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Anna Kravchenko
Doctor of Economic Sciences, Professor,
First Vice-Rector,
Kyiv University of Market Relations,
ORCID: https://orcid.org/0000-0001-5733-6582
Кравченко А. С.
Вищий навчальний заклад «Київський університет ринкових відносин»

Serhii Riabkov
Postgraduate Student,
Kyiv University of Market Relations
ORCID: https://orcid.org/0009-0003-3146-7260
Рябков С. О.
Вищий навчальний заклад «Київський університет ринкових відносин»

METHODS FOR ECONOMIC EVALUATION OF TELEMEDICINE: AN OVERVIEW

МЕТОДИ ЕКОНОМІЧНОЇ ОЦІНКИ ТЕЛЕМЕДИЦИНИ: ОГЛЯД

Abstract. *Telemedicine has evolved from a supplementary modality into an essential component of modern healthcare systems. Remote consultations, telemonitoring and other virtual care models are increasingly integrated into routine clinical pathways, particularly in chronic disease management and settings with limited access to in-person services. Telemedicine improves accessibility, continuity of care and reduces avoidable hospitalizations while enhancing patient routing efficiency. At the same time, it represents a resource-intensive and organizationally complex health technology requiring investment in digital infrastructure, software platforms, cybersecurity, workforce training and interoperability with electronic health systems. Therefore, clinical effectiveness alone is insufficient for large-scale adoption, and decision-makers require evidence of economic efficiency and affordability within Health Technology Assessment frameworks. Telemedicine functions as a complex intervention whose outcomes depend on interacting determinants including patient characteristics, clinical protocols, technological features, organizational workflows and digital literacy, limiting transferability of results across contexts. The study systematizes major economic evaluation approaches applied to telemedicine, including cost-effectiveness, cost-utility, budget impact and cost-consequence analyses, with emphasis on cost measurement, outcome valuation and uncertainty assessment. The methodological design combines systematic and scoping review elements aligned with PRISMA 2020 and CHEERS 2022 standards. Included studies compared telemedicine interventions with usual care and reported analytical perspective, time horizon and uncertainty analysis. Results indicate predominance of cost-effectiveness and cost-utility analyses, while budget impact analysis remains insufficiently applied despite its importance for implementation decisions. Economic benefits are mainly associated with reduced hospitalizations and quality-of-life improvements. Key methodological challenges include accurate costing, long-term outcome modeling and sensitivity to adoption rates and infrastructure costs. Telemedicine evaluation therefore requires integrated assessment of effectiveness, economic efficiency and affordability to support evidence-based healthcare decision-making.*

Keywords: *telemedicine, economic efficiency, health technology assessment (HTA), cost-effectiveness analysis (CEA), cost-utility analysis (CUA), budget impact analysis (BIA), quality-adjusted life years (QALY), incremental cost-effectiveness ratio (ICER), digital health, Markov models, real-world evidence, methodological standards.*

Анотація. *Телемедицина перетворилася з додаткового методу на важливий компонент сучасних систем охорони здоров'я. Дистанційні консультації, телемоніторинг та інші моделі віртуальної допомоги все частіше інтегруються в рутинні клінічні шляхи, особливо при лікуванні хронічних захворювань та в умовах обмеженого доступу до послуг особистого прийому. Телемедицина покращує доступність, безперервність медичної допомоги та зменшує кількість госпіталізацій, яких можна уникнути, одночасно підвищуючи ефективність маршрутизації пацієнтів. Водночас вона являє собою ресурсоємну та організаційно складну технологію охорони здоров'я, яка вимагає інвестицій у цифрову інфраструктуру, програмні платформи, кібербезпеку, навчання робочої сили та сумісність з електронними системами охорони здоров'я. Тому самої лише клінічної ефективності недостатньо для широкомасштабного впровадження, а особам, що приймають рішення, потрібні докази економічної ефективності та доступності в рамках оцінки медичних технологій. Телемедицина функціонує як складне втручання, результати якого залежать від взаємодіючих детермінант, включаючи характеристики пацієнтів, клінічні протоколи, технологічні особливості, організаційні робочі процеси та цифрову грамотність, що обмежує перенесення результатів у різних контекстах. У дослідженні систематизовано основні підходи до економічної оцінки, що застосовуються до телемедицини, включаючи аналіз економічної ефективності, корисності витрат, впливу на бюджет та наслідків витрат, з акцентом на вимірювання витрат, оцінку результатів та оцінку невизначеності. Методологічна розробка поєднує елементи систематичного та охоплюючого огляду, що відповідають стандартам PRISMA 2020 та CHEERS 2022. Включені дослідження порівнювали телемедицинські втручання зі звичайним доглядом та повідомляли про аналітичну перспективу, часовий горизонт та аналіз невизначеності. Результати вказують на переважання аналізів економічної ефективності та співвідношення витрат та корисності, тоді як аналіз впливу на бюджет залишається недостатньо застосованим, незважаючи на його важливість для рішень щодо впровадження. Економічні вигоди в основному пов'язані зі зменшенням кількості госпіталізацій та покращенням якості* *життя. Ключові методологічні проблеми включають точний розрахунок витрат, моделювання довгострокових результатів та чутливість до темпів впровадження та витрат на інфраструктуру. Тому оцінка телемедицини вимагає інтегрованої оцінки ефективності, економічної доцільності та доступності для підтримки прийняття рішень у сфері охорони здоров'я на основі доказів.*

