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TRANSLATIONAL ARTICLE

Anticipating climate change-related mobility in Karachi and Ho Chi Minh City: lessons from a hybrid foresight approach

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Abstract

Climate change exacerbates existing risks and vulnerabilities for people globally, and migration is a longstanding adaptation response to climate risk. The mechanisms through which climate change shapes human mobility are complex, however, and gaps in data and knowledge persist. In response to these gaps, the United Nations Development Programme's (UNDP) *Predictive Analytics, Human Mobility, and Urbanization Project* employed a hybrid approach that combined predictive analytics with participatory foresight to explore climate change-related mobility in Pakistan and Viet Nam from 2020 to 2050. Focusing on Karachi and Ho Chi Minh City, the project estimated temporal and spatial mobility patterns under different climate change scenarios and evaluated the impact of such in-migration across key social, political, economic, and environmental domains. Findings indicate that net migration into these cities could significantly increase under extreme climate scenarios, highlighting both the complex spatial patterns of population change and the potential for anticipatory policies to mitigate these impacts. While extensive research exists on foresight methods and theory, process reflections are underrepresented. The innovative approach employed within this project offers valuable insights on foresight exercise design choices and their implications for effective stakeholder engagement, as well as the applicability and transferability of insights in support of policymaking. Beyond substantive findings, this paper offers a critical reflection on the methodological alignment of data-driven and participatory foresight with the aim of anticipatory policy ideation, seeking to contribute to the enhanced effectiveness of foresight practices.

Policy Significance Statement

There is a surge in the adoption of foresight methods across various sectors in support of strategic planning and policy ideation. Given the dynamic, variable, and bespoke nature of foresight design, there exists a critical evidence gap in understanding its impact and efficacy, particularly in shaping policymaking processes. To advance both foresight theory and practice, more empirical evidence is needed to improve validation, replication, and verification. Critically reflecting on a 2023 UNDP applied foresight exercise focused on climate change-related human mobility, this work outlines how integrated, participatory foresight approaches that combine methods and data sources can offer insights into potential future mobility outcomes based on actions taken or neglected in the present. In addition, it suggests that policy ideas are stronger when they do not treat interconnected trends—environmental, socioeconomic, or mobility—in isolation and are grounded in

approaches that offer insights into trade-offs and potential levers for achieving desired outcomes. We expect these reflections to be relevant to researchers and practitioners interested in enhancing the design and conduct of foresight practices.

1. Introduction

The United Nations Development Programme's (UNDP) *Predictive Analytics, Human Mobility, and Urbanization Project*, implemented from August 2022 through July 2023, combined new statistical modeling techniques with qualitative foresight to collect and interpret data on the potential impacts of climate change on internal migration in Pakistan and Viet Nam from 2020 through 2050 (see UNDP, 2024a). The project's blended approach recognizes the value of attempting to quantify geographic variation in the intensity and directionality of human mobility, while acknowledging the uncertainty and limitations associated with such projections in helping to frame policy debates. The project attempted to position quantitative and qualitative methods in a tight feedback loop to test, validate, and update findings in an iterative process for policy ideation and programmatic recommendations for stakeholders in Pakistan and Viet Nam.

This translational article outlines the design, processes, and outcomes of the project and provides critical reflections on the implications of its design for engagement, sensemaking, and transferability of insights in support of policymaking. We begin with an overview of the climate change-human mobility nexus, addressing the challenges of measuring, predicting, and developing policies responsive to climate change-induced migration. Next, we highlight how foresight, as a set of anticipatory practices, effectively complements linear or quantitative approaches to data, broadening what constitutes "evidence" in evidence-based decision-making for climate-related mobility. We then detail the project's objectives, methods, and findings and critically reflect on the relationship between certain project design elements and outcomes. Finally, we offer recommendations for researchers and practitioners involved in similar multi-stakeholder processes, aimed at enhancing institutional responses to climate change-induced human mobility.

2. Measuring and predicting climate change-related human mobility

Human-induced climate change affects human mobility, though the precise mechanisms through which climate events and climate variability shape migration and displacement are complex (Huber et al., 2023). In the Asia Pacific region in particular, climate change influences mobility patterns and strains social and economic systems (Farbotko et al., 2018; Ranjan et al., 2023). Migration is a common and longstanding adaptation response (among many possible responses) to the impacts of environmental change. Climate change-related mobility most commonly occurs as internal migration rather than long-distance international movements (Burzyński et al., 2022; Intergovernmental Panel on Climate Change (IPCC), 2022; Kaczan and Orgill-Meyer, 2020), with recent research showing that climate change impacts reduce emigration for resource-constrained populations (Benonnier et al., 2023; Benveniste et al., 2022). Evidence suggests that both rapid- (e.g., floods) and slow-onset (e.g., coastal erosion) climate hazards directly drive involuntary migration and exacerbate pre-existing migration drivers for climate-sensitive communities, particularly from regions that are economically or politically fragile (Adger et al., 2020; IPCC, 2022). Substantial variation in the nature and distribution of environmental change—and variance in the capacity of populations to mitigate and adapt—is likely to exacerbate geographic disparity in migration in the coming decades (Burzyński et al., 2021; Gemenne, 2011).

There is substantial evidence that human migration is not exclusively driven by climatic change, but instead by complex interactions of economic, social, political, cultural, and environmental factors (Boas et al., 2019; Hoffmann et al., 2020; Šedová et al., 2021). While some studies show that climate change informs migratory patterns (e.g., Coniglio and Pesce, 2015), other studies find that climate change only

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indirectly influences migration patterns (e.g., Helbling and Meierrieks, 2021) or find no effects at all (e.g., Beine and Parsons, 2015). Despite the lack of uniform consensus around the links between climate change and migration, climatic change compounds pre-existing risks for millions around the world and the impacts of climate drivers are highly context-dependent and place-based (Berlemann and Steinhardt, 2017; Piguet, 2012). Variation in findings might be attributed to the fact that empirical studies on the environmental dimensions of migration are spread across a range of disciplines using an array of methods, climatic and migration variables, and differing modeling strategies and samples (Beine and Jeusette, 2021; Helbling et al., 2023). In addition, efforts to model the impact of climate change on migration flows are complicated by significant data constraints and the challenge of disentangling a causal human/environment relationship from dynamic social processes (Brown, 2008; Das and Basu, 2023; Piguet, 2022).

