Ex ante Evaluation of the Economic Efficiency of Enterprise Information and Communication Infrastructure Development Projects: A Differentiated Approach

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Abstract. Enterprise success in the digital economy is largely determined by the availability of necessary conditions for utilizing modern information and communication technologies (ICT). Consequently, the information and communication infrastructure (ICI) of enterprises is constantly evolving through the implementation of relevant projects. This article investigates the problem of evaluating the economic efficiency of enterprise ICI development projects at the justification and preparation stage, specifically the ex-ante evaluation. A wide range of methods exists for conducting ex-ante evaluations of investment projects, which differ significantly in their capabilities.

The objective of the article is to formulate a methodological approach for determining the procedure for the ex-ante economic efficiency evaluation of alternative enterprise ICI development projects, taking into account the unique characteristics of the organization. An analysis of scholarly publications was conducted to identify the capabilities of existing methods for evaluating the effectiveness of enterprise ICI development projects. To ensure an individualized approach in selecting the ex-ante economic efficiency evaluation methodology, a conceptual model was developed. The theoretical basis for the proposed model is the Technology-Organization-Environment (TOE) framework. A differentiated approach to determining the most appropriate ex-ante evaluation methodology for projects implementing new technological solutions is ensured by considering five defined groups of factors specific to each enterprise.

Keywords: economic efficiency, enterprise, ex-ante evaluation, information and communication infrastructure, projects.

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Introduction

An enterprise's Information and Communication Infrastructure (ICI) is a complex of hardware, communication, and intellectual components integrated into a unified system to establish the conditions requisite for executing information processes based on modern Information and Communication Technologies (ICT) [1]. The dynamic nature of the economic environment and the accelerating development of new ICT-based solutions necessitate the continuous adaptation of an enterprise's technological capabilities to emerging conditions. Consequently, the development of a modern enterprise's ICI is characterized by regular assessments of its alignment with current requirements and the implementation of specific projects within a defined strategy to bridge identified gaps. Accordingly, ICT expenditures continue to rise; according to Gartner, they are projected to increase by 10.8% in 2026, reaching $6.15 trillion [2].

The continuous growth of expenditures on ICI development, coupled with resource constraints, imposes stringent requirements on enterprises to conduct rigorous efficiency evaluations of projects during both their design and implementation stages. Currently, academic literature offers a wide variety of such assessment methodologies, with the total number having long since exceeded sixty.[3]. Each of these methods is characterized by specific capabilities, complexities, advantages, and limitations, which dictate their suitability for a particular enterprise. The proliferation of methodologies for evaluating the effectiveness of ICI development projects has given rise to a new challenge: selecting the most relevant assessment technique tailored to the specific conditions of an individual firm. Of particular practical relevance and scholarly interest is the problem of identifying appropriate methods for the ex-ante economic efficiency assessment during the preliminary stages of project preparation. Well-founded decisions at this stage establish the necessary foundation for the successful execution of the enterprise's strategic plans.

Literature Review

The recognition of the complexity inherent in evaluating the effectiveness of corporate ICT usage has sparked a long-standing scholarly debate regarding the so-called "IT productivity paradox", formalized in the well-known article by Erik Brynjolfsson [4]. This discussion served as a powerful impetus for developing new and refining existing methods to evaluate the effectiveness of ICT utilization. Following the emergence of a substantial number of methodological approaches, a need for their systematization arose, which became the focus of various authors' publications. Based on an analysis of 65 approaches to assessing the effectiveness of information system investments, Theo J.W. Renkema and Egon W. Berghout categorized them into four groups: financial, multi-criteria, ratio, and portfolio methods. [3]. The financial approach focuses on traditional economic metrics, seeking to quantify all benefits and costs in monetary terms. Multi-criteria methods extend beyond simple financial reporting to include a broader spectrum of factors that evaluate the contribution of IT investments to organizational goals. The ratio approach utilizes specific coefficients to measure performance. The portfolio approach considers IT investments not in isolation but as a collective set of projects that must be balanced by risk level and strategic value. A comparison of these methods revealed significant differences across numerous parameters, precluding definitive conclusions regarding their relative quality. At the same time, a nearly total lack of theoretical justification for non-financial assessment methods was noted. An important conclusion was reached regarding the necessity of selecting evaluation criteria that align with the circumstances of their intended application. Furthermore, the expediency of combining the specific features of different approaches was highlighted.

