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Spatio-dynamic assessment of key performance indicators (KPIs) for strategic startup valuation

Abstract. The modern entrepreneurial landscape is characterised by high dynamics and significant market uncertainty. The object of the study is the spatial-dynamic assessment of key performance indicators (KPIs) based on integral metrics. These indicators are crucial for an objective assessment of the viability and investment attractiveness of early-stage start-ups, requiring a shift from retrospective financial analysis to metrics focused on forecasting, primarily customer lifetime value.

Problem statement. Traditional methods of corporate financial valuation, in particular discounted cash flow models, are of little use to startups due to a lack of historical financial data, high growth rates, and significant operating losses during the expansion phase. There is an urgent need to develop a unified but contextually adapted system of metrics that would allow founders and investors to objectively assess internal efficiency and make comparisons with relevant market benchmarks.

Unresolved aspects of the problem. Scientific literature demonstrates a high degree of variability in approaches to startup valuation, resulting in significant subjectivity and a wide range of estimated values. There are significant methodological gaps in the use of integral indicators, in particular the ratio of LTV to CAC (customer acquisition cost), which is often incorrectly calculated or interpreted outside the context of industry benchmarks and business development stages, which can lead to wrong investment decisions.

Purpose of the article. The main purpose of the study is to systematise key performance indicators for start-ups by functional blocks. The key task is to scientifically substantiate the decisive role of the LTV/CAC integrated indicator for assessing viability, as well as to develop methodological recommendations for the application of spatial-dynamic benchmarking to improve the objectivity of strategic planning and evaluation of startups.

Presentation of the main material. The study is based on the application of general scientific methods of systematisation, structural-logical modelling, comparative and systematic analysis. A comprehensive KPI taxonomy covering marketing, sales, and financial metrics is presented. The central element of the analysis is the LTV/CAC ratio, its critical threshold values, and its spatial-dynamic interpretation using the example of a case study of three start-ups with different business models.

Conclusions. The developed systematisation provides a structured basis for monitoring key startup parameters, confirming that the LTV/CAC ratio is the quintessence of business model quality assessment. The practical significance lies in providing founders and investors with a validated toolkit for informed spatial-dynamic benchmarking, which contributes to a more efficient allocation of venture capital.

Keywords: *startups, benchmarking, key performance indicators, KPIs, strategic assessment, conversion.*

Formulas: 2; fig.: 4, tabl.: 4.

JEL Classification G32, M15

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Introduction. The relevance of this study is determined by significant structural changes in the global economy, where innovative start-ups are key drivers of development and value creation. The global economy is characterised by high dynamics and the need for quick decision-making, which requires entrepreneurs and investors to have clear, objective and predictive assessment tools. Unlike mature corporations, startups in their early stages tend to record operating losses while investing in growth and market development, which makes traditional financial statement analysis (e.g., discounted cash flow models) uninformative.

The problem under investigation is the need to assess future profitability potential based not on retrospective indicators, but on integrated metrics that reflect the fundamental viability of the business model. In this context, the focus shifts to traction metrics, which measure the effectiveness of customer acquisition and retention, in particular the ratio of Lifetime Value (LTV) to Customer Acquisition Cost (CAC), which is a key indicator of effectiveness at the individual customer level.

Thus, there is an urgent need to systematise and scientifically substantiate a set of key performance indicators (KPIs) that would allow for a comprehensive assessment of a start-up, taking into account its spatial and dynamic state. The spatial dimension refers to comparing a startup with cohorts (industry and stage benchmarks), while the dynamic dimension refers to analysing the trajectory of indicators over time. The development of such a KPI taxonomy, focused on different functional business blocks and adapted to innovative business models (SaaS, marketplaces), is critical for minimising investment risks and ensuring sustainable, profitable scaling.

Literature review. Modern methods of strategic assessment of start-ups require not only static analysis, but also consideration of the spatial and dynamic aspects of business model functioning. This approach allows us to study the evolution of KPIs over time and compare their effectiveness in the context of industry and geographical benchmarks [9].

The concept of unit-level assessment is an approach that allows the financial results of a company to be broken down to the level of a single unit of sale, most often an individual customer or transaction [1, 4]. This concept, which involves analysing the profitability of individual transactions and using integrated performance metrics, is known as unit economics. Its implementation is particularly relevant for innovative businesses, as it allows for the analysis of the cost and profitability of individual components of a product or service. This allows founders to determine the true effectiveness of invested resources and make informed decisions about pricing and scaling strategies. The lack of research and understanding of this concept of operational efficiency in the startup sector often leads to strategic failures, as companies may invest in growth that is fundamentally unprofitable [2].

