A Methodological Framework for the Geospatial Assessment of Women Employment and Business Opportunities in the Renewable Energy Sector

Methodology Report

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Executive Summary

The report, titled 'A Methodological Framework for the Geospatial Assessment of Women's Employment and Business Opportunities in the Renewable Energy Sector,' proposes an analytical framework to develop a methodology for geospatially assessing women's access to employment opportunities in the Renewable Energy (RE) sector, with a focus on Small Island Developing States (SIDS). Despite the rapid growth of RE in SIDS over the past decade, women continue to represent a small portion of formal employees in this sector. Conventional methodologies used to assess women's empowerment and employment opportunities frequently neglect geographic data when determining the factors that enable or restrict women's job prospects. Acknowledging this gap, the focus of this report is on identifying critical factors that vary geographically and contribute to creating an enabling environment for women to secure formal employment or business opportunities in the RE sector.

The geospatial methodology developed in this report is the first of its kind in assessing the spatial characteristics of environments that influence women's job access. It aims to support decision-making by enabling practitioners and policymakers to strategically target infrastructure investments based on spatial data. These investments have the potential to enhance women's employability, furthering gender equality and bolstering environmental resilience.

After an introduction that provides a global context for renewables and outlines the representation of women within this context, this report compiles insights from a thorough literature review. The aim is to identify the critical factors that significantly impact women's opportunities for securing formal employment in the RE sector in SIDS. In particular, this report identified three key dimensions that are relevant for assessing an environment in terms of the opportunities it offers for women to secure employment in the RE sector: (i) the Contextual Dimension, (ii) the Accessibility Dimension, and (iii) the Place-Characterization Dimension.

The **Contextual Dimension** comprises factors that provide insights into the legal and policy landscapes of regions, impacting workplace gender discrimination, women's financial autonomy, and the overall empowerment of women to participate in the workforce. Inherent gender biases often affect both recruitment processes and women's experiences in male-dominated fields. Women who pursue careers in these fields frequently face additional barriers to professional development, including harassment, lack of mentorship, and limited access to training opportunities. These challenges can hinder women's career progression, discourage them from pursuing higher positions, and contribute to a higher attrition rate for women. Many policies and legal protections that help women engage in business, obtain work, and succeed in their careers, such as childcare and parental leave, vary dramatically across SIDS. In addition, legislation

and social norms in many SIDS imply that women's access to finance in these countries is disproportionately low.

The **Accessibility Dimension** pertains to the ease with which women can reach specific locations, be it services or destinations and it is often determined by a measure of proximity. Therefore, accessibility factors are spatial factors that impact the day-to-day mobility of women. Accessibility factors found to be most relevant to women in SIDS include (i) women's travel patterns, (ii) access to public transport, (iii) access to education facilities, (iv) access to health facilities, and (v) access to financial facilities.

Women's travel patterns are intricately shaped by their multifaceted societal roles, juggling responsibilities as caregivers and employees. These roles often entail complex, multi-stop journeys that frequently occur during off-peak hours and significantly differ from the linear commuting patterns more commonly seen in men. The divergence in travel patterns, coupled with caregiving duties, means that, on average, women have less available time for their commutes, consequently limiting the maximum distance they can travel to work, in contrast to men. Globally, women tend to depend more extensively on public transportation than men. The distance to reach public transport routes significantly influences their ability to make use of these services, particularly when the access routes are poorly illuminated and pose safety concerns. With respect to education facilities, evidence of poor physical access to schools and higher education facilities is well documented as a significant factor contributing to low educational attainment for women. In the realm of healthcare, women typically bear greater responsibility for family health. Consequently, access to healthcare facilities holds more significant relevance for women compared to men. Finally, although financial inclusivity in recent years has been largely linked to digital inclusion; nonetheless, the physical location of financial facilities remains relevant.

The **Place-Characterization Dimension** encompasses attributes that define a specific geographical location or environment, independent of mobility considerations. The place-characterization factors considered most important for women's access to jobs include (i) ease of active transport, (ii) safety, (iii) fragility, conflict, and violence (FCV), (iv) the region's ratio of female STEM graduates, (v) digital inclusion, (vi) water and sanitation, and (vii) environmental hazards.

Women tend to rely more on walking and public transportation compared to men. Therefore, the availability of active transport options in a region plays a crucial role in either facilitating or discouraging women from pursuing formal employment. In the context of safety, women in SIDS face a disproportionate impact stemming from concerns about personal safety in public spaces, often attributed to elevated levels of violence and sexual harassment. Additionally, a region's access to essential resources such as clean water, sanitation facilities, and internet connectivity are pivotal spatial factors influencing women's access to employment opportunities. Finally, it is essential to acknowledge that the profound disparities women encounter in terms of resource accessibility, mobility restrictions, and personal freedoms have dire consequences in the face of climate change events. For instance, women constitute 70 percent of the population living in extreme poverty and a staggering 80 percent of the global refugee population. As a result, women and girls are 14 times more likely to lose their lives in the event of natural disasters, including tropical cyclones and heatwaves, rendering areas with high levels of vulnerability to such disasters particularly risky environments.

After discussing the spatial factors that determine the level of support for women's access to jobs at the local level, the report proceeds to outline previously developed analytical frameworks and geospatial analysis methods pertaining to women's empowerment, employment, spatial accessibility, and geographical characterization. The objective is to identify the most efficient methodologies for spatially measuring women's access to job opportunities.

Finally, the report introduces a Multicriteria Evaluation (MCE) methodology for spatially modeling women's access to employment and business opportunities in the RE sector across SIDS, proposing appropriate geospatial analyses for estimating the previously identified critical factors in a region. The proposed methodology and corresponding indicators are explained in detail, along with guidance on interpreting the results. The outcome of the methodology furnishes a score that categorizes regions on a scale from 0 to 5, indicating the extent to which they facilitate the integration of women into the RE sector, with 5 representing the highest score.

Notably, the diverse characteristics of SIDS, encompassing variations in geographic, political, and social contexts, along with varying accessibility to suitable geospatial data, pose a challenge to the widespread implementation of the methodology. Therefore, this section of the report also discusses the limitations of the methodology in more detail.

The MCE approach proposed in this report is designed to equip policymakers and institutions with data-driven insights, enabling them to make evidence-based decisions that take into account the geographic dimensions of disparity. These insights, in turn, can help ensure the efficient allocation of resources to achieve gender equity objectives. Furthermore, employing such an approach can bring added value by fostering a deeper understanding of the specific infrastructure needs of a demographic characterized by unique mobility patterns, increased domestic responsibilities, distinct perceptions, barriers to unrestricted travel, and attitudes toward distant locations.

Abbreviations and Acronyms

2SFCA	two-step Floating Catchment Area
ACT	Factor in the methodological framework representing active transport
ACLED	Armed Conflict Location and Event Data Project
AD	Accessibility Dimension
AIO	Atlantic and Indian Ocean
APT	Factor in the methodological framework representing availability of public transport
CCEFCF	Canada Clean Energy and Forest Climate Facility
CD	Contextual Dimension
CPTED	Crime Prevention Through Environmental Design
CRE	Factor in the methodological framework representing availability of public transport
DIG	Factor in the methodological framework representing digital inclusion
DPPA	Daily Potential Path Area
DOV	Factor in the methodological framework representing the level of exposure to domestic violence
E2SFCA	Enhanced two-step Floating Catchment Area
EDU	Factor in the methodological framework representing educational attainment
ELC	Factor in the methodological framework representing electrical access
ENV	Factor in the methodological framework representing exposure to risk due to natural environment and climatic factors
EPA	Environmental Protection Agency
ETF	Factor in the methodological framework representing access to tertiary education and training facilities
FCA	Floating Catchment Area
FCV	Fragility Conflict and Violence/Factor in the methodological framework representing exposure to fragility, conflict and violence
FEI	Female Entrepreneurship Index
FIF	Factor in the methodological framework representing access to financial facilities
FIN	Factor in the methodological framework representing women's access to financial services
GBV	Gender Based Violence
GEDI	Global Entrepreneurship Development Initiative
GHSL	Global Human Settlement Layer
GPI	Gender Parity Index
HEA	Factor in the methodological framework representing access to health facilities

HSA	Health Service Area
HCUP	Healthcare Cost and Utilization Project
HOU	Factor in the methodological framework representing quality of housing
ID	Individual Dimension
IEA	International Energy Agency
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
ILO	International Labor Organization
INC	Factor in the methodological framework representing income level
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ITDP	Institute for Transportation and Development Policy
IDW	Inverse Distance Weighted
IWRM	Integrated Water Resources Management
JOB	Factor in the methodological framework representing access to jobs in the renewable energy sector
LGBTQI+	Lesbian, gay, bisexual, transgender, queer, and intersex
LOU	Factor in the methodological framework representing level of urbanization
MCE	Multicriteria Evaluation
MPI	Multidimensional Poverty Index
NHTS	National Household Travel Survey
NPTS	National Personal Transportation Survey
O&M	Operation and Maintenance
OSM	Open Street Map
PBT	Factor in the methodological framework representing access to public transport
PCA	Principal Component Analysis
PD	Place Characterization Dimension
PLP	Factor in the methodological framework representing policy and legal protections against gender discrimination
PPA	Potential Path Area
PSUP	Participatory Slum Upgrading Program
PV	Photovoltaic
RE	Renewable Energy
SAF	Factor in the methodological framework representing safe urban design
SDG	Sustainable Development Goals
SEC	Factor in the methodological framework representing security and exposure to crime
SIDS	Small Island Developing States

STEM	Science Technology Engineering and Mathematics
TVET	Technical Vocational Education and Training
UNSD	United Nations Statistics Division
WAS	Factor in the methodological framework representing access to water and sanitation
WBL	Women Business and Law
WEAI	Women’s Empowerment in Agriculture Index
WEE	Women’s Economic Empowerment
WEOI	Women’s Economic Opportunity Index
WHO	World Health Organization
WTP	Factor in the methodological framework representing women's travel patterns, specifically access to facilities related to women’s role as caregivers

Definition of Terms

Term	Definition
Access	In the context of geospatial assessments, access refers to the ability to reach or utilize resources, services, or facilities within a specific geographic area. In this context, access may be used primarily to refer to spatial access, which is concerned with the physical distance or travel time between locations, such as the proximity of individuals to healthcare facilities, public transportation, or natural resources. This is often measured using Euclidean distance, network distance, or travel time calculations. However, economic, temporal, functional and social/cultural access can also influence the overall 'accessibility' of a resource. Geospatial assessments often integrate these dimensions of access.
Basic services	Basic services, also known as essential services or public services, generally refer to a set of services considered fundamental to ensuring an acceptable quality of life and supporting the functioning of society and the economy.
Dimension	A grouping of interrelated factors that constitute a distinct category for assessing or analyzing complex, multifaceted phenomena (e.g., education, health, the standard of living).
Factor	A characteristic or variable which influences the extent to which women can access and engage (in the case of this project) in employment opportunities within the renewable energy sector.
Indicator	A quantifiable measure that may be used to assess or illustrate a particular factor. For example, "Distance to Nearest School" is an indicator that measures the proximity of residences to educational institutions. This quantifiable metric provides valuable insights into the accessibility of social services, in this case, education.
Distance	The measure of separation between two entities or locations that may or may not be connected, such as two points.
Catchment area	The area from which a location such as a facility, service, institution or city, attracts a population that uses its services.
Data layer	A representation of a quantitative property or characteristic associated with a specific indicator (in GIS it may be referred to as a reference framework, data model, or spatial data feature class), often presented in a geospatial context. These layers can be combined either as summated or subtracted overlays or analyzed to better understand or visually represent the relationships between numerous indicators and their impacts on a given phenomenon.
(Spatial) Features (also referred to as feature class)	A collection of geographically located objects that share the same geometry type (such as points, lines, or polygons) and the same set of attributes or properties (such as Identifying codes, names, address fields elevations or other characteristics that define each of the individual items in the collection, as a unique entity).
Score	Scoring refers to the process of converting continuous variables, like distance, into discrete categories. This transformation allows for easier visualization, comparison, and understanding of spatial data.
Weights	Weights denote the assigned importance, influence, or significance of one indicator or factor compared to others. These weights (often expressed in numerical format) help prioritize certain indicators or factors over others based on their relevance or value in the spatial analysis.
Women's Economic Empowerment (WEE)	The capacity of women to participate in, contribute to and benefit from growth processes in ways that recognize the value of their contributions, respect their dignity and make it possible to negotiate a fairer distribution of the benefits of growth (OECD, 2011).

1 Introduction

"***Net Zero*", "*Green Jobs*", a "*Just Transition*": change is on the near horizon, and employment opportunities will transform as a result.** How will this affect employment opportunities for women in the renewable energy (RE) sector? A woman's ability to access formal employment opportunities or become an entrepreneur depends on a wide range of factors, with many existing studies focused on individual factors such as level of education, or contextual factors such as legislative policy and workplace gender discrimination. However, factors that vary geographically, such as access to training and learning opportunities, safety, transport, access to electricity, access to water, broadband availability, and exposure to natural disasters, are often not considered in analyses and are potentially of equal or greater importance in determining women's access to jobs.

Current approaches to assessing women's employment opportunities fail to recognize that geography and place play an essential role in enabling women to work outside the home (OECD, 2019d). Data is crucial in diagnosing problems, evaluating development, and identifying solutions that empower communities. In some developing nations, however, geospatial data is still scarce, especially gender-disaggregated spatial data, which is crucial to accelerating gender equality. Accordingly, this report aims to bridge the gap between geospatial data and women's employment opportunities by presenting a methodological approach to estimating women's access to formal employment and business opportunities in the RE sector in Small Island Developing States (SIDS) from a geospatial perspective.

This approach presents a unique opportunity to better understand how geography affects gender-specific socioeconomic interactions. By incorporating spatial factors essential in influencing women's mobility patterns and behavioral choices, the methodology aims to identify areas where enabling environments exist that make it easier for women to access formal employment in the RE sector. Moreover, recognizing and mapping the relationships between location-related factors and inequalities will support gender equality and the development of tailor-made solutions. Through infrastructure investments, policymakers can address spatial inequalities, which, in turn, will lead to two primary outcomes: (i) improving women's employment and empowerment and (ii) strengthening the RE sector in SIDS by expanding – and diversifying - the labor pool.

1.1 BACKGROUND TO THE PROJECT

This methodological approach forms part of the "Geospatial Assessment of Women's Employment and Business Opportunities in the Renewable Energy Sector" project funded by the Canada Clean Energy and Forest Climate Facility (CCEFCF) and implemented by the World Bank. Globally, women account for only 32% of employees in the RE sector, and their participation in high-quality STEM roles is much lower than in administrative jobs in the sector (IRENA, 2019). Increasing the proportion of women in sectors such as Solar and Wind, which are fast-growing RE sectors in SIDS, can create a more inclusive and sustainable future for these countrieso. Therefore, the primary goal of this project is to develop innovative geospatial open-source tools and spatial indicators that can provide valuable insights for renewable energy (RE) initiatives in Small Island Developing States (SIDS). These tools and indicators are aimed at promoting the economic empowerment of women while actively contributing to reducing gender disparities in employment within the RE sector Table 1.

Table 1 List of the 31 eligible SIDS by region

	Africa	**East Asia and Pacific**	**Latin America and Caribbean**	**South Asia**
N/A		Niue		
Low Income	Guinea-Bissau			
Lower-Middle Income	Cabo Verde Comoros São Tomé and Príncipe	Federated States of Micronesia Kiribati Papua New Guinea Samoa Solomon Islands Timor-Leste Vanuatu	Haiti	
Upper-Middle Income	Mauritius	Fiji Marshall Islands Palau Tonga Tuvalu	Belize Dominica Dominican Republic Grenada Guyana Jamaica St. Lucia St. Vincent and Grenadines Suriname	Maldives
High-income		Nauru	Antigua and Barbuda	

Source: World Bank, 2023d; World Economic Forum, 2022

The initial phase of the project involved the comprehensive compilation of open-source spatial and non-spatial datasets encompassing the 31 SIDS eligible in the project. These datasets were related to women's access (or lack thereof) to formal employment and business opportunities in the RE sector. This effort culminated in the creation of a Gap Assessment Report, summarizing the outcomes of the data collection process and outlining specific data gaps unique to each country. Additionally, meticulously curated spatial geodatabases were created for each of the 31 SIDS countries, housing all the open-source data layers with the highest available resolution[1].

Building upon the foundation laid during the Gender Spatial Data Gap Assessment effort leveraging the findings and insights derived from the Gap Analysis Report and utilizing the spatial geodatabases

[1] Geodatabase repository: https://datacatalog.worldbank.org/search/collections/genderspatial

assembled for each country, this report takes a deep dive into crafting a methodology and corresponding analytical tools for the assessment of women's access to employment opportunities in the RE sector in SIDS. Given that the information layers essential for developing this methodology primarily stem from the open-source spatial databases, the methodology's design inherently accommodates the constraints related to data availability within SIDS. The analytical tools proposed in this report incorporate spatial analyses to visually map out regions where conducive environments exist for women to access RE job opportunities in each SIDS country. In cases where such environments are lacking, the methodology serves as a decision-making tool, facilitating the reinforcement of critical factors (e.g., transportation, education, internet access) that currently act as barriers in these areas.

1.2 SIDS CONTEXT

One of the key challenges in identifying geographic enablers of women's employment is that each of the 31 SIDS eligible under this project has its own development trajectory and cultural context. These countries are grouped into four major geographic regions: (i) Africa, (ii) East Asia and the Pacific, (iii) Latin America and the Caribbean, and (iv) South Asia. Within these regions there are different development characteristics among the islands relating to poverty, labor force participation, unemployment (including informal employment), and socioeconomic inequality. Consequently, the challenges and opportunities faced by these SIDS regarding RE jobs and women's access to such employment are likely to vary significantly across regions and between individual island nations.

Spanning a range of high to low-income countries, SIDS feature a multitude of educational environments, different levels of gender-based violence, and a blend of urban and rural settings. Gender (in)equality indicators vary across the 31 countries, as can be seen from the World Economic Forum's Global Gender Gap Report, which measures gender-based gaps in access to resources and opportunities in 146 countries[2] (World Economic Forum, 2022). The 2022 report includes four sub-indices (Economic Participation and Opportunity, Educational Attainment, Health and Survival, and Political Empowerment) measured across 14 indicators. In the ranking of 146 countries' overall gender equality score, some SIDS do well (Guyana ranks 35), and some are highly unequal (Maldives and Comoros are near the bottom of the global ranking, at 117 and 134, respectively). The Economic Participation and Opportunity gender gap also varies dramatically across SIDS. Cabo Verde ranks 30, Fiji ranks 118, and Comoros ranks 129 out of 146 countries (World Economic Forum, 2022). SIDS also vary considerably regarding women's participation in the labor market. For instance, the Solomon Islands have a high rate of women's labor force

[2]As with the majority of global data bases and indices, many Pacific SIDS are missing from the WEF's Global Gender Gap Report.

participation (86%). In comparison, Samoa and Papua New Guinea have much lower participation rates of 31% and 46.3%, respectively (World Bank, 2023c).

Despite these divergences, women in SIDS share common challenges, including geographical isolation, limited resources, and potential exclusion from global dialogues and decision-making processes. Furthermore, SIDS share common challenges and vulnerabilities related to their exposure to natural disasters and climate change, global economic shocks, and unstable or limited domestic and international financial resources. In light of these challenges, a targeted methodological approach to identifying the spatial barriers that hinder women's access to jobs in the RE sector could offer a robust solution to improve gender parity in the sector. In addition to empowering women in SIDS, such a solution could improve women's resilience to environmental and economic disruptions by taking advantage of RE's unique potential.

1.3 RENEWABLE ENERGY CONTEXT

In today's world, renewable energies have become indispensable in our collective endeavors to combat climate change. These sustainable energy sources are vital in reducing carbon emissions, lessening our environmental impact, and preserving the environment for future generations. Moreover, renewable energies offer substantial economic benefits by generating job opportunities and enhancing overall societal well-being.

Employment in the RE sector globally has grown dramatically from 7.3 million in 2012 to 12.7 million in 2021. The solar PV sub-sector has led this growth, with the number of employees almost tripling from 1.4 to 4.21 million between 2012 and 2021 (see Figure 1). The wind sub-sector has seen the second-highest growth rate at 66%, from 0.75 to 1.37 million jobs. The bioenergy and hydropower sub-sectors stand in third and fourth place with 3.52 (29%) and 2.18 (19%) of all RE jobs, respectively (IRENA and ILO, 2022).

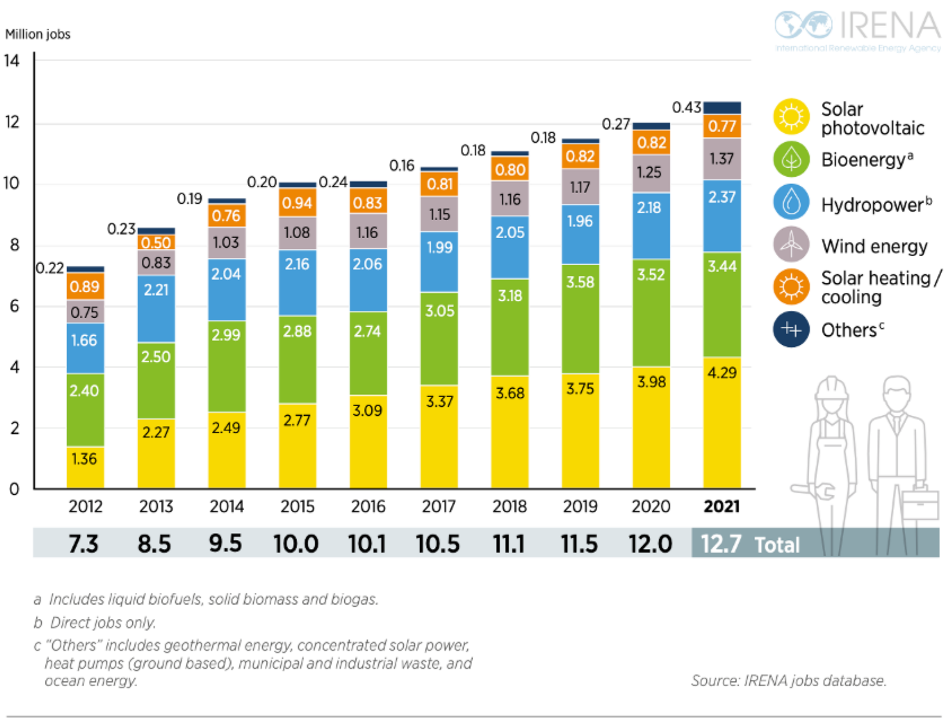


Figure 1. Evolution of global renewable energy employment by technology, 2012-202

IRENA's energy transition scenario, which envisions a climate-resilient future with a large-scale shift to renewable energy, calculates a total of 42 million jobs in the RE sector by 2050. Of these jobs, 45% (18.7 million) will be in solar PV, followed by 34% (14.1 million) in bioenergy and 15% (6.1 million) in wind energy.

The under-representation of women within the energy sector is widely acknowledged. In the traditional oil and gas industry, men significantly outnumber women, with women comprising a mere 22% of the workforce. The renewable energy sector demonstrates more encouraging figures, with women holding 32% of the available positions (IRENA 2022). To tap into a broader talent pool, the RE sector must proactively address the obstacles and barriers women encounter within the industry and unequivocally promote gender equality.

1.3.1 Solar PV

The solar photovoltaic (PV) sector is the leading source of employment in the RE sector, accounting for some 4.3 million jobs (IRENA and ILO, 2022). Solar PV is expected to continue being the primary catalyst for job growth in RE, generating 14 million jobs by 2030 (IRENA and ILO, 2022).

Its job creation potential throughout the value chain is immense. For a 50 Megawatt (MW) solar PV project, about 230,000 person-days are required for project planning, manufacturing, construction, installation, and operations and maintenance. This is a year's work for 885 people for a single large-scale facility (IRENA 2016).

Solar PV offers employment prospects to people with a wide range of skills in all stages of a typical project, from project planning to decommissioning (IRENA, 2022a). Most labor is required in operations and maintenance (56%). Overall, 64% of the required employment in these projects is allocated to employees with lower educational certifications who could be leveraged from different industries with minimum training. High-skilled employees, including STEM professionals, account for over a third (35%) of all labor requirements. (IRENA 2016)

Local formal direct employment in solar PV projects is most likely to happen in large on-grid projects in the later stages at the installation and grid connection, operations and maintenance, and decommissioning stages of the project. The solar PV value chain is highly localized, with 78% of the world's cell production and 72% of module output originating in China (IRENA, 2021)**.** While mini grids generate jobs through manufacturing, installation, and operations and maintenance, their job generation is mostly indirect and induced through the electrification of communities that did not previously have access to electricity (ESMAP, 2019). The sale of off-grid solar PV appliances produces jobs primarily in rural areas, supporting job creation and diversification among often economically disadvantaged and vulnerable communities (GOGLA, 2019).

Solar PV is the subsector with a better representation of women. According to the IRENA research on gender in the solar PV sector, the percentage of women working in full-time positions in the industry is 40%. This represents almost double the share of the wind industry (21%) and the oil and gas sector (22%) (IRENA, 2022)..

Within the solar PV industry, women find more significant opportunities in manufacturing, where they make up 47% of the workforce. Service providers and developers also exhibit high rates of female employment, with 39% and 37%, respectively. Conversely, women face greater challenges in securing positions as solar PV installers, representing just 12% of the total workforce in this role.

Most women in solar PV are employed in administrative jobs (58%), but they are not as well represented in technical non-STEM positions (38%) such as lawyers and procurement experts. Women also represent 35% of other non-technical positions such as marketing, sales, distribution, and product assembly and installation. Women currently occupy 30% of managerial positions, while their representation is notably lower in senior management, with just 13% of these top-level posts being held by women.

Women face challenges in the solar PV sector similar to those in other energy subindustries, experiencing obstacles in entry, retention, and career advancement. The most frequently cited barriers among IRENA survey respondents include perceptions of gender roles, a lack of fair and transparent policies, and cultural and social norms that influence behavior (IRENA, 2022).

1.3.2 Wind

The wind subsector is the fourth source of employment in the RE sector, but it is the second in electricity capacity. Global employment in onshore and offshore wind grew to 1.4 million jobs in 2021, up from 1.25 million in 2020. Most employment is concentrated in relatively few countries, with China alone contributing a significant 48% to the global wind employment total (IRENA and ILO, 20212).

The wind subsector provides strong opportunities for local employment generation. While the wind energy supply chain depends on globally sourced components, the large size of the wind and the weight of wind turbines encourage the development of local supply chains to source these materials for large onshore and offshore projects (Ladislaw et al., 2021).

Large wind onshore and offshore projects create sustainable jobs, which require a variety of skills across the full value chain of the sector. Direct jobs beyond manufacturing include employment by onshore and offshore project owners and primary contractors and tend to be concentrated in the installation and operations and maintenance (O&M) segments of the value chain. This job creation depends on a country's ability to establish a robust local supply chain, including investment in manufacturing, port infrastructure, and specialized vessels for offshore projects (Global Wind Energy Council, 2021). STEM skills are a priority for many of the most well-paid jobs in the wind subsector. However, non-STEM roles in factories and construction comprise the largest share of jobs in both on-shore and off-shore wind projects. Most (63%) of on-shore wind jobs are low-qualified, and STEM jobs account for only 27% of on-shore and 22% of off-shore wind jobs (IRENA, 2021).

Wind is the renewable sector with the lower representation of women. Women represent 21% of the sector workforce according to a gender survey done by IRENA in the wind energy sector, well below the 32% share of women in the workforce for all renewables. (IRENA, 2020).

Women have a low representation in senior positions in wind companies (8%), with only 13% in managerial positions. They are mostly present in administrative jobs (35%), followed by non-STEM positions (20%) and STEM positions (28%).

The field of developers sees a higher engagement of women. Specifically, developers and other activities along the wind value chain excel in employing women, with each sector contributing 27%, while service providers employ 24% of women. In contrast, female employment in equipment manufacturing is at 17%{, 2020, Wind Energy: A Gender Perspective}, representing a challenge, as manufacturing typically offers better-paying jobs than other segments of an industry (Mishel, 2018).

Cultural and social norms persist as the primary barriers for women in the wind industry. Obstacles to female entry, retention, and advancement include perceptions of gender roles, the enduring influence of specific cultural and social norms, issues related to fairness and transparency in internal policies and processes, and wage inequalities. Men generally perceive fewer gender-related barriers than women, with one-third of men acknowledging their existence compared to two-thirds of women (IRENA, 2020).

1.3.3 Hydropower

The hydropower sector experienced a second consecutive year of job growth, rebounding from a period of decline. In 2021, the sector directly employed 2.36 million people, a notable increase from 2.18 million in 2020. According to IRENA, the projection suggests that the sector is poised to employ 3.7 million people by the year 205 (IRENA and ILO, 2022). .

Most direct jobs are in manufacturing. Globally, two-thirds of direct jobs were in manufacturing, 30% were related to construction and installation activities, and about 6% were in O&M services. 94% of the current workforce is dedicated to the manufacturing and construction of large government-backed dams. Once again, China was the largest contributor to hydropower jobs, accounting for 37% of global employment.

At 25%, the share of women in hydropower is better than in wind but is lower than in the RE sector overall, according to an assessment of women's participation in the hydropower sector by ESMAP (Energy Sector Management Assistance Program) in 2023. The assessment is based on the results of online surveys of 468 women, 432 men, and 65 companies working in the sector (ESMAP, 2023).

Among women employed in hydropower, only 21% occupy technical and engineering roles, with the majority, comprising 79%, engaged in non-technical positions, such as administration, commerce, sales, marketing, human resources, and finance. Results from the ESMAP survey highlight the persistent underrepresentation of women at mid-level and senior management levels within hydropower companies, as well as on boards of directors, with women comprising only 29%, 24%, and 19% of these positions, respectively (ESMAP, 2023).

Women and men in the hydropower sector perceive distinct barriers. According to the 2023 ESMAP survey, women identified challenges such as the low promotion of women with relevant STEM skills, a scarcity of female role models, lack of awareness of opportunities, bias by senior management in favor of employing men, and unwelcoming workplace environments. Conversely, men highlighted the lack of awareness of opportunities among women, lack of interest among women, and lack of female role models (ESMAP, 2023).

1.3.4 Bioenergy

The bioenergy industry is losing its employment track record. IRENA's data reveals that in 2021, the global bioenergy industry supported approximately 3.44 million jobs, which represents a reduction for the second consecutive year in its employment generation power, decreasing 2.3% compared to 2020 (IRENA, 2021). Regarding technology, liquid biofuels claim the majority of jobs, totaling 2.42 million, followed by solid biomass with 716,000 jobs, and biogas with 307,000 jobs.

