$QoLI_{v2}$: A Data-Driven Model for Comprehensive Quality of Life Assessment

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***Abstract*—The assessment of Quality of Life (QoL) is a highly relevant and increasingly prominent topic, with numerous general or domain-specific metrics, either health-related or not, being developed to capture various levels of specificity in evaluating QoL. Following an in-depth review of some of the most widely recognized metrics that embrace the multidimensional nature of QoL, we identified several limitations that hinder the evaluation process. These encompass the limited number of incorporated indicators, the methods used for their aggregation, and the lack of a standardized framework to automate the assessment process. Consequently, we aimed to improve the Quality of Life Index (QoLI), initially introduced in 2019, by significantly expanding the number of indicators (from 32 to 76 in the updated $QoLI_{v2}$), revising the aggregation formula for its nine dimensions (eight objective dimensions and one subjective dimension) and their underlying indicators to produce more meaningful results. To evaluate the construct validity of $QoLI_{v2}$, Spearman correlation analyses were performed against two established benchmark indicators, Gross Domestic Product per Capita (GDP per Capita) and the Human Development Index (HDI). Strong monotonic relationships were observed with GDP per Capita ($\rho = 0.847$) and HDI ($\rho = 0.804$), confirming that $QoLI_{v2}$ is consistent with established development metrics while supporting its credibility as a multidimensional measure of quality of life.**

Keywords-Eurostat; Qualify of Life; Welfare; Well-being.

I. INTRODUCTION

The assessment of Quality of Life (QoL) has gained increasing visibility in recent years, with numerous studies proposing a wide range of metrics, both general and domain-specific, health-related or otherwise, for evaluating the population's QoL [1][2]. Although the term QoL has not yet received a universally accepted definition, nor is there a unified methodology for its assessment [3][4][5], it is generally regarded as a complex construct encompassing both objective (descriptive) and subjective (evaluative) factors that significantly influence individual and collective well-being.

Gross Domestic Product (GDP) has long been employed as the principal indicator for assessing population welfare [6][7][8], due to its ease of calculation and application as a macroeconomic measure. However, even its derivative, GDP per Capita, fails to provide a comprehensive view of societal well-being, as GDP primarily reflects the community's capacity to produce goods and services. Since the concept of QoL transcends the financial boundaries of GDP, researchers have increasingly turned their attention toward proposing multidimensional approaches for assessing QoL [9].

A wide range of studies from diverse branches of medicine illustrate this trend, ranging from the analysis of factors contributing to dental diseases and their associated consequences (e.g., pain, discomfort, impaired physical function) [10][11][12], to the examination of cancer-related variables and their influence on the well-being of patients [13], and to investigations into determinants of successful aging and strategies for enhancing the QoL in older adults [14][15]. These represent just a few examples from the medical field where researchers have developed targeted QoL metrics.

However, the development of such indicators extends well beyond the healthcare field. For instance, certain studies address the economic, social, cultural, and environmental impacts of tourism on residents' well-being [16][17], while others highlight the effects of urban development on quality of life [18][19]. In addition to these aggregated indicators that explore the well-being of the population within a specific domain, there is also a series of benchmark indicators that capture the complex and multivariate nature of life.

The Human Development Index (HDI) is an indicator developed by the *United Nations Development Programme* in 1990 and revised in 2010, which integrates three essential dimensions of human development: health, education, and a decent standard of living, aggregated using the geometric mean [20][21]. *The World Health Organization Quality of Life (WHOQOL)* is an initiative of the World Health Organization that assesses *"individuals' perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns"* [22], consisting of a set of 100 questions, organized into six distinct dimensions. *The Better Life Index (BLI)* is an indicator introduced in 2011 by the Organization for Economic Co-operation and Development (OECD) that encompasses measuring the material conditions of citizens, education level, health status, degree of security, social engagement, and other significant aspects influencing the population's QoL.

Unfortunately, although these indicators are widely used in assessing the population's quality of life, they present a series of limitations that constrain the scope of analyses and hinder the automation of calculations. The HDI integrates only three core dimensions, which may result in a partial representation of the multifaceted nature of well-being. The WHOQOL instrument relies on self-reported survey data, capturing individuals' subjective perceptions of well-being, which introduces methodological challenges related to response bias, cultural differences in self-evaluation, and cross-national comparability of aggregated results [22]. Regarding the BLI, OECD does not provide an official public calculation formula, and the published values refer exclusively to the organization's member states, thus limiting the global applicability of the indicator.

