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Assessing the Economic Efficiency of Using Information Technologies in Medicine: World Practice

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Abstract—The topic of how to assess the economic efficiency of medical information technologies in a model of the system of electronic medical records is considered in this paper. The paper also gives an analysis of foreign approaches that would be interesting to consider for application in Russian conditions to assess the economic benefits of introducing the above information system in inpatient and outpatient care facilities.

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Assessing the economic efficiency of medical information technologies calls for a quantitative comparison of costs and results. If the required indicators can be obtained, the efficiency can be estimated using known methods of economic efficiency evaluation for investment projects [1–4]. The latter approach is the most common and, therefore, most difficult to use for specific projects differing from traditional investment projects adopted by industry. The main difficulty in the application of this approach (as well as of all other approaches) to projects for introducing information technologies in medicine is how to estimate their economic effects.

The next step in coming closer to a solution for the above task is to analyze common approaches to evaluating the efficiency of information systems irrespective of their domain. We should note here the lack of methods reliable in terms of practical application. Practical designs are available only for particular cases where specific conditions related to the type and domain of information systems introduced are assumed.

Since a unified approach to the evaluation of information technologies' economic efficiency is not available, special methods must be developed for information systems aimed at solving particular management problems, especially in medicine. Such methods are mostly of a heuristic nature and are based on the study of costs and economic effects after the introduction of information systems in a particular case. If the costs and effects of implementing such systems can be evaluated, it is possible to subsequently apply the above common approach to assessing the economic efficiency of investment projects.

The preferred level in solving the problem of assessing the efficiency of medical information systems is hardly attainable; therefore, a positive achievement here would be revealing the positive effects of introducing a particular information system in which each effect is measured by specific quality parameters.

The above deductive logic in the development of methods for evaluating the efficiency of medical infor-

mation technologies is observed in the below analysis of the present state of studies in the topic in question.

A General Approach to Evaluating the Economic Efficiency of Investment Projects. Universal methodological recommendations for evaluating the efficiency of investment projects contain general principles and are suitable only for the most typical industrial projects. These methodological recommendations point to the need for using special procedures to assess the economic effects derived from non-standard situations (e.g., in projects for developing science and technology and environmental projects), one sign that the above methodological techniques are aimed at application broader than just the manufacturing of commodities. Such techniques for assessing efficiency should define the preferred area for investing funds among all potential areas in industry, science, public medical, and so on. The same methodological guideline should enable us to compare the efficiencies of any nonstandard projects with those of industrial projects, since the same financial resources are invested in both categories of projects.

One problem of evaluating the efficiency of information technologies is describing their effects, which are not revenues from sales of products output and thus differ from the effects of industrial investment projects. The existing methodical guidelines contain references to the probability of such situations. They underline especially that investment is made to acquire a benefit. The term “benefit” is used to show that the purposes of investment projects are not limited to a net profit in sales, but can take on other forms, e.g., the saving of funds and the prevention of losses.

Apart from the UNIDO manual [5], the recommendations contained in *Methodical Recommendations for Evaluating the Efficiency of Investment Projects*, approved by the RF Ministry of Economics, Ministry of Finances, and State Committee for Construction (Gostroi) [2], are followed in Russia. These guidelines meet the economic conditions of the transition to a market economy, which assume the unification of efficiency

evaluation methods and agree with the methods and approaches proposed in the UNIDO Manual [5] and in the Soviet recommendations of 1988 [6].

In accordance with the above methodical guidelines, four indicators are considered: net present value, profitability index, internal rate of return, and payback period. Since a single criterion is insufficient for evaluating a project, a decision should be made on the basis of all the criteria indicators.

The main obstacle to the use of these guidelines for evaluating economic efficiency of medical information technologies is the lack of a clear idea about the effects reached in each year of the period under evaluation.

Analysis of Studies on the Efficiency of Information Systems. The problem of evaluating the efficiency of information technologies emerged with the appearance of automated control systems. The guidelines in *Methodical Recommendations on Evaluating the Economic Efficiency of Automated Systems for Controlling Enterprises and Production Associations* were approved in 1975 [7]. However, the above guidelines had a limited sphere of application and were used only at enterprises where the objective accounting of expenditures and revenues was possible (e.g., at transport enterprises) [8].