Most biofuel positions are concentrated in planting and harvesting feedstock, where labor demand is higher. However, fuel processing, though employing fewer individuals, often offers higher wages. Latin America takes the lead, contributing 44% of all biofuel jobs globally, followed by Asia, particularly Southeast Asia, making up 36% of the total. In contrast, the more mechanized agricultural sectors in North America and Europe result in smaller employment proportions within the biofuel industry (IRENA and ILO, 2022).

In the corn ethanol industry in the USA, women make up approximately 28% of the workforce, as reported by the US Department of Energy's 2023 Energy and Employment Report. While this surpasses the overall gender representation in the energy workforce, which averages 22% in the USA, it still falls short of the national workforce average of 47%. The workforce in woody biomass and cellulosic biofuels tends to be more gender diverse, with 30% of workers being female, while the category of "other biofuels" stands out as the most gender diverse, with a third of workers identified as female (33%) (U.S. Department of Energy, 2023).

1.3.5 Renewable energy in SIDS

Different SIDS exhibit diverse RE resources based on their geographic and geological characteristics. Volcanic SIDS, prevalent in the Caribbean and the Pacific, often boast significant geothermal potential. Conversely, atoll island SIDS, characterized by low-lying topography and a lack of geothermal potential, tend to rely more on solar and wind resources (IRENA, 2022a). Hydropower potential is contingent on SIDS having sufficient water resources and elevation changes. Those with mountainous terrain, such as certain Pacific islands, may leverage these elevation changes for effective hydropower utilization. Notably, SIDS possess significant biomass potential, utilizing agricultural residues, forestry waste, and organic waste for bioenergy production, contributing to sustainable energy and reducing dependence on imported fossil fuels (IRENA, 2020a)

Solar and wind power are increasingly the choice for SIDS countries, followed by hydropower and biomass (Filho et al., 2022). As of 2019, SIDS had an aggregate installed RE capacity of approximately 5.3 GW, according to data from the International Renewable Energy Agency (IRENA, 2021). Although hydropower constitutes the majority of this capacity, solar energy has emerged as the predominant renewable installation since 2014, boasting a total installed capacity of approximately 680.4 MW (IRENA, 2021). Wind energy is another prominent renewable source in SIDS, with an installed capacity of around 510 MW (IRENA, 2021). Hydropower, constrained by specific geographical and hydrological conditions, contributes approximately 1.3 GW to the total installed renewable energy capacity in SIDS. Biomass follows with a total capacity of 859 MW. However, neither hydropower nor biomass is experiencing rapid growth compared to solar or wind sources (IRENA, 2021).

1.4 THE LOCATION OF RENEWABLE ENERGY JOBS

The geographical distribution of jobs within the RE sector plays a pivotal role in shaping access to employment opportunities (IRENA, 2021). The location of a job can exert a substantial impact on individuals' accessibility, closely tied to factors like transportation infrastructure and proximity to population centers (World Bank, 2020). In certain instances, job opportunities may be clustered in particular regions or urban areas, potentially amplifying prevailing spatial inequalities, diminishing social inclusion, and restricting access for individuals residing in more remote or disadvantaged areas (OECD, 2018).

Semi-skilled or unskilled direct jobs can be locally sourced. In 2023, the World Bank conducted an extensive analysis of the impact of the global shift toward clean energy on job quantity and quality in low and middle-income countries. This analysis highlighted the diverse job opportunities that can emerge throughout the project cycle. Direct jobs are generated directly by the core project activities, encompassing all roles related to installing, operating, and maintaining projects. RE projects generate numerous temporary but high-quality direct jobs during construction and fewer O&M jobs, which, however, tend to last several decades. Approximately two-thirds of these positions require semi-skilled or unskilled labor, and these roles typically do not experience significant skill shortages. These jobs are commonly recruited from local communities, promoting community involvement and enhancing project acceptance. However, in instances where projects are deeply rooted in local communities to minimize employee turnover, semi-skilled and unskilled workers may face challenges in securing long-term employment or integration into the mobile workforce commonly observed in construction companies executing clean energy projects{, 2023, Tracking Jobs in Projects Focused on Clean Energy and Productive Uses Of Electricity (Forthcoming)}.

In terms of location, formal direct jobs in the RE sector could be strategically situated in areas where the manufacturing of gridded RE infrastructure, along with its associated components, is concentrated. The solar PV value chain exhibits a high degree of localization, with 78% of the world's cell production and 72% of module output originating in China (IRENA, 2021). Additionally, the location of formal direct jobs and business opportunities may encompass places where components are manufactured, mini-grids are installed, off-grid products are sold, and components are transported. This extends to the industrial sites where steel and concrete pole manufacturing occurs and the rural areas where mini-grids are installed or off-grid products, such as solar lamps and home systems, are sold (Ladislaw et al., 2021).

However, in the context of SIDS, formal direct jobs in the RE sector tend to center on the physical location of large RE generation projects. These projects often involve the construction, installation, operation, and maintenance of RE infrastructure, such as solar power plants or wind farms, which directly employ a substantial number of workers in various roles. STEM skills are a priority for many of the most well-paid jobs in RE.

2 Factors that foster an enabling environment for women's access to formal employment and business opportunities in SIDS

This section examines the primary spatial factors that either promote or restrict women's access to formal employment and business opportunities, particularly within the context of SIDS. Factors are grouped into three dimensions. The first dimension focuses on contextual factors, which encompass the broader policy and legal framework of a country. This includes regulations that prevent gender discrimination and encourage women's participation in the labor force. The second dimension pertains to accessibility factors, highlighting the ease with which women can reach essential places or facilities, such as public transportation stops, universities, and health centers. Proximity to these places is crucial; without the ability to spatially access these facilities, their use becomes infeasible. Lastly, the third dimension addresses place-characterization factors, which define a geographical region's characteristics, such as safety and access to water and sanitation, but do not involve mobility considerations.

While accessibility and place-characterization factors vary within smaller geographical scales, contextual factors typically differ only between countries, as laws and policies are generally applied at the national level and not at subnational levels.

2.1 CONTEXTUAL DIMENSION

"Contextual factors" such as macro and local-level policies and practices also influence the gender relations that, in turn, promote or discourage women from working outside the home (Ridgeway & Correll, 2004; Risman, 2004; Thébaud & Pedulla, 2016; West & Zimmerman, 1987). While contextual factors provide information related to a specific place (such as the presence or absence of gender-based workplace discrimination laws), these factors often do not vary geographically within a country. As such, their evaluation is only likely to highlight differences between countries.

2.1.1 Workplace discrimination

Gender biases often affect both recruitment processes and women's experiences in male-dominated fields. There is frequently a lack of concerted efforts by employers in male-dominated industries to engage in women-focused recruitment processes (World Bank, 2014). Despite recent rhetoric embracing gender equality in some male-dominated sectors, research exposes the disconnect between equality-promoting statements and 'entrenched male preference for male recruits' (Baruah & Biskupski-Mujanovic, 2021).

Moreover, women who pursue careers in male-dominated occupations, such as the RE sector, often face additional barriers to secure or remain employed, including harassment, lack of mentorship or role models, and limited access to training and networking opportunities (Catalyst, 2021). These challenges can hinder women's career progression, discourage them from pursuing higher positions, and contribute to a higher attrition rate among female employees (WPC, 2016). Gender biases are particularly detrimental to women's career progression in sectors where male leaders are more likely to favor candidates that are like themselves, such as STEM fields (Schomer & Hammond, 2020).

According to IRENA's 'Measuring the Socioeconomics of the Transition: A Focus on Jobs', women face barriers to their retention within the sector, including lack of fairness and transparency in company policy, lack of flexible working, and lack of mentoring (IRENA, 2020b). The "Stepping Up Women's STEM Careers in Infrastructure" report (2020) echoes these observations and highlights challenges such as "unwelcoming work environments, the biases of coworkers, and the risks of gender wage gaps" (page 2, Schomer & Hammond, 2020). In contrast, a study of 64 companies in the RE sector in Africa showed that male managers were often unaware of barriers to women's employment and retention and stated that women's self-perception was the main inhibitor to their career progression, rather than systemic barriers and gender stereotypes (Energy2Energy, 2022).

Formal RE jobs, especially in the engineering and construction sectors, are largely dominated by men. Cultural stereotypes, gender biases, and social norms have contributed to the underrepresentation of women in these fields, as they are often perceived as unsuitable for women or incompatible with traditional gender roles (NASEM, 2018). Approximately 3% of workers constructing and commissioning solar projects are women, and a mere 1% of those work in operations and maintenance, but they represent 18% of the workers in solar office jobs such as design and pre-construction (International Energy Agency, 2019). Although data on female engineers in SIDS are not available, a 2017 UNESCO report of large-scale national surveys found that despite more women entering the STEM workforce than ever before, they are still significantly under-represented in these occupations in many countries (UNESCO, 2017).

2.1.2 Regulatory Frameworks

Formal rules, including but not limited to policies for childcare and parental leave, are key factors that affect women's ability to work (OECD, 2019c). Many of the policies and legal protections that help women engage in business, obtain work, and succeed in their careers on an equal footing to men are outlined in the World Bank's Women, Business, and the Law (WBL) Index. The WBL Index is based on statistically significant associations with outcomes related to women's economic empowerment, in particular, with women's labor force participation and measures the legal differences in access to economic opportunities between men and women in 190 economies (World Bank, 2023a). The WBL Index is structured around the lifecycle of a working woman, comprising eight indicators (including pay, entrepreneurship, and parenthood). Thirty-five questions about national laws and policies are scored across the indicators, with the combined indicator score denoting how gender-equal a country's laws are (scores range from 0 to 100, with 100 representing the highest possible score).

In the Pacific, every SIDS except for Timor-Leste scores below the global average in the WBL Index. Vanuatu and Palau have particularly gender-unequal legal and regulatory environments, with scores of 55.6 and 56.3, respectively. Beyond the Pacific, other SIDS score higher, with low-income Guinea and upper-middle-income Maldives and Suriname sharing the same WBL Index score (73.8), near the global average (77.1). Lower-income São Tomé and Príncipe has an above-average score of 83.1, including component scores of 100 for mobility, workplace, and assets, all critical dimensions of employment and entrepreneurship for women. It is imperative to note that the presence of laws and policies promoting equality can be considered positive in relation to women's employment and ability to do business. However, the WBL score does not measure the implementation or enforcement of these laws.

2.1.3 Financial Inclusion

Worldwide, women's access to finance is disproportionately low (IMF, 2020). This includes access to loans, financial services such as savings accounts, digital payment methods, and insurance. Globally, only 65% of women have access to a bank or other financial institution, including mobile money service providers, compared to 72% of men (World Bank, 2021). Across developing countries, there is a nine-percentage point gap between women and men with respect to having an account at a formal financial institution (World Bank, 2014). Furthermore, several studies have shown that women-managed firms have a lower probability of securing loans than their men-managed counterparts (Muravyev et al., 2009).

This financial disparity has direct implications for women's ability to find work or create job opportunities. For instance, limited access to credit hinders women's capacity to invest in education and vocational training, which is essential for securing employment in various sectors (World Bank, 2018). In addition, female entrepreneurs in developing countries are reported to receive different treatment relative to men with respect to accessing institutions and credit, property rights, and taxation, inhibiting their ability to start a business (ILO, 2015; OECD, 2019b).

Financial inclusion for women in developing countries, including SIDS, is likely to be more restricted than the global average. This restriction is driven by several issues women face when accessing finance, including (i) limiting social norms and (ii) low financial and digital literacy rates (Holliday, 2023). Discriminatory lending is well documented, but restrictive social norms often manifest in women having controlled access to assets like land, reducing their access to finance by limiting collateral to gain secure loans. Finally, due to low financial and digital literacy rates, which translate into difficulties navigating the complicated financial system, women may be less comfortable using financial services and products (AFI, 2016). Evidence for SIDS is limited, but in Vanuatu, only 25% of women had access to an account at a banking institution in 2016, compared to 37% of men (UN Women, 2021). The World Bank's Global Findex Database for 2021 found that 48.96% of women over the age of 15 in the Dominican Republic , and 71.55% of women over the age of 15 in Jamaica, had a bank account. In the Dominican Republic, 21.69% of women over the age of 15 had borrowed money from a formal financial institution, while in Jamaica 10.42% of women over the age of 15 had borrowed from a formal financial institution (World Bank, 2021).

2.2 ACCESSIBILITY DIMENSION

Spatial accessibility refers to the ability to reach or utilize resources, services, or facilities within a specific geographic area or the ease with which any land-use activity can be reached from a location using any form of transport (Dalvi & Martin, 1976). In the context of this report, "accessibility factors" incorporate a distance or time component when estimating women's proximity to enabling facilities, services, or jobs. For example, access to education facilities is dependent on the proximity to facilities, as well as the effort involved in traveling to those facilities (whether the effort is measured in time or distance). Accessibility factors often incorporate a threshold distance or time beyond which something is no longer accessible (Mayen Huerta, 2022). This threshold varies depending on the context and the population of interest (McGrail, 2012).

Accessibility has two common methods of estimation. The first, known as *cumulative opportunity measures*, quantifies the number of destinations reachable from a specific location within a given area or timeframe. For instance, the number of supermarkets a woman can reach in half an hour using public transit. The second, *gravity-based measures* of accessibility, reduce the accessibility value to destinations or opportunities based on the distance involved[3] (Geurs & van Wee, 2004). The further away an opportunity lies, the less accessible it is considered. This is often referred to as "distance decay".

The accessibility factors described below are broadly presented in order of their relevance with respect to creating an enabling environment for women to join the RE sector workforce. At the end of each subsection, potential indicators extracted from the literature are summarized in a table with relevant distance or travel time thresholds. Notably, (i) the relevance of each factor may differ depending on the context of a specific country; (ii) within a given context, several of these factors could be of equal relevance; and (iii) the order below assumes that quality data is available for each factor.

[3] A third category, utility-based accessibility metrics also exits. This assigns a distinct utility or value to each destination. It then computes the logsum of all destinations within a potential choice set to determine accessibility.

2.2.1 Women's Travel Patterns

Women's travel patterns refer to when, why, and how women travel between places. These patterns are influenced by the multifaceted role women play in society as caregivers, which often necessitate complex, multi-stop trips that frequently take place during off-peak hours and differ significantly from men's linear commute patterns (Kwan, 1999; World Bank, 2014). This phenomenon is sometimes referred to as "trip chaining," where women combine several errands into a single trip to save time (McGuckin & Nakamoto, 2005; NHTS, 2017).

The impact of women's unique travel patterns on their labor market participation is significant, as it reduces the time available for women to commute to employment and the time available for full-time work (Sanchez de Madriaga, 2013). This issue is exacerbated by the fact that transport networks for active, private, and public transport are usually designed for men's demand for on-peak travel to work rather than women's off-peak travel to multiple destinations, which constrains women in their transportation choices to work and elsewhere (Legovini et al., 2022). Unpaid work and caregiving responsibilities frequently leave women with limited time, forcing them to work part-time or not at all (Sanchez de Madriaga, 2013).

Overall, differential travel patterns for women have been well documented by empirical studies, most of which rely on detailed travel survey data (Vanderschuren et al., 2023). Indicators for many of these analyses are based on trip chaining and travel time rather than travel distance and include average trip time, time spent on different activities, the average number of activities per trip, or the average number of trips (Subbarao & Krishna Rao, 2013). A travel survey-based study in Mumbai, India, suggested that women make more stops during non-work commutes for family-related activities and estimated the effect of trip activities on economic characteristics (Subbarao & Krishna Rao, 2013). The results of the study showed that women spend up to 50% of their time on non-work activities and that trips can last up to 2.5 hours.

A study in the U.S., used the 1995 Nationwide Personal Transportation Survey (NPTS) and the 2001 National Household Travel Survey (NHTS) to compare differences in travel activities between working parent couples (McGuckin & Nakamoto, 2005). The study identified that women are likely to take twice as many trips to drop off or pick up a child and stop more often for shopping and other household-related errands compared to men (McGuckin & Nakamoto, 2005). However, the study is contextual and does not include any thresholds for the maximum distance women are willing to travel.

A 2007 study in the Netherlands investigated activity fragmentation in space and time, using travel diary data from 740 respondents, and found that the total area traveled by women in a day was significantly lower than for men but also did not explicitly investigate maximum travel distance thresholds (Alexander et al., 2011). Evidence relating to travel distance is generally not differentiated by gender and relates to single trips or activities. Two studies identified a maximum threshold walking distance of approximately 1.5 km or

1 mile. The first, a study from the U.S. using data from 2003 to 2006 analyzed amenities within a threshold distance of 1 mile for 379 addresses to validate the appropriateness of this threshold distance when estimating accessibility (Carr et al., 2011). The second, a 2000-2001 study in the UK which examined the potential for using accessibility methodologies to assist local planning authorities identified a maximum walking distance threshold of 1.5km, or 20 minutes of walking (Gleave & Halden, 2001).

Table 2 Indicators and thresholds for women's travel patterns taken from the literature

No.	Indicator	Threshold	Source
1	Access to childcare/ markets/ grocery stores/ green spaces/ pharmacies (activities)	Maximum distance to amenities: 1 mile (1.6 km) (U.S.)	Carr et al. (2011)
		Maximum walking distance: 1.5 km (Wales)	Gleave & Halden (2001)
		Maximum travel time per trip: 20 min	Gleave & Halden (2001)
		Time per activity: Up to 50% of women's time spent on non-work activities (Mumbai)	Subbarao & Krishna Rao, (2013)
		Number of activities per trip: No relevant threshold indicated in literature	McGuckin & Nakamoto (2005)
		Average trip time: 2.5 hours (Mumbai)	Subbarao & Krishna Rao (2013)

2.2.2 Access to Public Transport

Women are more inclined to rely on public transport (and walking) than men and therefore constitute most public transport users globally (ICLEI, 2021). One reason is that women are less likely to own a vehicle or have a driver's license. Additionally, women are, overall, less prone to undertake trips involving personal vehicles such as bicycles or other motorized modes of transportation (Criado Perez, 2019; World Bank, 2010). Women, especially those in lower income brackets, spend a considerable proportion of their income on public transport. The purpose of public transport is to facilitate livelihoods, but prohibitive fares intensify vulnerability to poverty (Uteng, 2012).

While evidence in SIDS is limited, a survey of 509 respondents in Trinidad, 49% of whom were women, found that 72% of respondents who indicated using public transport were women, while only 43% of those who reported using a private car were women (Wright & Townsend, 2020). Of the public transport users, only 2% of respondents used the government-owned bus service, despite acknowledging that it was the cheapest and the safest form of public transport (Wright & Townsend, 2020). This is thought to be because of the unreliability and lack of coverage of this service. Instead, the most common mode of public transport was maxi-taxis, a paratransit service of mini-buses holding between nine and 25 passengers. Maxi-taxis operate like unscheduled buses, from established stands along well-known routes. Across Trinidad there are 5 000 maxi-taxis, with an estimated annual ridership of 200 million passenger trips (Wright & Townsend, 2020). In this same survey, only 5% of respondents reported walking as their primary mode of transport (Wright & Townsend, 2020).

Moreover, a study of 100 respondents in Mauritius, 58% of whom were women, found that 48% of respondents opted for buses as their daily transport mode (Vencataya et al., 2018). In contrast, 46% used private cars, despite car ownership levels increasing by 98% between 2013 and 2023, while buses only increased by 9% over the same time period (Soomauroo et al., 2023). The primary reason stated for the high bus usage was extreme traffic congestion (Vencataya et al., 2018). The TOD (transit-oriented development) standard recognizes the availability of at least one transit option as a requirement for convenient travel, ideally with a service frequency of 20 minutes or less (ITDP, 2017).

The expansion of urban areas, informal settlements, and the emergence of satellite townships in cities across the world, and in SIDS, with no concomitant public transport, restrict women's mobility to a greater extent than men. This holds true for both low-income and middle-income women (Uteng, 2012). Moreover, because women are time-poor (Hyde et al., 2020) and often constrained to part-time and low-paying jobs (Sanchez de Madriaga, 2013),

In low-income SIDS, paratransit transport, such as mini-bus taxis, is frequently used (Wright & Townsend, 2020), while in Pacific SIDS, water-based transport is widespread and is commonly provided publicly (Britton, 2017). Nonetheless, data on relevant measures and distance accessibility thresholds for these unique forms of transport are limited. More general accessibility thresholds for acceptable walking distances to bus and rail stops exist for high and middle-income countries but not for SIDS.

A literature review of 41 existing studies in the U.S., Canada, the UK, Europe, China, Japan, and Australia, 30 of which were published after 2010, found that the maximum distances walked to public transportation stops varied between 400-800 m for buses (van Soest et al., 2020). In contrast, maximum thresholds for rail, or more frequent bus services, were higher, up to 1.2 km (van Soest et al., 2020). This review did not differentiate between women and men but did report that women generally walk shorter distances than men without specifying how much shorter. A study investigating how far transit users are willing to walk to public transport stops in Munich, Germany, based on a survey of 500 transit users, 55.6% of whom were women, found that people were willing to walk 10-15 minutes to reach these destinations (Sarker et al., 2019). Another study by public health researchers exploring the beneficial impacts of urban design on physically active populations, using data from 12 countries on five continents (including three cities from middle-income countries, Brazil, Colombia, and Mexico), defined accessibility thresholds for public stations as a density measure: 25 public transport stops per km^2 (Cerin et al., 2022).

Table 3 Indicators and thresholds for access to public transport taken from the literature

No.	Indicator	Threshold	Source
1	Access to public transport stops	Walking distance to bus stops: 400-800 m (Meta-analysis of literature from U.S., UK, Europe, China, Japan and Australia)	Van Soest et al. (2020)

		Walking distance to rail stops up to 1.2 km (China)	Van Soest et al. (2020)
		Walking time to transport stops: 10-15 minutes (Germany)	Sarker et al. (2019)
		Density of public transport stops: 25 per km² (12 countries on 5 continents)	Cerin et al. (2022)
		Average cost per km for public transport (bus/ rail/ boat): Currency per km² (no defined threshold)	
2	Access to transport routes with gender segregated carriages	Not available	Kabeer & Mahmud (2004)

2.2.3 Access to Education and Training Facilities

Access to education for women is complex and multifaceted. While this report has previously discussed the impact of a woman's level of education as a barrier to the labor market, access to education in this section deals with the role of physical distance to education and training facilities as a limitation to whether girls can attend school, and women can participate in vocational training facilities or universities. Access to both types of institutions influences a woman's ability, either now or in the future, to receive the education she needs to enter the labor market and take up employment in the RE sector (Massa et al., 2022; Yakubu, 2010).

Evidence of poor physical access to schools is well documented as a significant factor contributing to girls' low educational achievement. In parts of sub-Saharan Africa (Ghana, Malawi) and Asia (Nepal, India, and Sri Lanka), areas with poor roads, expensive transport services, and few education facilities exhibit low enrolment of children, especially girls, due to the high direct costs of travel (cost per trip) and high opportunity costs (including demands on girls to do housework and perform domestic chores) (Uteng, 2012). The converse is also true: increasing physical access to schools leads to higher enrolment for girls (J-PAL, 2017). Improving access to educational facilities comprises improvements in the quality of roads and increasing the number of schools and education centers**.** Data from Morocco in 2012 suggests that around major rural roads, which had been paved, the percentage of girls attending primary school tripled to 54% compared to areas where road improvements had not been made (Uteng, 2012). A study of 31 villages, which included 1,490 children in northwestern Afghanistan, found that introducing village-based schools had more of an impact on enrollment and test scores for girls than boys (Burde & Linden, 2013). Enrollment increased by 52% for girls but only 35% for boys. In addition, girls' average test scores increased by 0.65 standard deviations, whereas boys test scores increased by 0.40 standard deviations (Burde & Linden, 2013).

Physical access to universities and Technical Vocational Education and Training (TVET) institutions has a similar impact on the enrolment of women in higher education. A study in the U.S., which used data from the National Education Longitudinal Study of 1988 to track 17 000 students in 12th grade from 1992 until 2000, investigated the extent to which university proximity is associated with applying and enrolling in college. The study found that close proximity to universities significantly increased enrolments from 68% to 77%, and that the effect of gender on the relationship between proximity and enrolments was highly significant (Turley, 2009). In South Africa, the distance (and mode of transport) traveled to higher education institutions is recognized as playing a significant role in reducing (or increasing) enrolment rates in these institutions (Matsolo et al., 2016). Distances from homes to training centers, coupled with the lack of female boarding facilities , are also recorded as a barrier for women to access education in Rwanda (Nshimirimana & Kitula, 2020).

There are no global time or distance thresholds for the maximum travel time or distance considered as 'acceptable to access schools' (Macharia et al., 2022). However, a radius of 3 km from home was proposed in the 1970s as a standard (Gould, 1978), and more recently, a 5 km radius from home has been recommended for developing countries with low-density of populations (Theunynck, 2009). Work conducted by Mali's Ministry of Education, Literacy and National Languages between 2005 and 2009 used a threshold of 5km when determining whether children had access to a given school (Lehman, 2013). In Kenya, the Ministry of Education aims to have a school within 2 km walking distance of every household (Ministry of Education, 2017). In some instances, travel times are considered rather than travel distances to define access. For instance, in Kenya, the government identifies marginalized school-going children as those that live more than 24 minutes from a school (Macharia et al., 2022). Very little evidence exists for threshold proximities to higher education institutions, but the longitudinal study in the U.S. described above by Turley (2009) proposed a maximum distance of 12 miles in urban areas and 24 miles in rural areas, considering the car-dependent context of the country.

Table 4 Indicators and thresholds for access to education facilities

No.	Indicator	Threshold	Source
1	Access to education facilities	Distance to school: 2-5 km (Developing countries with low density, Mali, Kenya, Sierra Leone)	Theunynck (2009); Lehman, (2013); Ministry of Education (2017)
		Travel time to educational institutions: 24 min (Kenya)	Macharia et al. (2022)
		Distance to higher education facilities: 12 miles (urban), 24 miles (rural) (U.S.)	Turley (2009)

2.2.4 Access to Health Facilities

Access to health services denotes the ease with which residents of a given area can reach health services and facilities (Apparicio et al., 2008). While the concept is multi-dimensional[4], in the context of this report, access to health facilities can be gauged through the distance to health facilities. The maximum distance individuals are able to travel to attend a facility determines the catchment area from which a health facility draws its clientele.

Lack of access to necessary health services can lead to deteriorating health, which can subsequently impair a woman's ability to work effectively. In addition, women are less likely to use health services if they are far from home (Zhang, 2022). Moreover, the availability of specific health services, such as reproductive and maternal health care, profoundly impacts women's ability to manage their roles at home and work (Uteng, 2012). In Pacific SIDS, researchers have argued that to improve women's welfare, it is imperative to expand access to obstetric care facilities (Oyerinde & Baravilala, 2014).

Generally, estimating the optimal spatial distribution of health facilities is primarily based on patient catchment areas. In a study on six SIDS, Federated States of Micronesia, Kiribati, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu, between November 2005 and June 2008, researchers concluded that at least five emergency obstetric care facilities (including at least one comprehensive facility) were required for every 500 000 inhabitants to serve the population adequately and that the travel time to the comprehensive facility should not be more than two hours (Oyerinde & Baravilala, 2014). While Hainan Island is not a SIDS, one study there calculated the shortest travel times to healthcare institutions across three tiers before applying an 'Enhanced Two-Step Floating Catchment Area Method' to determine if most of the population lived within defined service ranges (defined in terms of travel time) of different healthcare tiers. The tiers included in the study were: 60 min for Tier 3 (hospitals), 30 min for Tier 2 (health centers), and 15 min for Tier 1 (clinics) (X. Wang et al., 2021).

The number of hospital beds per 1 000 people per health service area (HSA) is used in developed countries like the U.S., where data on hospital beds and granular population distribution are available (Jia et al., 2019). The recognized minimum threshold in this instance is one bed per 1 000 people. Standards focusing on maternal health in developing countries like India include guidelines that indicate that the primary health services delivered through a three-tier system should have a sub-center for a population of 5 000, a primary health center for a population of 30 000, and a community health center for a population

[4] The other aspects that may be used to estimate access to health include (i) availability (the supply of healthcare services, including the number of healthcare providers); (ii) affordability (the economic capacity of individuals to seek care); (iii) accommodation (degree to which healthcare services are organized to accommodate the preferences and constraints of patients) ; (iv) acceptability (patients' attitudes about personal and practice characteristics of healthcare providers) – see (Penchansky & Thomas, 1981) {, #0}

of 120 000 (Vadrevu & Kanjilal, 2016). Very few studies consider maximum travel distance as a threshold for access to health facilities. However, a study in the U.S., using state-level data on hospitalizations from the 2018 Healthcare Cost and Utilization Project (HCUP), found that the median travel distance to hospitals was 6.6 miles, and 75% of all trips were less than 14.35 miles (Weiss et al., 2021). This study included patient discharge information from 47 states and included 690 451 unique hospital/patient address combinations but did not distinguish between the gender of patients (Weiss et al., 2021). Of course, in the U.S., many patients have access to private vehicles, which is not necessarily true for women in SIDS.

Table 5 Indicators and thresholds for access to health facilities from the literature

No.	Indicator	Threshold	Source
1	Access to health facilities	Median travel distance to hospital: 6.6 miles 75th percentile travel distance to hospital: 14.35 miles (U.S.)	Weiss et al. (2021)
		Travel Time to hospital: Hospitals: 60 min; Health centers: 30 min; Clinics: 15 min (Hainan Island, Marinduque island, Philippines)	Wang et al., (2021)
2	Hospital beds per 1 000 people	1 bed (in developed countries like the U.S.)	Jia et al., (2019)
3	Access to maternal health services	Catchment population for Obstetric Care Facilities: 5 facilities (including one comprehensive) for every 500 000 inhabitants. Time travel to blood transfusion and obstetric surgical care: 2 hours (6 pacific SIDS countries)	Oyerinde & Baravilala, (2014)
4	Catchment population per health center	Threshold population per tier: Clinics: 5 000 people; Health centers: 30 000 people; Hospitals: 120 000 people (India)	Vadrevu & Kanjilal, (2016)

2.2.5 Access to Financial Facilities

Financial inclusion has been identified as an enabler for seven of the 17 SDGs, including SDG 5 (Gender Equality). Financial inclusion defines where and how individuals and businesses have access to useful and affordable financial products and services that meet their needs, including transactions, payments, savings, credit, and insurance (World Bank, 2022b). The “where” in this definition expands the factor into the spatial realm. Access to financial facilities in the context of this report refers to the proximity to large- and small-scale lending facilities.