That is why the key focus of research is on integrated performance indicators that have predictive power, as opposed to retrospective financial reporting. These metrics, which form the basis of unit economics, reflect the balance between customer acquisition costs and lifetime value, which is critical for determining the scalability and investment attractiveness of a start-up [3].

A key integrated performance indicator that is vital for evaluating startups is the LTV to CAC ratio. Customer acquisition cost (CAC) is the total amount of marketing and sales expenses required to acquire a single new customer. Customer lifetime value (LTV) is the projected total revenue that a customer will bring to a company over the entire period of interaction.

The LTV/CAC ratio is a key indicator for venture capitalists, as it allows them to assess the long-term financial viability of loss-making start-ups. A high LTV/CAC ratio signals successful fundraising, but the metric has significant methodological pitfalls that can lead to misguided strategic decisions. Key risks include incorrect CAC calculation (ignoring operating costs) and inconsistency in time cohorts for LTV and CAC. To mitigate these risks, it is essential to use additional metrics such as CAC Payback Period, which affects Burn Rate and financial stability. Ultimately, the most reliable approach to valuation requires a combination of quantitative analysis (integral LTV/CAC metrics) and qualitative analysis (founder characteristics and intellectual property) [6].

Modern scientific developments (especially in the period 2020–2025) actively integrate systematised KPIs into predictive models. For example, in the field of innovative financing, complex machine learning algorithms (Random Forest, XGBoost) are used to predict the success of start-ups (attracting financing, IPO). In this context, clearly defined and structured KPIs (LTV, CAC, MRR, Churn Rate) become not just operational indicators, but mandatory features for training these predictive models. Thus, the development of an accurate and unified KPI taxonomy is a necessary theoretical prerequisite for objectifying the data-driven investment analysis process [5].

Purpose, objectives and research methods. The main purpose of the study is to systematise key performance indicators for start-ups by functional blocks, scientifically substantiate the decisive role of the LTV/CAC ratio as an integral indicator of viability, and develop methodological recommendations for the use of comparative analysis (benchmarking) to improve the objectivity of strategic planning and assessment.

To achieve this goal, the following tasks were set:

1. Development of a model for spatial-dynamic KPI assessment for strategic evaluation of startups and determination of a set of interrelated stages for its implementation.

2. Justification and implementation of a comprehensive spatial-dynamic KPI assessment using integrated taxonomic analysis and presentation of graphs of fixed model effects, indicator elasticity, and a phase portrait of the overall integrated indicator.

3. Formulation of methodological recommendations on the application of industry benchmarking to improve the objectivity of strategic planning and assessment of start-ups.

Research results. The paper proposes a model for comprehensive spatial-dynamic assessment and research of key performance indicators (KPIs) for start-ups, the implementation algorithm of which is presented in Fig. 1.

The model consists of a set of interrelated stages [10]. Let us consider their content and objectives.

Stage 1. Formation of the information and analytical space of the study. This stage includes searching, collecting, and processing data on the main areas of KPI research for startups. The goal of this stage is to form a representative statistical database for evaluation.

The possibility of calculating KPI for startups using publicly available information on their performance was also taken into account [7].

Stage 2. Comprehensive spatial-dynamic assessment of startup KPIs. The study is based on the calculation of integral rating indicators for local components of startup KPIs and the assessment of the overall level of startup KPIs [5]. The algorithm for implementing the integral taxonomic assessment method consists of the following steps.