At present, the concept of information technologies being fundamentally unprofitable is rapidly being consolidated. "Application of computer technology merely adds a new quality to management, and does not change its essence. This is just a generational change in the tools for dealing with data" [9]. To spend time and money on calculating "the economic effect of introducing corporate information systems means an even greater increase in the losses associated with its introduction" [Ibid.].

Certain advantages from the introduction of information technologies are real, however. Primary advantages usually include well-informed management, reduced labor costs in accounting, fewer losses from errors in accounting, and increased precision and efficiency in routine management procedures. Secondary advantages include increased manageability, enhanced survivability on the market and competitiveness, fewer losses from management errors, and improved interaction with partners [8]. The difficulty is how to measure these benefits in economic terms.

Another approach was suggested and developed by Peter Strassmann in his numerous works [10]. Since it frequently seems impossible to follow quantitatively the economic effect of information technologies, the efficiency of introducing information systems can be considered in the aspect of their effect on such basic financial components as volume of sales, volume of circulating capital, product costs, and market share. Changes in these components are manifested as a result of modernization in the production management structure. Strassmann introduced the concept of Return on Management. His definition of this concept unites it with the concept of intellectual capital (or intangible

Table 1. Structure of costs in the introduction and servicing of information systems

Item	Share in total costs, %
1. Software	25
2. Management	21
3. Support	16
4. Development	6
5. Communications	4
6. Human factor	21
7. Idle time	7

Source: [13].

assets), estimated as the difference between the market value of a company's equity and its net equity assets. Strassmann believes that his Return on Management indicator thus reflects the effectiveness of information used at an enterprise. This concept, however, is much broader than the effect of using information systems.

The topic of our study is efficiency assessment methods specifically for information systems, and we may perhaps mention the Total Cost of Ownership (TCO) model as the general method used in this field. This model is aimed at comparative efficiency assessment, since it is based on the following premise: when two information systems are characterized by the same effect, comparing their implementation and maintenance costs is sufficient for choosing the more effective of the two. Thus, the need to solve the most complicated problem—assessing the benefits obtained thanks to information systems—disappears. The sphere of practical application of this method becomes substantially narrower, however, due to the assumption made with regard to the identity of the compared projects' output parameters.

The TCO is understood as the aggregate estimated annual costs of a company (and not only for its IT unit) that relate to the acquisition and—this is especially important—use of information technologies in business [11, p. 53; 12]. This implies not only the company's direct costs, but its indirect, hidden costs (e.g., losses due to users' idle time).

The work done under the TCO model focuses the estimation of costs, and substantial results have been achieved in classifying them, measuring them, and determining their structure. The Gartner Group's version of the TCO model, developed in the mid-1990s, has become the most popular variant [11, 13]. Microsoft distributed its costs under the basic TCO model in the following way (see Table 1). The human factor is understood as unscheduled indirect costs related to the errors and difficulties in working with information systems that lead to nonproductive expenditures of users' time and resources.

The latest results from research on the costs of information technologies are presented in manuals [14, 15].

Counting the costs associated with the introduction and use of information systems (ISes) can also help discover more effective versions of them by comparing them to systems with analogous effects. Such accounting is a vital stage in evaluating overall economic efficiency, since this assessment is a comparison of benefits gained with costs incurred.

In the absence of one generally recognized universal method, the process of evaluating economic efficiency in ISes is largely transformed into research work that requires us to devote the study to a particular subject. In our case, the subject was medical institutions.

Approaches to Evaluating the Economic Efficiency of Medical Information Technology. The main difficulty in applying our general approach to projects for introducing information technologies in medicine is assessing the economic impact of their effects. One opinion is that the introduction of medical information technologies (and, most likely, any other information technologies) is exclusively a matter of costs, while the return on them is expressed not in terms of value indicators, but only in qualitative evaluations: improvement in the quality of medical service, improved performance by medical staff, better patient medical, and so on. In fact, this opinion emerged not because of an actual lack of economic benefits from the introduction of information technologies, but because there were no developed methods for measuring their economic effect.