The complexity of interactions between climatic change and migration drivers make predicting future mobility trends with a high degree of certainty difficult. Further complicating efforts to predict movement is the fact that climate change-induced mobility is likely to interact with other patterns of migration and displacement, including other drivers like conflict, socioeconomic precarity, or violence (Detges et al., 2020; Kabir and Kamruzzaman, 2022; Savelli et al., 2022). Additionally, adverse environmental conditions driven by anthropogenic climate change are likely to evolve beyond the boundaries of observed historic conditions. As such there is a lack of empirical evidence upon which to estimate quantitative models, rendering it more difficult to predict the range of plausible migratory outcomes. Only recently have studies predicting climate change impacts on human populations begun to proliferate and receive more attention (Piguet, 2022).

Forecasts of the impact of climate change on future migratory flows vary widely, with estimates ranging from 50 million to one billion “climate migrants” by the end of the century (Ferris, 2020). The World Bank’s *Groundswell* report suggests that in the absence of significant, coordinated action to mitigate climate change, there is a potential for 143 million internal “climate migrants” by 2050 (Rigaud et al., 2018). Projections like these have, however, been criticized for being alarmist and contributing to manufactured narratives of a “climate refugee crisis” (Durand-Delacre et al., 2021; Scoville-Simonds et al., 2020). In addition to the gravity-based model used in the *Groundswell* series (see also Jones, 2020), a variety of other methods have been applied to model such future mobility, including exposure mapping (e.g., Andrew et al., 2019), multivariate regression (e.g., Gray and Wise, 2016), agent-based models (e.g., Entwisle et al., 2020), systems dynamics models (e.g., Ginnetti, 2015), and radiation models (e.g., Robinson et al., 2020).

Yet, these quantitative tools are constrained in a variety of ways. Many provide limited spatial detail and do not assess variation within country or migratory hotspots or do not disaggregate population subgroups to differentiate environmental impacts (Piguet, 2022). Baseline migration data, particularly intra-national, are difficult to come by and inconsistently compiled, while detailed analytical frameworks capable of guiding decisions about which measures best assess the influence of climate change on mobility are lacking (Helbling et al., 2023). Substantial population growth and redistribution (forecast in the absence of climate change), and significant uncertainty in climate outcomes at the local-level (both extreme events and slow-onset change), further confound estimates of climate-induced migration and displacement (Hugo et al., 2012). New approaches are needed to better explain internal migratory movements, anticipate possible future migratory patterns, and signal emerging migration trends—particularly at the local level—to ensure that those who move, and their hosting communities, have their human rights protected and are able to contribute safely and meaningfully to the communities in which they live.

3. A phased approach to anticipating climate change-related mobility in fast-growing urban centers

In recent years, UNDP has acted on “a broader desire to institutionalize systems thinking, anticipatory decision-making and agile practices—both in internal ways of working, and in what is offered to external partners and stakeholders” (Dhar et al., 2023). Building on this ambition, the project outlined in this paper

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leveraged foresight techniques to clarify and render explicit the parameters of quantitative scenario estimates so that the relative importance of climate and societal variables in driving potential migration outcomes could be examined.

3.1. Project scope

Beginning with forward signals on the climate change and mobility nexus that were submitted during iterative regional horizon scans conducted by the UNDP Regional Bureau for Asia and the Pacific (e.g., UNDP, 2022; , 2023), the *Predictive Analytics, Human Mobility, and Urbanization Project* focused on Ho Chi Minh City in Viet Nam and Karachi in Pakistan, two densely populated and fast-growing urban centers that are disproportionately impacted by climate change.

At the city level, climate change is already restructuring the economic landscape in many nations, leading to substantial changes in the geographic distribution of opportunities, particularly in countries highly dependent on primary sector activities (Adger et al., 2020). Consequently, more people around the globe are migrating to urban areas in response to climate change impacts (Black et al., 2011; Ionesco et al., 2017), though some studies show that migration to urban areas, particularly in low-income countries, may decrease, possibly due to liquidity constraints, among other factors (Benonnier et al., 2023; Helbling and Meierrieks, 2023; Peri and Sasahara, 2019). Many rural-to-urban migrants find themselves at risk of secondary exposure to climate-related hazards, essentially fleeing one set of risks only to assume another (Adamo, 2010). This is particularly true in cities, which themselves are disproportionately exposed to climate hazards (MacManus et al., 2021). It is important to differentiate between migration, which is within the scope of this project, and internal displacement in this context—migration refers to voluntary movement from one location to another, whereas internal displacement involves involuntary movement within one country, typically due to environmental hazards or conflict (Rigaud et al., 2018).

Karachi, located in Sindh province in southern Pakistan, is the country's largest city and economic capital. Karachi is responsible for roughly 12–15% of Pakistan's total GDP and contains the nation's only major port, a hub of foreign trade (The World Bank, 2018). As a result, the city is the primary destination of rural-to-urban migrants, making it one of the 20 fastest growing cities in the world (Satterthwaite, 2020). Similar qualities and dynamics characterize Ho Chi Minh City and the bordering Mekong Delta region. The Mekong Delta is simultaneously one of the most fertile places on earth, accounting for one-third of Viet Nam's GDP, and one of the most vulnerable to climate change impacts (Behr, 2019). The destabilizing effects of climate change-related threats on rural economic livelihoods in the delta create the conditions for substantial socioeconomic exchange and increased in-migration from the low-lying delta to Viet Nam‘s largest city (Alverio et al., 2023).

