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CURRENT QUALITY OF CROSSREF METADATA IN MACEDONIAN SCIENTIFIC JOURNALS (2025)

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ABSTRACT

Introduction: When a publisher registers a DOI with Crossref, they are also expected to submit associated metadata—structured information about the content, such as the title, authors, publication date, abstract, funding data, references, ORCID iDs, and more. We aimed to analyse the current quality of Crossref Metadata in Macedonian scientific journals, and to suggest mechanisms for increase of the Crossref metadata quality in Macedonian scientific journals.

Methods: On February 15, 2025, an analysis was conducted using Crossref's "Participation Reports – How good is your metadata?" tool (<https://www.crossref.org/members/prep/>) to identify publishers from the Republic of North Macedonia depositing Crossref metadata. The analysis, which focused exclusively on journal articles using the “All time” option (excluding books, book chapters, proceedings, and conference papers), revealed a total of 37 publishers and one co-publisher—Sciando, De Gruyter Poland Sp. z o.o., based in Warsaw, Poland. Altogether, 37,595 registered content items from these Macedonian publishers were included in the evaluation.

Results: The 2025 analysis of Crossref metadata in Macedonian scientific journals shows limited participation, with only 37 out of around 140 publishers represented. DOI deposits are led by a few key institutions, but reference, ORCID iD, affiliation, funding, and Crossmark metadata are largely missing, especially from major public universities. Abstracts are more widely deposited, though inconsistently across institutions. Text mining, license URLs, and similarity checks are poorly implemented, and no publishers have submitted ROR identifiers. Only three journals published via De Gruyter demonstrate strong metadata quality in several areas, but still lack key elements like ORCID, ROR, and funding data.

Discussion: Current Crossref metadata quality in Macedonian scientific journals (2025) is very low. Only smaller part of Macedonian scientific journals uses DOI numbers. Most of the

Macedonian scientific journals do not deposit Crossref metadata services (Metadata Retrieval, Content Registration, Reference linking, Cited-by, Funder Registry, Similarity Check, Crossmark).

Keywords: Crossref metadata; scientific journals; Macedonia

INTRODUCTION

Crossref plays a fundamental role in scholarly communication by acting as the principal registry for Digital Object Identifiers (DOIs) and their associated metadata (Van Eck and Waltman 2022). Its infrastructure supports discovery, citation linking, and interoperability across research systems. However, the quality of metadata submitted to Crossref varies significantly, raising concerns about discoverability, the accuracy of citation networks, and the integrity of bibliometric analyses.

Many academic publishers collaborate with Crossref to register DOIs for their outputs, and in doing so, they can deposit bibliographic metadata associated with those publications. Crossref makes this metadata openly accessible to the public. Through the large-scale availability of such open bibliographic metadata, Crossref has emerged as an increasingly valuable resource for bibliometric research (Hendricks et al. 2020). Open Crossref metadata supports more transparent, reproducible, and inclusive bibliometric analyses (Hendricks et al. 2021) and enables novel methods for discovering scholarly literature, as well as more responsible use of bibliometric indicators in research evaluation. Furthermore, metadata provided by Crossref underpins major downstream data infrastructures, including OpenAlex (Priem et al. 2022) and Dimensions (Hook et al. 2018).

One prominent issue is the phenomenon of “sneaked references,” in which citations are registered in Crossref metadata but do not actually appear in the published article’s reference list. Such manipulations can inflate citation counts and propagate through bibliometric platforms (Besançon et al. 2023). More recent work has confirmed that such manipulations persist at scale: for example, Besançon et al. (2025) detected over 80,000 sneaked references in metadata for a single journal, revealing systemic vulnerabilities in Crossref’s reliance on publisher-supplied citation data.

Given the scale and importance of Crossref, evaluating its metadata quality is critical. Poor-quality metadata can propagate errors across citation indexes, distort bibliometric measures, and undermine research discovery. Accordingly, this analysis aims to assess the current state of Crossref metadata along several dimensions — including completeness, accuracy, risk of manipulation, and multilingual consistency — in order to identify persistent weaknesses and propose actionable improvements.