Ключові слова: *телемедицина, економічна ефективність, оцінка медичних технологій (HTA), аналіз економічної ефективності (CEA), аналіз корисності витрат (CUA), аналіз впливу на бюджет (BIA), роки життя, скориговані з урахуванням якості (QALY), коефіцієнт додаткової економічної ефективності (ICER), цифрова охорона здоров'я, Марковські моделі, реальні дані, методологічні стандарти.*

Problem statement. Telemedicine services – including remote consultations, telemonitoring, telerehabilitation, and other digital forms of interaction between physicians and patients – have become an established component of healthcare systems in recent years. The practical value of telemedicine is associated with improved access to medical care, optimization of patient pathways, reduction in hospitalization rates for chronic conditions, and enhanced continuity of follow-up and long-term monitoring. At the same time, telemedicine represents a resource-intensive technology: it requires appropriate infrastructure, software solutions, staff training, integration with health information systems, cybersecurity measures, and compliance with regulatory requirements. Therefore, clinical effectiveness alone is not a sufficient basis for implementation; assessment of economic efficiency and financial feasibility is also necessary. Economic efficiency in healthcare describes the relationship between additional costs and additional outcomes when choosing among alternative interventions. In international practice, reimbursement and funding decisions are often based on Health Technology Assessment (HTA), which incorporates clinical evaluation, economic evaluation, and analysis of the organizational context.

Analysis of recent research and publications. Contemporary research demonstrates a significant expansion of the evidence base for the cost-effectiveness of telemedicine. One of the first large-scale studies was the cluster-randomized trial by Henderson et al. (a whole-system demonstrator) [9], which showed an increase in overall costs in the absence of acceptable cost-per-QALY thresholds, thereby highlighting the dependence of the cost-effectiveness of telemedicine on the organizational model of healthcare delivery. Similar findings were presented in the Health Technology Assessment (HTA) report by Pandora et al. [23], where the economic outcomes of telemonitoring in heart failure varied significantly depending on the monitoring structure and the completeness of the implementation cost assessment. A randomized controlled trial by Köhler et al. (TIM-HF2) [15] confirmed the clinical effectiveness of remote management in chronic heart failure, while a subsequent economic evaluation by Sydow et al. [28] showed that clinical benefits can be achieved with comparable or reduced overall healthcare system costs. Systematic reviews by Zakia et al. [32] and Ziegler et al. [33] also point to the potential economic value of telemonitoring, while highlighting substantial variability in the reported results. The most consistent economic evidence has been obtained in the area of stroke telemedicine services. Modeling by Nelson et al. [20, 21] and Switzer et al. [27] demonstrates that the cost-effectiveness of stroke telemedicine networks becomes most evident over long-term analytical horizons and is highly dependent on the distribution of infrastructure costs and patient volume. A systematic review by Lopez-Romero et al. [18] confirms the high cost-effectiveness of telemedicine interventions in stroke, while Tsou et al. [30] reflect current approaches to economic evaluation based on administrative data integration and analytical modeling. In other clinical areas, results remain highly context-dependent. A review by Lee et al. [16] reports a wide range of incremental cost-effectiveness ratios (ICERs) for telemedicine interventions in diabetes care. Hofer et al. [12] noted that telemonitoring in chronic obstructive pulmonary disease may improve clinical outcomes while potentially increasing costs, while the telEPOC study by Esteban et al. [7] linked cost-effectiveness primarily to a reduction in hospital readmissions. In dermatology, systematic reviews by Lopez-Liria et al. [17] and Wang et al. [31] demonstrate trends toward lower costs and improved access to care. Integrative analyses by Mudiyanselage et al. [19]; Ben-Assuli [2]; Hilti et al. [11]; Reinhardt et al. [26] show that the economic outcomes of telemedicine are determined primarily by the implementation conditions, the degree of integration into the healthcare system, the scale of the program, and cost-reimbursement mechanisms, rather than just by technological characteristics. Overall, the reviewed literature confirms the existence of prerequisites for the cost-effectiveness of telemedicine. However, most studies are characterized by methodological heterogeneity, differences in analytical approaches and time horizons, and incomplete consideration of organizational and infrastructure costs. These limitations highlight the need for further study and standardization of economic evaluation methodologies, broader application of longitudinal modeling approaches, and closer integration of health technology assessment frameworks with real-world healthcare conditions.

