

Working Paper

Measuring Spatial and Population Access in Passport Strength Indexing

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Preface

I come from Bosnia and Herzegovina, a small country whose passport is typically described as “mid-tier” in global mobility rankings. According to traditional passport indices, BiH citizens occupy a middle position in the global hierarchy of travel freedom. Yet when I examined where I could actually travel, this characterization felt incomplete.

I noticed that existing rankings treat visa-free access to a small island state and access to a continent-size country as equivalent. One country counts as one unit, regardless of its scale. For instance, with my national passport I can enter several very large countries without a visa, including some of the largest in the world by both land area and population. This grants me access to vast geographic regions that many holders of “stronger” passports cannot reach without prior visa authorization.

This observation raised a simple but fundamental questions

What does passport strength actually mean in practice?

How come some ‘weaker’ passports can open more of the world?

Is it merely about the number of borders one can cross, or does it also reflect the amount of physical space and human presence that becomes accessible once those borders are crossed?

In essence, I feel that not all visa-free access is “equal”. Most existing passport rankings ignore geography, because some passports open access to far larger portions of the planet than others. Most existing indices measure mobility only by counting the number of countries a passport holder may enter without a visa (and/or obtain it upon arrival). This is a useful metric, but it treats all countries, regardless of their size, as interchangeable units. As a result, these rankings capture quantity but not scale. They basically tell us how many borders can be crossed, but not how much territory or how many people become accessible in doing so. This is not incorrect in principle, but it feels imperfect.

This working paper does not claim that one passport or passport ranking system is “better” than another, nor does it seek to replace the methodologies used by established passport indices. Instead, it argues that mobility has multiple dimensions, and that geography is one of them.

The Spatial Passport Strength Index (SPSI) proposal described below emerged from this line of questioning. Its purpose is to complement existing rankings by addressing a specific blind spot, i.e. the assumption that all destinations are equivalent units. It is not a travel guide, nor a recommendation of citizenship or migration strategies.

This brief is intended for researchers, journalists, policymakers, and others interested in how mobility functions in practice. I also invite other groups of readers and the general public to engage critically with this proposal, consider its methodological implications, and contribute to the development of this perspective.

Thanks for your feedback!

Introduction

Most passport indices define mobility as the number of foreign jurisdictions a passport holder may enter without a pre-arranged visa. While informative, this methodology treats microstates and large countries as equivalent units. Conceptualizing the world as a set of discrete nodes (“countries and territories”), rather than as a continuous physical and demographic space, leaves substantial room for debate.

This working paper approaches passport strength measurements and rankings from a human-experience perspective and asks a different question, that is, how much of the world does a given passport actually open up?

Visa-free access to countries and territories with extensive land areas, of course excluding the uninhabitable, insecure, inaccessible, or internally restricted regions, is not equivalent to visa-free access to dozens of very small countries.

Assuming travel is motivated by experience, opportunity, or exploration rather than by collecting passport stamps, access to large countries can often enable exposure to more diverse landscapes, resources, markets, and cultural contexts than access to multiple microstates combined. From this perspective, indices based solely on counting destinations equally offer an incomplete account of real-world mobility, particularly if the goal is to measure freedom of movement across the accessible surface of the planet Earth.

This paper therefore explores alternative ways of conceptualizing passport strength by incorporating spatial and demographic dimensions. The intention is deliberately exploratory and thought provoking. It is not to challenge existing indices as flawed, but to question and debate the assumptions they embed. The goal is not to replace current metrics, but to add a complementary dimension that measures visa-free access to physical and human space, rather than to a simple tally of countries.

To this end, I propose the Spatial Passport Strength Index (SPSI). It focuses on how much of the world becomes accessible under visa-free or visa-on-arrival regimes (both are treated equivalently, following standard practice in existing passport indices).

Across its variants, the index combines traditional mobility counts with measures of accessible land area and, in more advanced formulations, population-weighted access. In its simplest form, the model considers

$$\textit{Visa-Free} + \textit{Visa-on-Arrival Access} \times \textit{Total Land Area}$$

The three SPSI variants presented in this paper examine passport strength in different ways access to global land surface, balanced geographic reach using logarithmic scaling, access to population-weighted land.

