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Bridging the Gap: Scenario Planning for Science and Technology in Breast Cancer

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Abstract

Background: The convergence of scientific research and technological breakthroughs is critical to societal health. However, both academic literature and patents can grow at separate rates, leading to gaps in fields like breast cancer. This study aims to identify and bridge the gap between science and technology in breast cancer research through scenario planning.

Methods: This research is a foresight study conducted using the scenario technique method. A total of 191,871 papers and 9085 patents on breast cancer, published between 2012 and 2021, were analyzed using data from the Web of Science Core Collection and PATSTAT databases. Text mining was conducted using the Latent Dirichlet Allocation (LDA) topic modeling technique with Python libraries to identify subject clusters and areas of asynchrony. The scenario technique was then developed, aimed at bridging the gap between science and technology.

Results: Our findings revealed that scientific output in breast cancer has greatly surpassed technical advancements, indicating gaps in several key domains. Scientific papers in our dataset, mostly concentrated on the complexities of breast cancer—including genetic mutations, hormone receptors, dietary factors, and environmental influences—whereas the analyzed patents frequently addressed lesser-known areas such as herbal medicine, medical devices, protective clothing, and micro ribonucleic acid therapies. To fill these gaps, 4 scenarios were created and, some effective actions for each scenario were recommended.

Conclusion: Different priorities emerged across the 16 proposed actions for the 3 specific scenarios—excluding the favorable scenario. In all scenarios, enhancing stakeholder ties, establishing cooperative networks, and developing collaborative incentive systems were identified as key strategies for diminishing the gap between science and technology in breast cancer.

Keywords: Scenario Planning, Science and Technology, Breast Cancer, Topic Modeling, PEST Analysis

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Introduction

Breast cancer continues to be a major worldwide health concern that requires innovative treatment strategies (1, 2). The increasing prevalence and high mortality rates of breast cancer are the most serious threat to women's health around the world, leading to numerous problems that affect the healthcare systems of different nations (3). According to the American Cancer Society in 2023, breast cancer is the

↑What is "already known" in this topic:
Breast cancer is a critical scientific, clinical, and social challenge that has garnered significant research attention across multiple dimensions—including early detection, treatment advancements, and the use of technologies like artificial intelligence, vaccines, and personalized medicine. However, there remains a substantial gap between scientific research and its practical applications.

→What this article adds:
This article identifies and bridges the science-technology gap in breast cancer research by applying a scenario planning approach and the Latent Dirichlet Allocation (LDA) topic modeling method. It uncovers some key thematic gaps and proposes strategies to enhance collaboration among stakeholders, facilitating the translation of scientific discoveries into practical and technological solutions for improving patient care.

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second most frequent cause of cancer-related death (4), accounting for 12.5% of all new cancer cases reported each year (5). This situation highlights the urgent need to implement innovative diagnosis and treatment strategies.

In response, numerous efforts in science and innovation research seek to increase our understanding of how breast cancer starts and evolves. For instance, the global decrease in breast cancer mortality rates reflects significant advancements in early detection, increased awareness of symptoms, and improved treatment options (6). Besides, several novel approaches for diagnosis and therapy are emerging in the literature—including the use of state-of-the-art technologies such as artificial intelligence for early cancer diagnosis (7-10). In addition, vaccine development (11-13) and research in targeted and personalized treatments are considered as other types of advancements in breast cancer treatment (1, 3, 14).

However, despite significant advances in scientific research and technological innovations, there is a significant gap between scientific research and technological applications in the field of breast cancer (15-19). Eccles et al conducted a comprehensive study on breast cancer research, revealing that significant gaps remain in translating new knowledge into clinical advances (17). Similarly, Thompson et al highlighted research needs across various areas of breast cancer (such as genetics, cancer initiation, disease progression, treatments, disease markers, prevention, and psychosocial aspects), noting that primary barriers to addressing these gaps were inadequate funding and poor interdisciplinary collaboration (16). Some studies in the field of breast cancer highlight gaps in thematic areas such as patient perspectives, health economics, and end-of-life care, suggesting a need for new technological interventions (20).

Other studies emphasized limited scientific activity in certain domains such as anticancer natural products and an essential need to strengthen technical exchanges (20). Furthermore, scientists are often unaware of the companies that could utilize their discoveries, and companies may not recognize which scientific breakthroughs could be valuable to them(21). This gap prevents the transformation of promising scientific discoveries into practical solutions (22), which can affect patient care and overall community well-being.

Bridging the gap between science and technology requires an emphasis on interdisciplinary and transdisciplinary approaches, integrating various academic disciplines with nonacademic participants. This integration enables research teams to address real-world patient care issues, generate practice-based evidence, and translate findings into clinical and social care settings (23). In particular, involving stakeholders beyond the medical field—such as patients, researchers, and inventors—is crucial for improving treatment strategies (15). As an example, a network of social actors in exchanging, analyzing, and utilizing information is considered an essential factor in the field of biotechnology in developing new breast cancer drugs. Such a network boosts collaboration among various factors—such as government agencies, universities, businesses, nongovernmental organizations, physicians, and hospitals—enhances synergy and fosters competition and innovation in the breast cancer treatment chain (24).

To effectively address the science-technology gap, it is essential to facilitate targeted communication between different stakeholders in the field of breast cancer (25, 26). Scenario, namely a notable qualitative technique in mixed methods, is widely acknowledged among future researchers and extensively utilized for aiding strategic decision-making (27, 28). This technique enables researchers, policymakers, healthcare professionals, and industry leaders to address key drivers and uncertainties in science and technology and identify potential pathways to bridging the science-technology gap. This scenario-based approach has been successfully applied in several studies across various fields—including human genome editing (29), the future service robot scenarios in South Korea (30), and potential applications in the field of global mental health (31).

Overall, previous studies have mainly concentrated on finding scientific gaps in breast cancer research by analyzing scientific articles or conducting expert surveys. While some health-related research has investigated the gaps between science and technology by comparing both scientific articles and patents, the literature does not contain any case studies using a scenario technique to bridge the gap between science and technology in certain topics. The present study attempts to fill this gap. Hence, the main goal of this study is to address the gap between science and technology in the field of breast cancer using a scenario-based approach.

