Risk Cash-Flow Evaluation of the E-Health Implementation Project in the Slovak Republic

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Abstract

SENDEK, S.: Risk cash-flow evaluation of the e-health implementation project in the Slovak Republic. The aim of this paper is to present a risk cash-flow evaluation of the e-health / health-IT implementation project in the Slovak Republic. The paper is focused on the economic modelling in the e-health environment. Introducing e-health tools, such as electronic health records or electronic prescription, is preceded by substantial initial investments as well as accompanied by operation costs during the duration of the project. The costs of e-health implementation in Slovakia, as demonstrated by foreign examples and studies, are expected to be overrun by cumulated benefits in medium to long term. The processes in the investment activities are characterized by different alternative cost and/or benefit entries in terms of financial inputs and outputs. According to the type of an investment activity, especially in the healthcare sector, it is necessary to identify and evaluate potential financial impacts. One of the solutions, currently popular in business world, is applying the computer simulation, based on the Latin Hypercube sampling method. By applying the method, potential financial effects of events could be evaluated; events - which might occur in combining different inputs and outputs, predictable with a respective likelihood of occurrence. Based on the e-health cost-benefit analysis (CBA), the probability distributions of the Net Present Value (NPV), as one of the basic indicators of measuring the investment efficiency, will be simulated, calculated and discussed.e-Health, cost-benefit analysis, simulated evaluation, Latin Hypercube sampling method, net present value

Introduction

e-Health is a term which has gone into a widespread use approximately at the turn of the millennium (Aanesena, 2010, Eysenbach, 2001) and, with the burgeoning role of information and communication technologies (ICT) in delivering health care, it is becoming almost a necessary topic worth mentioning in every health care-related research today.

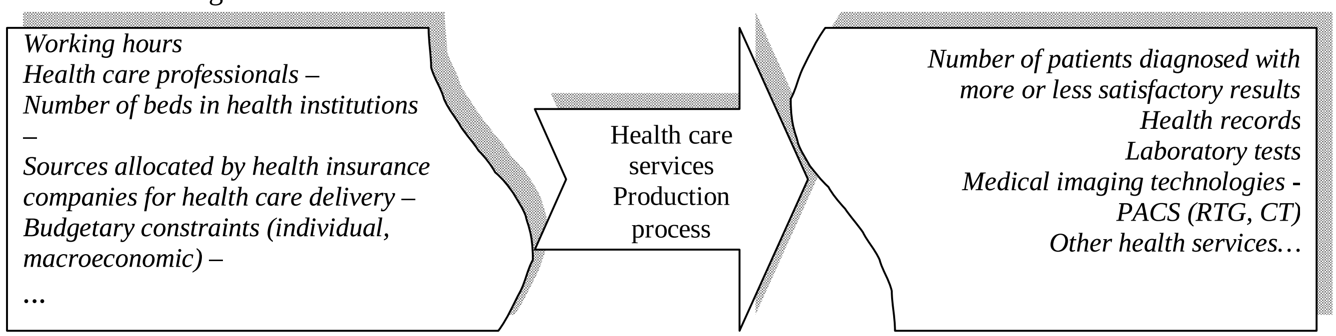
There is no solid definition of “e-health” but, basically, all sources do come into congruence that the term “e-health“, or electronic healthcare /services/, is used to characterize the field of the so-called "internet medicine"; or in other words, the application of ICT for health. The term was apparently first used by industry leaders and marketing people rather than academics alongside terms like e-society, e-business, etc. More concretely, under e-health application /services/ components, we can imagine electronic health record kept by our physician (general practitioner or any specialist); rather than a paper-based record, electronic health insurance cards, electronic prescriptions, telemedicine services (electronic conference calls between physician – physician; physician – patient; etc.), health portals (aiming at prevention, or serving for e-booking – electronic appointments with our doctor, etc.) to name the most important ones.

The goal of this development, at the background of which there are undoubtedly ICTs, is to facilitate, accelerate, and optimize all human activities. A supreme goal of this development and endeavours is to increase the individual’s quality of life. When seeking an increase of the (patient’s) quality of life in health care delivery, then the concept of ‘e-health’ is going to be the subject of scientific discussion. The area into which e-health is going to enter is manifold – conceptual, clinical, social, economic. In 2008 alone, about 80 recognized good e-health practices could be found, compare Aanesena (2010), representing exemplary e-health investment and financial models.

A great deal of influence in e-health implementation is attributable to the ineffective and inefficient clinical procedures, still done as paperwork. An increasing amount of medical and/or clinical errors resulting from the lack of information often leads to harming the patient, or endangering his life in the worst scenario.

Moreover, healthcare costs for treating preventable diseases account for 70% of total healthcare spending, see McGinnis (2001). Considering that the total healthcare spending now constitutes nearly 16% of the US GDP (compared to the 8.5% in the EU), see Heffler *et al.* (2005), moving to paperless form of communication processes in healthcare sector is expected to make also financial contributions in form of benefits that we discuss further.
As both healthcare sector and health care delivery are too time-consuming and demanding in terms of data processing, it is obvious that healthcare shall represent one of those sectors which are going to benefit most from computerization, from e-health, see European Commission (2004) and (2005).

Health Flows. To understand the flows being realized in the health care sector and analyse them, it is necessary to identify basic factors intrinsic to every health care setting, i.e. key inputs and outputs, which might be found in opposite sides to each other depending on the methodology we use.Compare Chilingerian, J.A (1990), Croll *et al.*, (2007), Empirica *et al.* (2005).Some basic inputs and outputs within the health care 'production process' are presented in the Fig. 1:



1: Health Flows. Source: Compare Bannick, 1995 and Empirica*et al.*, 2005.

e-Health benefits. Glasgow (2007), summarizing evidence based on several other studies, explains in detail that understanding the health flows - clinical and those of the whole healthcare system, is an indispensable precondition for identifying the potential benefits resulting from introduction of e-health applications; he goes even further by laying the fundaments for building the whole e-health concept on these flows and digitalization in healthcare setting.

Benefits resulting from the electronic way of health flows in health care are manifold – both quantitative and qualitative, even though the impact might not always turn out to be 'statistically significant' (refer to Aanesena, 2010), since this is dependent on the level of sending data in electronic way, too. The final positive financial impact in the form of decreased cost per unit may be lower, if the piece of information (e.g. a prescription) is sent in both electronic and paper form, i.e. if there are both old and new procedures in place. This is subject to the character and structure of the respective health system, the level of the present paperless form and other factors. These are the most common potential benefits resulting from paperless route of health flows, which are summarized by Frisse M.E *et al.* (2007).