Together, these variants highlight distinctions that remain invisible in conventional rankings. For example, two passports may each permit visa-free entry to 120 countries. Yet, as outlined, one may provide access primarily to small island states, while the other opens access to large continental

regions. SPSI makes this distinction visible. It does not claim that one passport is superior, but rather that passports can be “strong” in different ways.

Every index on anything privileges certain dimensions over others. Traditional passport rankings prioritize quantity, while SPSI model prioritizes scale. Neither approach is inherently correct or incorrect, they simply answer different questions.

SPSI does not evaluate politics, values, quality of life, or desirability of destinations. It measures only formal legal access, using publicly available visa and geographic data. Geography exists regardless of preference, and ignoring large countries does not make them irrelevant. By making spatial access explicit, SPSI broadens the analytical space in which global mobility can be also understood.

Passport strength is not a single number, but also a perspective shaped by underlying assumptions about what mobility means. As a result, SPSI assumes uniform usability of destinations once legal entry is granted and does not model differential internal accessibility. Scale is treated as a descriptive property of access, not as a proxy for value or importance.

What is SPSI About?

In practice, most passport rankings operationalize “strength” as a simple count of visa-free or visa-on-arrival destinations, reflecting the breadth of a country’s diplomatic agreements. This framing implicitly assumes that each destination contributes equally to mobility. However, such an assumption obscures meaningful differences in real-world access to physical space and population.

Under traditional rankings, access to one small island state counts the same as access to a country spanning millions of square kilometers or hundreds of millions of people. Consequently, some passports with fewer total destinations provide substantially greater access to global landmass or major population centers.

Conversely, some high-ranking passports derive much of their strength from access to numerous small territories. These distinctions remain invisible in destination-count-based indices.

The Spatial Passport Strength Index (SPSI) introduces an additional analytical dimension by explicitly incorporating scale into passport evaluation. Rather than replacing existing indices, SPSI complements them by measuring not only how many destinations are accessible, but also how much of the Earth’s land surface, and, in extended versions, how much of the global population, becomes accessible under visa-free or visa-on-arrival regimes.

SPSI is therefore not an alternative ranking in opposition to existing indices. It is a multidimensional extension designed to reveal differences in mobility that are structurally concealed by country-count methodologies.

Any resulting reordering of rankings is not ideological but mechanical, seen as a direct consequence of accounting for spatial and demographic access.

How It Works?

For each passport X , SPSI combines two core components, namely, Mobility Count (MC) - the number of destinations accessible visa-free or via Visa-on-Arrival (VOA).

Spatial Access Score (SAS) - a measure of the total land area, or, in extended variants described below, population-weighted land, accessible under those same conditions.

These components are combined into a Composite Passport Strength Score (CPSS) using normalized values

$$CPSS_X = \alpha \cdot MC_{\text{norm}} + (1 - \alpha) \cdot SAS_{\text{norm}}$$

where $\alpha \in [0.5, 0.7]$, ensuring that diplomatic breadth remains the dominant factor and preventing land area from fully dominating the index. Sensitivity analysis can test robustness across α values. Normalization is achieved using min-max scaling or z-score standardization to ensure comparability between dimensions measured in different units. This structure allows SPSI to preserve the

informational value of traditional mobility counts, differentiate passports with similar destination totals, and expose differences in spatial and demographic reach that are otherwise hidden.

Three primary SPSI variants are proposed

SPSI-A, which measures access to total global land surface (i.e. raw land area).

SPSI-B, which measures balanced geographic access using logarithmic scaling of land area to reduce dominance by extremely large countries.

SPSI-C, which measures population-weighted access, capturing potential access to global human systems rather than territory alone.

These variants are not competing models but analytical lenses. Each answers a slightly different question about what mobility means, i.e. spatial extent, balanced geographic reach, or human-centered access.

SPSI is designed for comparative analysis, academic research, and policy discussion. It does not measure quality of life, economic opportunity, political values, or desirability of destinations. Its purpose is to quantify formal legal access under clearly defined assumptions using transparent and replicable data.