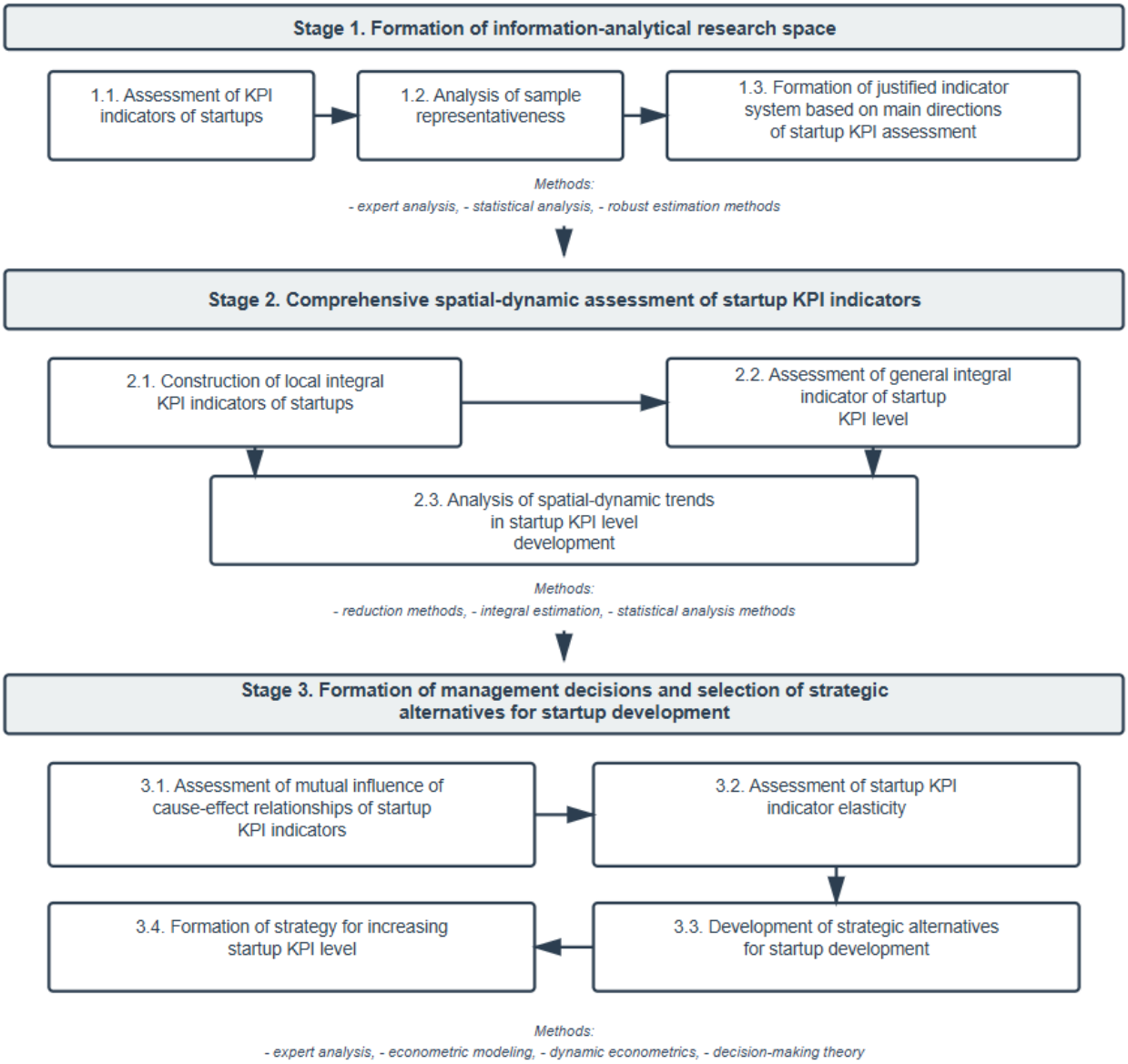

Fig. 1. Model of spatial-dynamic assessment of key performance indicators (KPIs) for strategic evaluation of start-ups
Source: developed by the author.

Step 1. Formation of the initial data matrix.

Step 2. Standardisation of initial data. Since the KPI indicators of startups are heterogeneous, the second step involves standardising their values using the formula:

$$z_{ij} = \frac{x_{ij} - \underline{x}_j}{s_j}, \quad (1)$$

where j = 1, 2, ..., m;

$\bar{x}_j$ – arithmetic mean of the j-th indicator;

s_j – standard deviation of the j-th indicator;

z_{ij} – standardised value of the j-th indicator for the i-th start-up.

Step 3. Differentiate the matrix characteristics into stimulants and deterrents. The basis for dividing the characteristics into two groups is the nature of the impact of each of the startup KPIs on their strategic assessment.

Step 4. Construction of a reference point.

Step 5. Determination of the Euclidean distance between objects (startups) and the reference point.