Methods

In this study, a combination of both quantitative and qualitative approaches was used. First, we conducted a comprehensive analysis of 191,871 (99.93%) original and review papers and 9085 (62.55%) patents in the field of breast cancer published over 10 years (from 2012 to 2021). The total number of retrieved documents initially included 192,004 papers and 14,525 patents. After eliminating retracted, expression of concern, and withdrawn publications, as well as duplicate patents with identical technical contents, the final dataset comprised 191,871 publications and 9085 patents. These 2 datasets of scientific articles and patents respectively retrieved from the in-house Web of Science Core Collection (WoSCC) and the European Patent Office (EPO) Worldwide Patent Statistical (PATSTAT) databases of the Center for Science & Technology Studies (CWTS) of Leiden University in the Netherlands using Structural Query Language (SQL) commands (see Appendix 1 for the search syntax and related queries). Then, we employed the Latent Dirichlet Allocation (LDA) technique, a widely recognized and powerful method for topic modeling (32-34). For mining the titles and abstracts of relevant scientific articles and patents in our datasets.

In the scenario implementation phase, an expert panel was conducted along with interviews and questionnaires to identify the key factors contributing to the science-technology gap. Various general frameworks for scenario-based planning in healthcare have been developed, often incorporating models such as PEST (Political, Economic, Social,

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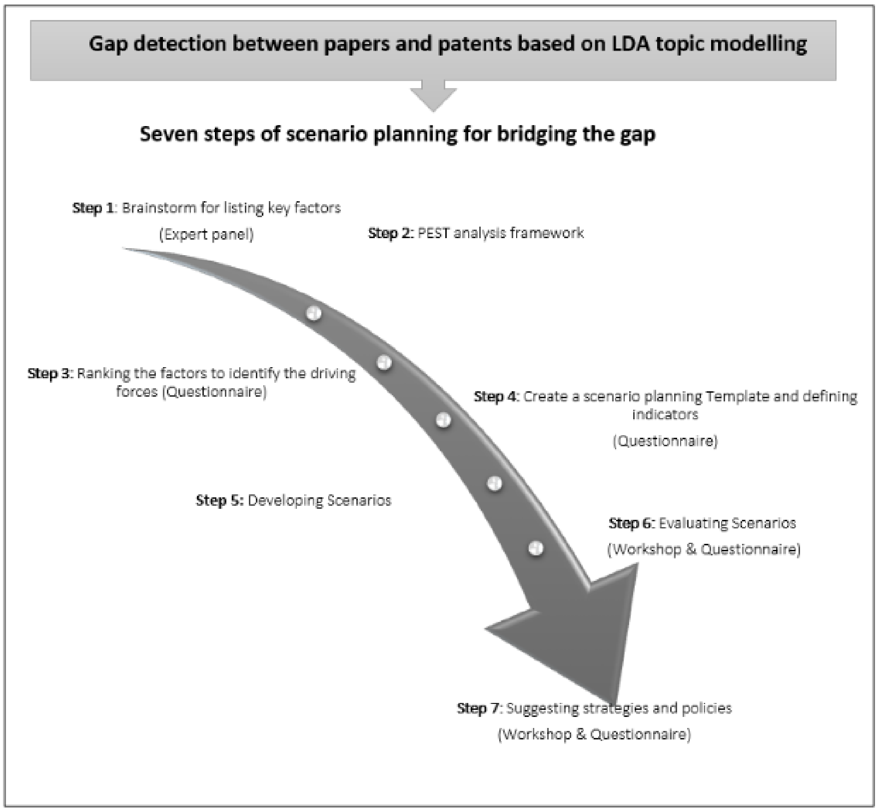

Figure 1. The framework of scenario planning for bridging the gap between science and technology in breast cancer (developed by the authors).

and Technological), STEEP (Social, Technological, Economical, Environmental, Political), or similar tools to identify key drivers and assess uncertainty level during the environmental scanning phase (35, 36). Accordingly, the framework developed in the scenario phase of the present study aligns with these established methods. Following these steps, the scenarios were then described over a 10-year time horizon. Finally, the credibility of the scenarios was determined and the solutions to achieve the scenarios were presented. The overall process is shown in the framework depicted in Figure 1. The detailed steps of the scenario planning framework are described in the following sections.

- Gap Detection Between Scientific Articles and Patents Based on LDA Topic Modelling

To determine the gap between science and technology in breast cancer, we employed a multiphase methodological approach. First, preprocessing the data (ie, removing duplicates, converting records into a text format suitable for text mining, filtering, removing punctuation and stop words, stemming, and generating a dictionary or bag of words, as well as creating N-grams) is done based on the retrieved datasets explained in the methodology section. Then, the Latent Dirichlet Allocation (LDA) topic modeling applied on the preprocessed data using Python libraries (such as Pandas, Numpy, NLTK, and Gensim). To optimize the model parameters, we used standard preprocessing and rigorous testing, applying coherence, perplexity, and elbow point methods to determine the ideal number of clusters, resulting in 9 topics for our dataset of scientific articles and 5 for the datasets of patents, divided into 2-year groups. In this phase, hyperparameters—such as chunk size, passes, iterations, alpha, and beta—were experimentally tested to achieve the best interpretability and quality of topics. For the evaluation and development of the model, we visualized clusters using Word Clouds and had them reviewed by subject-matter experts in breast cancer. Each model was assigned a special topic name based on the words and also the probability value of words in each cluster. Thereafter, in 4 sessions (lasting in total of eight hours) with 2 subject experts, the tagging was adjusted and finalized (for participant details, see row 1, Table 1). In the final step, a comparative analysis was performed based on the produced clusters to identify gaps between scientific literature and technological advancements in breast cancer research.

- Scenario Planning

Scenario planning was carried out in 7 steps (Figure 1) as described in the following sections.

Step 1: Brainstorming to Identify Key Factors Contributing to the Science and Technology Gap (Expert Panel)

After receiving the opinions of subject experts (see participant details, row 2, Table 1) based on the results of topic modeling analysis of scientific articles and patents, along with the identified gaps, the factors contributing to the science-technology gap in breast cancer were compiled (Table

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Table 1. Background Information on Experts Participating in Research Processes

Raw	Stage	Survey Method	No. of Participants	Expertise of Participants
1	Topic Modelling and Cluster Naming Process	In-person, Google Meet, E-mail	3	Researchers specialized in breast cancer terminology
2	Brainstorm for driver forces	Expert panel (Google Meet, WhatsApp, LinkedIn, E-mail, and Phone)	11	Breast cancer specialists, health futurists, patent experts, and policymakers
3	Ranking of driving forces	Online questionnaire	30	Breast cancer specialists, health futurists, patent experts, and policymakers
4	Defining indicators	Questionnaire	10	Health futurists, science and technology policymakers, patent experts
5	Evaluating Scenarios	Scenario workshop and questionnaire	11	Breast cancer specialists, science and technology policymakers, health policymakers
6	Ranking of strategies	Scenario workshop and questionnaire	10	Breast cancer specialists, science and technology policymakers, health policymakers

