Altmetrics "Scenario-Problem-Method" Research Framework for Multi-dimensional Applications

Authors: Zhang Yang, Xie Yinghua, Liang Yian, Yu Houqiang

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Abstract

Objective: Altmetrics analysis has been widely recognized and utilized, but domestically it is often limited to the perspective of scientific evaluation, neglecting the broad application scenarios of altmetrics. This paper aims to enrich the research design of altmetrics analysis and promote the healthy and sustainable development of altmetrics by constructing a "scenario-problem-method" research framework for altmetrics.

Method: By drawing upon mature frameworks from the science of science and informetrics, combined with the characteristics of altmetrics, a research framework is constructed.

Results: The application scenarios of altmetrics can be divided into three types: evaluation indicators, science communication, and knowledge diffusion. From the perspective of research questions, research directions for altmetrics analysis are constructed. For the evaluation indicators scenario, three directions of research questions are proposed: indicator application, influencing factors, and indicator construction; for the science communication scenario, four directions of research questions are proposed: communication strategies, communication structure, communication trends, and science-society interaction; for the knowledge diffusion scenario, three directions of research questions are proposed: diffusion strategies, diffusion structure, and diffusion effects. Finally, combined with three key analytical methods—causal inference, network analysis, and machine learning—the corresponding research design ideas for each type of research question are elaborated, and the future development of altmetrics is prospected.

Conclusion: The altmetrics framework proposed in this study is conducive to advancing altmetrics into a stage of connotative development.

Full Text

A "Scenario-Problem-Method"Research Framework for Altmetrics Oriented to Multidimensional Applications

Zhang Yang, Xie Yinghua, Liang Yian, Yu Houqiang
School of Information Management, Sun Yat-sen University, Guangzhou 510006, China

Abstract

[**Objective**] Altmetrics analysis has gained widespread recognition and adoption, yet in China it remains largely confined to the domain of scientific evaluation, overlooking its broader application scenarios. This paper constructs a three-dimensional "scenario-problem-method" research framework for altmetrics to enrich research design and promote healthy, sustainable development of the field. [**Methods**] Drawing upon established frameworks from the science of science and informetrics while incorporating altmetrics' distinctive characteristics, we propose a comprehensive research framework. [**Results**] Altmetrics applications can be categorized into three scenarios: evaluation indicators, science communication, and knowledge diffusion. From a research question perspective, we identify ten directions: for evaluation indicators—indicator application, influencing factors, and indicator construction; for science communication—communication strategies, communication structures, communication trends, and science-society interaction; and for knowledge diffusion—diffusion strategies, diffusion structures, and diffusion effects. Finally, by integrating three key analytical methods—causal inference, network analysis, and machine learning—we elaborate corresponding research designs for each question and discuss future prospects. **Conclusion** This framework facilitates altmetrics' transition to a connotative development stage.

Keywords: Altmetrics; Application Scenarios; Research Questions; Key Methods
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The scope of altmetrics continues to expand. Major international publishers now provide altmetric attention scores for every journal article, while mentions and dissemination of scholarly outputs on social media facilitate academic exchange and collaboration, reducing resources consumed by face-to-face science popularization. In recent years, altmetrics databases such as Altmetric.com have continuously increased their coverage of news and policy platforms to better reflect the societal impact of academic achievements.

Altmetrics research is maturing. In terms of research connotation, Costas et al. emphasize altmetrics' potential for investigating science-society interactions, proposing the new term "social media metrics" [1]. Regarding data quality, theoretical evaluation frameworks have been established [2], and platform-specific data quality assessments are underway [3]. Meanwhile, Yu Houqiang has constructed a theoretical framework for altmetrics research [4], and Liu Xiaojuan et al. have developed a methodological system for altmetrics analysis based on citation analysis [5]. However, altmetrics applications remain concentrated in citation prediction [6] and journal article clustering [7], leaving multidimensional application scenarios largely unexplored.

