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Normative Value of Information for Decision-Making in the Healthcare Environment

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ABSTRACT

With their ever-growing importance and usability, the healthcare sector has been investing heavily in medical information systems (IS) in recent years, as part of the effort to improve medical decision-making and increase its efficiency. This research aims to evaluate the contribution of information technology (IT) to improving the medical decision-making processes and to evaluate the degree to which IT investments are worthwhile.

The method included the assessment of normative value of information. A decision tree model was developed. The calculated tree results were summarized in a cost-effectiveness analysis and a return on investment (ROI) analysis.

This research aim to contribute: Researchers - by providing insights regarding decision theory, value of information and medical informatics; Practitioners - by promoting the design of medical IS; Physicians - by enhancing efficient use of information resources; Patients - by improving healthcare services; Policy decision-makers - regarding the advisability of investing and managing medical IS.

Keywords

Healthcare IT, electronic medical record (EMR), value of information, information systems evaluation.

INTRODUCTION

The information revolution of the last few decades has brought about a massive adoption of information technology by organizations of all types and in all sectors of the economy, with the aim of reducing the uncertainty of decision-makers and improving the decision-making process. In fulfilling their function of supporting decision-making, information systems perform tasks such as collecting, organizing, processing and analyzing data reflecting the organization's activities. The information they provide is a critical resource that has significant impact on the outcomes of managerial decision-making (Ahituv and Neumann, 1994).

However, information in itself is not the panacea of all ills. Indeed, one of today's main problems is information overload, and one of the most important issues in the area of research dealing with organizational information systems is assessing the value of information (Ahituv, 1989; Ahituv, 1980). Understanding the importance of assessing the value of information and developing methods which provide the ability to assess the value of information can improve the processes of planning, designing, developing, building and managing of decision support systems (DSS).

Information technologies today are considered critical to the operational, managerial and strategic levels of the organization. They play a significant role in managing healthcare systems. Hospitals and health service providers aim to provide their customers with qualitative healthcare services and at the same time to be efficient and to optimally cope with complicated and varying environments and activities (Shortliffe, Perreault, Wiederhold and Fagan, 2001). In order to provide the proper level of service, as well as to survive and compete, they need to use information efficiently.

Today, with the huge amounts of medical data and information and the growing number of medical information systems, there is an increasing need for medical information that is complete, homogeneous, precise, updated, reliable and accessible at the point of care. Information based on the historical medical data of the patient collected in real time from all relevant internal and external sources can be the basis for an optimal decision-making process (Brailer and Terasawa, 2003). This information is essential to insure the quality of the medical care process and healthcare service and it needs to be provided effectively and efficiently utilizing all the sophisticated techniques for collecting, browsing and presenting data that today's information technology has to offer.

RESEARCH GOALS

The main goal of this research is to examine and assess whether historical information provided to physicians by an information system during treatment improves decision making. The aim is to assess the added value of using a system. In other words, to find out: what: $\Delta C / \Delta Q$ is, when: ΔC is the added expected cost per patient, calculated as the difference of the added expected cost with the system and without the system. ΔQ measures the expected added Quality Adjusted Life Years (QALY) per patient per year (See the METHOD section for explanation regarding the QALY Index). An additional goal is the development of a normative model that will allow us to study the contribution of historical information and determine whether it really enables us to provide better medical service - more accurate diagnoses, better medical treatment including safety, and more efficient services.

METHOD

The method used to achieve these goals was based on a theoretical model for assessing expected value. This stage is characterized by the estimated value of information according to the normative approach, which includes 4 steps (Ahituv, 1989):

1. Analysis of a set of assumptions
2. Construction of a mathematical model
3. Running the model – assessing the value of information via sensitivity analyses and first- and second-order Monte Carlo simulation.
4. Results analysis

This examination was conducted by formulating a model that will measure and confirm the value of normative information. Decision tree was used to present the model, and decision nodes, along with possible occurrences of events, were defined. Moreover, probabilities and payoffs for each alternative were also defined. Finally, a calculation was made to evaluate the additional expected costs that result from using the system in terms of QALY. Also, a cost-effectiveness analysis was conducted. The objective is to understand – from the hospital's point of view - what is the estimated worthwhile cost of a system that provides historical information and how many QALY units such a system can actually contribute. This examination was conducted only in internal medicine departments because it was found that in internal medicine departments historical information receives higher importance than in other departments (Shabtai, Leshno, Blondheim and Kornbluth, 2007). The model was developed based upon the TreeAge Decision Analysis's DATA program.

Quality-Adjusted Life Year – The QALY Index

The QALY is a standard-accepted index that assigns a quantitative value to different health situations; this index relates not only to the *number* of years of life, but also to the *quality* of life for those years. The QALY approach is used as a general index for estimating the utility and effectiveness of improvements introduced into the field of medicine (Phillips and Thompson, 2001). A QALY unit is comprised of the weighted average life span of the patient, together with quality of life. Based on this measurement, decision makers can examine different alternatives and determine the extent of efficiency and utility derived from each. This analysis helps them to make decisions related to healthcare resource allocation (in the case of the present study: investing in an information system that provides physicians with historical information during treatment). The developer of this system, Ellen Williams, claims that it integrates both the life expectancy and quality of life factors and, at the same time, reflects the values and ethics of the society it serves (Williams, 1994).

