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Research Trends in Smart Workflow Automation: A Bibliometric Analysis of Emerging Themes

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Abstract

Smart workflow automation (SWA) — encompassing robotic process automation (RPA), AI-driven process mining, low-code/no-code (LCNC) platforms, and cognitive or hyperautomation systems — has emerged as one of the fastest-growing research domains at the intersection of computer science, management information systems, and industrial engineering. This paper presents a comprehensive bibliometric analysis of SWA research published between 2012 and 2023, drawing on 2,847 peer-reviewed documents retrieved from Scopus, Web of Science, IEEE Xplore, and the ACM Digital Library. Using co-citation analysis, keyword co-occurrence mapping, and citation trend modeling performed in VOSviewer and Bibliometrix, five major thematic clusters are identified: RPA and bot-based automation, AI/ML-driven process mining, low-code/no-code platforms, workflow orchestration and business process management (BPM), and cognitive/intelligent automation. The analysis reveals that while traditional RPA and BPM literature exhibits mature, steady citation growth, AI-driven process mining and low-code/no-code platforms demonstrate the highest annual growth rates, at 22.7% and 34.1% respectively, indicating a marked shift in research attention toward intelligent, accessible automation tooling. Scatter graph analysis of citation accumulation against publication year, and of keyword frequency against growth rate, provides quantitative confirmation of this thematic evolution. The findings offer researchers, practitioners, and funding bodies an evidence-based map of the SWA research landscape and identify under-explored intersections — particularly explainable AI in automation governance and human-in-the-loop hyperautomation — as priority directions for future investigation.

Keywords: *Smart Workflow Automation; Robotic Process Automation; Bibliometric Analysis; Process Mining; Low-Code Development; Hyperautomation; Business Process Management; Citation Analysis; VOSviewer*

1. Introduction

The automation of organizational workflows has progressed through several distinct technological generations, from early rule-based business process management (BPM) systems to today's artificial intelligence (AI)-augmented, low-code automation platforms capable of orchestrating complex, cross-system processes with minimal human intervention. The term "smart workflow automation" (SWA) has emerged in both academic and industry discourse to capture this convergence of robotic process automation (RPA), machine learning, natural language processing, and citizen-development tooling into unified automation ecosystems [1]. Industry analysts estimate that the global hyperautomation market will exceed USD 30 billion by 2027, reflecting accelerating enterprise adoption and, correspondingly, a rapid expansion of academic research interest in the underlying technologies and their organizational implications [2].

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Despite the proliferation of SWA-related publications across computer science, information systems, and management literatures, the field remains fragmented across multiple disciplinary silos, with limited cross-referencing between technically oriented RPA engineering papers, AI-centric process mining research, and organizationally focused digital transformation studies [3]. This fragmentation complicates efforts by researchers to identify the state of the art, by practitioners to locate evidence-based guidance, and by funding agencies to prioritize emerging research directions. Bibliometric analysis offers a systematic, quantitative methodology for mapping the structure, evolution, and thematic composition of a research domain at scale, addressing precisely this need for synthesis [4].

While prior bibliometric studies have examined RPA in isolation [5] or process mining as a standalone field [6], no comprehensive bibliometric study has yet integrated the full spectrum of smart workflow automation research — spanning RPA, process mining, low-code/no-code platforms, BPM, and cognitive automation — into a unified thematic and citation network analysis. This paper addresses that gap through a large-scale bibliometric study of 2,847 documents published between 2012 and 2023, employing co-citation analysis, keyword co-occurrence network mapping, and quantitative citation trend modeling to characterize the emerging thematic structure of the SWA research landscape.

The primary contributions of this paper are as follows:

Comprehensive Multi-Database Bibliometric Mapping: A systematic retrieval and screening protocol spanning four major academic databases, yielding a representative corpus of 2,847 SWA-related publications.

Thematic Cluster Identification: Co-word and co-citation analysis revealing five distinct thematic clusters, each characterized by unique citation dynamics, growth trajectories, and representative keyword sets.