Henryk Wojtaszek et al. conducted a thorough analysis of existing approaches to the classification of IT project evaluation methods and determined the importance of categorizing them primarily based on the project life cycle stages at which they can be applied [5]. Based on this criterion, two types of IT project efficiency evaluation are distinguished: preliminary (ex-ante) and actual (ex-post). Their primary objectives differ fundamentally. Ex-ante evaluation is conducted during the early stages of project development to determine expected outcomes and justify the selection of the most effective options among available alternatives. In contrast, ex-post evaluation is carried out after the project implementation has commenced to ensure effective management and the achievement of planned results.

Furthermore, the authors maintain a detailed classification by incorporating other approaches, categorizing evaluation methods into quantitative and qualitative. Quantitative methods include traditional financial investment approaches based on metrics such as Payback Period, Net Present Value (NPV), Internal Rate of Return (IRR), Return on Investment (ROI), and Total Cost of Ownership (TCO). These are further subdivided into deterministic and probabilistic models depending on the calculation methods employed. Qualitative methods encompass multi-criteria approaches (Multiple Criteria Decision Making – MCDM, Multiple Criteria Decision Analysis – MCDA, Multi-Attribute Decision Analysis – MADA, Multi-Objective Decision Support – MODM, Analytic Hierarchy Process – AHP, among others) and specialized strategic analysis techniques (Scenario Method, Structural Analysis, Function and Resource Matrix, and Portfolio Methods).

The authors concluded that an individual approach to evaluating IT system effectiveness is necessary to obtain reliable results. They also emphasized the importance of considering the complexity of applying the evaluation methods themselves, as this complexity can significantly impact total project implementation costs. A general model for evaluating the economic efficiency of information systems in enterprises was proposed, comprising four stages: identification of the objectives and subject of evaluation, quantitative analysis based on TCO, qualitative analysis based on AHP, and the final economic efficiency assessment of the IT system. In our view, the attempt to define a universal evaluation methodology is not entirely consistent with the conclusion regarding the necessity of an individualized approach for every project.

The development of an enterprise's ICI entails significant expenditures; consequently, financial evaluation methods remain de facto mandatory for justifying the budget of any project. Financial metrics such as ROI, NPV, IRR, Payback Period, and TCO are considered the most representative, scientifically grounded, and transparent tools for comparing alternative investment options in ICI development [6]. However, the inherent drawbacks and limitations of financial methods necessitate their refinement and the advancement of alternative methodological approaches. The primary directions for enhancing existing methods include increasing granularity, incorporating new parameters, and refining their application under specific predefined conditions. For instance, Haoran Sun analyzes the potential of using the Modified Internal Rate of Return (MIRR), which is a modification of the standard IRR [7]. Mingjun Liu explores the applicability of a new indicator △IRR and the Equivalent Annual Annuity (EAA) method in the evaluation of investment projects. [6].

Chongpeng You identifies the key disadvantages of the NPV, NPVR, and IRR methods for investment decision-making based on an analysis of their specific applications [8]. Despite the dynamic nature of these indicators, they fail to account for management flexibility and the uncertainty of market environment changes following the investment decision. The author justifies the expediency of using △IRR instead of the standard IRR and provides selection criteria for comparing mutually exclusive solutions based on specific practical cases.

In an article by Koen Milis et al., an analysis was conducted regarding the suitability of various approaches for evaluating the effectiveness of ICI development investments in service-oriented enterprises [9]. The authors acknowledge the widespread use of traditional financial methods while establishing their inherent shortcomings. The study concludes that relying on any single evaluation method yields low reliability in obtaining accurate results; consequently, the necessity of integrating multiple methods is recognized.

John Ward and his colleagues propose an evaluation approach based on the construction of a "Business Case," which differs from traditional financial justifications by recognizing various types of benefits, identifying measures for each benefit, and assigning benefit owners [10]. In effect, this approach represents an advancement of the portfolio methodology, allowing for the prioritization of investments across various projects and determining how the combination of IT and business changes will deliver each respective advantage.

