Hospital Information Systems Replacement and Healthcare Quality

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ABSTRACT

The aim of this paper is to develop a methodology for deciding when a Hospital Information System (HIS) must be replaced and in addition to discuss how the decision for system replacement affects the quality of healthcare services. In the hypothesis, the Hospital IS has been in operation for a period of time and the Hospital managers have to choose between the replacement with a new Information System (IS) and the continuation of its use. Leaving aside the economic factors concerning the return of a possible investment, the decision is still difficult and will be based on scientific and technological factors. The proposed methodology employs confidential information from the Hospital, which relates to the system operation and usability, the satisfaction of doctors and patients, etc. It also examines the entire working environment and common factors that affect the choice of Hospital managers (e.g., financial constraints).

Keywords: *Change Request, Hospital Information Systems, Maintenance, Replacement Factors, System Replacement*

INTRODUCTION

The typical lifecycle of an Information System comprises several steps, starting from the feasibility study and the requirements analysis and ending with installation and maintenance. This last step is usually the longest and leads to a new system lifecycle. During the maintenance period, the software engineers attempt to improve the system by fixing inefficiencies and boosting performance (perfective maintenance), to expand the system by adding new services that include the changing needs of the organization (adaptive maintenance) and mainly to fix problems that surface while the system is in use (corrective maintenance). Information System Replacement is the result of a strong request for change and usually follows a long period of maintenance. Replacing an Information System is complex and costly and the decision for an organization is a difficult one. For this

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reason, most organizations prefer the corrective maintenance solution instead of system replacement. However, after a long period of maintenance and a series of corrective actions, a lot of custom solutions have been attached to the original system. The custom solutions address specific needs but often conflict with each other and slowly disintegrate system stability. As a matter of fact, there is a critical point in the maintenance phase, after which the operational and maintenance cost of the system is bigger than the cost for replacement.

In the case of Hospital Information Systems, the balance between system maintenance and system replacement is even more difficult, since the final decision must be collectively taken by different bodies (managerial, governmental etc.) that use different criteria (financial, technical, organizational etc.). Moreover, it has to do with patient safety and proper operation of the hospital during and after the system replacement. A proper decision for replacement must examine all the different requirements and the respective cost for covering them with a new system or treating them with a short-term maintenance plan.

This paper attempts to list all the factors that affect the decision to abandon the maintenance actions and replace the hospital information system.

BACKGROUND

Research in Information Systems Replacement appears with many different terms in the literature such as software evolution, software maintenance, information system replacement etc. When talking about IS replacement, software is the first factor that comes into mind (Ng et al., 2002). Deprecated operating systems, software programs with inflexible user interfaces and legacy drivers that do not support new hardware and communication protocols, are some of the issues that a IS replacement analysis must examine and solve.

Apart from software, information systems also include people, procedures, data and hardware that gather and process digital information (Jessup & Valacich, 2008). As a consequence, a complete study on IS replacement must also focus on inflexible procedures, legacy hardware, data formats and communication protocols, which are not in use any more, and people who cannot further support the IS operation and need further training (Gupta & Raghunathan, 1988). The critical question that every replacement model tries to answer is: 'Maintain or Replace?' According to Gupta and Raghunathan (1988), system software maintenance includes defects' correction, design enhancements and modifications to the system's behavior. These maintenance actions affect the overall operation of the information system and propagate to all the other participants of the IS (hardware, people, data and procedures). The analysis of the maintenance cost (Lucas, 1975) and the justification of a replacement decision according to financial criteria (maintenance costs compared to the cost of investment in replacement and the expected return) is a difficult and complicated operation, which takes into account several factors (Bacon, 1992; Renkema, & Berghout, 1997).

The term evolution has been employed by researchers in order to bridge the two schools and put Maintenance and Replacement under a common strategy (Bisbal et al., 1999). Since, it is complex to replace an information system which is already in operation and is costly to maintain it forever, a practical solution is to evolve it in order to meet the current needs and adapt to the environment. In the context of a functional information system, evolution assumes that several attributes of the system are repaired, modified or replaced causing the information system to change, possibly through modifications to its' constituent elements. For example, when the operating system changes, then the software modules change in order to adapt to their new hosting environment. In order to bind the three different terms, which are found in literature, it can be said that: A system evolves while being maintained; when certain factors arise then the "evolution" of a certain information system might be its' replacement with a new one with "different," "better" functionalities.