The purpose of the article. The objectives of this article are to systematize and compare the main approaches to the economic evaluation of health technologies - such as cost-effectiveness analysis, cost-utility analysis, cost-benefit analysis, and budget impact analysis-in the context of telemedicine, as well as to describe the methodological features of modelling and interpreting results.

Presentation of the main material. Within the framework of health technology assessment (HTA), health technologies are defined broadly and include not only pharmaceuticals and medical devices, but also procedures, models of care, and digital services. Telemedicine is classified as a "complex intervention" whose final effect depends on many factors, including the patient profile, clinical protocols, platform characteristics, organizational model, intensity of interaction, and level of digital literacy. This distinguishes telemedicine from many traditional interventions and increases the methodological requirements for economic evaluation. For the economic evaluation of telemedicine, key characteristics include a significant share of fixed and "staged" costs (platform development, systems integration, hardware infrastructure); pronounced indirect effects (patient time costs, transportation savings, impact on physician and healthcare facility workload, and redistribution of healthcare pathways); heterogeneity of effects across different population groups (urban and rural settings; high-risk and low-risk patients; different levels of access to digital technologies). Organizational implications (changes in visit frequency, task shifts among health care workers, and changes in patient routing and service delivery models), the sensitivity of results to the scale of implementation, and reimbursement or pricing policies are of great importance. Thus, methodologies for assessing the cost-effectiveness of telemedicine should ensure proper comparison of alternatives, transparency of data sources, explicit consideration of uncertainty, transferability of results, and budget impact assessment (BIA) to support management decisions. The economic evaluation of telemedicine should be viewed as a lifecycle-based process: (i) early assessment (early health technology assessment) at the prototype or pilot stage; (ii) assessment during implementation and scaling; and (iii) re-assessment when reimbursement rates, platform functionality, or clinical protocols change. In the early stages, simplified models and scenario analysis may be appropriate, whereas scaling requires real data and a comprehensive budget impact assessment. It is also important to consider the "learning curve," as the first months of implementation may be associated with higher costs and reduced productivity. This should be reflected in economic models, for example, through a staged cost structure.

The review design combines elements of a systematic review and a scoping review. The reporting structure is guided by the PRISMA 2020 statement [24] and the accompanying PRISMA 2020 Explanation and Elaboration document. [25] Requirements for presenting economic outcomes and methodological components were aligned with the CHEERS 2022 reporting standards [13] and its extended version. [14] The literature search was conducted using key terms including "telemedicine," "telehealth," "remote monitoring," and "virtual care," combined with economic evaluation terms such as "economic evaluation," "cost-effectiveness," "cost–utility," "budget impact," "QALY," and "ICER." In addition, condition-specific terms were applied for selected clinical areas, including heart failure, stroke, diabetes mellitus, chronic obstructive pulmonary disease (COPD), dermatology, and psychiatry. Priority was given to studies published in peer-reviewed journals and to HTA reports. Studies were included in the review if: (i) the intervention was a telemedicine service or telemonitoring; (ii) an economic evaluation (CEA, CUA, CBA, BIA, or CCA) was conducted or a model-based cost–benefit analysis was presented; and (iii) comparable cost–effect data were presented relative to an alternative strategy (usual care or another telemedicine format). For included studies, the following information was extracted: clinical area, type of telemedicine service, study design, analytical perspective (health system, payer, or society), time horizon, discounting approach, estimation methods (CEA, CUA, etc.), primary economic outcome (ICER, incremental net benefit -INB, cost per QALY gained, or budget impact), and the approach used to account for uncertainty (one- or multi-way sensitivity analysis, probabilistic analysis). The synthesis was carried out as a qualitative narrative synthesis with a classification of methodological approaches and a discussion of their applicability.

