Multi-Criteria Optimisation for Building it Management Model within a Company

Larysa Globa[1], Stanislav Dovgyi[2], Oleh Kopiika[2] and Oleksii Kozlov[2]
[1]*Igor Sikorsky Kyiv Polytechnic Institute, Peremohy Avenue 37, Kyiv, Ukraine*
[2]*Institute of Telecommunications and Global Information Space of the National Academy of Sciences of Ukraine, Chokolivsky Boulevard 13, Kyiv, Ukraine*
lgloba@its.kpi.ua, sdovgii@gmail.com, okopiyka@gmail.com, alexey.ua84@gmail.com

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Abstract: The paper proposes approaches to multi-criteria optimisation when building an IT management model within a company using modern service-oriented IT solutions. It is proposed to employ a methodology that helps companies achieve appropriate levels of efficiency from IT implementation by maintaining a balance between the realisation of benefits, optimisation of risks and use of resources. The methodology enables administering and managing IT, both in the field of its functional responsibility and business tasks addressed by the company, while considering the IT needs of internal and external stakeholders. At the same time, a specific objective shall be defined, clarified, and specified in line with the balanced scorecard (financial, customer, internal processes, learning and growth). In addition, the task of effective IT implementation related to developmental priorities is fulfilled. In this case, the decision-making problem is characterised by a multi-criteria pattern. Specifically, the article proposes implementing decision-making principles using algorithms or procedures addressing multi-criteria optimisation problems. Almost all known approaches to solving these problems involve their scalarization, where consideration of the benefits is one of the main issues that must be addressed to select the best solution. Under this principle, the methods for solving multi-criteria optimisation problems are classified according to characteristics of information: decision-making under certainty; decision-making when information on the benefit system is unavailable; decision-making with the gradual acquisition of information on the benefit system; decision-making under multi-connectivity, heterogeneity, and multi-criteria information about the benefit system.

1 INTRODUCTION

Information is becoming an increasingly valuable business asset and, in many cases, the main one. The rapid development of information technology (IT) has removed physical barriers to producing and transmitting information and changed our understanding of how information is obtained (produced) and consumed. In the modern world of information technology, the share of services for storing and transmitting data through the "cloud" and software as a service (SaaS) models offered by software vendors, etc., is constantly growing.

The world's leading consulting companies believe that rapid improvement and spread of cloud computing is currently one of the key trends to significantly affect in the coming years the global development of the IT industry and business, finance, public administration, healthcare, education and many other sectors of human life [1-10]. In the context of advanced development of information and communications technology and yet another global downturn, the technology enabling organisations and other entities to eliminate high spending on their IT infrastructure and obtain all required IT resources online is viewed as a promising and cost-effective modernisation choice, and the best investment in the future.

All of the above determines the urgency of changing the company's IT management business model in line with developing a service-oriented information economy.

Mush research on this topic has already been done [11-16]. Notably, the evolution in IT service management has occurred more or less synchronously with fundamental societal changes and therefore was inevitable.

2 STAGES OF IT SERVICE MANAGEMENT GOALS EVOLUTION

In terms of IT development, three stages of IT service management goals and IT outputs evolution can be distinguished:

1) IT infrastructure management;
2) IT service management;
3) information business service management.

These stages are described in more detail in Table 1. To some extent, each stage may be associated with changes in the perceived role of IT within a company - the transition from a technology unit to a full-fledged partnership (Figure 1).

The enhanced IT role and importance should indisputably lead to evolution in understanding IT service management goals, and IT outputs [17].

Equally important is that evolution in the understanding of IT service management goals and IT outputs may be associated with a shift in social consciousness: transition from a product-oriented industrial economy to a service-oriented information economy (with certain reservations as the economic paradigm has been changing quite slowly and gradually).

Table 1. Three Stages of it management evolution.

Stage	Tasks	Priorities	Characteristics
Stage 1	IT infrastructure management	Stability and control over IT infrastructure	IT Department delivers IT systems. The goal of IT management is to mitigate the risk of IT system failure.
Stage 2	IT service management	Quality and efficacy of IT processes	IT Department delivers technological services. The goal of IT management is to maintain the agreed parameters of IT services.
Stage 3	Information business service management (Web-service)	Maximum IT efficiency	IT Department delivers information business services. The goal of IT management is to serve the business needs best.

Apart from general market factors, the evolution in the understanding of actual IT outputs has been driven by the need to lay the groundwork for solutions to complex practical issues in the IT industry.