Table 2. Driving Forces Shaping the Future of Science-Technology Interaction

	Factors mentioned by experts	Average importance	Average level of uncertainty	The geometric mean
	Barriers to collaboration between key players due to different goals	4.3	3.2	3.7
Political	Control of sovereignty and government oversight	3.9	3.2	3.5
	Variations in policies, laws, and regulations across countries	3.7	3.1	3.4
	Obstacles and complex regulatory frameworks	3.8	3.0	3.4
	Different research priorities of organizations and nations	3.9	3.0	3.4
Economical	Financing and investment challenges	4.5	3.0	3.7
	Competitive landscape ,market and business viability	4.0	3.4	3.7
	Infrastructure Limitations	4.3	2.8	3.5
	Conflict of interest	3.9	3.2	3.5
	Intellectual Property Protection	4.0	2.9	3.4
	Confidentiality Maintenance	3.6	3.0	3.3
	Divergent National Innovation Systems	3.7	3.0	3.3
Social	Resistance to adoption of new technologies by the public or medical professionals	4.4	3.5	3.9
	Significance of public perspectives and their needs, desires, and demands	4.1	3.4	3.7
	Uncertainty surrounding the safety and efficacy of new medical technologies	3.8	3.6	3.7
	High workload of doctors in this field, leading to insufficient focus on global issues	4.0	2.8	3.4
	Ethical considerations in certain areas of research	3.8	3.0	3.4
	Collaborative barriers among scientists, engineers, physicians, and industry partners	3.7	2.9	3.3
Technological	Scientific-practical innovation conversion challenges and obstacles	4.0	3.2	3.6
	Insufficient transparency in the methodologies of researchers and inventors	3.7	3.5	3.6
	Non patentability of certain aspects of breast cancer research	3.1	2.9	3.0
	Time lag between article publication and patent registration	3.4	3.0	3.2

2). Initially, 34 factors were identified. After removing overlapping elements, a total of 22 unique factors were confirmed and remained for further analysis explained in step 2.

Step 2: PEST Analysis Framework

The PEST stands for Political, Economic, Social, and Technological factors, representing the key elements identified in the analysis. It is a foresight method and strategic management tool used to evaluate external factors that might influence an organization or project (37, 38). In this step, we used the PEST analysis to categorize the 22 factors identified in the previous step.

Step 3: Ranking the Factors to Identify the Driving Forces (Questionnaire)

An online questionnaire (Appendix 2) with definitions for each factor was distributed to experts (for participant details, see row 3, Table 1). Participants rated the factors based on importance and level of uncertainty using a 5-point Likert scale. Out of 45 recipients, 30 experts completed the questionnaire. We calculated the average importance and average uncertainty level of each factor based on the responses. The factors were then prioritized using the geometric mean between the level of uncertainty and importance. Among the 22 factors, 8 key drivers with high levels of uncertainty and high importance were identified. Based on the clustering of these key drivers, 2 key uncertainties were identified, leading to the development of 4 scenarios.

Step 4: Creating a Scenario Planning Template and Defining Indicators

After clustering the 8 key drivers, we identified 2 primary uncertainties that were mapped into the scenario space: social-technological uncertainties (factors S1, S2, S6, and T1, T2) and political-economic uncertainties (factors P5 and E1, E3). These uncertainties formed the basis for developing 4 distinct scenarios. To describe the scenarios, the research team defined an index for each of the 8 key drivers and estimated their current status. Subsequently, the values of these indicators for each scenario were estimated based on the experts' opinions gathered through a questionnaire. Finally, definitions of the indicators were included in a 32-question survey, which was distributed to the experts for completion.

Step 5: Developing Scenarios

After the main drafts of the 4 scenarios were determined, they were named and then written as stories. The details of each scenario were described based on the key uncertainties. Using the current values of indicators and the estimated values of all eight indicators in the 4 identified scenarios, a precise description of the scenarios was provided.

Step 6: Evaluating Scenarios

The scenario text and validation questions were sent to all invitees. Then, a workshop was held to validate the scenarios, where subject experts evaluated the scenarios based on 5 criteria, as follows: believability; challengingness; internal consistency; relevance; and design. During the 3-hour workshop, the 4 scenarios were scored on a Likert scale from 1 (very weak) to 10 (very strong) across the 5 criteria. To analyze the results, the researchers calculated the average points received by the experts and established 2 ranges of acceptance and rejection. If the average of each criterion was 5 to 10, the scenario was considered acceptable; if it was <5, it would be rejected. The rejected scenario was rewritten.

Step 7: Suggesting Strategies and Policies

In the final phase, the research team identified the recommended actions and strategies for achieving the desired scenario. During the scenario workshop, participants rated the optimal actions for 3 scenarios on a scale from 1 (weakest) to 10 (strongest). The scores assigned to each action provided the basis for analysis in this step, with higher scores (close to 10) indicating higher priority actions. Consequently, the top actions for each of the 3 scenarios were ranked accordingly. The background information on all specialists involved in the implementation process of this article is summarized in Table 1.

Results

- Identifications of the Science-Technology Gap in Breast Cancer

In this phase, based on the retrieved publications and patents as explained in the methodology section, key science and technology clusters were identified using a thematic modeling of scientific articles and patents. A total of 70 clusters—including 25 patent clusters and 45 scientific article clusters—were visualized separately. By merging clusters with the same name, a total of 22 unique clusters in articles and 15 unique clusters in patents were identified.

In general, the number of patents is lower compared with articles in all topic clusters. Figure 2A shows the thematic clusters of articles whose corresponding clusters were not identified in the patent. A total of 14 subject areas had clusters in the articles for which there was no corresponding cluster in the patents. However, some of these topics—such as meta-analyses and epidemiological studies—fall into categories that are not patentable. Furthermore, Figure 2B shows patent topics whose corresponding clusters were not observed in the articles. The patent included 7 topics that have no equivalent in the article's cluster. Finally, one of the topics that has been of great interest to inventors is herbal treatments. However, we have only reported the nonoverlapping thematic clusters of articles and patents.