Just as Barabási' s team proposed four application scenarios and two analytical methods for the science of science [8], Wang Xianwen et al. presented an integrated framework of data, methods, and functions for scientometrics [9], and Li Changzhong et al. identified research objects and methods for webometrics [10], no researchers have yet systematically considered altmetrics application scenarios from a contemporary perspective, nor clarified the corresponding research questions and key methods.

Although scientific evaluation represents an important application scenario for altmetrics, it must be recognized that altmetrics encompasses far broader applications, numerous worthwhile research questions, and requires integration of cutting-edge methods. Therefore, this study aims to identify multidimensional altmetrics application scenarios, propose research questions aligned with paradigm shifts in science and the intelligent internet era, specify corresponding key analytical methods, and synthesize these into a research framework to promote high-quality altmetrics development.

2. Altmetrics Research Framework

Altmetrics emerges from the collision between the internet and science. On one hand, it inherits informetrics' application scenarios in information management and technology evaluation, drawing upon core statistical and network analysis methods. On the other hand, influenced by information technology advances and scientific paradigm shifts, machine learning trends in altmetrics have become increasingly prominent. Therefore, in [Figure 1: see original paper], we categorize altmetrics application scenarios into evaluation indicators, science communication, and knowledge diffusion. Building upon statistical analysis methods, we propose causal inference, network analysis, and machine learning as methods with broad application prospects in altmetrics. We then construct a network connecting altmetrics application scenarios, research questions, and key methods, termed the "research framework," and propose future development directions.

[Figure 1: see original paper] Research framework in altmetrics

Notably, the application scenarios and key methods in this framework do not correspond one-to-one, as different methods address different aspects of the same research question. For example, both network analysis and machine learning can study knowledge diffusion. However, when focusing on knowledge diffusion itself as the research objective, complex network analysis methods such as coupling networks and heterogeneous networks are required to uncover diffusion networks of different scholarly outputs. When using knowledge diffusion merely as a means to extract valuable information, machine learning methods are needed for subsequent prediction or classification tasks. Similarly, causal inference, network analysis, and machine learning can all investigate science communication. Yet when focusing on communication strategies, causal inference methods are needed to validate effectiveness. When examining the communication process—namely the roles and connections of different platforms and users—network perspectives are required to clarify node significance and link information. When focusing on communication outcomes such as scope and volume, machine learning methods are needed for scientific prediction.

Current altmetrics research does not yet encompass the full scope of this framework, necessitating further expansion of altmetrics analysis to promote field development.

2.1 Altmetrics Application Scenarios

This paper divides altmetrics into three major application scenarios: evaluation indicators, science communication, and knowledge diffusion. The rationale rests on three foundations: (1) Definition of altmetrics connotation. Yu Houqiang previously defined altmetrics in both narrow and broad senses—the former as social network metrics, the latter focusing on the context of altmetrics data generation: online academic exchange [11]. (2) Demands of altmetrics development. In fact, early altmetrics research concentrated primarily on evaluation indicators, with few studies examining online academic exchange [12]. (3) Dimensions of social interaction in the internet era [13]. When online academic exchange involves broad, flexible interactions among researchers, policymakers, news media, and the public, it constitutes science communication research. When confined to researcher communities with specific scientific value orientations, it constitutes knowledge diffusion research.

2.2 Altmetrics Research Questions

We organize the above application scenarios by means, process, and objectives, proposing ten research questions. [Figure 2: see original paper] Research question of altmetrics

The means layer represents the starting point of online academic exchange, influenced by platform functions and user preferences. Corresponding altmetrics research includes indicator application studies supported by platform functions and open data, science communication strategy studies, and knowledge diffusion strategy studies.

The process layer constitutes the core of online academic exchange, affected by mention forms, platform types, and user identities. This requires altmetrics research to examine both different mention forms of scholarly outputs and clarify dissemination processes across internet platforms and user groups. Corresponding research includes studies on indicator influencing factors, communication structure mining, and diffusion structure mining.