This paper aims to address the limitations of the aforementioned indicators by exploring a novel perspective on the methodology for assessing QoL, proposing and discussing in detail, in Section 2, a revised version of the Quality of Life Index (QoLI) formula [23], hereafter referred to as QoLI$_{v2}$. The updated formula addresses limitations identified in the initial version by revising the aggregation methodology and expanding the indicator set, while maintaining the same nine-dimensional structure of the index (eight objective and one subjective dimensions). Section 3 introduces the data sources, followed by an analysis of the correlation between the values produced by QoLI$_{v2}$ and two of the benchmark indicators: GDP and the HDI. Section 4 is devoted to outlining the study's conclusions.

II. QoLI$_{v2}$ METHODOLOGY

QoLI is a metric proposed in 2019 [23] that enables the measurement of population quality of life based on a broad range of factors. Unlike other well-known metrics such as HDI, which operationalizes three core dimensions using four specific indicators (hereafter referred to as atomic indicators), WHOQOL, which is derived from the application of a questionnaire, or BLI, which comprises 24 atomic indicators, the original version of QoLI included 32 atomic indicators selected from the set of indicators proposed by Eurostat [24] for assessing QoL.

QoLI$_{v2}$ expands the scope of the original QoLI to 76 atomic indicators by integrating measures of objective living conditions and subjective well-being evaluations, while introducing substantial revisions to the aggregation methodology. Unlike the original formula, which used the geometric mean to aggregate its dimensions, QoLI$_{v2}$ employs the logarithmic function for this purpose. Additionally, the new formula corrects errors and omissions identified in the initial version by updating, replacing, or adding new atomic indicators.

A. The Structure of QoLI$_{v2}$

The structure of QoLI$_{v2}$ is presented in Formula (1), where D represents the set of dimensions comprising QoLI$_{v2}$.

$$D = \{MLC, PMA, Education, Health, LSI, Safety, Governance, Environment, Overall\ Exp\} \quad (1)$$

where:
MLC = Material and Living Conditions dimension;
PMA = Productive or Main Activity dimension;
Education = Education dimension;
Health = Health dimension;
LSI = Leisure and Social Interactions dimension;
Safety = Economic and Physical Safety dimension;
Governance = Governance and Basic Rights dimension;
Environment = Natural and Living Environment dimension;
Overall Exp = Overall Experience of Life dimension;

Table 1 shows the indicators associated with the index's nine dimensions, where indicators listed in black have a positive connotation, while those shown in red have a negative connotation. To harmonize indicators that have a negative connotation, the *rev(x)* formula presented in Formula (6) is applied to them.

TABLE I. THE COMPOSITION OF THE 9 DIMENSIONS

Dimension Name	Indicator Name
Material and Living Conditions	Deprivation Ratio Dwelling Conditions Ratio Ends Meet Ratio Financial Satisfaction Ratio GDP per Capita Power High Income Ratio Income Quintile Ratio Lack of Baths Ratio Low Work Intensity Ratio Median Income Power Over Occupied Ratio Poverty Risk Ratio Under Occupied Ratio
Productive or Main Activity	Employment Ratio Inactive People Ratio Involuntary Part-Time Ratio Job Satisfaction Ratio Long Term Unemployed Ratio Low Wage Ratio Low Work Intensity Ratio Personal Time Left Researchers Ratio Temporary Employees Ratio Unemployed Ratio Working Flexibility Ratio Working Nights Ratio
Education	Digital Skills Ratio Dropout Ratio Early Education Ratio Education Ratio Inactive Young People Ratio No Knowledge of Any Foreign Language Ratio Pupils-to-Teachers Ratio Training Ratio $_{4w}$ Training Ratio $_{1y}$
Health	Body Mass Index Depressive Ratio

