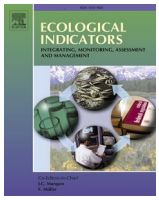
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A holistic approach to evaluate the synergies and trade-offs of city and country success

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ABSTRACT

The United Nations presented a global action plan of an integrated nature for sustainable development, and the role of cities is seen as central in efforts to implement these goals. Integrating city performance evaluation methods containing sustainability indicators is becoming increasingly popular. The United Nations and other international organizations and researchers analyze urban sustainability in the context of different countries. However, holistic assessment methods that can show if and to what extent a city is sustainable, measure its progress, and provide information for policy development are only just emerging. Our Synergies and Trade-offs Recommendation Method for Sustainable Cities and Communities (the STRICT method) proposes that country and city metrics are connected in multifaceted ways through tradeoffs and synergies. As a result of this analysis, city models and maps were created, and digital evidence-based recommendations were provided to urban and national policymakers based on the findings of the analysis. A 1% improvement in country success individual metrics led to a synergistic effect in 189 out of 219 city indicators (86.3%). The STRICT method suggests a notable impact of a country's social, cultural, and political success on the city indicators.

1. Introduction

Cities play a key role in determining the sustainability of human development (Wiedmann & Allen, 2021). It is estimated that seven out of ten people will live in urban areas in 2050. The most significant part of economic growth happens in cities, which account for more than 80% of the global gross domestic product (GDP). Yet these benefits of cities are accompanied by their substantial greenhouse gas emissions, which make up more than 70% of the global total (Sachs et al., 2022a). The United Nations (UN) Sustainable Development Goal 11 (SDG 11) is extremely important; it is phrased as to "make cities and human settlements inclusive, safe, resilient and sustainable" (Cf, 2015). Countries have integrated a commitment centered on cities within a nationally set agenda and have acknowledged the value of a place-based approach to development (Espey et al., 2023).

Limited resources and the need to balance multiple, often conflicting, objectives are the reality in addressing the challenge of achieving sustainable urban development and its related goals, such as reduced risk of disasters, economic development, equitable communities, opportunities for recreation and renewal, and sufficient food, water, and energy. Collaboration across sectors and disciplines from planning and policy authorities at local, regional, and national levels to engineering firms will be required to achieve the UN SDG 11 goal "sustainable cities and communities" (Keeler et al., 2019). Progress toward achieving the 17 SDGs needs to be quantified in order to guide policy development and implementation and to track global efforts toward sustainable development (Xu et al., 2020).

SDGs are inherently integrated and, thus, present a challenge in implementing the UN 2030 Agenda for Sustainable Development (Cf, 2015). Methods that are flexible and simple to apply are usually prioritized by decision makers, and the ability to provide understandable and directly actionable results is often preferred. People in charge of method development should pay particular attention to the practical value of applications to support resource-constrained organizations, decision

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makers, and anyone who wants to evaluate multiple cases (Di Lucia et al., 2021). Tradeoffs are situations in which the effort to achieve one goal undermines others, whereas synergies occur when efforts to achieve one goal help fulfill others. For SDG implementation plans to be ensured, the UN 2030 Agenda promotes integrated models, tools, and planning methods to support the assessment of options. Since the UN Agenda was adopted, numerous different methodological approaches have been adapted or developed with the aim of an integrated look at the SDGs (Di Lucia et al., 2021).

Researchers have used five methodological approaches, which are modeling (Collste et al., 2017; Pedercini et al., 2018; van Vuuren et al., 2015), literature-based analysis (Fuso Nerini et al., 2017, 2019; Vinuesa et al., 2020), statistical analysis (Kroll et al., 2019; Pradhan et al., 2017), multiple-criteria analysis (Kaklauskas & Kaklauskiene, 2022), and expert judgement (Nilsson et al., 2016, 2018; Weitz et al., 2018). For example, Xu et al. (Xu et al., 2020) developed and tested systematic methods to show in numbers the progress toward the SDGs at subnational and national levels in China. An operational method was developed by Hopkins et al. (Hopkins et al., 2020) to distinguish win–win options among other possible dual outcomes, such as lose–neutral and lose–lose.

Since SDGs are integrative in nature, Collste et al. (2017) believe that integrative modeling techniques are an especially useful tool. The Threshold21-iSDG model developed by Pedercini et al. (2018) integrates long-term environmental, economic and social policy analyzes that are important in efforts to address SDGs. An analysis by van Vuuren et al. (2015) is focused on different combinations of behavioral changes and technological measures and the way in which they could help to achieve certain sustainability objectives taking into account the interlinkages between them.

It is difficult to be certain whether governing by such broad targets as SDG 11 and urban quality of life (UQL) will be effective, and suitable holistic methods are scarce. Yet to develop actionable holistic methods that would help achieve SDG 11 is still a very challenging task. SDG 11 is multidimensional and complex, and incomplete solutions likely lack a holistic and more integrated method. Culture has been proposed as a fourth sustainability dimension by some scholars (Brocchi, 2010; James & Magee, 2016), the United Cities and Local Governments, and Agenda 21 for culture (Culture 21: Agenda 21 for Culture, 2006). Several experts (Biermann et al., 2022; Purvis et al., 2019) have also proposed the dimension of political sustainability. There are causal links between the five sustainability dimensions (C.-P. Chang & Lee, 2010; Funke & Zhong, 2020; Murphy, 2019).

Recently, composite indicator-based methods to evaluate city performance, comprising sustainability matters, have gained much consideration, such as the Mercer's Quality of Living, the UN Prosperity Index, the Global Power City Index, the Sustainable Cities Index, the Cities of Opportunity index, the IESE Cities in Motion Index, the Sustainable Assessment by Fuzzy Evaluation index, and the Spatially Adjusted Liveability Index Unit. In monitoring urban sustainable development, composite indicators have expanded notably because of the multiple-dimensional sustainability nature (Lo-Iacono-Ferreira et al., 2022).

Researchers have noticed that the context around content is often more important than the content itself, and that content is meaningless without an analysis of its surrounding context. Robitaille (2013) believes that if content is king, then context is god. Many researchers share the same opinion. Sloboda (2008), for instance, believes that context is king. Many researchers now think that urban quality of life can be very different in different contexts and cultures, and is thus a very complex field. A context can, for instance, be social (Andersen & Røe, 2017), political (Mocca, 2022), cultural (Wang et al., 2022), economic (Votsis, 2017), environmental (Liang et al., 2023), emotional (Theunissen & Elie, 2014) or stressful (De Berker et al., 2016), can show that someone is happy (Krumhuber et al., 2023) or angry (Rizzolatti et al., 2021), and can reveal other aspects. The research performed by Feldman Barrett (2021) suggests that emotions might be expressed in a context-specific manner and thus may be different in different instances, tailored to the specific context. In their research, Cowen et al. (2021) determine distinct associations between each type of facial expression and a set of contexts. Many other studies (Hsueh et al., 2023; Wu et al., 2021) have also emphasized the impact of context on the studied object.

The European Environment Agency (2021) specifies that individual urban context significantly impacts its evolution to city environmental sustainability. Urban studies, on the other hand, concentrate on city-level or micro-scale analyzes of sustainability, according to researchers, who point out that tools intended to support the transition to more sustainable urban futures typically focus on specific phenomena at the local level (Purvis et al., 2022), and city research emphasis on urban-level or micro-scale examination concerning sustainability (Buzási & Jäger, 2020). The need to supplement this micro-approach with more comprehensive integrated methods that address the interaction between various urban components and their relationship to processes and policies implemented at larger scales and country context is highlighted (Purvis et al., 2022).

According to a review of studies on urban sustainability, it is generally acknowledged that good governance is necessary to accomplish the 17 Sustainable Development Goals (SDGs). Therefore, it is essential to examine how various aspects of governance, such as participation, policy coherence, reflexivity, adaptation, and democratic institutions, affect the achievement of the SDGs at the national level while accounting for the impact of additional socioeconomic factors (Glass & Newig, 2019). Researchers point out that academic interest in urban sustainability transitions is growing. More attention should be paid to the political-institutional national contexts in which these urban sustainability transitions take place and by which they are sparked, shaped, or prevented. Therefore, research should build on earlier studies of sustainability transitions by incorporating a multi-level national governance perspective, as noted in the scientific literature (Ehnert et al., 2018). Therefore, the political and cultural dimensions were also examined in this study.

This study aims to demonstrate and approve the holistic approach in evaluating the spillovers of cities and countries and show that sustainable cities and communities, urban quality of life, and country success can augment the synergies between indicators of all dimensions and minimize their prevailing tradeoffs. The $SDG11^{CS}$ and UQL^{CS} Models are intended to assist city and national stakeholders in analyzing the relationships between the country's success, SDG 11, UQL, and five sustainability dimensions to disclose the most rational roadmap for realizing the SDG 11 and UQL goals and provide digital evidence-based recommendations. We applied regression and multiple-criteria analysis in this research to look at five dimensions of sustainable cities (economic, environmental, social, cultural, and political). We propose the Synergies and Trade-offs Recommendation Method for Sustainable Cities and Communities (the STRICT method) as a solution-oriented and analytical tool to identify and shape interventions that would help cities achieve sustainability. Our findings suggest that the political, cultural, and social metrics affect urban quality of life and SDG 11 both globally and locally. SDG 11, UQL, and country success and sustainability indicators are interlinked. Thus, while the number of countries, cities and their indicators has changed, the relative achievements and trends of countries and cities in SDG 11 and UQL remain quite similar. Taking into consideration the fact that global spillover effects play a positively dominant role, this study has considered that country success, interrelated with SDG 11 and UQL, could be added as the sixth dimension of sustainability.

2. Method for recommending synergies and trade-offs for sustainable cities and communities (the STRICT method)

The idea of the STRICT method is that all the indicators that make up a system of criteria that defines country success and sustainability are

interrelated, and that conditional country successes remain quite similar, even when the number of countries and related indicators change. The STRICT method is different from other techniques because of four key innovative elements:

- The method shows a link between sustainable cities and communities and a country's success.
- The SDG11^{CS} and UQL^{CS} models and maps demonstrate that the progress of a country's political, cultural, and social indicators has a significant synergistic effect on sustainable cities and communities and the quality of life of cities.
- The method demonstrates that environmental, social, cultural, political, and economic sustainability indicators move in similar ways.
- The method provides digital recommendations.

The STRICT method takes a system of UQL and SDG 11 statistical criteria that describe a country's policy alternatives in an adequate manner, looks at the values and weights of the criteria, and assumes proportional and direct dependence of the significance and priority of any given options. A 12-stage process is used to determine the priority, significance, and utility degree of the PO alternatives and to present quantitative recommendations.