Step 6. Calculation of the taxonomic indicator. The integral taxonomic indicator of startup KPIs is calculated using the formula [5]:

$$I_i = 1 - \frac{C_{i0}}{C_0}, \quad (2)$$

де $C_0 = \underline{C_0} + 3 \times S_0$;

$$\underline{C_0} = \frac{1}{w}\sum_{i=1}^{w} C_{i0};$$

$$S_0 = \sqrt{\frac{1}{w}\sum_{i=1}^{w} \left(C_{i0} - \underline{C_0}\right)^2}.$$

The presented local assessment indicators are calculated based on the corresponding indicators for all selected areas of KPI research for start-ups. The model for summarising the information space of indicators and assessing the overall KPI level of a start-up is as follows:

$$\mathrm{I}_1 = f(X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17,} X_{18}, X_{19}, X_{110}, X_{111}),$$
$$I_2 = f(X_{21}, X_{22}, X_{23}, X_{24}, X_{25}, X_{26}),$$
$$I_3 = f(X_{31}, X_{32}, X_{33}, X_{34}, X_{35}, X_{36}),$$
$$I_4 = f(X_{41}, X_{42}, X_{43}, X_{44}, X_{45}),$$
$$I = f(\{I_1\}, \{I_2\}, \{I_3\}, \{I_4\},$$

where Xi – are the indicators of the first level of the startup's KPI indicator system;

I_i – s the local integral indicator of the startup's KPI level;

I – is the comprehensive indicator of the overall KPI level of the startup.

The spatial-dynamic KPI assessment model is implemented through the sequential formation of a representative information base and comprehensive assessment. Based on this data, an integral taxonomic assessment method is applied, which, using standardisation and calculation of the Euclidean distance to the benchmark, allows the multidimensional KPI space to be reduced to a single comprehensive indicator (I). Thus, the model provides a quantitative basis for the strategic assessment of start-ups [9]. The created KPI taxonomy is the information basis for spatial measurement of evaluation, and the integral indicator I is used as a dependent variable for further dynamic analysis using econometric panel data models [8].

Let us consider a systematised taxonomy of key performance indicators (KPIs) covering the main functional blocks of a startup: marketing, sales, finance, and specialised models. The systematisation of metrics is a prerequisite for the formation of a single information space between founders and investors [6].

Group 1: Marketing KPIs

Marketing metrics reflect the effectiveness of spending on attracting potential customers (leads) and the quality of traffic. They are the first quantitative indicator of the effectiveness of a startup's strategy.

Table 1. Key metrics for evaluating startup marketing KPIs (I_1)

Metric	Description	Data source
Number of leads (X_{11})	Total number of potential customers who left their contact details for further interaction	CRM system, website forms, Google Analytics
Cost per lead (CPL) (X_{12})	he average cost of acquiring one potential customer through marketing channels	Advertising accounts, CRM/analytics systems
Cost per action (CPA) (X_{13})	Shows how much it costs for a user to perform one target action (registration, purchase, etc.)	Google Ads, Facebook Ads
Conversion rate (CR) (X_{14})	The percentage of users who performed a target action among all visitors	Google Analytics, CRM
Click-through rate (CTR) (X_{15})	The percentage of users who clicked on an ad after viewing it	Advertising accounts, email distribution services
Audience growth rate (X_{16})	Reflects the rate of increase in the number of subscribers in a community or on a platform	Facebook Insights, Instagram Insights
Reach (X_{17})	The number of unique users who have seen the brand's or campaign's content	Social media analytics, advertising accounts
Viral Reach (X_{18})	The number of users who have seen the content thanks to sharing by other users	Facebook Insights
Sharing ratio (X_{19})	Reflects audience activity in sharing content (reposts, shares)	Social media analytics
Bounce Rate (X_{110})	The percentage of visitors who left the site after viewing only one page	Google Analytics
Time to Conversion (X_{111})	The average time between the user's first contact and conversion	Google Analytics (conversion reports)

Source: developed by the author.

Group 2: Sales KPIs

Sales metrics reflect the effectiveness of monetisation and conversion of leads into paying customers. These metrics form the basis for calculating total revenue and average customer value.

Table 2. Key metrics for evaluating a startup's sales KPIs (I_2)

Metric	Description	Data source
Revenue (X_{21})	The total amount of money received from the sale of goods or services	Financial statements, CRM
Sales Volume (X_{22})	The number of units of goods or services sold during a specific period	CRM, warehouse system
Average order value (AOV) (X_{23})	The average amount a customer spends per order	CRM, payment system
Average revenue per customer (ARPC) (X_{24})	The average revenue generated from a single customer over a specific period	CRM, financial statements
Lead-to-sale conversion (X_{25})	Percentage of potential customers (leads) who became actual buyers	CRM
Sales cycle length (X_{26})	Average time from first contact with a customer to closing a deal	CRM

Group 3: Key Financial KPIs and Unit Economics

These metrics are crucial for investors, as they determine the long-term sustainability of the business, its financing needs, and overall investment attractiveness.