Key Assumptions and Units of Analysis

SPSI is constructed using two core metrics described above, applied consistently across three variants (SPSI-A, SPSI-B, and SPSI-C). The primary unit of analysis is the sovereign state (i.e. United Nations member states). Dependent or international unrecognized states/territories are included only if they appear as distinct destinations in the International Air Transport Association (IATA) visa dataset or equivalent authoritative visa-regime sources. Territories are treated consistently with source-data classifications, and no independent geopolitical judgments are imposed. SPSI does not adjudicate sovereignty disputes.

Land area is defined as total land surface area (km²), excluding inland water bodies and maritime zones (EEZs). Population is defined as de facto resident population, without citizenship filtering, as SPSI measures potential legal access rather than migration or settlement rights.

SPSI measures formal legal access only. It does not adjust for internal movement restrictions, infrastructure quality, security conditions, or travel feasibility within destination countries. These omissions are intentional, as such factors are opaque, heterogeneous, and difficult to model consistently at the global level.

SPSI-A Spatial Access to Global Land Surface

SPSI-A introduces physical access to the Earth's land surface as a complementary dimension to traditional passport indices. It measures the total land area that becomes legally accessible to a passport holder under visa-free or Visa-on-Arrival regimes.

Visa requirements are sourced from a global visa-regime dataset (e.g., IATA or equivalent), using the most recent data available for the reference year (for instance, 2025 in this implementation).

SPSI-A include all types of Visa-free access, Visa-on-Arrival (VOA) access. Electronic travel authorizations, if relevant and non-restrictive and pre-approved travel permits are excluded to preserve a strict interpretation of visa-free mobility consistent with most existing passport indices.

Land area data are sourced from internationally recognized statistical providers, such as the World Bank Land Area Indicator (latest pre-2025 release) or equivalent national or international statistical authorities. Land area includes total terrestrial surface and excludes inland water bodies and maritime zones.

Each sovereign state or separately listed territory is treated as an independent destination if it appears independently in the visa dataset. Dependent territories are not merged into sovereign states when listed separately.

Mobility count for each passport X can be computed as

$$MC_X = \text{Number of destinations with visa-free or visa-on-arrival access}$$

This component is conceptually equivalent to the core metric used in existing passport indices.

Spatial Access Score for each passport X can be computed as

$$SAS_X = \sum_{i=1}^n LandArea_i$$

Where i indexes each destination accessible visa-free or via VOA, $(LandArea)_i$ is the land surface area (km^2) of destination i, and n is the total number of such destinations.

This yields the total land surface theoretically accessible to the passport holder.

To ensure comparability between Mobility Count and Spatial Access Score, which are measured in fundamentally different units, both components are normalized across all passports using min-max normalization:

$$Normalized(X) = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Alternative normalization techniques (e.g., z-score standardization) may be employed for robustness checks, but min–max normalization is used in the baseline specification for interpretability.

The final Spatial Passport Strength Index (SPSI-A) is computed as

$$SPSI_A = 0.6 \cdot MC_{norm} + 0.4 \cdot SAS_{norm}$$

The weighting scheme assigns greater importance to diplomatic breadth (60%) while allowing spatial access (40%) to meaningfully differentiate passports with similar mobility counts. This prevents extreme land-area dominance while acknowledging that physical scale materially alters the nature of mobility.

The choice of weights is transparent and adjustable. Sensitivity analysis across alternative weightings can be used to test the robustness of rankings and identify thresholds at which spatial access begins to dominate diplomatic reach.

Higher SPSI-A scores indicate greater combined legal access across diplomatic and spatial dimensions. SPSI-A does not measure tourism attractiveness, infrastructure quality, population density, or economic opportunity.

Weighting rationale accounts for mobility breadth remains primary (60%) and spatial access meaningfully differentiates passports with similar diplomatic reach (40%). Weights are explicitly adjustable and reported transparently. Higher SPSI scores indicate greater combined diplomatic and spatial mobility. The index does not measure tourism attractiveness, population density, or economic opportunity. SPSI deliberately prioritizes legal comparability over behavioral realism.