The results layer centers on digital traces of scholarly outputs on internet platforms, enabling direct measurement of online academic exchange effects and indirect discovery of valuable academic information. Corresponding research includes construction of new evaluation indicators, diffusion effect studies, communication effect studies, and science-society interaction studies.

2.3 Key Methods in Altmetrics

Key altmetrics methods include causal inference, network analysis, and machine learning for three reasons: (1) Altmetrics is considered a new direction in webometrics [12], with webometrics methods classified into four categories: inferential statistics, graph theory, network analysis, and data mining [10, 14]. (2) Network analysis is a key altmetrics method [15]. Considering the complex structure of online academic exchange, altmetrics network analysis includes co-word networks, user networks, coupling networks, and heterogeneous networks. (3) Impact of scientific paradigm shifts. Referencing classifications in the science of science [16], we categorize causal inference methods in altmetrics into experiments, quasi-experiments, and matching with fixed effects. Following the ultimate purpose of information technology [17], we classify machine learning methods in altmetrics into classification, clustering, and prediction.

3. Altmetrics Analysis for Evaluation Indicators

As shown in , scholars primarily use causal inference methods to explore influencing factors of altmetrics indicators, aiming to characterize online academic exchange effects through maximal indicator values. Statistical analysis methods also investigate relationships between altmetrics and traditional citation indicators to uncover their value in scientific evaluation. However, deeper evaluation indicator research remains unexplored, and comprehensive altmetrics indicators have yet to be proposed, requiring expanded research along the directions outlined below.

Altmetrics analysis for studying evaluation indicators

3.1 Contextualized Altmetrics Indicator Application

Current altmetrics indicator application research concentrates on science and technology evaluation. In terms of research objectives, scholars have confirmed positive correlations between altmetrics and traditional evaluation indicators. Regarding key methods, statistical analysis predominates. These application contexts and methods are quite limited.

Because altmetrics captures substantial contextual information, indicator applications extend to researcher interest recommendation, public knowledge seeking, science news discovery for journalists, and scientific evidence support for policymakers—collectively termed altmetrics' contextual value. Realizing these applications requires machine learning support.

At the implementation level, graph methods represented by heterogeneous graphs show promise. We advocate establishing a unified framework centered on papers, incorporating altmetrics stakeholders into heterogeneous graphs. Papers can be attributed through abstracts and full texts, while mentioners can be characterized through user information, browsing records, or publication histories. Derived meta-paths can serve downstream scenarios such as identification and recommendation for different stakeholders. Prior to this, accurate user category identification is essential. User type identification algorithms are well-established, including those based on machine learning, graph techniques, and knowledge graphs. Additionally, altmetrics research must be integrated into platform services to enhance industry recognition.

3.2 Intrinsic Mechanism Research of Altmetrics Indicators

Current intrinsic mechanism research employs numerous experimental and quasi-experimental methods, substantially enhancing result reliability. However, altmetrics indicator formation mechanisms are complex, mismatched with direct application patterns of mention and retweet counts. Indicator quantities cannot represent social impact nor reveal the actual meaning of altmetrics data.

Investigating intrinsic mechanisms requires clarifying indicator formation processes and underlying significance. For a scholarly output' s mentions, read counts, like counts, and share counts on the same platform may correlate; mentions by authors or academic journals may differ in impact from public mentions; official news mentions may reflect different influence than social media mentions.

At the implementation level, experimental and quasi-experimental methods must be applied to multi-platform altmetrics research to identify significant influencing factors. Heterogeneous and coupling networks should be promoted to establish different node types and connection patterns, revealing complex relationships among platforms, users, and communication behaviors to clarify altmetrics indicators' actual meaning.

3.3 Construction of New Indicators for Measuring Academic Exchange

Future indicator construction research should evolve from fragmented to unified, from coarse to precise, considering scholarly outputs' popularity on internet platforms and measuring participation of diverse social groups in academic exchange.

