Journal of Futures Studies
2026,Vol. 30(3) 13-29
DOI: 10.6531/JFS.202603_30(3).0002

Article

A Foresight Study into Peru's Technological Progress Towards 2050

Billy Francisco Gonzales[1,*], Julio César Acosta-Prado[2], Carlos Guillermo Hernández-Cenzano[1,2], Amparito Gianina Acevedo Flores[3], Juvenal Uzi Galindo Ccallocunto[3], Jorge Alexis Ramos Muñoz[3]

[1]Pontificia Universidad Católica del Perú, Pulso PUCP – Instituto de Analítica Social e Inteligencia Estratégica, Lima 15088, Peru
[2]Pontificia Universidad Católica del Perú, Departamento de Ingeniería, Lima 15088, Peru
[3]Pontificia Universidad Católica del Perú, Maestría en Gestión y Política de la Innovación y la Tecnología, Lima 15088, Peru

Abstract

This study examines Peru's technological progress through innovation and development Scenarios Towards 2050, based in the theoretical foundations of technological foresight. This study examines trends and scenarios using the real-time Delphi method to identify key drivers in sustainability, the digital economy, education, and scientific-technological capacity. Four scenarios were developed using the deductive approach based on two uncertainties: "Innovative Synergy 2050: Peru as a Technological Epicenter of Latin America", "Disconnection 2050: Innovation Trapped in the Laboratory", "Technology Gap 2050, The Decline of Innovation in Peru", and "Technological Oasis in the Academic Desert, Peru 2050". The first one was defined as a target scenario through the Probability, Desirability, and Governability analysis. Finally, strategies to build this scenario were proposed using the backcasting method.

Keywords

Foresight, Technological progress, Target scenario, Delphi method, Peru

Introduction

Technological foresight is a critical tool to anticipate future trends and design strategies to shape desired outcomes. Defined as early analysis and strategic planning integration, foresight enables stakeholders to vizualize multiple potential futures and design adaptive strategies to navigate uncertainties (Godet et al., 2013; Rohrbeck & Schwarz, 2013). This study applies foresight methodologies to explore Peru's technological development towards 2050, focusing on key drivers such as sustainability, digital transformation, and scientific capacity.

The significance of this research lies in Peru's unique position: a developing country facing challenges in leveraging technological innovation for sustainable growth. As globalization reshapes economic activities, developing nations must integrate knowledge and technology strategically to remain competitive (Pietrobelli & Puppato, 2016). Despite progress in areas like renewable energy and digital economy, Peru's investment in research and development remains low, just 0.17% of GDP in 2020 (CONCYTEC, 2023). This study seeks to bridge these gaps by constructing actionable scenarios and strategies to position Peru as a technological leader in Latin America.

To achieve these objectives, this research employs real-time Delphi method, a tool that enhances traditional Delphi techniques by enabling synchronous and asynchronous consultations with experts. This approach is faster and more efficient than conventional Delphi, making it particularly effective for collaborative scenario building (Gordon & Pease, 2006). Previous studies have demonstrated its value in constructing future scenarios for diverse applications, such as sustainable transportation and wildfire management (Bengston, 2015; Meyer et al., 2022). Leveraging this advanced methodology allows for dynamic data collection and the identification of trends and drivers critical to Peru's technological trajectory.

---

* *Corresponding author.*
E-mail addresses: b.gonzales@pucp.edu.pe (B.F. Gonzales), jacosta@pucp.edu.pe (J. Acosta-Prado), carlos.hernadez@pucp.edu.pe (C. Hernández-Cenzano), aacevedo@pucp.pe (A. Acevedo), galindo.j@pucp.edu.pe (J. Galindo), jramosm@pucp.edu.pe (J. Ramos).

Received: 21 October 2024 and Accepted: 12 March 2025

This paper is structured as follows: the next section provides a - overview of Peru's technological landscape. The methodology section details the foresight framework and expert consultations. Key findings are presented through scenario analysis, followed by strategies to achieve the preferred future. Finally, the discussion highlights the implications of this work and suggests paths for future research.

Technological context of Peru

Technological indicators in Peru have been identified according to the following priority areas: awareness of sustainability and healthy living, development of the digital economy, productivity and competitiveness through new technologies, increased technological education, enhanced scientific and technological capacity, acceleration of innovation, improved efficiency and quality of public services, and digital democratization. Detailed descriptions of these indicators are available in Gonzales et al., (2024).

In terms of sustainability awareness, statistics from Lebedys et al., (2023) for IRENA (International Renewable Energy Agency) indicate that Peru utilized 6,431 MW of renewable energy in 2022. In the same year, carbon emissions amounted to 312,221,138.00 tCO2e, according to the Ministerio del Ambiente del Perú, (n.d.). Additionally, Peruvian Law No. 31111 imposes a 10-year moratorium on the entry and production of genetically modified organisms, potentially limiting the development of related markets and national technology.

Regarding the digital economy, 2021 statistics from the Institute of Statistics and Informatics of Peru show that e-commerce sales per capita were S/. 281.52, with 42% of the population purchasing online and 10% of formal companies marketing their products online. The percentage of online purchases with cards was 40%, according to the 2021-2022 e-commerce industry report.

For productivity and competitiveness, in 2021, 14.28% of jobs were highly qualified, and the general industry job percentage stood at 17%. Remote work accounted for 9% of employment, an increase from 59.4% of workers using the Internet in 2019 and 7% of jobs being automatable in 2020. In 2022, Peru imported USD 79.3 million (FOB) worth of automation items (PLCs), and the volume of blockchain and cryptocurrency transactions increased sixfold in the first half of 2021 compared to the previous year. The frontier technological readiness index reached 84 in 2023.

In technological education, the National Superintendency of Higher University Education (SUNEDU) reported that 7.2% of higher education programs were conducted in distance mode in 2023. In 2021, 50% of people aged 6 to 17 used the Internet for formal education, and the National Institute of Statistics and Informatics (INEI) recorded that 27.1% of primary schools and 46.7% of secondary schools had internet access.

In strengthening scientific and technological capacity, 31% of postgraduate programs were in Science and Technology (S&T) fields at the beginning of 2023, according to SUNEDU. CONCYTEC reported that, of every 1,000 economically active individuals, only 0.44 were qualified researchers, totaling 5,306 researchers in 2021. Investment in research and development was 0.17% of the national GDP in 2020, and only 25% of higher education centers were recognized by CONCYTEC as research, development, and innovation centers in 2023. According to SCOPUS, 8,881 indexed scientific articles were published in 2022.

In innovation, the World Intellectual Property Organization (WIPO) noted that 588 patents were granted in Peru in 2022, a 3% increase from the previous year. The Global Innovation Index (GII 2022) ranked Peru 65 out of 132 countries. In 2019, 200,000 startups were created, and there were 25 incubators registered with the Peruvian Association of Incubators.