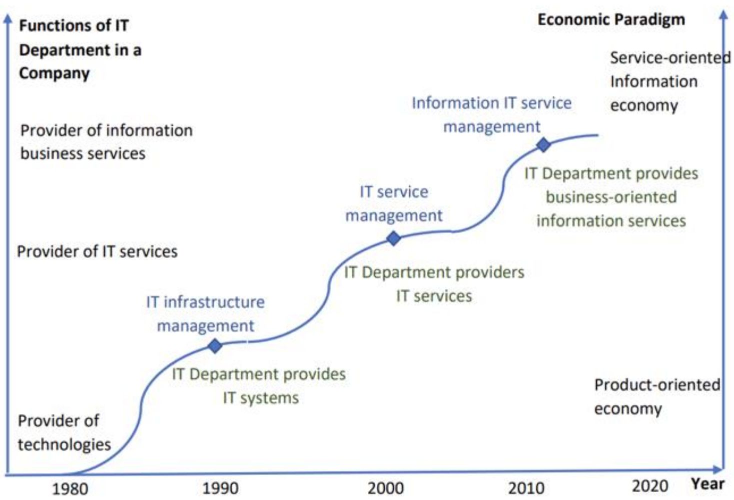

Figure 1: Stages in the evolution of IT service management goals and IT outputs.

IT executives constantly face numerous problems and lack systemic tools to address them. These problems include:

1) justification of continuous IT spending growth;
2) justification of the value generated through investing in IT; issues related to a mismatch between outputs and expectations;
3) management of IT requirements; issues relating to aligning business units' expectations and IT department capabilities;
4) persistent lack of IT resources, IT competencies, and problems associated with delegating complex tasks to external IT providers.

This paper aims to present approaches to multi-criteria optimisation when building a business model of IT management within a company tailored to the needs of business units in the modern service-oriented information economy setting.

3 METHODOLOGY FOR THE GOVERNANCE AND MANAGEMENT OF COMPANY IT

It is apparent that users need not an IT system as such but its operational results [18-24]. Achieving these results generally requires more assets than just an IT system. It is impossible to meet complex needs focusing on the IT system only. To move forward, all stakeholders should arrive at an understanding of common tasks and objectives.

It can therefore be concluded that information is an essential resource. At all stages of its lifecycle, information is critically dependent on specialised technologies. Information and rapidly developing information technology are vital for the development of society.

Today, more than ever, business leaders should strive to:

- maintain high quality of information to support managerial decisions;
- generate value for society from IT-enabled investments, i.e., achieve strategic goals and realise business benefits through effective and innovative use of IT;
- achieve operational excellence through the reliable and efficient use of technology;
- maintain IT-related risks at an acceptable level;
- optimise spending on IT services and technology;
- improve compliance with laws, regulations, contractual terms and policies related to IT use.

Thus, the modern characteristics of IT implementation are, namely:

1) control over information management services;
2) increased IT value;
3) IT department as a provider of information management services;
4) the goal of IT management – the most accurate compliance with the needs of society.

Therefore, to improve the efficiency of IT implementation, we propose a methodology designed to assist in addressing IT governance and management tasks.

This methodology helps in achieving the appropriate levels of efficiency from IT implementation and maintaining a balance between the realisation of benefits and the optimisation of risks and resources. The methodology enables administering and managing IT, both in the field of its functional responsibility and business tasks addressed, while considering the IT needs of internal and external stakeholders. The methodology is universal and of benefit to executives who make decisions.

The methodology is based on the five key principles of company IT governance and management, as shown in Figure 2.

Principle 1: Meeting Stakeholder Needs. The main task of any company is to create value for stakeholders by maintaining a balance between the realisation of benefits and the optimisation of risk and resources. The methodology describes all required processes and other factors supporting business value generation with IT. Since business tasks may vary, the methodology can be customised to suit the context of a particular company. This can be achieved by cascading high-level tasks to manageable and specific IT-related goals and associated processes and practices (Figure 3).

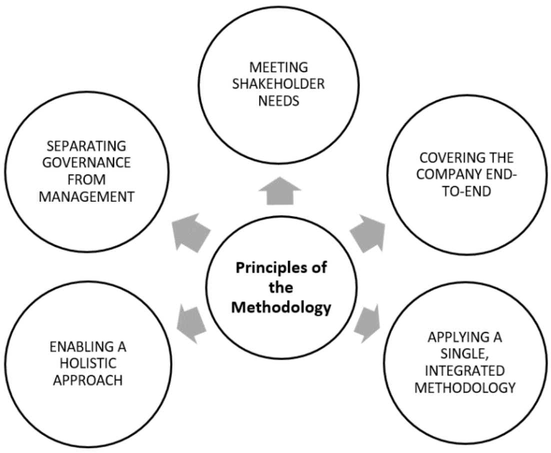

Figure 2: Principles of the methodology.