Moving from fragmented to unified requires identifying stakeholders in online academic exchange—such as policymakers, journal publishers, and the public—

and investigating participation levels across groups using large-scale datasets to achieve indicator normalization and standardization. When examining scholarly outputs' online exchange, read counts, like counts, comment counts, and even review texts from different platforms can be proportionally converted into a final indicator based on audience types, with computational difficulty also considered. However, no current database provides comprehensive Chinese altmetrics data; researchers can obtain data through term retrieval or entity recognition methods.

Transitioning from coarse to precise hinges on automatically identifying motivations for mentioning scholarly outputs. Given altmetrics' diverse scenarios, motivation identification is not simple text classification but emphasizes text characteristics, achievable through: (1) defining coding schemes for manual classification of altmetrics texts, or (2) employing pre-trained deep learning models for automatic identification. However, altmetrics data are not structured texts, facing challenges of short texts, variant terms, and multimodality. Future work could integrate user information, text information, and paper information based on graphs or knowledge graphs to identify diverse mention motivations.

4. Altmetrics Analysis for Science Communication

When altmetrics engages with the public, it joins the ranks of science communication research. In application scenarios, altmetrics research reflects the entire science communication process, creating a cyclical system from strategy selection to process transparency, effect summarization, and ultimately science-society interaction (). In terms of key methods, network analysis, machine learning, and causal inference provide effective tools for exploring the "black box" of science communication.

However, altmetrics research on science communication has yet to produce comprehensive strategy frameworks or penetrate stakeholders' ideological levels. Future research must employ causal inference methods such as experiments and quasi-experiments to construct systematic communication strategies, uncover value orientations of different actors, and promote better science-society interaction.

Altmetrics analysis for studying science communication

4.1 Communication Strategy Research Based on Causal Inference

Currently, research teams in medicine and related fields compare different communication strategies' effects on promoting societal discussion, aiming to enhance public trust in science while applying quasi-experimental methods to altmetrics research. At the research object level, the general public represents the primary audience, though the bridging roles of policymakers and journal publishers should not be overlooked. In independent variable design, current attention to language expression, information sources, and communication modes focuses on external conditions of scholarly outputs, neglecting impacts of content attributes and platform types. Methodologically, while quasi-experiments enhance robustness, they impose data scale requirements. Regarding results, diversity among actors, behavioral complexity, and motivational plurality have prevented validated strategies from being synthesized into unified patterns.

Future expansion should proceed along two dimensions: First, we must clarify multiple factors affecting science communication, employing simulation models to optimize scholarly output dissemination strategies and construct complete science communication systems. This includes authors, research topics, and publishing journals of scholarly outputs; topic and column functions on internet platforms; and target group preferences and expression forms. Addressing these factors requires matching and fixed effects methods, alongside graph algorithms and knowledge graph techniques for user classification. Second, future work must safeguard communication effects from behavioral and cognitive perspectives, necessitating experimental methods. To investigate different strategies' impacts on government officials, researchers must collaborate to involve them in experiments, applying different strategies to experimental and control groups, then using questionnaires or interviews to assess officials' attitudes toward scholarly outputs and compare results to identify optimal strategies. However, experimental methods require substantial funding and human resources, demanding increased support for altmetrics research.

4.2 Data-Driven Communication Structure Mining

Currently, communication structure mining in altmetrics predominantly focuses on Twitter, assuming different users and journal articles have distinct dissemination processes. Methodologically, scholars have extended bibliometrics' co-word and coupling networks to altmetrics research, developing user networks and heterogeneous networks suitable for altmetrics analysis, forming a relatively complete methodological system.

Future altmetrics research can advance science communication toward data-driven approaches. The fundamental idea involves obtaining exchange traces of scholarly outputs across multiple internet platforms, investigating distribution patterns of different mention forms such as titles, links, and DOIs, and using network analysis to explore roles and connections of different users and platforms in science communication. This approach emphasizes machine learning as the primary method for data acquisition and cleaning, with network analysis as the main analytical tool, achieving organic integration.