Although financial inclusivity in recent years has been largely linked to digital inclusion (Faboade, 2023), the physical location of facilities remains relevant. Access to financial facilities is dependent on how far customers may have to travel to access financial services (Fibæk et al., 2021). While evidence on access to financial facilities from SIDS is limited, parts of rural Africa share characteristics with low-density SIDS and can thus provide helpful evidence for determining geographic thresholds. Forster et al. (2013) explored access to financial facilities in East Arica based on minimum population densities and threshold distances. They found that rural settlements with population densities below 75 households per square kilometer required a catchment area with a 5 kilometer radius to support a mobile money facility (Forster et al, 2013). Additional evidence from Africa suggests that the accessibility to formal financial services drops off quickly as the distance from urbanized cores increases beyond 3 km (Peachey & Mutiso, 2019). In rural areas, agency banking, whereby a banking institution vets and hires a third party to offer financial services on its behalf, is often applied to improve financial inclusion. Services carried by such agents can include cash withdrawals and deposits, bill payments, and mobile banking services (Lotto, 2016). Therefore, the location of mobile money agents is a potential indicator when spatially defining financial inclusivity.

Table 6 Indicators and thresholds of access to financial facilities from the literature

No.	Indicator	Threshold	Source
1	Access to mobile money facilities	5km (rural) - Tanzania	Forster et al, (2013)
2	Access to financial facilities	Distance from urban core - 3 km (Zambia)	Peachey and Mutiso (2019)

2.3 PLACE CHARACTERIZATION DIMENSION

"Place-characterization factors" refer to attributes or features that describe a specific geographic location or environment and do not include a mobility component. These may include physical attributes like weather, infrastructure, as well as other aspects of places such as population density and the quality of basic services available. Similar to accessibility factors, the place characterization factors described below are broadly presented in order of their relevance with respect to women's access to employment, with a parallel caveat that these are likely to vary depending on context. For each factor, potential indicators extracted from the literature are provided in a table.

2.3.1 Active Transport

Active transport refers to the quality of road infrastructure and the extent to which it supports safe, efficient, and comfortable walking or cycling for women. This factor encompasses non-motorized transport modes, such as wheelchairs, or hybrid versions, such as electric bicycles and mobility aid equipment.

It is well-documented that women often walk more than men. For example, a study collating travel surveys for 19 major cities across 14 countries representing a mix of low, middle, and high-income countries (Ghana, Kenya, South Africa, India, Australia, England, Germany, Switzerland, Argentina, Brazil, Chile, Colombia, Mexico, and U.S.), found that women are more likely to rely on active transport (primarily walking), and, in most cities, they are more likely to use public transport than men (Goel et al., 2023). In general, walking and cycling in developing countries increase transport options and opportunities for low-income groups (Joewono & Kubota, 2006; Srinivasan, 2005). Thus, the quality and walkability of roads should be considered key factors in determining whether a region supports women's mobility.

Walkability indexes encompass various aspects of road safety, primarily focusing on street design, configurations, and public safety perceptions. Poorly maintained, unsafe, or non-walkable environments, which include elements such as inadequate street lighting, lack of pedestrian paths, lack of ramps, and unsafe crossing points, can deter women from choosing to travel by foot (Loukaitou-Sideris, 2014). High-quality street design and configurations consider elements such as the presence and condition of pavements, cycle lanes, and traffic calming measures such as pedestrian crossings, as well as street connectivity (Frank et al., 2010).

Land-use mix, and density also influence walkability. Mixed land uses that include high-density residential developments, retail, services, offices, education, health, leisure, and community centers in close proximity will promote walking between these different uses (Brown et al., 2009; Cervero & Kockelman, 1997). In addition, the availability of street lights to ensure a degree of safety at night is a critical factor that enables or detracts the movement of women (Loukaitou-Sideris, 2014; Pak & Gannon, 2023).

A number of tools have been developed to assess walkability. For instance, 'Pedestrians First' is a tool to measure walkability in cities and neighborhoods (ITDP, 2020). This tool considers 11 indicators (presence of walkways; presence of crosswalks, visually active frontage (if people can see in and out of buildings a space feels safer), physically permeable frontage, presence of shade and shelter for hot or rainy days, small block sizes, connectivity of streets, complementary land uses, access to local services, driveway density, and road widths - where narrower streets tend to make women feel more comfortable due to their human scale) to estimate the degree of walkability in neighborhoods (ITDP, 2020). When calculating walkability scores for entire cities, the tool considers the percentage of people near services (goal of 100%), the percentage of people near transit (goal of 100%), block density (goal of 80 blocks per square kilometer), population density (goal of 15 000 people per square kilometer) and the percentage of people living within 100 meters of car-free places (goal of 100%) (ITDP, 2020). The tool has not been implemented in many SIDS cities, but for those where it has, they do not generally score well in all categories, particularly with respect to car free spaces and distance to amenities. Additionally, data on public transit access was not available for any of these cities (Table 7). In 2017 the Institute for Transportation and Development Policy (ITDP) published the TOD (transit-oriented development) Standard, which identifies minimum standards to ensure "the rights of all to access the city: to walk and cycle safely, to easily and affordably reach the most distant destination through rapid and frequent transit, and to live a good life free of dependence on cars" (ITDP, 2017, pp. 4). The TOD Standard identifies an ideal block length of 110m for walkability, with a maximum walkable block length of 200m (ITDP, 2017).

Table 7 Pedestrians First Walkability Scores for SIDS cities (ITDP, 2020)

	Kingston (Jamaica)	**Santa Domingo (Dominican Republic)**	**Santiago de los Caballeros (Dominican Republic)**	**Port Louis (Mauritius)**	**Port-au-Prince (Haiti)**
People near services	38%	56%	41%	47%	79%

(Goal: 100% of residents)					
People near transit (Goal: 100% of residents)	Not available	Not available	Not available	Not available	Not available
Block density (Goal: 80 blocks per km²)	37	67	57	44	38
Population density (Goal: 15 000 per km²)	7 378	14 315	8 638	7 553	29 125
Car free places (Goal: 100% of residents)	14%	14%	9%	3%	37%

The National Walkability Index developed by the US EPA (Environmental Protection Agency) considers street intersection density, proximity to transit stops, and diversity of land uses to estimate walkability. While there are numerous other indicators contributing to walkability, the National Walkability Index focuses on these because they can be measured through variables in a nationwide database (EPA, 2021).

The Walkability Index developed by the Prince's Foundation in the UK is calculated at a building scale and focuses entirely on land use. For each building, the number of land uses that are accessible within a five-minute walk are determined, and the building is given a walkability score based on this number (The Prince's Foundation, 2020). A preliminary investigation to develop a "Global Walkability Index" proposed a more complex measure that incorporated additional factors such as cleanliness, pedestrian safety, education, and perceptions of convenience, which are difficult to estimate spatially. Each of the indicators for this index is estimated in the form of a Level-of-Service (LOS) unit on a scale from 1 to 5, and then walkability is calculated by adding up the scores (Krambeck & Shah, 2006).

Evidence relating to cycle use by women in SIDS is limited, but a study of 35 cities in 17 different countries, ranging from low to high-income countries, provides evidence in comparable contexts (Goel et al., 2022). The countries in the study included Kenya, South Africa, India, Japan, Australia, England, Finland, Germany, Netherlands, Switzerland, Canada, Mexico, U.S., Argentina, Brazil, Chile, and Colombia. The travel patterns in Brazil, Argentina, Colombia, Chile, Mexico, South Africa, Kenya, and India are most comparable to low and middle-income SIDS. The mode share for cycling in these countries was highest in Argentina at 8.3% and lowest in South Africa at 0.3% (Goel et al., 2022). For high-income countries, cycling rates were highest in the Netherlands at 27%, followed by Japan at 11%. The proportion of women cyclists in low to middle-income countries ranged from 8% in India to 42% in Argentina. Of the 35 cities in the study, cities in low to middle-income countries ranked between 13 and 35 concerning the proportion of women cyclists (Goel et al., 2022). The ratio of women cyclists was highest in Japan and the Netherlands at 56% and 54%, respectively. These results suggest that the use of bicycles and the proportion of women who use them is likely to be highly variable across SIDS. The TOD standard states that a complete cycling network is achieved when 100% of street and path segments are open and safe for cycling. Safe conditions mean that roads with a speed limit of over 30km/h should have segregated cycle paths, and streets below this speed limit should have cycleways indicated (ITDP, 2017). London Cycling Design Standards state a minimum cycleway width of 1.5m (TFL, 2019). The Urban Bikeway Design Guide written by the National Association of City Transportation Officials in the U.S. states a minimum width of 4ft but a preferred width of 6ft (or approximately 2m) for cycleways (NACTO, 2012).

Table 8 Indicators relating to quality and walkability of roads from the literature

No.	Indicator	Source
1	Road quality: Road surface condition and type (surfaced roads cause fewer accidents)	(S. Chen et al., 2017)
2	Walkability indicators: • Presence and condition of pavements • Density of pedestrian crossings (high density promotes walkability, no clear threshold, but if assume a minimum of one crossing per block, and ideal block density is 80 blocks per km², then ideal crossing density is the same) • Permeability of street frontages • Presence of shade and shelter • Small block sizes (maximum block length of 200m) • Connectivity of streets and walkways • Multiple land uses • Narrow streets • Distance to car free spaces such as parks	EPA (2021); ITDP (2017); ITDP (2020); Krambeck & Shah (2006); The Prince's Foundation (2020)
3	Presence of streetlights	Falchetta et al. (2019)
4	Incidents of petty crime/ road accidents (sourced from police records)	Pak & Gannon (2023)
5	Public Transport: Number of public transport options available (at least one)	ITDP (2017)
6	Cycleways: % of street and path segments safe for cycling. Minimum cycleway widths of 1.5-2 m.	ITDP (2017); NACTO (2012); TFL (2019)

2.3.2 Safety

Safety for women is a broad topic encompassing both experienced and perceived safety. It includes the right to move around freely, the ability to access public spaces and services, the freedom from sexual harassment and of choice concerning the place of work (Suri, 2011; Mayen Huerta & Utomo, 2022). A study in Mexico conducted 24 group interviews with junior high school, high school, and university students to understand the conditions resulting in insecurity in public spaces (Almanza Avendaño et al., 2022). The results, based on responses from 168 women with an average age of 16.7 years, found that 95% of young women experienced sexual harassment daily, both on the street and in public transport (Almanza Avendaño et al., 2022). Fear of harassment or violence directly impact women's desire to travel, attend work, and apply for work opportunities outside of the area in which they live (UN Women, 2023). As such, safety is a key enabler for employment in the RE sector.

For instance, a persistent issue that hinders public transport use, especially in many developing countries, is sexual harassment on public transportation services or in associated areas such as poorly lit adjacent streets, subway stations, and paths connecting informal settlements to bus stops (Anand & Tiwari, 2006; Tanzarn, 2008). These safety issues are a form of social exclusion that affects many aspects of a woman's life, including their economic opportunities (Deniz, 2016). A 2021 study on sexual harassment on public transport in Nigeria and Malawi analyzed travel survey data from 1,478 respondents (58% of whom were women) and found that women carry a significantly higher sexual harassment burden than men, affecting all aspects of trips including traveling to and from the system, while waiting for a vehicle and in it (Vanderschuren et al., 2023).

The importance of women's safety in guaranteeing gender equality is reflected in the specific inclusion of 'freedom from violence against women and girls' in SDG 5 (Gender Equality) (Chant & McIlwaine, 2015). In particular, women in SIDS experience high levels of fear and feelings of unsafety in public spaces. In a focus group including 236 girls between the ages of 14 and 24 in the Solomon Islands, for example, 93% reported feeling unsafe in public (Ro, 2021). Sexual harassment is also common in other SIDS (Fiji Women's Crisis Center, 2013; UN Women, 2023; UNDP, 2013; World Health Organization, 2021). For instance, in Grenada, 26.6% of women have experienced non-partner sexual harassment in their lifetime (Scantlebury, 2022).

Women's perceptions of safety are strongly linked to the physical characteristics of the built environment (Mayen Huerta & Cafagna, 2021). In recognition of this fact, the theory of 'crime prevention through environmental design' (CPTED) is focused on altering the built environment to reduce opportunities for crime in public spaces and, thus, enhance safety levels (Cozens et al., 2005). The physical aspects of the built environment that are recognized as important for CPTED can be used as key spatial indicators for improving women's perceptions of safety in public spaces and are discussed in more depth below.

Having a clear line of sight is fundamental to feeling safe in public spaces as it allows one to avoid danger and escape it when present (City of Cape Town, 2013; Matzopoulos et al., 2020). Several features of the built environment can enhance visibility and reduce feelings of entrapment. The street layout should promote visibility. For instance, straight streets and high network connectivity provide high visibility and reduce feelings of entrapment. If a woman can see clearly down a street and can turn off easily if she senses danger, she will feel safer and is more likely to choose to walk on that street (City of Cape Town, 2013; Matzopoulos et al., 2020). Street connectivity also helps slow down traffic, reducing the physical danger to pedestrians from automobiles (Stangl, 2015).

On the other hand, dense vegetation that blocks the line of sight reduces perceptions of safety (Jansson et al., 2013). The fear associated with the presence of woodland vegetation in urban parks and residential areas has been described by studies in the UK, Canada, and the U.S. and is particularly limiting for women (Jansson et al., 2013; Keane, 1998). In contrast, the presence of streetlights promotes visibility at night and enhances perceptions of safety (Fotios et al., 2019). Without streetlights, women tend to limit their work at night, reducing their employment options (Great Britain Office for National Statistics, 2021; Herbert & Davidson, 1994). While there are no clear guidelines on how far a woman needs to be able to see to feel safe, a study in the UK on the perceptions of safety found that uniformity of light was more important than its intensity (Fotios et al., 2019). The study investigated how changes to illuminance affect pedestrian reassurance when walking after dark; it included 24 participants with a mean age of 24 years and an equal balance of women and men (Fotios et al., 2019). In simple terms, the study found participants felt safer in areas where streetlights were evenly spaced (Fotios et al., 2019; Monteiro et al., 2018).

Another crucial aspect of safety for women in public spaces is passive surveillance, which is effective in reducing both crime and fear of crime (Cozens et al., 2005; Matzopoulos et al., 2020). The design of public spaces can promote passive surveillance so women can be easily observed by bystanders, thereby making it harder for crimes to take place without witnesses (Cozens et al., 2005). Spatially measurable indicators of passive surveillance include land use mix, city block layout, and street design. Land uses that have several functionalities encourage multiple users throughout the day (i.e., mixed-use), improving perceptions of safety by attracting more people and generating activity during the night and day (Basu et al., 2022; City of Cape Town, 2013; Cozens et al., 2005; Landman, 2012). Conversely, vacant land, car parks, and industrial districts reduce perceptions of safety as they are less populated, and people do not linger in them (Basu et al., 2022; Mayen Huerta & Utomo, 2022).

Similarly, block edge development, whereby buildings are positioned with a minimal setback from the street and fronting onto it, creates positive and activated edges and encourages casual observations of passers-by (Matzopoulos et al., 2020; Tsoriyo et al., 2021). Multiple-floor buildings also increase visibility and, thus, passive surveillance (Matzopoulos et al., 2020). However, when buildings become too tall or streets become too wide, they lose their 'human scale,' which is strongly linked to feelings of comfort (Freedman, 2014). A street is considered human scale when the street width to building height ratio is 1:1 (Freedman, 2014).

The presence of police should directly increase the perception of safety (Matzopoulos et al., 2020; Tsoriyo et al., 2021). However, in many SIDS, police are viewed with fear due to frequent incidents of police brutality and the use of excessive force (Forde, 2023). For instance, a qualitative study of police brutality in Trinidad and Tobago, which included interviews of 18 participants (15 men and three women) from low-income communities who had experienced police brutality in the past (ages ranging from 18 to 55), found common themes of physical abuse, verbal abuse, psychological abuse, distrust, and feelings of helplessness (Forde, 2023). The study proposed that the high levels of police force are a relic of colonialism, which is familiar to many SIDS (Forde, 2023).

A 2012-2013 survey of 352 students in Sweden, 49.1% of whom were women, found that women's perceptions of safety were heightened in the presence of uniformed officers (Camacho Doyle et al., 2015). Similarly, a study investigating the perceptions of safety of 500 pedestrians in a 2020 survey of rural towns in South Africa identified police presence as a prerequisite to street safety (Tsoriyo et al., 2021). Moreover, a study conducted in Mexico City using a photo-journal methodology to investigate the perception and use of public spaces found that nearly all women viewed the presence of police as a stressor, indicating a lack of confidence in the authorities (Mayen Huerta & Cafagna, 2021).

This mixed evidence suggests that police presence may be an unreliable measure of perceived safety, as public mistrust of police in SIDS makes it challenging to ascertain whether the presence and availability of police would enhance or reduce women's feelings of safety. A more reliable indicator of security of women is the occurrence of crime incidents in a location (Kmet' & Dvorak, 2020; Pak & Gannon, 2023). A study using household survey data collected between 2001 and 2015 in Queensland, Australia found that the negative mental health impact of crimes against the person (such as homicide, robbery, assaults and sexual offences) was 6.7 times larger than the effect of crimes against property (such as arson, unlawful entry, theft and fraud) (Pak & Gannon, 2023). Kmet' & Dvorak (2020) propose the use of a crime index, expressed as the ratio of registered crimes to the number of residents, to compare crime rates spatially.

Table 9 Indicators of safety from the literature

No.	Indicator	Description	Source
1	Street layout	Gridded, straight, many intersections enhance safety (no clear threshold in literature, but 80 blocks per square kilometer or block length of 200m are accepted thresholds of walkability which is closely linked to safety)	City of Cape Town (2013) ITDP (2017) ITDP (2020)
2	Density of vegetation	Vegetation that blocks line of sight in public space reduces safety	Jansson et al. (2013)
3	Street lighting	Areas with high density of night-time lights are safest.	Falchetta et al. (2019)
4	Land use and activity	Mixed use areas that include retail, commercial and residential and promote activity throughout the day and night are safest	City of Cape Town (2013)
5	Building height	Multiple floors provide elevated lines of sight; however, this reduces in safety when it exceeds the human scale (4-6 floors)	Freedman (2014)
6	Human scale street design (defined in text)	Ideal street width: building height ratio of 1:1	Freedman (2014)
7	Crime Index: Number of crime incidents per number of residents	Crime Index per 1000 people = (Registered Crimes/Number of Residents) x 1000	Kmeť & Dvorak (2020)

2.3.3 Fragility, conflict, and violence

Regions that experience fragility, conflict, and violence (FCV) often show exacerbated levels of gender-based violence (GBV) (Strachan & Haider, 2015; World Bank, 2023b). In this context, GBV is also a form of political and economic violence that heightens gender inequalities and instills fear and repression in communities (Davies et al., 2016). SIDS countries fall in the medium range of risk concerning FCV compared to other countries (Carment et al., 2006). According to the World Bank's Classification of Fragile and Conflict-Affected, no SIDS were in conflict situations in 2023 (World Bank, 2023b). Nonetheless, Comoros, Guinea-Bissau, Haiti, Marshall Islands, Federated States of Micronesia, Papua New Guinea, Solomon Islands, Timor-Leste, and Tuvalu were all listed as experiencing institutional and social fragility. In addition, between 2006 and 2022, many of these countries, as well as Kiribati and São Tomé and Príncipe, were listed as in 'fragile situations' on more than one occasion. Fragile situations cover a spectrum of vulnerability, including countries with deteriorating governance, those in prolonged political crisis, post-conflict transition countries, and those in gradual but still fragile reform processes (World Bank, 2023b).

Women who live in areas experiencing elevated levels of FCV are forced to take on more responsibilities related to family security and livelihoods (UNFPA, 2002). They experience increased levels of danger, and their daily tasks as providers and caregivers become more complex, especially as public services and household goods are less available. In these situations, women are often forced out of the formal sector, and with increasing competition in the informal sector, they may be pushed into dangerous illegal activities (UNFPA, 2002). GBV also spikes in post-conflict societies due to the general breakdown of the rule of law, the availability of small arms, the breakdown of social and family structures, and its “normalization” as an additional element of pre-existing discrimination (UN OHCHR, 2022). Thus, opportunities for women will be minimized not only in areas currently experiencing conflict but also areas that have experienced conflict in the past.

Spatially located FCV events that could serve as proxies of GBV and enhanced levels of danger for women include records of protests, riots, battles, explosions, and violence against civilians, both recent and in the past decade. The Armed Conflict Location & Event Data Project (ACLED) provides information with which to characterize regions of high vulnerability to FCV. It includes spatial data on dates, locations, fatalities, and types of violence and protest events around the world (number of events in a given time period). Event types are grouped into battles, explosions, violence against civilians, non-violent protests, riots, and strategic developments. The event types most likely to impact women include violence against civilians (which has been further expanded to identify events of violence targeting women), riots (violent events where groups are destructive and often violent against people), and explosions (when used against civilians) (ACLED, 2023). Likewise, the OECD Sahel and West Africa Club has developed a method of mapping violence in North and West Africa using the ACLED dataset and information related to population density, which considers the distribution and intensity of violent events in order to categorize conflicts into four types of conflict: (i) clustered high intensity, (ii) dispersed high intensity, (iii) clustered low intensity, and (iv) dispersed low intensity (OECD/SWAC, 2023).

Table 10 Indicators of fragility, conflict, and violence

No.	Indicator	Description	Source
1	Number and location of conflict, violence, protest events	Event types most likely to impact women include violence targeting civilians/women, riots and explosions.	ACLED (2023)
2	Category of conflict events	Four types of conflict based on distribution and intensity: Type 1: clustered high intensity (more events than mean and closer together) Type 2: dispersed high intensity (more events than mean and further apart) Type 3: clustered low intensity (fewer events than mean, closer together) Type 4: dispersed low intensity (fewer events than mean, further apart)	OECD/ SWAC (2023)

2.3.4 Women’s Education in STEM

The level of education in a region a crucial factor in determining women’s future employment opportunities and economic empowerment since education equips individuals with the skills and knowledge necessary to succeed in the workplace (OECD, 2019a). Education can also contribute to the development of non-cognitive skills such as communication, problem-solving, and teamwork, which are highly valued by employers (Heckman & Kautz, 2012). Eligibility for jobs in the formal sector and preparedness for starting a business generally requires completion of at least secondary education (typically schooling between the ages of 12 and 17). Post-secondary education at technical training colleges or universities can be the gateway to skilled positions or relatively senior roles (Tembon, 2022).

In the context of RE jobs, STEM (Science, Technology, Engineering, and Mathematics) qualifications are particularly important. However, there is a notable difference worldwide in the participation of women and men in STEM education and jobs (Schomer & Hammond, 2020). While girls often perform as well or better than boys at the primary and secondary school levels, they are often under-represented in STEM subjects at the tertiary school level and in the workplace. The reasons for this underrepresentation are varied and include social and gender norms, legal barriers, employer biases, inflexible working hours, sexual harassment, and lack of professional networks (Schomer & Hammond, 2020). Therefore, the rate of women graduating from or enrolling in STEM careers serves as a strong indicator of societal attitudes towards women in STEM roles.

Data collated by the UNESCO Institute for Statistics (2014-2016), which includes evidence from 115 countries and dependent territories, suggests that only 30% of all female students select STEM-related fields in higher education (UIS, 2016; UNESCO, 2017). Globally, only 6.6% of women graduate in Engineering and Manufacturing degrees, compared with 24.6% of men (World Economic Forum, 2022), while women fill only 28% of the STEM jobs in the RE sector, compared to 45% of the administrative jobs in the industry (IRENA, 2019).

Women in many SIDS make up a relatively small proportion of enrolments in STEM degrees and Technical Vocational Education and Training (TVET) Energy Programs. According to 2020 data from four major Pacific training institutions, there were dramatic gender gaps in enrolment. In the Australia Pacific Training Coalition, there were only seven women among 200 STEM students; at Fiji National University, there were 21 women among 100 STEM students; and at the Kiribati Institute of Technology, there were 60 women among 300 STEM students[5]. Moreover, no woman is enrolled in the College of the Marshall Islands' solar PV training course – in a country where 81% of rural homes have solar panels as their main source of energy (UN Women, 2021).

In developing countries, indicators related to women's STEM education include the number of women enrolled in and graduating from STEM programs. These data can be transformed into indices, such as the Women in STEM Education Index, to provide a comparative measure of female participation in STEM fields.

[5] The Pacific Energy and Gender Network study focused on engineering, chemistry, and marine science.

Other measures include survey responses on the quality of STEM education for women and the availability of resources specifically targeted at female STEM students.

2.3.5 Digital Inclusion

Digital inclusion refers to the equitable access to and meaningful use of digital technologies and services. In the context of employment opportunities for women, digital inclusion pertains to the ability of women to gain access to technological infrastructure, like mobile phones and the internet, as well as the skills to effectively utilize them. A crucial aspect of digital inclusion is that it promotes access to online education, which is increasingly seen as a method of overcoming spatial disparities in access to education (Atchoaréna et al., 2008). In Cabo Verde, for example, between 2002 and 2006, the number of students enrolled in online courses at Jean Piaget University increased from 427 to 5,285, although it is not clear how many of these enrolments were women (Atchoaréna et al., 2008).

Today, the 'digital gender gap,' the disparity between men and women regarding access to, use of, and influence on digital technologies and digital literacy, is large. This gap is especially considerable in developing countries (International Telecommunication Union, 2021). For instance, a study conducted by the World Wide Web Foundation and the Alliance for Affordable Internet in 2011 found that a third of women in developing countries were connected to the internet compared with almost half of men (Johnson, 2021). This trend had barely improved after ten years, increasing just half a percentage point from 30.4% to 30.9% in 2021. In developing countries, men are 21% more likely to be online than women, with 52% of men more prone than women to being online in poorer countries (Johnson, 2021).

In SIDS, the digital gender gap has been increasing in the Asia-Pacific region since 2013. The Pacific Islands region has the lowest mobile internet penetration rate of any world region, at just 18 %, with access significantly lower among women, especially those living in rural areas (Boccuzzi, 2021). For women who do have digital technologies access, there is a growing and persistent gap in the meaningful use of mobile technology. Women tend to use mobile phones (and mobile internet) differently and often less frequently than men (United Nations University, 2019). If women are to become more involved in the digital economy, improving their access to digital technologies and skills is critical.

While some of the barriers that prevent women and girls from accessing digital technology are non-spatial[6], access to digital technologies is spatially distributed. Globally, the share of internet users in

[6] Going online, including expensive handsets and data tariffs, social norms that discourage women and girls from being online, fears around privacy, safety, and security and a lack of money (Johnson, 2021). According to CARE, women's mobile use in the Pacific is

urban areas is almost twice as high as in rural areas. In SIDS, the disparity between urban and rural areas is more than double (urban: 77%; rural: 32%) (International Telecommunication Union, 2020), mainly due to the distribution of mobile networks and internet coverage.

Within cities, many informal areas across developing countries, even in well-connected cities such as Kigali, Rwanda, ICT Access Indicators – which include indicators measuring ownership of ICT assets such as radios, TVs, mobile phones, and computers and location of use, including home, office/school, cyber care – reflect urban inequalities in infrastructure provision, and exacerbate digital divides (Otioma et al., 2019). Spatial digital divides are aggravated by the lack of broadband access at home, which is increasingly of vital importance to access employment opportunities and for work. A combination of high infrastructure costs, low population density, and low competition is manifested in geographic disparities, which leave households, and women in these households, in marginalized conditions with limited or substantially lower accessibility (Reddick et al., 2020).

Measures of the digital divide center around survey data on access to ICT devices. These data include household surveys or census (Reddick et al., 2020). In developing countries, indicators related to digital divide include measures of access to computers and radios. Often these data are transformed into dimensionless indices such as the ICT Access Indicator. Other measures of internet access include survey responses to the availability of broadband internet access (Reddick et al., 2020). Finally, in some instances, access is measured by identifying whether households are located within a 1-3km radius of 3G towers (Dahmani-Scuitti et al., 2020).

Table 11 Indicators and thresholds of digital inclusion from the literature

No.	Indicator	Measure	Source
1	Internet access	Yes- 1; No -0	Reddick et al. (2020)
2	Digital literacy rates	% of the population	International Telecommunications Union (2020)
3	Tower coverage	1km-2km (urban); 3km (rural)	Dahmani-Scuitti, et al. (2020)

2.3.6 Water and Sanitation

Access to water and sanitation can be both a place-characterization and an accessibility factor. As a place-characterization factor, water and sanitation security refers to the "availability of an acceptable

circumscribed by gender norms dictating that males should control access to information within the household, and mobile phone use by female family members has been used as a rationale for GBV (CARE 2020, 9).

quantity and quality of water [and sanitation services] for health, livelihoods, ecosystems, and production" (Belmar et al., 2016 pp. 181). When piped water is not available inside the home, the distance that must be traveled to obtain clean water can be considered a barrier, making it an accessibility factor. However, the number of water sources within a defined area could also be represented as a density measure, which characterizes a place.

Access to freshwater is a major concern for many SIDS. Many are experiencing increasing shortages of freshwater as a result of multiple pressures and climate change impacts on their already vulnerable freshwater resources (UNOPS, 2021). The Integrated Water Resources Management (IWRM) in Atlantic and Indian Ocean (AIO) SIDS project in Comoros, Cabo Verde, Mauritius, Maldives, São Tomé and Príncipe, and Seychelles found that access to and management of uncontaminated freshwater was the biggest challenge for these countries with respect to climate change (UNOPS, 2021).

In many developing countries, rural women do not have access to piped water and sanitation. Similarly, women in urban informal settlements often do not have access to piped water (World Bank, 2017). Poor water and sanitation have an impact on family health; girls specifically are affected by poor access to water and sanitation during menstrual cycles when they tend to skip school, which impacts their ability to finish school and attain higher education levels (World Bank, 2022c). When water is not available inside the home, the burden of traveling (most often walking) to collect water most often falls on women and girls (Hallett, 2016).

Measures of access to water and sanitation are commonly linked to surveys. Household surveys and census definitions use a battery of questions to identify (i) where water and sanitation services are accessed and (ii) the quality of the services delivered. Responses to these questions are then used to identify whether households have access to improved or unimproved services (World Bank, 2017). The percentage of households with access to piped water, as well as the number of liters available per person, are indicators of access to water and sanitation as a place characterization factor.

The United Nations Human Rights Office of the High Commissioner defines the minimum amount of clean water required per person as 20 liters per day. In comparison, the full realization of the right to clean water is set at 50-100 liters per person daily (UN OHCHR, 2023). When piped water is not available inside the home, basic access to water is defined as water obtained from a source, if collection time is not more than 30 minutes for a walking round trip (WHO, 2023).

Table 12 Indicators and thresholds of access to water and sanitation from the literature

No.	Indicator	Threshold	Source
1	% households with access to piped water (%) (place-characterization)	% (no threshold)	World Bank (2017)

2	Number of liters accessed per person per day (place-characterization)	Min 20 liters per person per day Full realization of right to clean water: 50-100 liters per person per day	UN OHCHR (2023)
3	Density of water source locations within a region (place-characterization)	n/a	
4	Water source locations (time to water source) (accessibility)	30-minutes round trip	WHO (2023)

2.3.7 Environmental Hazards

The 2022 Intergovernmental Panel on Climate Change (IPCC) report on impacts, adaptation, and vulnerability to natural disasters confirmed that SIDS are increasingly affected by tropical cyclones, storm surges, droughts, changing precipitation patterns, coral bleaching, and alien invasive species (IPCC, 2023). As early as 30 years ago, it was noted that SIDS are particularly vulnerable to environmental disasters caused by climate change (UN SDG Knowledge Platform, 1994). More recently, the SAMOA Pathway (UN-OHRLLS, 2014) recognized the adverse impacts of climate change and sea-level rise on SIDS' efforts to achieve sustainable development as well as to guarantee countries' survival and viability.