The most important are a) reduction of duplicate health examinations (see Rathlev *et al.*, 2007;Aanesena, 2010), b) reduction of prescriptions – closely related to the duplicate medicines which should not have been prescribed because the patient is already in possession of them, further it is c) cost reduction in the wake of mistakes and errors (see FCG, 2003, p.14; European Commission, 2004, p. 33; Gartner, 2009, p.2, etc.) from preventable rehospitalisation (Dansky K.H. *et al.*, 2009; Rathlev *et al.*, 2007;Seiford, 1997), redundant examinations (Gartner, 2009), drug interactions - reduction in adverse drug events in the wake of the consumption of drugs which should not have been prescribed on account of an interaction(s) with another medicine (Aahern *et al.*, 2006, Babel'a *et al.*, 2008), law suits. It is also d) time reduction for administrative services (European Commission, 2004, pp. 14, 34, etc.), e) better allocation of scarce resources with health care professionals, and other.

However, there are few studies reflecting on quantitative aspects of e-health services until the end of the 2000s.Understandably, with the gradual implementation of e-health services, investment-driven aspects of e-health have been gaining the attention in this field.

There are many other indirect benefits resulting from e-health implementation incl. financial (in the insurance system), healthcare (reduction of morbidity and mortality), social (in terms of social disparities, social cohesion, esp. in remote and thinly populated areas), budgetary on the national level.

The study of Aanesena*et al.* (2010) is special in its methodological approach as it is evaluating quantifiable benefits from adoption of electronic referrals and discharge summaries between hospitals and surgeries, taking delays in adaptation to the new technology into account, i.e. the 'conversion time' needed for transition to new working procedures[1].An overwhelming majority of quantitative studies concentrate on (the benefits of) a selected e-health application[2] rather than demonstrating aggregate (nationwide) impacts and investments eventuating in robust surveys or studies.

One of the first comprehensive studies, based on the cost-benefit analysis (CBA), was issued in 2009, being commissioned by the EU (European Commission, 2004) responding to the EU *eHealth Action Plan*(2004) with a "target to assess the quantitative, including economic and qualitative impacts of e-health" in three investment time periods: planning & development, implementation, and routine operation. Costs include the initial and continuous e-health investments (e.g. cost in ICT and change management) here as well as the running costs of healthcare. This empirical study demonstrates that benefits from effective e-health investments[3] induce better quality, increased productivity which in turn liberate capacity, with greater access (to health care services) as a result. Another robust study, likewise on behalf of the European Commission, is the 2008 *Financing eHealth* report by European Commission (2008), covering analysis of financial opportunities in view of financial e-health investment needs (for governments, third parties). The study shall also help the member states in the investment decision-making process within their respective national e-health programmes. Investment risk in various stages is also covered here. In 2008, there were much more good examples of the e-health deployment (in the EU). Hence, a much more detailed analysis could be carried out than in 2004 (c. study on behalf of the European Commission, 2004).

It is not only in the wake of the on-going global economic and financial crisis since healthcare has become one of the most costly and time-consuming public sectors, challenged by massive cost overruns, serious quality problems, and posed with (healthcare cost) inflationary risk growing more quickly than healthcare expenditures. See Heffler *et al.* (2005).

Materials and Methods

Project background of e-health implementation in Slovakia. The Slovak implementation program (2008-2018), the most part of which being financed from the EU structural funds, is divided into two main stages, each with one central and several supporting sub-projects. Currently, the first stage is being realized which aims at making the basic electronic health services available for both health care professionals, citizens and other stakeholders (e.g. insurance companies) in the healthcare system. The first e-health stage focuses on the computerization of the following domains:
a) ePrescribing / eMedication – i.e. making the process associated with medical prescriptions paperless; controlling process of medicines; b) Electronic health records (EHR)[4] c) eReferrals, eBooking (eAllocation) – providing a more effective management of time and resources related to the provision of health care, and d)National Health Portal – providing relevant health-related information (healthy lifestyles, health best practices, etc.)

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[1] So, there are years accounted in which double procedures are applied, i.e. e-referrals from hospital to surgery are sent both electronically and in a paper form during an implementation period. Hence, benefits from introducing the electronic way of data exchange might be lower by as much as 50 % on the Dynamic Net Present Value comparison. Ibid.

[2] Aanesena et al. (2010) concentrate on economic benefits of electronic data exchange (discharge summaries and e-referrals in hospitals and surgeries). Among many authors it is also Wang et al. who report substantial gains to the providers when implementing a full electronic medical record system ($86,400 per provider over 5 years). Similarly on the electronic health records, c. Hillestad et al. and Heffler et al., 2005.

[3] Among the best practices there are included e.g. German insurance e-card, Danish health network, Swedish e-prescription, Czech health portal, etc.

[4] In its basic form comparable e.g. to the already partly implemented Czech health records "IZIP – Elektronickázdravotníknížka" URL: <http://www.izip.cz>.
EHRs are by far one of the biggest contributors to benefits within e-health (system). C. ref. 2.

It is not only in the wake of the ongoing global economic and financial crisis since healthcare has become one of the most cost- and time-consuming public sectors, challenged by massive cost overruns, serious quality problems, and posed with (healthcare cost) inflationary risk growing more quickly than healthcare expenditures. (Hill, Powell, 2009)

Quantitative risk-oriented studies are considerably missing in the (e-)health research despite the robustness of the (e)health investments (European Commission, 2008), and their impacts on the ever-more demanding health care sector and national budgets, challenged ever more by financial restraints.

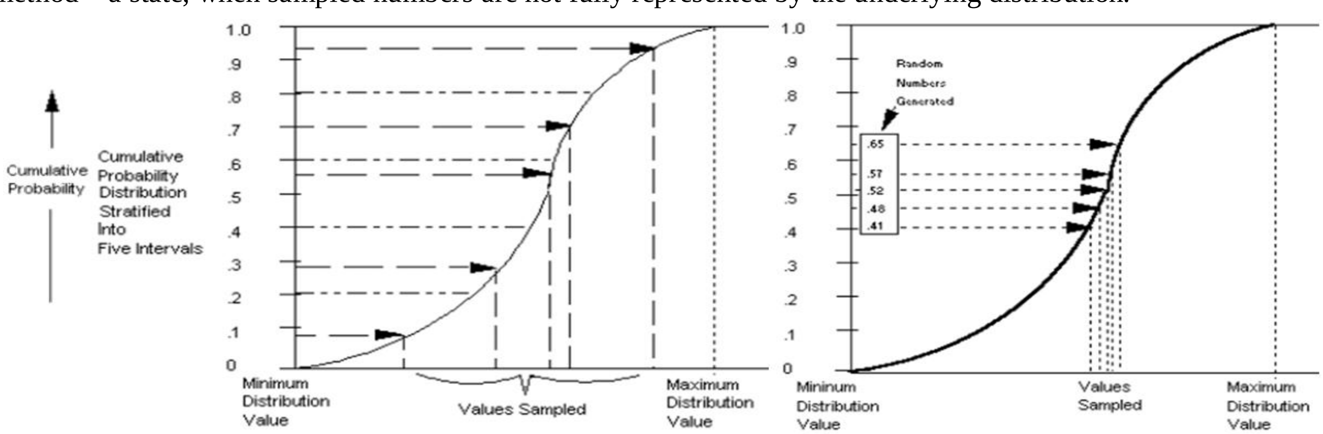
Every investment occurs in an environment characterized by several decision variants, alternative and estimated future costs and benefits and other inputs and outputs with likelihoods of occurrence (based e.g. on historical observations). Hence, for instance, we can assume how many e-referrals or e-prescriptions might be issued in different time periods (e.g. during a year) later with e-health system implemented or being implemented, how many adverse drug events occur after consumption of a medicine as a result of patient’s medical misinformation, or what percentage of running cost of an e-health application is going to be realized, etc.