Given these dynamics, the project concentrates on mobility toward Karachi and Ho Chi Minh City, while also considering the broader metro, regional, and national context to better understand the important socioeconomic and demographic dynamics driving urbanization and change. Research questions are: How many people will move internally to Ho Chi Minh City within Viet Nam and Karachi within Pakistan by 2050 accounting for the impacts of climate change? What impact will this climate change-related mobility have on Ho Chi Minh City and Karachi? How can Ho Chi Minh City and Karachi utilize the development potential of such in-migration and mitigate possible negative effects through adaptive interventions? The following domains were considered: a) spatial/urban development, including housing and land rights; b) climate and disaster risks; c) jobs/livelihoods, including social protection; d) accessibility of healthcare, education, and other key services; and e) social cohesion.

3.2. Design

The methods employed in this project considered both the advantages and constraints associated with predictive modeling and participatory foresight, aiming to leverage the strengths of each method while mitigating the respective limitations of the other. A summary of the five-phase research design is depicted in Figure 1.

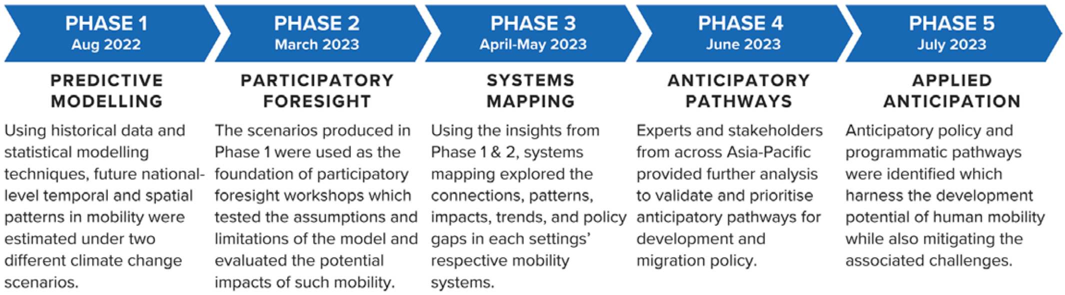

Figure 1. *Five-phase approach employed in the* Predictive Analytics, Human Mobility, and Urbanization Project *(adapted from UNDP, 2024a).*

3.2.1. Phase 1: Predictive modeling and scenario building

An external consultant led the predictive modeling to forecast the scale and spatial distribution of human mobility into Karachi and Ho Chi Minh City by 2050, inclusive of the impacts of climate change (Jones, 2023). The modeling produces scenario-based estimates of internal migration for each country, combining socioeconomic and climate projections. National-level population trends as well as urbanization rates are prescribed by the socioeconomic scenarios, while projections of greenhouse gas concentrations are prescribed by the climate scenarios. The models estimate the number of climate-induced migrants and their likely future destinations based on each scenario combination by comparing population distributions that incorporate climate impacts with a scenario based on a development trajectory only. To delineate the variability and uncertainty in outcomes under different emissions trajectories and socioeconomic development outcomes, two distinct scenarios were produced for each country. The scenarios are characterized as follows:

- Scenario 1: RCP2.6/SSP 1, in which climate change impacts are swiftly reduced on a global scale and there is rapid convergence toward higher levels of development in both countries. (RCPs, or Representative Concentration Pathways, are scenarios of a greenhouse gas concentration trajectory adopted by the IPCC. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases emitted in the years to come. SSPs, or Shared Socioeconomic Pathways, are scenarios of projected socioeconomic global changes up to 2100. The scenarios are: SSP1: Sustainability; SSP2: Middle of the Road; SSP3: Regional Rivalry; SSP4: Inequality; and SSP5: Fossil-fueled Development.)
- Scenario 2: RCP 7.0/SSP 3, in which climate change impacts are high, and significant challenges to socioeconomic development are present across low/middle income countries.

The scenario approach has several advantages. First, exploring migratory outcomes across alternative physical and demographic/socioeconomic futures allows researchers to begin to characterize the size and sources of uncertainty associated with projections of climate-induced migration. Second, it offers the ability to identify the impact of particular climate or socioeconomic factors on mobility. Third, varying both climate and demographic/socioeconomic pathways provides a means for considering and evaluating different policy options in terms of both impacts on spatial population outcomes and the potential avoided climate impacts of achieving more advantageous climate and societal outcomes.

The internal migration scenarios presented were developed using a spatial-allocation-type framework rooted in gravity models. Gravity-type models have a long history of application in the study of mobility (see Bierwagen et al., 2010; Clement et al., 2021; Jones, 2020; Jones and O'Neill, 2013; Jones and O'Neill, 2016; McKee et al., 2015; Rigaud et al., 2018). These models rely on the assumption that changes in human mobility are influenced by the relative attractiveness of and distance between different locations, accounting for geographic and political barriers. In this model, relative attractiveness was determined by factors such as

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socioeconomic and demographic characteristics of populations, economic conditions and livelihoods, history and existing connections, political systems and stability, geographic characteristics, and the impact of climate change on these systems. Despite recent critiques of gravity models' inability to appropriately capture basic temporal dynamics in international migration trajectories (e.g., Beyer et al., 2022) or model household-level decision-making processes, the model was chosen due to its relatively strong performance in replicating past patterns of aggregate spatial population change over larger areas in internal migration.

A preliminary data inventory of factors that impact relative attractiveness was initially constructed, utilizing available datasets and accounting for the known drivers of both climate change- and non-climate-change-related mobility. The data were subsequently refined through a literature review and consultations with regional experts in order to enhance the regional application of the model. Variables were tested and validated in separate models for each country. Those that demonstrated statistical or practical significance, as well as clear directionality of impact (i.e., positive or negative impact on relative attractiveness) were incorporated into the final model for each country, as outlined in Table 1.