At the implementation level, data on scholarly output mentions from platforms like WeChat and Zhihu can be obtained through web scraping, unique identifiers, or collaboration with publishers and social media platforms. Heterogeneous networks integrating multiple actors, behaviors, and platforms can clarify the complex structure of science communication. Descriptive statistics can quickly reveal distribution patterns of mention forms and actors. Simultaneously, altmetrics scholars must leverage social media platforms'advantages, advocating for standardized mention formats to help the public understand research processes from multiple perspectives and control science communication quality.

4.3 Communication Trend Detection Based on Machine Learning

Currently, scholars borrow factors influencing citation counts, employing deep learning methods to predict mention counts, retweet counts, and dissemination timelines of scholarly outputs on Twitter, achieving prospective prediction of communication outcomes. However, limitations remain: (1) excessive focus on prediction accuracy with insufficient interpretability; (2) prediction targets have not extended to communication intensity, depth, potential, or themes; (3) prediction results have not been applied to information management.

Addressing these limitations requires support from interpretable machine learning and network analysis methods. For instance, decision trees and Bayesian models can answer whether widespread dissemination results from article quality, disseminators, or communication structures. Co-word networks can reflect popular thematic features in science communication. Based on obtained science communication data, deep learning models and time series analysis can predict hotspots and manage public opinion, integrating altmetrics into platform functional models.

4.4 Social Interaction Research in Science Communication

Science communication aims to enhance public understanding and trust in science while amplifying public voices to the scientific community. However, we cannot evaluate science-society interaction effects because we lack understanding of whether the public truly accepts scientific thinking or possesses high scientific literacy, whether researchers value public concerns, or whether public liking behaviors reflect trust in science. This represents a future direction for altmetrics.

Future research must emphasize experimental and quasi-experimental methods in social interaction studies. For example, longitudinal cohort studies can observe whether participating public audiences develop higher scientific literacy, and whether engaging researchers pay more attention to societal hotspots. We also recommend behavioral experiments to examine public psychological characteristics and clarify the actual meaning behind different information behaviors to promote science-society interaction. These approaches challenge altmetrics data granularity, requiring real-time experimental data acquisition to ensure process transparency.

5. Altmetrics Analysis for Knowledge Diffusion

Altmetrics knowledge diffusion involves multiple stakeholders including mentioners, disseminators, discussants, and recipients; encompasses diverse social media platforms such as WeChat and Weibo; covers knowledge ranging from journal articles to implicit academic ideas; and includes spiraling academic exchange activities like knowledge sharing, transfer, absorption, and innovation. Currently, altmetrics knowledge diffusion research remains in its infancy. Below we propose three development directions.

5.1 Diffusion Strategy Research Integrating Multiple Knowledge Forms

Previously, knowledge diffusion occurred only after scholarly outputs were published as journal articles or conference papers, with micro-level keyword diffusion and macro-level journal and discipline diffusion all based on this form. Moreover, promoting linear knowledge growth seemed disconnected from practical applications, fueling ongoing debates about knowledge diffusion.

Altmetrics accelerates scientific communication, enabling knowledge diffusion to evolve from explicit to implicit and back, from theory to practice, and even realizing ideal scenarios of simultaneous multi-knowledge diffusion and coordinated knowledge growth with practical application. However, optimal strategies for promoting knowledge diffusion remain unclear, requiring support from causal inference and statistical analysis methods.

Knowledge diffusion strategy research identifies optimal academic exchange methods through comparison. Exploratory steps include: (1) drawing on classical knowledge diffusion theoretical frameworks and science communication strategy research to identify micro-level factors affecting knowledge diffusion; (2) selecting one strategy for study, using quasi-experimental or matching methods to control other influencing factors, ensuring experimental and control groups differ only in the selected diffusion strategy; (3) employing descriptive statistics and non-parametric tests to reveal outcome differences between groups with different diffusion strategies.