Taking this approach into account, in order to combine the dynamic CBA analysis based on a discount factor with probability functions, sampling methods (e.g. Monte Carlo and Latin Hypercube, which are discussed later), are among the best solutions to apply. (Varcholová, Dubovická, 2008).

When identifying the inputs and outputs, i.e. when quantifying the costs and benefits in the period 2010-2012, several perspectives had to be linked to subject the input and output variables to an evaluation. Each of the perspectives is analysed over the periods of planning and development, implementation and routine-operation. (Empirica*et al.*, 2005, Empirica GmbH, 2004)Benefits were defined as financial impacts of the interventions concerned, i.e. resulting from changing the form of information flows through computerization. The benefits were measured as reduced inefficiencies in the form of duplicate, fraudulent and erroneous prescriptions and examinations (in form of laboratory tests, x-rays, etc.) respectively as estimates which are measured on samples by Slovak health care insurance companies at least on a yearly basis. The benefits were coupled to the proportion of computerization which is expected to reduce these inefficiencies, i.e. to the proportion of the integration of health care professionals and citizens in the Slovak ‘e-health system’.

Thanks to the sampling method, we make the inputs variable with their probabilities of occurrence, and therefore all the other input/output values based on these inputs, when counting the project profitability with NPV or internal rate of return (IRR) indicators for instance, might also be calculated as results with the given probabilities rather than as static values when applying common calculation procedures. Even though this is not the aim of this article, we will further explain this process a little more in detail.

Sampling methods. Monte Carlo and Latin Hypercube sampling (LHS) methods are based on randomness (c. Ross, 2006, chap. 3), i.e. any output sample may fall from within the given distribution. In the Fig.2 of a cumulated distribution, each number is sampled randomly within 0 and 1. We can see that five numbers have been randomly selected close to each other, which may imply a potential crowding problem with Monte Carlo method – a state, when sampled numbers are not fully represented by the underlying distribution.



2: Five sampling iterations of Monte Carlo (right) and Latin Hypercube (left) sampling methods

Source: Palisade Corporation (2010); Varcholová, Dubovická (2008)

Monte Carlo method, named by S. Ulam in 1946, is a method by means of which it is possible to solve a problem by generating suitable random numbers and observing that fraction of the numbers following some properties. Since we do not have to know the exact numbers which might occur in reality, these properties might be given by a distribution. The method is very useful especially for obtaining numerical solutions to problems which are too complicated to solve (c. Weisstein, 2002).

Latin Hypercube sampling is an improved technique of Monte Carlo. Since its development in 1975 it has been used worldwide in computer modelling applications, risk assessment, propagation of uncertainty in complex systems and models. The most known software solutions for LHS application include Crystal Ball® and @Risk®[5] - the latter used for data analysis presented in this article. The LHS sampling method was designed by Conover as an improvement of efficiency of simple Monte Carlo. It is a stratified sampling method to avoid a possible crowding effect. This stratification is accomplished by dividing the vertical axis on the graph of the (continuous) distribution function of a random of the variable X_j into n no overlapping intervals of equal length, where $n$is the number of computer runs, i.e. iterations, to be made. See Varcholová (2008), Melnick (2008). For more about the simulations and how it works in detail see also Ross (2006) or Robert (2004).

In our analysis, the total number of 100 000 iterations has been used, which means that the distribution of our functions was vertically divided into 100 000 intervals, so random numbers were chosen from each interval, which is not the case in the Monte Carlo method itself since the latter selects a number randomly and independently each time. With Monte Carlo method it might happen, even though with extremely low probability, that within these 100 000 iterations the same number from a distribution could be selected, which is not desirable. See Melnick (2008).

Hence, with the LHS, we got a better representation of data based on the underlying distributions defined in inputs which were selected as uncertain. It means that these inputs have an associated degree of uncertainty represented by the given distribution that we (pre-) selected. Each of the distributions defined for a given ‘uncertain’ input describes a certain set of possible future input values in time, and is replaced by one fixed value chosen by the sampling method (LHS) in each iteration. We will demonstrate this further in more concrete examples.

e-Health Cash flow in the environment of the Slovak Republic. The dataset, upon which our CBA is based, is robust and complex. It has been assembled during a period of one year, and incessantly being updated in relation to the new fundamentals during the e-health project implementation.[6] The dataset extends through the period of 11 years with individual projected cost and benefit inputs. There are some underlying assumptions such as number of fraud prescriptions based on estimates of Slovak health insurance companies, number of health care professionals using the Slovak e-health information system once this is implemented in future, etc. Understanding the processes behind the e-health implementation is fundamental in the analysis.

Since the underlying dataset robust and extensive and cannot be presented here, the following Tab.I illustrates the fundamental cash-flow analysis of the underlying dataset with total costs and benefits of four e-health domains[7], cash flow (CF)/balance and cumulative cashflow (CCF) in 2010 through 2020. All inputs are based on the CBA analysis, expressed in monetary values (millions of euros). Some assumptions, such as total health care expenditures to 2020 are also proven Radvanský M., Dovaľová G. (2013). Tab. II illustrates some selected important assumptions which are expected to be realized when e-health implementation gradually proceeds in time.

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[5] @Risk for Microsoft Excel; Risk analysis and simulation Add-in for MS Excel by Pallisade Corporation. URL: <http://www.palisade.com/>.

