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UKRAINIAN INTERNET SERVICE PROVIDERS RANKING: MULTI-CRITERIA MODEL INCORPORATING CYBERSECURITY

Introduction

Internet services have become an indispensable facet of modern life, imposing stringent requirements on both quality and security. Selecting an Internet Service Provider (ISP) is a complex task because it involves many heterogeneous often mutually conflicting criteria. High demands for speed, stability and safety, combined with cost constraints, necessitate an approach that can reconcile diverse requirements within a single decision-making framework [1].

Multi-criteria optimization is well suited to this task, as it seeks solutions that are jointly optimal across several criteria. The present study aims to demonstrate a practical method for ISP selection based on multi-criteria analysis, supported by heuristic procedures for refining candidate optima [2].

Because clients invariably seek the "best" service, yet must choose a single provider from among many options and parameters, the selection process is formidable. Beyond technical specifications, one must consider provider ratings, user reviews, pricing, and contractual terms. Factoring these technical and commercial indicators into the analysis enables a more informed choice of provider capable of delivering reliable, high-speed connectivity [3–5].

Despite growing global attention to cybersecurity, this criterion is often omitted from integrated assessments in Ukrainian research. According to the 2023 market review, the telecommunications sector is among the most frequently targeted: more than 500 cybersecurity incidents were recorded that year. The National Security and Defense Council of Ukraine likewise emphasizes the importance of cyber-resilient ISP infrastructure, especially under conditions of hybrid warfare [6, 7].

Accordingly, a clear research gap exists: the absence of an integrated model that evaluates ISPs not only by classical quality parameters but also by their cybersecurity posture. A multi-criteria approach to ISP assessment can thus benefit both consumers by facilitating provider selection and service providers by guiding strategic development under competitive pressure.

The multi-criteria optimization problem that arises in selecting an effective solution requires the identification of a compromise alternative. The search process is heuristic in nature and takes place under uncertainty. At several stages, a decision maker (DM) is involved to formulate the task and interpret its results. Utility theory underlies this approach, postulating that the DM can assign a single, aggregated value or utility to each criterion.

Many numerical methods for such problems are based on selecting a point from the Pareto set corresponding to criterion weights. Choosing the best alternative requires taking account of conditional preferences, derived from additional expert information and processed according to utility theory [8].

The objective of this study is therefore to develop a multi-criteria model for evaluating Ukrainian ISPs that includes cybersecurity as an independent criterion, employs heuristic optimization methods, and involves the DM in refining criterion weights.

To this end, we propose a heuristic refinement procedure with DM participation. The procedure is an interconnected set of formalized methods for specifying the optimization criterion for the system under design, forming an initial set of design alternatives, identifying the Pareto-optimal subset, and narrowing this subset to a single best design alternative using additional expert information [9].

Methods

Before a single solution can be selected from among all feasible compromises, the fundamental principles (axiomatics) underlying the choice rule must be justified. This requires gathering supplementary data obtained by analyzing the system's objectives and formalizing its specific features.

A key stage of the analysis is to establish how important each partial criterion is; this information guides the most suitable compromise scheme. Depending on the amount and quality of information available, three decision-making scenarios are distinguished:

Scenario 1 – Exact weights known. Precise numerical values of the criterion weights are given.

Scenario 2 – Ordinal information only. Exact weights are unavailable, but the criteria can be ranked by importance; those ranks are converted into weights by means of appropriate formulae.

Scenario 3 – No weight information. Neither quantitative nor qualitative data exist; consequently, all criteria are assigned equal (or nearly equal) weights.

Under uncertainty, the role of the decision maker (DM) becomes pivotal. The DM assigns or revises criterion weights to reflect the current context; can adjust admissible intervals for criterion values in accordance with system goals, thereby shaping the Pareto domain; participates interactively, allowing the final choice to be aligned with real-world objectives and to be specified with greater precision.

Let $\{I\}$ denote the n-dimensional Pareto set of feasible alternatives in the multi-criteria optimisation (MCO) problem. The quality of the i-th alternative is described by an m-dimensional vector of partial criteria $Ki=(Ki_1,Ki_2,\dots,Ki_m)^T$.

The task is to determine an alternative I^* from $\{I\}$ that provides satisfactory values of all criteria Kij $(j=1,\dots,m)$ and yields the best possible compromise between them, given the structure of PPP and any a priori information about criterion importance. Three information cases are considered: pre-specified weights, comparative (rank-order) importance, and no information on importance.