A study of the literature that focuses on the replacement of Hospital Information Systems (Sikkel et al., 1999; Rada & Finley, 2004; Pusatli, 2009; Nizar et al., 2010) reveals that the factors affecting the decision for replacement vary from case to case. According to Rada and Finley (2004) it is wiser to record the various factors and let the hospital managers decide rather than strictly decide between replacement and maintenance.

In the case study presented in Sikkel et al. (1999), replacement was imposed by a break of the service contract; the new HIS supplier faced a complex mosaic of information systems and technologies, which was difficult to maintain and decided to redesign the HIS. The study of Wong et al. (1995) revealed that most hospitals follow the traditional systems development lifecycle which begins with requirements capture and ends with retirement, but in reality the retirement phase is ignored. The study of Rada and Finley (2004) concludes that the aging of the HIS results in replacement, but the decision is driven by the hospital strategy and not by technical factors. The politics that change over time result in mixing of user roles, increased complexity and partial operation of the workflow and thus make replacement inevitable. The work of Pusatli (2009) presents an interesting survey of replacement and maintenance strategies that can be applied to information systems in general and emphasizes on their application in Hospital IS. The work presents an initial model comprising factors that affect the decision for replacement and then evaluates and refines the model by using a questionnaire and interviews that help the author prioritize factors. In a similar manner, our work defines a model that captures technical and socio-economical factors that affect a replacement decision. However, instead of prioritizing factors we suggest a weighting scheme, which can be easily adapted to each specific case of hospital information system.

REPLACEMENT CRITERIA

Maintenance

Maintaining the Hospital IS in an appropriate operability level is usually the responsibility of an external supplier (support provider) and refers to a set of technically oriented functions, which are described in detail in the related contract between the supplier and the hospital's administration. The "terms and conditions" of the maintenance contract are supposed to serve and cover the Information Systems Department operational requirements, and are distinguished into four main categories. The first category refers to corrective actions that take part during the whole IS lifecycle and aim in fixing problems during the installation and the operation of both software and hardware. The second category refers to the provisions that must be taken as precaution in order to optimize system's performance. The next category contains all actions required by the supplier to accommodate the operational changes requested by the users to keep the IS in such a condition that the users demands are always satisfied. The last category describes how any future improvements will be handled by the supplier. Although, improvements can be easily confused and considered as extensions to the installed IS it should be made clear that this category foresees minor improvements on the existing services in order to adapt to technological advances rather than the creation of new services.

If the support contract does not cover any of the aforementioned cases or one of these maintenance categories is not foreseen then the system maintenance is not a feasible option. The aforementioned criteria can be presented in order of importance from the most to the less critical: a) bug fixing is critical for the smooth operation of the system, b) system optimization is necessary for supporting an increasing number

of users, c) maintenance activities are important in order to support operational changes, however they tend to decrease system stability (Eick et al., 2001), d) future amendments are desirable but are usually under negotiation between the hospital and the supplier.

Change Request

Alterations to the existing IS structure require the agreement between the supplier and the hospital's administration. The framework of this agreement comes from the maintenance support contract between the interested parties, the supplier and the customer. For a successful implementation of a change request from the customer, the hospital's administration, must obey the rules dictated in the existing contract. In any case, the request for change must define the duration of the changes' period and the necessary resources, both in financial and human terms. The frequency of change requests must be followed by the hospital's administrators in order to reach decisions on the IS quality. Frequent requests for changes imply poor planning. Also, the magnitude of costs related to changes reveals and indicates the purpose of requesting additional alterations to an existing IS. As the number of change requests rises, the organization should consider replacement, rather than evolution (Gupta & Raghunathan, 1988), since maintenance costs are bigger than the replacement cost.