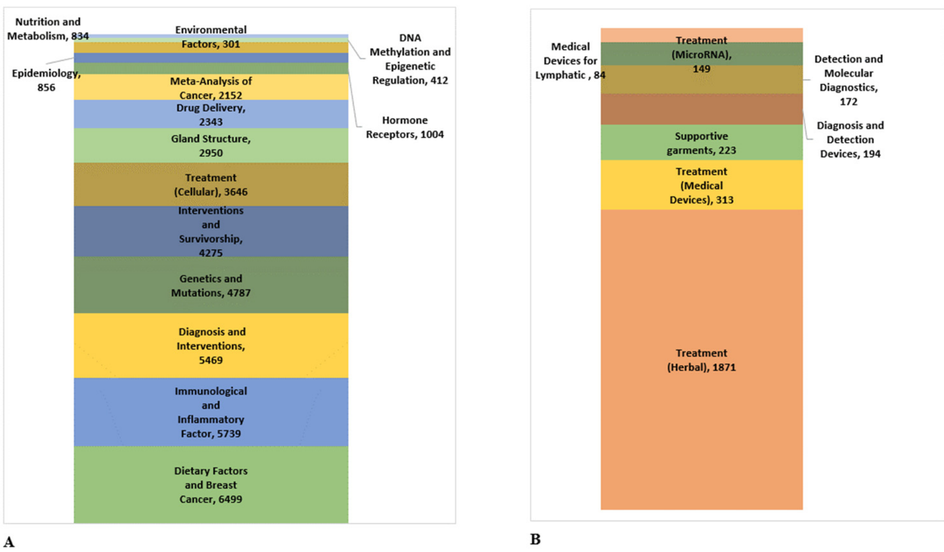

Figure 2. The identified nonoverlapped clusters in patents (A) and scientific articles (B)

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-Scenario Planning

Identification and Ranking of the Most Important Factors Contributing to the Science and Technology Gap Based on an Expert Survey

Table 2 presents driving forces shaping the future of science-technology gathered through expert panel discussions and an online questionnaire (Appendix 2). A total of 22 factors, categorized under the PEST framework were identified. The factors with the highest geometric mean scores are bolded in the table, highlighting the most significant drivers. As shown, the highest scores were assigned to 1 political factor, 2 economic factors, 3 social factors, and 2 technological factors. These 8 factors were identified as the key drivers of breast cancer science-technology gap.

Clustering of Key Drivers and Determination of 2 Key Uncertainties

Table 3 presents 8 key drivers with the highest importance and uncertainty level among the identified 22 factors. These key drivers were discussed and evaluated using 3 cluster models: sociotechnological/political-economic, sociopolitical/political-technological, and sociopolitical/technological-economic. The first cluster formation was confirmed, and the 8 essential drivers were divided into 2 key uncertainties. Table 3 presents critical uncertainties and their clustering, as well as the definitions of each factor.

Creating a Scenario Matrix

Based on the clustering of key drivers and determining uncertainties, the scenario space was designed to reduce the gap between science and technology in breast cancer (Figure 3). In this scenario, 2 key uncertainties, namely sociotechnological uncertainties (factors S1, S2, S6 and T1, T2) and political-economic uncertainties (factors P5 and E1, E3), formed the logic of the scenario. At this point, each of the future states of the 2 key uncertainties (namely the sociotechnological discourse and medical technology ecosystem) was represented on both the vertical and horizontal axes.

As shown in Figure 3, the 4 scenarios can be explained according to each possible situation. The positive dimension of sociotechnological discourse located on the upper vertical axis of the scenario space depicts the development of trust between service providers and recipients. In contrast, the negative dimension, which is located on the lower vertical axis, shows the opposite situation. The positive dimension of the medical technology ecosystem that is located on the right side of the scenario space's horizontal

Table 3. Clustering of Key Drivers and Generation of 2 Critical Uncertainties

Critical Uncertainty		Code	Key drivers (with high importance and uncertainty level)
1st dimension of Scenario	Socio-technological discourse	S2	Resistance to adoption of new technologies by the public or medical professionals
		S1	Significance of public perspectives and their needs, desires, and demands
		S6	Uncertainty surrounding the safety and efficacy of new medical technologies
		T1	Scientific-practical innovation conversion challenges and obstacles
		T2	Insufficient transparency in methodologies of researchers and inventors
2nd dimension of Scenario	Ecosystem of medical technologies	P5	Barriers to collaboration between key players due to different goals
		E1	Financing and investment challenges
		E3	Competitive landscape, market, and business viability

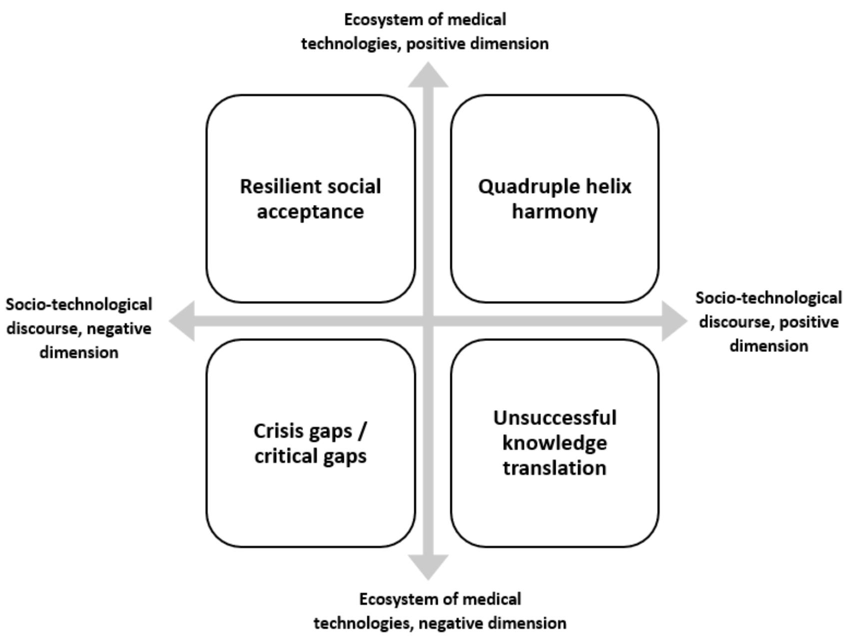

Figure 3. Scenario matrix based on clustering of key uncertainties (scenario cross model)