The Decision Tree

The field of decision analysis derives from the fields of performance research and games theory, and includes the identification and analysis of all possible alternatives and the possible results and implications of each alternative. Over the course of the analysis, a decision model structure is created, usually in the form of a decision tree. Decision trees are based on nodes, which represent choices, chances and outcomes. Implementation of this field in the world of medicine is usually expressed by a tree-like diagram used to present possible strategies to the decision-maker (the physician), and to calculate the probability of the occurrence of each outcome by adopting a certain strategy (Pauker and Kassirer, 1980). In addition, the

value of each result is defined as the utility on a pre-determined scale. The expected utility of a node is calculated by averaging of the weights of the utility of possible outcomes - the weights being the probability that each one of the outcomes will occur. For example, a node opportunity that describes a 5% chance of instantaneous death (with a life expectancy of 0), and a 75% chance of survival without angina (with a life expectancy of 15 years) will present a life expectancy of 12.65 years. The utility of the decision node is the highest among the benefits of the strategic components because the rational decision-maker will choose the alternative which, on average, will provide the highest possible utility.

DEVELOPING A MODEL

Description of the Basic Model – The Values Model

This model was built on the basis of receiving a patient into the hospital ward. The situation is as follows: a patient arrives in the ward and must be provided with medical service. In order to do this, the physician must either use or not use historical information. In the event of using historical information, three possibilities exist: the contribution of the information is high, low or not-exist. For each of these possibilities, there are three potential outcomes. Below, we provide a detailed description of the model, including its assumptions, terminal nodes, chance nodes and results.

Two different versions of the model were built. First, the model base was built, by assigning variable values that describe the likelihood of each branch. For each variable, minimum and maximum values were also determined. This version allows us to conduct sensitivity analyses, so that we can examine how the value of the different variables will influence the effectiveness calculation for each possibility. In the second version, values of different variables were replaced based on pre-determined assumptions. This version provides a basis for running Monte Carlo simulations, which enables an examination of the probability of each one of the situations actually occurring.

Assumptions

The model's assumptions were based on the results of previous studies (Shabtai et al., 2007). In addition, other data was added by the Central Bureau of Statistics, together with evaluations made by experts in the field.

Data Input for the Model (Based on a one-year terms):

Sample size: The total number of patients admitted to the sampled hospital's internal medicine departments per year is around 11,000.

Gender: 50.4% of the patients were males; 49.6% were females.

Type of insurance: 82.4% of the patients had "local" health insurance; 17.6% had "other" health insurance.

Age:

A. Among the entire sample: the average age is 68.22 ± 16.63 years.

B. Among males: the average age is 65.77 ± 16.73 years. Life expectancy among males[1] is: 77.6 years. Figure 1 presents the function of the males in the sample[2].

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[1] According to the Central Bureau of Statistics – 2005

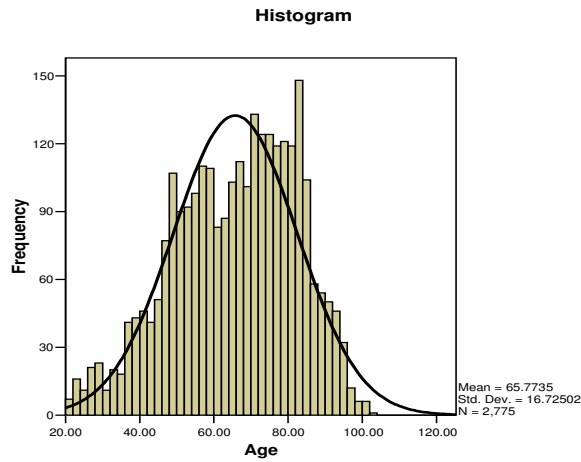[2] According to the hospital admission data records

Histogram

Figure 1. The Age Function among Males in the Sample

C. Among Females: The average age is 70.7 ± 16.2. Life expectancy for females[3] is: 81.8 years. Figure 2 presents the function of the females in the sample[4].
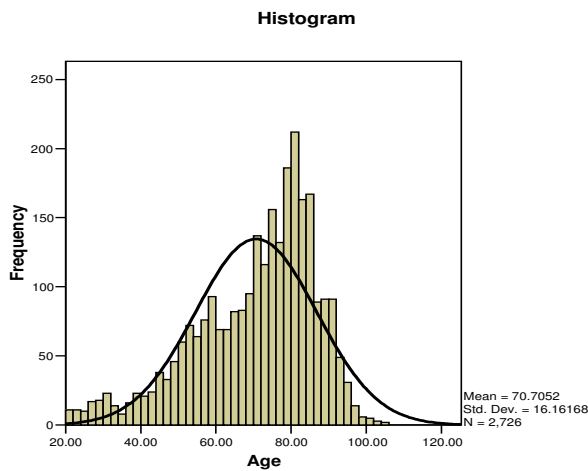
Histogram

Figure 2. The Age Function among Females in the Sample

Admission Period (in days):

A. Among the entire sample: the average number of days spent in hospital is: 3.53 ± 3.15 days.

B. Among males: the average number of days spent in hospital is: 3.43 ± 3.02 days. Figure 3 presents the function of admission days for males in the sample[5].