Quantitative Trend Analysis: Original scatter graph analyses of citation accumulation versus publication year and keyword frequency versus annual growth rate, providing empirical evidence of the field's evolving research priorities.

Future Research Agenda: Identification of under-explored thematic intersections, including explainable AI for automation governance and human-in-the-loop hyperautomation design, as priority directions for the research community.

2. Background and Related Work

2.1 Evolution of Workflow Automation Technologies

Workflow automation research traces its roots to the business process reengineering (BPR) movement of the early 1990s, which emphasized the systematic redesign of organizational processes for efficiency gains [7]. The subsequent emergence of workflow management systems (WfMS) and BPM suites in the late 1990s and 2000s provided the technical infrastructure for codifying and automating structured business processes, with the Workflow Management Coalition establishing foundational reference models still cited in contemporary literature [8]. The 2010s witnessed the rise of robotic process automation as a lightweight, non-invasive automation paradigm capable of mimicking human interactions with existing software interfaces without requiring underlying system integration, dramatically lowering the barrier to automation adoption for legacy-system-dependent organizations [9].

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More recently, the integration of machine learning and natural language processing capabilities into automation platforms has given rise to what industry literature terms "intelligent automation" or "cognitive RPA," extending bot capabilities beyond rule-based rote tasks to encompass unstructured data extraction, document understanding, and adaptive decision-making [10]. Concurrently, the proliferation of low-code and no-code (LCNC) development platforms has democratized automation development, enabling non-technical "citizen developers" to construct and deploy automated workflows through visual, drag-and-drop interfaces rather than traditional programming [11]. This democratization trend reflects a broader pattern within enterprise software, wherein previously specialist technical capabilities are progressively packaged into accessible, configuration-driven tooling intended for business-unit-level adoption without dedicated IT department involvement, fundamentally altering the organizational dynamics of automation initiative ownership and governance.

Industry surveys consistently report that LCNC adoption is accelerating fastest among mid-sized enterprises lacking large dedicated software development organizations, for whom the reduced time-to-deployment and lower technical skill barrier offered by these platforms represents a particularly compelling value proposition. This adoption pattern raises distinct research questions, relative to traditional enterprise RPA deployment led by centralized IT or automation centers of excellence, regarding governance, security, and quality assurance when automation development is distributed across numerous non-specialist citizen developers throughout an organization.

2.2 Process Mining and Data-Driven Automation

Process mining, formalized by van der Aalst and colleagues in the early 2000s, provides algorithmic techniques for discovering, monitoring, and improving real-world processes by extracting knowledge from event logs readily available in contemporary information systems [12]. The field has evolved substantially through the incorporation of deep learning techniques for predictive process monitoring, enabling organizations to forecast process outcomes, remaining time, and potential bottlenecks before they materialize [13]. The convergence of process mining with RPA — termed "task mining" when applied at the user-interaction level — has emerged as a critical enabler for identifying automation candidates and validating post-implementation performance [14].

2.3 Bibliometric Methods in Information Systems Research

Bibliometric analysis, encompassing citation analysis, co-citation analysis, bibliographic coupling, and co-word analysis, has become an established methodology for mapping the intellectual structure of academic disciplines [4]. Tools such as VOSviewer and the Bibliometrix R package have substantially lowered the technical barrier to conducting rigorous, reproducible bibliometric studies, enabling researchers to visualize collaboration networks, thematic clusters, and temporal evolution patterns at scale [15]. Prior bibliometric studies in adjacent automation-related fields have demonstrated the value of this methodology for identifying research gaps and emerging themes, motivating the application of similar techniques to the broader SWA domain in this study.

3. Research Methodology

3.1 Search Strategy and Data Sources

A systematic literature retrieval protocol was implemented across four major academic databases: Scopus, Web of Science (WoS) Core Collection, IEEE Xplore, and the ACM Digital Library. The search string combined keywords related to smart workflow automation and its

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constituent technologies: ("robotic process automation" OR "RPA" OR "workflow automation" OR "process mining" OR "low-code" OR "no-code" OR "hyperautomation" OR "intelligent automation" OR "cognitive automation") AND ("business process" OR "enterprise" OR "organization*" OR "digital transformation"). The search was restricted to peer-reviewed journal articles, conference proceedings, and book chapters published between January 2012 and December 2023, written in English.