Regarding public service efficiency and quality, the United Nations ranked Peru 59th in the digital government index with a score of 0.7524. The World Bank placed Peru in Group A for technological government maturity, and in 2022, the open data government index was 0.52.

For digital democratization, the World Bank recorded Peru's index of adoption of Information and Communications Technologies (ICT) at 45.7 and digital literacy at 3.36 out of 7 in 2019. In 2022, the network infrastructure index for communications and information management was 46.71, and the development index for 5G technology and high-speed connectivity was 40 out of 120, ranking 57th, according to ITU OSIPTEL.

Methodology

The methodology used in this study combines quantitative and qualitative approaches to provide comprehensive analysis. Quantitative techniques were used to gather structured information, while qualitative techniques focused on interpreting trends and constructing scenarios. This integrated approach ensures methodological rigor and enriches the research outcomes (Godet et al., 2000). To support this process, foresight and technological surveillance tools were employed alongside the real-time Delphi method (Ordon & Pease, 2006) enabling the collection of diverse perspectives and expert insights.

The Delphi method, while valuable, carries certain limitations due to its expert-centered nature, introducing potential biases that can affect results. Authority bias, where opinions from higher-status figures may dominate, was mitigated by using anonymity techniques and ensuring a diverse expert group (Rowe & Wright, 1999). Confirmation bias, where experts favor information aligning with their beliefs, was addressed by presenting alternative scenarios to encourage broader consideration of possibilities (Tetlock & Gardner, 2015). Group bias, or groupthink, was minimized by maintaining anonymity throughout feedback rounds to prevent conformity (Janis, 1982). The risk of a limited variety of perspectives was reduced by selecting multidisciplinary experts to avoid a technocentric outlook (Dalkey & Helmer, 1963). Finally, to address selection bias, clear expert criteria were established, and responses were analyzed for consistency to ensure the reliability of the results (Okoli & Pawlowski, 2004). These measures supported the exploration of Peru's technological futures towards 2050, and the development of scenarios aimed at inspiring key stakeholders to shape a promising future.

This study employs the Foresight approach to explore and anticipate future scenarios. As a collective process, foresight involves analyzing and communicating key elements that shape these scenarios, including technological trends, their social and economic implications, and the factors that drive positive outcomes. Additionally, it evaluates future needs and opportunities within the economic landscape of a specific region or country, ensuring a comprehensive understanding of potential developments (Díaz Vega & Ospina Ospina, 2014).

The methodology is organized into nine steps according to Ortega et al., (2018) with slight modifications, as follows:

1. Trend identification: Based on a bibliographic survey, eight current and emerging technological trends were pinpointed that are likely to significantly impact the future. This process aims to anticipate potential technological developments and their strategic implications.
2. Identifying Drivers of Change: Drivers of change are variables whose changes significantly affect the system's future (Borch and Rasmussen, 2002; Shantiko et al., 2021). The structure for identifying the drivers presented in Table 1.
3. First Iteration: Delphi method – In the initial round of validation, the Delphi method was employed with a research group to assess 46 identified drivers. This process categorised the drivers based on their importance and uncertainty, as illustrated in the Importance-Uncertainty Matrix (Schwartz, 1991).
4. Create Importance - Uncertainty Matrix: This step involves developing a matrix to further analyze the drivers' impacts.
5. Second Iteration: Delphi Method - A subsequent validation round refines the assessment of the drivers.
6. Perform Structural Analysis for Drivers in Quadrant III of the Schwartz Axes: This analysis focuses on drivers that present complex challenges and uncertainties.
7. Identification of Movements of the Axes of Uncertainty: This step delineates the potential shifts in the identified uncertainties.
8. Definition of Scenarios: This step involves the definition of four possible scenarios by the authors using the deductive approach through the 2x2 matrix from two uncertainties (Schwartz, 1991; Ramírez and Wilkinson, 2014) and selecting the target scenario, defined as the most desirable, probable, and governable.
9. Backasting: Finally, the backcasting method was employed to propose strategies to build the target scenario according to Robinson (1982) and Bibri (2018).

Each of the eight steps is meticulously detailed below:

Step 1 - Trend identification

The analysis of technological trends was based on classifications provided by several key reference sources, such as the Centro Nacional de Planeamiento Estratégico, (2020), the Korea Institute of Science & Technology Evaluation and Planning, (2022), and the framework developed by Ortega et al., (2018). This step identifies and structures major trends in the context of technological development, categorizing them as follows: sustainability awareness, digital economy development, productivity enhancements via new technologies, increases in technological education, strengthening scientific capacity, acceleration of innovation, improvement in public service quality, and progress in digital democratization.

Step 2 - Identifying drivers of change

To systematically identify the drivers, a structured format (Table 1) lists each driver's vertex, identifier, related trend, indicators, values, units, base year, and potential movements, both positive and negative. This structure ensures a comprehensive understanding of each driver's role and possible future changes.

Based on the technological trend analysis, forty-six (46) drivers were identified with the code “D1” to “D46”. The drivers are dated according to what is stated by Gonzales et al., (2024).

In the process of identifying drivers, a systematic approach was followed to mitigate potential methodological biases. As Ecken et al., (2011) point out, the selection of variables in technological trend analysis can be influenced by prevailing cognitive and cultural biases. To address this limitation, the following measures were implemented:

- Source triangulation: Multiple sources of information were used, including international databases, government reports, and academic studies.
- Expert diversification: Experts from various sectors (academia, industry, government) and disciplines were included to reduce sector-specific biases.
- Cross-validation: The identified drivers were validated through multiple rounds of Delphi consultation, enabling the identification and correction of potential biases.

Step 3 - First iteration: Delphi method (Table A1)

The selected 46 drivers of change were validated by experts using Delphi method. These drivers were categorized based on the Importance – Uncertainty Matrix. Figure 1 highlights the drivers identified as both highly critical and uncertainty, which are in the III quadrant.

Table 1: General structure of the drivers

Vertex	Identifier	Drivers	Trend	Indicator	Value	Unit	Base Year	Positive Movement	Negative Movement	Source	URL	Consultation Date

- Note. According to (Ortega et al., 2018) “The number of possible movements is flexible and can be any number from two (minimum uncertainty condition).”