A 2015 survey of women from 40 households on Rabi Island in Fiji, which examined the links between poverty levels and climate change impacts, found that drought, floods, and cyclones had the most impact on women's livelihoods (Moncada & Bambrick, 2019). Specifically, drought adversely affected drinking water quality and quantity, soil fertility (and thus income loss), and school attendance, while floods damaged roads, water pipes, and closed schools. Cyclones caused damage to crops and houses (Moncada & Bambrick, 2019). These impacts significantly increase women's unpaid workloads and reduced their ability to undertake formal employment (Moncada et al., 2021). Global datasets showing cyclone tracks and prevalence (World Bank, 2023c), drought occurrences (Tian et al., 2022), and floods based on either topographical and hydrological studies or through records of remote sensing during and immediately after flood events can help to identify regions of high vulnerability (Global Flood Database, 2023).

In the tropical Western Pacific, where several SIDS are located, rates of sea level rise of up to four times the global average (approximately 12 mm per year) have been reported (UN-OHRLLS, 2015). Socioeconomic impacts from hazards relating to sea level rise include fatalities and injury to people, destruction and damage to infrastructure, agricultural and other economic sectoral losses, disruption of human activities and services, loss of cultural heritage and sites, and increased overall human and infrastructural exposure and vulnerability (Martyr-Koller et al., 2021). In addition, sea level rise puts populations in SIDS at high risk of displacement. Population displacements, in return, result in significant interruptions to employment and education, among other factors (Massa et al., 2022). Sea level rise disproportionately affects women, because they commonly have reduced mobility and financial capacity to acquire new land and face systemic violence during periods of instability (McCarthy, 2020).

Many SIDS are characterized by uneven, variable, and hazardous terrain, with coastal regions being geographically close to mountainous and volcanic areas (UNEP, 2014). Topographic characteristics of women's environments also impact their access to employment opportunities because mountainous and geologically hazardous areas render land areas unsuitable for socioeconomic activities, are often inaccessible and remote, and make building roads and infrastructure challenging, which limits mobility (Internet Geography, 2022; UNEP, 2014).

Table 13 Indicators for natural environment and climatic factors from the literature

No.	**Indicator**	**Description**	**Source**
1	Sea level rise	Rise in sea levels	Martyr-Koller et al., (2021) UK National Oceanography Center (2011)
2	Temperature	Rise in temperatures	Mathew et al (2017)
3	Extreme events		
	Cyclones	Hazard maps Cyclone tracks and frequency	ArcGIS Hub, (2023); World Bank, (2023c)
	Floods	Flood occurrences	Global Flood Database, (2023)
	Droughts	Standardized moisture anomaly index	Tian et al., (2022)
4	Terrain	Relief maps/ volcanic maps/Digital Elevation Models	Earth Science Data Systems

3 Existing frameworks and analytical techniques

Spatial methodologies to classify geographical areas are becoming increasingly common. However, spatial methodologies that focus explicitly on women's access to employment opportunities are not. In this section, an overview of some critical frameworks and analytical techniques that can serve as a guide or basis to evaluate women's accessibility to employment in SIDS are presented. The section includes three subsections. (i) The first subsection reviews country-level indices of women's empowerment or related phenomena developed using individual and contextual factors. Despite not explicitly including spatial indicators, the indices included in the first subsection help inform a methodological approach to women's access to employment prospects in SIDS as they provide methods of combining multiple factors and dimensions. (ii) The second subsection reviews frameworks and analytical methods for estimating spatial accessibility. (iii) Finally, multidimensional spatial frameworks and methodologies are included in the third subsection. Despite not necessarily relating to gender or employment opportunities, the frameworks and methodologies included in the third subsection are relevant to developing a methodology to estimate accessibility, characterization of geographic regions, or ways of combining multiple spatial indicators to create indices. The purpose of each subsection is to identify the metrics being measured, the factors included, and the analytical techniques employed.

3.1 EXISTING COUNTRY-LEVEL FRAMEWORKS INCORPORATING CONTEXTUAL AND INDIVIDUAL FACTORS

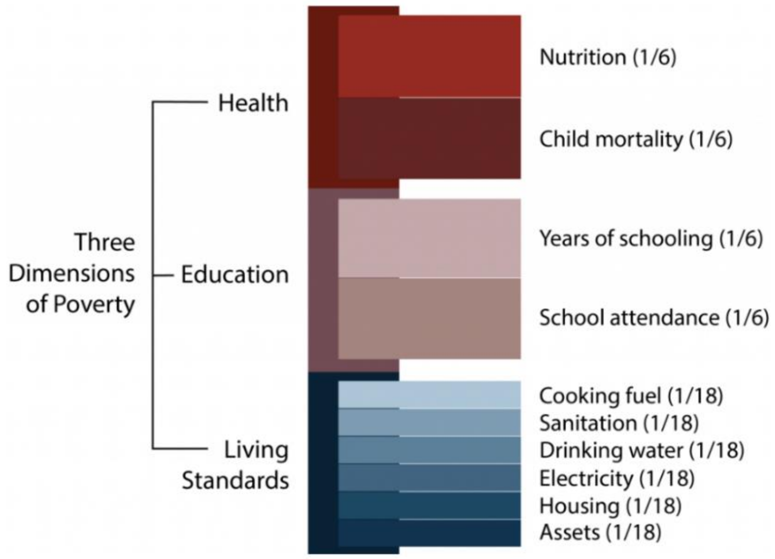
3.1.1 Women's Empowerment in Agriculture Index

The Women's Empowerment in Agriculture Index (WEAI), developed by the International Food Policy Research Institute (IFPRI), was designed to measure the empowerment, agency, and inclusion of women in the agricultural sector; it was piloted in Bangladesh, Uganda, and Guatemala in 2011 (Alkire et al., 2013). The WEAI comprises two subindexes: (i) the degree to which women are empowered (5DE) and (ii) a gender parity index (GPI). From these two indexes, the 5DE index identifies five key domains of disempowerment for women: (i) agricultural production, (ii) decision-making power over resources, (iii) control of income, (iv) leadership in the community, and (v) time allocation. The 5DE index is calculated by estimating the number of disempowered women for each domain and dividing this number by the whole population to obtain a value between 0 and 1. The value for each domain is then multiplied by a weighted percentage of the importance of that domain (the percentages of the importance of all domains add up to 100%) and then added together to obtain a 5DE overall value. The GPI is calculated by considering the number of households classified as inadequate in gender parity as a proportion of the total dual-adult households in the country to obtain a value between 0 and 1. The exact method of calculating the 5DE and the GPI is described in Alkire et al. (2013), but in the overall calculation of the WEAI, the 5DE score is weighted 90% while the GPI score is weighted 10%, and they are added together. The WEAI's indicators were estimated using a survey of women who scored themselves, which may lead to respondents' bias and would need additional data collection tools to be developed and implemented.

3.1.2 Multidimensional Poverty Index

While not focused on women specifically, the global Multidimensional Poverty Index (MPI) is estimated similarly to the WEAI. Poverty indicators are grouped into three dimensions: (i) health, (ii) education, and (iii) standard of living (Alkire et al., 2022). Within these dimensions are ten indicators: two for health, two for education, and six for the standard of living (Figure 2). A person's deprivation score is the sum of the weighted deprivations they experience. All indicators are evenly weighted within each dimension, so the health and education indicators are weighted 1/6 each, and the standard of living indicators are weighted 1/18 each. The global MPI identifies people as multidimensionally poor if their deprivation score is 1/3 or higher. The 2022 MPI results are based on the most recent survey and census data from 111 countries, covering 6.1 billion people.

Figure 2 The Multi-Dimensional Poverty Index (Source: Alkire et al., 2013)



3.1.3 Female Entrepreneurship Index

The Global Entrepreneurship Development Institute (GEDI) Female Entrepreneurship Index (FEI) recognizes the complex interaction between contextual and individual indicators and tries to account for this interaction by identifying indicators that can be estimated for individuals as well as institutions (Terjesen & Lloyd, 2015). The index identifies fifteen pillars of entrepreneurship: (i) opportunity perception, (ii) start-up skills, (iii) willingness and risk, (iv) networking, (v) cultural support, (vi) opportunity start-up, (vii) technology sector, (viii) quality of human resources, (ix) competition, (x) gender gaps, (xi) product innovation, (xii) process innovation, (xiii) high growth, (xiv) internationalization, and (xv) external financing. Each pillar is made up of an individual and an institutional indicator. For example, for the start-up skills pillar, the individual indicator is the perception of skills, and the corresponding institutional indicator is the secondary schooling level. Most frameworks consider either individual-level data or institutional-level data. However, the FEI captures the complexity of WEE by multiplying the individual indicator by the institutional indicator after they have both been normalized. The overall index is then calculated by averaging the values for each pillar to obtain a value between 0 and 1. The FEI has been estimated for 77 countries. A list of data sources and each indicator is reported by Terjesen & Lloyd (2015). Jamaica is the only SIDS for which FEI has been estimated and is ranked 47 out of 77 countries. Although this index does not consider geography, it introduces the possibility of incorporating interacting indicators into the methodological approach to similarly capture complex relationships.

3.1.4 Women's Economic Opportunity Index

The Women's Economic Opportunity Index (WEOI) developed by the Economist Intelligence Unit is a dynamic scoring model constructed from 26 indicators which are separated into five categories, that measures specific attributes of the environment for women employees and entrepreneurs in 113 countries (Economic Intelligence Unit, 2010). All 26 indicators are normalized between 0 and 100, and the overall WEOI index is calculated by averaging the normalized score for each indicator. They are not weighted. A principal components analysis was performed on the model to ensure the relevance and robustness of the chosen indicators and categories. The results obtained from the PCA model were very similar to those using the unweighted model, suggesting that the indicators and categories in the model had a direct bearing on women's economic opportunity. The formula for normalizing indicators differs depending on whether the indicator is positively or negatively correlated with WEE, such that a country with the highest level of WEE will score 100, while the lowest will score 0 (Economic Intelligence Unit, 2010).

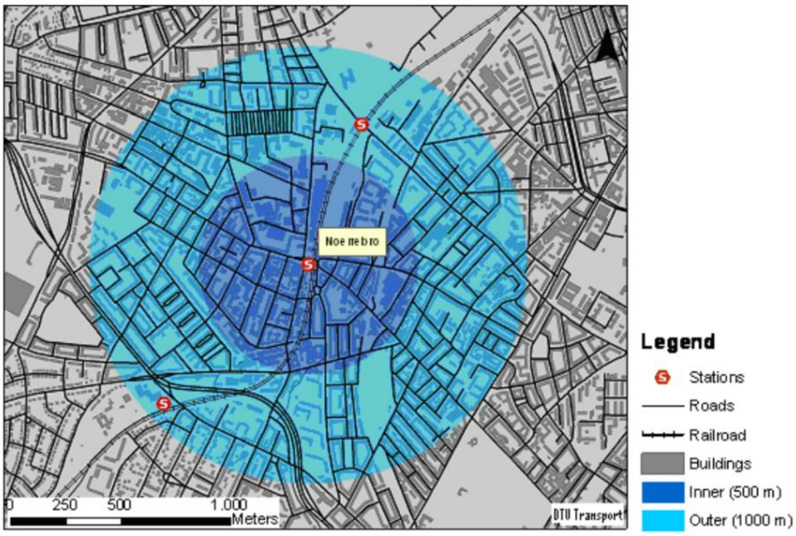
Only two of the 113 countries the index is calculated for are SIDS, Mauritius and the Dominican Republic, which rank 37t and 58t out of 113 countries, respectively. A detailed explanation of each indicator, how it is calculated, and the sources it uses are provided in the Economist Intelligence Unit (2010). Indicators are both quantitative and qualitative. For example, the adolescent fertility rate is a quantitative measure that has a negative correlation with WEE. In contrast, equal pay for equal work is a qualitative indicator estimated by scoring eight characteristics, and a country receives a score from 0 to 8 based on whether or not each characteristic exists (characteristics include whether that country has ratified the ILO Equal Remuneration Convention, whether the principle of equality of remuneration has been domesticated in law and whether mechanisms exist to enforce labor laws) (Economic Intelligence Unit, 2010).

3.2 SPATIAL ANALYSES AND FRAMEWORKS TO ESTIMATE ACCESSIBILITY

3.2.1 Catchment Area Analysis

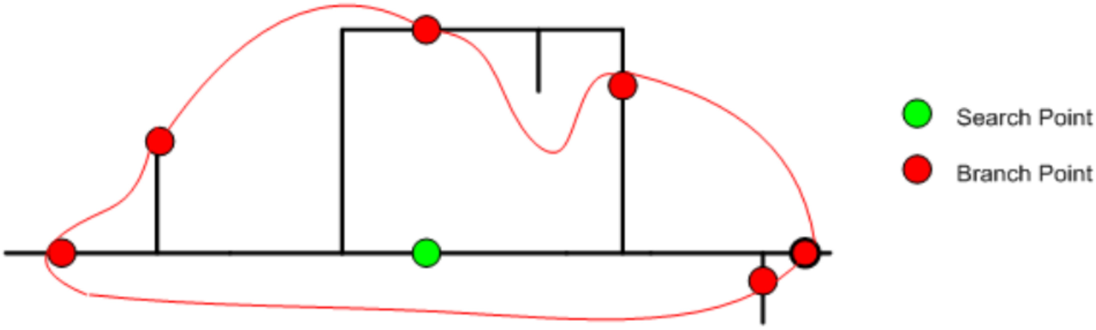
A catchment area can be defined as the area from which a location of interest (such as a facility, service, institution, or even city) attracts a population that uses its services (Elkj & Landex, 2009). Catchment area analysis is one of the simplest methods of estimating spatial accessibility and requires only the location of services and a threshold travel time or distance to be calculated. In contrast, when estimating catchment areas through network analysis, the road network and travel speeds on the network are also required. The circular buffer is the simplest method of estimating catchment areas. It establishes catchment areas as a circle with a radius equal to the defined distance threshold and assumes that the population located inside the circle enjoys equal accessibility to the service. The circular buffer approach is often used to determine optimal locations for transit stations (Figure 3) (Elkj & Landex, 2009).

Figure 3 Example of a circular catchment area for a rail station in Copenhagen. The catchment area is divided into an inner and outer ring, a commonly applied division to identify primary and secondary levels of access (Source: Elkj & Landex, 2009)



In contrast, the network analysis considers the road network around service locations and assumes that a population will only be able to access a service location using the roads. As such, the distance threshold is applied along road networks, and areas away from these networks are considered less accessible. An example of the principle is shown in Figure 4 (Elkj & Landex, 2009).

Figure 4 Diagram describing the principle of the service area approach to catchment area analysis. This approach assumes that people can only move along streets (black lines), so the travel distance threshold is applied along these networks. The green dot is the search point or the service location, and the red dots are the points along the network at which the distance threshold is reached. The red line represents the estimated catchment area for the service location (Source: Elkj &Landex, 2009)



Similar methods to estimating catchment areas have been used for decades. Some of them have been refined to incorporate spatial variation in supply and demand, such as the floating catchment area (FCA) method (F. Wang, 2000), which further evolved into the two-step floating catchment area (2SFCA) method (Luo & Wang, 2003). This method has been enhanced in several ways over the years and is now generally referred to as the enhanced two-step floating catchment area (E2SFCA) method (X. Chen & Jia, 2019), and is most commonly used to estimate health service areas. However, it requires detailed census and survey data linking the demand population locations to the service supply locations, so they are only implementable in places with high data availability.

3.2.2 A Spatial Analysis of Job Supply, Demand and Access

This analysis is one of the first to consider the supply and demand of jobs, as well as transit mode when calculating accessibility (Shen, 2001). It is concerned with characterizing geographic regions according to their overall accessibility to jobs, which is based on the spatial distribution of job openings, the spatial distribution of job seekers, the spatial distribution of employed people, and the travel time to jobs, which is also affected by transportation mode (Shen, 2001).

The analysis requires data on employed workers, unemployment and automobile ownership in residential locations, and employment by occupation in work locations (Shen, 2001). It also requires zone-to-zone travel-time matrices for automobiles and public transit, which are essential for calculating travel impedance (Shen, 2001). In a case study, census-based population and employment data from Boston, U.S., were aggregated into administrative polygons, and the mean travel-time between these polygons was represented in a matrix. Accessibility was calculated using equations that include parameters for the residential location of job seekers, the location of jobs, transit mode, and a travel impedance function based on the travel-time matrix. The travel impedance function used a time threshold of 30 minutes, such that when travel time was below 30 minutes, the function equaled one and zero otherwise (i.e., inaccessible). The transit modes considered in this framework were private cars and public transport (no active transport was included).

Since the development of this method, computational power and GIS capabilities have improved dramatically. Nevertheless, it presents a straightforward technique of estimating spatial accessibility between two points by a motorized vehicle (in this case, home and work) while considering the competition for jobs as a simple function of supply and demand.

3.2.3 Gender and Individual Access to Opportunities: A Space-Time Framework

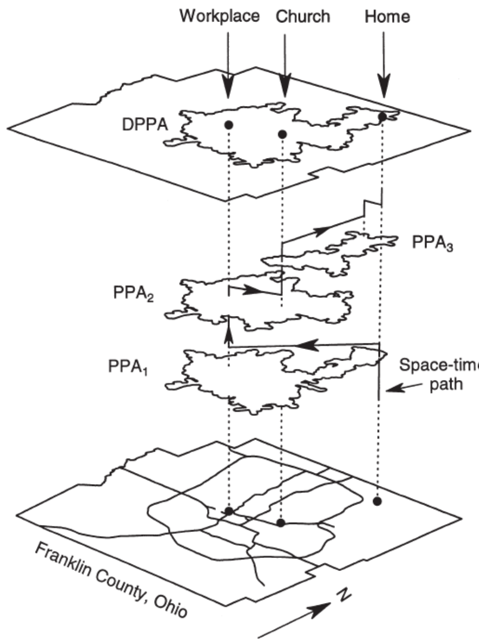
This framework recognizes the gender bias inherent in conventional measures of accessibility, such as that proposed by Shen (2001) and the simple methods of catchment area analysis outlined by Elkj & Landex (2009). It is centered around 'individual accessibility', or how easy it is for people to get to a location, depending on the time of day. This is important when considering gender because, as noted prior, women are more likely to trip-chain (Kwan, 1999).

Additionally, the framework rejects more conventional measures of accessibility that use a single reference and destination location and recognizes that some activities have fixed locations and time constraints, such as going to work (Kwan, 1999). For most people, work takes place in a fixed location at fixed hours of the day, and thus it is a “fixed” activity. Similarly, childcare has a fixed location, and generally, children need to be collected at a specific time, so it is also a “fixed” activity. In contrast, other activities have flexible locations and can be visited at any time of day and at multiple locations, such as grocery shopping, so these are considered “flexible” activities. Women tend to be more restrained by fixed activities than men (Kwan, 1999). To overcome the inherent gender insensitivity of place accessibility indices, this framework proposes a space-time accessibility measure based on how individuals move through time and space. In essence, a framework that is able to assess women’s travel patterns. It identifies that for any given pair of consecutive “fixed” activities, a given amount of time is available for travel and for engaging in “flexible” activities between them. Based on the locations of the pair of fixed activities in question, a network-based GIS analysis is performed on the transportation network to find locations of all flexible activities within reach, given the specific time constraint. The catchment area identified through the network analysis is considered the potential path area (PPA). If the individual has *n* out-of-home fixed activities to perform daily, then *n+1* distinct PPAs can be delimited. These individual PPAs are then aggregated to form a daily potential path area (DPPA) (Kwan, 1999).

The process to calculate the DPPA is depicted in Figure 5 for an individual with two fixed activities in their day, namely going to work and attending church. To calculate an individual’s DPPA, three things are required: (i) the location and time constraints of all fixed activities, (ii) information regarding the travel environment (such as the road network and travel speed), and (iii) the spatial distribution of the flexible activities of interest. Without road network information, Euclidean distances between fixed activities can be used, and the boundaries of the PPA could be calculated with a simple threshold time or distance buffer (Kwan, 1999).

This method is excellent for characterizing an individual woman's spatial movement patterns. Yet, it requires a detailed travel diary, time budget, location of all fixed activities, a realistic travel environment (e.g., transport network geometry and variations in travel speed), and the spatial distribution of flexible activities, which are generally not easily obtainable. However, with some assumptions made regarding fixed and flexible activities, and the order in which they occur, a similar concept could theoretically be applied to estimate PPAs that define women's travel patterns.

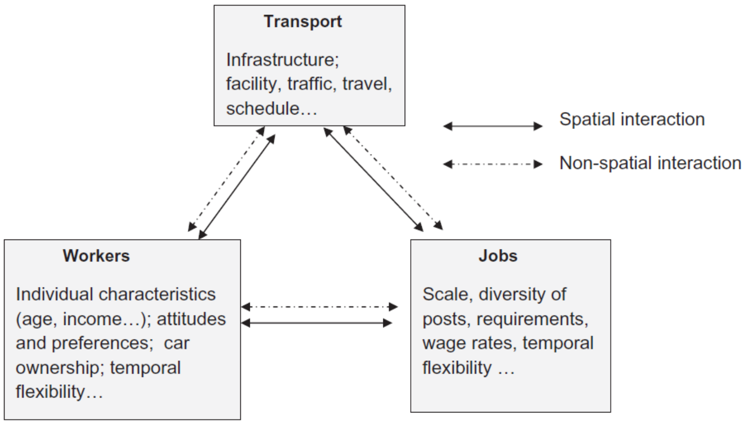
Figure 5 The process involved in deriving the daily potential path area (DPPA) for an individual with three fixed activities: home, work, and church. This process results in three consecutive PPAs based on the trip from home to work, work to church, and church to home (Source: Kwan, 1999)



3.2.4 Measuring job accessibility with distance decay, competition, and diversity

This framework aims to develop a measure of job accessibility that incorporates competition, diversity, and distance decay (distance decay refers to the fact that as distance to a destination increases, that destination becomes less accessible) components in an easily interpretable way (Cheng & Bertolini, 2013). Job accessibility as a complex system comprises three sub-systems: (i) transport, (ii) workers, and (iii) jobs. This framework extends this system to recognize that spatial and non-spatial elements also characterize each sub-system and that the interactions between these elements determine job accessibility (see Figure 6). For example, transport comprises the spatial distribution of infrastructure, facilities, and services, but also non-spatial elements such as service schedules, traffic management, and planning policies (such as park and ride schemes). Non-spatial individual factors, such as age, income, and flexibility in working hours, influence jobs and transport requirements. Meanwhile, contextual factors such as the scale and diversity of employment opportunities influence the demand for workers and the transport provision. In this way, both the spatial and non-spatial factors contribute to variation in mobility provision (Cheng & Bertolini, 2013).

Figure 6 Conceptual framework of job accessibility (Source: Cheng and Bertolini, 2013)

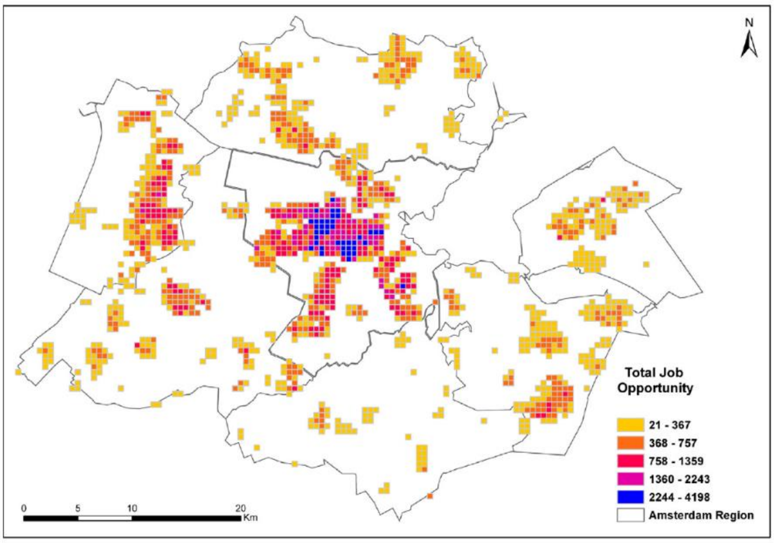


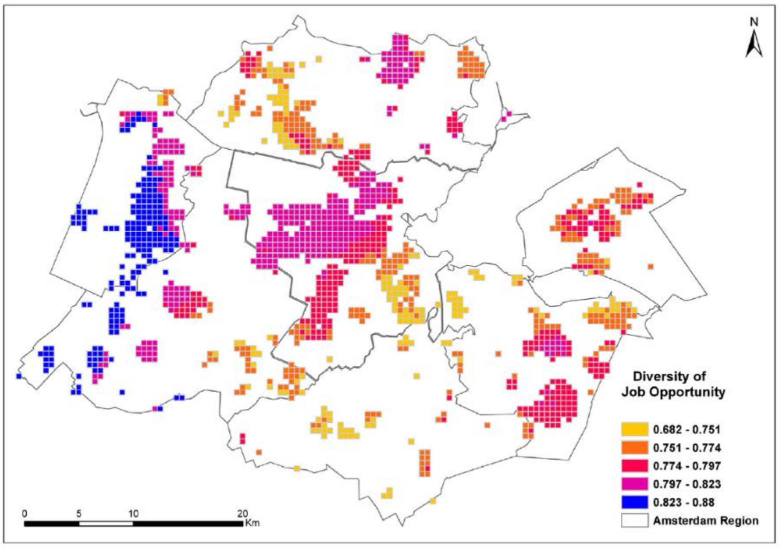
The degree of spatial separation between the residential locations of workers and their jobs represents a barrier to employment. This barrier can be represented by distance, time, or cost and is often referred to as generalized cost. It has been shown that job access is not linearly proportional to the generalized cost. Hence, a distance decay function is appropriate to capture how the cost increases as the distance between workers and jobs increases. When jobs or workers are scarce resources, competition will exist between workers or between employers. This competition will be reflected spatially by influencing the location of workers and jobs and is called location-based competition. For workers, job accessibility is influenced not only by location but also by whether the job is a social match. A social match can be interpreted as a skill match, educational match, wage match, or even a gender match. This framework is the first to attempt to incorporate these non-spatial factors of diversity (jobs and workers) into its measure of job accessibility (Cheng & Bertolini, 2013).

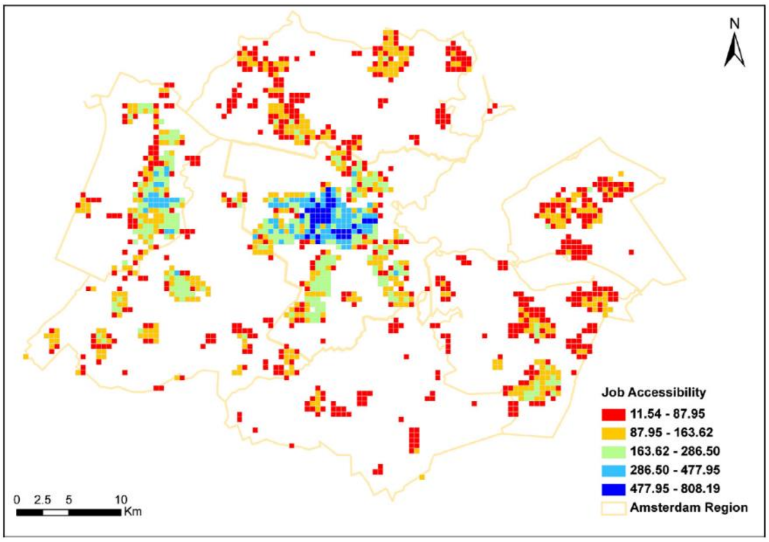
This framework requires data related to worker location, job locations and type, and the road network, including transit mode (Cheng & Bertolini, 2013). It allows incorporating public transit and private cars into the framework, using a threshold travel time of 30 minutes for both travel modes to estimate a distance decay function. These data and parameters are used to calculate the number and diversity of job opportunities and, finally, accessibility using network analysis. Implementing the framework in Amsterdam yielded outputs shown in

Figure 7.

Figure 7 Top: Number of job opportunities available (O). Middle: Diversity of jobs available (D), where 0 ≤D ≤. Bottom: Accessibility of job opportunities (Acc) where Acc = O^D (Source: Cheng & Bertolini, 2013)





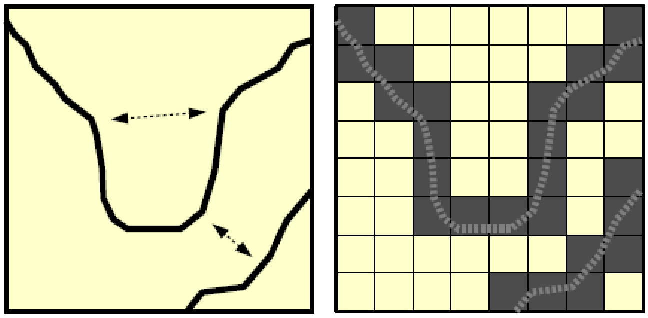


3.2.5 Comparison of raster and network methods of estimating geographic accessibility

This analysis compares methods of estimating accessibility to the nearest hospital, calculated first using a raster-based method and then a network-based method (Delamater et al., 2012). Both methods rely on road network data and destination (in this case hospitals) location data. Prior to the application of both methods, the road network line segments are assigned an estimated travel speed classification based on their hierarchy.

The raster-based method requires the rendering of road network vector data (process visualized in Figure 8), with the raster's assigned values being the road segment's speed classification. For road cells, the travel mode is assumed to be vehicular (which could encompass cars, buses, or some other form of vehicular transport). In contrast, for cells containing no roads, the travel mode is assumed to be walking, and these cells are assigned a speed of 3 mph as an estimate of walking speed. Travel time or cost for traversing each cell is calculated using the cell length and assigned travel speed (Delamater et al., 2012).