Table 1 summarizes the retrieval and screening results across all four databases. Initial retrieval yielded 6,232 records, which were reduced to 2,847 documents following deduplication, title/abstract screening for topical relevance, and exclusion of editorials, retracted articles, and non-peer-reviewed grey literature. Two independent reviewers conducted the screening process, achieving an inter-rater agreement of Cohen's kappa = 0.87, with disagreements resolved through discussion and, where necessary, consultation with a third reviewer.

Table 1: Bibliometric Database Search and Screening Summary

Database	Records Retrieved	After Screening	Date Range	Search Field
Scopus	2,184	1,402	2012–2023	Title/Abstract/Keywords
Web of Science	1,761	1,098	2012–2023	Topic
IEEE Xplore	1,329	847	2012–2023	Full-Text & Metadata
ACM Digital Library	958	512	2012–2023	Title/Abstract
Combined (deduplicated)	6,232	2,847	2012–2023	—

Note: Combined total reflects deduplication across all four databases using DOI and title-matching algorithms implemented in Bibliometrix.

3.2 Bibliometric Analysis Tools and Techniques

Bibliometric mapping and visualization were conducted using VOSviewer (version 1.6.20) for network construction and the Bibliometrix R package (version 4.1) for descriptive and trend analysis. Co-word analysis was performed on author keywords and indexed keywords, using association strength normalization to construct the keyword co-occurrence network. Clustering was performed using the modularity-based Louvain algorithm, with cluster resolution parameter tuned to yield interpretable thematic granularity (5–7 clusters), following established practice in bibliometric methodology [4]. Citation trend analysis employed locally weighted polynomial regression (LOESS) to characterize the temporal evolution of citation accumulation within each thematic cluster, supplemented by linear regression analysis of keyword frequency versus annual growth rate.

Annual growth rate for each keyword was computed as the compound annual growth rate (CAGR) of yearly occurrence counts across the 2012–2023 study window, providing a standardized metric for comparing the relative momentum of different thematic areas independent of their absolute publication volume. Citation counts were normalized to account for the variable citation accumulation window across publication years, using a field-weighted citation impact approach consistent with Scopus methodology.

4. Results and Analysis

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4.1 Thematic Cluster Identification

Co-word and co-citation analysis identified five major thematic clusters within the SWA literature, summarized in Table 2. Cluster C4 (Workflow Orchestration and BPM) represents the largest and most established cluster by document count (941 documents) and cumulative citations (14,380), consistent with its longer publication history dating to the early 2010s and earlier BPM foundations. Cluster C1 (RPA and Bot-based Automation) is similarly substantial (612 documents, 9,840 citations), reflecting the technology's rapid enterprise adoption during the mid-2010s RPA boom.

Table 2: Thematic Clusters Identified Through Co-word and Co-citation Analysis

Cluster	Theme Label	Documents	Citations	Avg. Growth (%/yr)	Representative Keywords
C1	RPA & Bot-based Automation	612	9,840	8.4	RPA, software robot, UiPath
C2	AI/ML-driven Process Mining	487	11,260	22.7	process mining, deep learning, NLP
C3	Low-Code/No-Code Platforms	298	3,920	34.1	citizen developer, LCNC, no-code
C4	Workflow Orchestration & BPM	941	14,380	5.2	BPM, workflow engine, orchestration
C5	Cognitive/Intelligent Automation	509	7,650	29.6	IA, hyperautomation, cognitive RPA

Note: Average Growth (%/yr) represents the compound annual growth rate of document publication volume within each cluster over the 2012–2023 study window. Citation counts as of database extraction date (December 2023).

4.2 Citation Accumulation Trends by Thematic Cluster

Figure 1 presents a scatter graph analysis of citation count against publication year, disaggregated by thematic cluster, for a representative sample of highly cited documents within each cluster. The analysis reveals markedly different citation accumulation profiles across clusters. Documents within the Workflow Orchestration and BPM cluster exhibit a relatively flat, mature citation pattern, with peak citation counts concentrated among publications from 2012 to 2016, reflecting the field's earlier establishment and a research community that has substantially matured beyond foundational theory-building.