Stages 1–7 in the STRICT method are identical to those in the INVAR method (Kaklauskas, 2016). The INVAR technique of multiple-criteria decision making (Kaklauskas, 2016) was applied to Asian countries (Kaklauskas et al., 2020) and post-Soviet countries (Kaklauskas et al., 2018) and in a global analysis (Kaklauskas et al., 2022, 2023a, 2023b; Kaklauskas & Kaklauskiene, 2022).

The steps of the STRICT method and the indicators used in these steps are discussed in detail below.

Stages 1–5 of the STRICT method are used to determine the efficiency (significance, Q_j), priority (P_j) and utility degree (N_j) of the entities being examined (countries, cities, recommendations and so on).

Stage 1. The first step is to create a weighted, normalized decision matrix D. Matrix D consists of criteria systems describing cities and countries, criteria values and their weights. We describe the sources of all indicators used in this research in the Data Availability section and the online links we provide in Table S1abc. All indicators analyzed are for 2020. The indicators selected for the study are representative of those commonly used in such multiple criteria analyzes. The rationale for the choice of all the indicators used in the study is presented in Table S1d. The statistical information presented in Table S1d demonstrates that the SDG 11 and UQL indicators analyzed in this study and the context surrounding them (sustainability indicators and country success) are examined in the same studies by other authors. The Table S1d provides statistical information on the indicators used in the study in the Web of Science, Nature portfolio, ScienceDirect and Google Scholar databases. For example, a search of these databases using the keywords UN + SDGs + "air quality" yielded 18, 41, 1,245 and about 27,200 articles respectively. A keyword search for UN + SDGs + wealth yielded 24, 98, 2,055 and about 56,500 articles, respectively. The indicators used in the study therefore describe the holistic approach to evaluate synergies and trade-offs of city and country success and the context surrounding this analysis. The indicator frameworks applied in this research analyze SDG 11 and UQLs and the context (sustainability indicators and country success) surrounding them. All indicators under analysis are presented in the tables and figures of the manuscript. In this study, in the multiple criteria analysis of countries and cities, all criteria weights were equal to one.

In their data selection methodology, Sachs et al. (2022b) point out that the official SDG indicators endorsed by the UN Statistical Commission are used in the Sustainable Development Report (Sachs et al., 2022b) where possible. Sachs et al. (2022b) include other metrics from both official and unofficial providers if there is insufficient data available from an official indicator or there are data gaps. The purpose of the Sustainable Development Report (Sachs et al., 2022b) is to be a source of robust data to help countries make informed decisions on their SDG priorities. To minimize biases related to data gaps, only countries for which the available data cover at least 80% of the variables included in the global SDG are included in the SDG Index.

SDG 11 covers ten targets and 16 indicators worldwide. The data for these indicators are, however, not available for some countries; four SDG 11 metrics (Sachs et al., 2022a), the Backdated SDG Index) were therefore analyzed, and their priorities were calculated for most of the countries in this study. The study looked at ten UN-defined SDG 11 targets and 16 indicators. Many of the 16 indicators, however, covered only between four and 137 countries from our total sample of 173, or between 2% and 79%. These indicators were, therefore, excluded from the analysis and calculations. Because of these data gaps and insufficient data and considering that many SDG priorities lack accepted statistical models (Sachs et al., 2022b), and also in order to minimize biases due to missing data, the metrics provided by Sachs et al. (2022a) were used in our analysis and calculations.

Different numbers of countries and cities were analyzed against different sets of indicators during this research. For example, one of the samples had 169 countries and another had 173 countries, with the first sample described by a set of 15 indicators and the latter by a set of 17 indicators. However, for some countries all the indicators we needed for our analysis were not available, and hence a smaller sample of countries (e.g., 89 or 151) was often analyzed to create our maps and models. However, the research results show that this diversity had only a small impact on the research results. Our SDG 11 study discusses in detail the measurement of the success of 169 nations based on 15 criteria (Table S1a), 173 countries based on 17 criteria (Table S1b), and 173 countries based on 25 criteria (Table S1c) and the results that were obtained. A set of variables taken from multiple websites and databases, such as the those of the World Bank and the World Health Organization, was used in this study (Data availability, Table S1). SDG 11 covers ten targets and 16 indicators worldwide. However, the data for these indicators were not available for some countries; thus, four SDG 11 metrics (Sachs et al., 2022a) (Backdated SDG Index) were analyzed, and their scores were calculated for most of the countries in this study.

Weighted, dimensionless values from the comparative indices should be determined at this stage. Once these dimensionless values are established, all the UQL (SDG 11) criteria can be compared, even though they originally had different dimensions. The following equation is used for this purpose:

$$d_{ij} = \frac{x_{ij} \cdot q_i}{\sum_{j=1}^{n} x_{ij}}, \quad i = \overline{1,m}; \ \ j = \overline{1,n} \tag{1}$$

where x_{ij} is the value of the i-th UQL (SDG 11) criterion in the j-th PO alternative, q_i is the weight of the i-th criterion, n is the number of PO alternatives compared, and m is the number of UQL (SDG 11) criteria.

The weighted, normalized decision matrix D is now ready (Formula 1). The sum of the weighted, dimensionless index values d_{ij} of each UQL (SDG 11) criterion x_i is always equal to the weight q_i of that particular criterion:

$$q_i = \sum_{j=1}^{n} d_{ij}, \quad i = \overline{1,m}, j = \overline{1,n}. \tag{2}$$

The value of the weight q_i of the given criterion is distributed proportionally among the given UQL (SDG 11) indicators a_j based on their values x_{ij}.

Stage 2. The second step is to calculate the sums of the normalized, weighted indices related to the j-th PO version. The PO versions are described by the minimizing index S_{-j} and the maximizing index S_{+j}. In the case of minimizing indices, a lower value denotes target achievement (e.g., cost of living index, property price to income ratio, traffic commute time index, pollution index). In the case of maximizing indices, a greater value denotes target achievement (e.g., healthcare index, safety index, purchasing power index). The following equation is

used to calculate the sums:

$$S_{+j} = \sum_{i=1}^{m} d_{+ij}; \quad S_{-j} = \sum_{i=1}^{m} d_{-ij}, \qquad i = \overline{1, m}; j = \overline{1, n} \tag{3}$$

The values S_{+j} (in this case, greater values for the country policy options (PO) "pluses" mean greater stakeholder satisfaction) and S_{-j} (in this case, lower values of PO "minuses" mean stakeholders achieve their goals to a greater extent) express the extent to which stakeholders have achieved their goals related to each PO. The sum of the "minuses" S_{-j} and the "pluses" S_{+j} of all the POs is always equal to all the sums of the weights of the minimizing and maximizing criteria, respectively. The sums of the normalized, weighted indices related to the j-th PO version are calculated. Equation (4) is used for this purpose:

$$\begin{aligned} S_{+} &= \sum_{j=1}^{m} S_{+j}; = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{+ij}, \\ S_{-} &= \sum_{j=1}^{n} S_{-j}; = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{-ij}, \qquad i = \overline{1, m}; j = \overline{1, n} \end{aligned} \tag{4}$$

Stage 3. The efficiency (significance) of the given versions has to be determined based on the descriptions of the features seen in the positive POs, or "pluses," and the negative POs, or "minuses." The following equation is used to calculate the relative significance Q_j of each PO a_j (where $S_{-\min}$ is the least value of the S_{-j}):

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{-j}}}, j = \overline{1, n} \tag{5}$$

Stage 4. Now the priorities of alternatives related to the axiom that greater Q_j means higher priority (P_j, efficiency) of a PO have to be determined.

Stage 5. The following equation is used to calculate the utility degree N_j of the PO a_j:

$$N_j = \left(Q_j : Q_{max}\right) \cdot 100\% \tag{6}$$

Here Q_j and Q_{max} are the significances of the PO alternative obtained from Equation (5).

Stages 1–5 of the multiple-criteria analysis are used and discussed throughout the manuscript, but their clearest manifestations are in the following tables:

- Table S1 presents a multiple-criteria analysis for 15 (Table S1a) and 17 (Table S1b) success indicators in, respectively, 169 and 173 countries.
- Table S2 presents a multiple-criteria analysis for four SDG 11 indicators (proportion of urban population living in slums, access to improved water source (piped), satisfaction with public transport, and annual mean concentration of particulate matter of less than 2.5 μm in diameter ($PM_{2.5}$)) in 164 countries.
- Table S3 presents a multiple-criteria analysis (for seven urban quality of life indicators and 17 country success metrics) of 173 countries.
- Table S4 presents a multiple-criteria analysis (four SDG 11 indicators and 25 country success metrics) of the SDG 11 policy.

Multiple-criteria analysis using the INVAR method determined an integrated SDG 11 indicator for the four metrics by country, and then the indicator was compared with the overall SDG 11 score by country (Backdated SDG Index) calculated by Sachs et al. (2022a). The 2020 figures related to SDG 11 rankings determined using Sachs et al.'s (2022a) method and the INVAR method for 164 countries and their comparisons are listed in Table S2 and are visually presented in Fig. S1. In the case of the INVAR method, for example, Switzerland was identified as the country with the highest value denoted by target achievement, but the Sachs et al. (2022a) method ranked Switzerland second (Table S2 and Fig. S1). The difference between the rankings that was established after comparing the results from each method was one rank position.

Our research presents the results related to PO evidence-based recommendations to urban policymakers that are obtained by applying Stages 6–7 of the STRICT method (Table S5 and Fig. 4).

In Stage 6 the following equation is used to show the extent to which (as a percentage) the value of the UQL (SDG 11) indicator x_{ij} of the quantitative recommendation i_{ij} has to be improved to make the indicator the best value $x_{i\ max}$ for the criterion X_i (Table S5):

$$i_{ij} = |x_{ij} - x_{i\ max}| : x_{ij} \times 100\% \tag{7}$$

where i_{ij} is the quantitative recommendation of the UQL (SDG 11) indicator x_{ij} showing the percentage of possible improvement in the value of the indicator x_{ij} for it to become equal to the best value $x_{i\ max}$ of criterion X_i. Meanwhile $x_{i\ max}$ is the value of the indicator of the criterion X_i of the variants under comparison.

In Stage 7 the UQL (SDG 11) indicator x_{ij} of the quantitative recommendation r_{ij} shows how much (as a percentage) the utility degree N_j of the PO alternative a_j can be improved by the presentation of $x_{ij} = x_{i\ max}$. This means that r_{ij} shows how much (as a percentage) the utility degree N_j of the alternative a_j can be improved assuming the indicator x_{ij} can be improved to become equal to the best value $x_{i\ max}$ of the criterion X_i. The following equation is used:

$$r_{ij} = (q_i \times x_{i\ max}) : (S_{-j} + S_{+j}) \times 100\% \tag{8}$$

where r_{ij} is the indicator x_{ij} of the quantitative recommendation showing the percentage of possible improvement in the utility degree N_j of alternative a_j when $x_{ij} = x_{i\ max}$.