Figure 8 Diagram representing the conversion of vector road data to raster cells. The figure on the left displays the original road network, which is converted to a cell-based representation on the right, with the cell's assigned value *being the road segment's speed classification. For cells containing no roads (yellow cells), the assigned speed is 3mph, as the assumed travel mode is walking (adapted from Delamater et al. 2012)*

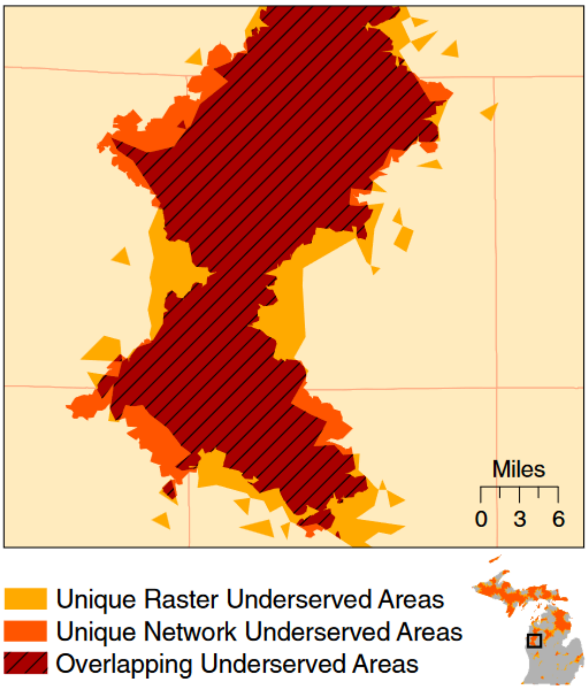


An accumulated cost surface is then created wherein cell values represent the total travel time from a cell to the nearest hospital. To identify underserved areas, the accumulated travel time surface is reclassified into a Boolean surface based on whether the cell is over a threshold travel time from a hospital (Delamater et al., 2012).

For the network-based method, data is converted to road network data format, and travel time is specified as the cost value for edges. Turn delays are defined to control traffic flow, and model expected slowdowns accompanying direction changes. After the road network is built, 30-minute travel time polygons are created for each hospital. Any areas not covered by these polygons are considered to not have access to hospitals (Delamater et al., 2012).

An example comparing the results from both methods is shown in Figure 9. The regions identified as underserved with respect to access to hospitals were similar in location for both methods, however, the raster method was more sensitive to travel speed classifications. A key point to note is that neither of these accessibility analyses requires the location of people as an input, as they are concerned with the accessibility of a given geographic region. However, the results were linked to aggregated census-based population data to determine the number of people who were identified as being underserved in terms of health facilities in each geographic area. The study found that the number of people identified as being underserved differed substantially between methods. The raster-based method identified more people as being underserved, while the network-based method was sensitive to the population's spatial aggregation level. Considering the similarity in results between methods, and the relative simplicity of the raster-based method, this framework could be implemented quite successfully in the data-scarce environments of many SIDS, provided road speed data were available (Delamater et al., 2012).

Figure 9 Example of similarities and differences between underserved areas calculated using the raster-based method (yellow) and the network-based method (orange). Hatched lines show areas identified as underserved by both methods (Source: Delamater et al., 2012)

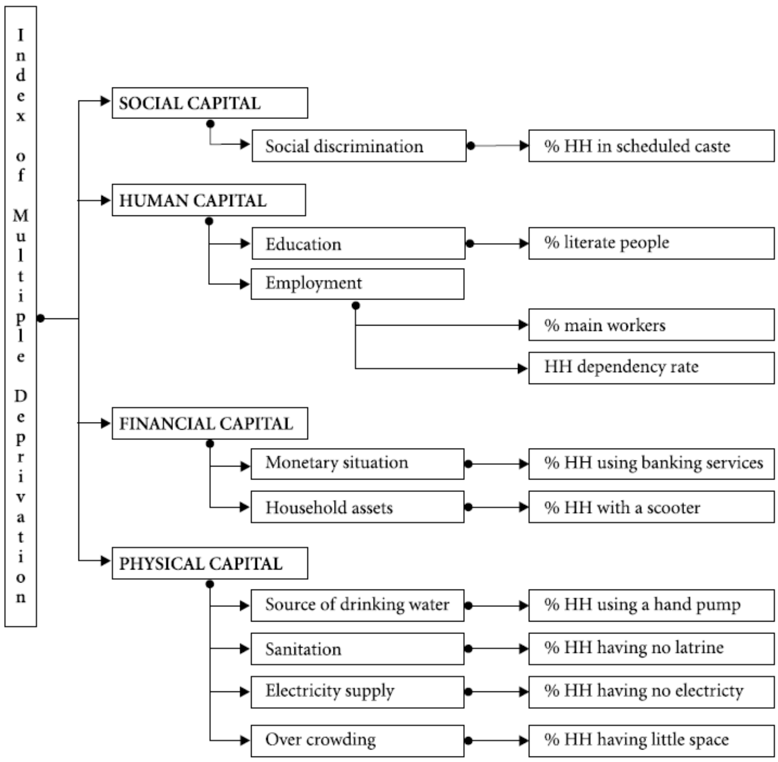


3.3 FRAMEWORKS AND METHODOLOGIES INCORPORATING MULTIPLE DIMENSIONS

3.3.1 Index of Multiple Deprivations: Mapping Urban Poverty in Delhi

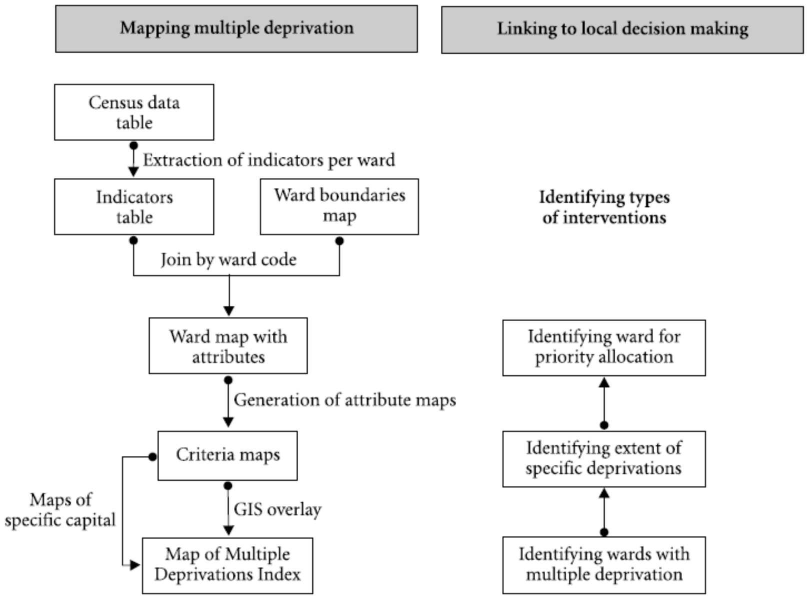
The Index of Multiple Deprivations is a framework developed to map regions of urban poverty using the 'livelihoods assets framework' in Delhi, India (Baud et al., 2008). It identifies four dimensions that influence deprivation: (i) social capital, (ii) human capital, (iii) financial capital, and (iv) physical capital. These dimensions are comprised of a number of indicators, shown in Figure 10. As the figure shows, the physical capital dimension aligns with this report's place characterization dimension, while the social and human capital dimensions align with the individual factors dimension at an aggregate level. Finally, the financial capital dimension aligns with some of the factors included in the contextual dimension (Baud et al., 2008).

Figure 10 Index of Multiple Deprivations (Source: Baud et al., 2008)



Data for each indicator are derived from census tables at the electoral-ward level and extracted to the attribute tables of the ward boundary map. The electoral ward is the lowest level of political representation for citizens to local government. An attribute map is created for each indicator, which is normalized to values between 0 and 1. The normalized indicators are then aggregated to the capital dimension using weighted sums, with each indicator having an equal value. The overall index is calculated using weighted sums, assuming equal weights for each capital dimension (Baud et al., 2008). The flowchart outlining the mapping methodology is shown in Figure 11. This simple method of incorporating multiple layers of spatial information could be adapted, and different weights could be applied to layers if they were known to have a similar significance to the outcome of interest.

Figure 11 Flowchart of the mapping methodology for Index of Multiple Deprivations (Source: Baud et al., 2008)



3.3.2 Identifying intra-urban food deserts using transit-varying accessibility and social inequality estimates

This framework combines place-characterization and accessibility measures to identify geographic regions with restricted access to healthy foods (food deserts) in a developing world context within Shenzhen, China (Su et al., 2017). Food deserts are defined as regions with low accessibility to healthy food and high socioeconomic disadvantage levels. The study further considers transit options and determines accessibility for each transit option separately (Su et al., 2017). The framework for estimating food deserts includes the following considerations:

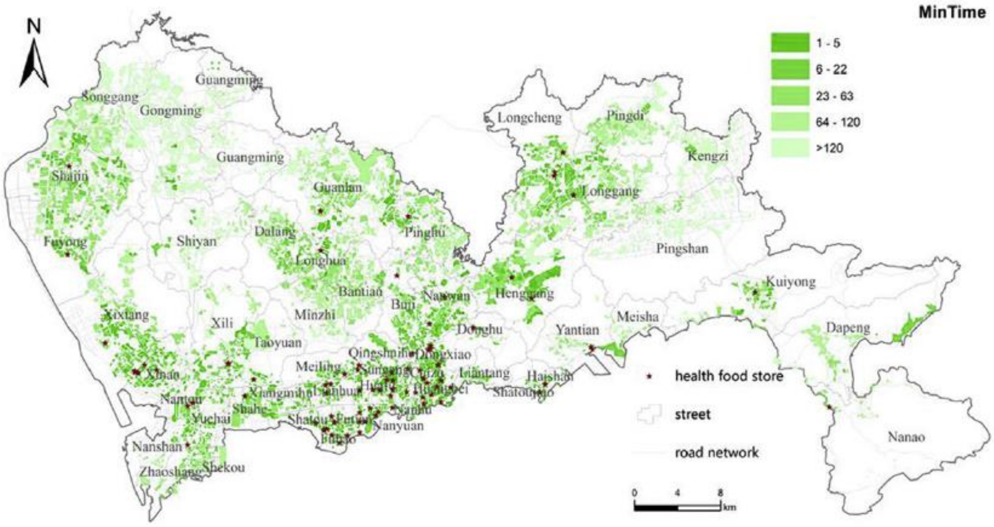
- Geographic region of analysis: The smallest geographic unit for census data in China is the 'Community', and so spatial polygons representing the Communities are used as the geographic unit of analysis.
- Transit options: For each Community, the preferred transit options are identified through a survey. Private car, walking, public transit, and bicycle were found to be the four most used transit options in the city.
- Healthy food stores: Healthy food stores are considered all full-service supermarkets, grocery stores, fruit stores and fruit markets, vegetable stores and markets, and seafood markets in Shenzhen, of which there were 102.
- Healthy food accessibility: Healthy food accessibility refers to the ease with which someone in a Community could travel to a healthy food store and is estimated separately for each transit option. The travel time to each healthy food store from each Community is calculated for each transit mode using Baidu Maps (http://map.baidu.com). Four baseline indicators of healthy food accessibility are then calculated for each Community: 1) the minimum travel time to a healthy food

store, 2) the maximum travel time to a healthy food store, 3) the weighted average travel time to all the healthy food stores, and 4) the standard deviation in travel time to all the healthy food stores. Thus, rather than just identifying the 'closest' healthy food store as the most accessible, these indicators also provide comprehensive information for the cumulative accessibility opportunity to healthy food for each Community.

- Socioeconomic characteristics: The socioeconomic characteristics that are used to characterize Communities according to their socioeconomic disadvantage are:
    - Proportion of people living alone, Proportion of people without property
    - Proportion of unemployed people
    - Proportion of people with a degree lower than middle school
    - Proportion of people aged 60 and above
    - Proportion of blue-collar workers,
    - Proportion of low-income household
    - Proportion of people who are unable to read or write
    - Proportion of adults without a job
    - Proportion of floating population
    - Proportion of households without access to tapped water
    - Proportion of divorced couples
    - Proportion of affordable housing

  The socioeconomic data is obtained from the local government. A principal component analysis (PCA) is run on these indicators to identify highly correlated indicators, followed by a regression analysis to determine which uncorrelated indicators have the greatest association with healthy food accessibility. Only those that were not correlated and had a high association with healthy food accessibility are retained.
- Identifying food deserts using overlay analysis: Finally, food deserts are identified by overlaying the healthy food accessibility estimates of each transit option for each Community with the values of the significant socioeconomic indicators for each Community. Food desert Communities are labeled as those that have lower healthy food accessibility scores and higher socioeconomic disadvantages. Figure 12 shows an example of the results from the study.

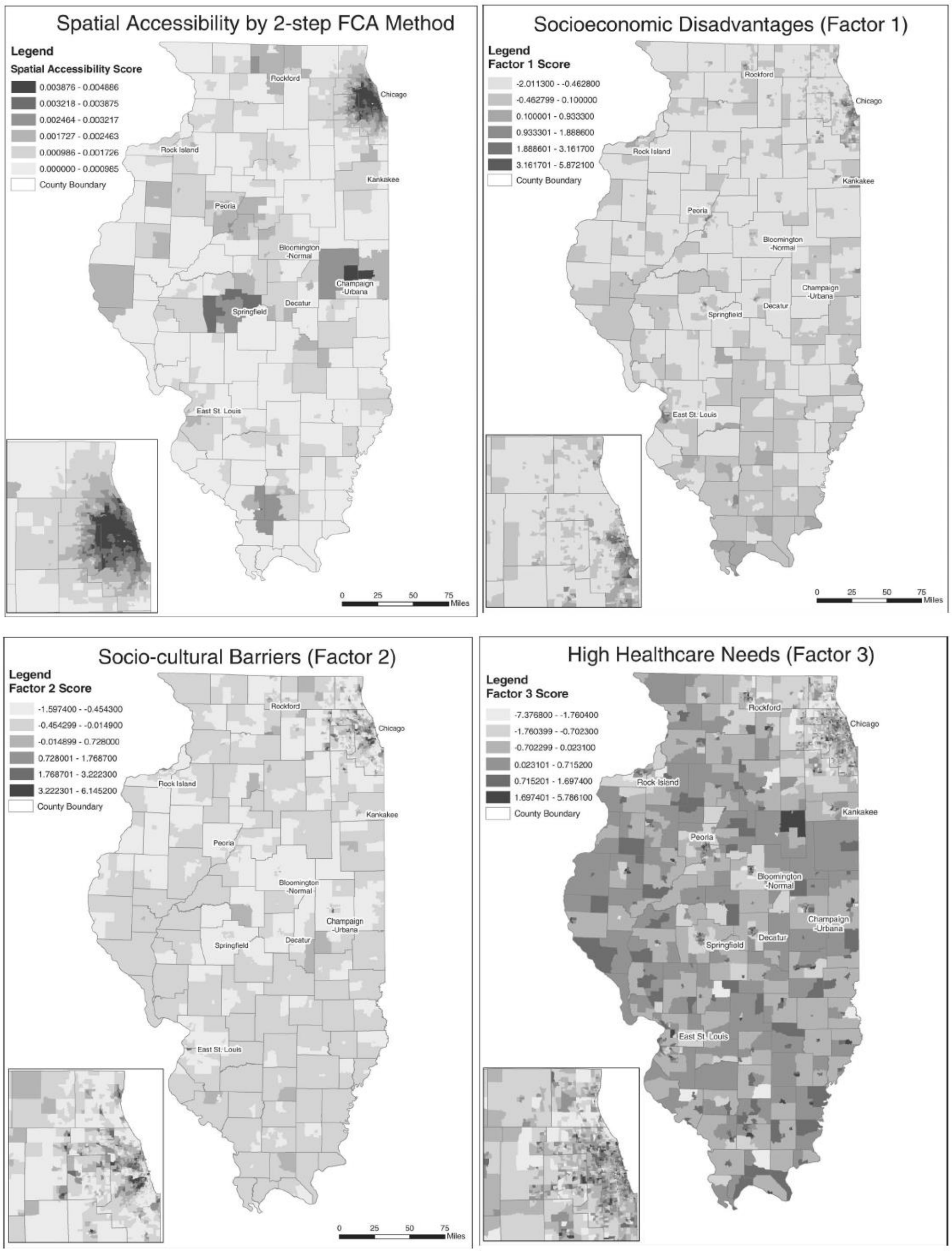
Figure 12 Map showing healthy food accessibility using minimum time in minutes to a healthy food store as the accessibility metric (Source: Su et al. 2017)



3.3.3 Integrating accessibility measures with socioeconomic indicators to identify areas of healthcare deprivation

This framework is also aimed at characterizing regions of 'deprivation' (this time with respect to healthcare) by considering the link between spatial accessibility and socioeconomic indicators (F. Wang & Luo, 2005). In this case, a two-step floating catchment area (2SFCA) analysis is used to estimate accessibility for administrative regions. Instead of using all socioeconomic indicators (which include demographic variables, economic status, and linguistic barriers), the indicators are assessed for autocorrelation using factor analysis and subsequently combined into three factors of importance: (i) socioeconomic disadvantages, (ii) sociocultural barriers, and (iii) high healthcare needs. A pairwise combination of socioeconomic deprivation estimations and accessibility thresholds is used to identify regions with low spatial accessibility and high socioeconomic deprivation levels (F. Wang & Luo, 2005). Maps showing results from the study are shown in Figure 13.

Figure 13 Maps showing spatial accessibility to health facilities, socioeconomic disadvantages, sociocultural barriers, and high healthcare needs (Source: F. Wang & Luo, 2005)



3.3.4 Mapping a vulnerability score for informal settlements in Mogadishu

This study aimed to develop a methodology to assess informal settlement vulnerability across Mogadishu using geospatial and household data (Pegasys & Triple Line, 2022). The methodology identified nine key factors that influenced informal settlement vulnerability: (i) tenancy, (ii) housing type, (iii) flood risk, (iv) water and sanitation, (v) education (perceived proximity to facilities based on survey responses), (vi) health (proximity to services based on survey responses), (vii) food security, (viii) protection, and (ix) access to schools, markets, and hospitals (based on geographic distances). Each factor has at least one indicator, and an area is categorized as being in need or not in need based on pre-defined thresholds for these indicators. For the access to schools, markets, and hospitals factor, a 3 km straight-line distance from the centroid of an informal settlement to the relevant amenity is used as a threshold, with a settlement categorized as being in need if the amenity is more than 3 km from the centroid. This distance was based on the assumption that 3 km equates to a walking time of approximately 30 minutes, which was considered the maximum travel time at which people are willing to walk to reach a facility. The vulnerability score is calculated through a multicriteria assessment approach, with an index calculated for each factor (with equal weights assigned per indicator) and then combined to calculate a score (with equal weights across factors). The combined index is then re-scored to create a prioritization index with scores ranging from 1 to 5, with a higher number pertaining to a higher vulnerability (Pegasys & Triple Line, 2022). The output from the assessment is shown in Figure 14.

Figure 14 Informal settlement vulnerability classification (Source: Pegasys & Triple Line, 2022)

3.4 CONCLUSION

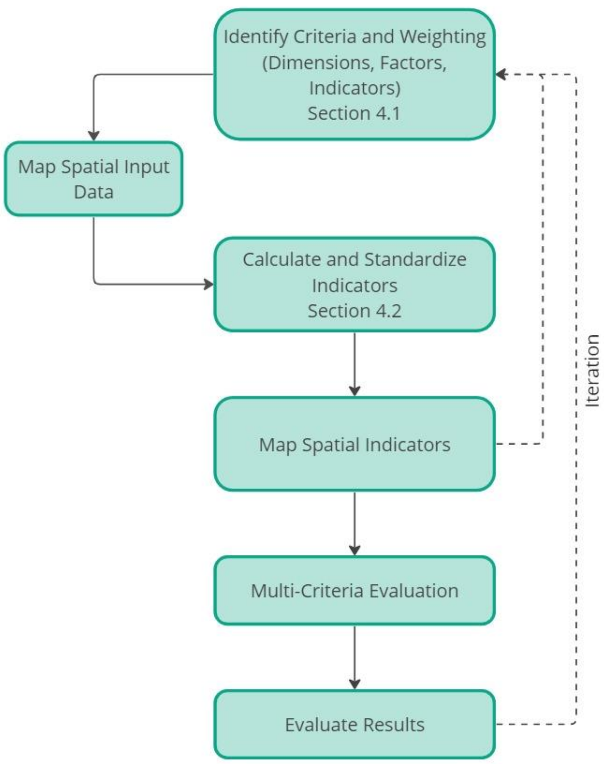
The frameworks and analytical techniques outlined above provide ideal methodologies to build an approach for undertaking a geospatial assessment of women's access to employment and business opportunities in SIDS. However, the diverse contexts of SIDS and the lack of spatially disaggregated data for factors such as education levels, water and sanitation, and digital access require significant simplification of these methodologies. Furthermore, the absence of data on road speeds and public transport availability restricts the framework's ability to fully characterize spatial accessibility. Due to insufficient detailed information on travel choices and road speeds in individual SIDS, threshold distances will primarily be based on walking access rather than other transport modes. Consequently, for several accessibility factors, a simplified approach using network analyses will be the most effective estimation method. Despite these limitations, these frameworks and techniques offer a robust foundation for developing a geospatial assessment of women's access to employment.

4 Proposed Methodological Framework

4.1 INTRODUCTION TO THE METHODOLOGICAL FRAMEWORK

Based on the preceding literature review of factors, potential indicators, appropriate thresholds, and existing frameworks, a Multicriteria Evaluation (MCE) framework is proposed to spatially characterize communities' access to formal employment and business opportunities in the RE sector in SIDS. The MCE framework facilitates the integration and evaluation of various dimensions, its corresponding factors, and associated indicators to pinpoint the presence of supportive environments for women to secure employment or business opportunities in the RE sector in SIDS. Concurrently, it identifies areas where women's ability to secure work is hindered or restricted. Figure 15 below provides a high-level overview of the MCE workflow process. The initial phase involves identifying the criteria considered essential for identifying enabling environments at a granular level. These criteria are based on the preceding literature review and are captured in Figure 16. Indicators are then computed and standardized, with detailed explanations for each indicator's calculation provided in section 4.2. Following the indicator calculations, they are assessed for the need to adjust the criteria. Once criteria are finalized, the multi-criteria equation described in section 4.1.2 is applied, and the results are shown (section 4.3).

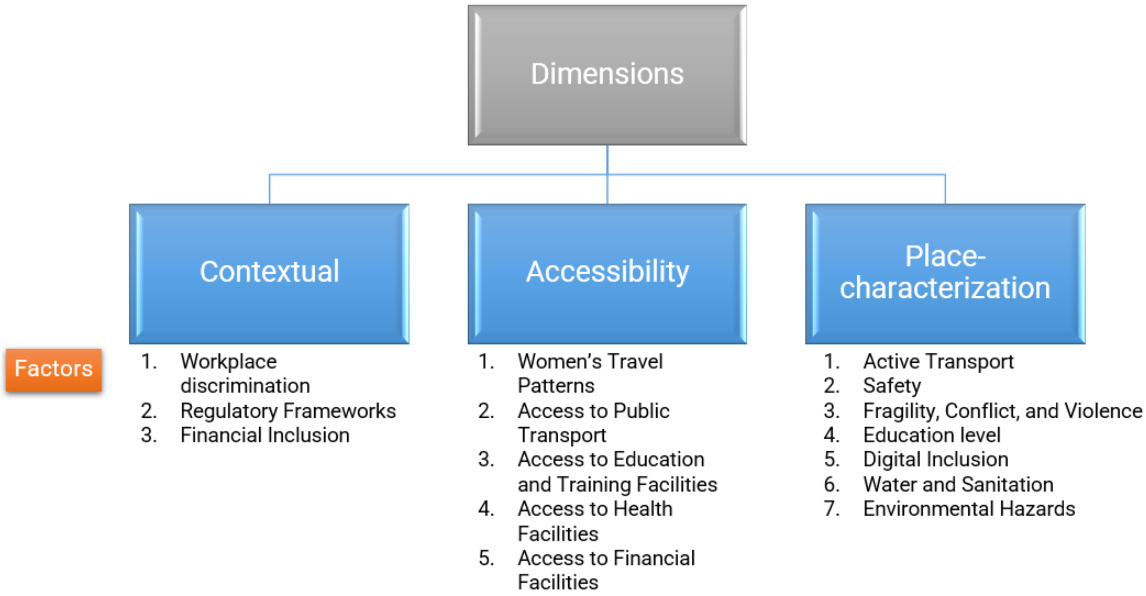
Figure 15 Multicriteria Evaluation Framework



4.1.1 Factors, dimensions and indicators

The present framework is loosely based on the construction of the Multidimensional Poverty Index (Alkire et al., 2022). It identifies 15 key spatial factors that influence women's ability to secure formal employment and business opportunities in the RE sector in SIDS. These factors are grouped into three dimensions based on their underlying nature: (i) Contextual (CD), (ii) Accessibility (AD), and (iii) Place Characterization (PD). Each factor is evaluated through one indicator. Figure 16 below presents the three main dimensions and the list of factors under each dimension. The geospatial data availability was previously assessed in Task 1 of the "Geospatial Assessment of Women's Employment and Business Opportunities in the Renewable Energy Sector" project in which a Gender Data Gap Analysis Report identified 59 open-source datasets available for the 31 SIDS considered in this project. APPENDIX C provides a list of these 59 datasets as well as additional freely available datasets compiled for use in applying this methodological framework.

Figure 16 Framework criteria (dimensions and factors).



4.1.2 Multicriteria Equation

The formula to determine W (women's access to formal employment and business opportunities in the RE sector in SIDS) aggregates the 15 indicators listed in Figure 16 above. Indicators represent spatial evaluations or characterizations of factors, and each indicator is represented by a single gridded raster layer. All indicators are represented on the same scale of values (from 0 to 5, with 0 representing the absence of the factor and 5 the highest level of said factor) and at the same resolution. The suggested raster output resolution is set at 100 m x 100 m. This resolution ensures that the output remains meaningful without imposing an excessively high computational burden during geoprocessing. Consistent scaling and resolution of raster outputs allows for simple raster calculations using the equations outlined in the following paragraphs. Section 4.2 provides a detailed description of the process of calculating a single raster layer for each indicator.

After developing a single raster layer of scores for each indicator, a single raster layer for each dimension is calculated by determining the arithmetic mean of the indicator scores within that dimension.

Factors within a dimension are allocated equal weight. However, the literature review revealed that the significance of each factor, along with social norms, infrastructure, and cultural constraints, varies widely across different contexts. This variability necessitates a tailored approach for each country, urban or rural setting, during the analysis phase. Consequently, the weight assigned to each factor within a dimension is flexible and can be adjusted to fit the context, provided the total weight within each dimension equals one (100%). In instances where data for calculating an indicator are unavailable, the relevant factor can be omitted from the framework, with adjustments made to the weighting within that dimension accordingly. The fundamental strength of this Methodological Framework is its detailed method for selecting indicators for the spatial analysis of each factor, incorporating geographical considerations into the examination. This approach emphasizes the thoughtful selection of indicators over the rigid allocation of weights for calculating the final score.

The two spatially varying dimensions within a country (AD and PD) account for two-thirds of the final score, emphasizing the spatial focus of this methodology. The final score (W) is calculated using the following equation:

$$W = \frac{1}{3}(CD) + \frac{1}{3}(AD) + \frac{1}{3}(PD)$$

The output of this equation would take the form of a single gridded layer and an example from Comoros is shown in Figure 17. Once again, it is crucial to highlight that users have the flexibility to adjust the weights of the dimensions based on the specific context, ensuring an accurate reflection of the ground realities. For example, in countries where domestic violence is a significant and pressing concern, the weight assigned to the individual dimension should be increased accordingly.

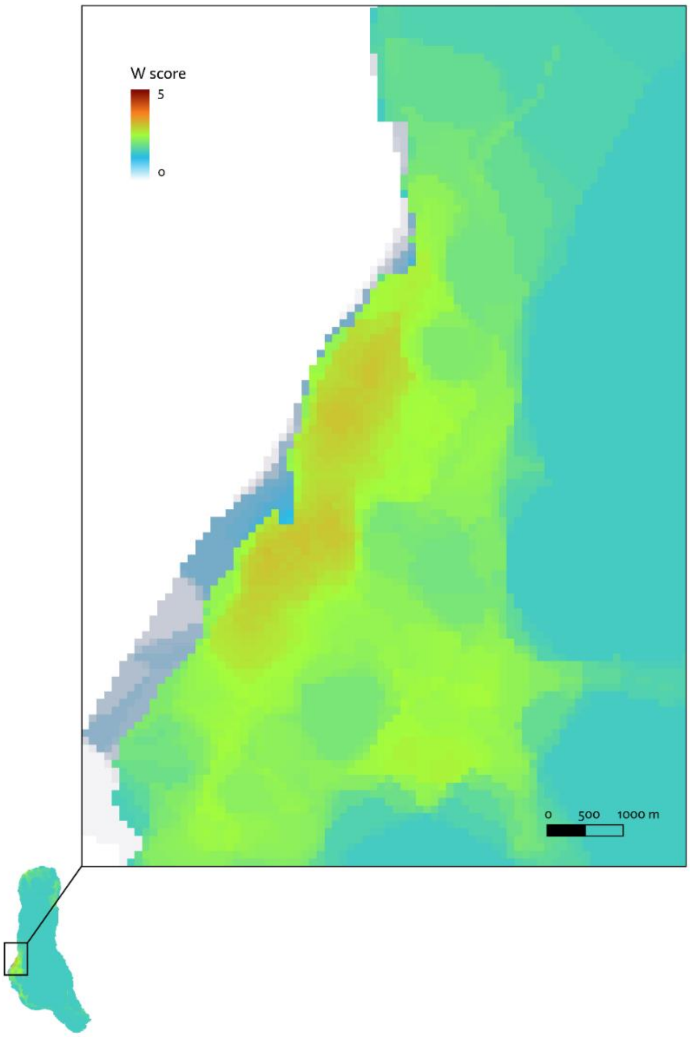
While the above equation is considered the most complete characterization of women's access to employment and business opportunities in the RE sector, the framework allows for flexibility in application such that users have the option to incorporate only the factors and dimensions for which data are available, or those considered crucial within the specific study's context. For example, a study concerned with the spatial variation of W within a country may choose to remove the CD from consideration and instead apply the following equation:

$$W = 1/2(AD) + 1/2(PD)$$

Here each dimension is given equal weighting, although it is worth noting that these weights can be further customized to align with the specific focus of the analysis. For example, if the spatial movement of women is of more interest than the characteristics of where they live, then the AD could be weighted more heavily. Similarly, a single dimension may be of particular interest, in which case only the results for that dimension would be assessed, and any aggregation of dimensions would not be necessary.

In some instances, data limitation may force a change to the MCE, rather than a shift in the analytical focus. The indicators identified for use in this framework are calculated as far as possible using datasets listed in APPENDIX C. In some instances where the proposed indicators cannot be measured due to a lack of data, this framework identifies potential alternative indicators that can be measured using supplementary datasets.

Figure 17 Example of the gridded output estimating W (women's access to formal employment and business opportunities in the RE sector in SIDS) in a section of Comoros. Blue pixels indicate low scores, while red pixels indicate higher scores.