Table 3. Key metrics for evaluating a startup's financial KPIs (I_3)

Metric	Description	Data source
Profit (X_{31})	Financial result of operations; difference between income and expenses	Profit and loss statement (P&L)
EBITDA (X_{32})	Profit before interest, taxes, depreciation and amortisation; reflects the operational efficiency of the business	Financial statements
Lifetime value of a customer (LTV) (X_{33})	The projected total revenue that a customer will generate over the entire period of cooperation	CRM, payment system
Customer acquisition cost (CAC) (X_{34})	The total cost of marketing and sales efforts to acquire one new customer	Marketing budget, CRM
Monthly recurring revenue (MRR) (X_{35})	Stable income that the company receives monthly from subscriptions or recurring payments	Payment system
Burn Rate (X_{36})	The rate at which the company spends its available financial resources before reaching profitability	Cash flow statement

Source: developed by the author.

Group 4: Specialised Metrics for Marketplaces

Bilateral platforms and marketplaces require specific metrics that reflect market liquidity and transaction monetisation efficiency.

Table 4. Metrics for marketplaces (I_4)

Metric	Description	Data source
Gross Merchandise Volume (GMV) (X_{41})	The total value of all goods or services sold through the platform during a given period	Marketplace analytics
Take Rate (X_{42})	The share of GMV that the marketplace retains as its own commission	Financial reporting
Buyer liquidity (X_{43})	The probability that a buyer will find the desired product and make a purchase	Internal analytics
Seller liquidity (X_{44})	The probability that a seller will sell a listed product or service	Internal analytics
Buyer/seller retention (Retention) (X_{45})	The share of users who continue to use the platform over a certain period	CRM, analytics system

Source: developed by the author.

The systematisation of key performance indicators (KPIs) provides a structured framework for strategic assessment, covering four key functional areas: marketing, sales, finance, and specialised models (marketplaces). This taxonomy integrates metrics from initial customer acquisition (leads) to long-term financial sustainability (LTV, CAC, MRR), which is critical for creating a unified information space between founders and investors [9]. Thus, it creates the necessary multidimensional database for further spatial-dynamic analysis [14].

Panel data modelling tools are used to visualise and quantitatively study the dynamics of the integral performance indicator (I). Based on the developed model, Fig. 2 shows a graph of fixed effect values that reflect the individual, time-invariant characteristics of each startup that affect their KPIs [11].

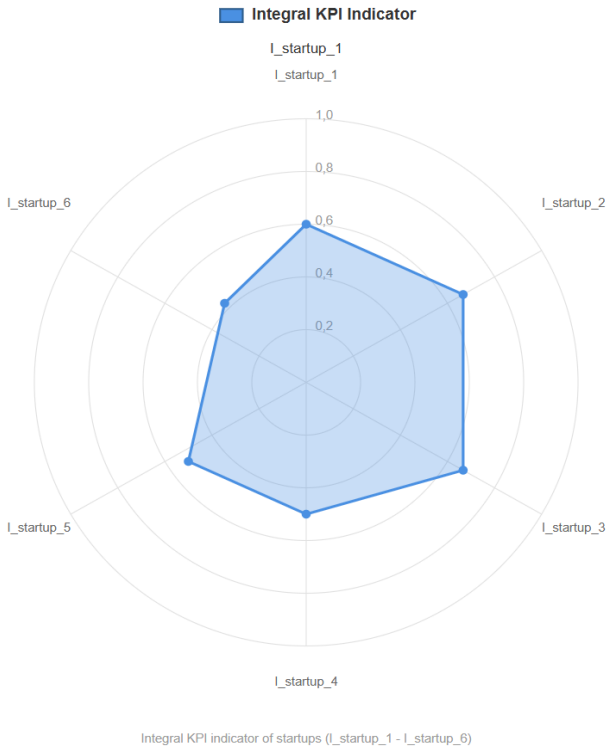

Fig. 2. Graph of fixed effects values of the panel data model for studying startup KPIs
Source: developed by the author.