The predictive nature of calculations and the uncertainty regarding future processes and events following project commencement represent a common challenge for all *ex-ante* methods of evaluating the economic efficiency of an enterprise's ICI [11]. Traditional financial methods for justifying investment decisions typically fail to account for such uncertainty, even though it can significantly impact the actual performance metrics of project implementation. However, research aimed at identifying ways to minimize the impact of this uncertainty is ongoing.

Currently, Real Options Analysis (ROA) has emerged as the primary tool for addressing this issue. The formation of ROA began with Stewart C. Myers' revolutionary idea regarding the applicability of financial derivative valuation logic to the field of real investments [12]. ROA represents a system of quantitative and qualitative evaluation techniques that integrate managerial flexibility into a project's financial model. In contrast to the static Net Present Value (NPV) method, which is based on the assumption that the investment project's implementation plan remains unchanged, ROA views it as a dynamic process with the possibility of making additional decisions [13].

The ROA methodology is applied in the strategic planning of large-scale investment projects, including urban development [14], the construction of energy facilities [15, 16], environmental protection [17], and the development of telecommunication infrastructure networks [18]. One of the seminal publications on the use of ROA to justify ICI investment decisions was the article by Benaroch and Kauffman, which focused on the deployment of a POS terminal network for debit services by the Yankee 24 network [19]. At that time, the debit card market was characterized by significant uncertainty regarding technology adoption rates among consumers and retailers. The authors utilized the Black-Scholes model to justify a "deferral option". They demonstrated that even with a positive NPV, immediate project implementation was less advantageous than waiting. Delaying allowed Yankee 24 to gather more market data and avoid the risk of investing in a network that might have remained underutilized. Chan et al. also propose using the ROA method for evaluating ICI investments, with a primary emphasis on the deferral option [20].

A significant driver for the development of new and the refinement of existing evaluation methods is the emergence of new ICTs and solutions based on them. Artificial Intelligence, Cloud Technology, Machine Learning, Big Data, and other emerging technologies are transforming the characteristics and capabilities of enterprise ICI, to which existing efficiency assessment methodologies may prove insensitive. This has even triggered a resurgence of the scholarly debate regarding the IT productivity paradox [21, 22]. Consequently, several recent studies aimed at enhancing approaches to evaluating the effectiveness of enterprise ICI development are specialized, focusing specifically on the application of these modern technologies. Černevičienė and Kabašinskas conducted a critical analysis of the Multi-Criteria Decision Making (MCDM) method to explore potential improvements in light of advancements in Artificial Intelligence. [23].

Building an ICI based on Cloud Technology not only radically alters the TCO cost structure but also provides the opportunity to increase the flexibility of infrastructure solutions by an order of magnitude. This flexibility is a source of new value that must be accounted for when justifying strategic decisions regarding an enterprise's ICI development. The ROA methodology has also become the primary method for evaluating the flexibility of cloud-based ICIs. In this context, the business value of flexibility is defined as the value of a real option, reflecting the right to make additional investment decisions in the future [24]. For strategic investment decision-making, Expanded NPV is utilized, enabling a more accurate project evaluation [25]:

$$Expanded\ NPV = NPV + ROV,$$

where ROV – Real Option Value.

The primary difficulties in evaluating via the ROA method are associated with the complexity of calculating the Real Option Value (ROV). The most common approaches to addressing this task include the Black-Scholes Option Pricing Model (BSOPM), the Binomial Option Pricing Model (BOPM), Monte Carlo Simulation (MCS), and Hybrid Real Options (HRO) [26]. Furthermore, various types of options can be considered: the Option to Defer, Option to Expand, Option to Abandon, Staging Option, and others. Consequently, there is a substantial body of literature examining the specific implementations of the ROA methodology, taking into account the nature of the problem and the selected tools. For instance, Lozano-Almansa et al. outline a procedure for evaluating investment in a cloud ERP system, incorporating the option to defer and calculating its value through the application of the binomial option pricing model [27]. Similarly, Na et al. identify specific characteristics of investment evaluation using the option to defer and determining its value via the binomial model, specifically for ground-based and floating solar energy projects [25].