Economic evaluation methods in healthcare include several main methodological approaches, each addressing different management and policy issues. In telemedicine, the choice of method must consider the type of effect (clinical, organizational, or social), cost structure, and data availability. Cost-minimization analysis (CMA) is applicable only when the clinical equivalence of alternatives has been demonstrated. In the context of telemedicine consultations, CMA may be appropriate if the equality of clinical outcomes and quality of care is confirmed (e.g., through standardized protocols for follow-up visits). In practice, equivalence is often uncertain; therefore, CMA is usually considered a complementary approach rather than a primary method. Cost-effectiveness analysis (CEA) measures outcomes in natural units, such as averted hospitalizations or prevented complications. A key metric is the incremental cost-effectiveness ratio (ICER). This method is particularly useful when clinical outcomes are clearly measurable and directly linked to patients and health systems, such as in telemonitoring programs for heart failure. Cost-utility analysis (CUA) uses composite outcome measures, most commonly quality-adjusted life years (QALYs). In telemedicine, CUA is particularly important when improved health-related quality of life represents the primary benefit, such as increased access to care or reduced anxiety due to continuous monitoring. However, assessing utility requires validated instruments, such as the EQ-5D or EQ-5D-5L [10], and appropriate extrapolation over time. Cost-benefit analysis (CBA) captures monetary effects, facilitating cross-sectional comparisons, for example, regarding increased productivity. In telemedicine, CBA is useful for accounting for indirect benefits related to time savings and reduced travel costs. However, it is methodologically limited by the difficulty of monetizing clinical outcomes. Even if telemedicine is cost-effective according to cost-effectiveness analysis (CEA) or cost-benefit analysis (CUA), its implementation may remain financially challenging under budget constraints. Budget impact analysis (BIA) answers the question, "How much will this intervention cost the budget if implemented?" Therefore, it is an important component of decision-making, particularly in publicly financed and insurance-based healthcare systems. Telemedicine interventions often result in multiple clinical, organizational, and social outcomes. Cost-consequence analysis (CCA) and multicriteria approaches present outcomes as an "outcome profile" without aggregating them into a single summary metric, thereby increasing transparency. Furthermore, when the relative importance of outcomes is uncertain or when tradeoffs between outcomes are complex, multicriteria decision analysis (MCDA) can be applied. Accurate cost measurement represents a significant methodological bottleneck in the economic evaluation of telemedicine. In general, two main costing approaches are used: top-down costing (allocating total costs across service delivery units) and microcosting (detailed identification and evaluation of individual resources). Microcosting is generally preferred for telemedicine, given the non-standard and highly heterogeneous cost structure of digital health interventions. The recommended cost breakdown for telemedicine services consists of fixed investment costs, such as software development or licensing, integration with delivery systems, hardware acquisition, and cybersecurity infrastructure; capital costs with depreciation, including servers and monitoring devices, taking into account assumptions about useful lives and replacement rates; operating costs, such as maintenance, upgrades, licensing fees, connectivity, hosting, and user support services. Additionally, costs of medical personnel are taken into account, reflecting the time spent on consultations, monitoring, triage, and communication with patients, including the redistribution of tasks between professional roles; costs incurred by the patient (from a societal perspective), including time costs, travel costs, and costs associated with connectivity or personal devices; training and change management costs associated with staff training and organizational adaptation; quality and safety costs, including validation activities, audits, and incident management. In this context, a practically relevant method is time-based costing (TDABC), which estimates costs based on the duration of a process and the cost per unit of time. TDABC is particularly well suited to describing telemedicine care pathways, such as remote monitoring followed by a physician referral when clinically indicated.