The results of the model scenarios for both Pakistan and Viet Nam were consolidated into an internal report, with each country treated independently. (The full findings of this project are published by UNDP (2024a).) The report also provided results in the following domains: 1) the spatial distribution of projected population change by scenario, 2) national-level aggregate estimates of climate-induced and total projected migration by scenario, 3) spatial patterns of climate-induced and total projected internal migration by scenario, and 4) the impact of climate-induced and total projected internal migration on Ho Chi Minh City and Karachi, by scenario.

Figures 2 and 3 show results for Ho Chi Minh City and the Mekong Delta as a brief illustrative example, with significant out-migration from the Mekong Delta and in-migration to Ho Chi Minh City estimated where climate change impacts are high. Specifically, Ho Chi Minh City's population could nearly double under a lower emissions scenario and grow by 10 million under a higher emissions scenario, highlighting substantial urban planning challenges (Jones, 2023).

3.2.2. Phase 2: Participatory foresight

The objectives of the participatory foresight phase were to assess gaps or blind spots in the predictive models; evaluate the implications of in-migration across key social, economic, spatial, environmental, and other variables; and explore possible policy interventions to achieve ideal future scenarios for climate change-related mobility in relation to the messy realities of decisions to migrate. To this end, two separate 2.5-hour interactive workshops were held with each of the UNDP Viet Nam and Pakistan Country Offices, with thematic experts and non-UNDP practitioners also present. The workshops comprised guided analysis to stress-test the limitations and assumptions behind the predictive model, collective intelligence exercises to work through implications of the predictive model over different time horizons, and structured reflections to draw out policy implications.

The objective of the workshops was to contextualize the data underpinning the scenario estimates and to calibrate the models according to the knowledge and expertise of participants. To account for the technical complexity of the predictive models and sheer volume of model parameters, workshop participants were guided through the results of the predictive modeling. Serving as representations of plausible futures, the two scenarios were presented and used to anchor and frame the workshops by making possible impacts tangible and illustrating the effects of various drivers. Consequently, participants were taken through a structured discussion of the variables responsible for variation between the scenarios. As such, the models served as a basis for causal discussions and as a tool to enrich long-term thinking (Hirsch et al., 2013).

In the subsequent stage of the workshops, the "Iceberg" model was employed to guide participants' collective thinking on the future scenarios introduced earlier. The model, grounded in systems thinking, is designed to facilitate the exploration of both the visible and less apparent components, dynamics, and influences associated with complex challenges (Senge, 2006; Stroh, 2015). A systems thinking approach, which views mobility as part of an interconnected system rather than an isolated phenomenon, underscored the importance of understanding the relationships, connections, and interdependencies which are essential for

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Table 1. *Datasets, variables, and sources used in the predictive model (Jones, 2023)*

Variable	Source	Resolution	Time series	Time step	Indicator	Climate driven	Model
Water Availability	ISIMIP	0.5°	1970–2100	5-year	Deviation from baseline	Yes	Both
Agriculture/Crop Yields	ISIMIP	0.5°	1970–2100	5-year	Deviation from baseline	Yes	Both
Biomes/Ecosystem Productivity	ISIMIP	0.5°	1970–2100	5-year	Deviation from baseline	Yes	Both
Fisheries/Marine Ecosystems	ISIMIP	0.5°	1970–2100	5-year	Deviation from baseline	Yes	Viet Nam
Flood Hazard (inland)	ISIMIP	1 km	1970–2060	5-year	5-year flood risk	Yes	Both
GRACE Groundwater	SEDAC	3°	2002–2016	n/a	Trends in terrestrial groundwater	Yes	Pakistan
Heat Extremes	CMIP6	1/8°	1990–2100	5-year	Average annual heat wave days	Yes	Both
Drought	CMIP6	1/8°	1990–2100	5-year	Average annual max consecutive dry days	Yes	Both
Sea-Level Rise	NASA	30 m	1990–2150	5-year	Changes in coastline (inundation)	Yeas	Both
Policial Stability/Violence	WGI	Vector	1996–2018	variable	Likelihood of political instability/ violence	No	Pakistan
Control of Corruption	WGI	Vector	1996–2018	variable	Use of public resources for private gain	No	Pakistan
Gross Domestic Product	IIASA	1°	1980–2100	5-year	GDP per capital (spatial; derived)	No	Both
Land Use	GLAD	30 m	2000–2020	1-year	Land use/land cover (distribution and change)	No	Viet Nam
Bilateral Internal Migration	WorldPop	Admin2	2010–2015	5-year	Counts of migrants (social connections; derived)	No	Viet Nam
Man-Made Structures (“Build-up”)	EC-JRC	250 m	1975–2015	10/15-year	Portion of grid cell “built-up”	No	Both
Urban Settlement Types	EC-JRC	250 m	1975–2015	10/15-year	Urban classification	No	Both
Informal Settlements	World Bank	Vector	2005, 2010, 2017	n/a	Distribution of informal settlements	No	Pakistan
Population (Totals; Age and Sex Structure)	WorldPop	100 m	2000–2020	1 year	Population counts by age and sex	No	Both
Elevation	SEDAC	30 m	2015	n/a	Corrected elevation	No	Both
Slope	SEDAC	30 m	2015	n/a	Average slope	No	Both
Water Bodies	ESRI	Vector	2019	n/a	Surface water	No	Both
World Database on Protected Areas	IUCN	Vector	2019	n/a	Mandate for protection	No	Both