Table 2: Drivers categorised by Trends

Trend1: Sustainability awareness and healthy living	Trend2: Development of the digital economy	Trend3: Productivity and competitiveness due to the use of new technologies	Trend4: Increase in technological education	Trend5: Strengthening scientific and technological capacity	Trend6: Acceleration of Innovation	Trend7: Efficiency and quality of public services	Trend8: Digital democratization
D01: Genetically modified organism. D02: Energy savings D03: Carbon footprint in manufacturing and ICT industries	D04: E-commerce sales D05: Population that buys online D06: Companies that sell online D07: Digitization of payment methods	D08: Highly skilled jobs D09: Remote work D10: Employees who use the internet D11: Automatable jobs D12: Industrialization D13: Automation and robotics in industry and services. D14: Blockchain technology and cryptocurrency D15: Cutting-edge technologies	D16: Hybrid or distance higher education programs D17: Internet access for educational purposes D18: Primary schools with internet access D19: Secondary schools with internet access	D20: Capacity to generate scientific knowledge D21: Technology parks D22: Indexed scientific articles D23: Institutions with R&D&I infrastructure D24: S&T career students D25: Investment in R&D D26: Impact of scientific production D27: Qualified researchers D28: National scientific journals	D29: patents granted D30: Startups formed D31: Incubators D32: Innovation capacity D33: Availability of scientists and engineers in companies D34: University-business collaboration	D35: Digital government D36: Maturity in GovTech D37: Open data D38: Cybersecurity	D39: Development of 5G technology and high-speed connectivity D40: Data processing and cloud storage capacity D41: Use of the Internet of Things (IoT) and the interconnection of smart devices. D42: Access to internet service D43: Mobile lines with internet D44: Adoption of ICTs D45: Digital literacy D46: Network infrastructure

Step 4 – Develop Importance – Uncertainty Matrix:

Figure 1 displays the distribution of drivers that are identified as the most important and uncertain, all of which fall within the III quadrant. These drivers were selected based on the analysis performed in the previous steps and are critical for understanding the potential impacts on the technological environment. It is important to acknowledge that in technological trend analysis, particularly the use of the Importance – Uncertainty matrix, certain limitations must be considered. As noted by Bradfield et al., (2016), the reduction to two main axes, while useful for the visualization and communication of scenarios, can oversimplify complex systems such as the technological development of a country. This caution is not limited to technological trend analysis or horizon scanning but applies broadly to approaches that seek to distill complex systems into manageable frameworks. This simplification, although necessary for the operability of the method, should be made explicit and considered when interpreting the results.

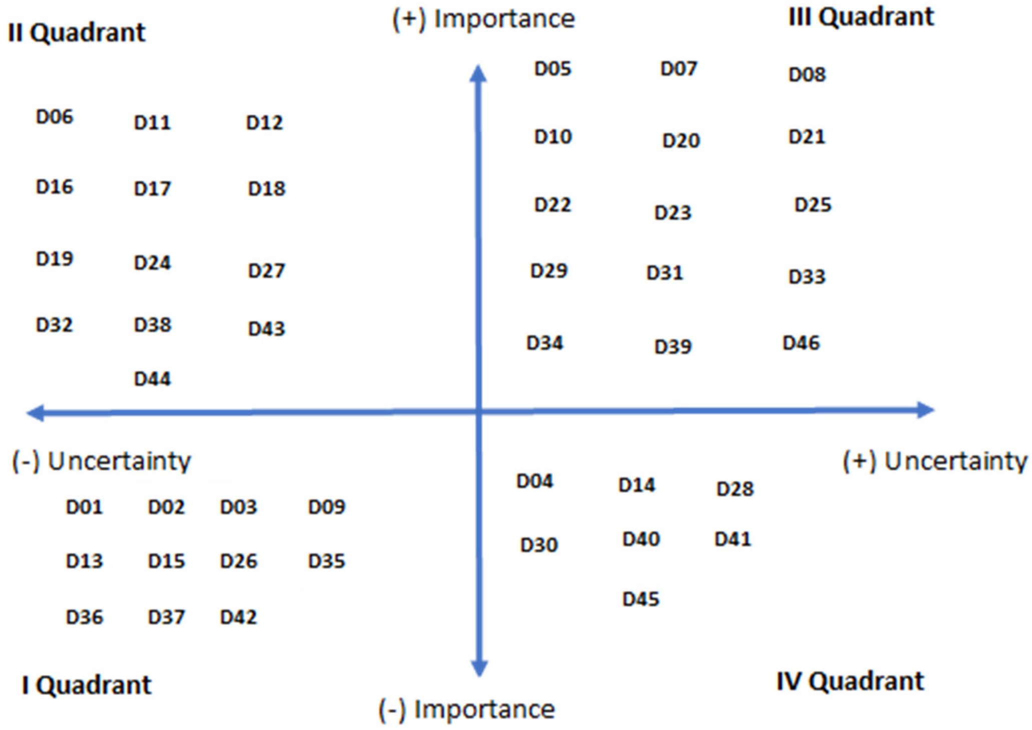

Fig 1: First Iteration -Importance – Uncertainty Matrix

Step 5 - Second Iteration – Delphi Method (Table A3):

The 15 drivers from Quadrant III in the initial Delphi survey underwent a second round with 233 experts, each with over six years of experience in technological sectors and affiliated with master's and doctoral programmes at the Pontificia Universidad Católica del Perú.

The results of the second iteration Delphi are presented in Table 3. All identified drivers were deemed important, with over 80% of respondents considering them to be moderately or highly important. To ascertain critical uncertainties, the average rating of each driver was calculated. Drivers averaging a rating of 3.0 or higher were classified as critically uncertain. identifying D21, D23, D25, D29, and D33 as critical uncertainties.

Table 3: Second Iteration - Delphi Method

Code	Driver	Importance			Uncertainty		
		Average	Undress	Coefficient of variation	Average	Undress	Coefficient of variation
D05	Population that buys online	2.7	0.5	19%	23	0.99	43%
D07	Digitization of payment methods	2.8	0.5	17%	23	0.90	39%
D08	Highly skilled jobs	2.7	0.5	19%	2.6	1.06	40%
D10	Employees who use the internet	2.8	0.4	15%	2.1	0.98	46%
D20	Scientific knowledge generation capacity	2.6	0.5	21%	2.6	1.06	40%
D21	Technology parks	2.6	0.6	23%	3.1	1.08	35%
D22	Indexed scientific articles.	2.5	0.6	23%	2.7	1.00	36%
D23	Institutions with R&D&I infrastructure	2.7	0.5	19%	3.0	1.07	36%
D25	Investment in R&D	2.6	0.6	24%	3.0	1.16	39%
D29	Patents granted	2.4	0.6	26%	3.0	1.09	36%
D31	Incubators	2.5	0.6	25%	2.7	0.95	35%
D33	Availability of scientists and engineers in companies	2.6	0.6	23%	3.2	1.21	37%
D34	University-business collaboration	2.7	0.6	21%	2.6	1.05	40%
D39	Development of 5G technology and high-speed connectivity	2.8	0.4	15%	2.7	1.02	38%
D46	Network infrastructure	2.7	0.5	18%	2.8	1.05	38%

Step 6 - Perform structural analysis for the drivers located in quadrant III

The structural analysis was conducted on the five drivers identified in quadrant III, as detailed in Table 4. It is evident from the analysis that the driver 'D25: Investment in R&D' exerts a significant influence on the other drivers within this quadrant.

