Strategic Science and Technology Intelligence: Practice and Reflection (Postprint)

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Date: 2024-10-06T00:00:00+00:00

Abstract

[Purpose/Significance] The ongoing wave of technological revolution and industrial transformation is accelerating, with increasingly profound and extensive impacts on national development and security. The complexity and uncertainty of scientific and technological innovation systems have become prominent, and science and technology policy agendas are also facing transformational changes to address increasingly fierce international technological competition. To sense the landscape of scientific and technological development, nations have universally adopted data-intelligence-driven practices in science and technology strategic intelligence.

[Method/Process] By investigating how various reports—including the "Innovation Management—Tools and Methods for Strategic Intelligence Management—Guidelines" issued by the International Organization for Standardization, the "Science, Technology, and Innovation Policy Agenda" publicly released by the Organisation for Economic Co-operation and Development, the "Securing America's Future: A Framework for Critical Technology Assessment" published following the U.S. recent national critical technology assessment, the "European Industrial R&D Investment Scoreboard" from the Joint Research Centre of the European Commission, Japan's "R&D Panorama Report," and the "Science Structure Atlas" from the Institutes of Science and Development of the Chinese Academy of Sciences—have developed and utilized science and technology strategic intelligence to support the agenda of "evidence-based decision-making" during their formulation processes.

[Results/Conclusion] The essence of science and technology strategic intelligence is to provide data, knowledge, and evidence for decision-making. The strategic intelligence operation cycle model is DIKI. Strategic intelligence data infrastructure and its analysis models, indicators, and tools oriented toward science and technology policy issues, establishing specialized strategic intelligence agencies

within organizations, understanding and utilizing science and technology strategic intelligence data and consciously incorporating it into the "evidence-based decision-making" agenda, and combining different types of strategic intelligence have become skills that science and technology policy makers should possess. Science and technology innovation policy makers should assume responsibility for the generation, maintenance, integrity, and accessibility of large amounts of administrative data related to monitoring scientific and technological innovation systems and policies.

Full Text

Preamble

Journal of Library and Information Science in Agriculture
DOI: 10.13998/j.cnki.issn1002-1248.24-0432

Practice and Reflection on Scientific and Technological Strategic Intelligence

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Abstract:
[**Purpose/Significance**] The new round of technological revolution and industrial transformation is accelerating, with increasingly profound and extensive impacts on national development and security. The complexity and uncertainty of the innovation system are becoming more prominent, and the science and technology policy agenda is facing transformation to address increasingly fierce international technological competition. To perceive the trends of technological development, countries are widely engaged in data-driven strategic intelligence practices. [**Method/Process**] This study examines how scientific and technological strategic intelligence is developed and utilized to support an "evidence-based decision-making" agenda by analyzing the standard *Innovation Management—Tools and Methods for Strategic Intelligence Management—Guidance* issued by the International Organization for Standardization, the *Science, Technology, and Innovation Policy Agenda* published by the Organisation for Economic Co-operation and Development (OECD), the *Securing America's Future: A Framework for Critical Technology Assessment* released following recent U.S. national critical technology assessments, the *EU Industrial R&D Investment Scoreboard* by the European Commission's Joint Research Centre, Japan's *R&D Overlook Report*, and the *Science Structure Atlas* from the Chinese Academy of Sciences. [**Results/Conclusions**] The essence of scientific and technological strategic intelligence is to provide data, knowledge, and evidence for decision-making. The operational cycle model of strategic intelligence is DIKI (Data-Information-Knowledge-Intelligence). Strategic intelligence requires a data infrastructure and analytical models, indicators, and tools oriented toward science and technology policy issues. Establishing dedicated strategic intelligence units within organizations, understanding and utilizing scientific and technological strategic

intelligence data, consciously incorporating it into the "evidence-based decision-making" agenda, and combining different types of strategic intelligence have become essential skills for science and technology policymakers. Innovation policy makers should assume responsibility for the generation, maintenance, integrity, and accessibility of large volumes of administrative data related to monitoring the innovation system and policies.