We can use foreign evaluations in assessing the economic efficiency of medical information systems, since developed countries have had many years of practice in computerizing their public health care systems. This paper analyses some literature sources on the problem in question.

The most important and instructive model among applied medical information technologies is the electronic medical record systems (EMRS) model. In European countries, electronic medical records have replaced traditional paper records by 50 to 90%, and in the United States by 70% [16].

Since the return on the introduction of medical information technologies is on the whole created with the funds saved in the areas of spending they affect, the end economic effect can be estimated by compiling as long a list as possible of the benefits they provide. The following benefits from the introduction of medical information technologies are the most appreciable:

- a reduction in the number of operations involving records and the possibility of easily copying records;
- cost benefits from more efficient use of pharmaceuticals;
- cost benefits from more coordinated laboratory and radiological investigations;
- shortened hospital stays;

—administrative benefits when dealing with payment paperwork.

It is also noteworthy that the above benefits from the introduction and wide use of EMRS are coupled with the economic effect of other factors, e.g., exchanging clinical information on patients between medical institutions. A particular case of such an exchange is the interaction between outpatient and inpatient care units. The economic effect of this aspect is, however, little studied so far.

The review [17] classifies in detail the benefits from the application of medical information technologies in the outpatient and inpatient sectors:

Outpatient sector:

- cost benefits from electronic medical records;
- reduced labor inputs in medical record keeping;
- cost benefits from the avoidance of duplicative and unnecessary testing;
- cost benefits from more efficient utilization of pharmaceuticals;
- cost benefits from the avoidance of needless radiological examinations.

Inpatient sector:

- cost benefits from reduced the amount of time nurses spend on paperwork;
- cost benefits from electronic medical records;
- cost benefits from the avoidance of duplicative and unnecessary testing;
- cost benefits from more efficient use of pharmaceuticals;
- cost benefits from shortened hospital stays.

The amount of savings from each of the above benefits were quantitatively estimated through timing the work of medical staff, interviewing experts, comparing costs before and after the adoption of information systems, direct accounting for pharmaceuticals, and so on.

We shall now consider the assessments of the financial effects of each kind of benefit from medical information technologies in succession.

Benefits from the Reducing the Number of Actions with Records and the Possibility of Easily Copying Records.

Outpatient sector. EMRS reduces or eliminates altogether the need for staff to fetch outpatients' paper records. Savings are achieved due to the absence of staff responsible for fetching and handling paper records; once a patient's data has been recorded, a physician can quickly retrieve them in the future and acquaint himself with all of the record's data; the data do not require any physical space that might be used for better purposes. Institutions that adopt EMRS do, of course, continue to receive paper documents in the forms of laboratory reports, orders to physicians, and so on. Cost saving is also possible here thanks to the EMRS scanning of paper documents and their use by any physician without additional searches through

paper documents for the information they need. Since a document is converted into the electronic form only once, staff labor inputs on work with documents can be further reduced.

The literature data on cost savings due to the introduction of EMRS vary. The cost savings over record keeping by medical staff are estimated at 63.4% [16].

Work [17] gives the following estimation: a reasonable period of time for copying out a paper record is about four minutes. The figure for copying out paper records of one doctor for one day exceeds the number of visits by a factor of 1.6 (e.g., for the reason, perhaps, that some copying out is done as a result of telephone contacts between a doctor and patient, or between doctors). With an average work load—15 patients a day 5 days a week for 48 weeks—one doctor copies out 5760 documents a year, the equivalent of 384 working hours or \$5530 dollars per year, according to data on the United States.

Inpatient sector. The EMRS allowing nurses to access patients' medical records provides savings due to the shorter amount of time the nurses spend on documents and superfluous data searches, the reduction in expenses associated with paper forms, and the prevention of many accidentally overlooked procedures. The decision making support mechanisms found in such systems can coordinate treatment by automatically reminding nurses of the need for assistance from auxiliary services.