[6] Some underlying basic data, some of which are presented in Tab. I and II, may be found on the Slovak official e-health information portal on URL: <http://www.ezdravotnictvo.sk/Documents/NZIS.pdf> or <http://informatizacia.sk/index/open_file.php?ext_dok=13237>. The whole cost-benefit analysis has been assembled on data inputs from Slovak health insurance companies, National Health Information Center (URL: <http://www.nczisk.sk>.), and Ministry of Health of the Slovak Republic (URL: <http://http://www.health.gov.sk/>).

[7] The e-health domains and their benefits were partly discussed above, or can be alternatively found in the studies cited here.

I Elementary cash-flow analysis of e-health system in Slovakia

[mil. €]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Total costs	6.7	15.0	36.2	34.5	14.5	10.5	10.5	11.1	10.8	10.8	10.9
Total CAPEX	6.7	15.036	31.535	23.875	3.918	0	0	0	0	0	0
Total OPEX	0	0	4.688	10.654	10.536	10.452	10.544	11.124	10.820	10.848	10.944
1.1 ePrescription	2.364	5.307	12.641	11.620	4.506	3.069	3.076	3.255	3.122	3.107	3.115
1.2 EHR	1.575	3.535	8.420	7.739	3.001	2.044	2.049	2.168	2.079	2.069	2.074
1.3 e-health portal	0.789	1.772	4.221	3.880	1.505	1.024	1.027	1.087	1.042	1.037	1.040
1.4 eReferrals	1.970	4.421	10.940	11.288	5.441	4.314	4.391	4.612	4.574	4.634	4.714
2. Total benefits	0.0	0.0	0.2	10.4	32.4	52.1	63.8	75.1	86.2	97.5	109.1
2.1. ePrescription	0	0	0.219	9.933	27.705	42.879	53.908	64.898	75.888	87.136	98.578
2.2 EHR	0 €	0 €	0 €	0.493	4.664	9.243	9.853	10.164	10.266	10.369	10.472
BALANCE(CF)	**-6.7**	**-15.0**	**-36.0**	**-24.1**	**17.9**	**41.7**	**53.2**	**63.9**	**75.3**	**86.7**	**98.1**
CUMULATIVE(CCF)	**-6.7**	**-21.7**	**-57.7**	**-81.8**	**-63.9**	**-22.3**	**31.0**	**94.9**	**170.2**	**256.9**	**355.0**

II: Some selected derived assumptions

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Savings from fraudulent prescriptions	0.00%	0.00%	0.01%	0.68%	1.59%	2.09%	2.60%	3.10%	3.61%	4.11%	4.62%
Savings from unnecessary duplicate prescriptions	0.00%	0.00%	0.00%	0.07%	0.51%	1.15%	1.47%	1.77%	2.06%	2.35%	2.64%
Savings from duplicate examinations	0.00%	0.00%	0.00%	0.14%	1.28%	2.51%	2.65%	2.71%	2.71%	2.71%	2.71%
Effectiveness of elimination of duplicate and unnecessary prescriptions	0%	0%	10%	67%	90%	90%	90%	90%	90%	90%	90%
% of health care providers connected	0%	0%	3%	70%	90%	93%	95%	95%	95%	98%	99%
% of citizens connected	0%	0%	6%	19%	32%	42%	52%	62%	72%	82%	93%

Based on these data, the actual cost and benefit inputs have been evaluated. The data for the first three time periods (years 2010 to 2012) are real, and hence certain, so they do not need to be represented by any distribution. First e-health benefits are expected in 2013.[8] As for the future values, we defined distributional (functional) behaviour of possible future occurrence or non-occurrence for two following fundamental inputs. Based on the rough estimates of governmental predictions, the distributions were selected and defined. This demonstrative selection and definition aims at incorporating the risk factors while trying to 'dynamically capture' the real possible occurrence of future events. These defined distributional inputs, as we explain further, are really essential for a well-functioning e-health system because without them only few (financial, socio-economic, etc.) benefits from e-health would materialize.

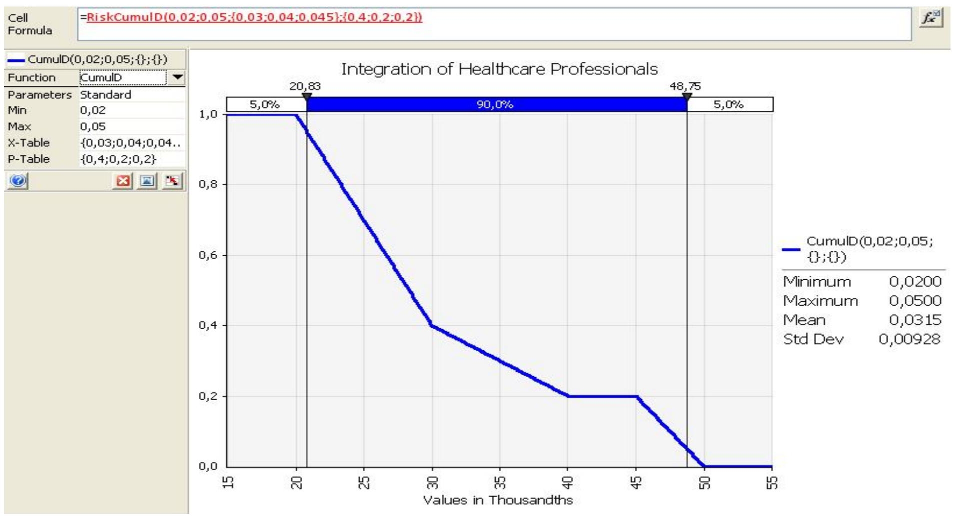
There are two crucial factors entering whatever e-health implementation design of any country, which is the measure of connectedness of health care providers on one side and citizens (patients) on the other. Without any of these two key stakeholders, e-health system would be hardly, or only on a very limited basis, functioning. This is why we focused our simulations on these two groups. There were two underlying functions selected from the set of functions predefined in @Risk® 6 which had to be selected after due consideration which consisted in judging the suitability with the function's parameters to be defined so as to reflect the future reality as much as possible. There were no previous studies found which would support the selection of these pre-defined functions in the software to predict the future. On the other hand, cumulative and triangular functions which were selected are easily definable, and are expected to reflect the real patterns. Each function has its own parameters to be entered. The function itself is then displayed and simulated by the software solution. This is one of the key reasons why computer-based simulations to predict the future is still more popular and used. The model can be incessantly updated throughout the life cycle of the project.

[8] However, a short suspension of the project due to political decision will postpone the realization of benefits further in time, which has not been incorporated in this study since we focus on basic risk fundamentals.

1) Percentage of health care professionals with e-health system integrated in their work environment.

Rather than governmental predictions counting on exact percentage of health care professionals integrated into the e-health system[9], a distribution function has been defined throughout the 8 years.