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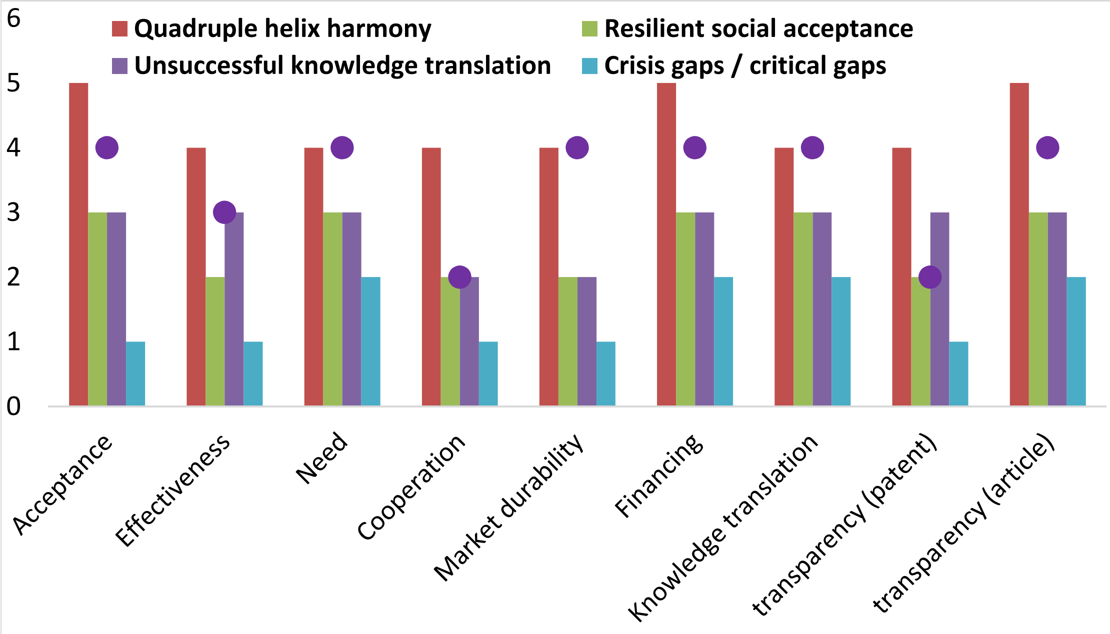

Figure 4. Estimated values of indices based on a survey of experts

axis, depicts collaboration among science and technology stakeholders (researchers, inventors, and industrial companies). Furthermore, the government provides financial support for scientific collaboration and industrial projects based on the needs of researchers. However, the conditions are reversed in the negative dimension of this uncertainty.

Estimating Key Indicators in Each Scenario

This section presents the current and estimated future values of the 8 key drivers that were determined through literature review, expert polls, and researcher consensus. Experts assessed each indicator's value across the 4 scenarios based on its current status using a questionnaire that was distributed to researchers and policymakers. Figure 4 depicts the values of the indicators over the 4 scenarios, with the purple ball symbol representing the current values. The scenario section provides detailed descriptions for each indication.

Description of Scenarios

Based on the researcher's perspective, each scenario was named and described in detail. Below are the descriptions of the 4 scenarios. The detailed descriptions—including the indicators and factors used to define each scenario—are presented in Appendix 3.

Scenario 1: Quadruple Helix Harmony (Ideal Scenario)

In this ideal scenario, sociotechnological discourse flourishes and the ecosystem of medical technologies thrives. The quadruple helix model, which includes universities, industry, government, and society, describes a future where these key stakeholders engage in constructive interaction. Government collaboration with researchers and technologists is notably robust, fostering a supportive environment for innovation.

Scenario 2: Resilient Social Acceptance

In this scenario, sociotechnological discourse continues to grow, but the ecosystem of medical technologies does not develop optimally. Unlike the ideal scenario, the government does not actively support or collaborate with universities, industry, or society. However, social acceptance and resilience persist among the recipient community, academicians, and technologists, even without governmental support and financing.

Scenario 3: Unsuccessful Knowledge Translation

In this scenario, sociotechnological discourse does not grow, while the ecosystem of medical technologies develops favorably. In this situation, scientific and technological outputs are not adequately transferred to society despite favorable conditions for financing and effective cooperation mechanisms among researchers, technologists, and industrial partners. This lack of social acceptance among key actors and stakeholders results in project failures.

Scenario 4: Crisis Gaps or Critical Gaps

In this most critical scenario, neither sociotechnological discourse nor the ecosystem of medical technologies grows optimally. This unfavorable future envisions all indicators influencing breast cancer science and technology in a poor manner. In this situation, mistrust and nonacceptance of technology prevail among key players and stakeholders, creating a deep gap among researchers, inventors, industrial partners, government, medical professionals, and the public, severely hindering progress.

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Validation of Scenarios: Suggesting Possible Strategies and Policies

Table 4 presents the average ratings assigned to the 5 identified key indicators (believability, being challenging, internal consistency, relevance, and design) for the 4 scenarios. Across the scenarios, all the indicators received scores >5 on a 1 to 10 scale, indicating the scenarios' validity and robustness.

*(1 to 10) 1 = weak 10 = strong

Table 5 lists the ranking actions for different scenarios aimed at closing the science and technology gap and attaining the desired outcomes. Appendix 4 provides detailed definitions for each action. The ranking was generated by aggregating the points awarded by experts on the subject using a scale of 1 to 10, with the highest values indicating the most effective actions for each situation. The measures highlighted in green in Table 5 reflect the optimal actions for their specific scenarios.

Although every action gained high scores, each scenario included specific priority actions to fill the scientific and technology gap in the field of breast cancer. In both the resilient social acceptance and unsuccessful knowledge translation scenarios, the most important steps are to improve stakeholder relationships and cooperative networks, as well as establish incentive programs. In the second scenario, reducing work pressure was prioritized, whereas needs-based research was the highest priority in the third scenario. The gap crisis scenario, similar to the other 2 scenarios, prioritized stakeholder relationships and cooperation networks. Furthermore, programs including enhancing safety facilities, enhancing access to information, and sponsoring applied research were recommended as critical strategies.

Discussion

This study used topic modeling for evaluating breast cancer-related scientific articles and patents, demonstrating major differences in subject focus among researchers and innovators. Using scenario planning and expert insights, 4 scenarios were created to address the science-technology gaps and suggest strategic options for connecting scientific breakthroughs with technical innovations in breast cancer research. Our findings show that scientific outputs exceed technological outputs, indicating gaps in numerous research domains over the last decade. This confirms prior studies that highlighted the ongoing challenges in combating breast cancer (18), identified significant limitations in translating recent advances into clinical practice (17), gaps in managing metastatic breast cancer, creating personalized medicines, and increasing patient survival (19), or gaps in genetics, cancer initiation, disease progression, treatments, disease markers, prevention, and psychosocial aspects (16).