In addition, to assess the sensitivity of the composite indicator I to changes in its local components, the elasticity of the indicators was calculated [13]. The results of this analysis are visualised in Fig. 3, which shows the average elasticity of KPI indicators for the entire sample of startups.

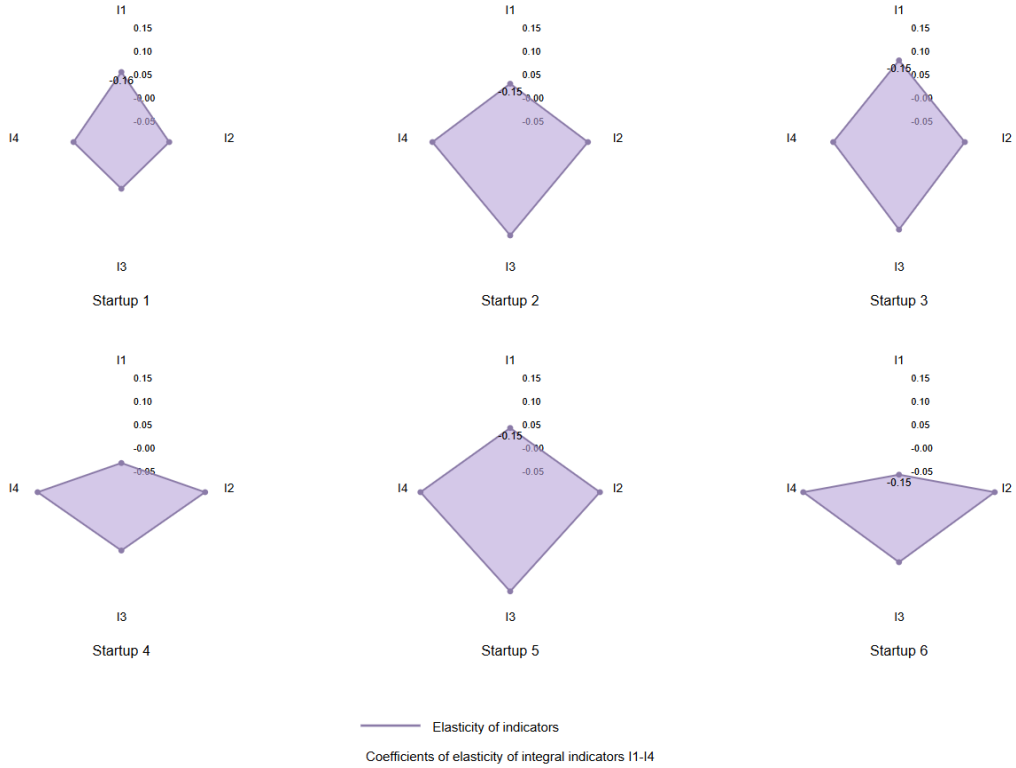

Fig. 3. Elasticity of KPI indicators for six different start-ups
Source: developed by the author.

Fixed effects analysis allows us to identify the unique internal factors of each start-up that improve the quality of the spatial-dynamic assessment. In turn, elasticity indicators point to priority areas where investments (e.g., marketing or sales) will have the greatest impact on the overall integral indicator (I). Thus, these graphs provide decision-makers with a quantitative basis for determining individual strategic priorities [14].

Discussion. The LTV/CAC ratio plays a central role in the evaluation of a start-up, especially in the active growth phase. This integral indicator combines the effectiveness of the product, marketing and financial model. Spatial-dynamic analysis shows that the optimal balance, which confirms customer profitability and triggers profitable scaling, is considered to be a ratio in the range of 3:1 to 5:1. Importantly, spatial (cross-industry) benchmarking allows this indicator to be interpreted correctly: if LTV/CAC exceeds 5:1, this may indicate insufficient investment in marketing, which limits growth potential and risks losing market share to competitors [4].

Spatial-dynamic analysis is a key tool for studying the qualitative state of a startup's dynamics. Constructing phase trajectories of the integral KPI (I) in phase space allows you to visualise changes in the I indicator over time (consecutive values of I and I+1). Phase portraits, as shown in Fig. 4, allow us to identify nonlinear dependencies and the nature of development. The trajectory forms a quasi-cycle (self-intersection or maximum approximation to the starting point), which indicates cyclicality or a return to the previous dynamic state of the startup's KPI.