The 4 to 5 % prediction of integration of health care professionals in the e-health system in 2012 has been defined by the cumulative distribution as the maximal possible, predicted also by the government. The minimal value was set to 2 %. The probabilities were set deliberately so as to reflect the fact that to 60 % (difference of probabilities 1.0 and 0.4 on the y-axis) no more than 3 % (x-axis) of health care professionals will be connected. The first part of the curve (from 2 % to 3 % on the x-axis) shows a steeper slope of the curve since, judging by the y-axis, this is the most probable area. In other words, the slope reflects the fact that 'most probably' up to 3 % of doctors are expected to be connected. The parameters of the distribution for the following remaining years were deliberately set through specified conditional formulae, i.e. based on the randomly sampled number in the previous year in order that no lower number than that of the previous year could be sampled. This is understandable since the integration of doctors will be continuous in time.See the Fig. 3.



3: Cumulative function of e-health integration of health care professionals in 2012.

Source: Self-assembly in software @Risk® 6.

The parameters and function are mathematically described in the following Tab.III:

Parameters	min	continuous parameter min < max
	max	continuous parameter
	$\{x\} = \{x_1, x_2, \ldots, x_N\}$	array of continuous parameters $\min \leq x_i \leq \max$
	$\{p\} = \{p_1, p_2, \ldots, p_N\}$	array of continuous parameters $0 \leq p_i \leq 1$
Density and Cumulative Distribution Functions	$f(x) = \frac{p_i - p_{i+1}}{x_{i+1} - x_i}$ for $x_i \leq x < x_{i+1}$ $F(x) = 1 - p_i + (p_i - p_{i+1})\left(\frac{x - x_i}{x_{i+1} - x_i}\right)$ for $x_i \leq x \leq x_{i+1}$ With the assumptions: The arrays are ordered from left to right The i index runs from 0 to N+1, with two extra elements : $x_0 \equiv \min$, $p_0 \equiv 1$ and $x_{N+1} \equiv \max$, $p_{N+1} \equiv 0$.	

III Parameters and distribution functions of the cumulative distribution (below)

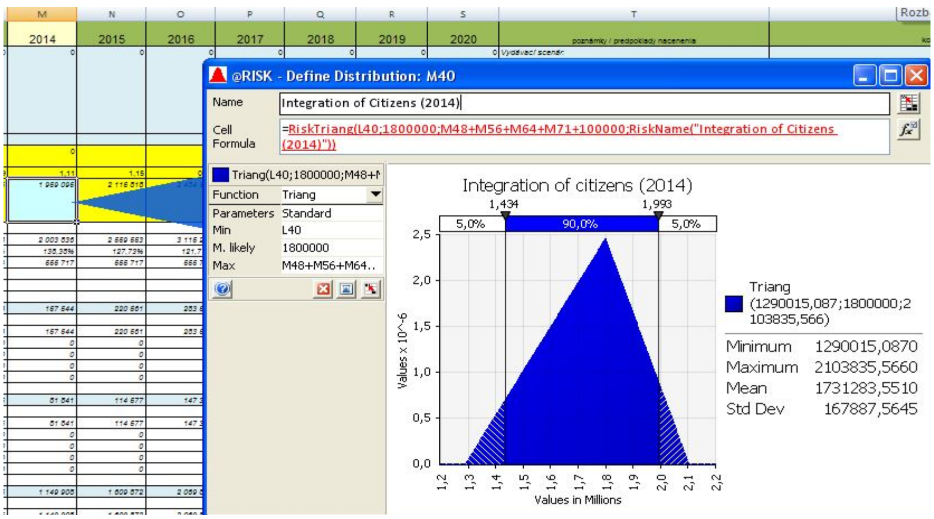
Source: @Risk® 6 Help. See also Palisade Corporation (2010).

[9] This assumption proved to be real since in 2012 the first 4 % of healthcare professionals should have been 'connected' to the e-health system which did not happen. Similarly, for a period of approximately one year, the e-health implementation in Slovakia was stopped, postponing thus the 'pre-defined' assumptions, not really accounted for previously, forward in time.

The @Risk 'RiskCumul' function (minimum, maximum,{X1,X2,..,Xn},{p1,p2,..,pn}) specifies a cumulative distribution with *n* points. The range of the cumulative curve is set by the minimum and maximum arguments. Each point on the cumulative curve has a value *X* and a probability *p*. Points on the cumulative curve are specified with increasing value and decreasing probability. Probabilities entered are cumulative descending probabilities, or the probability of a value greater than the entered X value. Any number of points may be specified for the curve.

2) Number of citizens with electronic identification card to be used in Slovak healthcare.

Similarly, we have defined a triangular distribution to predict the future possible and real values. The distribution has a number of desirable properties of real world processes. These include that it is simply definable, having a bounded range. This concrete distribution is characterized by three parameters: the predicted minimum, the most likely and the maximum values. The logic of the procedure, also in terms of the following data in time, is similar like in the previous example.



4: Triangular distribution of integration of citizens via e-Cards in 2014.
Source: Self-assembly in software @Risk® 6.

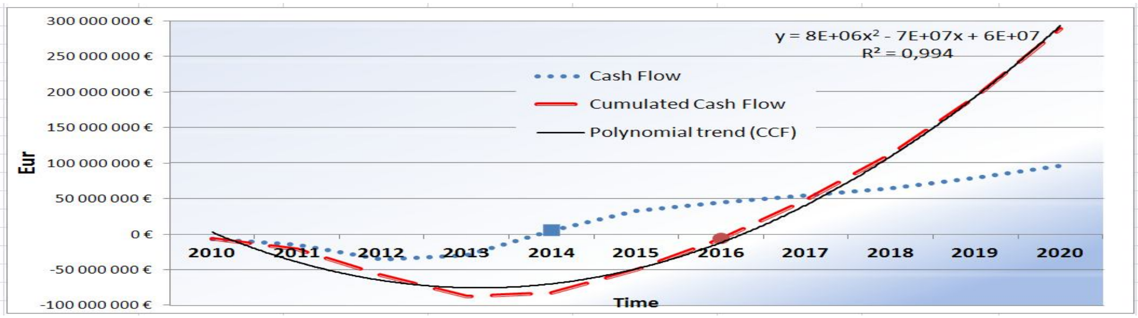
The direction of the "skew" of the triangular distribution is set by the size of the most likely value relative to the minimum and the maximum. Some characteristics are presented in the following table:

IV Parameters and distribution functions of the triangular distribution(below)
Source: @Risk® 6 Help. See also Palisade Corporation (2010).