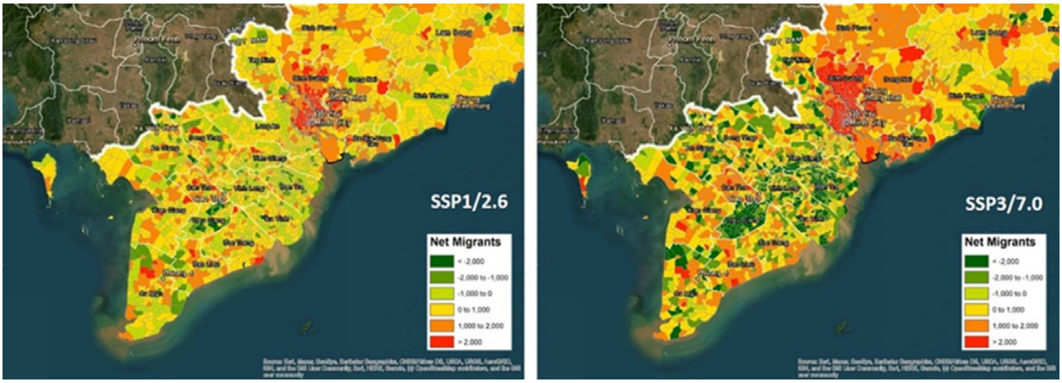

Figure 2. *Projected net climate-induced migration at the commune level in Greater Ho Chi Minh City and the Mekong Delta, 2050 (Jones, 2023, cited in UNDP, 2024b).*

		2030	2040	2050
Climate Migrants	SSP1/2.6	31,220	96,190	218,480
	SSP3/7.0	174,233	382,679	759,492
Total Migrants	SSP1/2.6	806,285	1,358,814	2,213,881
	SSP3/7.0	964,953	1,589,568	2,754,859
Population	SSP1/2.6	12,581,183	15,361,680	16,508,736
	SSP3/7.0	12,126,366	15,513,913	18,615,048

Figure 3. *Projected climate in-migrants, total migrants, and total population; Ho Chi Minh City, 2030–2050 (Jones, 2023, cited in UNDP, 2024b).*

analyzing and addressing complex problems such as human mobility (Hodgson, 2020; UNDP, 2021). Supported by prompts, participants were instructed to further explore interconnections, implications, and key risks that the model revealed, among other factors in the fields of urban development, livelihoods, social cohesion, social protection, and disaster risk. The workshop then culminated in a policy ideation session, where participants were invited to consider short-term, medium-term, and long-term strategies and policy interventions that could impact key variables in the direction of more desirable outcomes in domains of interest.

Guiding questions included:

- Are current urban policies fit to meet the possible dynamics of the future development systems you described? Where do they lack? What are the gaps?
- Looking at future disruptions that could either present risks or opportunities—what strategies are needed to harness them as opportunity?
- What uncertainties/trends do we need to continue to monitor (i.e., for risks that might throw us off course, with severe impact, but remain uncertain) or research further?
- Who else thinks these are priorities? Who might challenge these assumptions we have arrived at and why?

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Participants for each workshop are presented in Table 2 below:

Table 2. *Profiles of participants for the Pakistan and Viet Nam workshops*

Pakistan	Viet Nam
• ~40 participants were in attendance. • Participants attended from UN agencies, civil society, and government. • Specialties of participants included climate change, human mobility, livelihoods, economics, governance, human rights, health, and foresight. • A hybrid-remote approach was taken where participants attended the workshop in-person, and facilitators supported remotely.	• Nine participants were in attendance. • Eight participants were from UN agencies: seven staff from UNDP and one from IOM. Specialties of participants were inclusive growth, climate change, migration, economics, governance, and human rights. • One participant was an external regional specialist in climate change mitigation and adaptation, with a background within the UN system. • All participants and facilitators attended remotely.

The insights generated in the workshops captured the uncertainty and complexity within the mobility system and the implications for development, including potential risks to cultural cohesion and social solidarity, the trade-offs of balancing urban and rural investments, the impacts of rapid urbanization, and the role of social networks in adaptation strategies. These findings demonstrated a need for supplementary futures research and analysis to explore these dimensions and their implications. The insights from each exercise were therefore made available for the next stages of research, alongside facilitator notes and recordings of the sessions.

3.2.3. Phase 3: Systems mapping and sensemaking

Building on insights from Phases 1 and 2, further analysis was conducted to examine the connections, patterns, impacts, trends, and policy gaps in each settings' mobility system. This was achieved through systems mapping, where systems maps—visual representations illustrating the components, relationships, and dynamics within a system—provide a comprehensive overview of how elements interact and influence each other (Barbrook-Johnson and Penn, 2022). In this phase, researchers utilized the information obtained from the initial phases to develop a detailed systems map, identifying discernible gaps and interdependencies. Individual maps were then created for each country, and a combined, simplified map was developed to present a regional perspective. Through thematic analysis of these maps, several themes emerged as influential in both countries: water scarcity, food security, labor mobility, the future of cities, resilience, and changing perspectives on development and migration (see UNDP, 2024b). The dampening effects of climate change on the desirability of mobility to urban areas were not explicitly modeled. However, during the systems mapping phase, the impacts of climate change and in-migration—such as rising urban heat and the growth of informal settlements, for example—were extensively discussed and found to reduce urban appeal, potentially driving reverse urban-to-rural migration (see UNDP, 2024a). This finding underscores the value of blending quantitative modeling with participatory foresight and systems mapping approaches.

3.2.4. Phase 4: Validation and prioritization of anticipatory pathways

A crucial aspect of the project involved integrating desk research on policy interventions related to the thematic areas identified in Phase 3 with the exploration of policy options in the workshops conducted in Phase 2. In a 4-week virtual consultation period that aimed to ensure that policy options were relevant and feasible for target populations, regional stakeholders, and core team specialists in fields including strategic foresight, human mobility, social dimensions of climate change, and crisis

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preparedness validated and prioritized identified policy options for development and migration policy.

For each of the thematic areas identified in Phase 3, consultees were provided with summaries of existing research, national policies, and policy suggestions made during the workshops. Consultees were then invited to share their reflections on the following questions:

1) Considering potential climate change-related mobility outcomes by 2050, what policy solutions are most needed in the short-term (next 1–3 years) and medium term (3–10 years)? *Be as specific as possible to the [city/country] context.*
2) If you see a policy recommendation already on the board that you agree is highly influential, add a star to it. You can also add stickies that build on or suggest additional elements to an existing one.