The claims for alterations must be carefully designed in order to include the specific demands at a tolerable cost in relation to the IS value. According to Puslati (2009), by exposing and clustering reasons behind the change requests, the complexity of deciding whether to maintain or replace system components can be reduced.

Error/Failure Rate

The reason behind an error in a typical information system can be a faulty requirement definition, an incorrect data entry, a bug in coding or implementation or a hardware fault. Even an error free system in the time of creation may produce errors after a hardware change or when new and untrained users join the community of users. However, when the errors are handled immediately after been reported their impact is minimized, they do not trigger further errors, and the system reliability remains high.

The error/failure rate is associated with the frequency and importance of system errors or failures. The rate determines whether it will cause a request to change (change request). The failure rate is the expected number of failures of a system per a given time period and estimates the likelihood of failures. The Reliability of a system is a conditional probability that the system operates correctly throughout the interval (t1, t2) given that it was operating correctly at the time t1. On the other hand Unreliability is the probability that a system has not survived the time interval [t1, t2]. Mean Time To Failure (MTTF) is the expected time that a system will operate before the first failure occurs. Mean Time Between Failure (MTBF) is the average time between failures of a system. Finally, Mean Time To Repair (MTTR) is the average time to repair the system and place it back into operation (Kyoungwoo, 2011).

As far as it concerns the error/failure rate index, the metric must take into account the following criteria: a) Failure Rate, b) Reliability or Unreliability c) MTTF d) MTBF e) MTTR.

Productivity

Information Systems' productivity is a complex concept subject to much discussion in the literature. The productivity index refers to the ability of the software to be efficient, user friendly and effective. Studies in IS productivity (Hitt & Brynjoifsson, 1996; Myers et al., 1997) show that repeated errors in the operation of an information system, gradually affect the system performance and degrade the overall productivity. Several companies that capitalize on performance-based management of their information systems consider both strategic advantages and costs. For them, productivity, return of investment and net present value are some of the measures of performance that evalu-

ate the contribution of IS to the business (Stair & Reynolds, 2011). According to Petter et al. (2008), productivity is one of the net benefits from the use of an information system.

Overall productivity measures include operational performance, system availability and throughput (the number of transactions served in the unit of time) and the quality of the content of output. However, benefits of IT may not always be easy to measure as they can be in forms such as customer service or convenience (Hitt, 1996). Apart from this, the metric must take into account the following criteria in order to quantify the effect on productivity: a) how the system complexity affects the complexity of the operational workflow of everyday processes b) the connectivity to external systems and the degree of automation of processes that rely to external connections c) the system understanding from users.

Availability of User Support

The availability of user support is a requirement for the proper operation of any information system. Usually, the proper documentation of all system operations in a detailed "user's manual" and additional training sessions on every system expansion or modification are able to cover user needs and guarantee proper operation of the information system. Similarly, new employees attend training seminars and are also supported by frequently asked question lists (FAQ) and online user forums.

Modifications of the information system may provide temporary solutions to bugs and inefficiencies and improve the system performance by extending its functionalities but in the same time require additional training and repetitive delta-updates of the documentation that are not so easy to follow. Online user forums and help desks can be a solution, but any system change increases their operational overhead.

The overhead for user support is strongly connected to the popularity of the technologies that the existing system employs. For example, using an operating system, which is quite popular among hospital employees (e.g., an operating system that they also use at home, or using the web as a platform), increases users' flexibility and results in fewer requests for support. On the contrary, the use of custom technologies reduces the ability of users to interact with the information system and thus makes them prone to ask for support. Similarly, users must be familiar with the support services, must be trained to use the "Help" option of their applications, to read the documentation and browse the FAQ list before they "ask for help" to the forum or contact the help desk.

It is typical situation in a hospital information system, that the original system has been developed from an outside vendor, whereas the modifications and customizations are performed in-house. The need for technical support is even bigger in this case for the modifications to be performed, applied and be operational.