Keywords: Strategic Intelligence; DIKI; Data Infrastructure; Critical Technology Assessment; Evidence-Based Decision Making
CLC Number: G350
Document Code: A
Article ID: 1002-1248
Citation: LENG Fuhai. Practice and Reflection on Scientific and Technological Strategic Intelligence[J]. Journal of Library and Information Science in Agriculture, 2024, 36(5): 4-13.

Introduction: The Accelerating Technological Revolution and Strategic Intelligence Needs

Since 2000, a new round of technological revolution and industrial transformation has been accelerating, profoundly reshaping the global landscape of development and security. The impact of science and technology on global competition, economic development, and social welfare has become increasingly deep and extensive. This has highlighted the complexity and uncertainty of the innovation system, prompting major countries and international organizations to advance toward strategic intelligence practices to support policy transformation and address intensifying international technological competition.

International Strategic Intelligence Practices

The EU Industrial R&D Investment Scoreboard

In 2004, the European Commission's Joint Research Centre (JRC) launched the *EU Industrial R&D Investment Scoreboard*, which has been published annually since then. The Scorecard provides reliable, up-to-date benchmarking tools for comparing regions, monitoring and analyzing emerging investment trends and patterns. It aims to enhance public awareness of R&D investments by individual companies and encourage firms to disclose information about their R&D expenditures. Based on data analysis, the report includes commentary on policy implications.

In July 2019, JRC initiated a novel institutional activity to help address policy-related issues in national development, industrial innovation, and competitiveness using tools from the economic complexity framework. The project analyzes EU industrial competitiveness from three perspectives: the drivers of EU industrial competitiveness, innovation as a key driver, and support for the Green Deal policy agenda. The research methodology is based on statistics, econometrics, and complexity methods, building upon network science and complex dynamic systems to separate robust information from random noise in large datasets. This allows quantitative economic analysis to focus on issues traditionally addressed through qualitative or ad hoc quantitative measures.

The project provides a platform for analyzing and reporting information on private-sector research and innovation activities in the EU. It employs input-output matrices, data panels, and complexity methods for quantitative economic and financial analysis, supplemented by qualitative analysis from expert panels. As an outcome, JRC has constructed a corporate R&D investment data platform that includes two sample datasets: the world's Top 2500 enterprises and the EU Top 1000 enterprises. The platform contains basic corporate information, industry classification according to the Scoreboard, operating profit or loss, main enterprise indicators, and annual growth rates of key metrics such as R&D intensity and capital expenditure intensity. Industries covered include aerospace and defense, ICT production, ICT services, and other transportation vehicles.

U.S. Critical Technology Assessment Framework

On October 24, 2023, the U.S. National Science Foundation (NSF) released *Securing America's Future: A Framework for Critical Technology Assessment*. The NSF-funded National Network for Critical Technology Assessment (NNCTA) conducted pilot assessments that provided multi-dimensional measurement of current and future developments in critical technologies including biomedicine, energy storage, and critical materials. The pilot year activities demonstrated that data and analytics can provide meaningful information for national technology strategy, but the necessary capabilities do not belong to a single discipline, researcher, or organization type. Novel pairings and interdisciplinary collaboration, carefully orchestrated, became hallmarks of the effort.

The framework considers geopolitical dynamics and addresses the lack of rigorous methods to quantify the potential value of innovation and tools to quantify national objectives, opportunities, and trade-offs. The pilot experience revealed that the federal government needs to intentionally design a rapid critical technology assessment capability for Congress and the executive branch. This work is best led by an organizational unit responsible for thinking about national objectives and technology interdependencies, engaging subject matter project managers trained in the art of critical technology assessment to identify the most important questions and match methods to problems.