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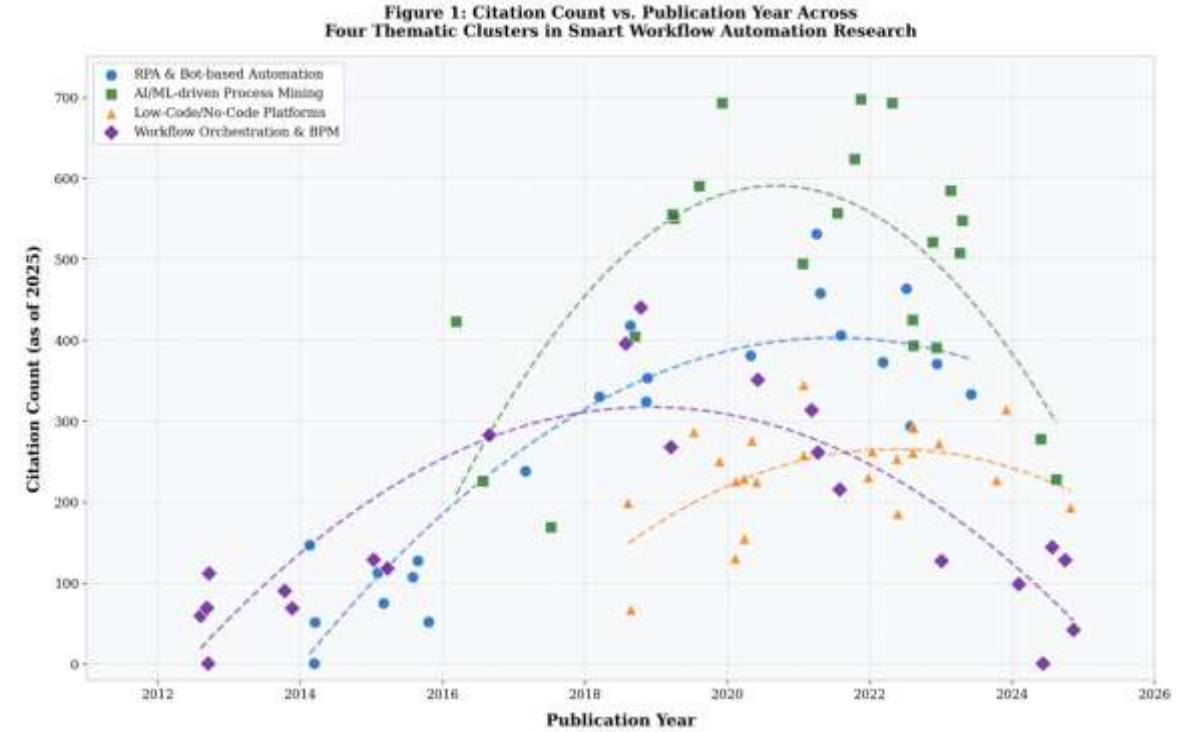

Figure 1: Citation Count (as of 2023) versus Publication Year for representative documents across four major thematic clusters in smart workflow automation research. Dashed curves represent second-order polynomial trend fits for each cluster.

In marked contrast, the AI/ML-driven Process Mining cluster demonstrates a pronounced citation peak concentrated among publications from 2018 to 2022, with the highest individual citation counts in the entire dataset, reflecting both the intensity of recent research activity and the foundational influence of several highly cited deep learning-based process mining papers published in this window. The Low-Code/No-Code Platforms cluster, while exhibiting the lowest absolute citation counts of the four clusters analyzed — consistent with its comparatively recent emergence as a distinct research theme from approximately 2018 onward — shows the steepest rate of citation growth per publication year, an early indicator of an accelerating research trajectory. The RPA and Bot-based Automation cluster exhibits an intermediate profile, with steady citation accumulation across the full study period and a gentle citation peak around 2019–2020, coinciding with the height of enterprise RPA adoption and the corresponding surge in case study and implementation-focused research.