As a conclusion, the existence of a strong technical support for the system works in favor of system maintenance and postpones replacement. If the hospital has a support contract with the software company that developed the information system, or if it has invested a lot for creating a help desk which covers its current needs for support then the system replacement is postponed (Smolin, 2008). In the opposite case, any modification, any increase on the system complexity will reflect to an increased request for support and will soon lead to a request for change (Gerace & Cavusoglu, 2009; Lahtela & Jäntti, 2010).

As far as it concerns the user support services, the metric must take into account the following criteria: a) existence of a technical support contract, b) the availability of technical support (i.e., 24/7, regular updates, custom bug fixing), c) existence of a help desk, d) existence of in-house support, e) existence of documentation and user manual, f) formal training sessions for new employees, g) in-house educators and trainers, h) support forum.

User Feedback

User feedback provides software engineers with useful information, which can be employed

towards the detection of programs' deficiencies, the reduction of system errors and the increase of systems' adaptability to user needs. The role of the user feedback collection process in the lifecycle of IS development is either to report implementation errors in the prototyping phase or to trigger system maintenance actions or system replacement in the post deployment stage through a strong request for change. User feedback can be positive or negative, suggesting enhancements or corrections to the system respectively. When the amount of negative user comments increases (e.g., user complaints for system bugs or missing features) this is an indication that the system needs repair, redesign and probably replacement. At the same time, positive user feedback is an evidence of a successful, well accepted system, which may need expansion but definitely no replacement.

However, user requests are not always in accordance to the targets of the hospital and their fulfillment is not always feasible, due to cost or other restrictions. As a result, user feedback is valuable for hospital managers to make decisions on when or what to change in the hospital IS, but user needs should be aligned to the hospital strategic plans. So, maintenance or replacement actions can be decided after collecting user feedback and prioritizing user needs. Another solution is the post-collection of user feedback on specific maintenance actions, which have been decided by the organization and are prioritized according to user needs. Detailed user feedback must be collected repeatedly (Bragge et al., 2005), organized by module and summarized by the IT department of the hospital, communicated to hospital managers who will prioritize requests and then forwarded to the software engineers as requests for update. User feedback can also be collected on purpose, through the evaluation of the information system by its end-users (Gardner et al., 2009). This type of user feedback will allow preventive system improvement. The benefit from exploiting user feedback is that a more focused maintenance plan can be achieved, which treats the most severe system faults and extends the IS lifecycle. Incorporation of user feedback in the system maintenance process increases the usability and the perceived quality of the system.

As far as it concerns the user feedback, the metric must take into account the following criteria: a) existence of a user feedback collection mechanism, b) existence of a user feedback aggregation and analysis process, c) the impact of user feedback to the strategic decisions of the hospital.

System Specialization

System specialization examines the dependencies that a system might have on the software level, as far as its operating system environment is concerned (ex. a hospital information system that works in a specific operating system and is not operable in future operating system versions). Similar dependencies might exist in the hardware level (ex. software requires minimum amount of memory to run). Dependencies on the software and hardware layer mean that a system is dependent on its operation environment. It also covers security requirements, in order for a system to be acceptable in terms of avoiding potential business impact in case of a security incident (ex. a cloud-based hospital information system, which is susceptible in sql injection attacks, is flawed in terms of security). The legal framework, which governs the system's operating environment, is another important factor that affects system specialization in regards to the functions that it can perform. The existence of specialized personnel must also be taken into account when the system has to be transferred to a new generation of employees, since the system's operation must not depend to individuals' expertise. Transferability is another important factor that defines if a system can be adjusted to a change to its operation environment in terms, for example, of an organizational, regulatory or environmental change. The system's functionality (performed functions, ability to extend) also affects the decision for replacement, since it is more complicated to replace a system that performs multiple functions within an organization. Lastly, the system's end of life defines whether the system is no longer supported (Pusatli, 2009).