4.2 CALCULATION AND STANDARDIZATION OF INDICATORS

Indicators represent spatial evaluations or characterizations of factors. The proposed process to calculate or standardize each indicator is outlined below. Where a proposed dataset is not available, and more locally appropriate datasets and processing methods exist for a given indicator or context, these can be applied instead.

D 1D 2D 2

4.2.1 Contextual Dimension

Factors in the Contextual dimension are macro- and local-level policies that influence gender relations, promoting or discouraging women's participation in the labor market. While Contextual factors provide information related to place (such as the presence or absence of gender-based workplace discrimination laws), these factors often do not vary geographically within a country. As such, their evaluation is only likely to highlight differences between countries.

Factor: Workplace Discrimination

Indicator: "Workplace" country rating from the Women, Business, and the Law Report

The Workplace indicator measures laws and regulations affecting women's decisions to enter and remain in the labor force through the following four questions:

1. **Are women able to work in the same jobs as men?**
    - This question examines whether there are legal restrictions on women working in certain jobs or industries that men are allowed to work in.
2. **Does the law mandate non-discrimination in employment based on gender?**
    - This assesses whether there is legal protection against gender-based discrimination in hiring, pay, and other employment practices.
3. **Is there legislation on sexual harassment in employment?**
    - This evaluates whether there are laws specifically addressing sexual harassment in the workplace, including protections and remedies for victims.
4. **Are there criminal penalties or civil remedies for sexual harassment in employment?**
    - This looks at the existence and enforcement of penalties or remedies for sexual harassment, ensuring that such laws are actionable and provide recourse for affected individuals.

These questions collectively provide a snapshot of the legal environment affecting women's participation in the workforce, focusing on equality, non-discrimination, and protection from harassment.

Process:

1. Reclassify to a standardized scale of 0 to 5 using a linear scaling process, such that 5 represents regions with high protective policies for workplace discrimination (score=100) and 0 regions with no protective policies in place (score=0). See Appendix D 1 for how to apply a linear scaling process.
2. Rasterize output.

Factor: Regulatory Frameworks

Indicator: "Pay" and "Parenthood" average country rating from the Women, Business, and the Law Report

The Pay indicator from the World Bank's Women, Business and the Law measures laws and regulations that impact women's earnings and address gender pay disparities through the following questions:

1. **Does the law mandate equal remuneration for work of equal value?**
    - This question examines whether the law requires that men and women be paid equally for performing jobs of equal value.
2. **Can women work the same night hours as men?**
    - This assesses whether there are any legal restrictions preventing women from working the same night hours as men.
3. **Can women work in jobs deemed hazardous, arduous, or morally inappropriate in the same way as men?**
    - This question looks at whether women face legal restrictions in working in jobs that are considered hazardous, arduous, or morally inappropriate, which could limit their employment opportunities and potential earnings.
4. **Are women able to work in the same industries as men?**
    - This evaluates whether women are legally permitted to work in all industries, without being restricted to certain sectors.

The Parenthood indicator measures laws and regulations that affect women's work after having children, focusing on maternity, paternity, and parental leave policies, as well as workplace protections for parents. The questions included are:

1. **Is paid leave of at least 14 weeks available to mothers?**
    - This question assesses whether the law mandates at least 14 weeks of paid leave for mothers, reflecting international standards for maternity leave.
2. **Does the government administer 100% of maternity leave benefits?**
    - This examines whether the government is responsible for administering and paying out maternity leave benefits, rather than employers.
3. **Is there paid paternity leave?**
    - This question looks at whether there is a legal provision for paid paternity leave, which supports the role of fathers in childcare.
4. **Is there paid parental leave?**
    - This assesses whether there is a provision for paid parental leave that can be taken by either parent, promoting shared childcare responsibilities.

Process:

3. Combine the available layers of information into a single layer by calculating the mean percentage across all available data layers.
4. Reclassify to a standardized scale of 0 to 5 using a linear scaling process, such that 5 represents regions with high protective policies for women (score=100) and 0 regions with no protective policies in place (score=0). See Appendix D 1 for how to apply a linear scaling process.
5. Rasterize output.

Factor: Financial Inclusion

Indicator: "Entrepreneurship" country rating from the Women, Business, and the Law Report

The Entrepreneurship indicator from the World Bank's Women, Business and the Law measures laws and regulations affecting women's ability to start and run businesses through the following questions:

1. **Does the law prohibit discrimination in access to credit based on gender?**
    - This question examines whether there are legal protections ensuring that women have equal access to credit and financial services, preventing gender-based discrimination by financial institutions.
2. **Can a woman sign a contract in the same way as a man?**
    - This assesses whether women have the same legal capacity as men to enter into contracts, which is crucial for conducting business transactions and entering agreements.
3. **Can a woman register a business in the same way as a man?**
    - This evaluates whether women face any legal barriers or additional requirements compared to men when registering a business, which can impact their ability to start and operate a business.
4. **Can a woman open a bank account in the same way as a man?**
    - This looks at whether women have the same legal rights as men to open and manage bank accounts, which is essential for business operations and financial independence.

Process:

1. Convert data to a standardized scale of 0 to 5 using a linear scaling process, such that 0 indicates areas with no financial inclusion, and 5 indicates countries with a score of 100. See Appendix D 1 for how to apply a linear scaling process.
2. Rasterize output.

4.2.2 Accessibility Dimension

Factors in the Accessibility dimension are those related to the ease with which women can reach or utilize resources, services, or facilities within a specific geographic area and are defined by the proximity to such resources or facilities. Accessibility factors incorporate a threshold distance beyond which something is no longer considered to be accessible (*distmax*). Where road network data are available, accessibility can be estimated using network analysis, where five service areas of incrementally increasing size are estimated using travel distances based on five equally distributed increments of *distmax* as outlined in Appendix D 3. The service areas are assigned accessibility scores between 5 and 0, where 5 indicates the highest level of accessibility, and 0 represents no access (the area beyond the calculated service areas). A walking speed of 5 km/hr is assumed for network analysis.

Factor: Women's Travel Patterns

Indicator: Access to facilities related to women's role as caregivers, including childcare facilities, markets, grocery stores, parks, pharmacies, and recreational areas

Women's travel patterns are influenced by the multifaceted role women play in society as caregivers and household managers, which often necessitate complex, multi-stop trips. The increased ease of making these trips influences women's ability to effectively perform household duties, leaving them with more time to access other opportunities such as education and employment.

Description: This indicator characterizes areas based on access to facilities related to women's role as caregivers, such as childcare facilities, markets, grocery stores, parks, pharmacies, and recreational areas.

Data Sources:

(i) Point locations of facilities related to women's role as caregivers, including childcare facilities, primary and secondary schools, markets, grocery stores, parks, and recreational areas.

(ii) Polyline road network, where available.

Process:

1. Facilities are indicated as point features, and each facility type is processed separately as follows:
    a. All facility types are assigned a *distmax* of 2 km, because this was identified as the maximum preferred walking distance in the preceding literature review (approximately 15 to 20 minutes walking), with no evidence of maximum distances for specific facility types.
    b. Accessibility scores are estimated for each facility type using a service area network analysis (see Appendix D 3). Five service areas of incrementally increasing size are estimated and assigned accessibility scores using travel distances proportionate to *distmax* as shown in the table below.
2. Outputs for each facility type are rasterized and combined by taking the mean score across all facility types to obtain a single raster layer.

Table 14 Travel distances used to estimate service areas for facilities in the Women's Travel Patterns factor, and associated accessibility scores.

Travel Distances	Accessibility scores
0 - 400 m	5
401 - 800 m	4
801 - 1200 m	3
1201 – 1,500 m	2
1 501 – 2,000 m	1
> 2,000 m	0

Factor: Access to Public Transport

Indicator: Access to Public Transport Stops

Proximity to public transport stops increases women's likelihood of using public transport, improving their ability to travel for work and, therefore, their job opportunities.

Description: This indicator characterizes areas based on access to public transport stops.

Data Sources:

(i) Point locations of bus stops, taxi stops, mini-bus taxi and other paratransit services, and railway stations; and

(ii) polyline road network data, where available.

Process:

1. Transport stops are indicated as point features.
2. Based on evidence from the preceding literature review, public transport stops are assigned a *distmax* of 1.5 km.
3. Accessibility scores are estimated for each transport stop using a service area network analysis (see Appendix D 3). Five service areas of incrementally increasing size are estimated and assigned accessibility scores using travel distances proportionate to *distmax* as shown in the table below.
4. Rasterize output.

Table 15 Travel distances used to estimate service areas for public transport stops, and associated accessibility scores.

Travel Distances	Accessibility scores
0 - 250 m	5
251 - 500 m	4
501 - 750 m	3
751 - 1000 m	2
1001 – 1,500 m	1
> 1,500 m	0

Factor: Access to Education and Training Facilities

Indicator: Access to tertiary education and training facilities

Young women tend to gain more from a tertiary degree in the labor market than their male peers, both in terms of employment and earnings. Therefore, access to tertiary education and training facilities are essential to increase women's ability to obtain skilled employment, particularly higher paid positions in the RE sector.

Description: This indicator characterizes areas based on access to education and training facilities, specifically, tertiary, and technical training facilities.

Data Sources:

(i) Point locations for tertiary education and technical training facilities; and

(ii) polyline road network, where available.

Process:

1. Facilities are indicated as point features and combined into a single spatial layer.
2. Based on evidence from the preceding literature review, access to tertiary and technical facilities are assigned a *distmax* of 10 km.
3. Accessibility scores are estimated for each education facility using a service area network analysis (see Appendix D 3). Five service areas of incrementally increasing size are estimated and assigned accessibility scores using travel distances proportionate to *distmax* as shown in the table below.
4. Rasterize output.

Table 16 Travel distances to estimate service areas for education facilities, and associated accessibility scores.

Travel Distances	Accessibility scores
0 – 2000 m	5
2,001 – 4,000 m	4
4,001 – 6,000 m	3
6,001 – 8,000 m	2
8,001 – 10,000 m	1
> 10,000 m	0

Factor: Access to Health Facilities

Indicator: Access to hospitals, clinics, and maternal health facilities

Lack of access to necessary health services can lead to deteriorating health, which can subsequently impair a woman's ability to work. In addition, women are less likely to use health services as the distance traveled to those services increases.

Description: This indicator characterizes areas based on access to hospitals, clinics, and maternal health facilities.

Data Sources:

(i) Point locations of hospitals, clinics, and maternal health facilities; and

(ii) polyline road network, where available.

Process:

1. All health facilities are combined into a single spatial layer.
2. Based on evidence from the preceding literature review, the maximum distance that women are willing to walk to reach a primary health facility is assumed to be 5 km, and as such all facilities are assigned a *distmax* of 5 km.
3. Accessibility scores are estimated for each transport stop using a service area network analysis (see Appendix D 3). Five service areas of incrementally increasing size are estimated and assigned accessibility scores using travel distances proportionate to *distmax* as shown in the table below.
4. Rasterize output.

Table 17 Travel distances used to estimate service areas for health facilities, and associated accessibility scores.

Travel Distances	Accessibility scores
0 – 1,000 m	5
1,001 – 2,000 m	4
2,001 – 3,000 m	3
3,001 – 4,000 m	2
4,001 – 5,000 m	1
> 5,000 m	0

Factor: Access to Financial Facilities

Indicator: Access to banks and mobile money facilities

Access to financial facilities can open economic opportunities for women, such as obtaining a bank account. In contrast, lack of access to financial facilities reduces women's ability to apply for or use financial services.

Description: This indicator characterizes areas based on access to banks and mobile money facilities.

Data Source:

(i) Point locations of banks and mobile money facilities; and

(ii) polyline road network, where available.

Process:

1. Financial facilities are indicated as point features, and all facilities are combined into a single spatial layer.
2. Evidence shows that financial facilities are generally assumed to have a catchment radius of 3 km. As such all facilities are assigned a *distmax* of 3 km.
3. Accessibility scores are estimated for each transport stop using a service area network analysis (see Appendix D 3). Five service areas of incrementally increasing size are estimated and assigned accessibility scores using travel distances proportionate to *distmax* as shown in the table below.
4. Rasterize output.

Table 18 Travel distances to estimate service areas for financial facilities, and associated accessibility scores.

Travel Distances	Accessibility scores
0 - 400 m	5

401 - 800 m	4
801 - 1200 m	3
1201 – 2,000 m	2
2,001 – 3,000 m	1
> 3,000 m	0

4.2.3 Place Characterization Dimension

Factors within the Place Characterization dimension is those with attributes or features that describe a specific geographic area and do not include a distance component. These may include physical attributes like infrastructure, as well as other aspects of places such as population density and the quality of available services. Although not all datasets proposed below are currently freely available for SIDS, the process to estimate the indicator is still described in the event that such data become available in the future. For most place characterization factors, the data are initially aggregated to the administrative level of interest using a spatial polygon layer representing the administrative level of interest.

Factor: Active Transport

Indicator: Availability of safe street design elements

This refers to the conditions of the road and foot path infrastructure, and the degree to which safe and efficient non-motorized travel for women is supported. This includes walking, cycling, and other non-motorized forms of transport.

Description: This indicator characterizes areas based on the degree to which they support safe and efficient active transport for women, through assessment of information relating to the presence of safe walkways and cycleways, density of pedestrian crossings, and block length.

Data Sources: This indicator incorporates the following data layers (where freely available):

(i) Point locations of pedestrian crossings (this information does not form part of the datasets listed in Appendix C),

(ii) Block length (this information does not form part of the datasets listed in Appendix C), and

(iii) Road network data, including attributes related to road types, footpaths, and cycleways.

Note: The calculation of the index is possible even if only one data layer is available.

Process:

The active transport score is determined by averaging the scores of each raster cell across the following four layers:

(i) **Street Crossings** (indicates safety and accessibility; measured by availability/presence per raster cell):

i. 0: No crossings
ii. 3: 1 crossing
iii. 5: 2 or more crossing

(ii) **Cycle Paths** (measured by availability/presence per raster cell):

i. 0: No cycle paths
ii. 3: 1 cycle path
iii. 5: 2 or more cycle paths

(iii) **Footpaths** (measured by availability/presence per raster cell):

i. 0: No footpaths
ii. 3: 1 footpath
iii. 5: 2 or more footpaths

(iv) **Block Sizes** (indicates encouraged walkability):

i. 1: Very large block sizes (>1 km)
ii. 2: Large block sizes (751m - 1 km)
iii. 3: Moderate block sizes (501m - 750m)
iv. 4: Small block sizes (251m - 500m)
v. 5: Very small block sizes (<250m)

Importantly, where all layers are not available, the score should be calculated using the layers that are available.

Factor: Safety

Indicator: Prescence of streetlights/nighttime lights

Women's perceptions of safety and their behavior, including their use of spaces, are strongly influenced by the physical characteristics of the built environment, such as the presence of streetlights.

Description: This indicator characterizes areas based on how well they are illuminated.

Data Source: This indicator incorporates point locations of streetlights, and spatially disaggregated land use data. Not all data relating to this indicator are currently readily available, but the calculation can still proceed even if only one data layer is available. When streetlight locations are not available, satellite derived nighttime lights data (Elvidge et al., 2021) can be used as a proxy of brightness (and thus safety).

Process:

(i) If streetlight locations are available, generate 20-meter buffers around them.The ideal number of streetlights is not known, but it is assumed that areas with more lights are perceived as safer.

(ii) Reclassify raster cells as follows:

- Cells with 80-100% of their area intersecting with the buffers should receive a score of 5.
- Cells with 60-79% intersection should be scored as 4.
- Cells with 40-59% intersection should be scored as 3.

- Cells with 20-39% intersection should be scored as 2.
- Cells with 1-19% intersection should be scored as 1.
- Areas without any overlap with streetlight buffers should be scored as 0.

(iii) D 1

(iv) If streetlight locations are not available, the nighttime lights raster layer can be used as a proxy by standardizing raster values using a linear scaling process in which *Rmax* is the highest (brightest) pixel value and *Rmin* is the lowest pixel value and resampling the raster to the required resolution.

Factor: Fragility, conflict, and violence (FCV)

Indicator: Hotspot map of conflict, violence, and protest events

Areas exposed to high levels of fragility, conflict, and violence reduce women's ability to undertake formal employment by increasing the prevalence of GBV and the likelihood of displacement.

Description: This indicator characterizes areas based on the number of FCV incidents per number of residents. This indicator considers all FCV incidents in aggregate.

Data Source: The Armed Conflict Location & Event Data Project (ACLED) is a disaggregated data collection, analysis, and crisis mapping project. ACLED is the highest quality and most widely used real-time data and analysis source on political violence and protest around the world, so while it is not strictly open access, it has been included in this framework as the best available data representing FCV.

Process:

1. Using point locations of FCV events, generate circular buffers to a radius of 5 km to estimate the spatial impact of events. When the impact radius of an event is known, this can be used instead.
    - Rasters overlapping with buffers indicating battles and explosions: Score of 0
    - Rasters overlapping with buffers indicating explosions and remote violence: Score of 1
    - Rasters overlapping with buffers indicating violence against civilians: Score of 2
    - Rasters overlapping with buffers indicating protests and riots: Score of 4
    - Areas not overlapping with any event: Score of 5
1. Rasterize output.

Factor: Education (EDU)

Indicator: Percentage of women aged 25 and over that have graduated from a STEM degree

Obtaining a tertiary education, particularly in STEM fields, whether it is through a university or a TVET program, better enables women to obtain skilled employment in the RE sector. Moreover, the percentage of women graduating from STEM fields in a region often serves as a strong indicator of societal attitudes towards women pursuing careers in STEM.

Description: This indicator measures the percentage of women in a region who have completed a STEM degree.

Data Source: Spatially disaggregated census or survey data representing the percentage of women who have completed a STEM degree.

Process:

1. Reclassify data to a standardized scale of 0 to 5 using a linear scaling process, such that 5 represents regions where women represent at least 50% of STEM degree graduates and 0 the areas where no women have a STEM degree. See Appendix D 1 for how to apply a linear scaling process.
2. Rasterize output.

Factor: Digital Inclusion

Indicator: Percentage of households with access to the Internet OR mobile tower coverage

Description: This indicator characterizes areas based on the percentage of households with access to the Internet.

Data Source: Spatially disaggregated census or survey data representing the percentage of households with access to the Internet. When spatially disaggregated information relating to Internet access is not available, point locations of mobile towers can be used instead.

Process:

1. If using Internet access rates:
   i. ii. Reclassify input data to a standardized scale of 0 to 5 using a linear scaling process, such that 5 represents areas where 100% of houses have Internet access, and 0 represents areas where no houses have Internet access. See Appendix D 1 for how to apply a linear scaling process.
   ii. Rasterize output.
2. If using mobile tower locations:
   i. Buffer locations to 3 km or adjust based on known cell tower range.
   ii. Create a binary layer where areas inside the buffer have internet access = 5, and outside buffer have no internet access = 0.
   iii. Rasterize output.

Factor: Access to Water and Sanitation

Indicator: Availability of water points

Having access to piped water and sanitation enhances hygiene and health levels and reduces the amount of time women spend collecting water.

Description: This indicator characterizes areas based on the availability of water features per raster.

Data Source: Point locations for water points, catch basins, water valves and fire hydrants.

Process:

1. First, the territory needs to be divided into 100m x 100m rasters. The scoring for each cell is as follows:

- Raster cell with no water points: score 0
- Raster cell with 1 water point: score 3
- Raster cell with 2 or more water points: score 5

If data points related to water sources are not available, the user can use Spatially disaggregated census or survey data representing the percentage of households with access to piped water. This information is not included in the list of datasets in Appendix C.

Process:

2. Reclassify input layer to a standardized scale of 0 to 5 using a linear scaling process, such that 5 represents areas where 100% of houses have access to piped water, and 0 represents areas where no houses have access to piped water. See Appendix D 1 for how to apply a linear scaling process.
3. Rasterize output.

Factor: Environmental Hazards

Indicator: Natural disaster risk classification

Areas with high vulnerability to natural disasters reduce women's ability to undertake formal employment by increasing the likelihood of property damage, displacement, and GBV.

Description: This indicator characterizes areas based on their vulnerability to natural disasters.

Data Source: Spatial layers representing flood risk, drought risk or landslide risk. In each dataset, areas are classified as either low-risk, medium-risk or high-risk.

Process:

1. Process each available layer (e.g., flood risk, earthquake risk, etc.) of information separately using the following steps:
    a. In the available datasets, areas are classified as having either low, medium, or high risk. Reclassify such that low-risk areas are assigned a score of 5, medium risk areas are assigned a score of 2, and high-risk areas are assigned a score of 0.
    b. Rasterize reclassified layers.
2. Combine the raster layers created in (1) into one output layer by taking the minimum score across all layers. In this way, an area is categorized according to the highest level of risk it is subject to, regardless of the type of risk.

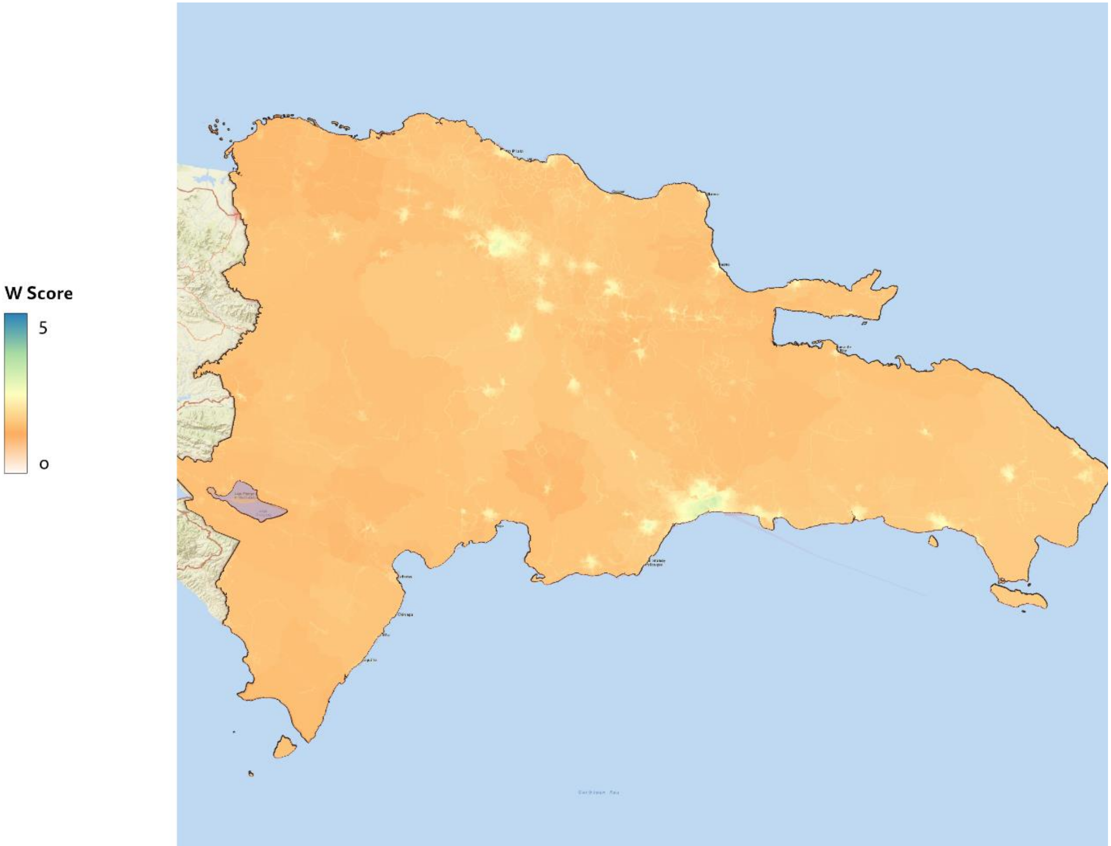
4.3 INTERPRETATION OF SCORES

4.3.1 Level of Confidence in Model Output

The methodology produces continuous values between 0 and 5 as depicted in Figure 18, with scores closer to 5 indicating the most enabling environments to support women to access employment or

business opportunities in the RE sector. The raw score output is in raster format with a pixel resolution of 100 m x 100 m.

Figure 18 Gridded output estimating W (women's access to formal employment and business opportunities in the RE sector in SIDS) in the Dominican Republic.



Although the model remains mathematically valid even when using just a single indicator as input for each dimension, the practical significance and interpretability of the output would be constrained. To reflect this limitation, the output is assigned a 'level of confidence,' based on the percentage of indicators included in the methodology according to the following scale:

0-24% = Very low confidence

25-49% = Low confidence

50-74% = Medium confidence

75-89% = High confidence

90-100% = Very high confidence

4.3.2 Reclassifying score outputs to discrete classes

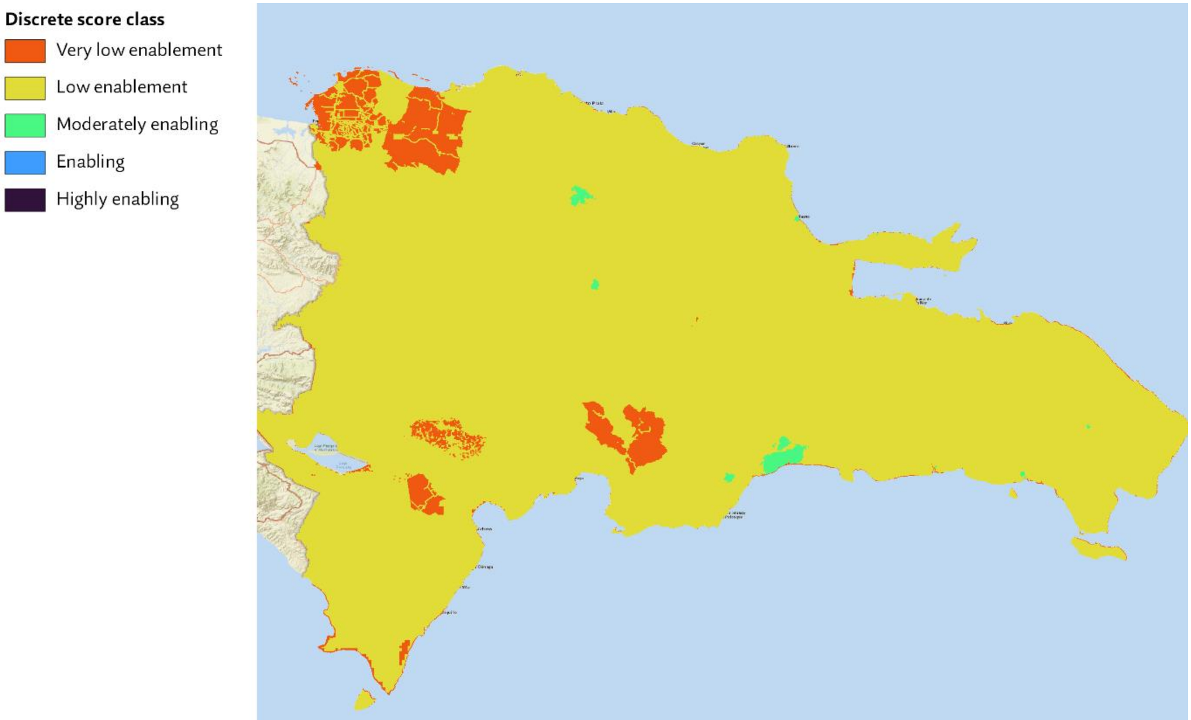
For interpretive purposes, it can be more useful to group the continuous score data as represented in Figure 18 into the discrete classes defined in Table 19.

Table 19 Proposed discrete score classes to enable simpler visual interpretation of raw score outputs and enable intersection with other layers of information.

Score range	Class	Interpretation
0.00-0.50	0	Not enabling
0.51 -1.50	1	Very low enabling
1.51 –2.50	2	Low enabling
2.51 – 3.50	3	Moderately enabling
3.51 – 4.50	4	Enabling
4.51 – 5.00	5	Highly enabling

Grouping the aggregate scores from the Dominican Republic into discrete classes yields the results shown in Figure 19. Depending on the assessment's specific context, it may be beneficial to explore additional insights regarding how scores correlate with the distribution of women and RE sites.

Figure 19 Raw output for the Dominican Republic grouped into the discrete classes defined in Table 19



4.3.3 The intersection between enabling environments and the location of women

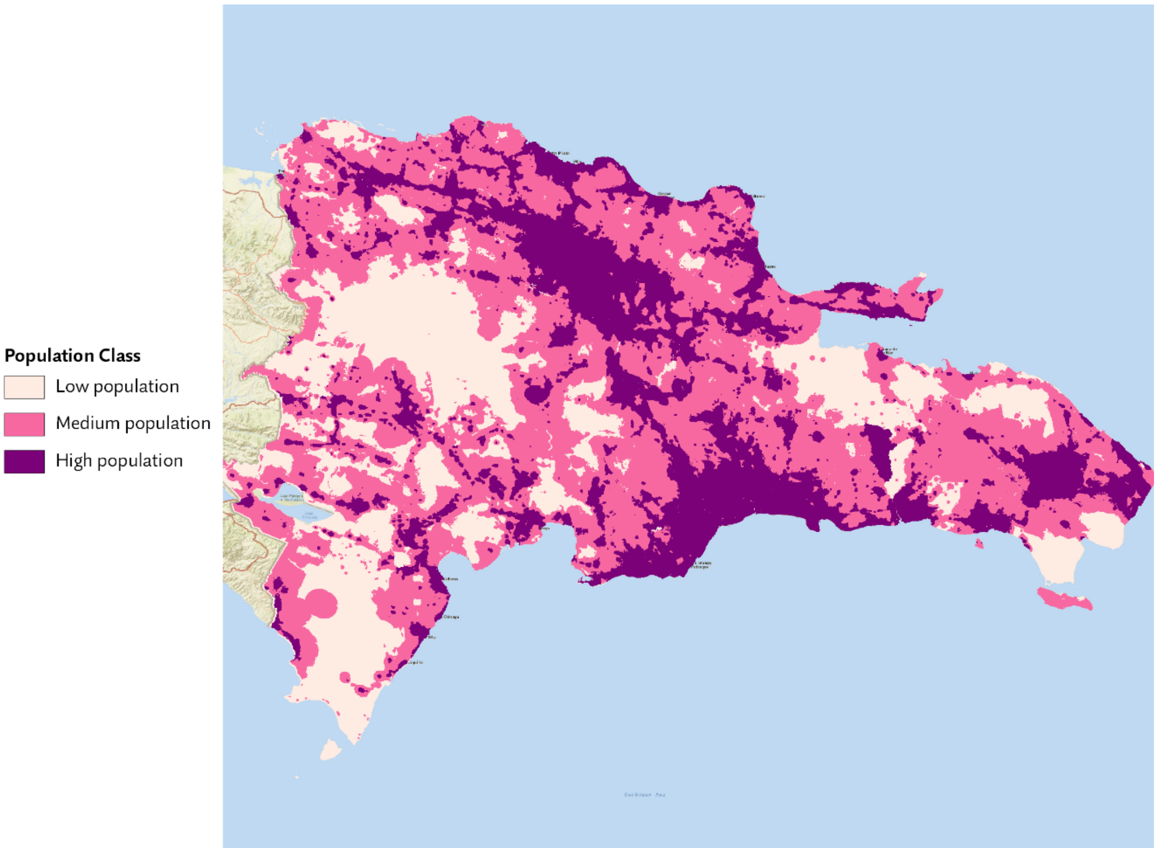
Of particular interest is the intersection between enabling environments and the geographical distribution of women. This focus is crucial because enabling environments have the most significant impact in areas where there is a substantial concentration of women who can benefit from them. Because population counts are also a continuous variable, the data are first grouped into discrete classes so that the information can be easily intersected with score outputs. Three classes are proposed: low, medium and high population. These are based on the underlying data distribution and defined in Table 20 by the lower, median and upper quartile ranges.