Table 4: Structural analysis of the five defined drivers

	Driver 21	Driver 23	Driver 25	Driver 29	Driver 33	Sum of dependence
Driver 21		4	2	1	2	7
Driver 23	1		4	2	2	10
Driver 25	1	2		1	2	8
Driver 29	1	2	4		2	8
Driver 33	1	2	4	1		14
Sum of influence	8	7	14	6	12	

Step 7 - Identification of Two Critical Uncertainty
The results, including the sums of influence and dependence, were plotted on a Cartesian axis as shown in Figure 2. From this plotting, two critical uncertainties were identified and graphically represented.

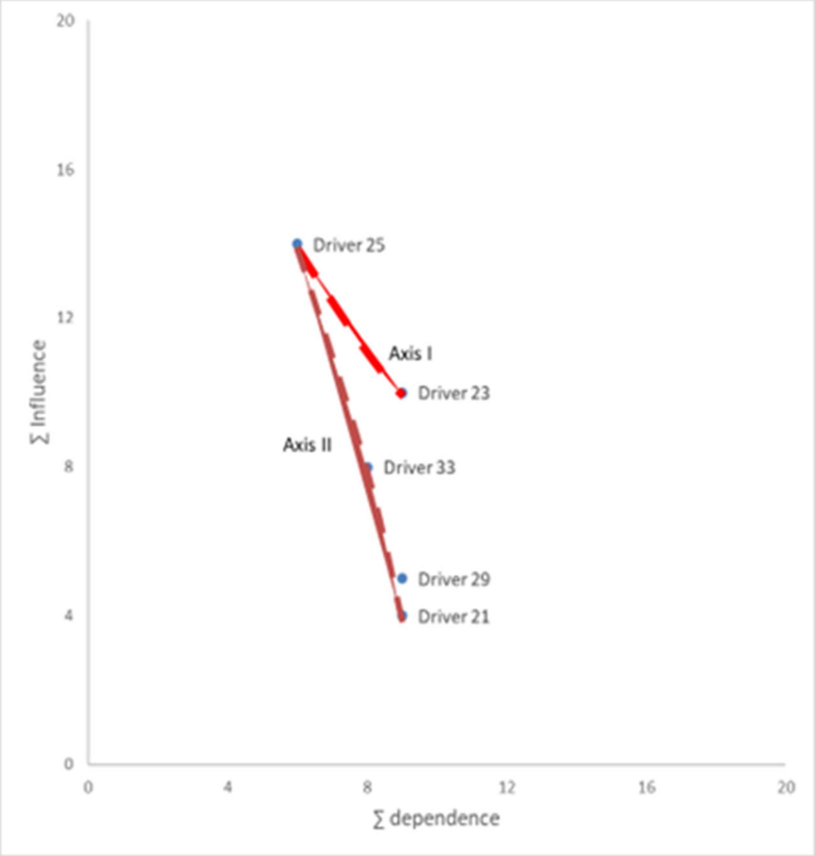

Fig 2: Identification of Two Critical Uncertainties

The first critical uncertainty, termed “Institutional Research Ecosystem,” underscores the importance of a stable institutional infrastructure to effectively leverage investment in R&D, and the second critical uncertainties is labelled as “Innovation and Human Capital Engine” reflects the multisectoral nature of this axis, which integrates financial, human, and legal resources to foster innovation.

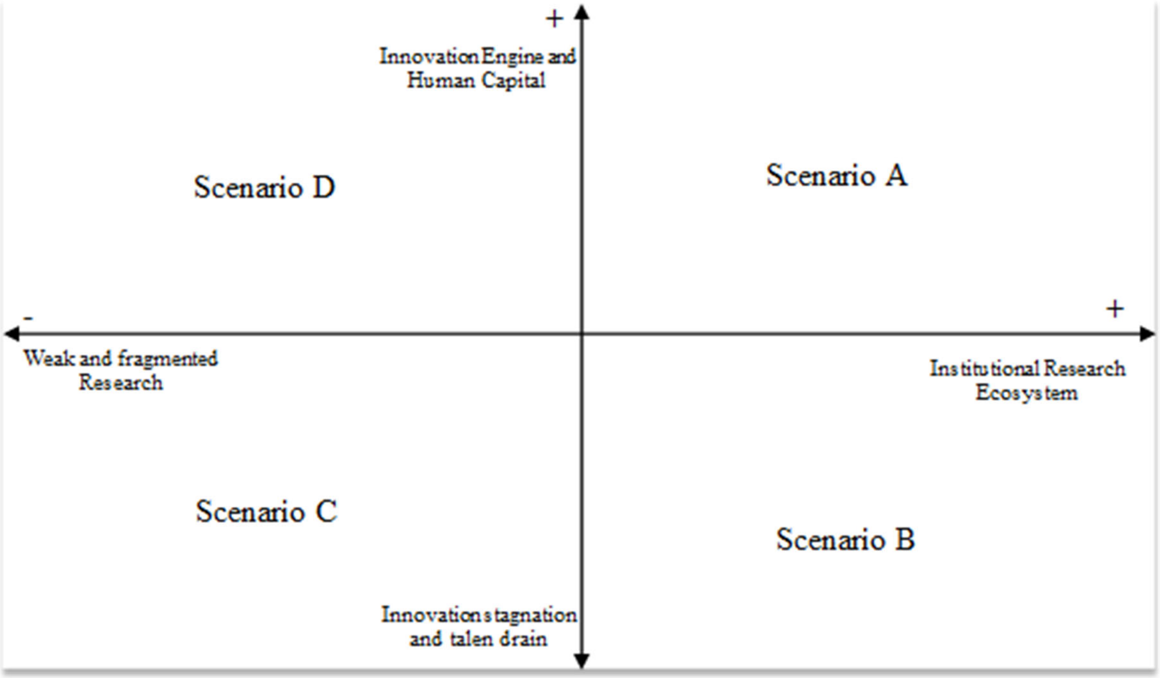

Figure 3: Four Scenarios framed by two critical uncertainties

Step 8 – Scenario Frames
Based on the scenario frame in step 7, the morphological box (Table 5) was employed to define future scenarios (Figure 4) using the deductive approach through the 2x2 matrix from two uncertainties (Schwartz, 1991; Ramírez and Wilkinson, 2014). Upon analyzing the coherence of these scenarios, each was found to be plausible and feasible within the proposed spatial and temporal framework.

Table 5: Morphological box for the construction of scenarios.

Morphological box		
Scenario	Axis I	Axis II
A	"+"	"+"
B	"+"	"-"
C	"-"	"-"
D	"-"	"+"

Scenario A:Innovative Synergy 2050: Peru as a Technological Epicenter of Latin America.
In this scenario, where both axes are positive, significant investment in R&D and the development of research institutions would foster an environment conducive to innovation. This setting would attract scientists and engineers while promoting the development of patents and technology parks.