Dimension Name	Indicator Name
	Health Personnel Ratio Healthy Life Years Healthy People Ratio Hospital Beds Life Expectancy at Birth Long Term Medical Issues Ratio Non-Alcoholic Ratio Non-Fruits & Vegetables Ratio Physical Activities Ratio Smokers Ratio Unmet Dental Needs Ratio Unmet Medical Needs Ratio Work Accidents Ratio
Leisure and Social Interactions	Asking Ratio Discussion Ratio *Getting Together Ratio *Frequency Contact Ratio *Non-Participation in Events Ratio *Participation in Events Ratio Recreational Areas Satisfaction Ratio Relationships Satisfaction Ratio Time Satisfaction Ratio
Economic and Physical Safety	Crime Ratio Non-Payment Ratio Offences Ratio Pension Power Social Protection Power Unexpected Financial Expenses Ratio
Governance and Basic Rights	Citizenship Rate Gender Employment Gap Gender Pay Gap *Population Trust *Voter Turnout
Natural and Living Environment	*Air Pollution Ratio Noise Pollution Ratio Pollution Ratio Water Supply Ratio
Overall Experience of Life	Happiness Ratio Life Satisfaction Ratio

*Indicators marked with an asterisk are calculated as the average of the sub-indicators that compose them

B. *What's New in QoLI$_{v2}$ in Terms of The Structure of The Indicators?*

One of the most significant developments in QoLI$_{v2}$ concerns the refinement of the indicators used to calculate each individual dimension. A detailed account of these updates is provided below.

1) *Material Living Conditions (MLC)*

A new indicator, *GDP per Capita Power*, has been introduced in the calculation of this dimension to measure GDP per Capita in terms that are comparable across countries. By expressing GDP per Capita in terms of Purchasing Power Ptandards (PPS), a more balanced comparison can be made between countries with varying stages of economic development.

2) *Productive or Main Activity (PMA)*

The *Overqualified Ratio* indicator was removed from the aggregated calculation formula due to the lack of data provided by Eurostat. However, this exclusion was offset by the inclusion of two new indicators: the *Working Flexibility Rate* and the *Low Work Intensity Rate*. The former captures the proportion of individuals benefiting from a flexible work schedule, while the latter measures the share of people living in households with very low work intensity. It is important to note that although the latter indicator is already part of the aggregated formula for the *Material and Living Conditions* dimension, it has also been included in *Productive or Main Activity*, as Eurostat tracks the evolution of this indicator within both dimensions.

3) *Education*

The age range for calculating the *Inactive Young People Ratio* has been extended from individuals aged 18–24 to those aged 15–29 in order to better capture contemporary patterns of education-to-work transitions, align the indicator with international statistical standards, and provide a more comprehensive measure of youth inactivity across both early school-leaving and delayed labour market entry stages. Regarding the *Training Ratio*, in addition to the participation rate in education and training over the past four weeks, the participation rate over the past twelve months has also been introduced. Since the *Pupils to Teachers Ratio* reflects the number of primary and secondary students per teacher (the higher the number of students per teacher, the less individual time the teacher can allocate to each student), QoLI$_{v2}$ addresses the methodological oversight in the initial version by applying the reversed value formula.

4) *Health*

This dimension has been enhanced by introducing a new indicator: the *Depression Rate* and by replacing consumption-based indicators with 'non' rates to better capture exposure to health risk and allow a clearer identification of populations not meeting minimum healthy lifestyle standards. *Alcoholic Rate*, measuring the proportion of daily alcohol consumers, has been replaced by the *Non-Alcoholic Rate*, which reflects the proportion of individuals who have not reported any heavy episodic drinking in the past 12 months. *Fruits and Vegetables Consumers Rate*, measuring the proportion of the population that consumes fruits and vegetables daily, has been replaced by the *Non-Fruits and Vegetables Consumers Rate*, which captures the share of the population that does not consume any fruits or vegetables on a daily basis.

In the initial version of QoLI, the *Body Mass Index* was calculated by applying the reversed formula to the share of overweight and obese individuals, thereby overlooking underweight and pre-obese categories. In QoLI$_{v2}$, the indicator has been revised to measure the share of the population with a normal body weight. The *Health Personnel* indicator now includes midwives, and in order to align the scale of this indicator and that of *Hospital Beds* with others expressed as proportions or calendar years, their values are now reported per one million inhabitants instead of per 100,000.

5) *Leisure and Social Interactions (LSI)*

The indicators reflecting *the share of the population that regularly meets with family and friends* have been consolidated into a single measure, calculated using the geometric mean of the two original indicators. Similarly, *the participation rates in social activities, informal volunteering, and formal volunteering* have been merged into a single indicator, also calculated using the geometric mean. In

addition to these changes, *Frequency Contact Rate* has been introduced, capturing the share of the population that maintains regular contact with family or friends. The dimension was also enriched with the indicator *Satisfaction with Recreational and Green Areas*.