Types of policy recommendations that emerged in this phase included investments in secondary cities outside of primary urban centers, investments in rural livelihoods, and increased political and civic participation (see UNDP, 2024b).

3.2.5. Phase 5: Applied anticipation

A final report integrated the insights from Phases 1 to 4, exploring the insights identified, potential anticipatory solutions capable of addressing opportunities and challenges, gaps in available data and knowledge for further research, and barriers to the implementation of new policy.

3.3. Findings and future research

The results of the research suggest net migration into urban areas is expected to increase significantly under more severe climate scenarios, while also demonstrating the complexity of mobility patterns at a granular level—that is, rural-to-urban migration is not uniform in every city and is contingent on a variety of local factors. The findings serve as a compelling justification for investments aimed at mitigating the effects of climate change on mobility and preparing for potential increases in rural–urban migration by the year 2050. Transforming knowledge about critical levers of change into effective policy, however, is not solely dependent on having accurate information. A range of potential future enablers and barriers to anticipatory decision-making were identified, including but not limited to evolving societal beliefs and values, the national and global political economy, and the effects of social movements on the balance of power and resources.

The research offers a foundation for evaluating the validity and resilience of current policies, pinpointing opportunities to enhance existing or establish novel anticipatory policy or risk mitigation measures, and prioritizing investments in additional research, including 1) targeting geographic "hotspots" of projected in-migration that might merit additional investigation or research to determine how an influx of people may impact quality of life, both for migrants and for host communities; 2) assessing the potential future impact of mobility on vulnerability associated with different socioeconomic and climate change futures; and 3) disentangling whether policy targeting mitigation or adaptation might have a larger impact on migration propensity.

4. Reflections on project design

There is a significant surge in the adoption of foresight methods and tools across various sectors in support of strategic planning and policy ideation. This translational article, which focuses on the transfer of knowledge from practice to research, offers a critical reflection on the blend of predictive modeling and qualitative foresight used to provide the data and space that stakeholders need to effectively adapt to and anticipate climate change-related mobility (UNDP, 2024b).

Empirical and evidence-based insights are critical to advance both theory and practice in the field of foresight as they allow for validation, replication, and verification of methods. This, however, is

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complicated by the complexity and variability of the processes involved, as they are often necessarily dynamic, variable, and bespoke. Addressing these challenges, foresight evaluation is emerging as a crucial aspect of futures studies (Ko and Yang, 2024). While generalizable insights into effect and effectiveness are therefore difficult, we aim to offer some insights into the trade-offs between the project's objectives, the hybrid design of the exercise, stakeholder engagement, and sensemaking of outcomes.

4.1. The utility of a hybrid foresight approach

Climate change-related mobility is characterized by non-linearity and is often driven by unpredictable shocks within complex systems, making it challenging to forecast or model using linear assumptions. This project sought to integrate quantitative and qualitative methods with the aim of enhancing the insights and overcoming the constraints of each method separately, particularly in a complex domain defined by contextual variability and inherent uncertainty. A widely recognized method for foresight is a hybrid approach, which fuses qualitative and quantitative methods for data gathering, trend analysis, and prediction or forecasting (Smith et al., 2011). Predictive modeling in particular is a significant asset, allowing for the examination of numerous variables and scenarios and the testing of incremental changes and their potential impacts, which increases the accuracy and validity of the foresight process (Hirsch et al., 2013). Drawing on a survey of senior leadership as part of the UNDP Regional Bureau for Asia and the Pacific's horizon scanning initiatives (UNDP, 2022; , 2023), a hybrid approach is perceived as adding objectivity, empirical validation, enhanced predictive power, and the ability to provide quantifiable evidence. Complementing modeling with participatory foresight is a potentially valuable strategy to build on and challenge the insights of quantitative models. Consequently, the decision to employ predictive models was aimed at bolstering the participatory foresight workshops, and vice versa.

Yet, drawbacks of the data-driven methods employed in each phase of the research became evident, particularly in the participatory foresight phase. First, the model scenarios were developed five months ahead of the workshops taking place. As a result, during the workshops, population projections for Karachi/Pakistan were contested by participants as recently updated population estimates already exceeded the models' projections; however, the disparity in population estimates could be explained by recognized and explicit uncertainties in the modeling process, particularly in local-level outcomes. Second, the model analyzed the scale of internal mobility only and did not account for cross-border mobility. Third, the model did not capture so-called "trapped populations"—or those who want to migrate but are unable to due to liquidity constraints—or fully account for temporary or seasonal migration. Fourth, the model had limited ability to capture the impacts of future climate change adaptation or mitigation measures. Finally, it is difficult to model rapid onset events or account for non-linear dynamics, though they are captured to some degree in the projections. Because the model is fit to spatial patterns of change in consecutive census periods, if the available census data reflects the redistribution of the population that results from extreme events like the severe flooding that occurred in Pakistan in 2011, the signal of cumulative flooding events over time will be reflected; however, future projections of flood events do not predict the impacts of specific catastrophic events, but instead the annual likelihood of such events. The non-linear nature of these events and potential human responses to the threat of these events likely means the projections are on the lower end of the plausible range of outcomes, but the model does not attempt to include tipping points or non-linear response patterns because of the lack of robust data concerning how these trends evolve or where tipping points might lie. Despite these challenges and critiques, there is value in attempting to quantify the potential impacts of climate change on migration, particularly from a policy perspective.