Scenario B: Disconnection 2050: Innovation Trapped in the Laboratory:
In this scenario, while axis I is positive, and axis II is negative, substantial investment in R&D and research infrastructure fails to translate into applied innovation due to the absence of an adequate business ecosystem.

Scenario C: Technology Gap 2050, The Decline of Innovation in Peru:
In this scenario, where both axes are negative, the lack of investment in R&D coupled with weak innovation infrastructure in the business sector would likely result in Peru falling behind in technological development.

Scenario D: Technological Oasis in the Academic Desert, Peru 2050:
Here, axis I is negative, and axis II is positive. This scenario might be less viable over the long term, as robust business innovation typically requires a strong academic foundation to sustain. However, in the short term, it might be possible for companies to offset the lack of academic support with private investments and imported talent.

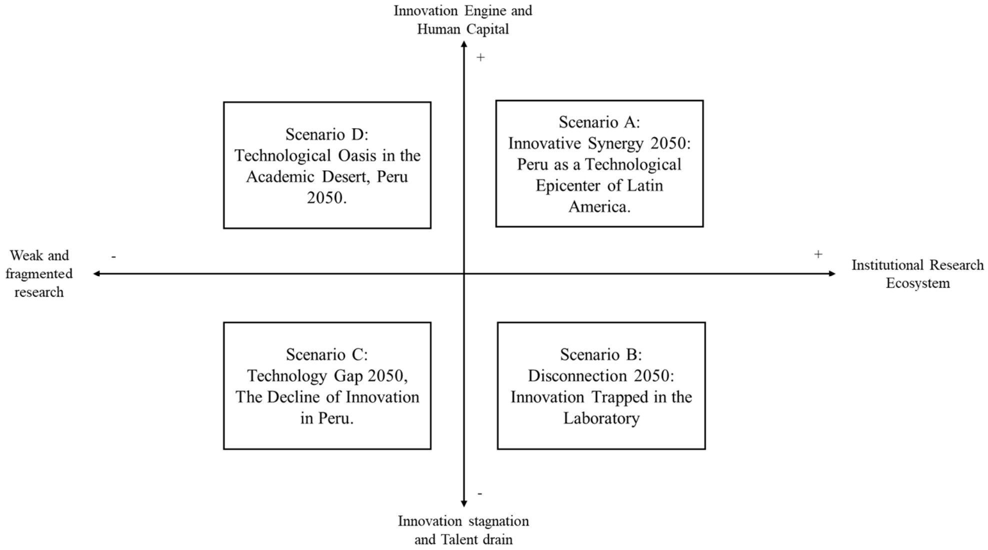

Figure 4: 2x2 Scenario Matrix for the two critical uncertainties

After identifying and describing the scenarios, the PDG (Probability, Desirability, and Governability) analysis was applied to estimate the possibilities of future construction (Table 6), with a score between 1 and 4, with 1 being the scenario that best embodies each of the three characteristics and 4, the one who does it the least. Finally, the target scenario, it means the most probable, desirable, and governable was obtained as mentioned by Ortega, (2016), by applying a third iteration of Delphi survey with the response of 17 experts of 30 invited (Table A3).

Table 6: PDG (Probability, Desirability and Governability) analysis of the scenarios.

Scenario	P	D	G	Total	Valuation
A	44	23	35	102	Possible (Target)
B	32	38	40	110	Possible
C	53	60	53	166	Possible (Inertial scenario)
D	41	49	42	132	Possible

Step 9 – Backcasting

The strategies proposed in this study were designed exclusively by the authors, following the flexibility inherent in Robinson's backcasting methodology, which does not provide a standard procedure for generating strategies but rather offers guidelines to explore alternative development paths (Robinson, 1982). As Bibri (2018) highlights, this approach often emphasizes technical analysis and policy recommendations without necessarily including stakeholder participation in the design of strategies. Hence, the proposed strategies serve as a preliminary framework to guide future efforts. Acknowledging the absence of direct stakeholder involvement in this phase, these strategies are intended as a starting point for further refinement and validation through participatory processes. Figure 5 showed the horizon towards 2050 to reach the target scenario, with milestones set at 6-year intervals.

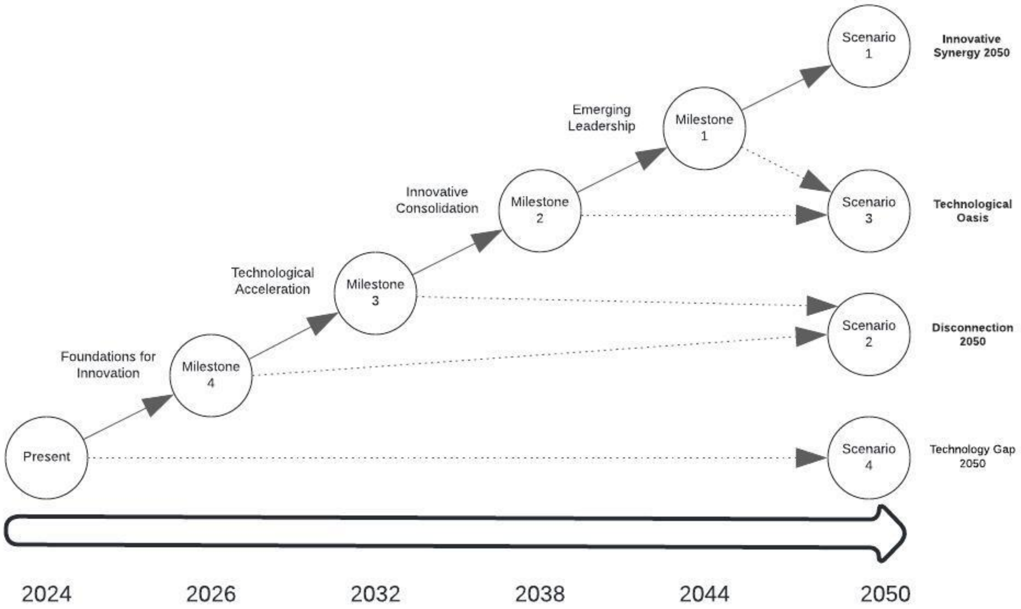

Fig 5: Backcasting for Strategy Development 2024-20250

The strategies to achieve the target scenario are defined in table 7:

Table 7: Strategies 2024-2050 to achieve the target scenario.