Parameters	min continuous boundary parameter min < max * m.likely continuous mode parameter min ≤ m.likely ≤ max max continuous boundary parameter *min = max is supported for modelling convenience, but gives a degenerate distribution.
Density and Cumulative Distribution Functions	$f(x) = \frac{2(x-min)}{(m.likely-min)(max-min)}$ min ≤ x ≤ m.likely $f(x) = \frac{2(max-x)}{(max-m.likely)(max-min)}$ m.likely ≤ x ≤ max $F(x) = \frac{(x-min)^2}{(m.likely-min)(max-min)}$ min ≤ x ≤ m.likely $F(x) = 1 - \frac{(max-x)^2}{(max-m.likely)(max-min)}$ m.likely ≤ x ≤ max
Variance	$F(x) = \frac{min^2 + m.likely^2 + max^2 - (max)(m.likely) - (m.likely)(min) - (max)(min)}{18}$

Results

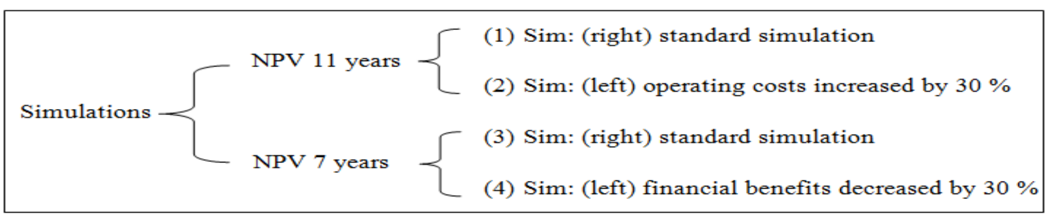
The results of our analysis are also presented in the form of 'risk curves' with some statistical characteristics. Before running the simulations, we calculated the cash flows in time (based on Tab. I discussed above) which is depicted in the following Fig. 5. By comparison, the cumulated cash flow (CCF) line was added a polynomial trend based on the method of least squares, and which can be explained by ca. 99.4 (characteristic of R^2) of values by the polynomial trend.



5: Cashflows and Cumulated Cashflow of the e-health CBA. (Self-assembly)

Judging by the Fig.5, we see that it is not earlier than 2014 when benefits exceed costs if e-health implementation proceeds according to the plan. Cumulated benefits should be significantly increasing in time once all the components and all parties are fully connected.

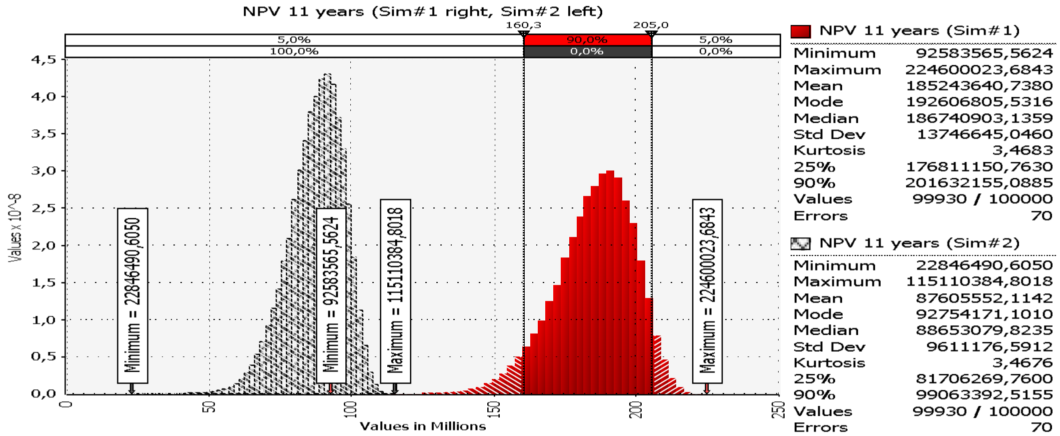
With the distributions of selected values set, we simulated the calculation of the NPV value of 11 years and of 7 years[10]various times with two alternatives defined in each. So four simulations were run together.The first simulation of counting NPV was run normally. The second, though, was run under a pre-set condition of ('artificially') increasing the running costs by 30 %. This seems to be a common method to reflect optimism bias and contingencies in models; as applied by Empirica *et al.* (2005). Similarly, to predict another negative impact, we adjusted the financial benefits when calculating the NPV for 7 years.



NPV 11 years

The following Fig.6 depicts the probability distributions – results of the simulations (1) and (2). Even though both NPVs are positive (≈ 185 mil. € and 87 mil. € respectively), the second NPV, Fig.6 (left), is shifted to the left, representing thus a less profitable alternative. However, with the operating cost higher by 30 % in the second simulated alternative (on the left), the minimum value decreased more significantly from ≈ 92 mil. € down to 22 mil. €.This is primarily attributable to the high benefits in the last three years when all subjects are fully integrated in the e-health system. The supplementary table as a result of simulation is also presented. The characteristics (modus, median, etc.) represent the NPV values since this NPV was counted 100 000 times.

[10] We decided to simulate the NPV for 7 years (2010-2016) – coinciding with the implementation period during which the first and second e-health stages are planned – to show what would happen if in the year of the first positive cumulative cashflow (2016; c. Fig. 5**Error! Reference source not found.**), for various reasons, the e-health implementation would be suddenly stopped in Slovakia, and relaunched later or not earlier again than in 2021.

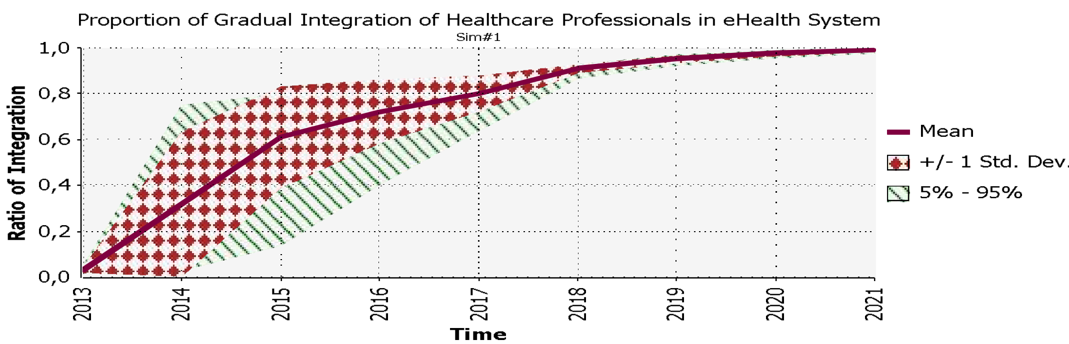


6: NPV 11 years (2 simulations).

Source: Evaluated by @Risk® 6.