The decision algorithm evaluates each criterion's influence on overall system performance via weight coefficients (importance factors) Pj $(j=1,\dots,m)$ that satisfy $\sum^m P_j = 1$

The utility of the i-th alternative is modelled by the general additive function

$$Q_i = \sum_{j=1}^{m} P_j q_{ij}, \tag{1}$$

where $q_{ij} = \xi_{ij}\left[K_{ij}(x)\right]$ is the normalised utility of the j-th partial criterion for i-th alternative.

To address this problem, the functional form of the partial-criterion utility function must first be justified.

Such a function must be universal yet readily adaptable to the specific features, goals, and criteria of the system under study. Accordingly, it should satisfy the following requirements:

- be dimensionless;
- have a unit measurement interval (0,1);
- be invariant with respect to the extremum direction of each criterion (min or max), so that the best value of a criterion maps to 1 and the worst to 0;
- permit characteristic non-linear dependencies.

One function that meets these requirements is proposed in [8]. A suitable form is

$$\xi_{ij}\left(K_{ij}\right) = \left[\frac{K_{ij}-K_{j\,worst}}{K_{j\,best}-K_{j\,worst}}\right], \tag{2}$$

where Kij is the value of the j-th partial criterion for the i-th alternative, and Kj *best*, Kj *worst* denote the best and worst permissible values of that criterion, respectively. Equation (2) quantifies the degree to which Kij approaches the local optimum for criterion j.

To establish the bounds of the compromise region X that is, the values Kj *best* and Kj *worst*, the following procedure [5] is employed.

Over the feasible set of alternatives PPP, optimization is performed separately for each partial criterion Kj. This yields the criterion-specific extremal solution

$$X_j^0 = \arg \underset{x \in X}{\text{extr}} K_{ij}(x), \; j = \overline{1,m}, i = \overline{1,n}, \tag{3}$$

together with the corresponding values of all partial criteria.

Consequently,

$$K_{j\,best} = K_j(X_j^0), \; K_{j\,worst} = \begin{cases} \max\limits_i K_j(x_j^0), K_j(x) \to \; min \\ \min\limits_i K_j(x_j^0), K_j(x) \to \; max \end{cases}. \tag{4}$$

Thus, *Kj best* and *Kj worst* define the image of the approximated compromise region in the space of partial criteria.

Weight determination often encounters serious difficulties and is typically reduced to expert judgment. To ease the expert's task, it is sometimes sufficient to request only an ordinal ranking of criteria by importance; the ranks are then transformed into weight coefficients via predefined formulae. In the absence of any quantitative or qualitative information from the DM, it is logical to adopt equal (or nearly equal) weights for all criteria.

Search Procedure for the Optimal Solution:

1. Initial exploration. The entire set of feasible alternatives {I} is examined, and separate optimization is carried out for each partial criterion *Kj (j=1,…,m).* The resulting maxima form the vector *Z1*. This vector contains the "best-possible'' values of the partial criteria across all alternatives in PPP and is presented to the decision maker (DM) for reference.

2. Global-utility optimization. Optimization is next performed with respect to the aggregated utility function *Qi* defined in (1). The alternative that attains the largest utility value $Q_1 = max\{Q_i\}$ is identified. Its partial-criterion values constitute the vector

$$Y1 = \begin{vmatrix} K_{l1} \\ \cdots \\ K_{lm} \end{vmatrix}$$

which is submitted to the DM as a candidate solution.

3. Satisfaction check. The DM is asked: "Are all criteria satisfactory?" The decision is based on *Z1*. If the answer is no, the DM selects the most unsatisfactory criterion *Kr* and specifies a threshold value C_r deemed acceptable for that criterion.

4. Constraint tightening.

A new feasible domain $I^* = \left\{ i \left| \left(K_{ir} \le C_r(K_{ij} \to max) \right) \vee \left(K_{ir} \ge C_r(K_{ij} \to min) \right) \right. \right\}$ is defined, and Step 1 is repeated on *{I*}* to obtain an updated vector of maxima *Z2*.

The DM is then asked: "Is the reduction from Z1 to Z2 acceptable?"

If no, the threshold *Cr* is relaxed (made less demanding), and Steps 4–3 are repeated.

If yes, the compromise value *Cr* is fixed for all subsequent iterations.

5. Utility re-optimisation within the restricted set. On the refined set *{I*}* the aggregated utility function (1) is maximised again, yielding a new vector *Y2*, which is presented to the DM. The procedure returns to Step 3.