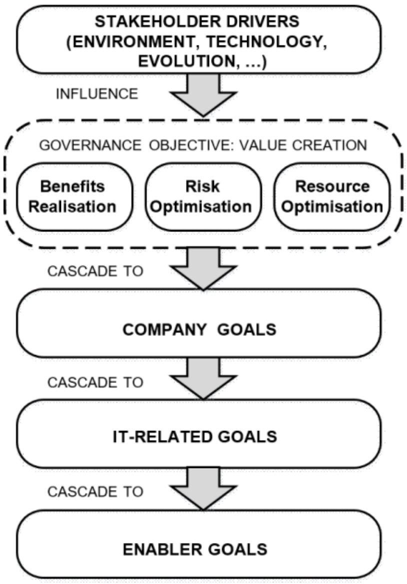

Figure 3: Goals cascade.

Principle 2: Covering the Company End-to-End. The methodology integrates IT management into company management; it covers all functions and processes within a company.

The methodology focuses not only on "IT-function" performance but also on information and related assets of the company that shall be managed like any other assets. It is based on the fact that IT-related governance and management enablers operate company-wide and across the entire value generation chain, including all internal and external aspects and roles relevant to IT governance and management.

Principle 3: Applying a Single, Integrated Methodology. There are many IT-related standards providing guidance on specific IT activities. The methodology ensures compliance with these standards. Thus, it provides an integrated approach to the governance and management of company IT.

Principle 4: Enabling a Holistic Approach. Efficient and effective governance and management of company IT require a structured approach considering numerous interacting components of the goal.

The methodology defines a set of enablers that support the implementation of IT governance and management system. Enablers can be broadly defined as anything that can help achieve specified objectives. The methodology includes seven categories of enablers (Figure 4): Principles, Policies and Approaches; Processes; Organisational Structure; Culture, Ethics and Behavior; Information; Services, Infrastructure and Applications; People, Skills and Competencies.

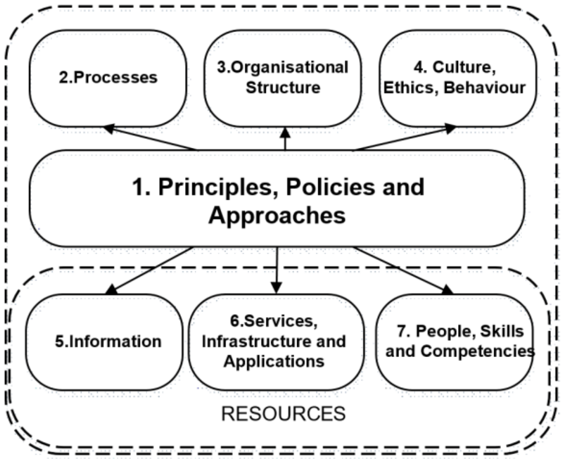

Figure 4: Enablers.

Principle 5: Separating Governance from Management. The methodology makes a clear distinction between governance and management. These two processes encompass different activities, require different organisational structures, and serve different purposes. According to the methodology, the difference between governance and management is as follows:

- in most cases, governance is the responsibility of the Board of Directors chaired by the Chairman;
- some functions may be delegated to special business units at an appropriate level;
- to a large extent, management is the responsibility of company directors who report to the director general (CEO).

Together, these principles help to build an effective governance and management methodology that optimises investments in information technology for the benefit of stakeholders.

The importance of this goal is that it enables setting priorities for the implementation and improvement and ensures IT governance based on understanding of company (strategic) objective and associated risks. In practice, this goal:

1) defines important and reasonable objectives and tasks at different levels of responsibility;
2) allows retrieval from the knowledge base of all data relating to the defined objectives that may be of use for implementation, improvement or quality assessment projects;
3) clearly identifies and demonstrates (in some cases in great detail) how the enablers help achieve company objectives.

The Table of concordance between the company and IT-related goals (Table 2) is given for illustrative purposes only and should be used with reservations.

Table 2. IT-related goals.