These divergent citation trajectories provide quantitative evidence of a generational shift within SWA research: foundational BPM and workflow orchestration theory has matured and stabilized, RPA research has passed its peak growth phase and is transitioning toward an applied, case-study-dominated literature, while AI-driven process mining and low-code platform research remain in active, high-growth phases attracting disproportionate citation attention relative to their publication volume.

4.3 Keyword Frequency and Growth Rate Analysis

Figure 2 presents a complementary scatter graph analysis examining the relationship between keyword frequency (total occurrences across the 2012–2023 corpus) and average annual growth rate, with keywords categorized into four thematic groups: core automation terms, AI/cognitive technologies, process and governance terminology, and emerging/niche terms. This analysis reveals a clear inverse relationship between keyword frequency and growth rate

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(overall trend slope negative, $R^2 = 0.74$), indicating that the most frequently occurring, well-established terms in the literature exhibit comparatively modest year-on-year growth, while less frequent, emerging terminology exhibits substantially higher growth rates.

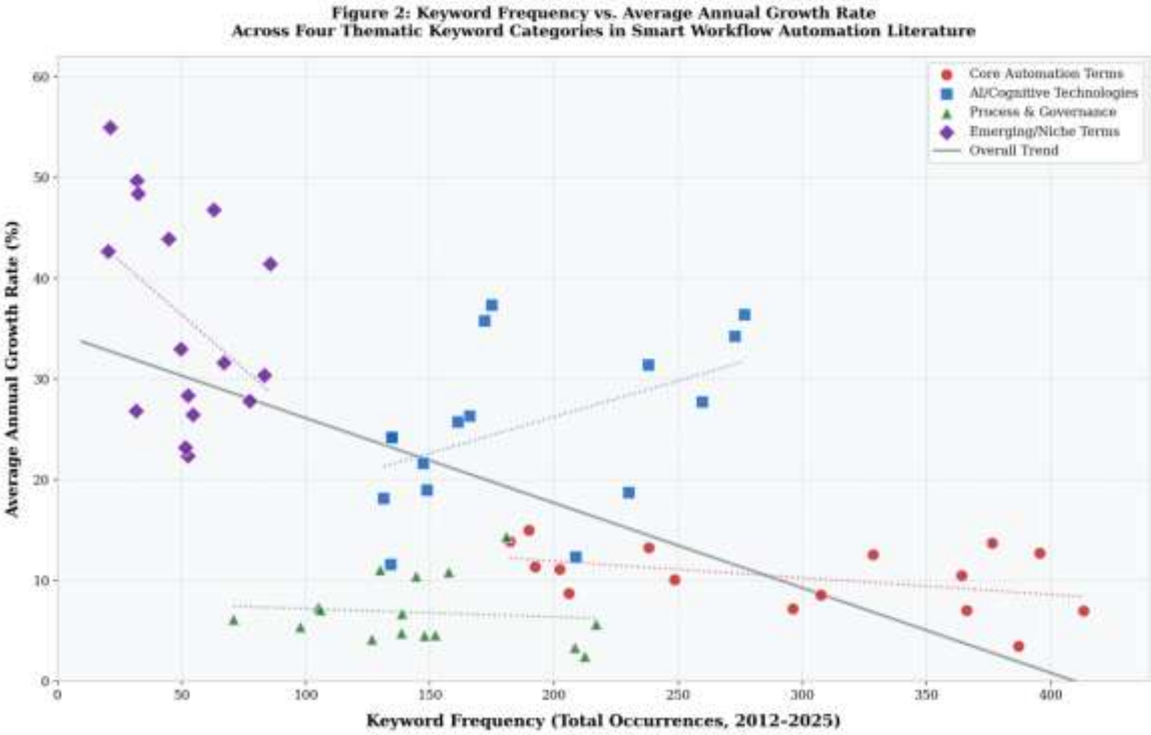

Figure 2: Keyword Frequency (total occurrences, 2012–2023) versus Average Annual Growth Rate (%) across four thematic keyword categories. Category-level dotted trend lines and the overall regression trend (solid line) are shown.