In more advanced implementations, SPSI-A could exclude the land area of the passport holder’s own country, uninhabitable or permanently inaccessible regions, territories subject to severe internal movement restrictions. Domestic territory would be excluded in all SPSI variants., in principle, but would be included in baseline due to uniform treatment across passports.

These refinements are not implemented in the baseline model due to data limitations and the risk of introducing subjective judgments. The baseline SPSI-A therefore measures formal spatial access, not effective or practical usability.

SPSI-B Balanced Geographic Access

While total land area captures the physical extent of mobility afforded by a passport, raw land area values are highly skewed. A small number of countries account for a disproportionate share of the Earth's land surface, which can cause composite indices to be dominated by access to a single large destination. This effect risks obscuring meaningful differences in geographic reach among passports with otherwise similar mobility profiles.

To address this issue, SPSI-B applies logarithmic scaling to land area values. Logarithmic transformation is a standard technique in economics, geography, and network science for handling heavy-tailed distributions. It reduces the dominance of extreme values while preserving ordinal differences between destinations of different physical sizes.

For each destination i , land area is transformed as

$$AdjustedLandArea_i = \log (1 + LandArea_i)$$

The additive constant ensures mathematical stability and preserves zero-value edge cases.

For each passport X , the Spatial Access Score under SPSI-B is defined as

$$SAS_X^{(B)} = \sum_{i=1}^n \log (1 + LandArea_i)$$

where n is the number of destinations accessible visa-free or via Visa-on-Arrival.

As in SPSI-A, both the Mobility Count and the log-scaled Spatial Access Score are normalized using min-max normalization prior to aggregation. Alternative transformations (e.g., square root, Box-Cox) yield qualitatively similar results.

The composite SPSI-B score can be computed as

$$SPSI_B = 0.6 \cdot MC_{norm} + 0.4 \cdot SAS_{norm}^{(B)}$$

This weighting scheme maintains continuity with SPSI-A, ensures that diplomatic breadth remains the dominant component, and allows spatial access to function primarily as a structural differentiator rather than a dominant driver of rank.

Logarithmic scaling reduces the disproportionate influence of extremely large landmasses (e.g., Siberia or the Sahara) while still recognizing that access to large and medium-sized countries meaningfully expands geographic mobility.

SPSI-B measures balanced spatial freedom. It emphasizes access to large and mid-sized countries while reducing sensitivity to sparsely inhabited or geographically extreme outliers. Importantly,

logarithmic scaling does not eliminate size differences; it models diminishing marginal spatial returns.

Under this formulation, gaining access to an additional continent-scale country still increases a passport's spatial reach, but not linearly relative to already extensive access. This reflects the intuition that once substantial geographic coverage is achieved, each additional unit of land contributes less to marginal mobility.

If SPSI-A and SPSI-B are applied empirically, the following qualitative patterns are expected

Upper-middle mobility passports (e.g., parts of the Balkans, South America, and the Gulf) tend to benefit under SPSI-B, as they often combine moderate destination counts with access to large and mid-sized countries.

Top-tier passports (e.g., Japan, Singapore, Germany) are likely to remain relatively stable, as their high diplomatic breadth continues to dominate even after scaling.

Passports whose strength derives primarily from access to numerous microstates or small island territories may lose some tie-breaking advantage, though they remain strong in absolute terms.

These shifts are not evaluative judgments but mathematical consequences of incorporating spatial scale under diminishing returns.

SPSI-C Population-Weighted Spatial Access

Physical land area alone does not fully capture the practical relevance of mobility. Large portions of the Earth's land surface are sparsely populated or uninhabited, while relatively small countries may provide access to dense human, economic, and cultural systems. SPSI-C therefore weights spatial access by population, reframing passport strength as access to global human presence rather than territory alone.

SPSI-C measures the potential population to which a passport holder is legally permitted entry under visa-free or Visa-on-Arrival regimes. It does not measure migration rights, labor market access, or the ability to settle or remain long-term.

Population figures are drawn from internationally recognized statistical sources (e.g., United Nations Population Division or World Bank population estimates), using the most recent pre-2025 data available. Population is defined as de facto resident population, without citizenship or residency-status filtering.

This definition reflects SPSI's focus on potential access to human systems rather than legal integration into them.

