The Knowledge Management Archipelago

A Bibliometric Analysis of Knowledge Management Related Research

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ABSTRACT

The theory and practice of knowledge management shares concerns and approaches with a number of other areas of research, some of which preceded its formalization as a field. In the age of the internet, the challenges that the field of knowledge management addresses, such as the difficulty of synthesizing, interpreting, and managing large streams of information, are no longer confined to professional disciplines and are present in everyday life. The commonality and timelessness of these concerns presents a potential problem for the field of knowledge management that, ironically, the field itself often seeks to address: the creation of silos, sometimes referred to as "islands", in the knowledge base. The purpose of this paper is to present an exploratory bibliometric analysis of the various areas of research which share concerns, approach, and scope in common with knowledge management. Search-strings associated with selected areas of research were used to query Google Scholar in various combinations in search of co-occurrence, results were quantified and visualized. The results show variable couplings and differential prevalence of keywords, and serve as a starting point for targeted analyses and next steps.

Introduction

Knowledge management has had the distinction of being a formally-defined field of research for at least three decades [1–3]. However today, knowledge management and a number of related fields still suffer from a lack of consensus on definitions and scope [2,3]. When considering the source of this lack of consensus, there are two features in particular that are worth noting. First is the fact that the challenges addressed by knowledge management are not novel but simply more pronounced due to the advent of digital technology and the internet [2]. Second, many challenges that knowledge management is concerned with are not specific to any particular class of organization. For example, effective allocation of intellectual capital and content [3–9], facilitation of research, situational awareness, the creation of intelligence products [3,9], and efficient use of human expertise [3,9,10] are challenges faced by organizations such as research and education institutes, intelligence agencies, industrial and manufacturing companies, militaries, law firms [3,9], and even citizens [11,12]. Thus many domains are in need of support in overcoming technical and cognitive challenges in making sense of the world [2,13].

This lack of novelty in concerns and their being so widely shared presents a potential problem for the field of knowledge management that, ironically, the field itself often seeks to address: the creation of silos (sometimes referred to as "islands" [14–18]) in the knowledge base due to differences in ontology and the lack of network connections between knowledge workers working on common issues [3,9,13]. In other words, there is disorder and disarray in the management of knowledge related to knowledge management itself—potentially leading to unrecognized solutions, redundant efforts, and incompatible or contradicting research, frameworks, and products. With the potential value of solving this problem in mind, an exploration of the literature, and even of the myriad definitions of knowledge management itself, reveals a number of distinct, formally-defined fields that are also addressing this common set of challenges, often with the same or similar approaches—chief among them are information management and library science.

Knowledge management, library science, and information management are difficult to separate, even at high levels of expertise, due to underlying confusion "around the concepts of knowledge and information" [19,20]. Even when clarifications are made however, those clarifications are accompanied by a lack of consensus regarding knowledge management being its own field rather than being either a modern update to information management [3,21,22] or an extension of library science and information management [1,3,19,23]. Further, the deep interconnectedness between information management, library science, and knowledge management theory and practice often causes attempts to define the differences between these disciplines to result in them being only more difficult to tell apart [24–29].

The practices most commonly associated with library science, information management, and knowledge management at least afford a common audience and base of stakeholders [3], but other fields with common concerns and research interest might not. For example, command and control or C2 systems, supervisory control and data acquisition or SCADA systems, intellectual capital management, and data, information, and sensor fusion are all areas which share challenges, requirements, and approaches in common with knowledge management. Worse still, many of these areas of research, including knowledge management and information management, are of interest, as stated earlier, to governments, militaries, intelligence agencies, and commercial organizations and therefore it stands to reason that an unknown fraction of research products are classified or otherwise uncirculated due to concerns regarding trade secrets and national security [3,9]. This problem isn't specific to government and industry research products—even within the domain of peer-reviewed academic research, publications are often only legally accessible to those with institutional affiliations. Today, even in cases where a team has the resources to make a deep search into all publicly available research regarding these disciplines, there may still be difficulty in performing comprehensive searches because of the aforementioned divergent ontologies. Thus a variety of challenges beset the area of knowledge management, with serious implications for workers and projects of many different kinds.