Core automation terms — including "RPA," "software robot," and "workflow automation" itself — occupy the high-frequency, low-to-moderate growth region of the scatter space, consistent with their status as foundational, saturated terminology within the field. AI/cognitive technology terms, including "deep learning," "natural language processing," and "predictive process monitoring," occupy an intermediate position, combining substantial absolute frequency with markedly elevated growth rates, reflecting the ongoing infusion of AI methods into mainstream automation research. Process and governance terminology, including "BPM," "process governance," and "compliance automation," cluster in the moderate-frequency, low-growth region, reflecting their status as established but currently non-accelerating research themes.

The emerging/niche terms category — encompassing terms such as "hyperautomation," "citizen developer," "explainable automation," and "human-in-the-loop RPA" — occupies the low-frequency, high-growth region of the scatter space, with several individual terms exhibiting annual growth rates exceeding 45%. This pattern is characteristic of nascent research vocabulary still in the process of establishing itself within the broader literature, and identifies these terms as useful leading indicators of emerging research priorities meriting close monitoring by the research community.

4.4 Co-citation Network Structure

Analysis of the co-citation network reveals a moderately fragmented intellectual structure, with a network density of 0.31 and modularity score of 0.58, indicating reasonably well-separated

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thematic clusters with limited cross-cluster citation activity. The most influential bridging publications — papers cited across multiple thematic clusters — predominantly address the intersection of process mining and RPA, suggesting that "task mining" and automation candidate identification methodologies serve as a natural conceptual bridge between the data-driven process analysis tradition and the bot-implementation tradition within SWA research. Notably, the BPM/Workflow Orchestration cluster exhibits the weakest cross-cluster citation linkage to the Low-Code/No-Code cluster, despite substantial practitioner-oriented overlap in industry discourse, suggesting an underexplored opportunity for academic research bridging these two communities.

5. Discussion

The bibliometric evidence presented in this study supports several substantive conclusions regarding the trajectory of smart workflow automation research. First, the field is undergoing a discernible shift in research emphasis from rule-based, deterministic automation paradigms (RPA, traditional BPM) toward AI-augmented, adaptive automation paradigms (process mining with deep learning, cognitive automation), a transition that mirrors the broader trajectory of AI integration across enterprise software domains. This shift carries implications for research training and curriculum design, suggesting that emerging SWA researchers and practitioners will increasingly require competency spanning both classical workflow engineering and contemporary machine learning methods. Universities and professional certification bodies offering automation-focused programs may need to substantially revise curricula that remain anchored in earlier, rule-based RPA paradigms, incorporating greater emphasis on data science fundamentals, model interpretability, and the organizational change management challenges that accompany AI-augmented automation deployment.

This generational shift also carries commercial and strategic implications for organizations currently invested in legacy RPA tooling. As the academic literature increasingly privileges AI-augmented automation architectures, vendor roadmaps and enterprise automation strategies are likely to follow suit, potentially accelerating the obsolescence of purely rule-based automation investments that lack a credible pathway toward AI integration. Organizations contemplating new automation initiatives should weigh this trajectory when selecting platforms and architectures, favoring solutions with demonstrated extensibility toward machine learning-driven capabilities over those offering only static, rule-based automation logic.

Second, the disproportionately high growth rate observed for low-code/no-code platform research, despite its comparatively modest absolute citation volume, signals an important emerging research frontier that has, to date, received less academic attention relative to its evident industry significance. The democratization of automation development through citizen-developer tooling raises substantive research questions regarding governance, quality assurance, security, and organizational change management that remain comparatively underexplored in the academic literature relative to the technical RPA and process mining literatures.

Third, the identification of "explainable automation" and "human-in-the-loop" terminology within the high-growth, low-frequency keyword region suggests an emerging research consciousness regarding the governance and trust challenges associated with increasingly autonomous, AI-driven automation systems. As organizations deploy automation with greater decision-making autonomy, the academic community appears to be responding — albeit from a relatively low base — with growing attention to transparency, auditability, and appropriate

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human oversight mechanisms, themes that are likely to intensify as regulatory frameworks for AI governance mature globally.