We aimed to analyse the current quality of Crossref Metadata in Macedonian scientific journals, and to suggest mechanisms for increase of the Crossref metadata quality in Macedonian scientific journals.

Methods

Identification of publishers from Macedonia which deposit Crossref metadata = 37 publishers and 1 co-publisher (Sciendo, De Gruyter Poland Sp. z o.o., Bogumiła Zuga 32a, 01-811 Warsaw, Poland) were included in the study. Macedonian publishers were analysed on February 15, 2025, with the Crossref tool, Participation Reports, How good is your metadata? (<https://www.crossref.org/members/prep/>).

The option “All time” was used for publisher analysis of journal articles. Books, book chapters, proceeding, and conference papers were not included in this presentation. Total number of 37 595 registered content items were analysed for each publisher from RN Macedonia.

Results

At the moment, there are 12 members of Crossref from RN Macedonia, mainly from governmental institutions (Ss. Cyril and Methodius University in Skopje, Faculty of Economics – Skopje; University of Tetovo; European Scientific Institute, ESI; International Balkan University; Macedonian Academy of Sciences and Arts; and University St. Kliment Ohridski – Bitola) and societies (Macedonian Pharmaceutical Association; Albanians' Stomatological Society; Union of Researchers of Macedonia; Society of Chemists and Technologists of Macedonia; Association-Institute for English Language and American Studies, Tetovo; and Balkan Studies Foundation). The number of scientific journals is bigger than 12, because there are similar DOIs with different suffixes (Table 1).

Table 1. Members of Crossref from RN Macedonia (n = 12).

Name of the Crossref member	DOI prefix
Ss. Cyril and Methodius University in Skopje, Faculty of Economics - Skopje	10.47063
Macedonian Pharmaceutical Association	10.3332
Albanians' Stomatological Society	10.62636
Union of Researchers of Macedonia	10.37418
Society of Chemists and Technologists of Macedonia	10.2045
Association-Institute for English Language and American Studies, Tetovo	10.58885
University of Tetovo	10.62792
European Scientific Institute, ESI	10.19044
Balkan Studies Foundation	10.51331
International Balkan University	10.69648
Macedonian Academy of Sciences and Arts	10.20903
University St. Kliment Ohridski – Bitola	10.20544
TOTAL	12

The biggest number of DOIs are sponsored by National and University Library – St Kliment of Ohrid – Skopje (18), followed by Scientific Foundation SPIROSKI (3), and the rest of DOIs are sponsored by Albanian Canadian Development Alternative (1), Institute of Knowledge Management (1), ASOS Publishing (1), and Han Yazilim Bilisim Hilzetmleri (1), or in total 25 DOIs from RN Macedonia are sponsored. The number of scientific journals is bigger than 25, because there are similar DOIs with different suffixes (Figure 1).

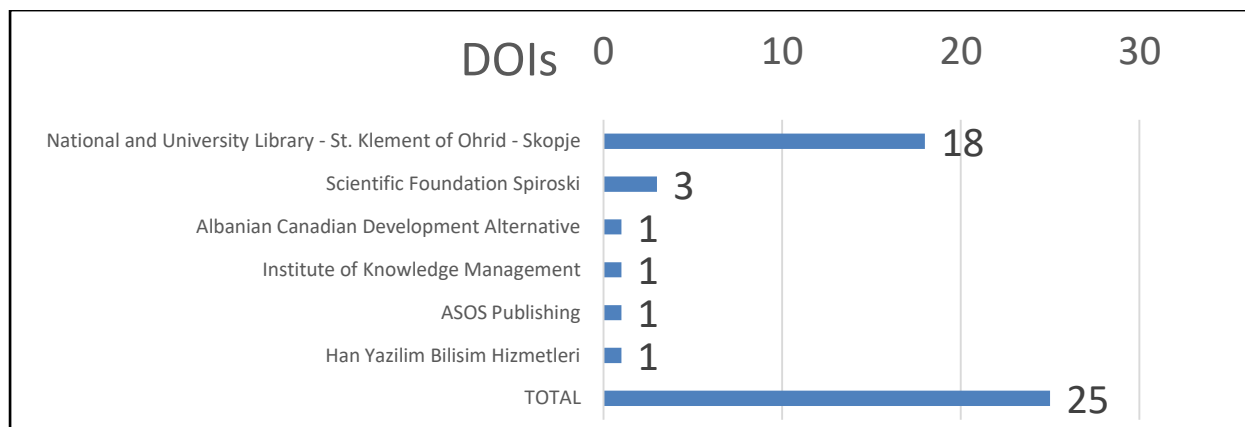


Figure 1: Sponsor organisations for DOIs in RN Macedonia

The current quality of Crossref metadata in Macedonian Scientific Journals (2025) is shown in Table 2.