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[3] According to the Central Bureau of Statistics - 2005

[4] According to the hospital admission data records

[5] According to the hospital admission data records

Histogram

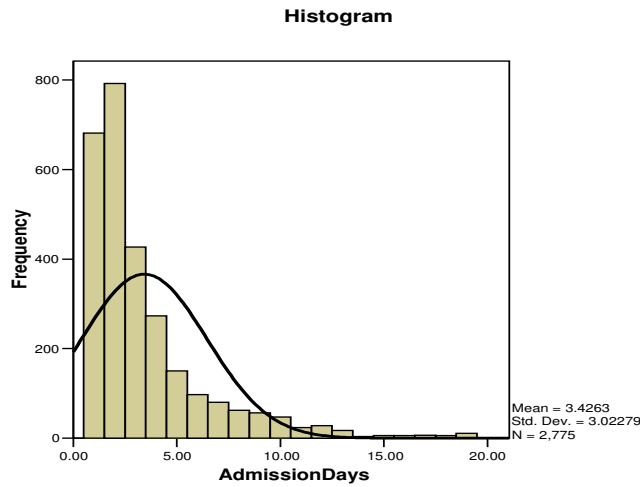Mean = 3.4263
Std. Dev. = 3.02279
N = 2,775

Figure 3. The Average Number of Admission Days for Males in the Sample

C. Among females: the average number of admission days is 3.63 ± 3.27 days. Figure 4 presents the function of admission days for females in the sample[6].
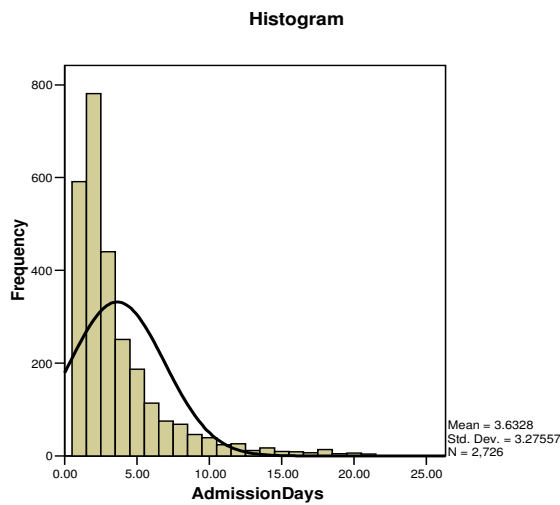
Histogram

Mean = 3.6328
Std. Dev. = 3.27557
N = 2,726

Figure 4. The Function Number of Admission Days for Females in the Sample

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[6] According to the hospital admission data records
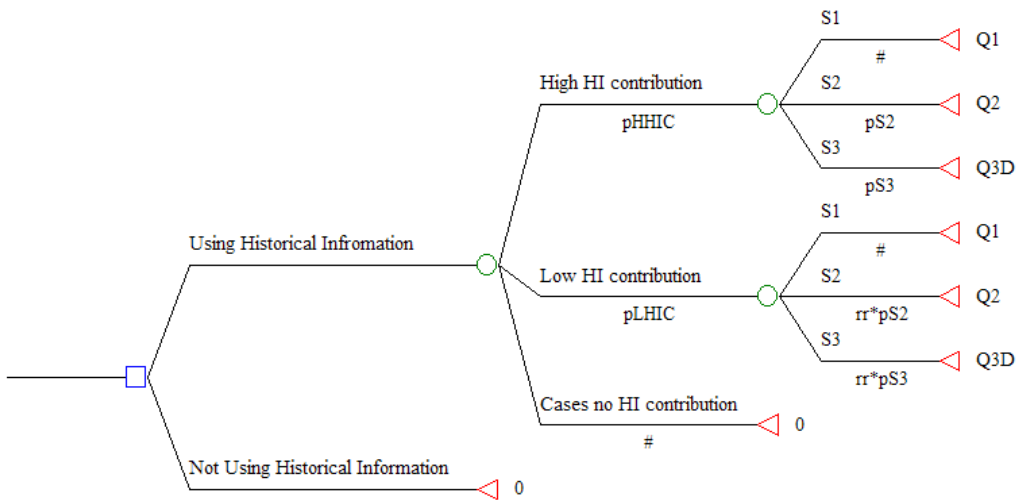
The Model Structure

Figure 5. The Decision Tree Model – Values Version

Figure 5 presents the schematic structure of the model. The root node in the model is the decision node presented to the decision maker at the point of care – the physician who is carrying out the treatment. When a patient comes to a physician, he must choose various alternatives, after which he must provide the patient with suitable medical service.