The assessment examined five selected domains: (1) Global competitiveness, (2) Artificial intelligence, (3) Semiconductors, (4) Biopharmaceuticals, and (5) Energy storage and critical materials. For global competitiveness, the assessment focused on using publication and citation data from Web of Science, Microsoft Academic Graph, and Open Alex, exploring the use of open datasets to fulfill the Office of Science and Technology Policy's mandate on open science. For artificial intelligence, Carnegie Mellon University teams developed machine learning algorithms to parse U.S. Patent and Trademark Office patents and identify AI-related patents, providing a univariate measure of AI intensity for each patent. Georgetown University's Center for Security and Emerging Technology (CSET) defined the AI workforce by mapping the skills needed to design, develop, and deploy AI systems to Department of Labor occupations, analyzing data from LinkedIn Insights and Burning Glass (now Lightcast). Stanford University collaborated with the Census Bureau to survey U.S. enterprises on AI adoption, providing visibility into the extent and process by which American companies adopt AI technologies created by others.

Japan's R&D Overlook Report

Since 2003, the Center for Research and Development Strategy (CRDS) of the Japan Science and Technology Agency (JST) has conducted domain overview activities, using them as a foundation for enhancing capacity to formulate important R&D strategies. The *R&D Overlook Report* is an intellectual asset that defines the structure shown in the report and clarifies understanding of relevant issues. The report aims to broadly share information with science and technology stakeholders. While it contains data already published by many institutions, it is more than just a data compilation.

The 2023 *R&D Overlook Report* on Life Sciences and Clinical Medicine first examines global social and economic issues in these fields, surveys major national science and technology policy trends, and explores the latest R&D developments. Chapter 1 provides a summary of all subsequent content, clarifying the history, current status, and future direction of target thematic areas from multiple perspectives. Chapter 2 introduces 30 R&D domain highlights and the innovation ecosystems that enable them, extracting nine emerging trends. The report provides a novel approach to identifying patents related to digital sustainability technologies, analyzing top R&D investors in the health industry from the perspective of the world's top 2,500 corporate R&D investors.

Chinese Strategic Intelligence Practices

Science Structure Atlas and Technology Structure Atlas

Since 2014, the Chinese Academy of Sciences has collaborated with Clarivate Analytics to develop the *Science Structure Atlas* series, with ten editions published to date. The 2023 report extracted 12,620 research fronts from highly cited papers between 2016-2021 through co-citation clustering analysis, yielding 1,389 research areas and creating a global scientific structure map. This reveals the macro-structure of scientific research and its evolution, showing hotspots of international concern and measuring the disciplinary diversity of each research area.

The *Technology Structure Atlas 2023* report clustered 12,293 technology focal points from U.S. and European patent families published between 2016-2021, constructing a world technology focal point database and mapping global technology competition patterns. By overlaying patent shares from different countries across two periods (2016-2021), the analysis reveals each country's technology emphases and identifies China's gaps. The report selected the top 100 technology focal points in 32 technology domains under four major categories, conducting detailed interpretation and assessment to determine five critical technology focal points.

The DIKI Model and Strategic Intelligence Cycle

ISO Standard on Strategic Intelligence Management

In November 2021, the International Organization for Standardization issued *Innovation Management—Tools and Methods for Strategic Intelligence Management—Guidance* to standardize matters related to scientific and technological strategic intelligence. The standard is divided into three parts: (1) Strategic intelligence fundamentals, including purpose, requirements, core processes, timing, and expected outcomes; (2) Strategic intelligence cycle, covering operational planning and control, data collection and analysis; and (3) Intelligence communication, including recommendations to top management and distribution control.

The DIKI Operational Cycle

Strategic intelligence is defined as intelligence provided to senior management to influence organizational vision, policies, and objectives, helping manage uncertainty by responding to opportunities and risks. The DIKI model (Data-Information-Knowledge-Intelligence) represents a modification and upgrade of the DIKW pyramid. It describes an ideal/progressive concept that can be achieved through implementing appropriate intelligence management processes.

The DIKI operational cycle involves: (1) Continuously monitoring the environment for risks and opportunities, actively and/or passively; (2) Collecting and analyzing data to output information; (3) Understanding information to output knowledge; and (4) Communicating knowledge to output intelligence. The process is inseparable, highly personalized through expert judgment, and has been transformed by big data and AI technologies. Data mining can discover entities, information scanning can obtain information, but generating reliable intelligence requires professional expert knowledge.