Our analysis discovered that patents in breast cancer research frequently focus on lesser-known topics in the sci-

Table 4. Average Scores of Validation Criteria Across the 4 Scenarios

Evaluation criteria	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Believability	5.9	6	6	5.2
Challenging	7.8	7.5	7.1	6.9
Internal consistency	8.2	7.6	7.2	7
Relevancy	7.9	7.4	7.2	6.8
Designing	8.4	8	7.6	7.6

Table 5. Actions Ranked Across 3 Scenarios According to Expert Assessments (1 = Lowest Score, 10 = Highest Score)

Field	Action	Scenario 2	Scenario 3	Scenario 4
Translation	Knowledge transfer and commercialization	7.3	7.1	8.6
	Knowledge translation centers	6.7	8.6	8.4
Acceptance	Educational programs	6.3	8.6	8.9
	Community participation	6.4	8.7	9
Need	Patient-centered research	7	8.1	9
	Needs-based research	7.3	9.3	8.9
Transparency	Access to information	6.8	8.3	9.4
	Standard protocols	7.2	7.8	8.8
Cooperation	Stakeholder relationships	9	9.7	9.9
	Cooperation networks	8.9	9.3	10
	Incentive mechanisms	8.7	9	9.3
Financial	Funding for applied research	7.8	7.9	9.4
	Safety facilities	7.4	8.2	9.6
	Encouraging investment	7.7	7.9	9.1
Effectiveness	Simplified legal processes	7	7	8.9
	Reducing work pressure	8.4	7.9	9.2

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entific literature, including herbal remedies, medical devices, protective garments, and micro ribonucleic acid therapies. Such industries have the potential to promote innovation and attract investment, which was noted by Shen et al, who discovered that anticancer natural product technologies frequently appear in patents before academic papers, indicating a need for more scientific activity and technical exchanges (39). Certain fields, such as the chemical-pharmaceutical and biotechnology industries, are naturally science-oriented with a focus on the discovery and marketing of active substances and formulations (24). This emphasis can greatly motivate inventors to actively participate in scientific research and seek collaborations with scientists. The analysis of scientific articles indicated their importance in understanding the complexity of breast cancer, such as genetic mutations, hormone receptors, dietary factors, and environmental factors. However, there is an urgent need to create a technology that can transfer these insights into clinical practice. As emphasized in the literature, research on triple-negative breast cancer focuses primarily on therapeutic targets, prognosis, and mechanisms but ignores patient perspectives, health economics, and end-of-life care, emphasizing the need for new technologies to fill these gaps (20).

To reach the future scenarios of breast cancer science and technology, our study identified 8 out of 22 key factors influencing the gap between science and technology in breast cancer research: resistance to new technologies, community needs, safety uncertainties, challenges in converting scientific developments, lack of transparency in research, cooperation barriers among key players, financial constraints, and market competition. Some of these factors are in line with the findings of Thompson et al who identified low funding and poor interdisciplinary collaboration as the key obstacles to addressing the gap in breast cancer (16). Canongia et al emphasized the necessity of a network of social actors for exchanging, analyzing, and using information, including government agencies, colleges, corporations, non-governmental organizations, physicians, and hospitals. This collaborative network is believed to enhance synergy, strengthen competition, and foster innovation in the breast cancer treatment chain (24).

Finally, the clustering of 8 factors into 2 uncertainties led to the proposal of 4 scenarios to address these gaps. The ideal scenario depicts a future in which all stakeholders cooperate effectively together. With coordination from the government, universities, industry, and society, this scenario presents an appropriate setting for bridging the science-technology gap in breast cancer research. However, in scenario 2, despite significant community acceptance, a lack of government support and collaboration restricts the development of the medical technology ecosystem. In scenario 3, even with favorable collaboration and funding conditions, inadequate knowledge translation prevents scientific and technical advances from reaching society. The most alarming scenario, scenario 4, predicts a future in which both sociotechnological discourse and the medical technology ecosystem fail, resulting in significant gaps and stagnation of progress. Furthermore, this study takes advantage of scenario planning to provide techniques for avoiding unforeseen consequences and more effectively preparing policymakers, demonstrating its efficacy as a powerful technique utilized in a variety of sectors for forecasting future events and proposing strategic responses. Eight key indicators are defined in this study as essential indicators for obtaining the intended outcome and closing the science-technology gap in breast cancer, which are as follows: increasing technology acceptance; satisfying community needs; guaranteeing safety; overcoming barriers to technology transfer; encouraging scientific transparency; removing collaborative barriers; gaining funding; and supporting market sustainability. If these 8 indicators receive sufficient attention in the scenarios, we have the opportunity to move toward a desired future.

To effectively bridge the gap between science and technology in breast cancer, our study suggested several strategies across different scenarios. For instance, in the second scenario, resilient social acceptance, and in the third scenario, unsuccessful knowledge translation, actions such as stakeholder relationships, cooperation networks, and incentive mechanisms are identified as the most effective actions for achieving the desirable scenario and closing the science-technology gap. All collaboration indicators were emphasized in both scenarios. Moreover, the second scenario emphasized minimizing work pressure, while the third scenario prioritized conducting needs-based research.

In addressing the gap crisis scenario in our study, stakeholder relationships and cooperation networks emerged as top priorities, alongside actions like improving safety facilities, ensuring access to information, and securing funding for applied research. This aligns with the results of other studies that identified inadequate funding and weak interdisciplinary teamwork as major barriers to progress (16) or those that highlighted the importance of cooperation networks among diverse participants—including government agencies, academic institutions, and healthcare providers (24). In conclusion, working on collaboration indicators, attending to the demands of patients and healthcare providers, and receiving sufficient funds are necessary for ensuring an optimistic future in breast cancer research.

Limitations

Similar to other studies, this research has several limitations, particularly concerning data constraints related to scientific articles and patents. The extraction of data was restricted to publications until 2021 due to the PATSTAT database's delayed update compared with the WoS database at the time of data collection. These databases were chosen due to their outstanding indexing and high quality of trustworthiness. Furthermore, the present study is limited to 2 output types (namely papers and patents), and other technological and scientific works were not included in the study. This should be addressed in future studies by using a wider variety of scientific outputs. Another major restriction is the reliance on an internal panel of Iranian policymakers and professionals. The proposed solutions may be influenced by unique socioeconomic and cultural settings, and the actions suggested may not be directly applicable to other societies unless further investigated. We propose conducting further studies using a scenario-based

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methodology that involves surveying patients to look deeply into the interaction between science, technology, and the receiving society. Furthermore, a systematic review based on both scientific publications and grey literature is recommended to reveal the gap between research priorities and current patient demands. Finally, we suggest that, for an in-depth understanding of scientific and technological study, a combination of an intra-cluster analysis together with qualitative interviews with specialists from specific topic clusters could be considered a useful approach for future research.