It is generally the reduction in the time needed to deal with documents that is assessed. It has been determined that EMRS allows clinics to reduce the number of operations with medical records by 60–70% and to cut the staff that deals with documents by 50%. The time saved on paperwork can be used at least in three ways: (1) to cut down the number of nurses recruited; (2) to take better care of the same number of patients; and (3), to treat additional patients without lowering the quality of services.

A model example of the effect EMRS has on reducing nurses' nonproductive time is the study of the time they spend in intensive therapy units [18]: use of EMRS cuts the time a nurse spends on her paperwork by 52 minutes per 8-hour shift. This allows clinics to reduce their need for nurses by 11%.

A study in Norwegian clinics has shown a 10% saving of nurses' time as a result of adopting EMRS [19]. In work [20], these savings were estimated as ranging from 12 to 20%.

Cost Benefits from More Efficient Use of Pharmaceuticals. Medicine costs are reduced owing to the introduction of modules for computerized physician order entries and clinical decision support. Physicians are given the opportunity to use electronic databases on pharmaceuticals, their combinations and contraindications, and so on. The databases help select a therapy that conforms to medical standards and takes into account the cost of the medicines involved, their rational combination, and their

optimum period of use. The various expert evaluations given in some of the literature agree on the point that an electronic system for offering alternative medicines allows clinics to cut their total spending on pharmaceuticals by 15% [16, 17, 21].

Cost Benefits from the Avoidance of Duplicative and Unnecessary Testing. Savings on laboratory tests are considerable at medical institutions that have adopted EMRS with modules for prescribing procedures and tests, and for the support of clinical decisions, owing to the reduced number of unnecessary or duplicated tests. This is because EMRS not only makes it possible for physicians to familiarize themselves with the results of all current and preceding analyses, but to design the best possible schedule for themselves, e.g., in accordance with the administration of particular medicines or with moving from one stage of treatment to the next. EMRS also helps form structured prescription set for analyses to exclude needless testing. Estimates of the savings in these costs put them at around 22.4% of the total cost of laboratory tests in the outpatient sector, and at 11.8% in the inpatient sector. Spending on x-ray investigations in the outpatient sector is reduced by 14% [16].

Benefits from Shortened Hospital Stays. Inpatient hospital stays are accompanied by a multitude of different time losses: delays in orders for tests and treatment, searches for documents, coordinating the orders of different specialists, and so on. EMRS allows clinics to cut time losses to a minimum, thereby shortening inpatient hospital stays. Different estimates based on random checks show that this shortening is anywhere from 10 to 30% of the actual hospital stay.

Benefits from Administrative Work with Payment Documents. More complete recording of all treatments and procedures that have been performed allows them, thanks to EMRS, to be entered in patients' bills, enlarging their bottom line by 2%. Errors made in preparing bills are reduced by 78% [16].

We have so far considered one type of information system introduced in medical institutions, the EMRS. Other information systems, however, are also being developed and adopted, particularly those for computerizing the operation of administrative services. The adoption of information technologies in the management of medical institutions thus provides cost savings on the registration of payment documents by 63% of the average cost [17].

Comparison of the Costs and Effects of Adopting Medical Information Technologies. Work [17] presents a cost model for EMRS in American hospitals, created on the basis of data gathered from the literature or supplied by the hospitals themselves for a total of 27 inpatient units. The model allows us to forecast EMRS costs through consideration of such key parameters of inpatient units as their size and operating expenses. The model does not include technical specifications of EMRS; rather, it characterizes a general

Table 2. Total cost benefits from the adoption of information technologies in American medical institutions

Kind of benefit	Potential annual savings, billions of dollars	Average annual savings, billions of dollars	Share in total savings, %
<i>Outpatient sector</i>			
Cost Benefits from EMRS	1.9	0.9	8.4
Cost benefits from reduced paperwork	1.7	0.8	7.5
Cost benefits from the avoidance of duplicate laboratory tests	2.2	1.1	10.3
Cost benefits from better use of pharmaceuticals	12.9	6.2	57.9
Cost benefits from unnecessary radiological tests	3.6	1.7	15.9
Total	22.3	10.7	100
<i>Inpatient sector</i>			
Cost benefits from facilitating nurses' paperwork	12.7	7.1	22.7
Cost benefits from EMRS	2.5	1.3	4.1
Cost benefits from the avoidance of duplicate laboratory tests	3.0	1.6	5.1
Cost benefits from better use of pharmaceuticals	3.7	2.0	6.4
Cost benefit from shortened hospital stays	36.7	19.3	61.7
Total	58.6	31.3	100
Total by outpatient and inpatient sectors	80.9	42.0	

Source: [17].