Table 20 Proposed discrete population classes to enable simpler visual interpretation of population distribution, and enable intersection with other layers of information.

Population range	Class	Interpretation
Lower quartile range	1	Low population
Median quartile range	2	Medium Population
Upper quartile range	3	High Population

Grouping the population counts for women aged 30-34 in the Dominican Republic into discrete classes yields the results shown in Figure 20.

Figure 20 Population counts for women aged 30-34 in the Dominican Republic, reclassed into areas of low, medium and high population as defined in Table 20.



The information in the reclassed score and population layers are then combined to create 15 categorical classes, defined according to Table 21. The distribution of the 15 categorical classes across the Dominican Republic is displayed in Figure 21.

Table 21 Combined score and population classes, and how to interpret each class.

Score class	Population class	Combined Class	Interpretation
1	1	1	Very low enablement, low population
1	2	2	Very low enablement, medium population
1	3	3	Very low enablement, high population
2	1	4	Low enablement, low population
2	2	5	Low enablement, medium population
2	3	6	Low enablement, high population
3	1	7	Moderately enabling, low population
3	2	8	Moderately enabling, medium population
3	3	9	Moderately enabling, high population
4	1	10	Enabling, low population
4	2	11	Enabling, medium population
4	3	12	Enabling, high population
5	1	13	Highly enabling, low population
5	2	14	Highly enabling, medium population
5	3	15	Highly enabling, high population

Use case example:

If a planner was interested in identifying areas for infrastructure investments that would yield the most significant benefits, their primary focus might be on locating regions with a substantial female population but lacking a supportive enabling environment. In the example figure below, the dark red zones are these areas: very low enablement scores and a high population of women. These zones are located in the north-west and south-central parts of the Dominican Republic. Consequently, it follows that investments in these areas would have the most significant positive impact on women. The planner may then be interested in understanding what in particular is driving the low enablement scores in these areas. A closer look at factor and dimension outputs shows that the factors that show the lowest scores in these areas are Digital Inclusion, and Environmental Hazards (Figure 22). In addition, all factors in the Accessibility Dimension exhibited low scores across most of the country, including the two zones of interest (Figure 23). This would suggest to the planner that to improve women's ability to access jobs and opportunities in these areas, the best investment would be in digital and transport infrastructure.

Figure 21 The fifteen combined score and population classes as defined in Table 21 can be used to help identify areas which are both enabling and support a large number of women (or conversely, areas which support a large number of women but are not enabling).

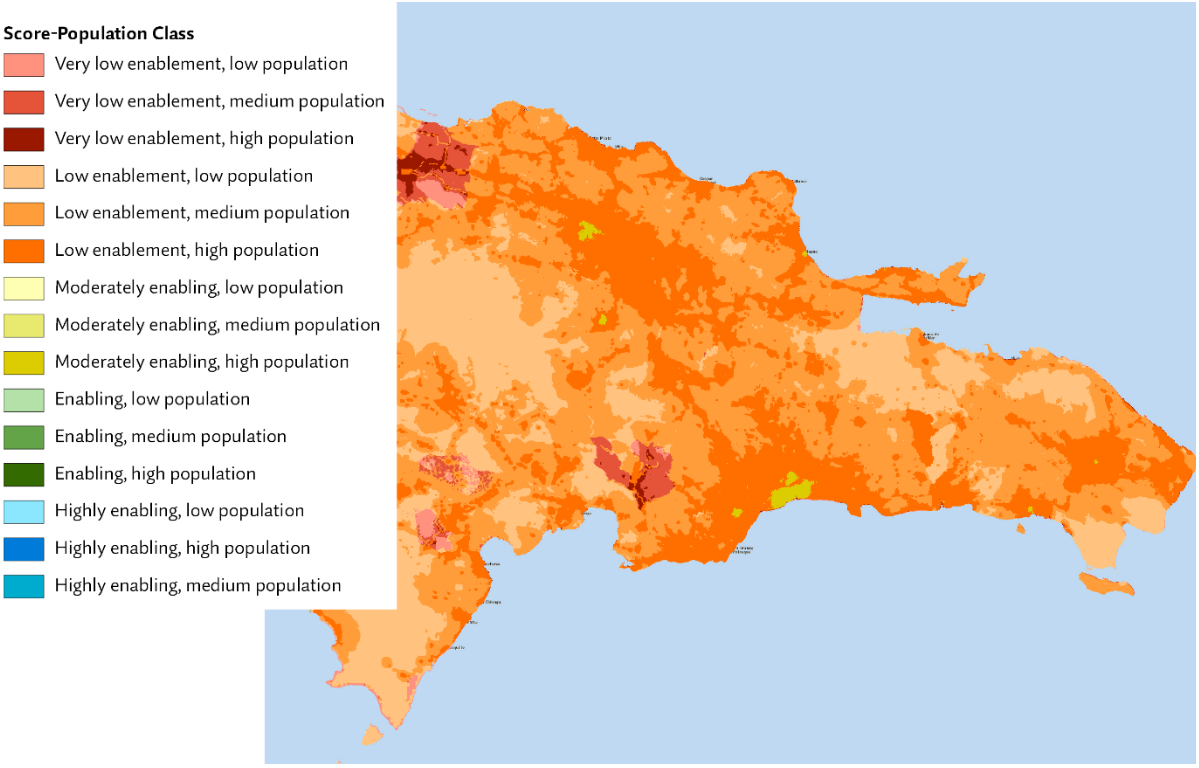
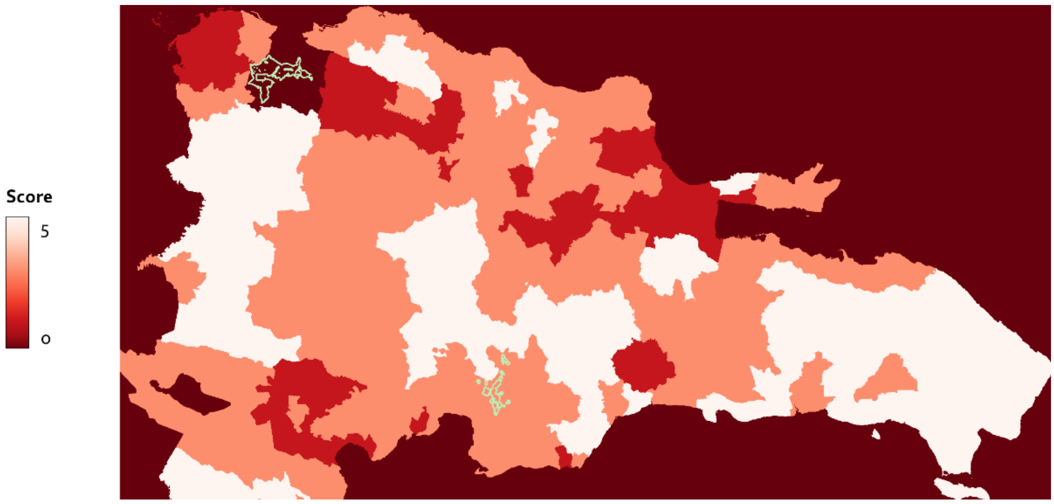


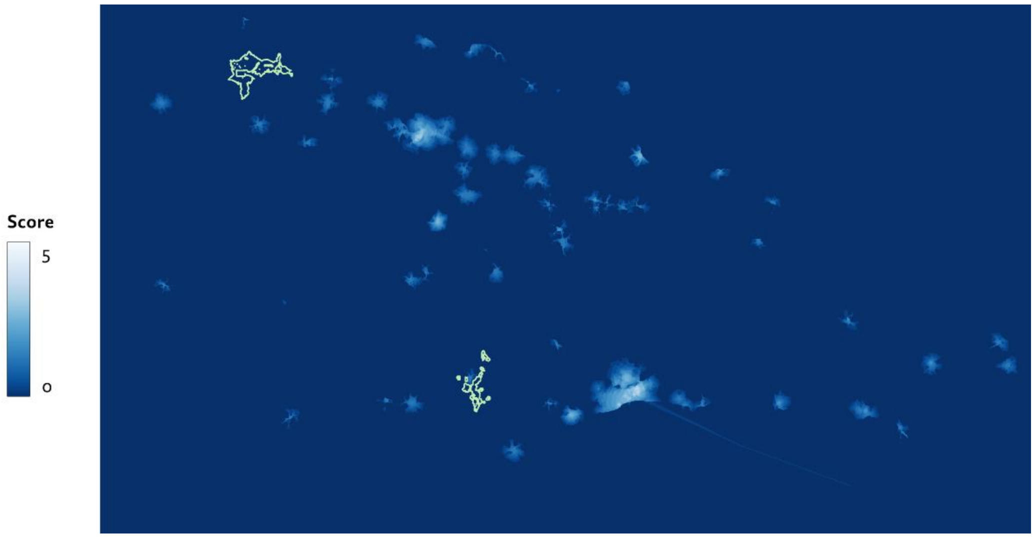
Figure 22 Raw score outputs for the three factors found to be driving low scores in one or both zones of interest (outlined in green). These factors are digital inclusion, natural and environmental factors, availability of public transport.

Digital Inclusion



Environmental Hazards

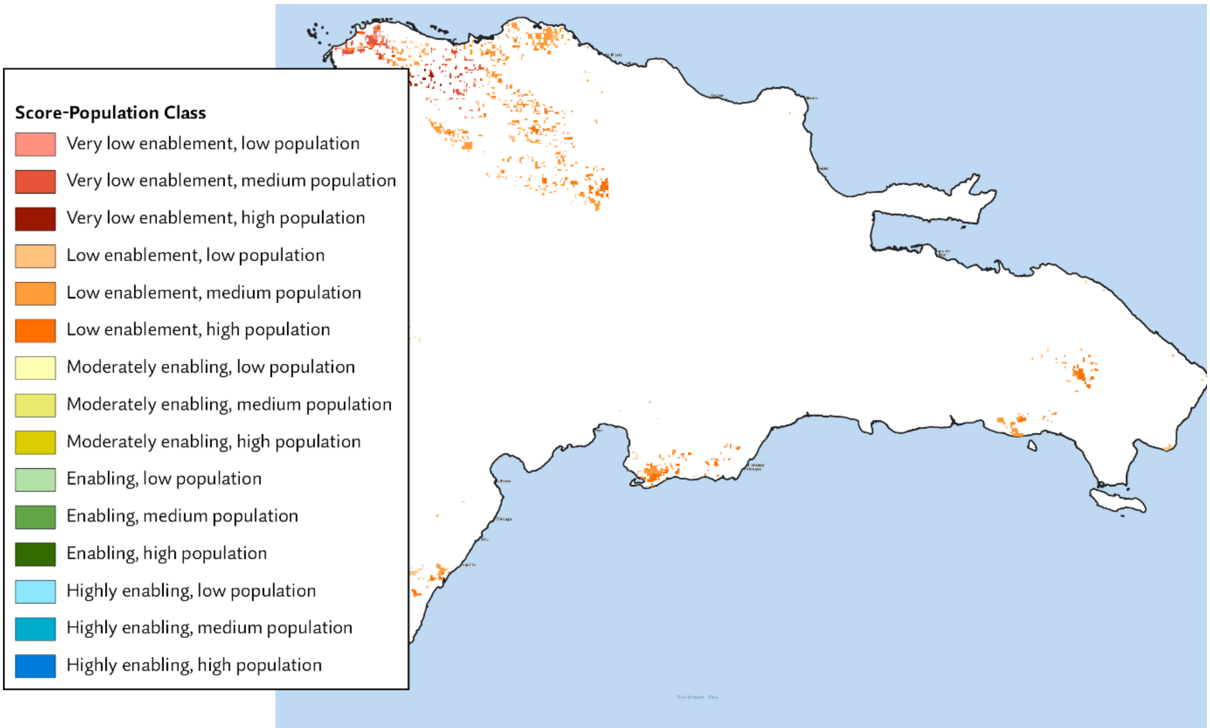
Figure 23 Accessibility Dimension Scores in the Dominican Republic



4.3.4 Linking outputs to potential renewable energy sites

Potential RE sites are usually depicted as areas of high solar/wind energy potential and are commonly stored in raster format. By extracting the layers of scores generated above in only zones of RE potential, a quick and insightful assessment can be made to determine their suitability as project sites or locations for further infrastructure investment. Figure 24 shows the distribution of the 15 categorical classes across zones of high wind energy potential in the Dominican Republic.

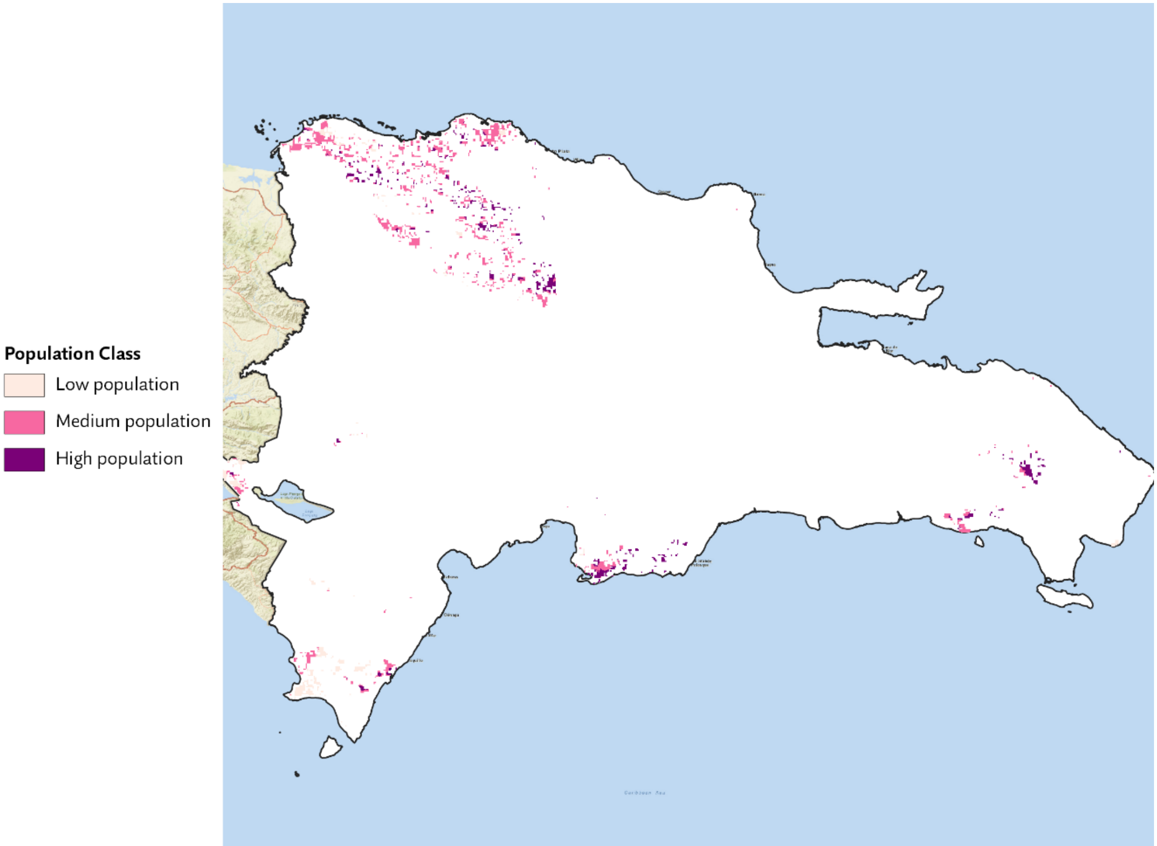
Figure 24 The fifteen combined score and population classes shown only in zones of high RE (wind) potential in the Dominican Republic.



Use case example:

If a company were looking to invest in a wind energy project in the Dominican Republic, the results in the figure above suggest that none of the high wind energy potential zones provide an enabling environment for women. The company may then choose to develop a project in an area that has a high population density to ensure that they have access to a large workforce and then invest money to improve opportunities in these areas. In this instance, Figure 25 illustrates that concentrating projects in the far east, south-central, or central to northwest regions of the country will extend access to the largest number of women.

Figure 25 Population counts in zones of high wind energy potential in the Dominican Republic



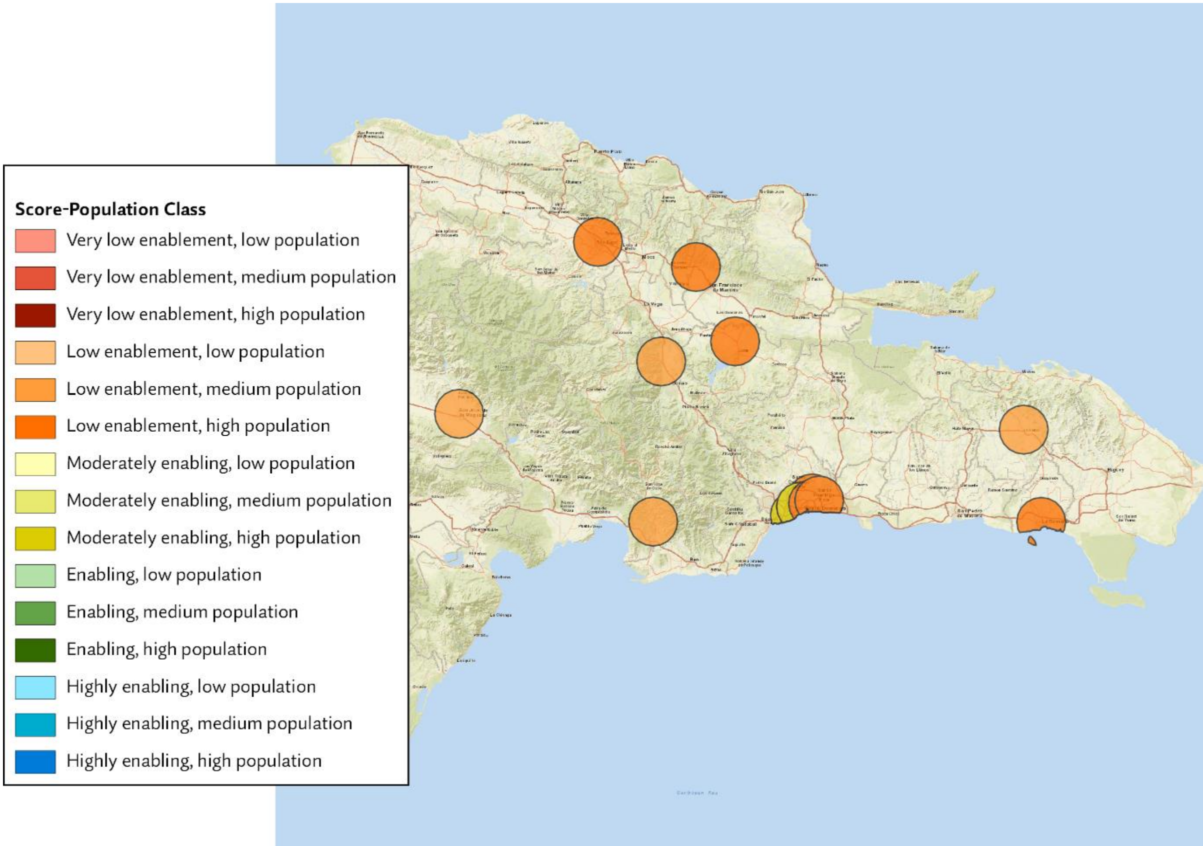
4.3.5 Linking insights to point locations of interest

In some instances, rather than zones defined by a raster layer, there may be specific point locations for which insights are required. To characterize the environment surrounding points of interest, a circular buffer of 10 km is placed around the points, and the results within that buffer zone aggregated. While continuous variables such as the output scores can be aggregated using the mean or median, a categorical variable such as the score-population class cannot be aggregated in this way. Instead, the majority class (most common class) within the 10 km buffer zones of interest is identified to characterize the central tendency of these zones. Figure 26 shows the results of an analysis such as this in the Dominican Republic.

Use case example:

If a company had a selection of locations in mind for RE projects, and wanted to ensure that projects were placed in areas that already provide enabling environments, they could run this analysis with outputs as depicted in Figure 26. The results suggest that the locations in and around Santo Domingo in the south have high populations and are surrounded by more enabling environments (although still only moderately enabling), and thus would require less overall investment.

Figure 26 Majority class within a 10 km radius of points of interest in the Dominican Republic.



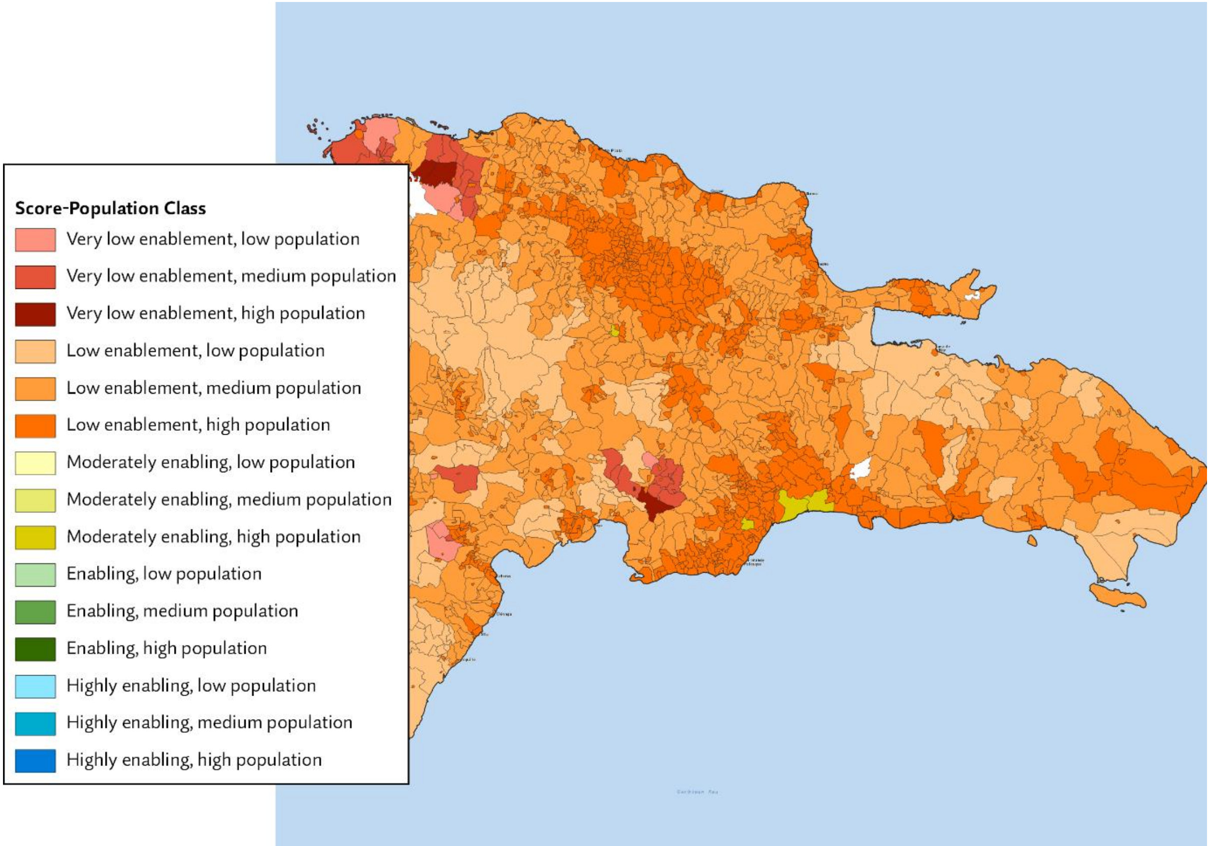
4.3.6 Spatial aggregation of results

Raw score outputs and the reclassed score-population classes are represented in raster format at a resolution of 100m x 100m. However, they can be aggregated to any spatial level of interest by calculating the central tendency within the spatial aggregation of interest. As for the previous example, the majority class is used rather than the mean or median. Figure 27 shows the majority class in each level 5 administrative region in the Dominican Republic.

Use case example:

This analysis could prove invaluable for government decision-makers looking to prioritize investments in municipalities with notably low scores of enabling environments. Los Ranchitos in the south-central region, and Hato Del Medio Arriba and Juan Gãmez in the north-west, are the municipalities with the highest population levels and lowest scores.

Figure 27 Majority class for each level 5 administrative region in the Dominican Republic.



4.4 LIMITATIONS IN DEVELOPING AND APPLYING THE METHODOLOGY

This methodology for spatially assessing regions' levels of enablement for women's access to employment in the renewable energy sector is the first of its kind, with a specific focus on the context of Small Island Developing States (SIDS). . As a result, various challenges were identified when designing and establishing the indicators and executing the analyses.

Research and literature on women's access to formal RE employment and business opportunities are not often applicable to a SIDS context. As the assessment takes on a spatial dimension, available research becomes even more limited. Some of the best-applicable methodological approaches presented in the literature review are from high-income countries or emerging economies where the local context differs significantly from that of SIDS.

Generally, existing frameworks, such as those described in Section 3, consider only one or a few factors. Therefore, complex analytical techniques can be applied. Nevertheless, this methodology must integrate several factors over a wide area to produce an output. The lack of spatially disaggregated data, the high number of indicators, and the wide spatial scale of analysis mean that the analytical techniques applied in this methodology are necessarily simpler in nature than the reviewed analyses.

A number of factors and indicators are identified for the Contextual Dimension that may be applied to assess women's access to RE jobs in the formal sector. There may, however, be more appropriate indicators available for specific SIDS. In these instances, the indicators most appropriate to the local context should be used.

Applying any grid to a spatial dataset invariably causes challenges resulting from where the grid's origin is placed. In the case of SIDS, where islands can be very small, this placement may significantly impact how the data is presented spatially. However, the output raster resolution for all indicators is intended to be 100 m x 100 m, so the challenge associated with the grid origin point should be reduced to an acceptable margin.

Regarding the selection of indicators, application of thresholds, and utilization of data to represent indicators, there are significant opportunities to improve the application of the methodology to SIDS. It is recommended that specific studies be developed, motivated for, and embarked on to fill the data gaps and support the collection and distribution of disaggregated data within SIDS.

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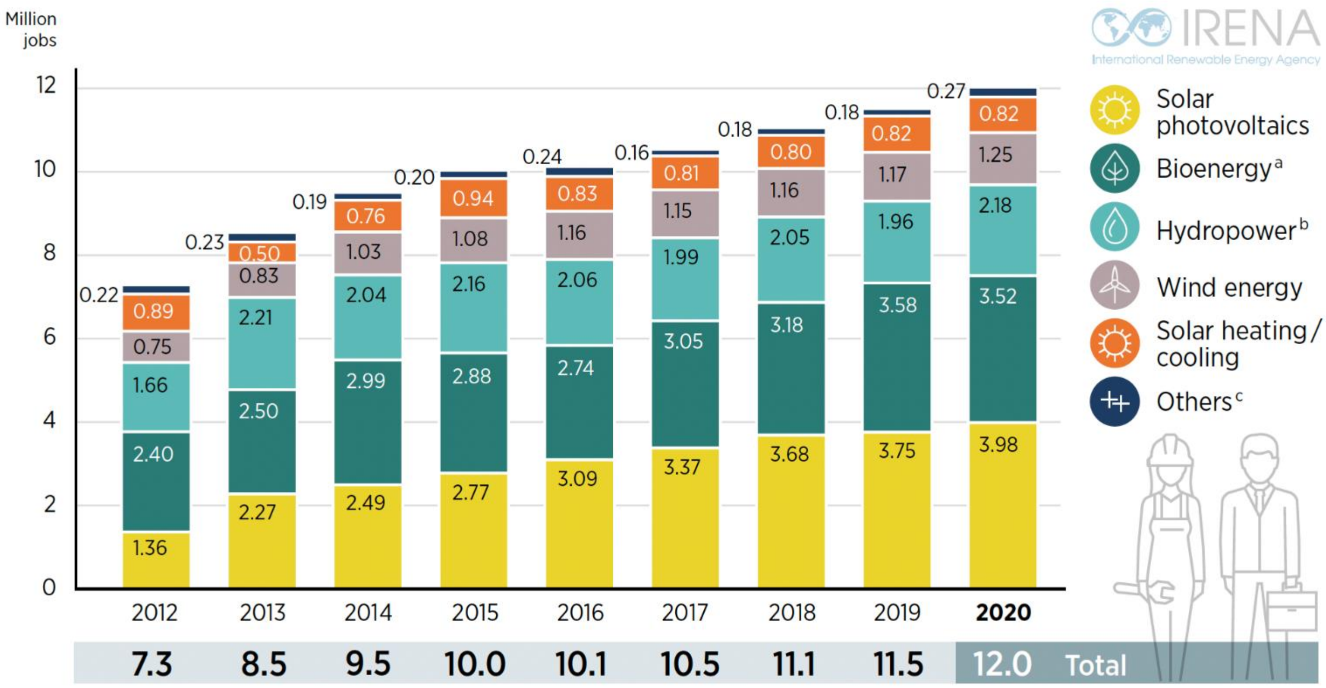
APPENDIX A The Renewable Energy Sector and Employment

Employment in the RE sector globally has grown dramatically from 7.3 million in 2012 to 12 million in 2020. The solar PV sub-sector has led this growth, with the number of employees almost tripling from 1.4 to 4 million between 2012 and 2020 (Figure 28). The wind sub-sector has seen the second-highest growth rate at 66%, from 0.75 to 1.25 million jobs. The bioenergy and hydropower sub-sectors stand in second and third place with 3.52 (29%) and 2.18 (19%) of all RE jobs, respectively (IRENA, 2021).

Figure 28 Employment in the renewable energy sector



a Includes liquid biofuels, solid biomass and biogas.
b Direct jobs only.
c "Others" includes geothermal energy, concentrated solar power, heat pumps (ground based), municipal and industrial waste, and ocean energy.

Source: IRENA jobs database.