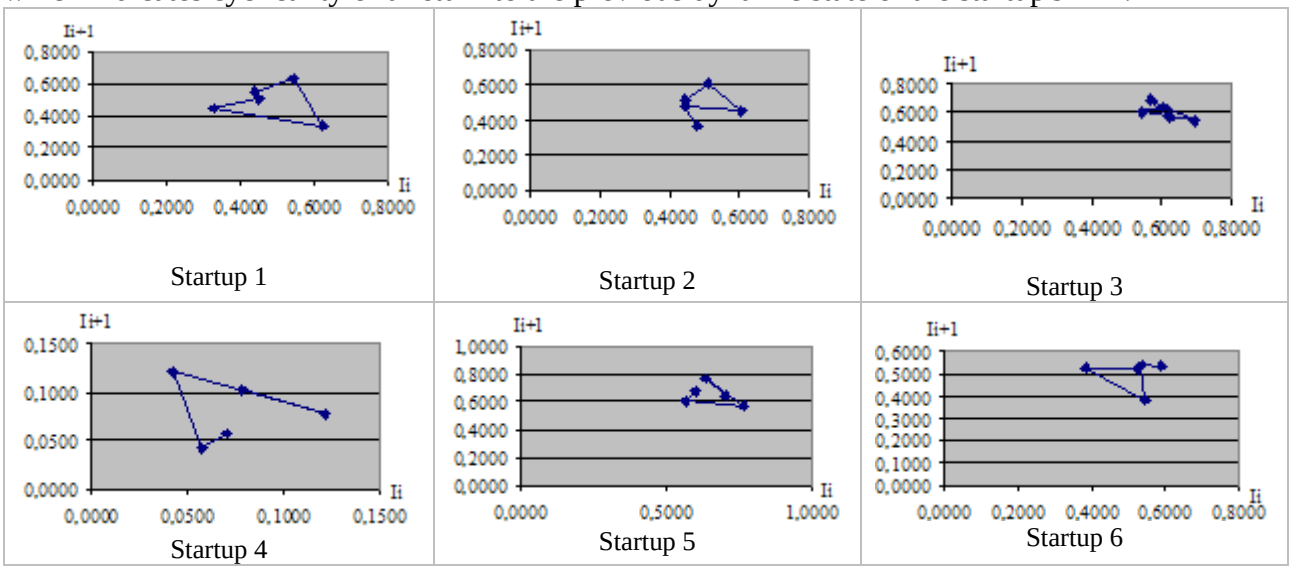

Fig. 4. Phase portrait of the overall KPI indicator for start-ups
Source: developed by the author.

Analysis of the phase portraits of six start-ups demonstrates a variety of dynamic modes: from steady growth (trend towards the upper right corner) to cyclical stagnation, when the indicator fluctuates around a certain value. This visualisation is critical for identifying startups whose trajectories converge to attractors (stable states), indicating to investors the level of risk and potential for long-term financial viability.

To make informed strategic decisions, internal KPI tracking should be supplemented with benchmarking. This allows you to assess the competitiveness of a startup in an industry context. High reliability of comparative assessment requires internal stability of indicators (analysis of cohort data for 3–6 months) and identification of a relevant comparison group, taking into account the industry (FinTech, EdTech), business model (SaaS, marketplace) and stage of development (Seed, Series A) [12].

The proposed toolkit for spatial-dynamic analysis allows decision-makers to conduct a comprehensive assessment of the dynamic state of KPI levels, taking into account its characteristics and development trends. This improves the quality of management decisions regarding the choice

of strategic alternatives for startup development in the face of negative external and internal environmental factors, taking into account all interrelated financial and economic processes.

Conclusions. The scientific novelty of the research lies not so much in the systematisation of KPIs as in the development and implementation of a model of spatial-dynamic KPI assessment for the strategic evaluation of start-ups. This has been achieved thanks to the first-ever comprehensive analytical toolkit, which combines the taxonomy of key metrics, integral taxonomic analysis to obtain a single indicator I, and methods of dynamic nonlinear phase analysis. The model uses dynamic nonlinear phase analysis for qualitative research into the development trajectories of startups, which allows for the identification of cyclicality and the prediction of a return to previous states. It is critically justified that the reliability of the interpretation of the integral KPI indicator is achieved only under the condition of mandatory benchmarking with relevant industry and stage cohorts, which helps to overcome methodological gaps and subjectivity in financial evaluation.