Despite the extensive body of research focused on the further development of specific methods for evaluating the economic efficiency of ICI investment projects, there is a notable lack of studies dedicated to the selection and adaptation of existing methods for application within the context of a particular enterprise. In their study, Anggraeni Widya Purwita and Apol Pribadi Subriadi attempted to identify the "best" method for ICI investment evaluation by analyzing the most common approaches found in the literature [28]. They examined methods such as Return on Investment (ROI), Cost-Benefit Analysis (CBA), Multi-Criteria Decision Making (MCDM), Real Options Analysis (ROA), and Information Economics (IE). The comparison was based on characteristics including the ability to evaluate tangible and intangible assets, advantages, disadvantages, types of investment, and application methods. The IE method was identified as the most accurate because it allows for the assessment of tangible, intangible, and quasi-tangible assets. However, the inability to prioritize different projects for implementation was noted as a drawback. In our view, the very attempt to identify a single "best" or "most accurate" evaluation method is inconsistent with the conclusion reached by many scholars regarding the expediency of an individualized approach when assessing investments in ICI development projects.

Analysis of recent literature suggests that more research is needed to establish an *ex-ante* evaluation framework for ICI projects that incorporates firm-specific operations, business environment conditions, and technological flexibility. The objective of this article is to formulate a methodological approach for determining the procedure for the ex-ante economic efficiency evaluation of alternative enterprise ICI development projects, taking into account the specifics of the enterprise's activities, business environment characteristics, the flexibility of technological solutions, and the level of outcome uncertainty.

Results

The selection of an ex-ante efficiency evaluation method for enterprise ICI development projects is a critical stage in corporate planning. As previously established, the selection of an appropriate method or combination of methods must be performed individually for each project. Based on the analysis of general characteristics of ex-ante assessments for ICI projects, five key categories of factors were identified that must be accounted for when justifying the choice of an evaluation method (Figure 1). The Technology-Organization-Environment (TOE) theoretical framework was applied to define these factors [29].

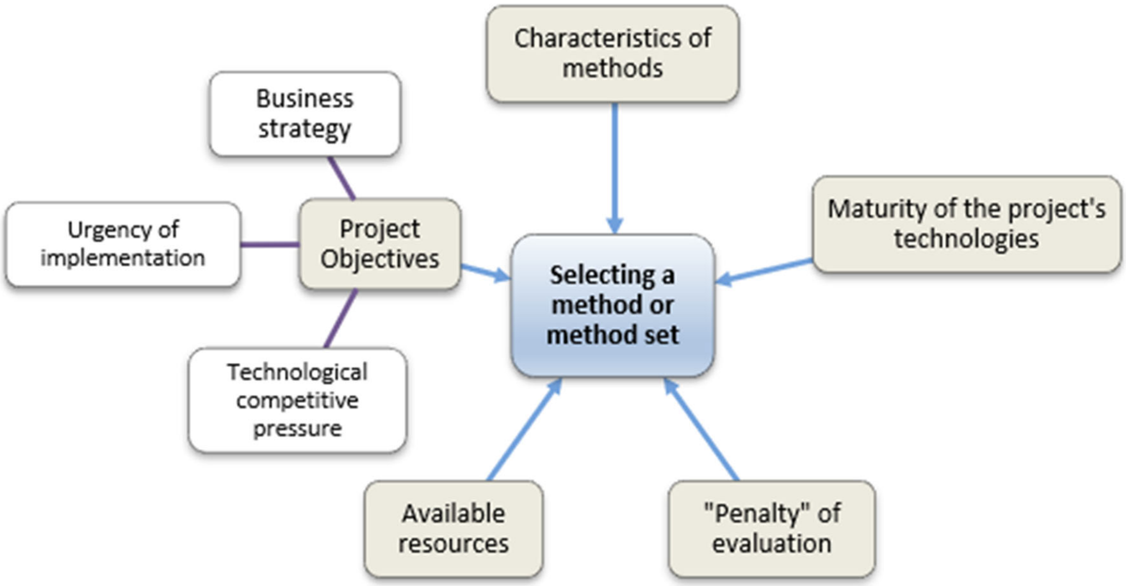

Figure 1. Conceptual model of the differentiated selection of the *ex-ante* evaluation method for enterprise ICI development projects

Source: created by the author

Characteristics of methods. To ensure a reasoned selection of the appropriate method or their combination for the ex-ante efficiency evaluation of enterprise ICI development projects, it is essential to understand their capabilities and specific application features. Various methodological approaches are characterized by distinct advantages and disadvantages, input data requirements, assessment duration, and the accuracy of results. The key characteristics of the evaluation methods across the three primary groups are summarized in Table 1.