DOI Deposits - The highest number of DOIs was deposited by: (1) InTouch Publishing; (2) European Scientific Institute; (3) Scientific Foundation Spiroski; and (4) Ss. Cyril and Methodius University in Skopje. Despite the number of active scientific journals in Macedonia being around 140, only 37 publishers are represented in Crossref, indicating that DOI assignment remains limited (Table 2).

Reference Metadata - Only 7 publishers have deposited references in Crossref metadata. The top contributors are: (1) Macedonian Pharmaceutical Association; (2) Scientific Foundation Spiroski; and (3) Journal of Special Education and Rehabilitation. Notably, several major universities, such as Ss. Cyril and Methodius University in Skopje, St. Clement of Ohrid University of Bitola, and the University of Tetovo, have not deposited reference metadata (Table 2).

Abstract Metadata - More than half of the publishers have deposited abstracts in Crossref. However, governmental Universities perform poorly: University of Tetovo: 100% abstract deposition; Goce Delchev University in Shtip: 0%; and Ss. Cyril and Methodius University in Skopje: 2% (Table 2).

ORCID iDs - The highest number of deposited ORCID iDs came from: Association for Educational Development "To Future"; International Balkan University; and Scientific Foundation Spiroski. Major Governmental Universities have not deposited ORCID iDs (Table 2).

Affiliation Metadata - The Macedonian Pharmaceutical Association leads in affiliation metadata deposition. Most others are underrepresented or missing completely (Table 2).

Research Organization Registry (ROR) - No Macedonian publisher has deposited ROR identifiers (Table 2).

Funding Registry and Award Numbers - Only Scientific Foundation Spiroski has deposited a small percentage of funding information and award numbers. All others have submitted none (Table 2).

Crossmark Metadata - Only two organizations included Crossmark metadata: Institute of Knowledge Management; and European Scientific Institute (Table 2).

Text Mining and License URLs - Text mining metadata is poorly deposited. Two-thirds of journals have no text mining entries. License metadata is similarly incomplete, with better results only from a few institutions such as: Society of Science and Technology of

Macedonia; Scientific Foundation Spiroski; Macedonian Academy of Sciences and Arts; and American Studies in Tetovo (Table 2).

License URLs - Universities like Ss. Cyril and Methodius, St. Clement of Ohrid, and University of Tetovo did not deposit license metadata (Table 2).

Similarity Check - Only one-third of the analyzed content includes similarity check metadata (Table 2).

Table 2. Current Quality of Crossref Metadata in Macedonian Scientific Journals (2025).