2024 - Strategies
Gradually increase investment in R&D to 0.25% of GDP, focusing on strategic sectors.
Expand Law 30309 to include additional tax benefits for hiring PhDs in companies.
Create an "Open Innovation" program that connects startups with established companies.
Develop a platform for patent analysis and scientific information integrated with PERU CRIS.
Implement an "Innovation Ambassadors" program to promote the adoption of the NTP for innovation management in the business sector.
Launch a public-private co-investment fund for R&D&I projects in priority areas.
2026: Milestone 4: Foundation for Innovation
Increase investment in R&D to 0.35% of GDP, with a focus on private sector participation.
Establish a "PhDs in Industry" program that partially subsidizes the incorporation of PhDs in companies for 2 years.
Create a network of specialized innovation labs in collaboration with universities and companies.
Implement an "Innovation Seal" system for companies that adopt the NTP and demonstrate innovative practices.
Launch an international mentoring program for Peruvian tech-based startups.
Establish a seed capital fund for innovation projects arising from university-industry collaboration.
2032 Milestone 3: Technological acceleration
Raise investment in R&D to 0.5% of GDP, with at least 40% coming from the private sector.
Implement an "Innovation Clusters" program in strategic sectors, integrating companies, universities, and research centers.
Create a national network of centers of excellence in emerging technologies (AI, biotechnology, renewable energy).
Establish a "National Innovation Challenges" program to address critical national issues through technological solutions.
Launch a crowdfunding platform specialized in R&D&I projects with state support.
Implement a "Scientific Diplomacy" program to position Peru in international innovation networks.
2038 Milestone 2: Innovative consolidation
Increase investment in R&D to 0.7% of GDP, with 50% coming from the private sector.
Create a "Long-term Innovation Missions" program in critical areas (e.g., food security, personalized health, smart cities).
Establish a sovereign innovation fund for strategic investments in frontier technologies.
Implement a "Regional Innovation" program to develop tech hubs in different regions of the country.
Launch a "Frugal Innovation" initiative to develop low-cost, high-impact technological solutions.
Create a network of "Advanced Fablabs" across the country, integrating technologies like 3D printing, robotics, and IoT.
2044 Emerging leadership
Raise investment in R&D to 0.9% of GDP, with 60% coming from the private sector.
Implement a "Critical Technologies" program to develop capabilities in strategic areas for technological sovereignty.
Create a "Distributed Supercomputing" network for advanced research in multiple fields.
Establish a "Technological Social Innovation" program to address challenges of inclusion and sustainable development.
Launch a "Space Innovation" initiative to develop capabilities in satellite technology and space exploration.
Implement a national "Technological Foresight" system to anticipate and prepare for future technological disruptions.
2050 Target Scenario
The target scenario “Innovative Synergy 2050: Peru as a Technological Epicenter of Latin America” will be established.

Scenario narratives

This section presents detailed narratives of the scenarios developed in this study, providing a vivid and accessible depiction of possible futures for Peru's technological development by 2050. These narratives are essential as they translate abstract concepts and strategic insights into relatable stories, allowing readers to visualize the implications of each scenario. By immersing readers in these potential realities, this section fosters a deeper understanding of the opportunities, risks, and decisions that could shape the nation's trajectory, ultimately serving as a foundation for informed policymaking and strategic planning. Hence, a brief narrative description of these scenarios is provided below.

Innovative Synergy 2050: Peru as a Technological Epicenter of Latin America

The transformation began in the late 2020s when Peru prioritized R&D investment. At first, it seemed like an ambitious leap for a country that had historically underfunded scientific innovation. However, the decision to build technology parks in Lima and Arequipa catalyzed a seismic shift. These parks became vibrant ecosystems, bridging universities, startups, and corporations. I still remember the turning point: a small biotech firm from Arequipa patented a revolutionary biofertilizer, sparking international recognition. Suddenly, the narrative around Peruvian innovation changed. It wasn't just about exporting raw materials anymore—it was about exporting ideas and solutions. University-industry collaboration flourished, and initiatives to integrate scientists into private companies accelerated. It wasn't easy at first. Many researchers struggled to transition from academic curiosity to applied problem-solving. Yet, by the mid-2030s, patents tripled, and Peru emerged as a regional leader in fields like sustainable agriculture, AI, and renewable energy. By 2050, the country was unrecognizable. The synergy between academia and industry created a virtuous circle: talent drove innovation, innovation attracted investment, and investment sustained the ecosystem. Today, Peru is not just a participant in global technology; it's a pioneer. It's incredible to think how far we've come.

Disconnection 2050: Innovation Trapped in the Laboratory

I still remember the excitement when Peru's investment in R&D began to show results in the 2030s. Universities were buzzing with activity, producing groundbreaking research in biotechnology, renewable energy, and artificial intelligence. It felt like we were on the brink of a technological revolution. State-of-the-art laboratories became symbols of academic excellence, and scientific publications surged. But something was missing. The technology parks that were meant to bridge academia and industry remained underutilized. Startups struggled to gain traction, and companies rarely collaborated with universities. Scientists stayed confined to their labs, focused on theoretical advancements that never made it to market. By the 2040s, the gap between academic innovation and the economy became impossible to ignore. Despite the wealth of knowledge generated, patents were rare, and few engineers found roles in private companies. The lack of technology transfer created a bottleneck, leaving Peru's potential untapped. Now, in 2050, the disconnect between academia and industry stands as a cautionary tale—a missed opportunity for real impact.

Technology Gap 2050, The Decline of Innovation in Peru

I remember how surprising it was to see Peru's tech sector flourish in the absence of strong academic institutions. By the 2030s, technology parks and private companies had taken the lead, attracting both international and local talent. Startups sprang up rapidly, filing patents and developing innovative solutions in renewable energy, AI, and agritech. The private sector seemed unstoppable, driving economic growth and technological breakthroughs. But beneath this success lay a troubling reality. Universities remained underfunded, and R&D&I institutions were few and far between. The lack of a strong academic foundation meant that most innovations focused on immediate market needs, with little investment in long-term research. Without academia to back it up, the ecosystem lacked depth, relying heavily on imported expertise and technologies. Now, in 2050, Peru's tech-driven economy thrives on short-term gains. Yet, the absence of sustainable research infrastructure looms large, casting doubt on whether this oasis can endure the challenges of the future.

Technological Oasis in the Academic Desert, Peru 2050

Looking back, it's hard to pinpoint when things started to unravel. By the 2030s, Peru's investment in R&D had fallen to negligible levels, leaving academic institutions struggling to stay afloat. Laboratories once full of potential were abandoned, and talented scientists sought opportunities abroad. Without funding or direction, universities could no longer produce meaningful research or attract bright minds. The private sector fared no better. Companies faced a critical shortage of engineers and innovators, stifling their ability to compete. Technology parks, envisioned as hubs of progress, never fully materialized. By the 2040s, the number of patents had plummeted, and Peru had lost its place in the global innovation race. Now, in 2050, the country's stagnation is undeniable. The disconnect between academia and industry, compounded by years of neglect, has left Peru trailing behind its regional neighbors. What remains is a sobering reminder of how fragile progress can be without sustained effort and collaboration.

Strategies for the target scenario

The target scenario selected by the experts was "Innovative Synergy 2050: Peru as a Technological Epicenter of Latin America." Although it was not the third most probable, it proved to be the most desirable and governable (achievable), which globally allowed it to be identified as the preferred scenario according to Table 6. The strategies for creating this scenario (Table 7) were developed considering the drivers that comprised each axis of uncertainty, thus considering milestones with a 6-year interval.