Table S5 lists the recommendations for improvement of the seven NUMBEO urban quality of life criteria. The recommendations are added to the matrices using Equations (7) and (8) during Stages 6 and 7. For example, if the safety index in Caracas, Venezuela (X_2, $i_{2\ 44}$) were to be improved by 487.42% from $x_{2\ 44}$= 15.1 up to the best value for a_1 ($x_{2\ 1}$=88.7, Abu Dhabi (United Arab Emirates)), the increase in the utility degree N_{44} for the Caracas urban quality of life ($a_{2\ 44}$) would then be r_{44}=68.27%. Likewise, if the healthcare index in Caracas, Venezuela (X_3, $i_{3\ 44}$=39.3) could be improved by 120.36% from $x_{3\ 44}$=39.3 up to the best value for a_{200} ($x_{3\ 200}$=86.6, Taipei, Taiwan), the increase in the utility degree N_{44} for the Caracas urban quality of life would then be r_{44}=13.49%. Analyzing pollution parameters, if the pollution index in Kathmandu, Nepal (X_7, $i_{7\ 101}$) was reduced by 86.73% from $x_{7\ 101}$=95.7 to the best value for a_{84} ($x_{7\ 84}$=12.7, Helsinki (Finland)), the increase in the utility degree N_{101} for the Kathmandu urban quality of life would be r_{101}=16.28% (Table S5).

In Stage 8 and Stage 9, the UQL^{CS} and $SDG11^{CS}$ model and map are developed, and in this way, a holistic approach to urban quality of life and sustainable cities and communities is validated (Results).

During Stage 8, the $SDG11^{CS}$ and UQL^{CS} models, and four $SDG11^{CS}$ and seven UQL^{CS} sub-models, are created to analyze 15 (Table S1a), 17 (Table S1b), and 25 (Table S1c) success indicators in 169 and 173 countries. The $SDG11^{CS}$ and UQL^{CS} models and sub-models are developed using IBM SPSS V.26 software. This study develops the $SDG11^{CS}$ and UQL^{CS} models by applying the five sustainability dimensions (the social, political, environmental, economic, and cultural dimensions) to evaluate the interconnection between UQL and SDG 11 and country success and sustainability. These models estimate the synergies and trade-offs among the five worldwide sustainability dimensions by applying the STRICT method. The $SDG11^{CS}$ and UQL^{CS} models include, respectively, four and seven sub-models. Data for 2020 were used in this study.

The UQL^{CS} and $SDG11^{CS}$ models are analyzed by applying 15 independent variables (country success metrics) from 169 countries (Table S6). All the model's independent variables that had a statistically insignificant effect on the dependent variable are then removed from the model to produce the UQL^{CS} model as presented in Table S7.

Table S8 details the spillover effect for the four $SDG11^{CS}$ and seven

UQL^{CS} sub-models (urban quality of life indicators by NUMBEO) due to changes in a country's success (the 17 country success indicators which are listed with the data presented in Table S1b).

This evidence-based analysis confirms that the $SDG11^{CS}$ and UQL^{CS} models are holistic.

Also, the effect size indicators for the models are calculated. The integrated analysis of the effect size indicators of the given policy options for urban quality of life (UQL) and sustainable cities and communities (SDG 11) are presented as grouped decision matrices. The columns represent *n* alternative country policy options (success indicators) and the rows represent the related UQL (Table S3) and SDG 11 (Table S4) quantitative details.

The STRICT method analyzes seven UQL and four SDG 11 effect size indicators. These effect size indicators can help identify the country success metrics (POs) that have the most significant influence on the improvement in the four SDG 11 and seven UQL indicators. The case study discussed in our research focuses on the following effect size metrics:

- A factor's degree of impact (If). This degree is a function of the t-statistics of the coefficient B (p_t), the correlation weight (p_c), the correlation coefficient (r), and the coefficient β of the dependent variable in the regression model: If=f(r, p_c, β, p_t). For each dependent variable, the impacts on UQL (Table S3a) and SDG 11 (Table S4a) in the regression models were determined, and Tables S3a and S4a list the results.

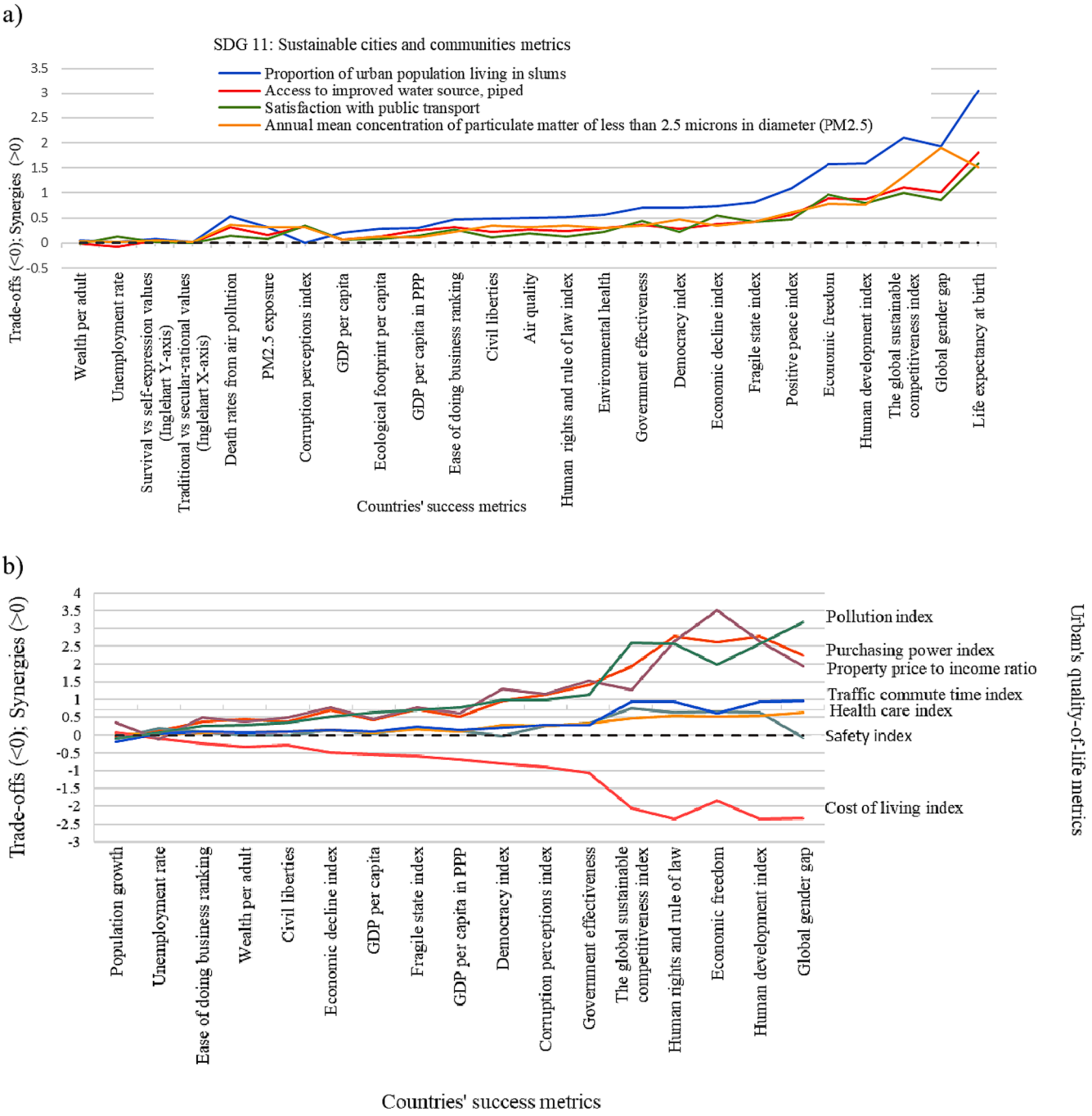


Fig. 1. The synergies and trade-offs between (a) sustainable cities and communities and (b) changes in the variables of a city's quality of life when the values of the variables of a country's success go up by 1%.

- Elasticity. An increase/decrease in the UQL (Table S3b) and SDG 11 (Table S3b) indicators is caused by an increase of 1% in a nation's success expressed as a percentage (P_{id}).
- The determination coefficient (R2). R2 estimates the degree to which the countries' success metrics in the models predict the UQL (Table S3c) and SDG 11 (Table S4c) variables.

Seven UQL and four SDG 11 effect size indicators are applied to identify the PO that has the most influence on the simultaneous improvement of SDG 11 and UQL. The case study in this research focuses on the following effect size metrics: the factor's degree of impact (If=f(r, pc, β, pt), the elasticity, and R2 (Tables S3 and S4)). The weights of the impact for the dependent variables of urban quality of life show that changes in the values of indicators such as ease of doing business ranking (If_3=42.367), economic freedom (If_7=41.923), and corruption perceptions index (If_4=41.407) have the most substantial integrated impact on all the urban quality of life indicators. Looking at the values of these indicators for country success, the degree of impact is higher than the average impact of the indicator values (M=35.27; Table S3a). Likewise, the weights of the impact for sustainable cities and communities (SDG 11) are calculated. The most substantial impact on the variables of SDG 11 is seen in the case of the human development index (If_5= 23.871; Table S4a). Table S3c shows the links between the coefficients of determination (R^2) of the regression equations for the independent country success indicators and the dependent UQL indicators. The values of this coefficient, therefore, show us how well a respective UQL indicator can be forecast based on the country success indicator. Looking at the average coefficient of determination of a given country success indicator in relation to the UQL indicators, we see how well all the UQL indicators can be explained based on a specific country success indicator. Analogously, Table S4c takes specific SDG 11 indicators (R^2) and shows the extent to which the dispersion of their values is explained by changes in the values of a corresponding country success indicator.

The UQL^{SC} and $SDG11^{CS}$ models provide the big picture for UQL and SDG 11 and the associated context, while their maps provide a simplified but visually much more comprehensible representation of the current reality. In Stage 9, the UQL^{CS} and $SDG11^{CS}$ maps are created to allow the visualization of the impact of a country's success on the improvement of urban quality of life and sustainable cities and communities (Figs. 3 and 5):

- In the $SDG11^{CS}$ map, the X-axis represents the success of 151 countries, and the Y-axis represents the integrated SDG 11 metric calculated from the four SDG 11 indicators. The dimensions of a country's success reflect the 15 variables and the related results. SDG 11 is defined by four indicators (Fig. 3).
- The UQL^{CS} map is created to allow a thorough examination of the ways in which country success (Table S1a) and UQL are linked. The cities are distributed over the UQL^{CS} map along the Y-axis (urban quality of life) and the X-axis (nation success). In the map, the set of 15 indicators includes the country success dimensions (higher success value is denoted by target achievement) determined for 169 countries. UQL (higher is characterized by target achievement) is defined by the seven NUMBEO urban quality of life indicators that were used to calculate the overall UQL for 227 cities (Fig. 5).