6) Economic and Physical Safety (Safety)

The *Offences* indicator has been enriched with statistics related to acts against computer systems, bribery, corruption, fraud, money laundering, organized criminal groups, and sexual exploitation.

7) Governance and Basic Rights (Governance)

The calculation of the *Voter Turnout* indicator has been enhanced by including not only parliamentary election results but also those of European Parliament and presidential elections. Additionally, for the *Gender Employment Gap* and *Gender Pay Gap* indicators, the calculation formulas have been adjusted to ensure that the presence of negative values (e.g., a higher proportion of men employed compared to women) does not result in an aggregated dimension value that is negative and lacks meaningful interpretation. This issue remained unnoticed in the initial version of QoLI, as both indicators consistently recorded values with the same sign, and their product therefore always resulted in a positive number.

8) Natural and Living Environment (Environment)

To provide a more comprehensive perspective on air quality, in addition to the population's exposure to particulate matter smaller than 2.5 µg/m³ and 10 µg/m³, the *Air Pollution* indicator has been enriched with data on exposure to acidifying gas emissions (NH3, NOX) and ozone precursors (CH4, CO, NMVOC, NOX).

9) Overall Experience of Life (Overall Exp)

This dimension has not undergone any changes.

C. $QoLI_{v2}$ Calculation Method

The approach used to calculate the $QoLI_{v2}$ value and its underlying dimensions has changed compared to the original formula, by applying the logarithmic function to the product of the aggregated parameters instead of using the geometric mean. This change was motivated by the asymmetric nature of these parameters [25], and by the fact that although the geometric mean also prevents a low value in one indicator from being offset by a high value in another [23], it provides results that are less interpretable than those produced by the logarithmic function [26].

We denote by *D* the set of all 9 dimensions that make up $QoLI_{v2}$, *d* a specific dimension from the set *D*, *e* an atomic indicator that is part of dimension *d*, and *e'* a sub-indicator of atomic indicator *e*. As shown in Formula (2), the calculation of $QoLI_{v2}$ involves applying the logarithmic function to the product of the values of the 9 constituent dimensions, while Formula (3) illustrates that each dimension is calculated using the same procedure, applied to the transformed values of its specific indicators.

$$QoLI_{v2} = \ln\left(\prod_{i=1}^{n} d_i\right) \ \forall\, d \in D,\ n = |D| \tag{2}$$

$$Dimension_{v2} = \ln\left(\prod_{i=1}^{n} t(e_i)\right) \ \forall\, e \in d,\ d \in D,\ n = |d| \tag{3}$$

To better clarify what is meant by *the transformed value of the indicators*, Formula (4) describes the method used to determine this value. Thus, three specific cases can be distinguished: i) the determination of values for composite atomic indicators; ii) the calculation of values for atomic indicators with a negative connotation; iii) the computation of values for regular atomic indicators.

$$t(x) = \begin{cases} avg(x), & x \text{ is a composite value} \\ rev(x), & x \text{ is a value with a negative connotation} \\ x, & \text{for other cases} \end{cases} \tag{4}$$

The first case refers to those atomic indicators that are composed of other indicators describing a related state, measured using the same unit. For these, the geometric mean described in Formula (5) is applied. For example, to determine the value of the *Voter Turnout* indicator, the geometric mean is applied to the indicators representing participation in European Parliament elections, parliamentary elections, and presidential elections.

$$avg = \sqrt[n]{\prod_{i=1}^{n} e'_n} \ \forall\, e' \in e,\ e \in d,\ d \in D,\ n = |e'| \tag{5}$$

Regarding the second case, a negatively connotated atomic indicator is one that expresses an adverse condition such as *the share of the population experiencing depressive symptoms*, *the proportion of inactive young people*, or *the percentage of the population that smokes*. Therefore, to avoid distorting the result by multiplying indicators that express positive states with those that reflect negative ones, Formula (6) allows for the transformation of the latter into positively connotated indicators. Thus, *the share of the population that experienced depressive symptoms* will be transformed into *the share that did not experience such episodes*; *the proportion of inactive young people* will be converted into *the share of young people who are not inactive*; *the percentage of smokers* will be replaced by *the percentage of non-smokers*, and so on.

$$rev(x) = 100 - x \tag{6}$$

Finally, if an atomic indicator is neither composite nor negatively connotated, it can be used as is, without any need for preprocessing.