Name (15.02.2025)	Total registered content items (all time)	References (%)	Abstracts (%)	ORCID iDs (%)	Affiliations (%)	ROR IDs (%)	Funder Registry IDs (%)	Funding award numbers (%)	Crossmark enabled (%)	Text mining URLs (%)	License URLs (%)	Similarity Check URLs (%)
University St. Kliment Ohridski Bitola - Scientific Tobacco Institute	0	0	0	0	0	0	0	0	0	0	0	0
University St. Kliment Ohridski - Bitola	460	2	11	0	2	0	0	0	0	0	0	0
University Ss. Cyril and Methodius in Skopje	2 375	0	2	0	0	0	0	0	0	0	0	0
University of Tetovo	361	0	100	0	0	0	0	0	0	0	0	0
Union of Researchers of Macedonia	1 627	0	27	0	3	0	0	0	0	0	0	99
TEMEL Citizens' Association Center for Development, Organization, Research, Promotion of Values, Education and Promotion of Youth, Bitola	47	0	0	0	0	0	0	0	0	0	0	0
Ss. Cyril and Methodius University in Skopje, Faculty of Economics – Skopje	176	0	95	5	5	0	0	0	0	0	5	95
Society of Chemists and Technologists of Macedonia	420	0	94	14	0	0	0	0	0	94	95	94
Scientific Foundation Spiroski	6 654	58	93	28	0	0	3	2	0	92	91	95
Qendra për marrëdhënie ndërkombëtare e studime ballkanike	68	27	91	5	0	0	0	0	0	95	25	95
Public Scientific Institution Institute of Old Slavic Culture - Prilep	130	0	0	0	0	0	0	0	0	0	0	0
Matematichki Bilten, Union of Mathematicians of Macedonia	159	0	0	0	0	0	0	0	0	0	0	0
Macedonian Pharmaceutical Association	897	97	24	0	86	0	0	0	0	0	0	99
Macedonian Marketing Association Marketing – Skopje	0	0	0	0	0	0	0	0	0	0	0	0
Macedonian Geographical Society	70	0	0	0	0	0	0	0	0	0	0	0
Macedonian Ecological Society	98	0	0	0	0	0	0	0	0	0	0	0
Macedonian Archaeological Society	0	0	0	0	0	0	0	0	0	0	0	0
Macedonian Academy of Sciences and Arts	175	0	98	0	0	0	0	0	0	99	100	99
Macedonain Heraldic Society	85	0	0	0	0	0	0	0	0	0	0	0
Journal of Special Education and Rehabilitation	116	30	12	0	0	0	0	0	0	0	0	24
Journal of Liberty and International Affairs, Institute for Research and European Studies – Bitola	287	0	0	0	0	0	0	0	0	0	0	0
International Vision University	110	0	0	0	0	0	0	0	0	0	0	0
International Balkan University	70	0	92	44	0	0	0	0	0	0	0	0
Integrated Business Faculty	15	0	0	0	0	0	0	0	0	0	0	0
İntaç Eğitim Danışmanlık Organizasyon Araştırma İnşaat Sanayi ve Ticaret Limited Şirketi	12 177	0	8	8	8	0	0	0	0	0	0	0
Institute of Knowledge Management	1 755	14	100	0	1	0	0	0	4	80	13	84

Goce Delchev University – Shtip	799	0	0	0	0	0	0	0	0	0	0	0
Geobalcanica Society	116	0	0	0	0	0	0	0	0	0	0	0
Federation of Sport Pedagogues of Republic of Macedonia	40	0	0	0	0	0	0	0	0	0	0	0
Faculty of Tourism and Hospitality, Ohrid	0	0	0	0	0	0	0	0	0	0	0	0
Faculty of Philosophy, Skopje	555	0	0	0	0	0	0	0	0	0	0	0
European Scientific Institute, ESI	7 292	0	78	0	0	0	0	0	1	70	23	70
DOOEL OTA PUBLICIRANJE s.Lavci Bitola	16	0	0	0	0	0	0	0	0	0	0	0
Association-Institute for English Language and American Studies, Tetovo	305	8	100	13	0	0	0	0	0	99	75	99
Association of Practitioners of TCM Tong Da Tang TCM, Skopje	49	0	0	0	0	0	0	0	0	0	0	0
Association of Education and Thought Fettah Efendi	77	0	75	97	0	0	0	0	0	0	0	0
Albanians' Stomatological Society	14	0	100	0	0	0	0	0	0	0	0	0
TOTAL	37 595											

Exception (Journals via De Gruyter) - Three journals (Balkan Journal of Medical Genetics, Macedonian Veterinary Review, and PRILOZI) have deposited data through Walter de Gruyter. These journals show very good to excellent metadata quality for references, abstracts, affiliations, text mining, licenses, and similarity check, but lack ORCID iDs, ROR, funding, and Crossmark metadata (Figure 2).