For each destination country i

$$HumanAccess_i = Population_i$$

For each passport X, the population-weighted Spatial Access Score is defined as

$$SAS_X^{(C)} = \sum_{i=1}^n Population_i$$

where n is the number of destinations accessible visa-free or via Visa-on-Arrival. This yields the total population theoretically accessible to the passport holder under SPSI-C assumptions.

As in SPSI-A and SPSI-B, both Mobility Count and the population-weighted Spatial Access Score are normalized prior to aggregation. Composite Index Construction would be

$$SPSI_C = 0.6 \cdot MC_{norm} + 0.4 \cdot SAS_{norm}^{(C)}$$

Mobility breadth remains the dominant component, while population access refines and differentiates rankings by highlighting passports that enable entry into large human systems. Alternative transformations may be explored in future work.

SPSI-C measures human-centric mobility. A higher SPSI-C score indicates that a passport enables legal entry into countries encompassing a larger share of the global population. This includes access to

dense cultural, social, and economic environments, without implying the right to participate in labor markets, access welfare systems, or obtain residency.

Population-weighted access captures a qualitatively different dimension of mobility than land-based measures. If a passport enables visa-free entry to a country containing a substantial fraction of the world's population, this constitutes a meaningful mobility advantage under this definition. Population size does not imply economic opportunity, political openness, or quality of life.

SPSI-C measures legal entry permission, not the right to work, reside, or settle. It measures permission to enter population centers, not integration into them. It explicitly does not evaluate income levels or economic performance, quality of institutions, desirability or attractiveness of destinations, or the lived experience of travel.

Empirically, SPSI-C is expected to favor passports with visa-free or Visa-on-Arrival access to highly populous countries such as China, India, Indonesia, Brazil, and other large population centers. Passports whose strength derives primarily from access to high-income but low-population countries are likely to experience minimal change or modest relative decline under SPSI-C. Conversely, regional passports with asymmetric access to populous states may experience significant upward movement.

These shifts reflect differences in population access, not normative judgments about economic opportunity or development.

Illustrative Results and Expected Recalibration Effects

Any full-scale implementation of the Spatial Passport Strength Index must be conducted with methodological care, using complete global datasets rather than selective country samples. Rankings should be computed symmetrically across all passports and destinations, accounting for exact land area and population values. Partial or selective application risks producing results that appear precise while being methodologically unsound.

Accordingly, the examples presented here are illustrative only. They are not intended as definitive rankings, but as heuristic demonstrations of how incorporating spatial and population dimensions can recalibrate passport strength assessments.

Under traditional destination-count indices, passports such as Japan and Germany typically rank at or near the top due to their extensive diplomatic reach. Under SPSI-A and SPSI-C, these passports remain strong but may experience modest relative declines as spatial and population access are introduced as differentiating factors. Conversely, some passports traditionally classified as “mid-tier” may rise in relative position if they provide access to large landmasses or populous regions despite having fewer total destinations.

For illustrative purposes only, a stylized comparison might resemble the following pattern

Passport	Traditional Rank	SPSI-A Rank	SPSI-C Rank
Japan	1	4	9
Germany	2	6	11
Bosnia and Herzegovina	45	28	31
Brazil	20	14	12

These shifts reflect the mechanical consequences of incorporating spatial and population scale, not evaluative judgments about the desirability, quality, or usability of destinations.

Bosnia and Herzegovina is referenced here solely as a motivating example. Its inclusion is not intended as a normative claim about passport quality. In spatial terms, the Bosnian passport provides visa-free or Visa-on-Arrival access to tens of millions of square kilometers of land that are not accessible under the same conditions to some top-ranked passports. Under SPSI-A, this spatial reach translates into a higher relative position. Under SPSI-B, the upward movement is moderated by logarithmic scaling. Under SPSI-C, outcomes depend heavily on continued access to populous regions, particularly in Asia.

More broadly, SPSI highlights that passports may be strong in different ways. Some excel in diplomatic breadth, others in spatial reach, and others in population access. SPSI does not declare winners or losers; it exposes dimensions of mobility that conventional indices do not measure.