The theoretical significance of the study lies in expanding the methodological basis of entrepreneurial finance, as the systematised key performance indicators embedded in the spatial-dynamic model create a clear, structured framework. These indicators can serve as a universal set of features for predictive modelling of startup success, contributing to further objectification and automation of investment analysis driven by machine learning methods.

The practical significance lies in providing founders, managers, and investors with a validated and structured toolkit for diagnosing operational efficiency and justifying scaling strategies. Critically, the toolkit ensures transparency and objectivity in the process of attracting venture capital, as spatially dynamic benchmarking based on the integral indicator I confirms the competitiveness of a startup compared to relevant cohorts.

The socio-economic effect of implementing scientific results is reflected in the increased overall efficiency of venture capital allocation in the innovation ecosystem, which contributes to the support of more viable and profitable business models and accelerates economic growth based on sustainable innovation.

Further scientific research should focus on developing more detailed and dynamic startup assessment models that integrate quantitative key performance indicators with qualitative factors. Promising areas include the creation of detailed, publicly available industry benchmarks for key performance indicators broken down by geography and funding stage, using large aggregated data sets. Another promising area is the development of adaptive predictive models for startup financing that use systematised key performance indicators in combination with unstructured data analysis, including assessments of team quality, intellectual property, and market dynamics, to improve the accuracy of investment risk assessments.

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Просторово-динамічне оцінювання ключових показників ефективності (KPI) для стратегічної оцінки стартапів

Анотація. Сучасний підприємницький ландшафт характеризується високою динамікою та значною ринковою невизначеністю. Об'єктом дослідження є просторово-динамічне оцінювання ключових показників ефективності (KPI), що базується на інтегральних метриках. Ці індикатори є визначальними для об'єктивної оцінки життєздатності та інвестиційної привабливості стартапів на ранніх стадіях, вимагаючи переходу від ретроспективного фінансового аналізу до метрик, орієнтованих на прогнозування, перш за все довічної цінності клієнта.

Постановка проблеми. Традиційні методи корпоративної фінансової оцінки, зокрема моделі дисконтованих грошових потоків, є малозастосовними до стартапів через дефіцит історичних фінансових даних, високі темпи зростання та суттєву операційну збитковість на етапі експансії. Існує нагальна потреба у розробці уніфікованої, але контекстуально адаптованої системи метрик, яка б дозволяла засновникам та інвесторам об’єктивно оцінювати внутрішню ефективність та здійснювати порівняння з релевантними ринковими бенчмарками.

Нерозв’язані аспекти. Наукова література демонструє високу варіативність у підходах до оцінки стартапів, що спричиняє значну суб'єктивність та великий розкид оціночної вартості. Існують значні методологічні прогалини у використанні інтегральних показників, зокрема співвідношення LTV до CAC (вартість залучення клієнта), яке часто некоректно розраховується або інтерпретується поза контекстом галузевих бенчмарків та стадії розвитку бізнесу, що може призвести до хибних інвестиційних рішень.

Мета статті. Головною метою дослідження є систематизація ключових показників ефективності стартапів за функціональними блоками. Ключовим завданням є наукове обґрунтування визначальної ролі інтегрального показника LTV/CAC для оцінки життєздатності, а також розробка методологічних рекомендацій щодо застосування просторово-динамічного бенчмаркингу для підвищення об'єктивності стратегічного планування та оцінки стартапів.

Основний матеріал. Дослідження грунтується на застосуванні загальнонаукових методів систематизації, структурно-логічного моделювання, порівняльного та системного аналізу. Представлено комплексну таксономію KPI, що охоплює метрики маркетингу, продажів та фінансів. Центральним елементом аналізу виступає співвідношення LTV/CAC, його критичні порогові значення та просторово-динамічна інтерпретація на прикладі кейс-аналізу 6 стартапів з різними бізнес-моделями.

Висновки. Розроблена систематизація забезпечує структуровану основу для моніторингу ключових параметрів стартапу, підтверджуючи, що співвідношення LTV/CAC є квінтесенцією оцінки якості бізнес-моделі. Практичне значення полягає у наданні засновникам та інвесторам валідованого інструментарію для обґрунтованого просторово-динамічного бенчмаркингу, що сприяє ефективнішому розподілу венчурного капіталу.

Ключові слова: *стартапи, бенчмаркінг, ключові показники ефективності, KPIs, стратегічне оцінювання, конверсія.*

JEL Classification G32, M15

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