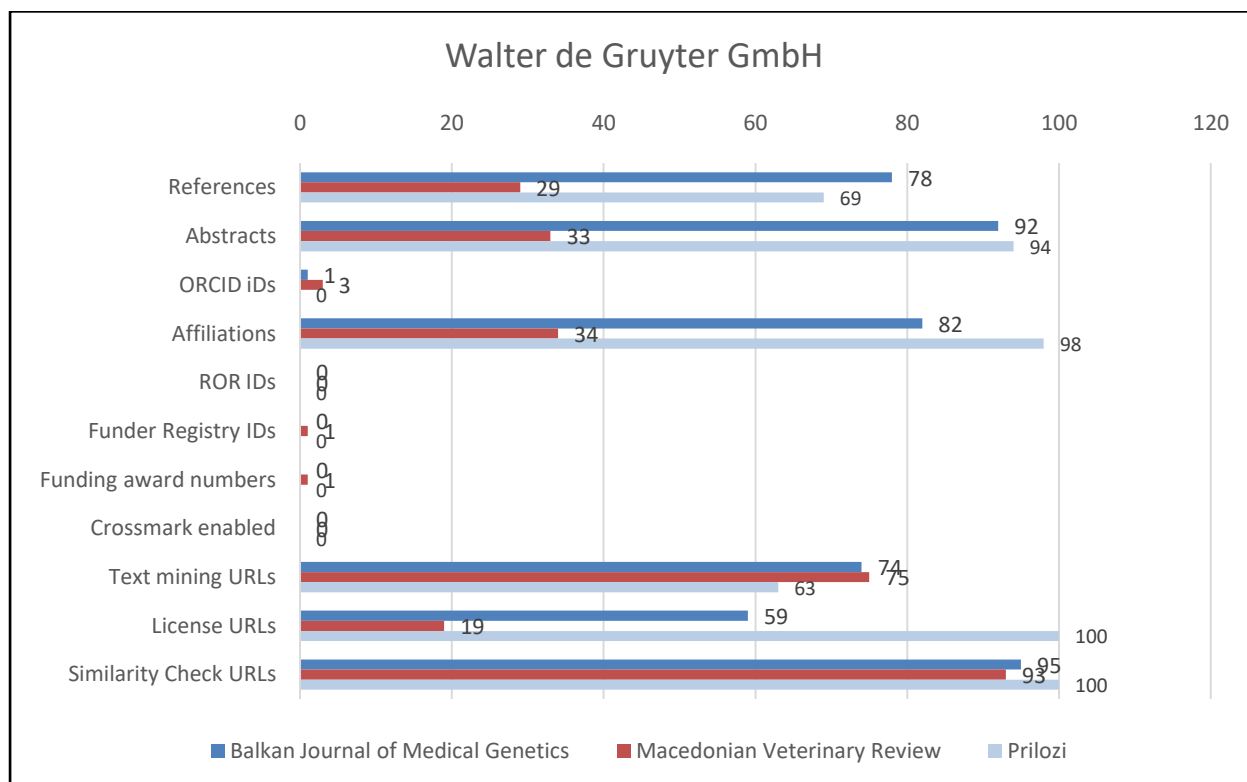


Figure 2: Crossref Metadata of Macedonian Journals co-published with Walter de Gruyter GmbH (results in % of deposited DOIs)

One successful case involved a journal formerly hosted on www.heraldika.org.mk. The editor-in-chief decided to upgrade the journal and partnered with Scientific Foundation Spiroski to improve the metadata. Initially, on February 15, 2025, the journal had zero metadata quality across all 11 items. One month after corrections and resubmission, the metadata quality significantly improved - demonstrating that progress is possible with active collaboration (Figure 3).