In Stage 10, the elasticity coefficient for each independent country success variable included in the initial model is calculated to measure the way in which changes affect the dependent variables of the UQL and SDG 11. The elasticity coefficient shows the magnitude of the change in

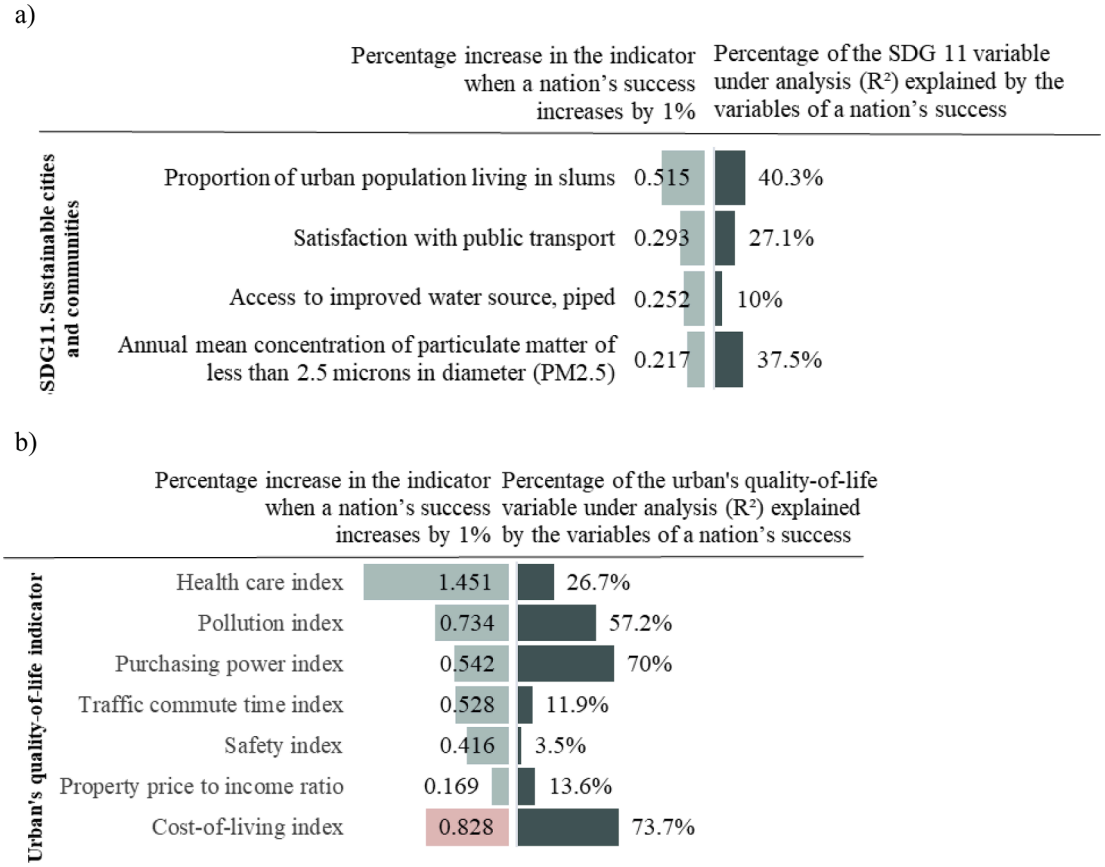


Fig. 2. Effect of country success and its factors on SDG 11 (a) and UQL (b) indicators: the percentage increase in the city's quality-of-life indicator when a country's success increases by 1%; and the percentage of the urban's quality-of-life metrics (dependent variable) under analysis (R^2) explained by the metrics of a country's success (independent variables).

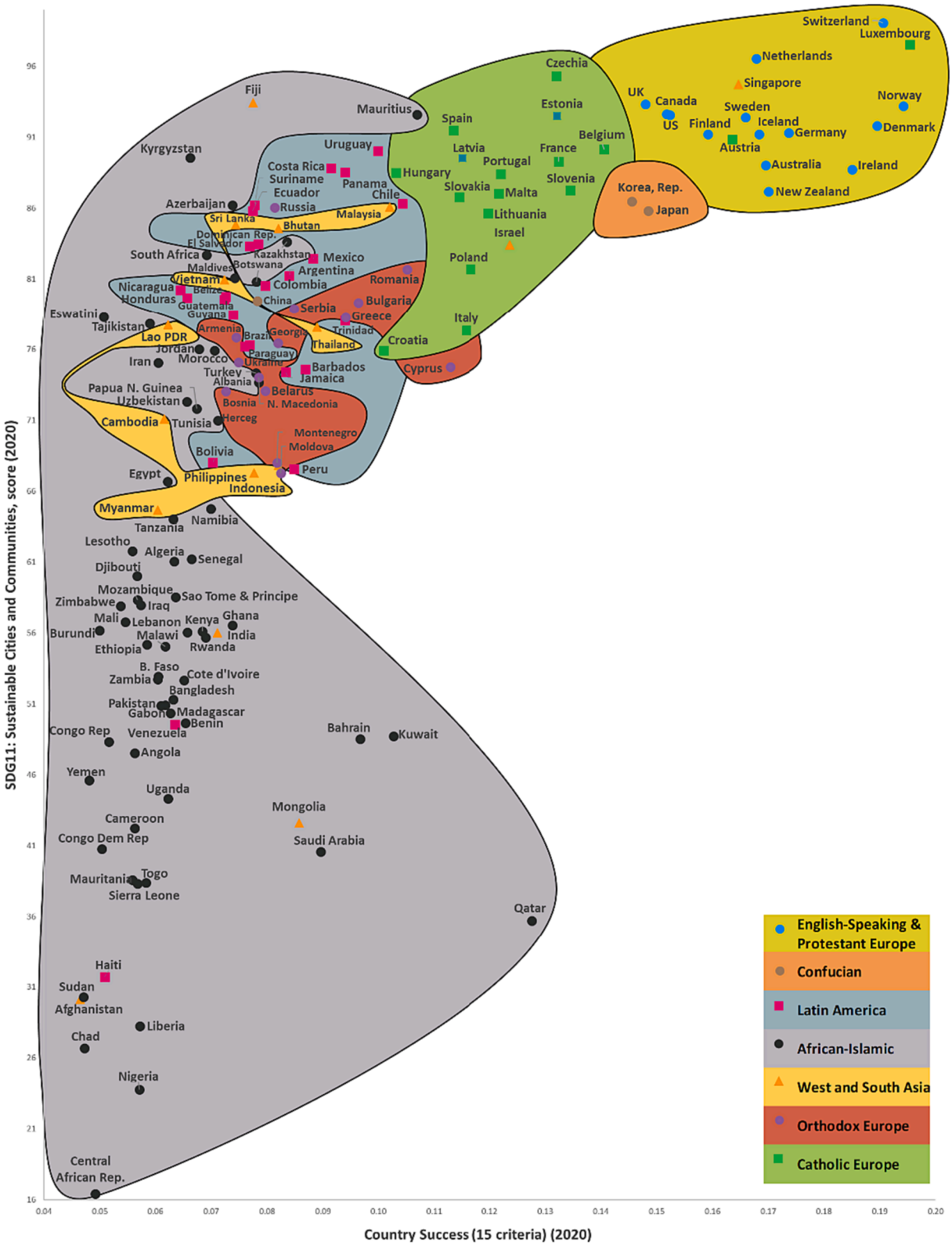


Fig. 3. Sustainable Cities and Communities and Country Success Map of the World ($SDG11^{CS}$ Map). In the $SDG11^{CS}$ Map, the X-axis represents the success of 151 countries, and the Y-axis represents the SDG 11 goal score (Sachs et al., 2022a). The dimensions of a country's success reflect 15 variables and the related results. SDG 11 is defined by four indicators. When a country is closer to target achievement, the country moves toward the right side of the map, whereas improvements related to SDG 11 result in an upward movement. A country's location on the map can help us forecast how countries respond to the changing situation of SDG 11. Countries that are closer to target achievement tend to have a greater chance of achieving improvements in SDG 11. The map includes concentrated clusters of polarized and interconnected countries and systematically displays them. The choice of countries makes no difference in these clusters. The number of the descriptive variables also makes no difference.