Conclusion

Thematic gaps discovered in this study represent a solid foundation for research policymakers, innovators, and researchers to concentrate on specific topics and address the gap. In all scenarios, prioritizing cooperation indicators—such as improving stakeholder relations, enhancing cooperation networks, and implementing incentive mechanisms—would be the most effective approach to bridging the gap.

Authors' Contributions

HA: Conceptualization, Methodology, Software, Formal analysis, Writing - Original Draft. MHG: Methodology, Validation, Writing - Review & Editing. ZZ: Conceptualization, Validation, Investigation, Writing - Review & Editing. MA: Conceptualization, Validation, Investigation, Writing - Review & Editing. MO: Supervision, Conceptualization, Validation, Investigation, Writing - Review & Editing.

Ethical Considerations

Not applicable.

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Conflict of Interests

The authors declare that they have no competing interests.

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Appendix 1. Search syntax used in WoSCC and PATSTAT databases

		Search Terms/Keywords
WoS	Title, Abstract, Keywords 2012-2021	(Neoplasm and Breast) OR (Tumor and Breast) OR (Cancer and Breast) OR (Cancer and Mammary) OR "Malignant Neoplasm of Breast" OR "Breast Malignant Neoplasm" OR "Breast Malignant Neoplasms" OR "Malignant Tumor of Breast" OR "Breast Malignant Tumor" OR "Breast Malignant Tumors" OR ("Mammary Carcinoma*" and Human) OR (Carcinoma* and "Human Mammary") OR "Human Mammary Carcinoma*" OR ("Mammary Neoplasms" and Human) OR "Human Mammary Neoplasm*" OR (Neoplasm* and "Human Mammary") OR (Breast and Carcinoma)
PATSTAT	Title, Abstract, Keywords 2012-2021	"Breast Neoplasms" OR "Breast Neoplasm" OR (Neoplasm and Breast) OR "Breast Tumors" OR "Breast Tumor" OR (Tumor and Breast) OR (Tumors and Breast) OR (Neoplasms and Breast) OR "Breast Cancer" OR (Cancer and Breast) OR "Mammary Cancer" OR (Cancer and Mammary) OR (Cancers and Mammary) OR "Mammary Cancers" OR "Malignant Neoplasm of Breast" OR "Breast Malignant Neoplasm" OR "Breast Malignant Neoplasms" OR "Malignant Tumor of Breast" OR "Breast Malignant Tumor" OR "Breast Malignant Tumors" OR "Cancer of Breast" OR "Cancer of the Breast" OR ("Mammary Carcinoma" and Human) OR (Carcinoma and "Human Mammary") OR (Carcinomas and "Human Mammary") OR "Human Mammary Carcinomas" OR ("Mammary Carcinomas" and Human) OR "Human Mammary Carcinoma" OR ("Mammary Neoplasms" and Human) OR "Human Mammary Neoplasm" OR "Human Mammary Neoplasms" OR (Neoplasm and "Human Mammary") OR (Neoplasms and "Human Mammary") OR "cancer based on breast" OR "breastcancer" OR "mammalian breast carcinoma" OR "mammacarcinoma" OR "mammary tumor" OR "breast carcinoma" OR "mammary carcinoma" OR "cancer the breasts" OR "cancer in the breasts" OR " Breast Carcinoma" OR " Breast Carcinomas" OR (Carcinoma and Breast) OR (Carcinomas and Breast)

Appendix 2. Questionnaire for identifying key drivers and uncertainties to develop scenarios

Component	Drivers	Importance Degree (1 to 5)	Uncertainty level (1 to 5)
Political	– Control of governance and government – Policy differences and regulations in different countries – Regulatory barriers and complexities – Divergent research priorities among organizations and countries – Barriers to collaboration among scientists, engineers, doctors, and industrial partners (goal differences)		
Economical	– Financing and investment – Limitations and insufficiency of advanced facilities and equipment – Competitive outlook, market sustainability, and business durability – Differences in national innovation systems among countries – Intellectual property protection – Confidentiality maintenance – Conflicts of interest		
Social	– Importance of public perspectives, needs, desires, and demands – Public or physician rejection of new technologies and innovations – Work pressure on physicians in this field and lack of attention to global trends – Barriers to collaboration among scientists, engineers, doctors, and industrial partners – Ethical concerns related to certain areas – Uncertainty about the safety and effectiveness of new medical technologies		
Technological	– Barriers and complexities in translating scientific discoveries into practical innovations, and vice versa – Lack of transparency in methodologies among researchers and inventors – Non-patentability of certain aspects of breast cancer research – Differences in time required for publishing articles versus patent registration		

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Appendix 3. Full Scenario Descriptions