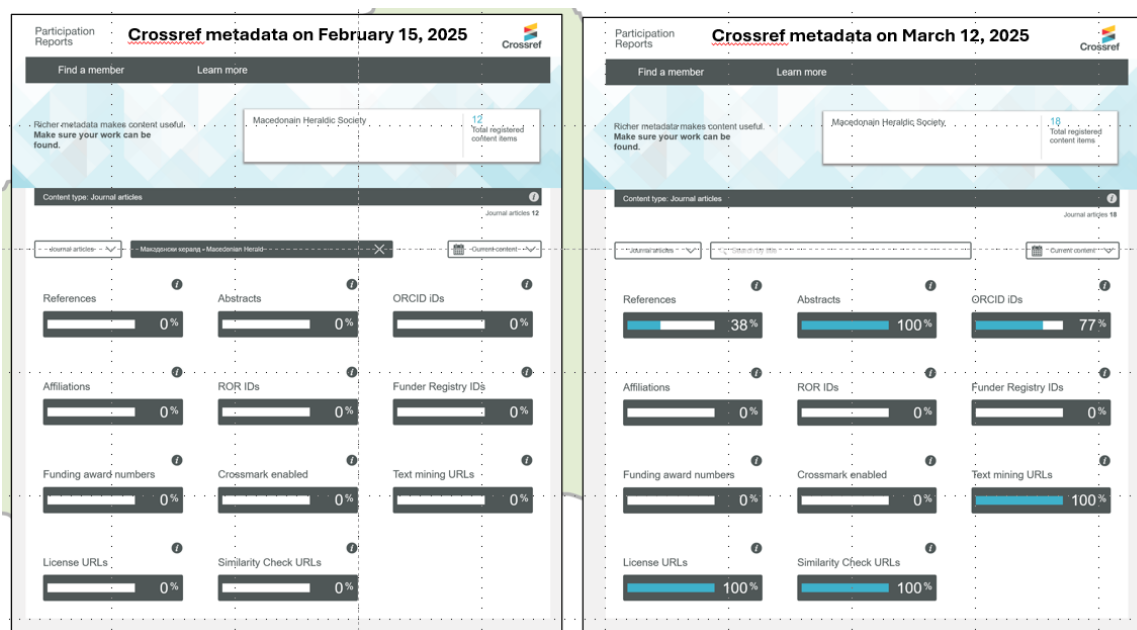


Figure 3: Macedonian Heraldic Society moved the content of Macedonian Herald journal to <https://journals.mk/index.php/mkherald>. We updated URLs and metadata. The results are shown before (left February 15, 2025) and after update (right March 12, 2025) to increase the quality of metadata

DISCUSSION

In this paper, we present the results from the current analysis of Crossref metadata in Macedonian scientific journals (2025). Our assessment reveals several significant gaps in metadata practices. Although Macedonia hosts approximately 140 active scientific journals, only 37 publishers are represented in Crossref, with the most DOI deposits coming from InTouch Publishing, the European Scientific Institute, Scientific Foundation Spiroski, and Ss. Cyril and Methodius University in Skopje. However, reference metadata is deposited by only seven publishers, led by the Macedonian Pharmaceutical Association and Scientific Foundation Spiroski. Major academic institutions, including Ss. Cyril and Methodius University and University of Tetovo, have not deposited reference metadata at all. Abstract metadata coverage is inconsistent: while University of Tetovo achieves full(100%) deposition, other universities such as Goce Delchev and Ss. Cyril and Methodius, report extremely low rates.

Additional gaps are evident in the deposition of ORCID iDs, affiliation data, and other advanced metadata elements. ORCID iDs are primarily submitted by smaller institutions, such as the Association for Educational Development "To Future" and the International Balkan University, while government-funded universities remain largely inactive. Only the Macedonian Pharmaceutical Association shows substantial affiliation metadata, and no publishers have deposited Research Organization Registry (ROR) identifiers. Funding information and award numbers are almost entirely absent, with minimal contributions from Scientific Foundation Spiroski. Similarly, Crossmark metadata is deposited by just two publishers, and text mining and license metadata remain highly incomplete. Universities such as Ss. Cyril and Methodius, St. Clement of Ohrid, and Tetovo failed to provide license URLs. Overall, only one-third of journals include similarity check metadata, underscoring the widespread need for improved metadata practices across Macedonian scholarly publishing.

To improve metadata quality in Macedonian scientific journals, we must take action. Crossref provided data indicating that 12 Macedonian publishers are full members of Crossref. They are independently responsible for their metadata quality. Additionally, some organizations act as sponsors for Crossref in Macedonia: Institute of Knowledge Management; National and University Library "St. Clement of Ohrid"; and Scientific Foundation Spiroski. As sponsors of Crossref, they are expected to support metadata quality improvement among their members (National and University Library: 18 DOIs; Scientific Foundation Spiroski: 3 DOIs; Other sponsors (e.g., Acco Publishing, Turkish-based Yazim Bilisim Hizmetleri): 1 DOI each). Scientific foundation Spiroski was included as a sponsor of Crossref in January of 2025, and they are committed to support all Crossref services (including DOI assignment; metadata retrieval; content registration; reference linking; cited-by; ror; similarity check; and crossmark), as well as training and educational resources such as webinars, instructional videos, and website materials (<https://www.journals.mk/index.php/index/crossref>).