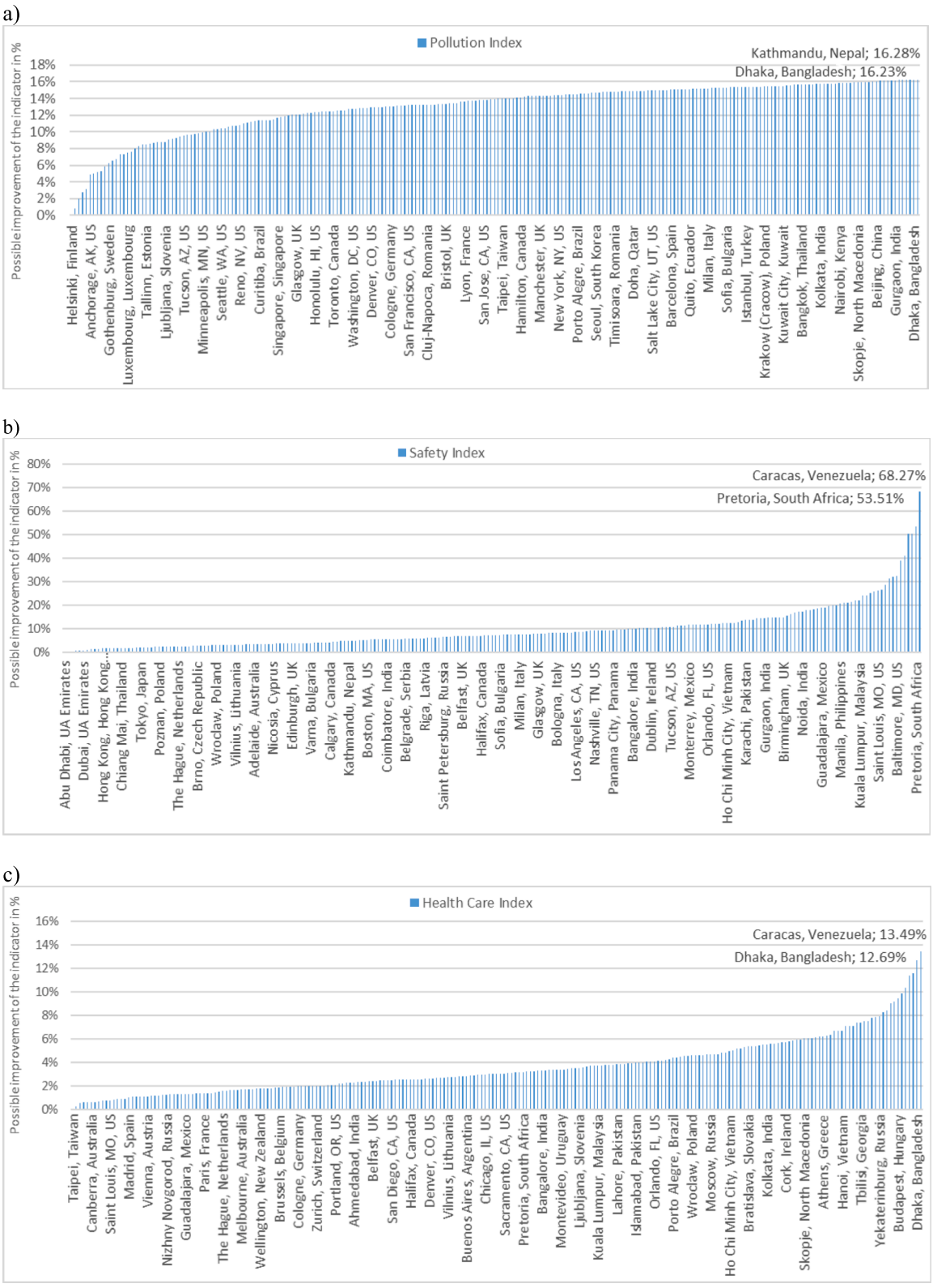


Fig. 4. By what percentage can urban quality of life (*Y*-axis) be improved in cities worldwide by reducing pollution (a), increasing safety (b), and improving health care (c)? On the *X*-axis, from left to right, 227 cities around the world are ranked according to their potential to improve their quality of life. The cities on the left side of the *X*-axis have already reached the maximum values of the indicators under consideration, while on the right, their achievements are minimal. For example, if the pollution index in Kathmandu (Nepal) were to be reduced to the best value for Helsinki (Finland), Kathmandu's urban quality of life would then improve by 16.28%. Likewise, if the safety index in Caracas (Venezuela) were to be improved to the best value for Abu Dhabi (United Arab Emirates), the urban quality of life in Caracas would then improve by 68.27%. If the health care index in Caracas (Venezuela) were to be improved to the best value for Taipei (Taiwan), its urban quality of life would then would then improve by 13.49% (Table S5). In this way, these figures demonstrate the extent to which reducing pollution (a), increasing safety (b), and improving health care (c) in cities can improve the urban quality of life (*Y*-axis, %).

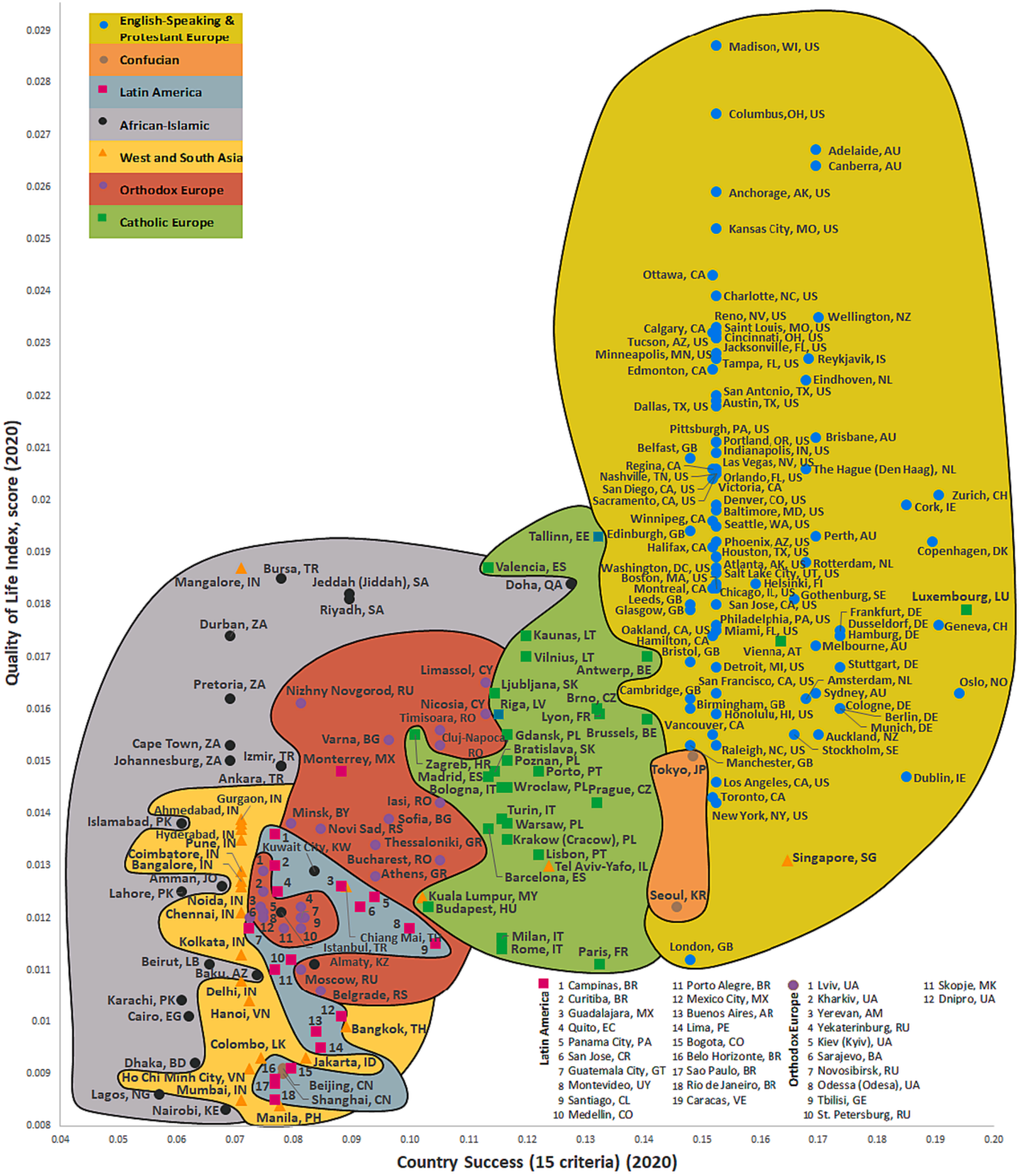


Fig. 5. The Country Success and Urban quality of Life Map of the World (UQL^{CS} Map). The UQL^{CS} Map has been created for a thorough examination of the ways that country success and UQL are linked. The cities are distributed over the UQL^{CS} Map along the Y-axis (urban quality of life) and the X-axis (nation success). Countries are analyzed, and their success and UQL are mapped to see whether any relationships exist between them. In the map, a set of 15 indicators includes the country success dimensions (higher success value is denoted by target achievement) determined for 169 countries. UQL (higher is characterized by target achievement) is defined by seven NUMBEO urban quality-of-life indicators, which were used to calculate the overall UQL for 227 cities. The UQL^{CS} Map clearly shows that as a country's success grows, the UQL increases in parallel. This UQL^{CS} Map was compiled using data related to UQL from 227 cities. The map, however, shows only 219 cities from 80 countries. The two main dimensions, which are UQL on the Y-axis and country success on the X-axis, show in what ways different clusters, cities, and societies differ. These two dimensions determine the location of each city on the UQL^{CS} Map. Indicators of UQL and country success represent the common values specific to a country cluster.

the value of the UQL and SDG 11 variables when the value of the country success variable increases by 1%. Table S6 presents the elasticity coefficients of the 15 independent variables for the (a) $SDG11^{CS}$ and (b) UQL^{CS} models.

In Stage 11, the synergies and trade-offs are analyzed when the country success indicators increase by 1%. The matrices of the synergy and trade-off results for the UQL indicators are shown in Fig. 1. The matrices of the synergy (marked in teal) and trade-off (marked in rosy brown) results for the SDG 11 indicators are shown in Fig. 2. Fig. 1 and Tables S3b and S4b present the synergies and trade-offs between (a) sustainable cities and communities (four SDG 11 and 25 country success metrics, Table S4b) and (b) a city's quality of life (seven urban quality of life indicators by NUMBEO and 17 country success metrics, Table S3b) when the values of the variables for country success go up by 1%.

Fig. 2 and Table S8 presents the effect of country success and its factors on (a) UQL: the percentage increase in the city's quality of life indicator (seven urban quality of life and one integrated country success metric) when a country's success increases by 1%; and the percentage of the urban quality of life metrics (dependent variable) under analysis (R^2) explained by the metrics of a country's success (independent variables) and (b) the SDG 11 (four SDG 11 and one integrated country success metric calculated from 17 country success indicators).

The findings from Stage 11 are consistent with those from other available studies (Kroll et al., 2019; Pradhan et al., 2017). An understanding of both negative (trade-offs) and positive (synergies) effects is very important in efforts to pursue integrated research and decision making toward action on SDG 11 and UQL. In Kroll et al.'s (2019) opinion, these interactions can be either trade-offs, in which progress in one goal makes a negative impact on progress in another, or synergies, in which progress in one goal helps with progress in another. With improvements in country success indicators, the metrics of urban quality of life and sustainable cities and communities saw advances of 77% and 97%, respectively. In most of the 227 countries, the positive correlations between indicator pairs for a given SDG were found to be greater than the negative correlations (Pradhan et al., 2017).

For analyzing policy options for urban quality of life (PO, Table S3) and discovering the most efficient solutions, Stage 12, regression and multiple-criteria analysis, is applied. Stage 12, with regression and multiple-criteria analysis, was used to develop policy options (POs) for urban quality of life and to find rational solutions. The matrices of the input data are available at Table S3. An example of a specific country's policy options (PO) and urban quality of life (UQL) is discussed below to show how the STRICT method works. Table S3 shows the STRICT method and the decision matrices that were used as tools to search for the most efficient ways to improve all the UQL indicators at the same time and in an integrated manner. We used this method to analyze 17 country success criteria (POs) and determine the extent to which these can improve UQL. Twenty-five policy options for sustainable cities and communities (Table S4) were likewise analyzed, and the extent to which they can enable advances toward the goals for sustainable cities and communities (SDG 11) was established. A system of seven UQL criteria was used to assess the 17 POs. Seventeen PO statistical variables were analyzed to determine rational options to make improvements in the seven UQL indicators at the same time in an integrated manner. This analysis aimed to determine which of the 42 PO-related metrics have the greatest cumulative impact (Q_j (Stage 3), P_j (Stage 4), N_j (Stage 5) on the advances in UQL and SDG 11.