Table 1. Comparative characteristics of the key groups of *ex-ante* evaluation methods for ICI development projects

Method Group	Tools	Accuracy	Resource Requirements	Advantages	Disadvantages
Quantitative (Financial)	Deterministic (ROI, IRR, Payback Period, NPV, TCO)	Low in a dynamic environment	Low	Clear to management; low labor intensit	Ignores development uncertainty
	Probabilistic (ROA, Monte-Carlo, Fuzzy)	Medium/High	High/Very High	Accounts for development uncertainty	High labor intensity and high skill requirements for executors
Qualitative	SWOT, benchmarking, expert assessments	Low	Medium	Accounts for "soft" factors; provides strategic vision	High subjectivity
Complex (Hybrid)	MCDM, AHP, TOPSIS, Information Economics, Balanced Scorecard, Portfolio	Medium/High	High	Multi-faceted evaluation	Difficulty in obtaining high-quality data

Source: compiled by the author based on [3, 5–9, 13, 20, 23, 26, 28]

Project Objectives. To achieve success, every ICI development project must have a clearly defined objective that aligns with the enterprise's business strategy in accordance with the Strategic Alignment Model [30]. The primary objective of a project is directly linked to the reasons for its development. In the context of this study, projects can be categorized into three types based on their goals, which we have termed "survival," "optimization," and "expansion."

"Survival" projects arise when a company's financial position deteriorates due to the loss of customers caused by technological backwardness. For example, if a company lacks a website while virtually all direct competitors provide customers with the convenience of online ordering, the company must urgently implement a familiar and user-friendly online ordering system to avoid the final loss of its clientele under such technological competitive pressure. Consequently, for the evaluation of these projects, the simplicity and speed of assessing financial results are more critical than precision or multi-faceted analysis.

"Optimization" projects are initiated to maintain a company's competitiveness and involve improving business processes, optimizing costs, and enhancing customer service quality. These projects may also involve scaling activities within a defined development strategy. Therefore, financial methods are also essential for their evaluation, often in combination with other approaches.

"Expansion" projects are innovative in nature and are designed to create new strategic competitive advantages through the use of cutting-edge ICT, potentially involving the implementation of new business models and other innovations. For the assessment of such projects, a financial evaluation alone is insufficient and must be supplemented by the application of other methodological approaches.

Maturity of the project's technologies. Even the most advanced and revolutionary ICTs eventually become so widespread that they no longer provide a basis for competitive advantage. In this process, they transition from being a source of strategic advantage to a standard service for supporting business processes, requiring corresponding expenditures [31]. Consequently, the level of market maturity of a technology is a critical factor determining its current ability to provide strategic competitive advantages and the potential duration of their maintenance.

The outcomes of implementing mature technologies that have already achieved significant adoption can be predicted much more accurately than those for technologies in the early stages of development. However, such technologies are unlikely to serve as a source for creating new strategic advantages or significantly increasing the enterprise's economic efficiency. Conversely, investments in projects based on technological solutions at the early stages of their life cycle can provide substantial strategic market advantages, though the level of uncertainty regarding future results remains very high

A study conducted within the MIT NANDA project on the success of over 300 publicly announced AI initiatives demonstrated a low level of alignment between obtained financial results and initial expectations. Out of a total corporate investment in GenAI ranging from $30 billion to $40 billion, only 5% of pilot projects proved to be profitable [32]. According to a 2020 study by the Standish Group, the overall success rate of IT projects stood at 31% (Figure 2).