The following Fig.7illustrates another risk curves depicting the summary trend (1 sim)of gradual networking of doctors to the national e-health information system. It shows the summary trend – a type of a chart summarizing changes in multiple probability distributions or an output range. The summary Fig.7 takes five parameters from each selected distribution — the mean, two upper and two lower band values — and graphs the changes in the five parameters across the output range. The upper band values default to +1 standard deviation and the 95th percentile of each distribution, while the two lower band values default to -1 standard deviation and the 5th percentile of each distribution.

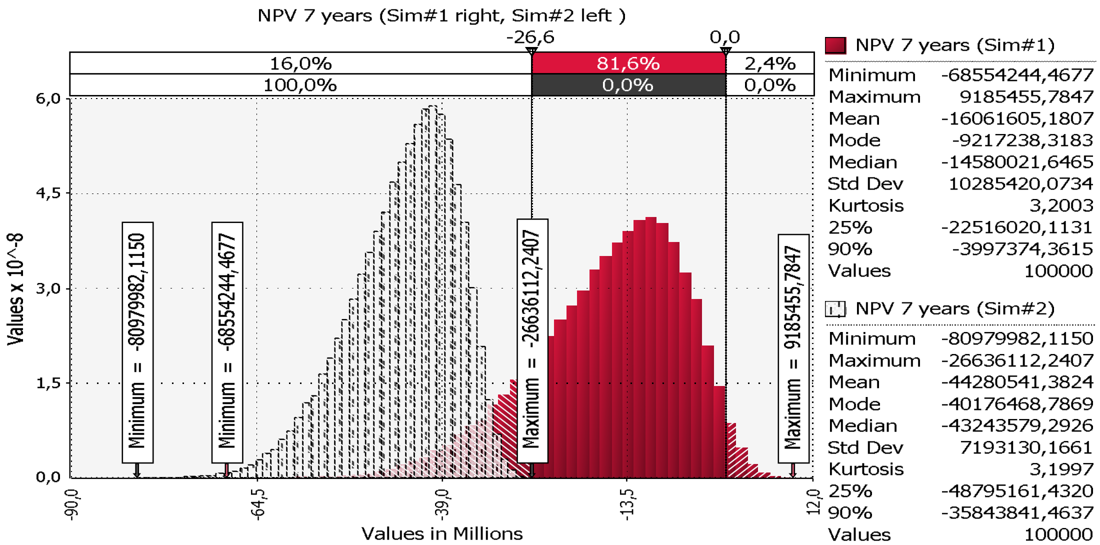
As shown, the years 2013 through 2016 are represented by relatively large intervals of physicians' IT interconnectedness. For instance, up to 60 % of physicians on average are supposed to share the e-health solutions in 2015, but it also might be 80 % of them or only 10 % in the adverse scenario. This is explained with a higher degree of variance in these years. It is almost certain, that from 2017 to 2020 nearly all doctors should be in. Furthermore, we see that from 2014 to 2017 it is highly probable that extreme values of interconnectedness will come from lower ranges than higher, i.e. it is more likely that a lower (extreme) number of physicians will be connected than the higher (striped range on the bottom).



7: Summary trend of percentage of health care professionals' integration.

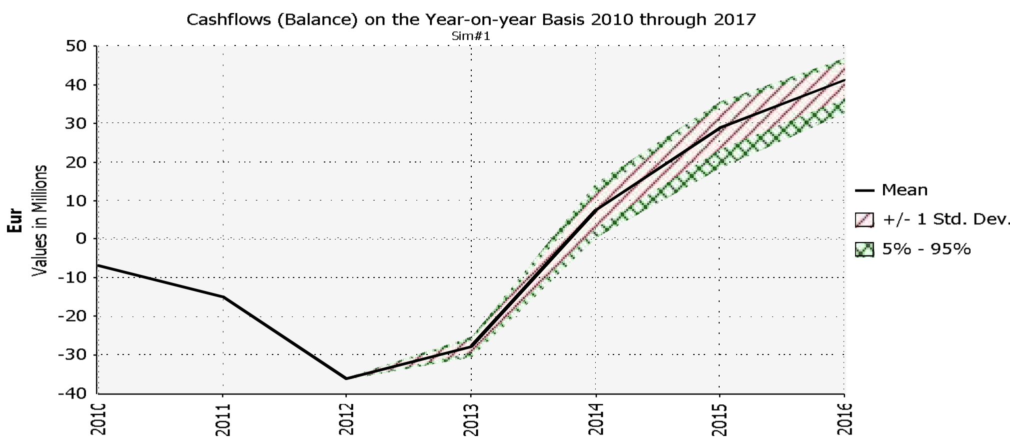
Source: Evaluated by @Risk® 6.

NPV 7 years. The following Fig.8depicts the probability distributions – results of the simulations (3, on the right) and (4, on the left). Abjuring the last three years of the e-health implementation would not be profitable. We see that the mean of the predicted NPVs is ≈ -16mil. € and ≈ -44.3 mil. € respectively. The NPV (3) is negative to 97,6 %, so it has no sense to start the project and have it in 7 years stopped. Moreover, with the financial benefits lower by 30 % (Sim 4), by the distribution behaviour of the NPV, we may say that the project is definitely (for 100 %) not profitable. This fourth simulation tells us more about possible shift of NPV in the negative direction if real financial benefits would not materialize as expected.



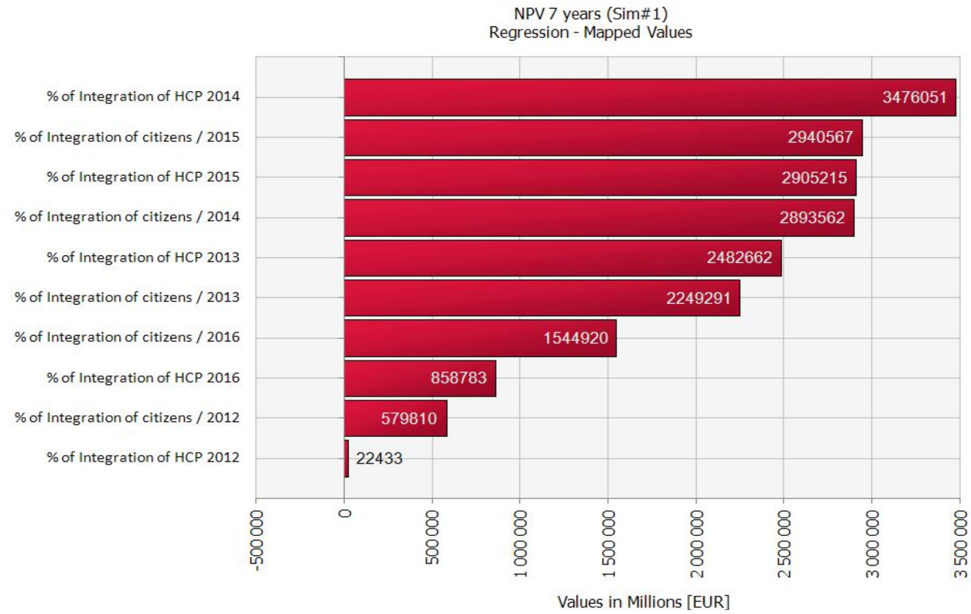
8: NPV 7 years (2 simulations).
Source: Evaluated by @Risk® 6.