The potential for 17 country success criteria (POs) to enhance UQL is evaluated. The STRICT approach and decision matrices are shown in the following tables and can be used as tools for identifying the most effective strategies for simultaneously and comprehensively improving all UQL (SDG 11) indicators:

- Figure 4 presents graphical recommendations, demonstrating the percentage by which urban quality of life (Y-axis) can be improved in cities worldwide by reducing pollution (a), increasing safety (b), and improving health care (c). Detailed recommendations are presented in Table S5.
- Table S3 submits quantitative recommendations (seven for urban quality of life and 17 for country success metrics) for the 173 countries.
- Table S4 presents quantitative recommendations (four for SDG 11 and 25 for country success metrics) for the SDG 11 policy.

For example, seven UQL criteria are utilized to evaluate the 17 POs. Table S3 shows the results of the multiple-criteria assessment of a given PO. The analysis of the 17 PO statistical factors yields logical suggestions for simultaneous, integrated improvements to the seven UQL indicators. This analysis tries to identify which of the 17 PO-related indicators (Qj, Pj, Nj) have the most significant overall impact on the developments in UQL. The utility degree N_j of the PO a_j shows the extent to which stakeholders are satisfied.

In the 12th stage, we analyse whether cities' and countries' comparative quality of life changes over time. Many studies around the world look at the way SDGs and other indicators change over time. They allow one to determine contrasts between nations and over time in various areas such as the way in which the Sustainable Development Goals (SDGs) interact (Nilsson et al., 2016), how much we have progressed towards the SDG targets related to education (Friedman et al., 2020), how much we have progressed towards sustainable development in terms of time and space (Xu et al., 2020), and how the growth and development of children and adolescents have diminishing benefits brought about by urban living (NCD Risk Factor Collaboration (NCD-RisC) et al., 2023).

To ensure the accuracy of our analysis, we use indicators that were all from the same 2020 year. This study started at the end of 2021 when the latest available data were from 2020. We also compared the 2012–2015 and 2018–2022 quality of life index for 58 cities and 51 countries from the NUMBEO database. The multiple-criteria analysis of 58 cities (Table S9a) and 51 countries (Table S9b) was done using the INVAR method, shows that the rankings of cities and countries changed little during the period. The analysis is presented below.

Seven indicators (purchasing power index, safety index, health care index, cost of living index, property price to income ratio, traffic commute time index, and pollution index) were analyzed to calculate the quality of life index for each city (city success, Q_t^i). To check the changes in Q_t^i for each city in question, the annual change for each city is first calculated as a percentage using the following equation:

$$\Delta_t^i = \frac{Q_t^i - Q_{t-1}^i}{Q_{t-1}^i} \bullet 100\% \tag{9}$$

where Δ_t^i is the annual change in the success of the *i*-th city; Q_t^i is the current year's success value of the *i*-th city; and Q_{t-1}^i is the previous year's success value of the *i*-th city.

These changes in the success values of the 58 cities are calculated for each city and each year of the period in question. Then the average of the annual success changes is calculated for each city:

$$\overline{\Delta_i} = \frac{\sum_{t=1}^{n} \Delta_t^i}{n} \tag{10}$$

where n is the number of years in the period in question; and $\overline{\Delta_i}$ is the average of the annual success changes of the *i*-th city.

The averages of the annual changes calculated for each city in question are then used to calculate the overall average of these averages:

$$\overline{\Delta} = \frac{\sum_{i=1}^{m} \overline{\Delta_i}}{m} \tag{11}$$

where *m* is the number of cities.

For 58 cities, the overall average of the average values of their annual

success changes is M=2.010 (SD=1.452). The average of their annual success changes is, therefore, below 3%. This means that these indicators changed little and the changes are within the limits of the standard possible research error.

Equivalent calculations were done with the quality of life in 51 countries. Seven indicators (purchasing power index, safety index, health care index, cost of living index, property price to income ratio, traffic commute time index, and pollution index) were analyzed to calculate the quality of life index by country (country success, Q_t^i). For the countries, the overall average of the average values of their annual success changes is M=1.934 (SD=1.157). The average of their annual success changes is, therefore, below 2%. This means that these indicators changed little over the years, and the changes were within the limits of the standard possible research error.

The results are presented and discussed in the Discussion and Conclusions section.

3. Results

3.1. Country success and sustainable cities and communities model and map of the world (SDG11^{CS} model and map)

The SDG11^{CS} Model integrated the four sub-models (Table S8b) with equal weighting to identify the spillovers of cities and countries and show that country success and sustainable cities and communities can augment the synergies between indicators of all sustainability dimensions and minimize their prevailing trade-offs. Four sub-models estimate country sustainability and success spillover effects (elasticities).

Using the STRICT method, a multiple-criteria and correlation analysis of urban quality of life (UQL) and sustainable cities and communities (Sustainable Development Goal 11, SDG 11) was performed. As a result of this analysis, SDG11^{CS} and UQL^{CS} Models and Maps were created, and digital evidence-based recommendations were provided to urban (Table S5) and national (Tables S3b and S4b) policymakers based on the findings of the analysis.

As a percentage, we found synergies and trade-offs between SDG 11 and urban quality-of-life metrics when individual indicators of national success improved by 1%. These positive or negative spillovers are displayed in Fig. 1. As seen in the Figs. 1, 1% improvement in country success individual metrics (25 criteria in Fig. 1a and 17 criteria in Fig. 1b) led to a synergistic effect in 97 out of 100 SDG 11 indicators (97%) and that 3 indicators had a negative impact (Fig. 1a); it also shows a synergistic effect in 92 out of 119 urban quality-of-life indicators (77%) and that 27 indicators had a negative impact (Fig. 1b). The synergies in the figure are shown along the Y-axis in the area of positive values and trade-offs along the same axis in the space of negative values. The X-axis represents the country success indicators analyzed in this research. Supplementary Tables S3 and S4 detail SDG 11 and the urban quality-of-life spillover effect (green-colored synergies and pink-colored trade-offs) due to the changing country success metrics.

Fig. 2 demonstrates the effect of country success and its factors (173 countries, 17 criteria) on UQL and SDG 11 indicators: the percentage increase in the SDG 11 indicator and the city's quality-of-life indicator when a country's success increases by 1%; and the percentage of the SDG 11 and city's quality of life (dependent variable) under analysis (R^2) explained by the metrics of a country's success (independent variables).

The rosy-brown color represents the trade-offs and synergies (market in teal) observed in the urban's quality-of-life metrics when a country's success increases by 1%. Supplementary Table S8 details SDG 11 and the city's quality-of-life spillover effect due to changes in a country's success. Overall country success value was calculated using INVAR multiple-criteria method (Kaklauskas, 2016) by looking at 17 social, political, and economic indicators (Table S1b), and the impact of the analysis is shown in Fig. 2.

The SDG11^{CS} model analyzes SDG 11 and the related context in much more detail than the map, which is a simplified but visually a much more comprehensible representation of SDG 11. The SDG11^{CS} Model (Table S6a) assesses how a dependent variable (sustainable cities and communities) relates to 15 independent metrics (the nation success criteria). The SDG11^{CS} Model appropriately characterizes the SDG11^{CS} Map. The SDG11^{CS} Model was verified and deemed suitable for analysis ($p<0.05$), and the changes in the values of its full set of independent variables explain the dispersion of the values of the dependent variable in 71.9% of the cases. However, the impact of some of its 15 independent variables on the dependent variable is not statistically significant. When all independent variables with negligible impact on the dependent variable are removed from the model, an adjusted SDG11^{CS} Model of sustainable cities and communities is produced with the following analytical expression:

$$\text{SDG } 11 = 11.567 - 0.000322 \bullet X_1 + 34.096 \bullet X_2 + 3.701 \bullet X_3 + 4.187 \bullet X_4 + 0.812 \bullet X_5 - 0.391 \bullet X_6$$

here: X_1 - GDP per capita in PPP, X_2 - human development index, X_3 - freedom and control, X_4 - democracy index, X_5 - healthy life expectancy, X_6 - fragile state index

Our regression analysis also determined that changes in the values of the SDG11^{CS} Model's independent variables explain the dispersion of the values of the dependent variable at the rate of R^2=69.6%. In addition, the fragile state index (β=-0.512) was determined to make the most significant impact on the dependent variable. The growing stability of a country then leads to a higher value of the SDG 11 variable.

Changes in the country's success values were determined to explain the dispersion of the values of the SDG 11 variable in 43.0% of the cases. Also, an increase of 1% in the overall value of the nations' success (independent variable) leads to an increase of 0.414% in the overall value of SDG 11.

To assess the effect size of each country's success metrics (independent variable) of the initial SDG11^{CS} Model on the SDG 11 metrics (dependent variable), we calculated the elasticity coefficient for each country's success metrics. The coefficient shows how much the value of the variable of sustainable cities and communities varies when an independent variable's value increases by 1%. For example, when the score on the human development index increases by 1%, the average value of SDG 11 goes up by 1.004%; and as the value of the fragile state index increases by 1%, the SDG 11 average value improves by 0.521%. We also identified that when the global social, political, economic, environmental, and cultural indicators improve on average by 1%, the four SDG 11 indicators advance on average by 0.722%, 0.647%, 0.282%, 0.276%, and 0.03%, respectively. The results of these calculations are presented in Supplementary Table S4b (the synergistic effect is marked in green and trade-offs are marked in pink).

An average moderate correlation between countries (r=0.532) was obtained. These findings are represented in Supplementary Table S10b. Table fields with a country correlation coefficient of 0.8–1.0 and −0.8 – −1.0 are marked in green, and areas with a country correlation coefficient of 0.6–7.999 and −0.6 – −7.999 are marked in yellow.

The application of four sub-models decreased the SDG11^{CS} Model's overall level of uncertainty.

We estimated and compared the effect of each sustainable development dimension (economic, social, cultural, environmental, and political) based on a clustering of countries and worldwide metrics and then looked at their potential mutual spillover effects. We analyzed seven country clusters taken from the 2020 World Cultural Map (Haerpfer et al., 2022) (Confucian, Latin America, African-Islamic, West and South Asia, Catholic Europe, Orthodox Europe, and English-speaking and Protestant Europe). The analysis indicates mostly positive spillover effects from the dimension metrics (Tables S3b and S4b). This means that various countries' clusters show synergistic relationships (instead of trade-offs) related to country success and sustainability. This finding is consistent with other studies from multiple countries (Maes et al., 2019;

Sharifi, 2020). The results of this study suggest that all countries' clusters would benefit from efforts to make their interactions with each other stronger as a result of the expected positive spillover elasticities. Despite the fact that spillover effects between countries' clusters differ, sustainable development in general offers benefits to all the clusters. Thus the world needs to step up its collaboration efforts for better sustainability and success across the clusters. Such findings support global integration to make the sustainable development dimensions stronger.