The aforementioned facts confirm that innovative enterprise ICI development projects based on cutting-edge ICTs, implemented to establish competitive advantages, are characterized by an increased level of uncertainty regarding their outcomes. This conclusion also aligns well with the Hype Cycle concept [34], utilized by Gartner. Each of the five defined phases of the life cycle is characterized by a specific level of value expectations for the technology and the subsequent direction of its evolution (Figure 3).

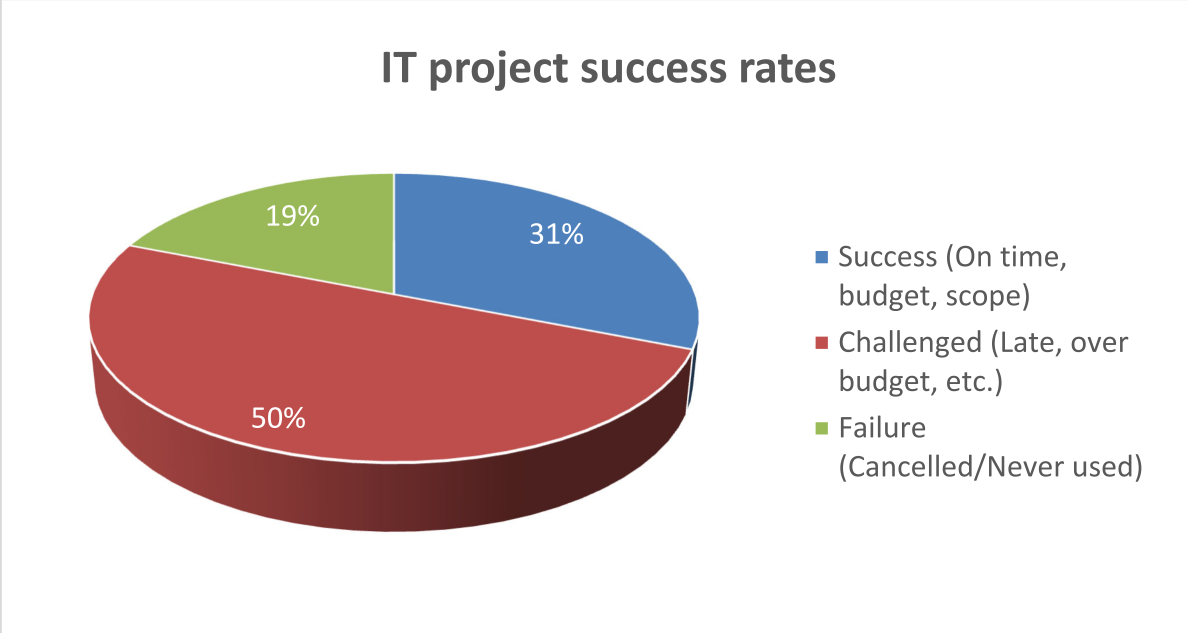

Figure 2. IT project success rates, 2015–2025
Source: compiled by the author based on [33]