While limitations of predictive modeling were communicated, as the model developer was not included in the workshop facilitation, these concerns could not meaningfully be addressed, nor trust reinstated in the model's intent to illustrate—and not predict—future scenarios. Where workshop participants were skeptical of the utility of the quantitative models, it could likely be attributed, in part, to this emphasis on the model's uncertainties and limitations in how the workshop was framed by facilitators. Moreover, logistical constraints and organizational capacity dictate project timelines, which

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should be considered when designing similar projects in the future. To limit confusion and generate confidence to navigate uncertainty, it is therefore imperative for the hybrid process to characterize, incorporate, and leverage known uncertainties in conjunction with qualitative approaches to fortify the validity, trust, and buy-in of the overall approach, for participants as well as decision-makers intending to use the findings.

4.2. Expert engagement through participatory foresight methods

A common practice in the field of foresight is to engage experts to validate findings and add legitimacy to a process. According to Smith et al. (2011, 86), expert-based approaches and involvement in foresight efforts provide a diverse range of perspectives among workshop participants. Similarly, van Alphen (2016, 176) argues that combining the knowledge of different experts can lead to new insights and enhanced creativity. This project took an innovative approach by engaging experts in earlier phases—through predictive modeling and participatory foresight—and subsequently handing over expert insights to generalists to use in further sensemaking. There are several benefits and drawbacks resulting from project design choices made regarding the profile of participants and the timing of their engagements in the process.

While participatory evaluation and validation through expert workshops adds legitimacy to findings, it is crucial to consider alternative means of facilitation to challenge experts effectively on their thinking and potential biases and alleviate the possible "discomfort when asking [participants] to venture beyond the certainties of present knowledge" (Smith et al., 2011, 86). Furthermore, the project approach could have benefited from a rapid data literacy assessment. Awareness of experts' comfort in working with data can then inform workshop design and facilitation (e.g., present model parameters or findings more qualitatively) to ensure meaningful insights from data can be drawn, disengagement can be prevented or mitigated, and skepticism can be productively incorporated and engaged.

Despite possible data literacy concerns, the utilization of scenarios provided a solid baseline for the initial discussions during the workshop, as it quickly engages participants in narratives rather than abstract data. Moreover, by presenting the scenario findings alongside their limitations to a different set of participants in every phase of the process, the project incorporated and triangulated multiple perspectives. This enhanced robust validation of the elements supporting the scenarios, as well as their implication pathways. As such, the predictive model provided a more targeted framework for discussion, while the participatory nature of the process was able to address some limitations of the predictive model. The project design dictated that the scenarios were developed by the data modeler ahead of the workshops. Due to time and resource constraints, the intended iteration of the scenarios based on expert feedback provided during the workshop did not materialize and was compensated by generalists' additional research in the sensemaking phase. While this approach to strengthening the scenarios with other quantitative and qualitative methods generated an acceptable level of analytical rigor, in the future, several closed feedback loops could strengthen the quality, trust, and buy-in of the predictive model for more effective sensemaking and resonance for policymaking.

Finally, generalists from the core team were responsible for the evaluation of the workshop outcomes and findings, as well as conducting additional research and sensemaking to support the final report. Their absence from the scenario development or workshop phases had both advantages and disadvantages. On the one hand, the independent assessment of the workshop findings enabled a critical examination of the material generated; however, it also meant that some nuances of the expert discussions that were difficult to capture in the hybrid remote workshops were inevitably lost. As a result of staffing constraints, for example, Phase 3 was coordinated by an analyst who had no prior involvement in the process up to this stage, though the analyst had been involved in previous foresight projects alongside members of the current team and was familiar with the foresight strategies adopted in this project.

4.3. Policy ideation to inform applied anticipation

Research indicates that there remains a persistent gap between "knowing" the future and implementing related considerations in policymaking (Heo and Seo, 2021). Traditionally, foresight seeks to consider future scenarios at the front end of the policy process and not concern itself with policy ideation or policymaking. Nevertheless, as Hines and Zindato (2016) point out, the pressure on foresight endeavors to deliver applied and policy relevant insights is increasing.

This project sought to inject policy relevance in the sensemaking phase where workshop outcomes were aligned with policy insights derived from desk research. Moreover, the model sought to provide more nuanced predictions of climate-related human mobility patterns at higher resolution and for specific contexts with more utility for policy formulation. Mobility represents an appropriate adaptation response to changing physical and socioeconomic conditions. Beginning to understand geographic variation in the intensity and directionality of mobility, while acknowledging the uncertainty associated with any such projections, will help to understand the potential impacts of climate-induced mobility and, subsequently, help frame the policy debate. This design allows stakeholders to consider alternative policy decisions to achieve desired goals (e.g., improving access to education for migrants) with combinations of societal, economic, and technological change.

The abundance of data, coupled with innovative technologies and analytical methods, has the potential to enhance anticipatory decision and policymaking by providing insights into interconnected dynamics, thus enabling more effective responses to complex challenges. Predictive modeling, for example, facilitates rapid implication pathway or impact assessments, resulting in shorter feedback cycles and more agile decision-making. Grounded in evidence-based policymaking, data increasingly improves and legitimizes policy outcomes; however, engaging relevant actors in data assessment and interpretation is crucial to prevent distrust (Van Veenstra and Kotterink, 2017). Other scholars suggest that policy advisors are more likely to accept data-driven insights when mediated by expert involvement and local knowledge (van Rij et al., 2024).

Active engagement of policymakers with empirical evidence during the development process is argued to mitigate the influence of ideological beliefs, personal convictions, or political concerns on policy choices (Idem). The project aimed to employ new techniques and applications of existing data to evaluate policy mechanisms and create targeted interventions for positive climate-related mobility outcomes. Consequently, significant resources were dedicated to identifying policy levers throughout the process, involving various stakeholders. However, realizing data-driven policymaking is complex, presenting challenges in data capture, integration, reuse, and stakeholder involvement (Van Veenstra and Kotterink, 2017).