The Sustainable Cities and Communities and Country Success Map of the World (SDG11^{CS} Map) of 151 countries (seven countries' clusters) demonstrate the link (strong and positive correlation, r=0.656) between the success of these countries and the sustainable cities and communities (SDG 11) (Fig. 3).

3.2. Country success and urban Quality-of-Life Model and Map of the World (UQL^{CS} Model and Map)

The UQL^{CS} Model analyzes five sustainability dimensions (social, political, environmental, economic, and cultural). We evaluated city sustainability and success elasticities using the seven UQL^{CS} Sub-models with equal weights (Table S8a). Based on the sub-models, we analyzed the links between 15 (Table S1a) and 17 (Table S1b) economic, social, political, environmental, and cultural country success indicators and seven urban quality-of-life indicators (property price to income ratio, purchasing power, health care, pollution, safety, traffic commute time, and cost of living indices taken from the NUMBEO Quality of Life Index 2020) to identify spillovers between them. We analyzed 163 and 173 countries and 227 cities from 87 countries from all seven country clusters considered in this study.

The UQL^{CS} Model was verified (Table S6b) and deemed fit for analysis ($p<0.05$), and changes in the values of its full set of 15 independent variables (countries' success metrics) from 169 countries explain the dispersion of the values of the dependent variable "urban quality-of-life" in 66.9% of the cases. All the model's independent variables that had a statistically insignificant effect on the dependent variable were then removed from the model to produce the UQL^{CS} Model as presented in Supplementary Table S7. The adjusted UQL^{CS} Model is fit for analysis, and changes in the eight independent variables explain the dispersion of the values of the dependent variable "urban quality-of-life" for 227 cities in 66.0% of the cases. The variable "Fragile state index" made the most significant synergistic effect on the variable "urban quality-of-life" (β=0.366) (Table S7).

To assess the impact of changes in each country's success metrics (independent variable) of the initial UQL^{CS} Model on the UQL metrics (dependent variable), we estimated the elasticity coefficient for each country's success metrics. When an independent variable's value increases by 1%, the coefficient shows how much the value of the UQL metrics changes. The outcomes of these calculations are given in Supplementary Table S3b.

We found what effect size has on the individual UQL indicator after a 1% increase in the value of a nation's success indicator (synergistic marked in green, trade-offs marked in pink). We identified that when government effectiveness, GDP per capita in PPP, and human development index indicators improve by 1%, the seven city UQL indicators advance on average by 0,565%, 0,228%, and 1,107% respectively (Table S3b).

Correlations between 227 cities were also analyzed using seven variables from the NUMBEO Quality of Life Index 2020. Supplementary Table S10a presents the correlation coefficient matrix related to these cities and the seven quality-of-life criteria. The average correlation between the 227 cities stands at r= 0.596. Table fields with a city correlation coefficient of 0.8–1.0 and −0.8 – −1.0 are marked in green, and areas with a city correlation coefficient of 0.6–7.99999 and −0.6 – −7.99999 are marked in yellow.

To identify a specific city's priorities that would boost its quality of life, we took advantage of multiple-criteria analysis using the INVAR method (Kaklauskas, 2016); the seven criteria that can lead to improvements in quality of city life were also thoroughly considered.

Fig. 4 and Table S4 present what percentage of urban quality of life can be improved in cities worldwide by (a) reducing pollution, (b) increasing safety, and (c) improving health care.

Country Success and Urban Quality-of-Life Map of the World (UQL^{CS} Map) (Fig. 5) is similar to the SDG11^{CS} Map (Fig. 3). It includes seven countries' clusters (Confucian, African-Islamic, West and South Asia, Catholic Europe, Orthodox Europe, Latin America, and English-speaking and Protestant Europe) taken from the 2020 World Cultural Map (Haerpfer et al., 2022). The UQL^{CS} Map and multiple-criteria and correlation analyzes of 227 cities validate the association between cities and 169 countries – their quality of life and success metrics (the map plot displays a strong positive correlation between 219 cities from 80 countries, r=0.724).

Fig. 1b and 2b show the countries' success metrics spillovers and their metrics on UQL indicators. Urban quality-of-life indicators can, therefore, be projected based on these metrics.

4. Discussion and Conclusions

This study encourages countries' success by demonstrating the significant and synergetic role in improving worldwide sustainability. This outcome is based on the SDG11^{CS} and UQL^{CS} Models created in this study to measure a country's success, SDG 11, UQL, and relationships between the five sustainability aspects to develop digital evidence-based recommendations for urban (Fig. 4 and Table S5) and national (Tables S3b and S4b) policymakers by applying the STRICT method.

SDGs are presented as considerably interrelated and indivisible and their implementation needs coherent policies (McGowan et al., 2018). It has been argued for decades that environmental, social, and economic sustainability evolves in tandem (Funke & Zhong, 2020; Murphy, 2019; J. E. Stiglitz, 2002) with national indices of success. This work helps determine strategies for more efficient, effective, and equitable implementation of the most rational UQL and SDG 11 solutions. Our findings are supported by global research in several directions.

The ability of humankind to resolve the existing trade-offs and maximize synergies between the SDGs will be crucial to the achievement of the Agenda 2030 and its 17 SDGs (Kroll et al., 2019). Since the SDGs provide a multidimensional and holistic view on development, their interactions may cause results that head in different directions (Pradhan et al., 2017). The analysis by van Vuuren et al. (2015) was also focused on trade-offs and synergies in efforts to achieve various objectives, and their conclusion was that a comprehensive approach is required to achieve the objectives. Various interactions between SDGs and the character of these interactions have emerged as an important aspect in the implementation of the 2030 Agenda because of the effect these interactions may have on the choice of actions and on their effectiveness. The typical starting point is one SDG. From there, the number of interactions is counted, and then trade-offs and synergies are discussed in relation to a specific issue area (Weitz et al., 2018).

United Nations (Conceição, 2020; UN System; UN-Habitat, 2019), European Environment Agency (2021), and individual researchers (Ehnert et al., 2018; Gumbo et al., 2022, 2022; Krueger et al., 2022; Momoh et al., 2022; Thornton et al., 2020) analyzed urban sustainability in the context of different countries. For example, researchers analyzed the urban sustainability context in the UK (Durrant et al., 2018; Zheng et al., 2014), China (I.-C. C. Chang & Sheppard, 2013; Li et al., 2019; Meng et al., 2020), Spain (Lo-Iacono-Ferreira et al., 2022), Portugal (Rodrigues & Franco, 2020), Hungary (Buzási & Jäger, 2020), etc.), Nigeria (Momoh et al., 2022), South Africa (Gumbo et al., 2022) and other countries and regions. Many of the indicators mentioned above are applied in our study as well. Since each national urban policy will be based on the specific needs and vision of the stakeholders and the **national context**, the types of national urban policies that will emerge from the formulation process will differ significantly between countries

(UN-Habitat, 2019).

Thus, this study took a holistic approach and considered cities in the context of the environment in which they are located. Therefore, additional focus is given to the context of cities during the analysis, evaluation, and presentation of the research results, i.e., analysing how the national context influences cities and the analyzed urban quality of life indicators. Therefore, our research aim is to study cities in a country context.

The focus of our study was of a similar nature, and the findings confirmed prior studies. Four sub-models of sustainable cities and communities ($SDG11^{CS}$) were created to analyze 15, 17, and 25 datasets of economic, social, political, environmental, and cultural country success indicators (Table S1). We identified the average SDG 11 utility degree in the models for the analyzed factors – 61.50% for political, 46.60% for social, 42.31% for economic, 41.43% for environmental, and 33.83% for cultural – by analyzing 25 country success indicators (Table S4). The same trend was confirmed by the ten metrics with the most significant impact on the SDG 11 goals as well as the degree of impact and explanation. The ten most impactful indicators (out of the total 25 that were analyzed) included one (out of four) economic, five (out of 11) social, all three political, and one (out of five) environmental indicators. This means that political and social factors make the most significant impact on the achievement of the SDG 11 goals (Fig. 1a, Table S4). Seven UQL^{CS} Sub-models were created to analyze 15 and 17 datasets of economic, social, political, and environmental country success indicators (Tables S1a and S1b). We found the average UQL utility degree in the models for analyzed factors – 60.6% for economic, 75.96% for social, and 84.19% for political by examining 17 countries' success indicators (Table S3). The same trend was also confirmed by the ten metrics with the most significant effect size on the urban quality-of-life goals as well as the degree of impact and explanation. The ten most impactful factors (out of the total 17 that were analyzed) included one (out of four) economic, six social (out of ten) and all three political indicators. Above results demonstrate that political and social factors play a significant role in achieving urban quality-of-life goals (Fig. 1b, Table S3). Evidence from other researchers has also indicated these links (Chaigneau et al., 2021; Potts et al., 2016). In their analysis of efficient efforts to achieve SDG goals, researchers have emphasized the social dimension (Bunge et al., 2022; Mastrángelo et al., 2019) and the political dimension (Mastrángelo et al., 2019; Peng et al., 2021). The findings by Mastrángelo et al. (2019) show that effectiveness of governance systems, improved knowledge on feedback between ecological and social systems, and the influence of institutions on the social distribution of ecosystem services are required if we want to achieve global sustainability goals.

Global research and our findings suggest that some areas are underexplored, such as human development (Hao, 2022), corruption (Nest et al., 2020) reduction, better gender equality (Solomon et al., 2021), advances in democracy (Burnell, 2012), and improvements in happiness (Mynaříková & Pošta, 2022). Various studies emphasize cultural factors (Karakas & Mitra, 2020; Nartova-Bochaver et al., 2022) and social factors (Bain et al., 2019; Palinkas & Wong, 2019) and also supports the findings from our multiple-criteria and regression analysis that in this set of countries, UQL and SDG 11 indicators can be improved by using means beyond just economic, environmental, and other traditional instruments.

Based on the analysis results, we argue that countries'' success and its indicators affect UQL and SDG 11 indicators. For example, when government effectiveness, GDP per capita in PPP, and human development index indicators increase by 1%, the seven city UQL indicators improve on average by 0,565%, 0,228%, and 1,107% respectively (Table S3b). Similar results have been obtained with the indicators of SDG 11; when the global social, political, economic, environmental, and cultural indicators increase on average by 1%, the four SDG 11 indicators improve on average by 0.722%, 0.647%, 0.282%, 0.276%, and 0.03%, respectively (Table S4b). Based on the analysis results, we argue that countries'' success and its indicators affect UQL and SDG 11 indicators.