At present, the strategies focus on gradually increasing investment in R&D, improving tax incentives, fostering collaboration between startups and established companies, and developing analytical tools to support R&D&I. This is an important point due to the particular focus of the scientists regarding their research objective, research from academia tends to lead their work for curiosity (Siegel et al., 2023), therefore, it is necessary to strengthen technology transfer in academia and the inclusion of scientists in companies. The synergy between these elements creates a virtuous circle: investment attracts talent, talent drives innovation, and innovation draws further investment, solidifying Peru's status as a leader in technology and innovation. In 2026, Peru must prioritize increasing private sector participation in R&D (Koh & Lee, 2023; Zheng et al., 2023), integrating PhDs into the industry (Shen & Wang, 2024), creating collaborative innovation infrastructure (Blezer et al., 2023; Huang et al., 2024), and establishing support mechanisms for startups and university-industry projects. In 2032, the emphasis must be on creating innovation clusters, centers of excellence in emerging technologies, national challenge programs, and positioning Peru internationally in innovation networks. In 2038, Perú must focus on long-term innovation missions, strategic investments in frontier technologies, the development of regional tech hubs, and the promotion of frugal innovation and advanced fab labs. Finally, in 2044 Peru must concentrate on developing critical technologies for technological sovereignty, advanced research infrastructure, technological social innovation, and capabilities in space technology and technological foresight.

Despite the outlined path, the betting scenario can be disrupted by the failure to implement the described strategies, as observed in Figure 3. The failure of the strategic actions in the current year could lead Peru to the scenario "Technology Gap 2050, The Decline of Innovation in Peru." Failure to achieve the strategic actions of Milestone 4 could trigger Scenario 2 "Disconnection 2050: Innovation Trapped in the Laboratory," due to inadequate foundations for technological progress. Failing with the strategic actions of Milestone 3 could lead Peru to the previous scenario. Failure in Milestones 2 and 1 would result in Peru's future falling into the scenario "Technological Oasis in the Academic Desert, Peru 2050." It is important to note that stagnation at each milestone can be reversed with new strategies that should be proposed at the temporal moment of the future event.

The construction of scenarios using 2x2 matrix, while providing a clear structure for analysis, must be interpreted with its inherent limitations in mind. As Burt and Nair, (2020) argue, that the resulting scenarios represent simplified archetypes of possible futures, useful for strategic planning but requiring supplementation with more granular analyses. The selection of the two main axes reflects both the technological reality of Peru and the priorities identified in the expert consultation process, acknowledging that other factors not included in the main axes could significantly influence the country's technological trajectory.

Conclusion

Technological foresight plays a pivotal role in shaping Peru's future, offering a structured approach to identify and analyze key trends and drivers within the technological landscape. This study highlights the vital importance of fostering investment in research and development (R&D) and encouraging stronger collaboration between academic institutions and the private sector to drive innovation in technology. By 2050, the foresight study envisions an ambitious target scenario where Peru emerges as a technological hub in Latin America. This envisioned future includes an R&D investment level equivalent to 1% of GDP, robust private sector engagement, a resilient and self-sustaining innovation ecosystem, regional leadership in critical technologies, and seamless collaboration among academia, industry, and government in research, development, and innovation (R&D&I).

The process of scenario development and analysis employed in this study offered valuable methodological insights. By integrating the Delphi method with the Schwartz axes framework, the study systematically examined uncertainties and identified the most influential drivers shaping Peru's technological advancement. This approach emphasized the necessity of engaging experts collaboratively to reach a consensus on both plausible and desirable futures. Additionally, the analysis illuminated the intricate interconnections among drivers, enabling the creation of strategies that align with specific milestones. The iterative application of backcasting proved essential in connecting long-term strategic goals with short- and medium-term actions. These insights underscore the value of foresight as an adaptive and participatory tool, equipping policymakers and stakeholders to effectively address the complexities of uncertain and dynamic futures.

To realize the target scenario, a series of strategies were formulated to tackle key priorities, including scaling up R&D investments, strengthening the infrastructure for innovation, fostering partnerships across sectors, and enhancing capabilities in emerging and critical technologies. The successful implementation of these strategies is anticipated to enhance economic competitiveness, improve societal well-being, expand human capital, advance strategic technological domains, address environmental challenges with innovative solutions, and bolster Peru's geopolitical standing. Together, these initiatives provide a solid foundation for sustainable and inclusive development, positioning Peru as a prominent player in the global knowledge economy.

Future Research

This study establishes a foundation for future research by highlighting promising directions for advancing technological foresight. Future work could employ diverse methodologies, such as longitudinal studies to track trend evolution, comparative analyses across regions or sectors to address contextual variations, and complementary methods like General Morphological Analysis (Ritchey, 2018) or Cross-Impact Analysis (Weimer-Jehle, 2006) to explore complex interrelations. Addressing the study's reliance on specific data sources, future research should incorporate more diverse inputs, including grassroots organizations and international databases, to ensure broader applicability. Additionally, dynamic systems modeling could enhance understanding of evolving technological landscapes. An interdisciplinary approach that integrates insights from economics, sociology, and environmental science would further enrich research, offering a holistic view of how technology interacts with societal, economic, and environmental factors. These efforts will help design strategic, sustainable interventions, supporting policymakers, educators, and industry leaders in navigating the complexities of technological innovation.

Acknowledgements

This research was supported by Pulso PUCP – Instituto de Analítica Social e Inteligencia Estratégica, and the researchers want to thanks to expert panel for their participation in Delphi surveys.

References

Bengston, D. (2015). Asynchronous online foresight panels: The case of wildfire management. Journal of Futures Studies, 19, 1–12.

Bibri, S. E. (2018). Backcasting in futures studies: a synthesized scholarly and planning approach to strategic smart sustainable city development. European Journal of Futures Research, 6(1). https://doi.org/10.1186/s40309-018-0142-z

Blezer, S., Abujidi, N., & Sap, H. (2023). Urban living labs as innovation infrastructure for local urban intervention acceleration and student social learning: the impacts on community wellbeing in Heerlen. Frontiers in Public Health, 11, 1242151. https://doi.org/10.3389/FPUBH.2023.1242151/BIBTEX

Borch, K., & Rasmussen, B. (2002). Commercial use of GM crop technology: Identifying the drivers using life cycle methodology in a technology foresight framework. Technological Forecasting and Social Change, 69(8), 765–780. https://doi.org/10.1016/S0040-1625(01)00164-0

Bradfield, R., Derbyshire, J., & Wright, G. (2016). The critical role of history in scenario thinking: Augmenting causal analysis within the intuitive logics scenario development methodology. Futures, 77, 56–66. https://doi.org/10.1016/J.FUTURES.2016.02.002

Burt, G., & Nair, A. K. (2020). Rigidities of imagination in scenario planning: Strategic foresight through