Telemedicine often impacts not only "hard" clinical outcomes (such as mortality or hospitalization rates) but also broader aspects, including access to care, time to intervention, patient anxiety, treatment adherence, and satisfaction with health services. In economic evaluation, this poses a methodological challenge regarding the appropriate choice of outcome measures. In cost-effectiveness analysis (CEA), effects can be expressed in natural units, such as avoided hospitalizations or the achievement of predefined clinical goals. In cost-effectiveness analysis (CUA), outcomes must be converted into quality-adjusted life years (QALYs), either by directly measuring health utilities using tools such as the EQ-5D-5L [10] or by using matching methods that convert clinical scale scores into utility values, which introduces additional uncertainty. For telemedicine technologies, it is recommended to explicitly describe the relationship between process improvements (e.g., reduced time to consultation) and clinical outcomes; justify the use of utility measures and methods used for extrapolation over time; include patient-reported outcomes (PROs) as secondary endpoints; and use cost-consequence analysis (CCA) when effects are The willingness-to-pay threshold and interpretation of the ICER require comparison with the willingness-to-pay (WTP) threshold per unit effect (e.g., per QALY gained). This threshold is institution-specific and depends on the country and payer context; therefore, studies should report cost-effectiveness acceptability curves (CEACs) as well as results in terms of net monetary benefit (NMB), which facilitates statistical analysis and comparison of alternatives. The methodological foundations for representing uncertainty using CEACs have been discussed in detail in the health economics literature. [8]

Distributional effects and equity in the economic evaluation of telemedicine are controversial. While telemedicine has the potential to reduce geographic barriers, it may also exacerbate digital inequality. Therefore, for some projects, it is appropriate to supplement standard economic evaluation with a distributional analysis (allocational cost-effectiveness analysis) or, at a minimum, a stratified analysis by age, place of residence, and level of access to digital technologies. This allows decision-makers to avoid situations where an intervention that is generally "cost-effective" may nevertheless impair access to services for vulnerable populations. Telemedicine is often used to treat chronic conditions, where costs and effects are distributed over time. Therefore, model-based research is a key tool for extrapolating data from clinical trials and observational studies to longer time horizons.

Decision tree models are used when the time horizon is relatively short and the number of events is limited, for example, in teletriage or remote consultations during acute episodes. Markov models are used for chronic conditions in which patients transition between health states over time; such models are often used to evaluate telemonitoring for heart failure and stroke. An example is a model-based evaluation of the effectiveness of telemedicine for stroke, which demonstrates high cost-effectiveness over the entire patient lifecycle. [21] Discrete event modeling (DES) and microsimulation are particularly relevant for complex care trajectories and systemic effects such as wait times, patient routing, and resource constraints. These approaches enable the assessment of scale effects, systemic bottlenecks, and organizational changes. Telemedicine services are characterized by uncertainty regarding both clinical effectiveness and implementation costs. Therefore, it is recommended to apply probabilistic sensitivity analysis (PSA), present cost-effectiveness acceptability curves (CEACs), and conduct scenario analyses based on key assumptions, including coverage metrics, usage rates, platform costs, and reimbursement rates.

Table 1 present the studies included in this review were categorized by clinical area (cardiovascular disease, stroke, diabetes, COPD, and others) and by type of telemedicine service (telemonitoring, remote consultations, and telerehabilitation). Cost-effectiveness analysis (CEA) and cost-feasibility analysis (CUA) were most frequently used, while cost-benefit analysis (CBA) and cost-consequence analysis (CCA) were used less frequently. Budget impact analysis (BIA) was used inconsistently, despite its critical importance for management and reimbursement decisions.

The choice of analytical perspective (payer, health system, or society) when evaluating telemedicine significantly impacts the conclusions. For example, remote consultations may provide only limited savings to the payer but significant societal benefits by reducing travel costs and patient time. Therefore, the chosen perspective and the included cost components should be clearly stated. [14] Short-term studies often underestimate the effects of telemedicine. In the case of telemedicine for stroke, using a lifetime horizon has been shown to significantly improve ICER estimates compared to a 90-day horizon. [21] Therefore, for chronic conditions, modeling approaches that allow for appropriate long-term extrapolation are generally preferred. A high proportion of fixed costs implies that cost-effectiveness improves with increased coverage, provided that quality and outcomes are maintained. For small patient volumes, telemedicine may become economically unattractive. This is particularly evident in hub-and-spoke stroke telemedicine networks, where the distribution of implementation costs among participating centers significantly impacts ICER results. [27] Economic outcomes are often highly context-dependent, reflecting differences in reimbursement rates, cost structures, and care delivery organization. Therefore, country-specific decision-making requires local adaptation of model parameters, justification of transferability, and provision of