When looking on the behaviour of risk of our measured output (NPV) in Fig.9, by the increasing deviation around the mean (striped and chequered ranges) in the summary trend of net cash flows on the year-on-year basis of our e-health CBA, we see that the risk is growing in time. It is also associated with a high variability of integration of doctors (c. Fig.7).



9: Summary trend of net cashflows in respective years.
Source: Evaluated by @Risk® 6.

For tornado graphs showing the mapped values (of our NPV), like depicted in Fig.10, samples for an input are grouped in a set of equal sized bins or “scenarios”, ranging from the input’s lowest value to its highest. A value for a statistic of the output (such as its mean) is calculated for the output values in the iterations associated with each bin. The tornado graphs, by the length of the bar shown for each input distribution, are depicting the amount of change in the output due to a +1 standard deviation change in the input. The values shown on each bar of this type of graph are the output value associated with +1 standard deviation change in the input. Thus, when the input changes by +1 standard deviation, the output will change by the X-axis value associated with the length of the bar. So the Fig.10 characterizes the linkage of 10 selected inputs on the output – NPV. We see that the integration of doctors and citizens in the e-health system is crucial in 2014 through 2015 and onwards since the NPV is very sensitive upon them. Thus a due focus should by paid especially to these years not only by policy makers but also by IT designers from the early stages of the project planning.



10: Tornado graph of inputs with mapped values.

Source: Evaluated by @Risk® 6.

Discussion and Conclusions

The paper focuses on the basic characteristics of the risk analysis of the e-health CBA within the Slovak e-health implementation program. The paper does not look in detail at other factors which might be measured and analysed such as discount factor, tax policy, or other input variables, incessantly being updated in relation to changing fundamentals in time. So these are some of the issues which may be subject to the further research.

We have identified two prevailing mainstreams in the methodology of the research: the qualitative and quantitative one. When brought to comparison, there are fewer studies going into details of aggregate (nationwide) quantitative aspects of e-health deployment and/or implementation, let alone studies dealing with risk-adjusted quantitative approaches.

The structure of the e-health evaluation might be subjected to several methodological approaches. See Babeľa *et al.* (2008), Ahern *et al.* (2006).In the paper, contrary to the e-health impact study by Empirica GmbH. (2004), for instance, the present underlying CBA analysis was not summarized horizontally in the health care sector, i.e. reflecting the costs and benefits particularly for different stakeholders (citizens, health care professionals, or respective medicinal sectors such as radiology departments, intensive care units, etc.). Like presented in the study by Gartner (2004) we tried to demonstrate the connection between political goals, e-health technologies and, contrary to the governmental static and rather optimistically biased predictions, potential predicted benefits with a certain level of risks reflected in the computations of the standard NPV value.

Furthermore, the underlying benefits and costs were from 2012 on predicted on the historical observations of trends in mainly cost of health care on the national level, drug consumptions etc. The reader must be aware of the fact that with the extending period in time (beyond 2015) predictions might be further considerably less exact and are based on constants. This is why the data must be incessantly being updated over time. The paper primarily aims at the demonstration of simulated inputs and results. Respective concrete inputs and outputs will be subject to further statistical analyses in order to make the future studies based on these simulations, and in view of quantifying the e-health benefits in the Slovak health care setting, more exact. The methodology used can be easily used also in other settings in other countries provided that the data set, being often especially hard to procure due to the particularly more sensitive health care data, will be available.e-Health / Health-IT, as a promising medium of computerization (paperless form of) processes in the healthcare sector, and having been naturally developed in the wake of an ever-more extensive use of ICT in everyday human activities, is a relatively new means shaping the communication processes of healthcare sectors in developed countries today.

There are few studies reflecting the quantitative aspects of e-health investments, though. If there are any, they are mostly based on static cost-benefit or cost-effectiveness analyses and do not reflect the risk factors in time, lacking any sensitivity or stress analyses.

This is partly 'understandable' since the huge IT projects are generally being implemented under the auspices of governments which are interested in marketing these projects well at home, so any hints of doubts related to the time risk of predicted variable inputs and outputs are simply not desirable. This is not the case when it comes to focusing on the financial markets when investing in the financial instruments which have increasingly been under a close scrutiny of both public and private sectors, of academics and scholars for the last fifty years, so the risk issues have always played a key role and enjoyed both the interest and emphasis in the academic world, research and business. Unfortunately, perhaps due to the much lower interconnectedness with supranational financial markets, this is not so true for sometimes much larger governmental investments on domestic markets in health care or traffic sectors or any other.

A successful development and implementation of electronic healthcare services are subject to an effective application of robust investments which cover these activities. Hence, many factors need to be considered, including various research approaches on both microeconomic and macroeconomic level. The former will survey the impacts of the implementation of respective concrete e-health solution in health care settings, and the latter will explore the nationwide aspects of e-health by studying the underlying macroeconomic health-related flows. As expressed by several authors we have mentioned, there is a strong need of further research activities in this relatively new health area.

Summary

The paper focuses on the basic characteristics of the risk analysis of the electronic healthcare – e-health based on the cost-benefit analysis within the Slovak e-health implementation program.

The Latin Hypercube sampling method, being an enhanced version of the earlier Monte Carlo simulation method, makes the incorporation of risk factors associated with uncertainties in time of the project possible. The Slovak official e-health implementation schedule is subject to various more or less positive and negative scenarios in this paper. With present parameters set and calculations, the Slovak e-health implementation program is worth almost 200 mil. Eur in building its basic infrastructure in the long-term. Any postponement of the project since the start would be detrimental to the project financial profitability, let alone the suspension. Taking huge financial flows upon health data flows within the healthcare system into consideration, the empirical evidence demonstrated in this study highlights not only the importance of thorough knowledge of healthcare patterns in terms of computerization of health care data flows, but it also brings into focus the timing of behavioural change in the overall project design of e-health integration in the form of proven e-health applications, most notably electronic health records and electronic prescriptions and medication. These challenges predominantly assume measures of involvement and representativeness at both patient-citizen and healthcare setting levels.

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