A paradox discovered by the economist Richard Easterlin in the 1970s was that a steady increase in U.S. economic growth over the previous decades had not been accompanied by increasing happiness among Americans (Easterlin, 1974). This phenomenon, named the "Easterlin paradox" after the economist, has been confirmed across countries in recent years (Easterlin & Angelescu, 2012). These findings prompted policymakers to recognize that monetary factors are not the only aspects that shape citizens' societal progress and wellbeing and that nonmonetary factors, such as optimism and societal trust, contribute as well (J. Stiglitz et al., 2009). Feeling time poor, for instance, can lead to negative effects on subjective wellbeing (e.g., positive affect, life satisfaction), work performance, mental health, relationship quality, and creativity (Giurge et al., 2020). Higher subjective wellbeing not only improves the quality of life but also leads to higher productivity and fewer health problems and, therefore, is of interest to researchers and governments (Hills et al., 2019). When compiling four $SDG11^{CS}$ and seven UQL^{CS} Sub-models, 15, 17, and 25 success indicators were analyzed, respectively, of 169 and 173 countries. This evidence-based analysis confirmed that the $SDG11^{CS}$ and UQL^{CS} Models are holistic. Supplementary Tables S3 and S4 offer a confirmation of our holistic idea that improvements in urban quality of life and sustainable cities and communities can be achieved by means other than the usual economic, environmental, and conventional measures. Another aspect clear from our research is that improvements in such social and political metrics as happiness, human development, gender parity, and government effectiveness can also enhance the quality of life in the city and sustainable cities and communities.

The Organisation for Economic Co-operation (2022) believes that big cities display more similarities (relationships) with each other than with the countries where they are located. They are places where huge populations live in limited spaces and often are two sides of the same coin with upsides and downsides. OECD (2022) indicated that New York, London, and Shanghai, rather than nation states, offer meaningful comparisons. The challenges these cities face—in housing, transport, education, jobs, security, migration and so on— are often similar (OECD, 2022). The results of our study confirm this trend. The average moderate correlation between the examined 227 cities was 0.596 (Table S10a). National laws and strategies apply to cities located within respective countries. Many scientists have pointed out the importance of this territorial context (Deng et al., 2021; Najjar, 2022). After looking at 219 cities from 80 countries, the assumption can be drawn that a country's priorities largely determine the priorities of its cities, especially of large cities where large populations and significant economic potential are concentrated. A country that adopts a green course must, therefore, first ensure sustainable development of its cities, in particular, its megacities. The results of correlation analysis support this statement. They show that the success of countries and their cities is linked by a positive, strong ($r=0.724$), and statistically significant correlation (Fig. 5). According to our research, there is an average and strong correlation between country success, SDG 11, and UQL indicators, and they all trend in the same direction over time. In addition, changes in country success values explain the dispersion of the values of the variable "urban quality-of-life" in 52.2% of cases. Meanwhile, an increase of 1% in the value of the variable "country success" increased the value of a city's quality of life by 0.636%.

One important aspect in tracking global efforts towards sustainable development and finding the right course for policy development and implementation is that to do so we need to quantify progress towards SDGs. There is, however, a lack of systematic methods that can help us assess how much we have progressed towards the SDGs over space and time (Xu et al., 2020). In this study, we develop and test the STRICT method to measure progress in the quality of life index in 58 cities and 51 countries over time 2012–2015 and 2018–2022. We find that the rankings of cities and countries in terms of their quality of life index

changed little 2012–2015 and 2018–2022, and that cities with very low rankings improved slightly over time (Table S9a). Thus the structure of country quality of life is stable over time, instead of being sensitive to any protracted trends or repeated crises.

Our results reveal aspects that are important for both theory and policy. For instance, they suggest that the way in which progress towards sustainable development through SDGs over space and time is perceived, and the related attitudes, are more stable than previously thought, despite the emergencies that follow one after another (COVID-19, the war). Similar research to ours (Bansak et al., 2023) has found similar stability in sustainability and SDGs and slight improvements in the rankings of poor cities over time.

Other studies have also shown that certain indicators are relatively stable over time. Graetz et al. (2018) look at data from 2015 and demonstrate that, in many areas across Africa, gaps remain in educational attainment between the sexes that have been relatively stable over time. These findings by Graetz et al. (2018) suggest that progress in educational attainment has been experienced by both men and women, but that much of Africa is still far from achieving equality between the sexes. The illusion of moral decline is the focus of Mastroianni and Gilbert (2023). Their analysis clearly shows that people always report the same level for the current morality of their contemporaries, and that this level remains stable over time. Chetty et al. (2022) state that, across areas, differences in economic connectedness change relatively little over time; they base their argument on the high correlation with economic connectedness observed in recent birth cohorts, as measured using Instagram.

Policymakers do not have the means to identify interactions that should be a priority to address, and they lack evidence to show the way in which specific policies and interventions help or obstruct progress toward the goals. For strategies and policies to be coherent, policymakers need a way to systematically look at the many interactions and to go beyond viewing things through the simple lens of trade-offs and synergies in order to identify without delay the groups that could act as their allies and groups with which they will have to negotiate. They also need a constant the latest empirical knowledge on how the interventions and goals of one sector lead to positive or negative changes in another sector (Nilsson et al., 2016). Our research enriches and complements prior research findings and differs from other similar and advanced worldwide studies in four key innovative ways. First, the models and maps of 169 and 173 nations and 227 cities created by the STRICT method based on statistical and multiple-criteria analysis outline links between the nation's success, quality of life of the cities, and sustainable cities and communities. The rate for quality of life of the cities and sustainable cities and communities' dispersions are 66.9% and 71.9%, respectively. An improvement of 1% in a nation's success overall value leads to a corresponding improvement of 0.636% in urban quality of life and 0.414% in cities and communities' sustainability. As a country's success individual indicators improved, UQL and SDG 11 metrics increased by 77% (92 out of 119) and 97% (97 out of 100), accordingly (Tables S3 and S4, Fig. 1). Second, we developed $SDG11^{CS}$ and UQL^{CS} Models and Maps of the world, which show that as nations improve political, cultural, and social indicators, their sustainable cities and communities and urban quality of life also advance.

Thirdly, SDG 11, UQL, country sustainability and success indicators are interrelated. While the number of countries, cities and their metrics has altered, the comparative achievements and trends of countries and cities in SDG 11 and UQL field remain similar. Also, the seven-country clusters show slight variation in the various system of indicators used to analyze them. Finally, we provide evidence that social, political, economic, environmental, and cultural sustainability metrics usually demonstrate similar behavior and move together in the same general direction. The way in which these four innovative features of the STRICT method, which include a multidimensional and comprehensive view on the spillover effect, work in practice is demonstrated in the article.

Cultural similarities in countries' success and sustainability are reflected in the seven countries' clusters, as cultures in a similar context tend to move in the same direction regarding their sustainability, and success.

This research shows that the success of countries is an important factor because they play an essential and synergistic effect role in global sustainability. Our results show that various countries' clusters are mostly interrelated by synergetic and commonly beneficial relationships. The average correlation of seven UQL indicators and 25 country success indicators between 227 cities from seven country clusters is moderate and positive (r=0.466). This study analyzes the elasticities of success and sustainability across the world. Most elasticities of success and sustainability, as shown by the results, are positive, suggesting that the spillover effects are synergetic in nature. This analysis shows that the success and sustainable development seen in countries that belong to one country cluster brings benefits to other clusters, too. UQL indicators correlate more significantly with the newly proposed 6th sustainability dimension, "Country success". The average correlation between seven UQL indicators and country success values (173 countries, 17 criteria) of 227 cities from seven country clusters is r=0.463. This is more significant than with economic (r=0.508), social (r=0.445), political (r=0.502), environmental (r=0.476), or cultural (r=0.418) dimensions (links analyzed between seven city UQL indicators and 25 country success indicators). This means that the success of countries plays a significant role in sustainability. In view of this implication, this study proposes to add country success as the sixth dimension of sustainable development.

It is only natural that this research is not free of limitations and weaknesses. For example, relevant statistical data is not readily available for many cities in underdeveloped/developing countries, especially when the cities are small. The weights of all the indicators we analyzed was equal to one. We have several plans for the future. We plan to improve the accuracy of $SDG11^{CS}$ and UQL^{CS} Models and Maps by making further assessments of indicator significances. We intend to examine the complicated mechanisms behind the synergies and trade-offs among SDGs and suggest practical ways to address their conflicting aspects. We plan to analyze a much bigger set of country success indicators (policy options for cities and SDG 11) and determine their combinations that would be the most efficient options to improve the quality of life in cities and would help to achieve the goals for sustainable cities and communities (SDG 11). We plan to apply the STRICT method to perform similar integrated statistical and multiple-criteria analysis with all SDGs.

All the raw data for the indicators used in graphical displays or for calculation and statistical analyzes were collected directly from various publicly available online sources. 2020 data was used in this study. Sources data and sources links for the indicators of countries' success (economic, social, environmental, political, and cultural dimensions) are listed in Supplementary Table S1. Economic data were taken from the World Bank and the Fund for Peace dataset. Social data were taken from Transparency International, the United Nations Development Programme, the World Economic Forum, the Sustainable Development Solutions Network, the World Bank, the World Health Organization, the Fund for Peace, TheGlobalEconomy.com, SolAbility, Credit Suisse Group AG, and the Institute for Economics and Peace dataset. Environmental data are from the Socioeconomic Data and Applications Center, the Global Footprint Network, and the Our World in Data dataset. Political data were taken from the Freedom House, the Heritage Foundation, the Economist Intelligence Unit, and TheGlobalEconomy.com dataset. Cultural data were taken from the World Values Survey Association World Values Survey site dataset. The urban quality-of-life data was retrieved from the NUMBEO database. The SDG 11 data was retrieved from the Sustainable Development Report database (the 2020 Dashboard by Sachs et al. (Sachs et al., 2022a)). We also used publications and national and global statistics.

The data generated during, and analyzed in the current study are provided in this paper and in the Supplementary Information. All the

data supporting this study's findings are available from the corresponding author on request.

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CRediT authorship contribution statement

Arturas Kaklauskas: Conceptualization, Data curation, Investigation, Formal analysis, Methodology, Validation, Supervision, Visualization, Writing – original draft. **Shaw Rajib:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Loreta Kaklauskiene:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Les Ruddock:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Massimo Bianchi:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Ieva Ubarte:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Romualdas Kliukas:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Virgis Milevicius:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Laura Tupenaite:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Andrius Stasiukynas:** Data curation, Investigation, Formal analysis, Validation, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2024.111595.

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