The algorithm terminates when, at Step 3, the DM responds affirmatively, i.e. when the current vector of criterion values satisfies all requirements.

Compilation of the Input Dataset

Most ISPs offer broadly similar baseline services and differ mainly in the number of value-added options and the quality of service (QoS). Consequently, these criteria are decisive for distinguishing one provider from another. Current Ukrainian market surveys [9] typically evaluate ISPs against the following parameters:

– Service cost;
– Connection speed;
– Optimal balance of services and price within the tariff plan;

– Connection stability;
– Availability of high-quality technical support and the practical ability to obtain effective assistance 24/7;
– Range of auxiliary services supplied by the ISP;
– Subscriber reviews and reputational feedback.

Ukraine hosts roughly 6 500 registered ISPs and network operators, most of which operate in large population centres. Provider categories and their characteristics are summarised in Table 1.

Table 1

Provider type	Characteristics	Remarks
Primary providers	Deliver global Internet connectivity at international traffic-exchange points (e.g., NAP – Network Access Point; MAE – Metropolitan Area Exchange; CIX – Commercial Internet Exchange).	Absent in Ukraine.
Tier-1 providers (primary regional)	Supply Internet access to local users and to downstream ISPs; purchase upstream transit from foreign carriers at international exchange points via domestic backhaul links.	≈ 20 in Ukraine.
Major providers	Tier-1 operators plus large Tier-2 companies that serve extensive subscriber bases.	≈ 40 in Ukraine.
Other providers (Tier-2/Tier-3; small and medium-sized)	Lease bandwidth of varying capacity from higher-tier providers; operate dozens to hundreds of access lines.	The majority of Ukrainian ISPs fall into this category.

These categorical distinctions and evaluation parameters form the core of the input data used in the subsequent multi-criteria analysis.

Such a high market concentration means that residents of a single multi-storey building may receive offers from five to seven different companies. This forces operators to launch aggressive promotional campaigns featuring bonus periods and temporary discounts to attract subscribers. However, these promotions usually expire quickly, after which customers are migrated to the full tariff. As for price dynamics, it is worth noting that Ukraine still enjoys some of the lowest Internet prices in the world, making service cost a critical selection criterion.

Different access technologies inevitably deliver different levels of quality of service (QoS). As the number of networked devices and the intensity of Internet usage increase, quality requirements become more stringent. Below, we outline the principal characteristics that determine this quality.

Technical parameters – the specifications that govern the performance and reliability of a service, device, or system – are central to ensuring a stable, high-speed connection. When choosing an ISP, one should pay close attention to parameters such as data-transfer rate, bandwidth, and connection stability, all of which have a direct impact on perceived Internet quality.

The most familiar indicators are upload and download speeds, routinely expressed worldwide in megabits per second (Mbps) or gigabits per second (Gbps).

Data-transfer and download speeds depend on several factors, including:

1. Channel bandwidth. Throughput is limited by the capacity of the physical link between the subscriber and the ISP. The greater the bandwidth, the higher the attainable data-rate.

2. Access technology. Cable, fibre-optic and wireless connections support different maximum speeds.

3. Distance to the provider's node. A long physical distance from the ISP's point of presence can degrade speed: the closer the subscriber is to the node, the lower the signal loss and the smaller the throughput reduction.

4. Network load. Regional or provider-side congestion may also curb both upload and download rates; simultaneous activity by many users can lead to noticeable slow-downs.

Data-rate performance determines how quickly information can be uploaded to or downloaded from the network; it affects page-load times, streaming quality, file-transfer duration and other online activities. Average upload and download speeds for Ukrainian ISPs are summarised in Table 2.

Latency (measured in milliseconds) indicates the time required for a signal to travel from the user's device to the server and back. Lower latency enables faster interaction and better real-time responsiveness. It is therefore a critical indicator of connection quality and data-transfer efficiency. Latency influences the time needed to send requests and receive server responses and is affected by several factors:

1. Physical distance. Greater separation between sender and receiver increases round-trip time.
2. Access technology. Fibre links typically exhibit low latency, whereas wireless links may suffer higher latency.
3. Network configuration. Heavy traffic, insufficient bandwidth or misconfigured equipment can all elevate delay; the more congested or impaired the network, the greater the latency.
4. Equipment and infrastructure quality. The performance of routers, switches, cabling and other hardware also contributes to overall delay.

Latency is especially important for services requiring rapid feedback—such as online gaming or video calls—because optimal latency ensures higher quality and smoother user experience. Average latency figures for each Ukrainian ISP are presented in Table 3.