Scenario 1: Quadruple Helix Harmony (Ideal Scenario) In this ideal scenario, socio-technological discourse flourishes, and the ecosystem of medical technologies thrives. The quadruple helix model, which includes universities, industry, government, and society, describes a future where these key stakeholders engage in a constructive interaction. Government collaboration with researchers and technologists is notably robust, fostering a supportive environment for innovation. Indicators[1] are classified into five categories: very bad, bad, average, good, and very good. In this ideal scenario, all indicators are expected to fall within the good or very good range. For instance, the acceptance index for technological products among patients, doctors, and specialists in the treatment field is projected to grow by 20%. Similarly, the effectiveness index of these products will also experience a 20% increase. Research and technological priorities of researchers and technologists will align closely with societal needs. Knowledge translation centers, particularly those focusing on breast cancer, will become increasingly active, ensuring that the need for and translation of knowledge remains at a good level. Researchers and inventors will enhance the transparency of their outputs to facilitate reproducibility and prevent the dissemination of redundant content. Due to effective collaboration among inventors, scientists, and funding bodies, technologies in production will be subject to rigorous testing and evaluation, ensuring higher confidence in their efficacy and compliance with safety regulations. This collaborative environment will lead to a 20% increase in the cooperation index among stakeholders. Overall, this favorable scenario predicts extensive collaboration among the government, universities, industry, and society, resulting in a stable market and higher-quality products. As social, technological, governmental, and industrial interests align, the gap between research and technology in breast cancer will close, resulting in a dynamic and thriving technological ecosystem.
Scenario 2: Resilient Social Acceptance In this scenario, socio-technological discourse continues to grow, but the ecosystem of medical technologies does not develop optimally. Unlike the ideal scenario, the government does not actively support or collaborate with universities, industry, or society. However, social acceptance and resilience persist among the recipient community, academicians, and technologists, even without governmental support and financing. In this scenario, most indicators fall into the average or bad categories. This situation arises because effective communication between science and technology cannot be sustained by the limited number of actors. Consequently, the acceptance, effectiveness, and need indices are expected to decrease by 20%. Due to the inability of researchers and inventors to prioritize patient needs, knowledge translation and the presentation of medical technologies and discoveries to the public will likely diminish. The lack of suitable cooperation conditions will also hinder the transparency of research activities, resulting in a 20% decrease in this index. While the tolerance and acceptance of technology by the recipient community remains steady, the level of collaboration between researchers and inventors does not improve. Furthermore, the absence of financial support and a 20% decrease in funding will lead to a 40% reduction in the quality of products and the durability of the market. This decline can be attributed to market control by the government and insufficient power and authority of researchers and inventors. Overall, despite the growing discourse and acceptance of technology, the lack of a conducive environment for cooperation, unfavorable competitive prospects, and insufficient government support hinders the growth and development of the medical technology ecosystem. This scenario highlights the challenges in addressing breast cancer, ultimately widening the gap between science, technology, and society.
Scenario 3: Unsuccessful Knowledge Translation In this scenario, socio-technological discourse does not grow, while the ecosystem of medical technologies develops favorably. Scientific and technological outputs are not adequately transferred to society in spite of favorable conditions for financing and effective cooperation mechanisms among researchers, technologists, and industrial partners. This lack of social acceptance among key actors and stakeholders results in project failures. Similar to Scenario 2, most indicators in this scenario fall into the average or bad categories with a 20% drop in the acceptance rate. However, the effectiveness index remains stable, which is likely due to the collaboration among the government, scientific community, and industry. The absence of engagement from the public and medical professionals prevents a proper understanding of societal needs, leading to a 20% reduction in the need index. Ongoing studies in treatment and prevention are unclear to researchers and inventors and knowledge translation is inadequate, resulting in a further 20% decrease in this index. Although researchers and inventors strive for clarity through effective cooperation and increased interaction with government support, the lack of attention to public, medical, and user community reception hinders their success, causing products to struggle in the market. Despite government support and a collaborative environment between academia and industry, lack of communication with the target community leads to project failures, demonstrating that partial support from health system entities is insufficient. Comprehensive support from all actors and entities is essential for success.
Scenario 4: Crisis Gaps or Critical Gaps In this most critical scenario, neither socio-technological discourse nor the ecosystem of medical technologies grows optimally. This unfavorable future envisions all indicators influencing breast cancer science and technology in a poor state. Mistrust and non-acceptance of technology prevail among key players and stakeholders, creating a deep gap among researchers, inventors, industrial partners, government, medical professionals, and the public, severely hindering progress. In this stagnant and adverse scenario, nearly all indicators experience a reduction by more than 50%, falling within the very bad range. The acceptance index and effectiveness index decrease by 60% and 40%, respectively. Researchers' and inventors' attention to societal needs and implementation priorities significantly diminishes, with the translation of scientific discoveries into practical innovations reducing by 40%. Therefore, research transparency and patenting are decreased. Industry-academia cooperation declines from an already poor state to a very bad one. Despite current relatively good financing conditions, funding levels drop, leading to reduced market durability by 60%. Overall, all indicators exhibit a downward trend decreasing by 20-60%, which is exacerbated by the lack of interaction, absence of social discourse, and government support. This situation emphasizes how crucial it is to have all parties work together and provide support to prevent such a poor infrastructure.

[1] The indicators mean key uncertainties that significantly influence the gap between science and technology in the field of breast cancer. These uncertainties were identified through a survey conducted with 30 experts. The current values of each indicator have been relatively determined by analyzing existing literature, available statistics, and insights gathered from the research team.

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Appendix 4. Detailed definitions of actions for bridging the science-technology gap

Field	Action	Definition of Action	Scenario 2	Scenario 3	Scenario 4
Translation	Knowledge transfer & commercialization	Facilitating the transfer of knowledge and commercialization of technology while adhering to intellectual property policies	7.3	7.1	8.6
	Knowledge translation centers	Expanding and strengthening knowledge translation centers for constructive interaction among stakeholders and the target audience	6.7	8.6	8.4
Acceptance	Educational programs	Organizing educational and informational programs to raise awareness among the public and physicians, addressing potential concerns, and increasing social acceptance	6.3	8.6	8.9
	Community participation	Encouraging community participation and creating opportunities for greater public involvement in the research process and the development of medical technologies, thereby increasing trust and social acceptance	6.4	8.7	9
Need	Patient-centered research	Prioritizing patient-centered research	7	8.1	9
	Needs-based research	Encouraging researchers and inventors to conduct research based on real needs	7.3	9.3	8.9
Transparency	Access to information	Facilitating access to scientific and technological information and creating appropriate mechanisms for transparency in research and technological activities	6.8	8.3	9.4
	Standard protocols	Creating standard protocols for the registration of scientific information and patent documents, especially ensuring proper metadata registration in patent databases	7.2	7.8	8.8
Cooperation	Stakeholder relationships	Facilitating purposeful relationships among stakeholders to overcome treatment, prevention, and care challenges (strengthening the service provider-recipient relationship)	9	9.7	9.9
	Cooperation networks	Developing cooperation networks among researchers and inventors (interaction between academia and industry)	8.9	9.3	10
	Incentive mechanisms	Creating incentive mechanisms for greater interaction and cooperation between academics, industry, and the community	8.7	9	9.3
Financial	Funding for applied research	Providing financial capital to facilitate and conduct applied research by governments and policy-making institutions	7.8	7.9	9.4
	Safety facilities	Providing facilities, equipment, and sufficient resources to enhance the safety reliability of products	7.4	8.2	9.6
	Encouraging investment	Encouraging investors to provide financial support for innovative research activities	7.7	7.9	9.1
Effectiveness	Simplified legal processes	Facilitating the legal process of publishing and inventing while reducing regulatory barriers	7	7	8.9
	Reducing work pressure	Reducing work pressure and creating more communication opportunities between physicians, researchers, and inventors	8.4	7.9	9.2

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