There are several key moments when it is especially valuable for journals to audit or update their metadata: a) when URLs change; b) when switching publishing platforms; and c) when a journal is transferred to another publisher. Additionally, if a journal begins collecting new types of metadata—such as funding information—those records should be updated accordingly. Ideally, journals should also set a regular schedule to review and audit their metadata in line with any changes in internal policy. This ensures the records remain accurate and complete.

If metadata such as author affiliations are missing—as is the case with many Macedonian journals—then institutions cannot be accurately linked to their research output. A past study on AI in Macedonian publications showed that over 2.07K papers lacked proper affiliation metadata and were only attributed to "Republic of Macedonia" (Spiroski and Spiroski, 2025).

The Crossref Participation Reports tool can help identify the most essential metadata elements. While Crossref allows for a wide range of metadata types, journals with limited resources can focus on the 11 key metadata elements that significantly enhance content discoverability. Prioritizing quality over quantity is crucial. Accurate, well-maintained metadata—even if limited in scope—is far more valuable than having numerous but inaccurate records. Regularly auditing and improving just these 11 elements can greatly improve visibility and compliance. Many research organizations in Macedonia are not registered in the Research Organization Registry (ROR), making it impossible to link them accurately. For improved metadata to truly support collaborations and visibility, a national effort is required to ensure institutions, authors (via ORCID), and papers (via DOI) are properly registered and linked.

We discovered a general lack of understanding of how to properly submit or maintain metadata. Until now, most scientific journals in Macedonia have only deposited DOIs and landing pages—without additional, valuable metadata. This is not about blaming any institution; it reflects a widespread unpreparedness to meet modern scientific publishing standards. Of the six sponsors linked with Macedonian metadata, three are foreign institutions. Interestingly, these foreign sponsors tend to have higher metadata quality, highlighting the need to improve domestic capacity. Historically, depositing DOIs was seen as sufficient. However, to truly benefit from metadata, all 11 key elements should be included. Full Crossref members are responsible for ensuring that their metadata goes beyond just DOIs.

In the published paper about Identifying Metadata Quality Issues Across Cultures, authors concluded (Shi et al. 2025) that metadata records should be treated as sites in need

of critical, intellectual engagement to surface the perspectives and identities embedded and obscured in their creation. In taking up the responsibility of describing a researcher's output in a record, journal editors and publishers also have a responsibility to the researcher to ensure that their contributions and identity are represented as fully as relevant and possible to their work and the communities most affected by it.

There is an interesting notification where Ansorge 2023 compared the citation frequencies of articles published in *European Science Editing* using the Dimensions and Scopus databases and concluded, “Data on citations in the Dimensions database could be more accurate if the references appended to the citing articles listed in the Crossref database were under an open license.” He concluded that this issue arises when the publishing company neglects to include references when depositing the DOI to Crossref.

While some may consider changing sponsors as one possible path forward, the core issue is education. Universities must understand that metadata completeness is crucial. Whether or not journals choose to work with sponsors or independently, what matters most is recognizing the need for complete, high-quality metadata.

CONCLUSIONS

Crossref metadata quality in Macedonian scientific journals is very low. Only a smaller part of Macedonian scientific journals uses DOI numbers. Most of the Macedonian scientific journals do not deposit Crossref metadata services (Metadata Retrieval, Content Registration, Reference linking, Cited-by, Funder Registry, Similarity Check, Crossmark). Macedonian scientific journals should increase Crossref metadata services by resubmission of corrected metadata and provide more complete metadata services free of charge.

Crossref Macedonia is prepared to accept current Macedonian scientific publishers for resubmission of corrected metadata services and to enable more precise future depositions.

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