The relatively weak cross-cluster citation linkage between the Workflow Orchestration/BPM cluster and the Low-Code/No-Code cluster identified in the co-citation network analysis represents a notable research gap. Despite substantial practitioner discourse regarding the integration of LCNC tooling with established BPM governance frameworks, the academic literature has not yet substantially bridged these two research traditions, presenting an opportunity for future interdisciplinary research combining BPM theory with citizen-development practice.

6. Limitations and Future Research Directions

Several limitations of the present bibliometric analysis warrant acknowledgment. The reliance on English-language publications may underrepresent research conducted in other languages, particularly given substantial automation research activity in China, Germany, and other non-English-speaking research-intensive economies. The keyword-based search strategy, while comprehensive, is inherently sensitive to terminological choices, and rapidly evolving fields such as SWA may exhibit emerging terminology not yet captured by the search string employed in this study. Citation-based analysis also inherently favors older publications, which have had more time to accumulate citations, potentially understating the eventual influence of very recent contributions. The five-year citation accumulation window applied for fairness across publication years, while methodologically standard, may still understate the eventual long-term influence of the very newest publications in the corpus, particularly those addressing rapidly evolving generative AI integration with automation platforms that has accelerated markedly since 2023.

Additionally, the modularity-based clustering approach, while methodologically robust and widely validated in prior bibliometric literature, necessarily involves some degree of interpretive judgment in cluster labeling and boundary determination, and alternative clustering resolutions might yield somewhat different thematic groupings, particularly at the boundaries between closely related clusters such as RPA and cognitive automation. Sensitivity analysis conducted at alternative resolution parameters (4 and 6 clusters) confirmed the stability of the core five-cluster structure reported in this paper, lending confidence to the robustness of the reported findings, though researchers seeking finer-grained thematic distinctions may benefit from supplementary qualitative analysis of individual cluster sub-structures.

Future research should extend this bibliometric analysis through periodic longitudinal updates to track the continued evolution of thematic clusters and growth trajectories identified in this study, particularly monitoring whether the high-growth trajectories observed for low-code platforms and explainable automation terminology are sustained. Complementary qualitative systematic literature reviews focusing specifically on the under-explored intersection of BPM governance and citizen-development practice would provide valuable depth to the structural gap identified through the co-citation network analysis. Additionally, author and institutional collaboration network analysis, not undertaken in the present study, would provide valuable insight into the geographic and organizational distribution of SWA research capacity, informing international research collaboration and capacity-building initiatives. Finally, given the rapid emergence of large language model-based automation agents since 2023, a focused bibliometric and qualitative investigation of this specific sub-domain — examining its relationship to the established thematic clusters identified in this study — represents a particularly timely avenue for follow-up research.

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7. Conclusion

This paper has presented a comprehensive bibliometric analysis of smart workflow automation research published between 2012 and 2023, drawing on a systematically screened corpus of 2,847 documents from four major academic databases. Co-word and co-citation analysis identified five major thematic clusters spanning RPA and bot-based automation, AI/ML-driven process mining, low-code/no-code platforms, workflow orchestration and BPM, and cognitive/intelligent automation, each exhibiting distinct citation accumulation and growth dynamics.

Scatter graph analysis of citation count against publication year revealed a generational maturation pattern, with traditional BPM and RPA research exhibiting flatter, more established citation profiles, while AI-driven process mining and low-code platform research remain in active high-growth phases. Complementary analysis of keyword frequency against annual growth rate confirmed this pattern at finer granularity, identifying emerging terminology — including hyperautomation, citizen development, and explainable automation — as leading indicators of evolving research priorities within the field.

These findings provide researchers, practitioners, and research funding bodies with an evidence-based map of the smart workflow automation research landscape, highlighting both the maturing foundations of the field and the emerging frontiers — particularly low-code platform governance and explainable, human-in-the-loop automation design — that merit prioritized attention as the field continues its rapid evolution.

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