The Root Node

The first alternative **–** using historical information

The second alternative **–** not using historical information

If the second alternative was chosen, then the payoff is: 0 because the goal is to measure the added utility as a result of using historical information; therefore, this alternative was defined as a reference point.

If the first alternative was chosen, then there are three possible probability situations, at the first chance node.

The First Chance Node - Possible Probabilities

1. The contribution of the historical information is high (appears in the figure as - high H1 contribution). The probability (pHHIC) that this situation will occur is: 8%. The necessary field of values for the sensitivity analysis is between 5%-15%.
2. The contribution of the historical information is low (appears in the figure as – low H1 contribution). The probability (pHHIC) that this situation will occur is 14%. The necessary field of values for the sensitivity analysis is between 10%-20%.
3. The historical information does not contribute anything at all (appears in the figure as – H1 no contribution cases). The probability of this situation appears as the "#" sign (in other words, the probability that completes the first two options to 100%). In this situation, there is no added utility; thus, 0 QALY units are gained.

Regarding each one of the two situations where the historical information provides some sort of contribution, there is a chance node, which includes three possible scenarios– S1, S2, S3 - for which occurrence probabilities are defined, along with gained QALY units. Below, we present a detailed discussion of the three possible scenarios:

The Second Chance Node – The First Scenario: High contribution of historical information

S1 – Describes a situation where the historical information shortens the diagnostic process, but without clinical significance and without shortening the hospitalization time or unnecessary hospitalization period. In this situation, the physician benefits, rather than the patient.

Probability **–** Appears as #, meaning completion to one (100%) of the amount of probabilities of the other possibilities along the branch.

Utility – Defined as Q = 0.001, meaning: 1/1000 QALY units resulting from reduced stress and anxiety and additional implications as a result of a shorter diagnostic process. Increased utility in this case derives from examining prior studies that focused on similar situations[7], where a decrease in patients' stress and anxiety levels was considered a utility in QALY units. For example, we find that in an anxiety-causing situation, the utility in the case of reduced anxiety levels is 0.4-0.8 QALY units. In light of the fact that in the case of the model examined in the current study we are talking about a decrease in the level of stress and anxiety over the course of a few days (the length of the hospitalization period – 2-3 days), the relative part is estimated at 0.001.

S2 – describes a situation where the historical information shortens the diagnostic process and, as a result, also shortens the number of days spent in the hospital and also perhaps prevents unnecessary hospitalization, and brings about improved clinical performance.

Probability **–** Defined as pS2 = 0.072. The probability results from the fact that the reduction rate of days spent in the hospital is: 7.2%. This rate derives from the fact that the narrowing down of the number of patients hospitalized on the first day is: 5.2%. To this, 2% are added on the second and third days. The defined field of values for the sensitivity analysis is: 5%-20%.

Payoff – defined as: *Q2* and calculated by the following equation:

$$Q2 = \frac{\left(MHRate \times MHDays + WHRate \times WHDays \right) \times UHos}{365}$$

where:

MHRate – is the percent of hospitalized males (50.4%).

MHDays – is the average number of days spent in the hospital for men (3.63).

WHRate – is the percent of hospitalized women (49.6%).

WHDays - is the average number of days spent in the hospital for women (3.53).

UHos – is the added utility when hospitalization is prevented (0.2)[8].

The result of the calculation is: *Q2* = 0.002.

S3 – Describes a situation where the historical information shortens the diagnostic process and significantly improves medical outcomes, even to the point of saving a life, i.e., a situation of endocarditis or pulmonary embolism.

Probability: defined as: pS3 = 0.005 (1:200[9]. The defined field of values for the sensitivity analysis is: 0.01- 0.001.

Payoff – is defined as: *Q3* and is calculated by the following equation:

$$Q3 = U1 \times \left(MHRate \times \left(MLifeExp - MAgeAvg. \right) + WHRate \times \left(WLifeExp - WAgeAvg. \right) \right)$$

where:

U1 is the utility of a patient at the age of 70 (0.9) in QALY units.

QALY quality coefficient – 0.9[10]

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[7] See: http://www.hsph.harvard.edu/cearegistry

[8] The patient is asked (using the the Visual Analog Rating Scale): "How much is it worth to you not to be hospitalized?" Estimate: 0.2. Estimate for sensitivity analysis: 0.1-0.6.

[9] According to the evaluations of experts (Results from a pilot and prior studies that was conducted by the authors)

MHRate – is the percent of hospitalized males (50.4%).

MLifeExp – is the average life expectancy for men[11] (77.6).

MAgeAvg – is the average age of the men hospitalized in the internal medicine

department (65.8).

WHRate – is the percent of hospitalized women (49.6%).

WLifeExp – is the average life expectancy for women[12] (81.8).

WAgeAvg – is the average age of the women hospitalized in the internal medicine

department (70.7).

The result of the calculation is: *Q3* = 10.3.