‘Unlearning.’ Technological Forecasting and Social Change, 153, 119927. https://doi.org/10.1016/J.TECHFORE.2020.119927

Centro Nacional de Planeamiento Estratégico. (2020). Perú 2050: tendencias nacionales. www.ceplan.gob.pe

Dalkey, N., & Helmer, O. (1963). An Experimental Application of the DELPHI Method to the Use of Experts. Management Science, 9(3). https://doi.org/10.1287/mnsc.9.3.458

Díaz Vega, M. I., & Ospina Ospina, M. J. (2014). Identificación de variables que afectarían la valoración de productos de las micro, pequeñas y medianas empresas dedicadas al desarrollo de software por encargo en Colombia. Informador Técnico, 78(1). https://doi.org/10.23850/22565035.70

Ecken, P., Gnatzy, T., & von der Gracht, H. A. (2011). Desirability bias in foresight: Consequences for decision quality based on Delphi results. Technological Forecasting and Social Change, 78(9), 1654–1670. https://doi.org/10.1016/J.TECHFORE.2011.05.006

Godet, M., Durance, P., & Gerber, A. (2013). Strategic Foresight La Prospective Use and Misuse of Scenario Building. The Circle of Future Entrepreneurs, 65(1), 421. http://innovbfa.viabloga.com/files/LIPSOR___Strategic_Foresight.pdf

Godet, M., Monti, R., Meunier, F., & Roubelat, F. (2000). La caja de herramientas de la prospectiva estratégica. Cuadernos de LIP, Número 5.

Gonzales, B. F., Acevedo Flores, A. G., Galindo Ccallocunto, J. U., & Ramos Muñoz, J. A. (2024). Drivers of technology foresight - Peru 2050. 1. https://doi.org/10.17632/HF93Y6CKY7.1

Gordon, T., & Pease, A. (2006). RT Delphi: An efficient, “round-less” almost real time Delphi method. Technological Forecasting and Social Change, 73(4), 321–333. https://doi.org/10.1016/J.TECHFORE.2005.09.005

Huang, Q., Zhao Ziwei, Wang, C., & Wang, W. (2024). Thoughts on fostering industries of the future based on innovation infrastructure clusters. Bulletin of Chinese Academy of Sciences (Chinese Version), 39(7), 1163–1171. https://doi.org/10.16418/j.issn.1000-3045.20240507002

Janis, I. (1982). Groupthink: Psychological studies of policy decision and fiascoes. Houghton Mifflin:Boston, 349.

Koh, Y., & Lee, G. M. (2023). R&D subsidies in permissive and restrictive environment: Evidence from Korea. Research Policy, 52(1), 104620. https://doi.org/10.1016/J.RESPOL.2022.104620

Korea Institute of Science & Technology Evaluation and Planning. (2022). The 6th Science and Technology Foresight (2021-2045). https://www.kistep.re.kr/board.es?mid=a20401000000&bid=0046&act=view&list_no=42923

Lebedys, A., Akande, D., Elhassan, N., Escamilla, G., Arkhipova, I., & Whiteman, A. (2023). Renewable Capacity Statistics 2023. In IRENA.

Meyer, T., von der Gracht, H. A., & Hartmann, E. (2022). Technology foresight for sustainable road freight transportation: Insights from a global real-time Delphi study. Futures & Foresight Science, 4(1), e101. https://doi.org/10.1002/FFO2.101

Ministerio del Ambiente del Perú. (n.d.). Huella de Carbono PERÚ. Retrieved January 20, 2024, from https://huellacarbonoperu.minam.gob.pe/huellaperu/#/estadisticas/medicion

Ortega, F. (2016). PROSPECTIVA EMPRESARIAL. Manual de corporate foresight para América Latina (1st ed.). Universidad de Lima.

Ortega, F., Hernández, C., Cano, N., Capatinta, M., Céspedes, C., Lucero, P., Sánchez, A., & Vásquez, P. (2018). Bases para un estudio prospectivo de la descentralización en el Perú al 2030. https://hdl.handle.net/11362/43883

Pietrobelli, C., & Puppato, F. (2016). Technology foresight and industrial strategy. Technological Forecasting and Social Change, 110, 117–125. https://doi.org/10.1016/j.techfore.2015.10.021

Ramirez, R., & Wilkinson, A. (2014). Rethinking the 2×2 scenario method: Grid or frames? Technological Forecasting and Social Change, 86, 254–264. https://doi.org/10.1016/j.techfore.2013.10.020

Ritchey, T. (2018). General morphological analysis as a basic scientific modelling method. Technological Forecasting and Social Change, 126, 81–91. https://doi.org/10.1016/J.TECHFORE.2017.05.027

Robinson, J. B. (1982). Energy backcasting A proposed method of policy analysis. Energy Policy, 10(4), 337–344.

https://doi.org/10.1016/0301-4215(82)90048-9

Rohrbeck, R., & Schwarz, J. O. (2013). The value contribution of strategic foresight: Insights from an empirical study of large European companies. Technological Forecasting and Social Change, 80(8), 1593–1606. https://doi.org/10.1016/j.techfore.2013.01.004

Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: issues and analysis. International Journal of Forecasting, 15(4), 353–375. https://doi.org/10.1016/S0169-2070(99)00018-7

Schwartz, P. (1991). The Art of the Long View: Planning for the Future in an Uncertain World. Bantam Doubleday Dell Publishing Group.

Shantiko, B., Liswanti, N., Bourgeois, R., & Laumonier, Y. (2021). Land-use Decisions in Complex Commons: Engaging Multiple Stakeholders through Foresight and Scenario Building in Indonesia. Environmental Management, 68(5). https://doi.org/10.1007/s00267-021-01470-1

Shen, W., & Wang, C. (2024). Historical Trends in PhD Study Abroad and Their Implications for Transforming the Chinese Higher Education System. 309–333. https://doi.org/10.1007/978-3-031-53847-6_12

Siegel, D., Bogers, M. L. A. M., Jennings, P. D., & Xue, L. (2023). Technology transfer from national/federal labs and public research institutes: Managerial and policy implications. Research Policy, 52(1). https://doi.org/10.1016/j.respol.2022.104646

Tetlock, P. E., & Gardner, D. (2015). Superforecasting: The art and science of prediction. In Superforecasting: The art and science of prediction. Crown Publishers/Random House.

Weimer-Jehle, W. (2006). Cross-impact balances: A system-theoretical approach to cross-impact analysis. Technological Forecasting and Social Change, 73(4), 334–361. https://doi.org/10.1016/J.TECHFORE.2005.06.005

Zheng, Q. , Li, J. , Duan, X., Zheng, Q., Li, J., & Duan, X. (2023). The Impact of Environmental Tax and R&D Tax Incentives on Green Innovation. Sustainability 2023, Vol. 15, Page 7303, 15(9), 7303. https://doi.org/10.3390/SU15097303