BSC Dimension	Information and Related Technology Goal
Financial	1) Alignment of IT and business strategy 2) Foreign laws and regulations IT compliance and support for business compliance 3) The leading role of executive management in making IT-related decisions 4) Managed IT-related business risks 5) Realised profit from IT-enabled investments and services portfolio 6) Transparency of IT costs, benefits and risks
Customer	1) Provision of IT services in response to business requirements 2) Adequate use of applications, information and technology solutions
Internal processes	1) IT flexibility 2) Security of information, processing infrastructure and applications 3) Optimisation of IT assets, resources and capabilities 4) Ensuring the operation and support of business processes by integrating applications and technology into business processes 5) Benefiting from programs and projects implemented within the established time frame and budget while meeting requirements and quality standards 6) Availability of reliable and relevant information for decision-making 7) Internal policies compliance
Learning and growth	1) Competent and motivated IT personnel 2) Knowledge, expertise and proactivity for business innovation

Therefore, it is necessary to define the company goal, clarifying and detailing it in accordance with the balanced scorecard (financial, customer, internal processes, learning and growth). Besides, the problem of effective IT implementation, associated with different priorities, is addressed.

4 MULTI-CRITERIA OPTIMISATION METHODS

In the case under consideration, the decision-making is based on multiple criteria. Therefore, special attention should be paid to identifying the causes for such a multi-criteria pattern and finding ways to use appropriate mathematical methods for the goals cascade.

Consequently, “IT implementation” aims to establish the values for a larger number of qualitative and quantitative parameters, i.e. partial goals. These goals may compete with each other.

One more argument for the multi-criteria decision-making pattern is the time-space factor. The results of activities and costs are distributed, so the “value” of IT implementation today, tomorrow and in a year, development prospects, etc., are to be compared. Known convolution techniques (for example, for time distribution, i.e. discounting) are characterised to a large extent by subjectivism (coming from an author of the method, not from the decision-maker expert (DM)).

Setting up multi-criteria decision-making problems essentially involves two aspects. On the one hand, these problems are very similar to the problems of making decisions under uncertainty because different options must be evaluated regarding their possible benefits and associated risks. On the other hand, multi-criteria decision-making under certainty and considering a large number of criteria is based on the rejection of the traditional assumption that one of the alternatives is always selected using one criterion only. In such situations, a scalar optimisation problem is replaced with a vector optimisation problem.

To take account of these two aspects, a mathematical model that reflects a multidimensional system of targeted functions shall be developed as a scalar criterion of optimality. This approach requires the decision-maker to have special preference functions. The validity of this assumption is not obvious in advance. However, this approach has a well-developed theory for solving such problems [25].

Specifically, the decision-making principles are implemented as algorithms or procedures for solving multi-criteria optimisation (MCO) problems. Almost all known approaches to solving these problems include their scalarization. At the same time, one of the main issues is to consider the DM benefits when choosing the best solution. According to this principle, the methods for solving multi-criteria optimisation problems can be classified based on the characteristics of information about DM benefits:

1) decision-making under certainty;
2) decision-making when information about the DM benefit system is unavailable;
3) decision-making with a gradual acquisition of DM benefit system information;

4) decision-making under multi-connectivity, heterogeneity, and multi-criteria benefit system information.

Classification of multi-criteria decision-making methods is shown in Figure 5.

A) The first group of tasks related to the context of certainty regarding the DM benefit system is discussed below.

1) A particularly large class of decision-making methods is based on the existence of vector estimates of the preference relationship, which depends on the system of objective functions only. In this case, it is possible to construct the corresponding value function. In addition, the value function determines the structure of DM benefits precisely. More detailed information about the theory of the value function is given in [26].
2) One of the decision-making methods for multi-criteria optimisation, which allows narrowing the Pareto set, implies arranging the criteria according to their importance. Questions about the criteria importance addressed to the DM are, on the one hand, quite clear to the DM. On the other hand, DM's advice can be effectively used in optimisation algorithms. However, many methods require the DM to precisely define the importance of the criteria (weight coefficients). An example of the qualitative ordering of criteria (without defining weight coefficient) is lexicographic ordering, and multi-criteria problems with criteria strictly ranked by importance are called lexicographic optimisation problems. The range of multi-criteria problems relating to lexicographic ordering is obviously too narrow. The lexicographic ordering principle can be used when the threshold (minimum allowable) values of the criteria are set in the criterion space. In such a case, the specified ordering of initial prioritized criteria will be defined by a sequence of these criteria maximization up to the corresponding threshold values. As a result, the multi-criteria problem converts into a lexicographic problem with a vector criterion. However, it should be noted that, in general, the lexicographic optimisation problems may be unstable because minor changes in their parameters (source data) can seriously affect the choice of optimal alternatives. Therefore, special methods are used to solve them.
3) Another algorithm for decision-making under certainty includes the methods of targeted programming. The targeted programming method for solving multi-criteria problems is based on ordering criteria (goals) according to their importance. The initial problem is solved by sequentially solving several problems with one targeted function in such a way that solving a problem with a less important goal cannot