Capitalization of the Model Values

In order to receive realistic results, we entered a capitalization calculation into the equation:

Q3D = QALY Discounted

Assumption: The capitalization rate is: r = 0.03.

The capitalization equation is: $q = \dfrac{1}{1+r}$.

Hence: $$Q3D = Q3 \times \frac{q - q^n}{1 - q}$$

The Second Chance Node – The Second Scenario: Low contribution of historical information

In a situation where the second scenario occurs, there is also an additional node on the first chance node, together with the three situations – S1, S2, S3. However, in this case, we are talking about a possibility where the determined probabilities are multiplied by a factor of[13]: 0.5 (Rr=0.5), where Rr is defined as the relative reduction rate of the payoff in a situation where the contribution of the historical information is low. The use of this factor results from the need to assign a relative weight to the probability of the utility received when the contribution of the historical information is either high or low.

RESULTS

Result No. 1: Added Expected Utility

Figure 6 presents the calculated tree. The calculation was carried out by rollback of the tree via the software. The calculation was carried out by weighing the averages of both the probabilities and utilities from the different branches, starting with the branches located on the tree's edges and working inwards towards the root node.

It was found that the added expected utility in QALY units (Q) resulting from the use of historical information is: 0.0687.

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[10] According to the evaluations of experts (Results from a pilot research that was conducted)

[11] According to the Central Bureau of Statistics

[12] According to the Central Bureau of Statistics

[13] According to the evaluations of experts (Results from a pilot research that was conducted)

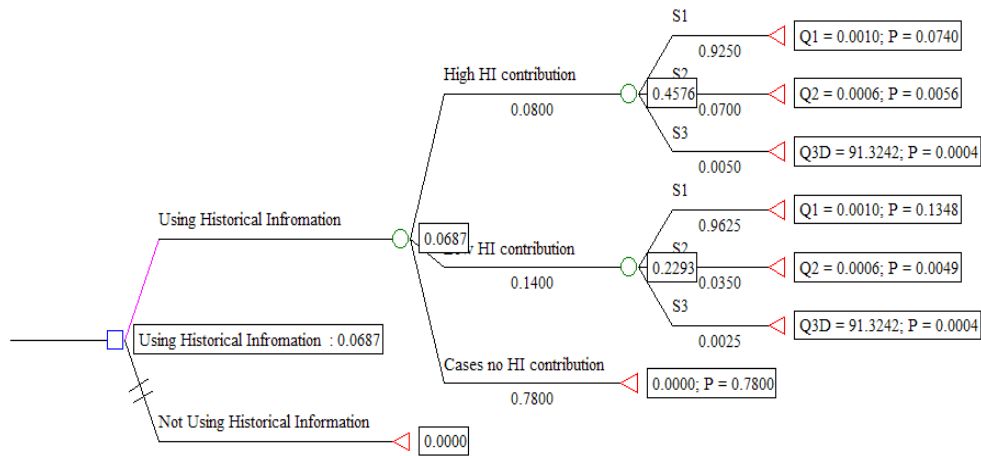This value will be used as a basic assumption for the cost/effective analysis.

Figure 6. The Decision Tree Model – after rollback

Cost-Effectiveness Analysis

Assumptions:

- Life expectancy of the information system: 15 years
- Number of hospitalized patients per year in the internal medicine department of the sampled hospital: 11,000
- Added expected utility for the patient (Q) as a result of using historical information is 0.0687 QALY units.
- The cost of adopting the system, in the first year, for the sampled hospital's internal medicine department is: $1,000,000.
- The cost of the system for every additional year (for a 15-year period) is 15% of the system's initial cost.

Result No. 2: The worthwhile investment cost of the information system

Table 1 presents the utility calculation of using historical information versus the cost of adopting the information system. First, the cost of hospitalization for the patient (ΔC) was calculated, by dividing the Total Cost (C) by the number of hospitalized patients (N). The result was: $91. Next, the added expected utility in QALY units was calculated by dividing the Total Cost of hospitalization for the patient by the added expected utility for the patient (ΔQALY).

Year	N admitted patients	ΔQALY for admission	Total Cost of the System (C)	Patient's admission Cost	ΔC/ΔQALY
1	11,000.00	0.0687	1,000,000.00	91.00	1,325
2	11,000.00	0.0687	145,631.07	13.24	193

Table 1. Worthwhile Investment Cost (in US dollars) for the Information System

The first row of the table shows that, according to the model's assumptions, in the first year of adopting the system, the added expected utility of one QALY unit is $1,325 per patient per admission. The second row presents the data in the second year, which includes only management and maintenance costs at a rate of 15% of the system's initial cost. The result is that the added expected utility for one QALY unit for the patient is: $193 (at a 3% capitalization rate). The discussion section below explains this result in the context of decision and policy making.

Result No. 3: Sensitivity Analysis of the added expected utility

In order to achieve broader results, sensitivity analyses on the cost-effectiveness results were conducted.