III. Application to Real Data

Considering that this study aims not only to propose an improved version of a metric designed to assess population QoL but also to validate it, we will include correlation analyses of $QoLI_{v2}$ with GDP and HDI to determine the degree of association between the dependent variable $QoLI_{v2}$ and the two independent variables. It is worth noting that the correlation analysis is limited to the independent variables GDP and HDI, while WHOQOL and BLI are excluded from the calculations for objective reasons.

In the case of WHOQOL, WHO does not publish indicator scores but only offers a QoL measurement methodology. Similarly, OECD does not publish calculated values of BLI, offering only a methodology through which users can determine the ranking of the 38 member countries based on the weighting assigned to each dimension. Furthermore, OECD is an intergovernmental organization comprising a very limited number of countries, and three EU member states (Croatia, Bulgaria, Romania) are not part of this forum, making correlation analysis between $QoLI_{v2}$ and BLI more challenging.

A. *Data Provenance*

The primary source is the QoL database provided by Eurostat [27], which, as the official statistical office of the EU, annually collects, aggregates, and publishes statistical data from both EU member countries and candidate countries seeking accession to the community space. However, since Eurostat does not provide statistics on voter turnout, their scores are sourced from the International Institute for Democracy and Electoral Assistance portal [28]. Regarding GDP values, these are also sourced from statistics provided by Eurostat [29], while the HDI values are extracted from the official UNDP report, *"Human Development Report 2025"* [30].

B. *Correlation Analysis*

To validate the newly introduced formula, Spearman's rank correlation coefficient was calculated between the $QoLI_{v2}$ values presented in Table 2 and two of the most widely used indicators, namely GDP and HDI.

TABLE II. THE VALUES OF THE COMPARED INDICATORS RECORDER BY THE EU MEMBER STATES IN 2023

Country Code	Country Name	GDP per Capita	HDI	$QoLI_{v2}$
AT	Austria	45,510	0.930	30.711
BE	Belgium	44,120	0.951	30.556
BG	Bulgaria	10,970	0.845	29.753
CY	Cyprus	28,670	0.913	30.227
CZ	Czechia	21,660	0.915	30.375
DE	Germany	47,780	0.959	30.587
DK	Denmark	58,640	0.962	30.697
EE	Estonia	21,210	0.905	30.277
EL	Greece	18,670	0.908	29.997
ES	Spain	27,510	0.918	30.363
FI	Finland	43,430	0.948	30.734
FR	France	37,570	0.920	30.406
HR	Croatia	16,060	0.889	30.129
HU	Hungary	16,060	0.870	30.238
IE	Ireland	86,090	0.949	30.560
IT	Italy	32,560	0.915	30.182
LT	Lithuania	19,160	0.895	30.276
LU	Luxembourg	101,450	0.922	30.735
LV	Latvia	17,390	0.889	30.132
MT	Malta	32,740	0.924	30.461
NL	Netherlands	51,010	0.955	30.361
PL	Poland	15,950	0.906	30.390
PT	Portugal	22,020	0.890	30.394
RO	Romania	13,030	0.845	29.966
SE	Sweden	48,510	0.959	30.741
SI	Slovenia	25,050	0.931	30.531
SK	Slovakia	18,750	0.880	30.294

Spearman's rank correlation coefficient, denoted by the Greek letter ρ (rho) or by r_s, is a nonparametric measure of the strength of association between two variables. The values calculated based on this measure range from -1 to 1, with the two ends of the interval representing a perfect relationship, and the value 0 indicating no relationship between the two compared variables.

The results of calculating Spearman's rank correlation coefficient, presented in Figure 1 and Figure 2, indicate a strong monotonic relationship in both cases, with a slight predominance of the correlation with GDP per Capita

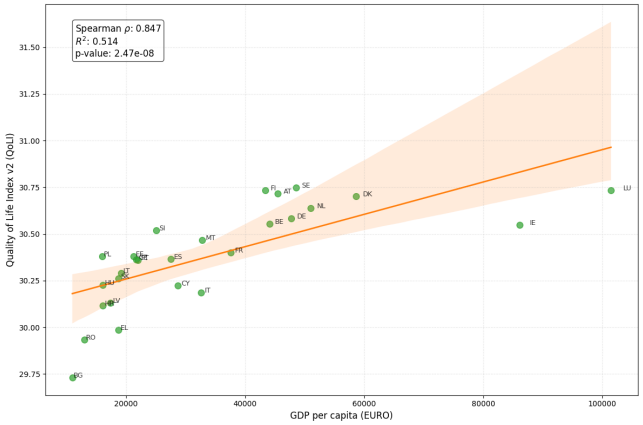

Figure 1. Bivariate plot determined for the variables $QoLI_{v2}$ and GDP per capita (2023).