Table 1 – Economic Outcomes and Determinants of Cost-Effectiveness of Telemedicine Interventions Across Clinical Areas

Source	Clinical area	Telemedicine intervention	Key determinants of cost-effectiveness	Economic outcomes
Boodoo C. et al., 2020 [3]	Heart failure (ambulatory chronic heart failure management)	Nurse-led heart failure telemonitoring program	Reduction in mortality and hospitalizations over a long-term horizon (25-year microsimulation model)	ICER ≈ CAD 8,850 per QALY gained; incremental health benefit: +0.566 QALYs per patient compared with usual care; probability of cost-effectiveness >85% at a willingness-to-pay threshold of CAD 50,000/QALY
Thokala et al., 2013 [29]	Heart failure and chronic cardiovascular conditions	Post-discharge telemonitoring	Reduction of hospitalizations, mortality effects, program costs, implementation scale	ICER ≈ £11,873 per QALY in base-case scenario
Boyne et al., 2013 [4]	Heart failure and chronic cardiovascular conditions	Telemonitoring vs usual care (TEHAF)	Institutional structure, organizational implementation factors	High uncertainty of economic results
Sydow et al., 2022 [28]	Heart failure and chronic cardiovascular conditions	Structured telemedical management (TIM-HF2)	Cost structure, clinical outcomes, large-scale program implementation	Favorable cost-effectiveness results
Nelson et al., 2011 [21]	Stroke / Teleneurology (Telestroke)	Remote neurological consultation networks	Increased timely treatment, improved functional outcomes	Highly cost-effective over lifetime horizon
Switzer et al., 2013 [27]	Stroke / Teleneurology (Telestroke)	Hub-and-spoke telestroke networks	Network organization, patient volume, cost allocation	Cost-effectiveness dependent on system design
Dixon et al., [5, 6]	Cardiovascular risk prevention	Telecoaching and remote monitoring (Healthlines program)	Risk reduction, adherence, model-based implementation effects	Probable cost-effectiveness at £20,000/QALY threshold
Padwal et al., 2019 [22]	Hypertension	Home blood pressure telemonitoring with case management	Monitoring intensity, reimbursement conditions	Economically attractive under specific reimbursement models
López-Liria et al., 2022 [17]	Dermatology	Teledermatology consultations	Reduced waiting time, fewer face-to-face visits, improved patient routing, contextual variability	Potential cost savings

Source: authors based on [3–6, 17, 21, 22, 27–29]

scenario-based analyses. In telemedicine, key parameters such as usage rate, treatment adherence, platform cost, and digital literacy levels are characterized by significant uncertainty. In practice, the choice of evaluation method involves reimbursement and financing decisions – CUA (based on QALYs) combined with BIA; for chronic disease management programs – Markov or DES models with probabilistic sensitivity analysis (PSA); for organizational innovations with multiple outcomes – conversion criterion analysis (CCA) and/or multicriteria decision analysis (MCDA). A mandatory analysis for scaling is a sensitivity analysis with a focus on coverage metrics and fixed cost structure. To systematically assess the quality of telemedicine economic evaluations, it is advisable to use reporting checklists such as CHEERS 2022, [13,14] as well as tools for assessing the methodological quality and risk of bias in decision models, including ECOBIAS. [1] Typical sources of bias include incomplete consideration of implementation costs, inappropriate choice of time horizon, reliance on short-term effects without sound extrapolation, and lack of probabilistic sensitivity analysis. Publication bias is an additional concern: telemedicine economic evaluations are often conducted within the context of implementation projects and may reflect the interests of technology providers.

Conclusions. Telemedicine services, as health technologies, require rigorous economic evaluation to support decisions on implementation and financing. The most widely applicable methods are cost-effectiveness analysis (CEA) and cost–utility analysis (CUA); however, budget impact analysis (BIA) is critically important for managerial decision-making, while cost–consequence analysis (CCA) and multi-criteria decision analysis (MCDA) are particularly relevant for interventions with complex and multidimensional effects. Key methodological requirements include the appropriate choice of analytical perspective and time horizon, comprehensive inclusion of organizational and infrastructure-related costs, modelling of long-term outcomes, and transparent handling of uncertainty. Promising future directions include further standardization of HTA frameworks for digital health technologies and the increasing role of real-world evidence.

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