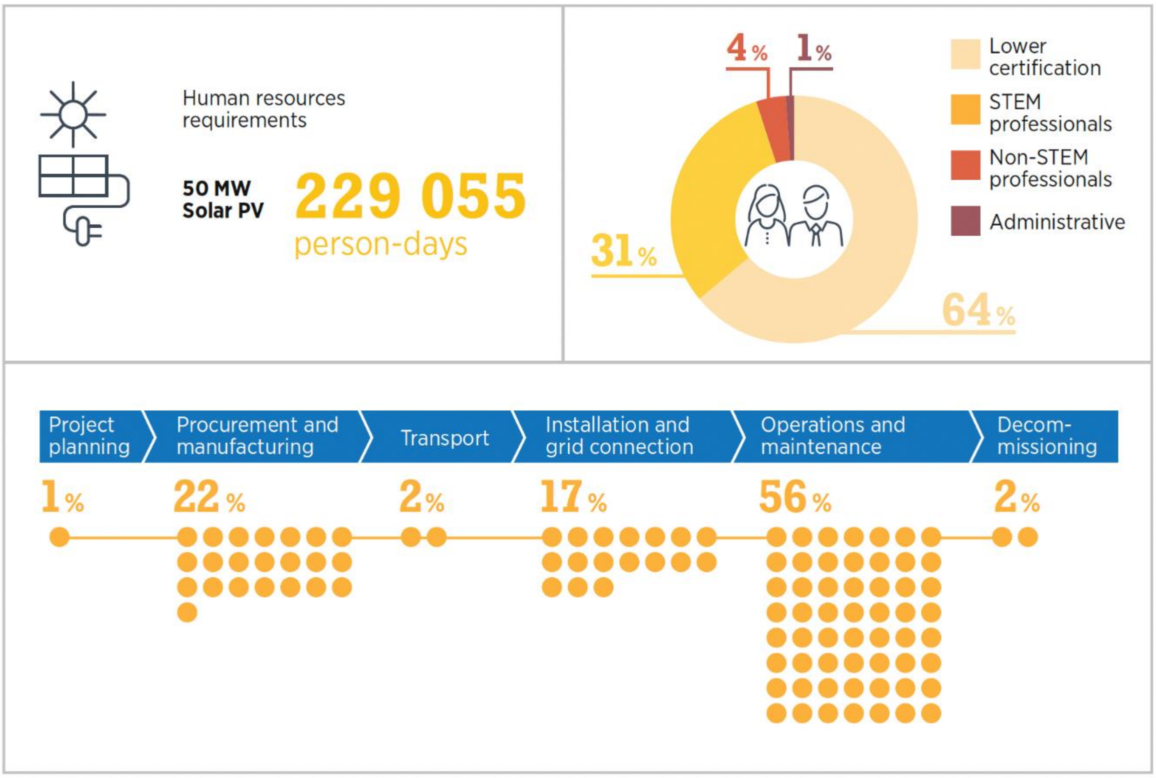
A 1. SOLAR PV

The solar PV and wind energy sub-sectors provide the highest promise for formal direct employment in the RE sector (IRENA, 2020a). IRENA's energy transition scenario, which envisions a climate-resilient future with a large-scale shift to renewable energy, calculates a total of 42 million jobs in the RE sector by 2050. Of these jobs, 45% (18.7 million) will be in solar PV, followed by 34% (14.1 million) in bioenergy and

15% (6.1 million) in wind energy. This scenario does not see significant growth in employment in the hydropower sector, where 94% of existing employment relates to the manufacturing and construction of large government-backed dams. While bioenergy will still represent the second highest overall employer in the RE sector, the majority of the jobs in the sector are casual and seasonal agricultural jobs rather than full-time formal jobs (IRENA, 2021).

Solar PV offers employment prospects to people with a wide range of skills in all stages of a typical project, from project planning to decommissioning (IRENA, 2022a). For a 50 Megawatt (MW) solar PV project, most labor is required in operations and maintenance (56%). Overall, 64% of the required employment in this kind of project is allocated to employees with lower educational certifications. High-skilled employees, including STEM professionals, account for over a third (35%) of all labor requirements (Figure 29).

Figure 29 Labor requirements alongside the Solar PV value chain



Source: IRENA (2022a)

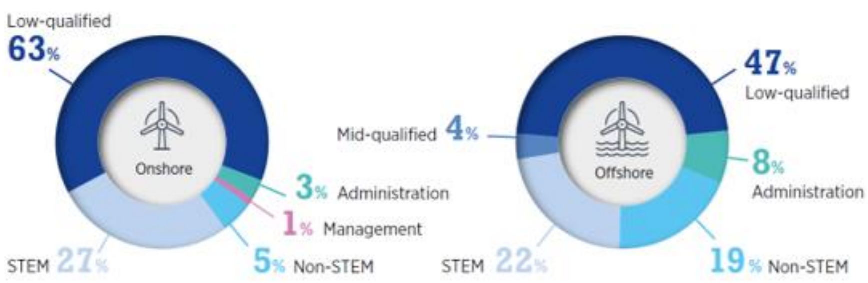
Local formal direct employment in solar PV projects is most likely to happen in large on-grid projects in the later stages at the installation and grid connection, operations and maintenance, and decommissioning stages of the project. The solar PV value chain is highly localized, with 78% of the world's cell production and 72% of module output originating in China (IRENA, 2021). While mini-grids generate jobs through manufacturing, installation, and operations and maintenance, their job generation is mostly indirect and induced through the electrification of communities that did not previously have access to electricity (ESMAP, 2019). The sale of off-grid solar PV appliances produces jobs primarily in rural areas, supporting job creation and diversification among often economically disadvantaged and vulnerable communities (GOGLA, 2019).

A 2. WIND

The wind sub-sector provides strong opportunities for local employment generation. While the wind energy supply chain depends on globally sourced components, the large size of wind and the weight of wind turbines encourage the development of local supply chains to source these materials for large onshore and offshore projects (Ladislaw et al., 2021).

Large wind onshore and offshore projects create sustainable jobs, which require a variety of skills across the full value chain of the sector. Direct jobs beyond manufacturing include employment by onshore and offshore project owners and primary contractors and tend to be concentrated in the installation and operations and maintenance (O&M) segments of the value chain. This job creation depends on a country's ability to establish a robust local supply chain, including investment in manufacturing and port infrastructure and specialized vessels for offshore projects (Global Wind Energy Council, 2021). STEM skills are a priority for many of the most well-paid jobs in the wind sub-sector. However, as Figure 30 below shows, unskilled, non-STEM roles in factories and construction comprise the largest share of jobs in both on-shore and off-shore wind projects. The majority (63%) of on-shore wind jobs are low-qualified, and STEM jobs account for only 27% of on-shore and 22% of off-shore wind jobs (IRENA, 2021).

Figure 30 Skills priorities in the wind sector



Source: IRENA (2021)

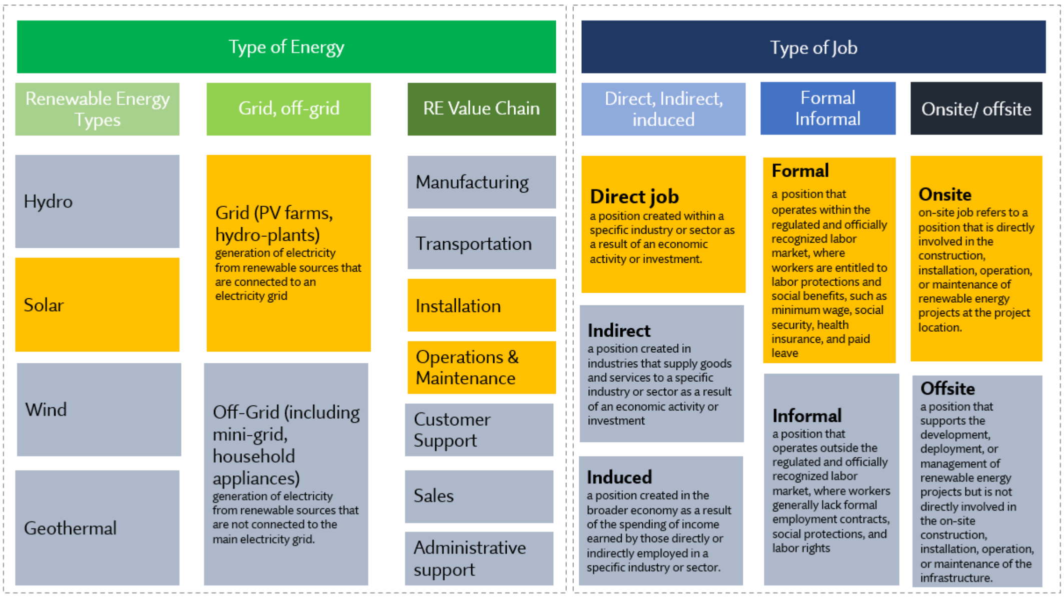
APPENDIX B The Location of Renewable Energy Jobs

The location of jobs in the renewable energy (RE) sector is crucial in determining access to employment opportunities (IRENA, 2021)**.** A job's location can significantly influence whether individuals can easily access it, as this factor is closely related to aspects such as transportation infrastructure and proximity to population centers (World Bank, 2020). In some cases, job opportunities may be concentrated in specific regions or urban areas, potentially exacerbating existing spatial inequalities, reducing social inclusion, and limiting access for those living in more remote or disadvantaged areas (OECD, 2018).

The location of RE jobs and business opportunities encompasses any place where work related to the RE sector[7] takes place. This broad definition covers a wide range of job categories and various types of RE initiatives. Job categories can include direct, indirect, or induced jobs, as well as formal and informal positions, both on-site and off-site. These jobs may be associated with different forms of RE generation, such as hydro, wind, solar, or geothermal energy, and involve grid-connected or off-grid energy production. Furthermore, they can span various segments of the RE value chain, including manufacturing, transportation, installation, operations and maintenance, sales, customer support, and administrative support (GOGLA, 2019; IRENA, 2021). An indication of the different combinations of RE energy sources and types of jobs – along with their definitions - are included in Figure 31.

[7] The RE sector comprises of all sources of energy derived from natural resources, which are replenished at a higher rate than they are produced. The main RE technologies are solar energy, wind energy, hydropower, bioenergy and biofuels, geothermal energy, and ocean energy (United Nations, n.d.).

Figure 31 RE Jobs



Source: Pegasys

In the context of this report, the focus is narrowed to RE jobs in Small Island Developing States (SIDS) based on two principles. These principles were chosen considering the extensive range of potential job categories in the RE sector and the unique characteristics and challenges faced by SIDS. The principles include:

- Resource Potential, Suitability. and Opportunities for Women: We prioritize RE energy sources that are highly relevant to a SIDS context based on their suitability for local energy generation and the ability of different countries to capitalize on their comparative advantages. We also focus on the types of RE sources likely to benefit women workers (see below).

- Local Value Creation and Economic Development Potential: We aim to identify opportunities for local value creation, local economic development, and economic empowerment for women in SIDS by focusing on direct, formal, and on-site jobs in specific value chains, such as manufacturing, installation, and O&M. RE projects that feed into the grid are typically larger in scale and generate more jobs than off-grid RE projects, and this further informs our investigation (see below).

Different SIDS have varying RE resources depending on their geographic and geological characteristics. For instance, volcanic SIDS such as those found in the Caribbean and the Pacific often have significant geothermal potential, while atoll island SIDS are typically more reliant on solar and wind resources due to their low-lying topography and lack of geothermal potential (IRENA, 2022a). According to various sources, SIDS, mostly located in the Caribbean, have geothermal potential (IRENA, 2017; Joseph, 2008). This potential has led countries like Guadelupe to pursue geothermal energy projects to meet their energy needs and reduce dependence on imported fossil fuels, although the total installed capacity for geothermal energy remains negligible (IRENA, 2022c). On the other hand, atoll island SIDS, which typically have low-lying topography and lack geothermal potential, have greater potential for solar and wind generation – and are currently generating a higher proportion of their renewable energy from these sources. Hydropower potential is limited to SIDS with sufficient water resources and elevation changes. SIDS with mountainous terrain, such as some islands in the Pacific, may have the necessary elevation changes to utilize hydropower effectively. Here, hydropower capacity generation is estimated at 542 MW, or more than 50% of the total renewable electricity installed capacity (957 MW) (IRENA, 2022c). SIDS do have notable biomass potential, as they can utilize agricultural residues, forestry waste, and organic waste to produce bioenergy, which can contribute to sustainable energy production and reduce their reliance on imported fossil fuels (IRENA, 2020a)

Solar and wind power are increasingly the choice for SIDS countries, followed by hydropower and biomass (Filho et al., 2022). According to the International Renewable Energy Agency (IRENA) data, as of 2019, the total installed renewable energy capacity in SIDS was approximately 5.3 GW (IRENA, 2021). While hydropower accounts for the majority of this capacity (Figure 33), solar energy has made up the dominant renewable installations since 2014, with a total installed capacity of around 680.4 MW (IRENA, 2021). Wind energy is another prevalent renewable energy source in SIDS, with an installed capacity of approximately 510 MW (IRENA, 2021) While Hydropower generation potential is limited by specific geographical and hydrological conditions, it accounts for around 1.3 GW of the total installed renewable energy capacity in SIDS and remains the primary source of energy; biomass follows with a total capacity of 859 MW. Neither of these sources is growing at a fast pace as solar or wind (IRENA, 2021).

Figure 32 Total installed renewable capacity for SIDS, 2014-2019

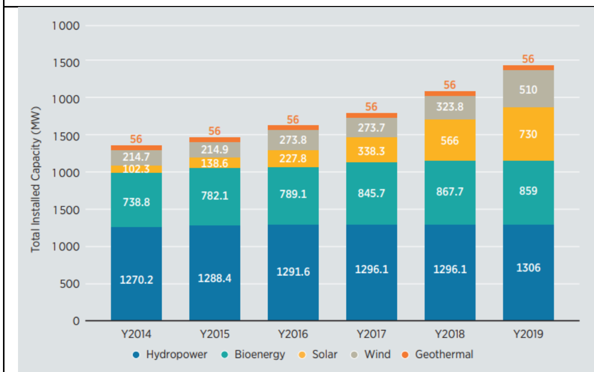
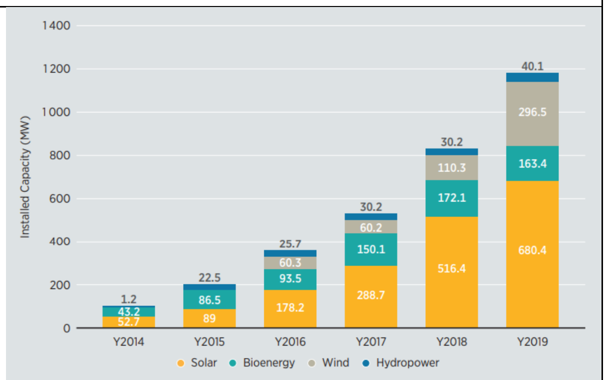


Figure 33 New Cumulative renewable energy installations since 2014



Source: IRENA, 2021 – SIDS Lighthouses Initiative

A literature review on RE and jobs (Cameron & van der Zwaan, 2015) provides a comparison of direct employment factors in person-years for the deployment of onshore wind technologies and solar PV technologies from different academic sources, showing that solar PV has a higher potential to generate employment compared to wind.

Table 22 Direct employment factors for the phases of deployment of wind and solar PV technologies

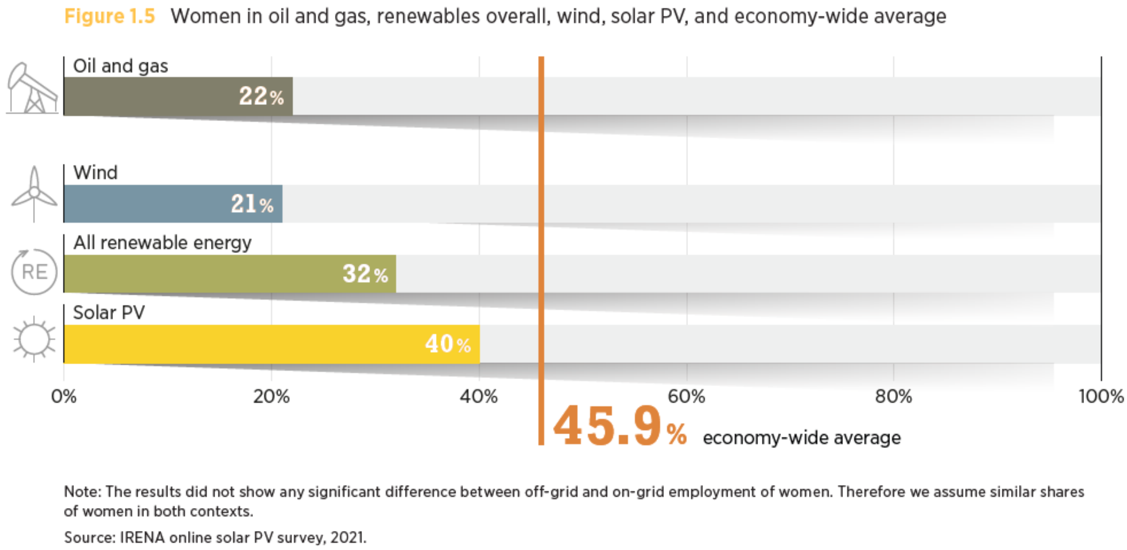
Economic Empowerment	**Manufacturing (person-years/ MW)**	**Installation (person-years/ MW)**	**O&M (jobs/MW)**
Onshore Wind	Minimum: 2.7 **Median: 4.0** Maximum: 12.5 Std: 3.3 Studies: 8	Minimum: 0.5 **Median: 2.0** Maximum: 6.7 Std: 2.4 Studies: 10	Minimum: 0.1 **Median: 0.3** Maximum: 0.7 Std: 0.2 Studies: 16
Solar PV	Minimum: 6.0 **Median: 18.8** Maximum: 34.5 Std: 9.3 Studies: 9	Minimum: 6.4 **Median: 11.2** Maximum: 33.0 Std: 9.7 Studies: 9	Minimum: 0.1 **Median: 0.3** Maximum: 1.66 Std: 0.4 Studies: 12

Source: Cameron & van der Zwaan (2015)

Women's employment in the solar sector is high, presenting a significant opportunity for promoting gender equality and economic empowerment in Small Island Developing States (SIDS). While comprehensive gender-disaggregated data specific to SIDS is limited, global studies have shown that the renewable energy sector, particularly solar and wind, has a higher percentage of women employees compared to the overall energy sector. According to the International Renewable Energy Agency (IRENA), women represent 32% of the renewable energy workforce globally, whereas they account for only 22% of the workforce in the broader energy sector (IRENA, 2019). Solar accounts for the largest number of jobs in the wider RE sector (30%), and its job creation potential all along the value chain is 'immense' (IRENA, 2022b). Solar is by far the most equal when it comes to employing women - forty percent of workers in the on-grid and off-grid solar sector are women.[8] However, women continue to be employed in lower paid, non-technical, administrative, and public relations positions than in technical, managerial, or policymaking positions (IRENA, 2020b).

[8] In contrast, at 21%, women's presence in the global wind energy sector is substantially below the RE sector overall (32%). Female participation is highest in 26% in Europe and North America and lowest in Africa at only 8%. Asia-Pacific and Latin America and the Caribbean come in at 19% and 15%, respectively - both very low averages, but in fact, likely to be higher than the statistics for individual SIDS (IRENA, 2019).

Figure 34 Women representation in RE and oil and gas



Source: IRENA (2022b)

In terms of location, formal direct jobs in the RE sector could focus on areas where manufacturing of gridded RE infrastructure – and its associated components - takes place. The solar PV value chain is highly localized, with 78% of the world's cell production and 72% of module output originating in China (IRENA, 2021). To a lesser extent, the location of formal direct jobs and business opportunities might also refer to places where components are manufactured, mini-grids installed, off-grid products sold, and components are transported. This includes the industrial location where steel and concrete pole manufacturing take place and the rural areas where mini-grids are installed or off-grid products, such as solar lamps and home systems are sold (Ladislaw et al., 2021)[9].

However, in the context of SIDS, formal direct jobs in the RE sector tend to center on the physical location of large RE generation projects. These projects often involve the construction, installation, operation, and maintenance of renewable energy infrastructure, such as solar power plants or wind farms, which directly employ a substantial number of workers in various roles. STEM skills are a priority for many of the most well-paid jobs in RE.

The location of these projects depends on a number of indicators, including the availability of the resource (e.g., solar radiation and wind speeds), population densities, distance to roads and electricity lines, and land cover:

[9] For a more comprehensive overview of employment in the RE sector, see 0.

- Firstly, the availability of renewable resources, such as solar irradiation and wind speeds, is a key consideration when selecting the location for renewable energy projects. Solar and wind resources must be sufficient and consistent to maximize energy generation and provide a reliable power supply.
- Secondly, population densities and proximity to urban centers or load centers are important factors in determining the location of RE projects. High population densities or proximity to urban areas can increase the demand for electricity, making it economically viable to develop renewable energy projects close to these locations to serve these locations (ADB, 2017).
- Thirdly, the distance to existing infrastructure, such as roads and electricity transmission lines, is a vital consideration when planning the location of RE projects. Closer proximity to existing infrastructure can significantly reduce the cost of transporting equipment and materials, as well as facilitate the integration of the generated electricity into the grid.
- Lastly, land cover and land use characteristics are essential factors to consider when selecting the location of RE projects. Areas with suitable land cover (or lack thereof) and slope, such as flat or gently sloping terrain for solar and wind projects, can reduce construction and maintenance costs. Additionally, land use policies and regulations must be considered to ensure that RE projects align with the local and national development plans and respect land rights and environmental considerations.

There are several existing spatial datasets that can be used to estimate ideal locations for renewable energy (RE) generation sites. These datasets often provide geospatial information on additional factors, such as natural resources, geographic features, and socioeconomic aspects.

- Global Solar Atlas: Developed by the World Bank Group, the Global Solar Atlas provides global high-resolution solar resource data (Global Solar Atlas, 2023). It includes information on solar irradiation, photovoltaic power potential, and solar resource maps. It also includes World Bank Global Photovoltaic (PV) Power Potential, which estimates power potential by country.

- Global Wind Atlas: Similar to the Global Solar Atlas, the Global Wind Atlas, also developed by the World Bank Group, offers high-resolution wind resource data (Global Wind Atlas, 2023). It includes wind speed and power density maps, as well as data on wind turbine energy production.

- Global Land Cover Database (GLC2000): Created by the European Commission's Joint Research Centre, the GLC2000 provides land cover data at a global scale, which can help identify suitable land areas for RE projects (Fritz et al., 2003).

- The World Bank ReZoning Tool[10] provides locations for wind energy projects based on wind speed, elevation, slope, population density, and distance to transmission lines. Additionally, the tool provides economic parameters, including the type of turbine and generation capital, as well as weighting options.

[10] https://rezoning.energydata.info/

APPENDIX C List of datasets required to compute each factor and possible sources

DIMENSION	FACTOR	Layer	Source
CONTEXTUAL	Workplace Discrimination	WBL 2024 Workplace Score	Women, Business and the Law
	Regulatory Frameworks	WBL 2024 Pay+Parenthood Score	Women, Business and the Law
	Financial Inclusion	WBL 2024 Entrepreneurship Score	Women, Business and the Law
ACCESSIBILITY	Women's Travel Patterns	Location of kindergartens/childcare	OSM, Humdata
		Location of primary schools	OSM, Humdata
		Location of groceries	OSM
		Location of pharmacies	
		Location of green spaces	OSM, NDVI
	Access to Public Transport	Location of public transportation stops, including maritime (OSM)	OSM
	Access to Health Facilities	Location of hospitals and clinics (OSM)	OSM
	Access to Education and Training Facilities	Location of universities and technical schools (OSM, Humanitarian Data Exchange)	OSM, Humdata
	Access to Financial Facilities	Location of Banks and other FF (OSM)	OSM
PLACE CHARACTERIZATION	Active Transport	Location of street crossings	OSM, Mapillary
		Location of cycle paths (OSM)	OSM
		Location of footpaths (OSM)	OSM
		Block Layout (OSM)	OSM
	Safety	Streetlights/Nighttime lights	Mapillary
	FCV	ACLED data (Violence Estimated Events)	ACLED
	Education	5.7% of the labor force comprising women with university degrees	Central Statistics Office

	Digital Inclusion	Individuals using the Internet (% of population)	World Bank
	Environmental Hazards	Global Natural Hazards Data	National Centers for Environmental Information
	Water sanitation	Water points (OSM), catch basins, water valves and fire hydrants (Mapillary)	OSM, Mapillary

APPENDIX D Classification Processes

D 1. LINEAR SCALING

Linear scaling is used to assign standardized scores to continuous indicators when they cannot be assigned discrete scores based on thresholds. Figure 35 depicts the linear scaling process graphically for an indicator represented by percentages. Malczewski (1999) suggests the use of the following equation to perform linear scaling:

$$X_i = (R_i - R_{min}) / (R_{max} - R_{min}) \times m$$

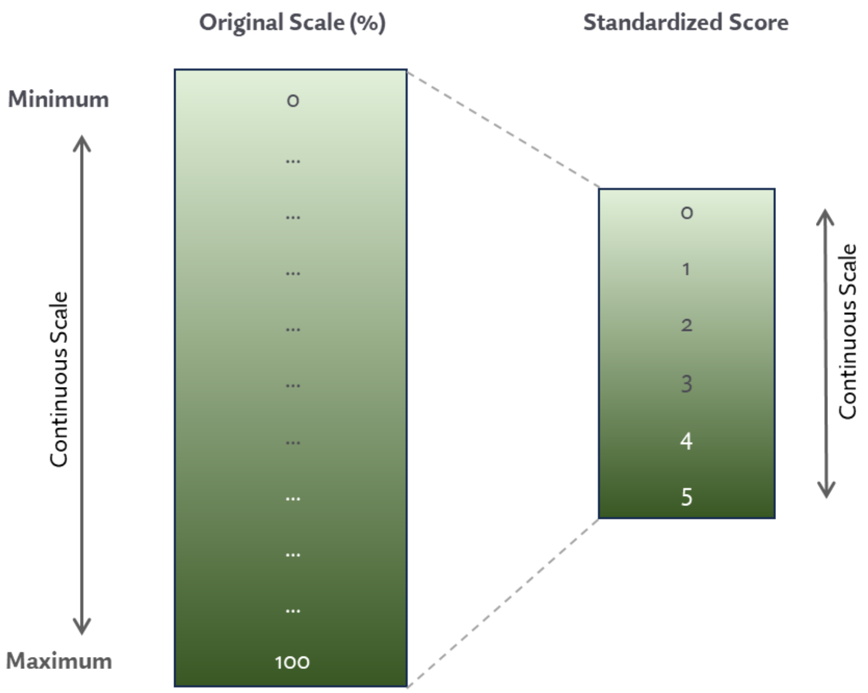
Where *Ri* is the raw value

Rmin is the minimum value of the input data

Rmax is the maximum value of the input data, and

m is a multiplier representing the upper standardized score (in this framework *m* = 5)

Figure 35 Diagram depicting the linear scaling process for a continuous indicator represented by percentages.



This process of linear scaling should be used when indicators are considered to have a more favorable metric when they have a higher value, such as the percentage of women with a tertiary education. In this instance *Rmin* = 0, *Rmax* = 100 and *m* = 5, such that communities where *Ri* = 100% would be assigned a standardized score of 5.

D 2. INVERSE LINEAR SCALING

Some continuous indicators, such as the percentage of women who have suffered domestic violence, are considered to be more favorable when they have a lower value, as illustrated in Figure 36 . As such the equation to scale these indicators is altered slightly from the linear scaling process to become:

$$Xi = (Ri - Rmax)/(Rmin - Rmax) \times m$$

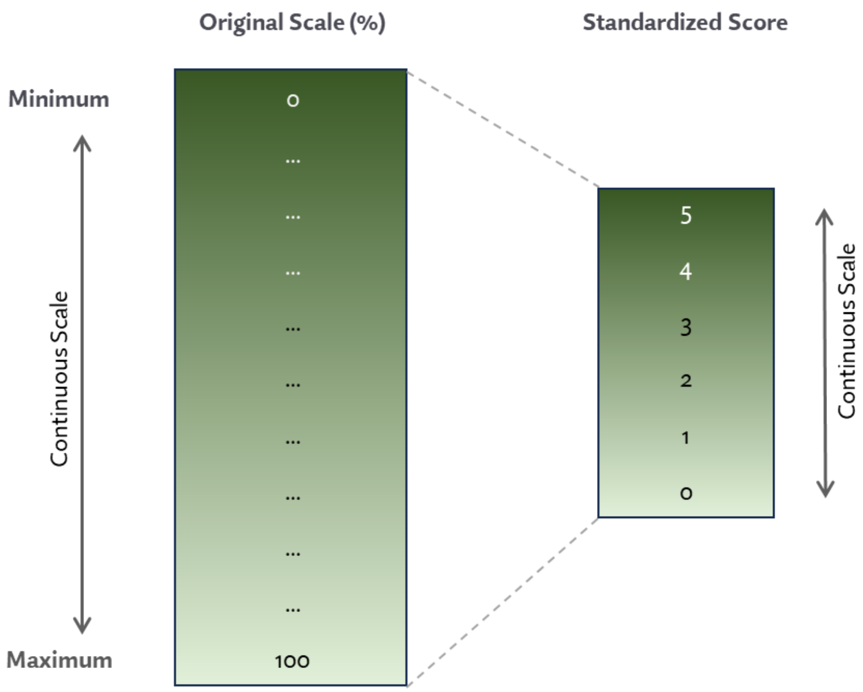
Where *Ri* is the raw value

Rmin is the minimum value of the input data

Rmax is the maximum value of the input data, and

m is a multiplier representing the upper standardized score (in this framework *m* = 5)

Figure 36 Diagram depicting the inverse linear scaling process for a continuous indicator represented by percentages, where a high value indicates an undesirable metric.



Inverse linear scaling should be used for continuous indicators such as the percentage of women who have suffered domestic violence, where 0% is most favorable and 100% is least favorable. In this instance areas with 0% would receive a score of 5, and areas with 100% would receive a score of 0.

D 3. ACCESSIBILITY CLASSIFICATION USING NETWORK ANALYSIS

When road network data are available, a service area network analysis technique can be used to estimate more accurate catchment areas and accessibility scores. A walking speed of 5 km/hr is assumed for all roads, and the network analysis is applied using five successive travel distances as shown in Table 23 (where *distmax* is the maximum distance from a facility beyond which the facility is no longer considered to be accessible).

Table 23 Travel distances for application in the network analysis

Travel distance
distmax x 0.2
distmax x 0.4
distmax x 0.6
distmax x 0.8
distmax

The result is five catchment areas, based on the road network, of increasing size and decreasing accessibility. These catchment area polygons are rasterized and combined, and the areas between the catchment boundaries reclassified to accessibility scores as depicted in Figure 37.

Figure 37 Simplified depiction of the network analysis reclassification procedure