Table 2

Internet Service Provider	Transmission speed, Mbps	Download speed, Mbps
Datagroup	31.78	32.6
Fregat	39.65	39.48
Kyivstar	42.56	46.67
Lanet	64.82	66.17
O3 Freenet	48.8	51.17
Triolan	54.56	56.48
UkrTelecom	11.24	6.1
Vega Telecom	33.2	33.58
Volia	45.45	27.58

Table 3

Internet Service Provider	Delay, ms	Internet Service Provider	Delay, ms	Internet Service Provider	Delay, ms
Datagroup	59.67	Lanet	25.88	UkrTelecom	65.17
Fregat	39.8	O3 Freenet	29.22	Vega Telecom	39.88
Kyivstar	33.8	Triolan	30.64	Volia	32

Security is arguably the most critical factor when choosing an ISP. A provider must be able to safeguard both customer data and its own infrastructure. A positive indicator is the presence of a robust backup system that can restore lost or corrupted data under any unforeseen circumstance. Likewise, safe operating conditions for servers (adequate ambient temperature, reliable power supply, and so forth) must be maintained.

The need for an information-security function within organizations becomes more evident each year. Growing cyber-crime, an increasingly tense geopolitical climate, and other external pressures push information-security risks to the foreground. Threat-response time therefore serves as a key indicator of a provider's ability to defend connections against external attacks.

Selecting an optimal ISP is essential for high-quality Internet connectivity. Connection quality depends directly on download and upload speeds as well as latency. Equally important is reliable protection, because no user wants an attacker to gain access to personal information or to disrupt service by targeting the provider. Cost constitutes a further decisive factor: users want many features yet prefer to pay less, so price must be integrated into the decision model. Although dependency analysis yields general guidelines, choosing a single provider that meets all requirements remains a challenging task [12].

To tackle this challenge, a heuristic multi-criteria optimisation (MCO) procedure was employed. The principal criteria influencing ISP selection are:

– Upload speed – efficiency of transmitting large data volumes;
– Download speed – stability and convenience when accessing media resources;
– Latency – critical for real-time applications such as video conferencing and gaming;
– Service cost – key economic consideration for users;
– Threat-response time – indicator of the provider's ability to protect the connection from external threats.

Tables 4 and 5 list the partial criteria and initial dataset for the MCO task involving the five most popular Ukrainian ISPs. The problem is analysed under the assumption of known criterion weights; the relative importance of those criteria supplies additional information that constrains the selection process.

Table 4

	CRITERIA CHARACTERISTICS			
Number of criteria m = 5 Number of vectors n = 5	Number	Name	Type of extremum	Weight
	1	Upload speed	max	0.2
	2	Download speed	max	0.2
	3	Delay	min	0.2
	4	Cost	min	0.1
	5	Response speed to attack	min	0.3

Table 5

ISP	Upload speed, Mbit/s	Download speed, Mbps	Delay, ms	Cost, UAH	Response speed to attack, s
Kyivstar	42.56	46.67	34	250	5
UkrTelecom	11.24	6.1	65	260	20
Triolan	54.56	56.48	31	99	120
Volia	45.45	27.8	32	150	90
Datagroup	31.78	32.6	60	200	60

Solution Procedure and Results Analysis

A JavaScript application was developed to solve the multi-criteria optimisation (MCO) problem using the heuristic procedure; HTML and CSS were employed for visualisation [5].

Five of the most popular Ukrainian ISPs—Kyivstar, Ukrtelecom, Triolan, Volia, and Datagroup—were analysed. For each provider the values of all partial criteria were determined.

The initial run assigned highest priority to threat-response time. Under this weighting scheme, the corresponding optimal outcomes for every provider were obtained; they are presented in Fig. 1.

Результат вирішення задачі БКО

Провайдер	Швидкість завантаження, Мбит/с	Швидкість скачування, Мбит/с	Затримка, мс	Вартість, грн	Швидкість реагування на атаку, с	Qi, При заданих вагах аддітивних критеріїв	Qi, При відстутності інформації о вагах аддітивних критеріїв
Київстар	0.722	0.805	0.911	0.062	1	0.792	0.698
Укртелеком	0	0	0	0	0.869	0.26	0.172
Triolan	1	1	1	1	0	0.7	0.8
Volia	0.789	0.43	0.97	0.683	0.26	0.583	0.625
Datagroup	0.474	0.526	0.147	0.372	0.521	0.421	0.405

Fig. 1. Output of the program under the decision scenario "priority = threat-response time," assuming no prior information about criterion importance

Subsequent testing modified the criterion weights to emphasise service cost (Table 6), enabling identification of the alternative that offers the best quality-to-price balance. The results obtained with cost-minimisation priority are shown in Fig. 2.