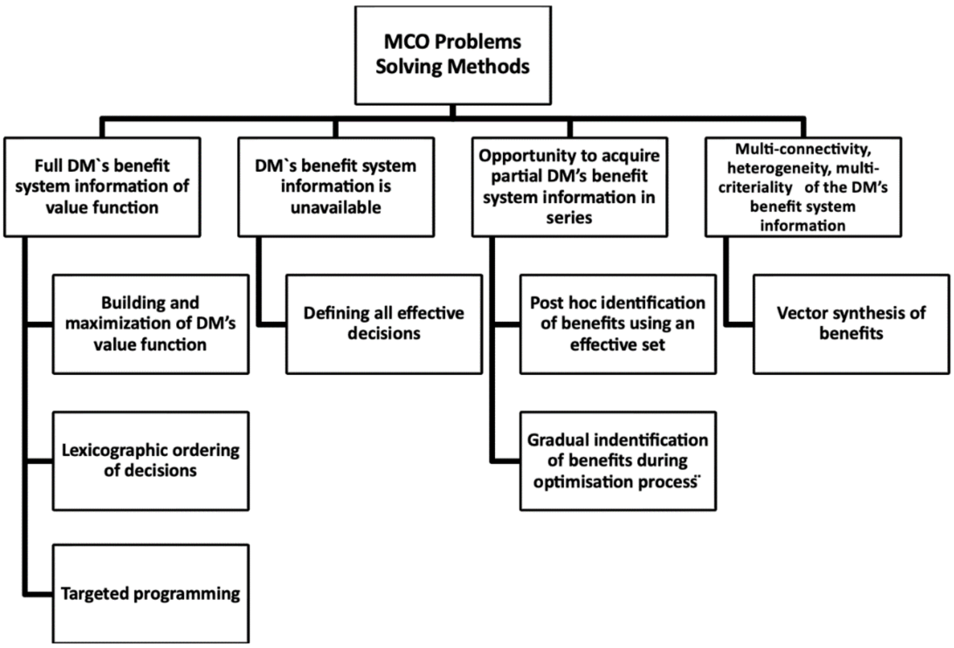

Figure 5: Classification of methods for solving multi-criteria problems.

affect the optimal value of a higher-priority objective function. The result is a satisfactory solution to the problem. The targeted programming is usually applied to linear models. Its main difference from linear programming is that many goals are formalized not as targeted functions but as restrictions in another, more general model. For this purpose, the estimated quantitative values of targeted functions are applied together with the so-called variable deviations characterizing the degree of goals' achievement for a particular decision.

B) The standard procedures for identifying effective solutions are used if no information about the DM benefit system is available. Then, the DM selects the best alternative by explicit evaluation.

C) In the case of gradual acquisition of DM benefit system information, there are two groups of multi-criteria methods for decision-making.

1) 1) Below is an example of a multi-criteria optimisation method, which belongs to the group specified on the classification scheme as a "post hoc identification of benefits using an effective set". In this case, the so-called ELECTRA methods are used, proposed by a well-known DMT (decision-making theory) [27].

   The ELECTRA methods aim to narrow the Pareto set of alternatives, which is accomplished as follows. Based on the DM responses, the weight (value characterising the importance of the specific criterion) is determined for each criterion (it is assumed that the criteria are numerical). All modifications of the ELECTRA methods include obtaining qualitative information from the DM about the relative importance of the criteria (expressions such as "criteria 3 and 4 are equally important and have greater importance than criterion "1") and its transformation into quantitative, numerical one. The problem here is that it can generally be done in various ways.

2) Interactive or human-computer procedures for solving MCO problems (HCPs). With HCPs, the ranges of acceptable values can be explored to find the best solution. The search for a solution is carried out in coordination with the DM and decision-making support system (DMSS). The source data for the HCPs are the decision options and the criteria used to evaluate the decision. HCPs include two phases: the analysis phase performed by the DM and the calculation phase performed by a computer.

