addition to the financial indicators, many aspects must be factored into the decision analysis for PACS; for instance, radiologist and technologist productivity, increased throughput, reduced turn-around time for images and reports, improved image management and distribution, and elimination of film loss. The total impact of the solution must be taken into consideration. The Department of Radiology has to work with health system clinics, referring physicians, and administrators, educating them on the value of this proposition. Simply speaking, film has become incompatible with the increased density of radiological images and with today's demand for fast information.

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