Table 6

CRITERIA CHARACTERISTICS			
Number	Name	Type of extremum	Weight
1	Upload speed	max	0.2
2	Download speed	max	0.2
3	Delay	min	0.2
4	Cost	min	0.3
5	Response speed to attack	min	0.1

Результат вирішення задачі БКО

Провайдер	Швидкість завантаження, Мбит/с	Швидкість скачування, Мбит/с	Затримка, мс	Вартість, грн	Швидкість реагування на атаку, с	Qi, При заданих вагах адитивних критеріїв	Qi, При відсутності інформації о вагах адитивних критеріїв
Київстар	0.722	0.805	0.911	0.062	1	0.604	0.698
Укртелеком	0	0	0	0	0.869	0.086	0.172
Triolan	1	1	1	1	0	0.899	0.8
Volia	0.789	0.43	0.97	0.683	0.26	0.666	0.625
Datagroup	0.474	0.526	0.147	0.372	0.521	0.391	0.405

Fig. 2. Program output under the modified weighting scheme (priority = service cost)

A further experimental scenario increased the weights assigned to the speed-related criteria (Table 7), thereby identifying the optimal choice for users who prioritise maximum bandwidth. The corresponding test results are presented in Fig. 3.

Table 7

CRITERIA CHARACTERISTICS			
Number	Name	Type of extremum	Weight
1	Upload speed	max	0.3
2	Download speed	max	0.3
3	Delay	min	0.2
4	Cost	min	0.1
5	Response speed to attack	min	0.1

Результат вирішення задачі БКО

Провайдер	Швидкість завантаження, Мбит/с	Швидкість скачування, Мбит/с	Затримка, мс	Вартість, грн	Швидкість реагування на атаку, с	Qi, При заданих вагах адитивних критеріїв	Qi, При відсутності інформації о вагах адитивних критеріїв
Київстар	0.722	0.805	0.911	0.062	1	0.744	0.698
Укртелеком	0	0	0	0	0.869	0.086	0.172
Triolan	1	1	1	1	0	0.9	0.8
Volia	0.789	0.43	0.97	0.683	0.26	0.652	0.625
Datagroup	0.474	0.526	0.147	0.372	0.521	0.417	0.405

Fig. 3. Program output under the modified weighting scheme (priority = speed)

The results indicate that Kyivstar is the optimal choice for security-conscious users, whereas Triolan offers the best price-to-speed ratio for budget-oriented customers.

Conclusions

The study has developed and validated an integrated multi-criteria decision-making (MCDM) framework for selecting Ukrainian Internet Service Providers (ISPs) that explicitly incorporates cybersecurity alongside conventional quality-of-service (QoS) metrics. The main findings are as follows:

Holistic evaluation model. By combining upload/download throughput, latency, cost, and threat-response time in an additive utility function, the framework captures the trade-offs most relevant to both residential and enterprise users.

Interactive heuristic refinement. An iterative weight-adjustment procedure allows decision-makers to converge quickly on Pareto-efficient solutions that reflect evolving priorities, demonstrating higher adaptability than static, one-shot weighting schemes.

Scenario analysis. Three weighting scenarios (security-oriented, cost-oriented, and bandwidth-oriented) were examined. Kyivstar emerged as optimal when rapid cyber-incident response was paramount, whereas Triolan dominated under cost- and bandwidth-focused criteria, illustrating the framework's sensitivity and practical relevance.

Cybersecurity integration. Treating threat-response time as an explicit minimisation criterion fills a gap in existing Ukrainian ISP assessments and aligns provider selection with national cyber-resilience goals.

Scalability and extensibility. Although demonstrated on a limited dataset, the model can ingest larger provider pools and additional criteria (e.g., service-level-agreement compliance, customer-support quality) with minimal modification.

Limitations and future work. The current study relies on publicly available averages rather than real-time network telemetry and incident-response logs. Future research will source live performance feeds, incorporate threat-intelligence indicators, and explore machine-learning techniques to automate weight calibration based on user profiles and risk tolerance.

Collectively, these results indicate that embedding cybersecurity into multi-criteria ISP evaluation yields more robust and context-aware provider rankings, empowering stakeholders to make data-driven, security-conscious connectivity decisions.

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