Total Cost	ΔC/ΔQALY
500,000	663
750,000	994
1,000,000	1,325
1,250,000	1,654
1,500,000	1,984
1,750,000	2,317
2,000,000	2,648

Table 2. Sensitivity Analyses of the added expected utility

Table 2 presents the sensitivity of the results – added utility per QALY unit in the first year – as a function of system's cost. The left column presents different cost possibilities of the system. The right column presents the added expected utility per QALY unit as a function of the system's cost. A direct relation may be seen between the cost of the system and the added expected cost per QALY unit. Likewise, it can be seen that when the system's cost doubles ($2,000,000), the added expected cost per QALY unit will be $2,648. In the discussion later it will be explained that, according to what is generally accepted in the medical field, this is the cost that is considered worthwhile.

Tornado Sensitivity Analysis

Result No. 4: The variables with the biggest potential influence

The purpose of sensitivity analyses is to examine how the changes made to the values of the model's variables will influence the model's final results (Q = 0.0687). In order to examine which variables have the most influence, a Tornado sensitivity analysis was conducted. Tornado diagrams allow us to map out the results of a first-order sensitivity analysis[14] for each set of variables in the model along a one-axis system. For each variable, the diagram shows the range of possible results in descending order, where the variable from the widest value appears at the top, and thus shows which of the model's variables have the greatest potential influence on the model's results.

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[14] First-order sensitivity analysis makes it possible to examine the sensitivity of model's results to the changes in the value of only one variable, where the rest of the variables remain constant.
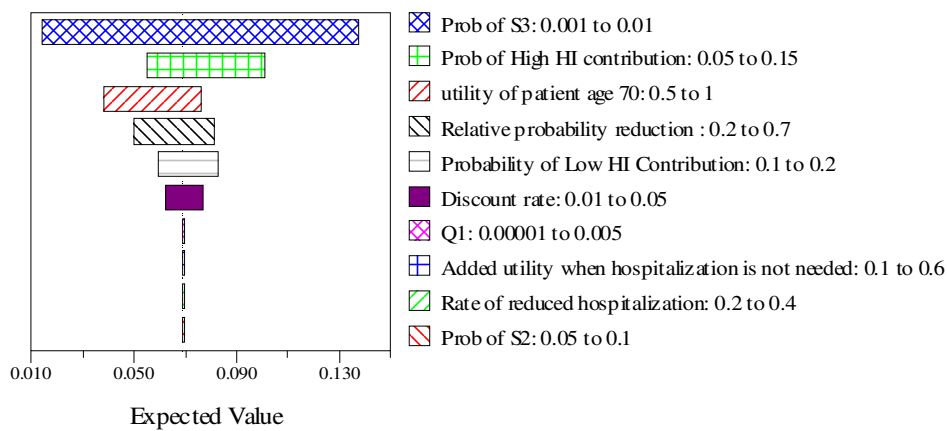
Figure 7. Tornado Sensitivity Analyses

In Figure 7, we see that there are 6 variables for which it is worthwhile to conduct a sensitivity analysis. Below is a detailed explanation of these variables, arranged by their order of influence:

pS3 – the probability that possibility S3 will occur – a situation in which the historical information shortens the diagnostic process and causes a significant improvement in the medical results, even to the point of saving life.

pHHIC – probability in the case where the contribution of the historical information is high.

U1 – The utility of a patient at the age of 70.

Rr – The relative reduction rate of the utility between the case where the contribution of historical information is high, and the case where it is low.

pLHIC – probability in the case where the contribution of the historical information is low.

R – rate of capitalization.

Sensitivity Analyses of the Model

Sensitivity analysis was conducted for the three most influencing variables of the model (according to the Tornado Analysis).

Result No. 5: Sensitivity Analysis for the (pS3) probability
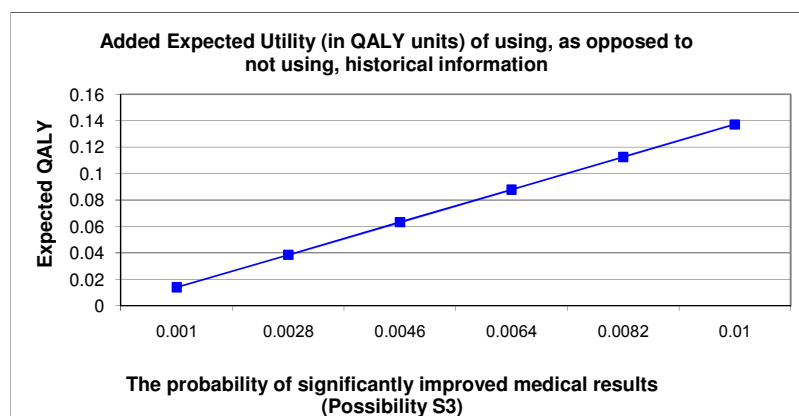

Figure 8. Sensitivity Analysis for the pS3 Probability

Figure 8 presents the results of the sensitivity analysis for the pS3 variable. S3 describes a situation where the historical information shortens the diagnostic process and significantly improves the medical results, even to the point of saving life. The results of the sensitivity analysis - which examines how the changes in the probability of this situation occurring between the values 0.01 – 0.001 - indicate that the range of added QALY for the patient is between: 0.14-0.014 QALY units.