Popularity

The popularity of a system is defined firstly by the system's reputation, which depends largely on the age of the system or the company as well as the company's share in the market. A system becomes more popular when the providing company has available support facilities and forums, which can support the organization, that uses the system, overcome a crisis or solve a minor system glitch that hinders operations or make better use of the system. The system is only as popular within an organization as people exist in the market, which have the skills to use or support the system. Thus, existing staff, that can be recruited, is a factor that influences system's popularity. In order to measure a system's popularity a person has to take into account user's satisfaction whether it is expressed through client satisfaction surveys, existence of multiple users discussion groups, providing company's website popularity (PRchecker, 2011) and share in the job market (Monster, 2011). Lastly, a system that reaches end-user support becomes less popular for any organization that needs a system, which is still being supported.

A METRIC FOR IS REPLACEMENT IN HEALTHCARE

The healthcare domain and more specifically the Public Health sector and Hospitals possess a multilevel and complex structure that does not facilitate the long-term maintenance of Hospital Information Systems. National Health Systems are continuously revised and developed, international health standards aiming to support interoperability and internationalization of services are adapted to a different degree for each National Health System and affect differently the strategic decisions of each country. As a result, hospital information systems must continuously evolve in order to meet multiple and sometimes contradicting requirements (e.g. cost cutting and improved quality of services).

A fundamental difference of HIS in comparison to other Information systems is that their operation directly affects humans (i.e., patients) and as a result they must be reliable, secure and flexible at all times. Speed and accuracy are two principal aims of an HIS, which attempt to organize everyday operations and give extra time to doctors and nurses and improve quality of services offered to the patient. Having in mind all the aforementioned characteristics, we will be able to correctly prioritize all the factors that affect our decision on HIS replacement and reach the most profitable result for all.

The hospital managers should evaluate the organizational and financial gains from the replacement strategy, the cost of maintenance and costs from possible system errors and decide between maintenance and replacement solutions. If they decide to partially replace system components, they should balance the budget distribution between maintenance actions, replacement actions and interoperability tasks and estimate the running costs and expected increase on profits via improved performance.

We divide the evaluation criteria into eight main categories matching the factors presented in the previous section. Each factor is further analyzed in a series of criteria that should be evaluated on a continuous basis in order to assure the quality of the HIS and the respective decision for maintenance or replacement. We have defined an extended set of evaluation criteria that cover all factors and use a 4+1 levels scale for grading. The scale ranges from 'Fully Adequate' -when the solution fulfills the criterion- to 'Not Adequate' -when it does not fulfill the criterion at all- and 'Not Measured' -when it is unclear whether the community fulfills the criterion. In some criteria a 1/0 scale is used to indicate whether the criterion is matched (1) or not (0) or a numerical scale which must be mapped to the 4+1 levels scale before the next step.

The criteria organized by factor as depicted in Table 1, examine the degree in which the operating HIS meets the expected standards and at the same time provide evidence on issues that must be solved by the HIS managers.

Table 1. Criteria for evaluating the need for HIS replacement

Maintenance
i) existence of a maintenance contract, ii) the degree of support contract adequacy in fixing system bugs (on site support, 24/7 support), iii) the support contract covers system optimization activities, iv) the support contract supports maintenance activities, d) the support contract covers future requests for system amendments
Change request
i) frequency of change requests, ii) average cost for serving a request iii) response to change requests, iv) are change requests for the same subsystem grouped together
Error/failure rate
i) failure rate, ii) system reliability degree, iii) expected time of system operation before the first failure occurs (MTTF), iv) average time between failures of a system - Mean Time Between Failure (MTBF), v) average time to repair the system and place it back into operation - Mean Time To Repair (MTTR), vi) MTBF evolution over time
Productivity
i) the system is available in a 24/7 basis, ii) the system's throughput is adequate, iii) number of transactions, which are served in the unit of time and evolution of this number, iv) quality of offered output, v) the degree that system's complexity affects the complexity of the operational workflow of everyday processes, vi) connectivity to external systems and degree of automation of processes that rely to external connections vii) users understand how the system operates
Availability of user support
i) existence of a technical support contract, ii) the availability of technical support (i.e., 24/7, regular updates, custom bug fixing), iii) existence of a help desk, iv) existence of in-house support, v) existence of documentation and user manual, vi) formal training sessions for new employees, vii) in-house educators and trainers, viii) support forum.
User feedback
i) existence of a user feedback collection mechanism, ii) existence of a user feedback aggregation and analysis process, iii) the impact of user feedback to the strategic decisions of the hospital.
System specialization
i) dependencies to other systems on the software level, ii) system works in a specific OS and is not operable in future OS versions, iii) software has minimum hardware requirements, iv) existence of security requirements, (e.g., in a cloud-based hospital information system), v) existence of a legal framework, which governs the system's operating environment, vi) the system requires specialized personnel, vii) systems' transferability to a new operation environment, viii) system is no longer supported
Popularity
i) system's longevity, ii) supporting company age and share in the market, iii) supporting company has support facilities and forums, iv) existence of people in the market, which have the skills to use or support the system, v) users' satisfaction expressed through client satisfaction surveys