EMRS functional unit that includes elements for the computerized entering of physicians' orders and for reports on patient management.

EMRS are divided into two parts: capital investment due to the adoption of EMRS and the yearly ongoing cost of maintenance. The value of service is estimated as a share of the capital costs.

In a majority of cases, the capital investment in EMRS is likely to be scheduled for a period of three to five years, and includes the value of EMRS software, expenditures on local infrastructure (such as networked units and computers), plus labor inputs on the inpatient unit staff involved in adopting and modernizing operations on the basis on information technologies.

The above is illustrated in [16] by the following example: for a clinic that invests \$42 900 in information technologies over a five-year period, the discounted value of the money thereby saved over the same period will be \$129 300. This means a level of profitability of around 200% for the money spent on adopting, operating and maintaining medical information technologies, i.e., an order of magnitude higher than the profitability of costs in the most efficient industries of the economy.

On the whole, the financial benefits that can be derived from the adoption of medical information technologies have been estimated for the entire United States health care system (Table 2).

The potential value of benefits exceeds their average actual value by a factor of almost 2. The table's last column gives the structure of profits from the outpatient and inpatient sectors in percents. As seen from the table, the most significant benefits in the outpatient sector are savings from more efficient use of pharmaceuticals (57.9% of the total savings), savings on radiological tests (15.9%), and savings on laboratory tests (10.3%). In the inpatient sector, they are the profits from shortened hospital stays (61.7%) and from facilitating nurses' paperwork (21.7%).

A different correlation (ignoring the benefits from shortened hospital stays) is presented in paper [16]: most of the benefits from adopting EMRS are derived due to better use of pharmaceuticals (33%), avoidance of needless radiological tests (17%), and fewer errors in bills (15%).

The above effects allow researchers to focus on the same kinds of benefits when conducting analogous studies, if all the advantages of an electronic medical record system are associated with difficulties in obtaining information on costs. The authors of all the works studied emphasize that some benefits were ignored because there were no financial accounts on them available, while other kinds of benefits could not be determined quantitatively, e.g., better quality of medical care and fewer medical errors.

The data of Table 2 allow us to assess the economic efficiency of introducing information technologies in

the American health care system. Since the annual spending for these purposes by the inpatient sector totals \$6.7 billion [17] and the average financial benefits are \$31.3 billion (see Table 2), the profitability of expenditures for medical information technologies in this sector exceeds 350%. However skeptical of this economic efficiency we may be, it exceeds the average efficiency of all branches of the economy to such a degree that these estimates remain demonstrative even if we assume that the cost benefits from adopting medical information technologies are greatly exaggerated in the works that were examined.

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Using the foreign experience on the effects obtained, we can estimate the cost benefits from the adoption of EMRS. To do this, we will need data on all of a medical institution's line items: nurses' annual salaries, according to department; values of all the pharmaceuticals consumed per year; total annual laboratory costs; total annual costs for radiological tests, according to department; the cost of one bed-day, and the total number of bed-days for all patients per year; and all administrative costs. We will need also data on the cost of adopting and operating the medical information systems themselves to logically compare costs and effects in order to assess the economic efficiency of projects to invest in medical information systems.

The need to form the above economic indicators for the functioning of medical institutions poses a new task for medical information systems, that of incorporating an economic segment into such systems. The analyzed results of foreign countries' experience in evaluating the economic efficiency of medical information systems would largely determine the content of such a segment and the sort of work needed to create it. As EMRS is introduced at Russian medical institutions, we shall be writing another paper on the creation of our own system of cost-benefit criteria, and on using them to performing a more precise evaluation of the efficiency medical information technologies.

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