Result No. 6: Sensitivity analysis for the variable that represents patient utility at the age of 70
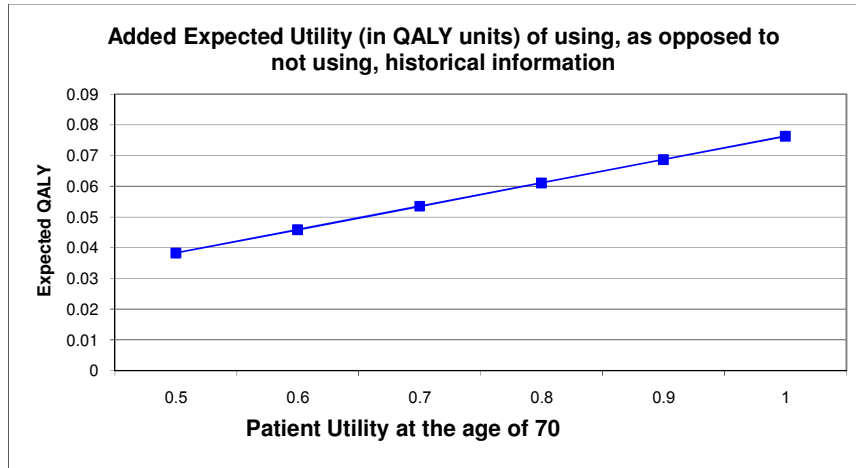

Figure 9. Sensitivity Analysis for the Variable: U1

Figure 9 presents the results of the sensitivity analysis for the U1 variable (patient utility at the age of 70). The results of the sensitivity analysis - which examines the influence of a change in this value between the values 0.5-1 - indicate that the range of added QALY to the patient is between 0.038-0.076 QALY units.

Result No. 7: Sensitivity Analysis for the variable that represents the relative reduction rate of utility between a case of high contribution and one of low contribution
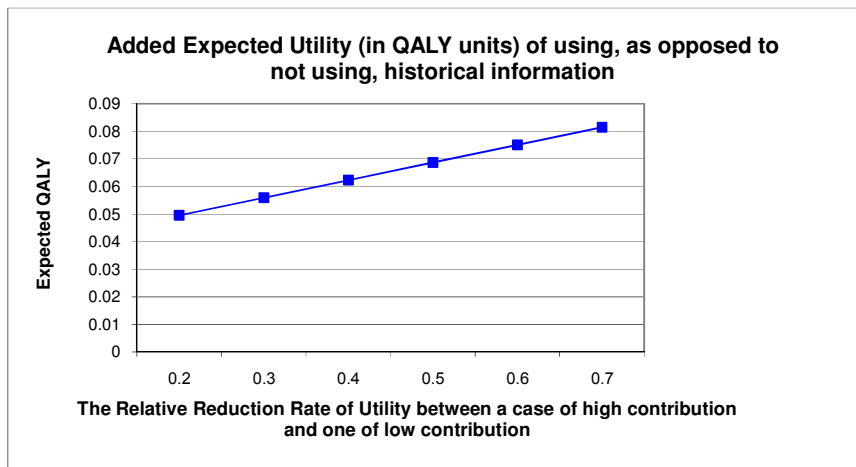

Figure 10. Sensitivity Analysis for the Variable: Rr

Figure 10 presents the results of the sensitivity analysis for the Rr variable (the relative reduction rate of the utility between a case where the contribution of historical information is high, and the case where it is low). The results of the sensitivity analysis - which examines the influence of a change in this value between the values 0.2-0.7 - indicate that the range of added QALY to the patient is between 0.049-0.081 QALY units.

Monte Carlo Simulation

The model that has been described is a values based model, which provides a base for running sensitivity analyses. The second version of the model, which includes functions instead of values, was built in order to provide a base for running Monte Carlo simulations. Monte Carlo simulations allow us to examine the likelihood of the utility expected values, rather than just the possible utility values, in terms of QALY units. The probability calculation is based on assigning a possible distribution for each variable value, rather than just a value field, as was done in the sensitivity analysis. In the research field of medical science, it is common to assign a value field for variables, divided according to a β function – which provides values between 0-1 (Pauker and Kassirer, 1987). Monte Carlo simulations assign values for each of the variables in the model according to defined functions, and calculate the result for each and every case. The number of cases in the simulation is pre-determined. In the end, the calculated results function for all of the cases is presented.
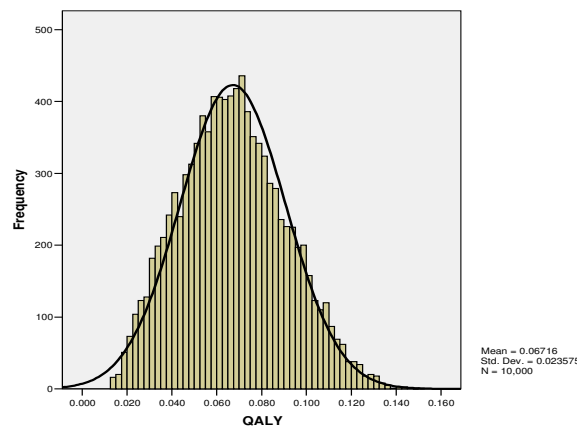
Result No. 8: Monte Carlo Simulation