Despite the project's iterative approach, which leveraged stakeholder intelligence through various prompts, data, and feedback avenues, future applications should more explicitly engage decision-makers in project design. This method can broaden support for findings and ensure the project's goals of influencing anticipatory planning and policies are met. Closer involvement of decision-makers in design is likely to enhance the relevance and impact of project outcomes in decision-making. Nonetheless, decision-makers may introduce their own interests and biases based on organizational priorities. Additionally, it is crucial to consider the types of data policy decision-makers use and the judgments they inform. For instance, research indicates policymakers generally accept data analyses for scoping and defining issues but tend to neglect them when deciding on actions (van Rij et al., 2024).

As of August 2024, project findings have not yet been communicated or sensitized. The instrumentalization of findings and their influence on policymaking on climate-change informed mobility therefore cannot be meaningfully reflected upon at this stage. However, obtaining the input of stakeholders, including decision-makers, throughout all stages of the foresight process, not just in the design and knowledge transfer phases, will be essential. Despite UNDP decision-makers' stated confidence in quantitative approaches, as communicated through the previously mentioned survey, there is a risk of overreliance on, and misinterpretation of, quantitative data. Moreover, as Krishnan and Robele (2024) point out, the translation of foresight insights into development decisions and investments requires shifts in risk appetite and perspectives, including a need to interrogate what counts as legitimate and relevant evidence for policy decisions. While these reflections are difficult to assess in relation to this project,

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insights from the workshops did indicate that continuous engagement of policy and decision makers can ensure a more profound comprehension of the methodologies and presumptions behind both qualitative and quantitative techniques can be acquired. This participation facilitates knowledge transfer and applicability of findings, allowing for more meaningful interaction with insights generated through hybrid foresight methods and processes.

5. Lessons learned

Lessons learned from this project are relevant for researchers and practitioners interested in applying data-driven foresight approaches not only to anticipatory climate change-related mobility policy, but for a range of other policy areas as well. Above, we detailed the project's approach and key design decisions and reflected on its benefits and challenges after implementation. Here, we close with a few recommendations based on our experience and reflections that we hope will strengthen future anticipatory processes at the regional, national, or sub-national level:

- *Integrate predictive models with qualitative insights*: Combining statistical modeling techniques with qualitative foresight to collect and interpret data on a policy area—in this case the potential impacts of climate change on internal migration—offers a generative approach to testing, validating, and updating findings relevant to the development of evidence-based policies and programmatic recommendations. The predictive models provided a structured framework for exploration, policy ideation, and analysis, while the participatory nature of the process was able to address some limitations of the predictive modeling.
- *Consider data literacy as a facilitation challenge*: Effective engagement and participation in data-driven foresight processes can be hindered by challenges concerning the interpretation of complex statistical models. A data literacy assessment can help inform project decisions on the timing and nature of engagement with predictive analytics, as well as the facilitation and preparation required to ensure constructive participation of relevant stakeholders.
- *Engage predictive analytics experts in the participatory and sensemaking phases*: Including model designers, or predictive analytics experts, in the participatory and sensemaking stages of the project allows for meaningful engagement with relevant stakeholders on queries, critiques, and skepticism concerning underlying datasets and limitations of the model, and allows for iteration of the model, if and when time and resources within a project allow. This approach enhances the incorporation of multiple perspectives as well as the perceived legitimacy of the model, as well as trust and buy-in in related interpretations and findings.
- *Decision-maker engagement*: Decision-makers and "end users" of research findings should be engaged explicitly throughout the project phases, from shaping research scope and methodology parameters to validation and prioritization of participatory foresight insights. Process awareness heightens the support for findings, and as such ensures the goals of influencing anticipatory planning and policymaking are met.

Data availability statement. The data that support the findings of this study are openly available from:

- Copernicus Climate Change Service, Climate Data Store (previously known as Global Monitoring for Environment and Security (GMES)), CMIP6 Climate Projections (1990–2100 time series) at https://doi.org/10.24381/cds.c866074c.
- International Institute for Applied Systems Analysis (IIASA) (1980–2100 time series) at https://doi.org/10.1016/j.gloenvcha.2016.05.009.
- DeLorme Publishing Company, Inc. and Esri. World Water Bodies at https://hub.arcgis.com/content/e750071279bf450cbd510454a80f2e63/about.
- European Commission Joint Research Centre (EC-JRC), Global Human Settlement Layer [Dataset]: Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS-POP R2019A—GHS population grid multitemporal (1975–1990–2000–2015)—OBSOLETE RELEASE. European Commission, Joint Research Centre (JRC) [Dataset] at https://doi.org/10.2905/0C6B9751-A71F-4062-830B-43C9F432370F. Data Package, public release GHS P2019 at https://doi.org/10.2760/290498.
- Global Land Analysis and Discovery (GLAD) (2000–2020) at https://doi.org/10.3389/frsen.2022.856903.
- International Union for Conservation of Nature (IUCN) and United Nations Environmental Programme (UNEP), World Database on Protected Areas (WDPA) (2019 time series) at https://doi.org/10.34892/6fwd-af11.

- NASA, Sea Level Change (1990–2150) at https://doi.org/10.5281/zenodo.5914709.
- NASA Socioeconomic Data and Applications Center (SEDAC)
  - Trends in Global Freshwater Availability from the Gravity Recovery and Climate Experiment (GRACE), v1 (2002–2016) at https://doi.org/10.7927/H4TT4P2C.
  - Digital Elevation Data Collection (DEDC), Altimeter Corrected Elevations (ACE2), v2 (1994–2005) at https://doi.org/10.7927/H40G3H78.
  - Delta Urban–Rural Population and Land Area Estimates, v1 (1990, 2000, 2014, 2015) at https://doi.org/10.7927/4hgr-db70.
- World Bank, Informal Settlements (2005, 2010, 2015) at https://datacatalog.worldbank.org/search/dataset/0039832/Karachi–Pakistan——Informal-Settlements–ESA-EO4SD-Urban-.
- United Nations Department of Economic and Social Affairs (UN DESA), World Population Prospects (1950–2023) at https://population.un.org/wpp/.

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