For example, the absence of a user help desk may not directly lead to a decision for system replacement, but should definitely be solved since it will assist in system's endurance. As a consequence, the criteria we presented do not necessarily point to the replacement of the HIS. They rather act in favor of long term maintenance and, when they are checked in a frequent basis, facilitate the hospital managers to foresee system's deficiencies and act proactively.

In order to provide a complete evaluation template that can be applied on a constant basis in the operating Hospital Information System and reassure its overall quality, we perform a quantification of the evaluation results collected using the aforementioned criteria. The individual marks can be used to calculate separate scores for each sub-category, category and a final score for the full set of criteria. Supplementary weights can be applied in each

category or sub-category depending on the priorities of the community. The resulting formula will have the following form:

$$Score = W_A * \sum_{i=1}^{asize} w_{ai} * m_{ai} + ... + W_H * \sum_{i=1}^{hsize} w_{hi} * m_{hi} \quad ,$$

where W_A, .., W_H, denote the priority of the respective aspect, w_{xi} represents the interest on sub-category i of aspect x and xsize is the number of subcategories that apply in aspect x. Finally, m_{xi} stands for the median of the individual criteria values in the sub-categories of category x. Also:

$$W_A + ... + W_H = 1$$

and

$$\sum_{i=1}^{xsize} W_{xi} = 1 \text{ (for x in \{A,…,H\})}$$

The detailed presentation of the evaluation form has been omitted due to space limitations. However, it is on our next plans to make the form available in public and use it for the evaluation of an HIS in operation. Factor analysis and the statistical process of the factors being evaluated will give us a better view on their role in the maintenance or replace decision.

EFFECTS OF REPLACEMENT TO HEALTHCARE QUALITY AND RELIABILITY

The reliability of the HIS before the replacement is covered by the "error/failure rate" set of criteria. When the criteria in this set are not fulfilled then system replacement is obligatory. Normally, the replacement of the old HIS with a new one includes a short testing period during which system faults are minimized and system stability is strengthened. As a result, the failure and error rates decrease and the system's reliability increases.

When it comes to quality, things are more complicated. In order to evaluate the effect of system replacement to the quality of healthcare services a quality control plan must be established (Kastania, 2011). If we focus only on the HIS software the quality indices comprise correctness, maintainability, and integrity (Troster et al., 1993), but in a wider aspect they also include usability, user satisfaction, personnel and equipment quality etc.

A solution for measuring the effects from the replacement is to use the same set of criteria and the aforementioned formula in order to evaluate the new HIS. A comparison between the old and the new system's score will highlight the success or failure of the replacement action.

CONCLUSION

Information Systems' research provides many examples of techniques and processes that reduce system failures, collect and assess user feedback, increase functionality, schedule maintenance, measure productivity, etc. The answer to the question "what is better, to replace or maintain a hospital information system" is still complex. Some consider it as an organizational decision, others as a strategic decision and others rely on a financial analysis in order to decide.

The evaluation of an operating HIS is a difficult and multi-facet task, which usually results in huge evaluation checklists that covers all aspect. The definition of a strict set of criteria may lead to an inflexible decision support system that fails to adapt to the individualities of each specific case. The suggested evaluation framework is general and can be easily adapted to the national decision framework, to the hospital managers' strategy and to the end-users needs by adjusting the interest to each evaluation factor.

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