Evidence-Based Decision Making and Policy Transformation

OECD Agenda for Transformative STI Policies

In April 2024, the OECD published its *Agenda for Transformative Science, Technology, and Innovation Policies*, which had been developed with input from its working groups and several OECD directorates. The agenda articulates how to develop and utilize scientific and technological strategic intelligence to support policy transformation. The scope of transformation is broad, characterized by non-linear dynamics and structural changes in complex systems. Simple empirical extrapolation and models are no longer applicable.

The agenda outlines four tasks for strategic intelligence to support policy change: (1) Supporting novel distributed strategic intelligence sources, including stakeholders from vulnerable and marginalized communities; (2) Developing arrangements to combine different types of strategic intelligence, addressing the challenge that data comes in different formats and with different assumptions; (3) Building skills and capabilities to use strategic intelligence, including training programs for policymakers; and (4) Implementing infrastructure to promote the production and use of strategic data, with policymakers taking responsibility for data generation, maintenance, integrity, and accessibility.

Case Study: AI Drug Design—An International Comparison

The AI drug design domain provides a concrete example of strategic intelligence application. Table 1 presents an international comparison of AI drug design capabilities.

Table 1 International Comparison of AI Drug Design

Country/Region	Basic Research	Applied R&D
United States	Effectiveness particularly significant: NIH-NCATS multi-drug discovery research using AlphaFold; Harvard-MIT and West Coast institutions leading	Effectiveness particularly significant: Illumina and AstraZeneca pursuing drug discovery through human omics analysis; numerous AI drug discovery startups (Atomwise, InveniAI, Aria Pharmaceuticals, Genesis Therapeutics); MELLODY consortium includes major pharma and IT companies

Country/Region	Basic Research	Applied R&D
Europe	Effectiveness particularly significant: DeepMind's AlphaFold and AlphaFold Protein Structure Database widely adopted; large biobanks (Genomics England, FinnGen) building AI drug discovery platforms	Effectiveness particularly significant: BenevolentAI, Relation Therapeutics, and Exscientia attracting investment and out-licensing new target patents
China	Effectiveness significant: Basic research for new drugs conducted at Peking University, Shanghai Institute of Materia Medica, Chinese Academy of Sciences; multiple national projects underway	Effectiveness significant: Domestic pharmaceutical and biotech companies, Hong Kong firms (Insilico Medicine) advancing AI drug discovery
Japan	Effectiveness significant: Multiple national projects; government policy explicitly supports AI-driven drug discovery	Effectiveness significant: Several AI drug discovery startups emerged; joint research between academia and pharmaceutical companies progressing

Conclusions and Recommendations

Strategic intelligence practices from the EU Joint Research Centre, Japan's CRDS, and the Chinese Academy of Sciences demonstrate several common principles. First, dedicated strategic intelligence units are essential for systematically monitoring technological trends and providing evidence-based support for policy decisions. Second, the DIKI operational cycle provides a robust framework for transforming raw data into actionable intelligence. Third, combining different types of strategic intelligence—quantitative and qualitative, top-down and bottom-up—is necessary to address the complexity and uncertainty of modern innovation systems.

The U.S. NNCTA pilot year activities demonstrate that effective strategic intelligence requires: (1) Building knowledge foundations across multiple government departments, (2) Designing rapid assessment capabilities for critical technologies, (3) Leveraging the nation's diverse analytical capabilities across disciplines and institutions, and (4) Creating dynamic exchanges between machine-driven and expert-driven perspectives.

For China to advance its strategic intelligence practice, several steps are crucial. Policymakers must develop the skills to understand and utilize strategic intelligence data, consciously incorporating it into evidence-based decision-making agendas. They must take responsibility for generating, maintaining, and ensuring the integrity and accessibility of administrative data related to innovation system monitoring. Learning from international standards and best practices—such as the ISO guidance on strategic intelligence management and the OECD's transformative agenda—can help China's strategic intelligence practice modernize and more effectively support national innovation policy.

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Note: Figure translations are in progress. See original paper for figures.