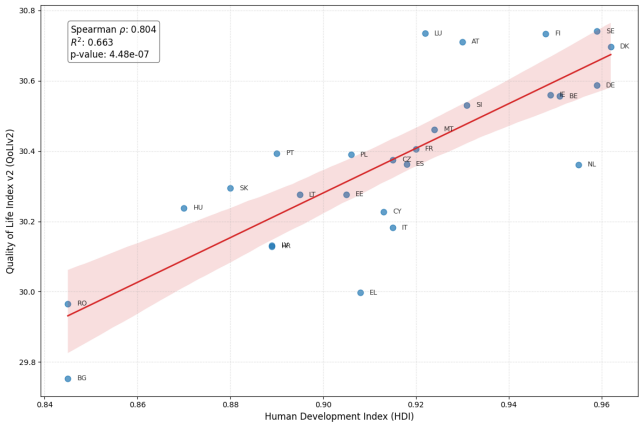

Figure 2. Bivariate plot determined for the variables $QoLI_{v2}$ and HDI (2023).

($\rho = 0.847$, $p < 0.001$) compared to HDI ($\rho = 0.804$, $p < 0.001$), suggesting that the hierarchical positioning of countries is very consistent between economic wealth and the new $QoLI_{v2}$ index.

To reinforce the explanatory power of the indicated relationships, the calculation of R^2 helps us better understand the proportion and variation of $QoLI_{v2}$ explained by the other two variables. Thus, we can observe that 51.40% of the variation in $QoLI_{v2}$ can be attributed to its association with GDP per Capita, while 66.30% of the variation is explained by the correlation with HDI. This difference is largely driven by *economic outliers* like Luxembourg and Ireland, whose exceptional wealth does not translate into a proportionally higher quality of life. This confirms that $QoLI_{v2}$, like HDI, is a multidimensional construct that levels out purely fiscal extremes, offering a more balanced view of social development

IV. Conclusion And Future Work

Although a universally accepted definition for the term QoL has not yet been established, recent years have seen growing interest in examining the indicators that influence population QoL and in developing new metrics to assess it, whether general or specific, related or unrelated to health.

Following a thorough examination of the most well-known metrics and of the techniques used to aggregate indicators, the formula for calculating the QoLI, initially proposed in 2019 [23], has been revisited, and a series of both structural and methodological changes have been introduced. The new version, $QoLI_{v2}$, incorporates a much broader range of atomic indicators than its predecessor (76 indicators compared to 32), significantly expanding the coverage of factors that Eurostat uses in its annual QoL assessments. All these atomic indicators are aggregated into eight objective and one subjective dimension, which are then further aggregated to determine the overall $QoLI_{v2}$ value. In the new formula, aggregation is performed using a logarithmic function instead of the geometric mean.

To validate the new formula, correlation analyses were performed between $QoLI_{v2}$ and two of the most widely recognized indicators: GDP per Capita and HDI. After calculating Spearman's rank correlation coefficient, a strong monotonic correlation was observed in both cases, with values of 0.847 for the relationship between $QoLI_{v2}$ and GDP per Capita, and 0.804 for the relationship between $QoLI_{v2}$ and HDI.

Beyond statistical validation, an important direction for future work involves expanding the interpretative analysis of country-level results. Further investigation is required to substantiate how the rankings produced by $QoLI_{v2}$ reflect socio-economic realities in different national contexts. Comparative case studies between countries exhibiting similar $QoLI_{v2}$ outcomes could provide deeper insight into how distinct economic structures, social policies, or institutional environments lead to comparable QoL results despite differing macroeconomic conditions.

Future research will therefore focus on extending the validation framework through qualitative and comparative analyses, incorporating expert feedback and contextual interpretation of national performances. This includes examining clusters of countries with similar $QoLI_{v2}$ scores, identifying divergence from traditional indicators such as GDP or HDI, and exploring whether $QoLI_{v2}$ captures multidimensional aspects of well-being that remain insufficiently represented in existing development metrics.

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