5.2 Diffusion Structure Mining Based on Bibliometrics

Currently, knowledge diffusion processes among researchers have received little attention, possibly due to difficulties in precisely identifying researchers on comprehensive internet platforms or their limited enthusiasm for online academic exchange. Although professional platforms like Mendeley, Figshare, and ScienceNet exist, we lack understanding of diffusion processes for journal articles, conference papers, and patents on professional platforms; the convenience internet platforms provide for exchanging scientific ideas and diffusing academic frontiers; and differences between internet-based and citation-based knowledge diffusion. Consequently, we cannot reveal the complex structure of knowledge diffusion.

Therefore, altmetrics diffusion structure mining should emphasize diverse scholarly outputs as research objects, examining researcher exchanges on comprehensive platforms, exploring professional platforms' roles in knowledge diffusion, and fully drawing on classical informetrics experience. Implementation can proceed along three dimensions: (1) using time-series modeling and complex network dynamics to mine diffusion processes of different knowledge carriers on internet platforms; (2) employing quasi-experiments, matching, and fixed effects models to analyze roles of professional organizations and researchers' diffusion motivation, capacity, and knowledge level; (3) using coupling and heterogeneous networks to explore diffusion processes of scholarly outputs across internet platforms and citations, creating a knowledge diffusion chain connecting multiple platforms and combining online and traditional forms to achieve process transparency.

5.3 Diffusion Effect Research Promoting Scientific Progress

As shown in , altmetrics diffusion effect research primarily focuses on journal articles, aiming to achieve article clustering, emerging topic detection, and breakthrough research identification. Key methods include network analysis and machine learning. These approaches pay insufficient attention to researchers—the main group in knowledge diffusion. We remain unclear whether knowledge diffusion helps researchers find ideas, write papers, and promote knowledge innovation, or whether it facilitates scientific knowledge growth.

Altmetrics analysis for studying knowledge diffusion

Addressing these questions requires network analysis, causal inference, and machine learning. Implementation can proceed as follows: (1) construct coupling networks with researchers as nodes and different exchange behaviors as edges to clarify diffusion effects; (2) employ quasi-experiments or matching to investigate knowledge diffusion' s impact on researchers' knowledge transformation, absorption, and innovation; (3) in research on knowledge diffusion' s impact on scientific knowledge growth, establish large-scale altmetrics datasets through term retrieval and entity recognition techniques.

Conclusion

The three application scenarios proposed in this study integrate altmetrics definitions with social interaction in network environments, reflecting altmetrics' positive role in internet contexts. The three key methods synthesize classical informetrics and science of science approaches, reflecting altmetrics' potential for transcending disciplinary boundaries and addressing complex problems. The ten research questions provide specific directions for deepening altmetrics research, serving as intermediaries to organically combine application scenarios and key methods.

In evaluation indicator research, future altmetrics studies must employ network analysis to explore formation mechanisms of different indicators; transcend science evaluation by using machine learning to promote altmetrics' predictive and recommendation functions; and develop comprehensive indicators with broad applicability and strong interpretability.

In science communication research, future altmetrics studies must employ causal inference to construct science communication systems and understand value orientations; use network analysis to clarify roles of academic journals, news media, and other stakeholders; apply machine learning to mine communication quantity, scope, and impact; and utilize experiments to promote science-society interaction.

In knowledge diffusion research, we should grasp diverse knowledge forms in online academic exchange, employ machine learning to clarify diffusion traces, develop indicators suitable for online contexts, use causal inference to construct knowledge diffusion frameworks, and leverage machine learning to discover scientific ideas and promote scientific growth.

These three prospects are expected to guide altmetrics research in the coming five years and provide actionable pathways for field development.

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Corresponding author: Yu Houqiang, ORCID: 0000-0002-9241-6630, E-mail: yuhq8@mail.sysu.edu.cn.

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