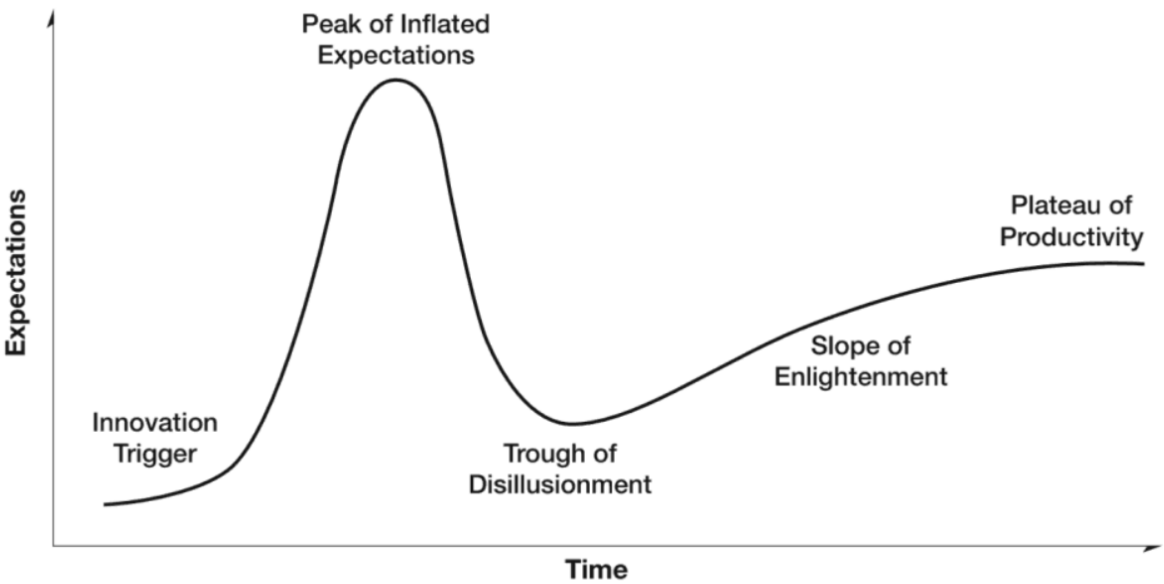

Figure 3. Gartner Hype Cycle [34]

Inflated expectations regarding the effectiveness of new technologies at the "Peak of Inflated Expectations" stage arise from extensive coverage in the media and professional communities of early success stories, combined with human perceptions of innovation. At this point, objectively verified assessments of the new technology's capabilities remain unavailable due to the lack of sufficient empirical data. The level of uncertainty regarding potential outcomes is exceptionally high; therefore, using traditional financial evaluation methods to assess the implementation of such solutions cannot provide reliable results. However, the competitive advantages for a first-mover, if the project is successful, can be substantial and long-lasting.

The implementation plans for these projects may evolve based on the success of specific stages. Consequently, when evaluating such projects, it is crucial to account for the value of the enterprise's ICI flexibility. As previously demonstrated, probabilistic methods that incorporate the value of ICI flexibility based on ROA are best suited for such tasks. Conversely, the outcomes of ICTs that have reached the "Slope of Enlightenment" and "Plateau of Productivity" are much easier and more accurate to predict, as sufficient statistical data regarding their implementation has been accumulated. Therefore, depending on other circumstances, the expediency of using complex probabilistic methods must be carefully determined.

Available resources. As shown in Table 1, the time and financial costs associated with the evaluation process itself can vary significantly depending on the method used. Requirements for the qualifications of the executors also differ. Therefore, when selecting a method, it is essential to compare the resources required for its implementation with the enterprise's existing capabilities. Methods that are highly accurate but expensive to implement are not always expedient. In any case, the costs of conducting the evaluation should not constitute a significant portion of the total project cost.

"Penalty" of evaluation. The results of an enterprise's ICI development project evaluation are utilized by management to make decisions aimed at improving operational efficiency. Delays in decision-making due to a prolonged evaluation process effectively lead to losses equivalent to the unrealized benefits during the assessment period. Accounting for the "penalty" of evaluation is most critical for "survival" and "optimization" projects, according to our defined classification. In contrast, projects of a strategic nature are typically formulated and reviewed well in advance; therefore, this characteristic generally does not hold significant weight for them

Conclusions

The conducted analysis of publications regarding the effectiveness evaluation of ICI development projects confirms the existence of a significant disparity in the capabilities of various methodological approaches. It is established that it is impossible to define a single, universally effective *ex-ante* method for evaluating the economic efficiency of ICT utilization and the implementation of corresponding ICI development projects. The classification of *ex-ante* evaluation methods for ICI development projects has been refined, and the key characteristics of their primary types have been summarized.

Based on the application of the TOE theoretical framework, a conceptual model for the differentiated selection of an appropriate ex-ante evaluation method for enterprise ICI development projects is proposed. This model incorporates five groups of factors: Characteristics of methods, Project Objectives, Maturity of the project's technologies, Available resources, and the "Penalty" of evaluation. The utilization of the proposed model is intended to ensure the selection of the most suitable methodology for conducting the *ex-ante* evaluation of ICI investments, taking into account the unique operational characteristics of the enterprise. Further research should be directed toward clarifying the nature of the relationship between the maturity level of ICT and the accuracy of forecasts regarding its impact on enterprise performance.

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