The calculation phase. The DMSS:

1) performs calculations based on preliminary information or data obtained from the DM in the previous step;
2) calculates the decision (decisions);
3) produces the supporting information for the DM.

The analysis phase. The DM: (1) evaluates the presented decision (decisions) and determines whether the decision (one of them) is acceptable. If so, the HCP is complete; otherwise, the DM analyses supporting information, (3) provides the DMSS with additional information to calculate a new decision (decisions).

D) The fourth group of tasks characterised by multi-connectivity, heterogeneity and multi-criteria information about the DM's benefit system is discussed below.

Such information includes a balanced scorecard (financial, customer, internal processes, learning and growth) and information about effective IT implementation related to business development priorities. This information is influenced by the time-space factor. Both the results of activity and costs are distributed, so it is necessary to compare the "value" of IT implementation today, tomorrow and a year from now, and the development prospects, etc.

Finding the optimal solution will be called synthesizing information about the DM's benefit system. The synthesis aims to find a system which compromises and optimises indicators with limited input data and a spectrum of defined conditions. Note that the synthesis of a system of this type must be vector, i.e. performed taking into account the values of a set (vectors) of indicators, including technological and economic ones, which are taken into account in advance (predicted) in the criteria of superiority (criteria of optimality of the system).

Synthesis is called a vector, which is performed taking into account several indicators, that is, based on vectors $K(\kappa_1, \kappa_2, ..., \kappa_m)$. This is determined by the properties of a multi-criteria complex system. In contrast to the vector, synthesis, carried out according to one quality indicator, is called a scalar synthesis.

Therefore, when conducting a vector synthesis, it is necessary to determine such values of the control variables $x \in D$ that simultaneously provide a minimum of all the introduced optimality criteria $Q_k(x)$, κ = 1,2, ..., s. These criteria are certainly contradictory; optimisation according to each of them leads to different values of the control variables x. Therefore, to take into account the entire set of partial criteria, it is necessary to analyse the vector optimality criterion Q(x) = [Q1(x), ..., Qs(x)], which leads to the solution of the multi-criteria optimisation problem.

Solving the optimal synthesis problem is selecting variables *x* that belong to the permissible domain *D* and providing the optimal value of the characteristic *Q(x)*. The characteristic that shows the relative "advantage" of one option compared to others is called an optimality criterion (objective function, efficiency criterion, utility function, etc.).

The extreme value of the optimality criterion Q(x) (quantitative value) characterises one of the essential properties of the system. Depending on the specific task, it is necessary to obtain either the maximum or the minimum of this function.

Thus, for each criterion $Q_1(x), Q_2(x),..., Q_s(x)$, it is necessary to find the vector $x = (x_1\ x_2,, ..., x_n)$ that provides the minimum (maximum) value criterion of optimality

$$Q=Q(x_1,x_2,\dots,x_n), \quad (3)$$

when solving the system of inequalities

$$Q(x_1,x_2,\dots,x_n)\geq 0, \quad (4)$$

$$x_{j-} < x_j < x_{j+},\ j = 1,2,...,n, \quad (5)$$

where x_{j-}, x_{j+} — values of the j-th controlled variable, characterising the range of its possible changes based on real conditions.

Therefore, the solution of the optimisation problem is reduced to solving the optimisation condition of expressions (3) - (5), that is, to determine the optimal value that satisfies the inequalities (4), (5) and finding the minimum (maximum) value of the optimality criterion (3).

5 CONCLUSIONS

1) The paper discusses the stages of IT service management goal evolution.

2) It is proposed to use a methodology that helps companies achieve optimum efficiency from IT implementation, maintaining a balance between obtaining benefits and optimising risks and resources.

3) The methodology is based on five key principles for business IT governance and management: meeting stakeholder needs; covering the company end-to-end; applying a single, integrated methodology; enabling a holistic approach; separating governance from management.

4) The methodology aims to build a goal that: defines necessary and reasonable objectives and tasks at different levels of responsibility; allows the retrieval from the knowledge base of all data relating to the defined objectives that may be required for implementation, improvement or quality assessment projects; clearly identifies and demonstrates (in some cases in great detail) how the enablers help achieve company objectives.

5) Under this principle, the methods for solving multi-criteria optimisation problems are classified according to characteristics of information: decision-making under certainty; decision-making when information about the benefit system is unavailable; decision-making with the gradual acquisition of information about the benefits system; decision-making under multi-connectivity, heterogeneity, multi-criteria information about the system of benefits.

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