Limitations and Scope

SPSI does not invalidate existing passport indices. Rather, it exposes their underlying assumptions and extends the analytical space in which mobility can be examined. Like all indices, SPSI is shaped by deliberate methodological choices that prioritize transparency, comparability, and replicability over behavioral realism.

First, SPSI measures formal legal mobility potential, not travel convenience, lived experience, or economic opportunity. It does not account for flight connectivity, travel costs, language barriers, infrastructure quality, security conditions, or tourism attractiveness. These omissions are intentional. Incorporating subjective or unstable variables would reduce cross-national comparability and introduce normative bias.

Second, SPSI assumes uniform internal accessibility once legal entry is granted. Internal movement restrictions, regional permit regimes, or informal barriers within destination countries are not modeled. Such restrictions are heterogeneous, opaque, and frequently changing, and no globally consistent dataset exists to incorporate them without subjective judgment.

Third, large portions of land counted under SPSI-A and SPSI-B are sparsely populated, climatically inhospitable, or lack infrastructure. Rather than smoothing away these effects, SPSI treats them as analytically meaningful. Access to large territories alters the spatial profile of a passport regardless of how that space is ultimately used. SPSI-C is introduced precisely to test how rankings change when spatial access is weighted by population rather than territory alone.

Fourth, SPSI does not distinguish between different durations of visa-free stay (for instance 14 days, 90 days, or indefinite entry). Reliable, globally comparable duration data are not consistently available across all destinations. Including duration would significantly reduce dataset completeness and transparency.

Fifth, SPSI does not assess qualitative differences between destinations. All destinations contribute equally after transformation (raw, logarithmic, or population-weighted). Introducing qualitative scores, such as “importance,” “attractiveness,” or “opportunity”, would introduce normative assumptions and undermine the index’s descriptive purpose.

Sixth, the treatment of dependent territories and non-recognized entities follows source-data classifications rather than independent geopolitical judgments. SPSI does not adjudicate sovereignty disputes. Any inconsistencies reflect underlying data sources rather than methodological preference.

Finally, SPSI is not designed as a policy prescription, travel advisory, or citizenship recommendation tool. It is an analytical instrument intended for comparative research and methodological exploration. Misuse outside its stated scope represents a failure of interpretation rather than a flaw in the index itself.

Concluding Remarks

This working paper has proposed the Spatial Passport Strength Index (SPSI) as a complementary framework for evaluating passport-based mobility. While existing passport indices provide valuable information by counting visa-free and Visa-on-Arrival destinations, they implicitly assume that all destinations contribute equally to mobility. SPSI relaxes this assumption by explicitly incorporating spatial and demographic scale into the measurement of legal access.

By combining traditional mobility counts with measures of accessible land area and population, SPSI highlights dimensions of mobility that are structurally invisible in destination-count-based rankings. The three SPSI variants, SPSI-A (raw spatial access), SPSI-B (log-scaled geographic reach), and SPSI-C (population-weighted access), demonstrate that passports can be strong in qualitatively different ways. Some maximize diplomatic breadth, others spatial reach, and others access to global population centers.

Importantly, SPSI does not claim to measure travel desirability, quality of life, economic opportunity, or lived experience. It does not seek to replace existing indices, nor does it assert that spatial or population access is inherently more important than diplomatic reach. Instead, SPSI makes explicit a dimension of mobility that is already present in practice but absent from most measurement frameworks.

The contribution of SPSI is therefore methodological rather than normative. It exposes the implicit assumptions embedded in conventional passport rankings and expands the analytical space in which mobility can be examined. Any reordering of passports under SPSI is a mechanical consequence of incorporating scale, not a judgment about countries, citizens, or travel preferences.

Future research may refine this approach by incorporating sensitivity analyses, alternative transformations, exclusion of domestic territory, duration-weighted access, or improved data on internal mobility constraints. Future work will test robustness across alternative weightings, normalization methods, and transformations.

Regardless of such refinements, the central claim remains, passport strength is not a single number but a perspective shaped by what dimensions of mobility we choose to measure. By acknowledging geography and population explicitly, SPSI contributes to a more transparent and multidimensional understanding of global mobility.