Figure 11. The function of Added Expected Utility via Monte Carlo Simulation – 10,000 Cases

Figure 11 presents the results of the Monte Carlo simulation for 10,000 virtual cases. The figure presents the function of added expected utility in the simulation. The average is 0.067162 and the s.d. is 0.02357. These results correspond with the results received in the first model and are within the range of one s.d. unit.

DISCUSSION AND CONCLUSIONS

The main finding of this research is that according to the normative model, it is economically worthwhile (under cost assumptions) to adopt an information system that provides historical information to physicians during the treatment process. It was found that the added expected utility derived from utilizing historical information is 0.0678 QALY units per patient for hospitalization. From the cost-effectiveness analysis, we learned that under the assumed terms of the model, the added cost per QALY unit in the first year of adopting the system is $1,325 for the patient. The results are valid as regards the internal medicine department at the sampled hospital. It is limited to in-patient and it is less obvious for outpatient. It is unclear whether the results are generic or not and whether it is possible to claim generalization with certainty regarding other departments in other hospitals.

The important issue is the worthwhile cost for adopting an information system. In the world of medical decision-making, and among the factors that determine healthcare resource allocation there are certain recognized and accepted work regulations. There are also certain rules of thumb regarding healthcare policies in general. In the Medicare organization in the US, the accepted rule is that an investment geared towards improving the medical process which costs more than $50,000 (as a threshold value) per QALY unit per patient, is not worthwhile. Everything below this amount is perceived as worthwhile. The most famous case of this type was in 1970, when this organization decided to authorize a dialysis treatment for chronically ill patients whose cost was within the $50,000-range (Neumann, 2005). This is not a usual practice. Other cases show that the wider range of between $50,000-$100,000 is more accepted among other health-care organizations in the US. Research literature also relates to the WTP (willingness-to-pay) index. According to past precedents (for example, in 1997), there were cases where a solution costing over $200,000 per QALY unit was adopted (Hirth, Chernew, Miller, Fendrick and Weissert, 2000). In Britain, the accepted threshold cost is between £20,000- £30,000 (Devlin, Nancy, Parkin and David, 2004).

Regarding the case discussed in the current study, where the cost of the information system ($1,325 per patient), which provides historical information, is lower than the accepted cost threshold, the conclusion is that the investment is extremely worthwhile.

REFERENCES

1. Ahituv, N., Neumann, S. (with Riley, N.) (1994) Principles of information systems for management, *WM. C. Brown*, 4th ED.

2. Ahituv, N. (1989) Assessing the value of information: Problems and approaches, *Proceeding of ICIS – 89, Boston, MA.*, pp. 312-325.

3. Ahituv, N. (1980) A systematic approach toward assessing the value of an information system, *MIS Quarterly*, pp. 61-75.

4. Shortliffe, E. H., Perreault, L. E., Wiederhold, G., Fagan, L., M. (2001) Medical informatics - Computer applications in health care and biomedicine, *Springer, 2nd Edition*, New-York.

5. Brailer, D.J., Terasawa, E.L. (2003) Use and adoption of computer-based patient records, *HealthCare Foundations*, Oakland, CA.

6. Shabtai, I., Leshno M., Blondheim O., Kornbluth J. (2007) Value of information for decision making processes in the healthcare environment, *Medical and Care Compunetics 4*, IOS Press.

7. Neumann, PJ. (2005) Using cost-effectiveness analysis to improve health care: Opportunities and barriers, *Oxford University Press*: Oxford, pp.157-158.

8. Hirth, RA, Chernew ME, Miller, E, Fendrick AM, Weissert WG. (2000) Willingness to pay for a Quality-Adjusted Life Year: In search of a standard, *Medical Decision Making*, 20:332-342.

9. Devlin, Nancy, Parkin, David. (2004) Does NICE have a cost-effectiveness threshold and what other factors influence its decisions? A binary choice analysis, *Health Economics*, 13(5):437-452.

10. Phillips, C, Thompson, G. (2001) What is a QALY ?, *http://www.evidence-based-medicine.co.uk*

11. Williams, A. (1994) Economics QALY's and medical ethics: A health economist's perspective, *Center for Health Economics*, University of York, No. 121.

12. Pauker, S.G., Kassirer, J.P. (1980) The threshold approach to clinical decision making, *The New England Journal of Medicine*, Vol. 302, No. 20, pp. 1109-1117.

13. Pauker, S.G., Kassirer, J.P. (1987) Decision analysis, *The New England Journal of Medicine*, Vol. 316, No. 5, pp. 250-258