We hypothesized that an exploratory bibliometric analysis of targeted domains would characterize the structure of connection or fragmentation of different bodies of literature published by various sectors related to knowledge management. Our assessment of the literature connectivity was among the targeted areas defined individually in the following paragraphs.

C2 - Command and Control Systems

A command and control system can be defined as the set of "procedures and techniques" which "synchronize battles and engagements and which contribute toward the decisive application of combat power" [30] and facilitate "planning, directing, coordinating, and controlling" operations [31]. In practice, a command and control (C2), command, control, and communications (C3), or command, control, communications, and computer (C4) system generally takes the form of a distributed digital system that synthesizes and facilitates the generation of intelligence products and situation assessments, supports decision making, and provides situational awareness and opportunities to monitor, coordinate, and control operations in real-time [32,33].

SCADA - Supervisory Control and Data Acquisition

Supervisory control and data acquisition (SCADA) systems provide features such as credential and role management, generation of and access to assessments, reports, and other intelligence products, real-time monitoring and surveillance, and control over physical systems. [34,35]. The development of SCADA systems began with the need for "increased knowledge of real-time status" or situational awareness of industrial infrastructure [35], and while this area of research is traditionally focused on monitoring and control of critical infrastructure, interests and concerns within this domain have a notable crossover with those within command and control systems and knowledge management research [36–39].

KM - Knowledge Management

While hundreds of definitions for knowledge management have been generated as a result of sustained academic interest and use in a variety of fields, a potentially comprehensive, albeit general, definition is as follows: "Knowledge Management is the process of creating, sharing, using and managing the knowledge and information of an organization" [3]. Knowledge management, depending on its implementation, may also have within its scope areas such as intellectual capital attribution and governance (intellectual capital management), human and cultural dynamics, situational awareness facilitation, and learning management [3,9,20,39,40].

DF - Data, Information, and Sensor Fusion Systems

Data Fusion is the domain, as the name suggests, of combining disparate types of data, be they from sensors or databases. Similar in some ways to the relationship between knowledge management, library science, and information management—

data fusion, information fusion, and sensor or multi-sensor fusion systems are difficult to separate, have many definitions, and are often used interchangeably or fused together (e.g. "multisensor data fusion") [41,42]. Most definitions, however disparate, tend to have consensus that these terms refer to systems or aspects of systems which combine, consolidate, and otherwise synthesize information from various sources in order to provide situational awareness and create new value or deliverables, regardless of the fusion prefix used (e.g. data, information, sensor) [41]. In some cases, these definitions place emphasis on knowledge, information, intellectual capital, and document management as a part of such a process or system [41].

IM - Information Management

Information management, separate from its blurred boundaries with library science and knowledge management, also has both internal and other external confusions regarding definition, scope, and ontology [23]. For example, information management is sometimes difficult to separate from information engineering, information systems management, management information systems, executive information systems, decision support systems, information resources management, and information science [23]. A general definition of information management might see it as concerned with the creating, sharing, using, retrieving, searching for, curating, recognizing, and managing content, data, and information within an organizational context [23,43,44]. However, definitions of the scope of information management generally also include concerns for elements such as knowledge management, supporting decision making, maintaining situational awareness, commoditizing information as intellectual capital, increasing knowledge creation, and synthesizing information from numerous sources [23,43,44].

IC - Intellectual Capital Management

Intellectual capital management is an area of research that frames knowledge products, intelligence products, and formal intellectual property as intangible assets which can be invested, synthesized, and allocated in order to fuel the generation of new intangible or tangible assets [8,45]. Intellectual capital management is sometimes seen as either an aspect of knowledge management or as its own field which shares overlap with knowledge management [8]. Further, intellectual capital management often includes consideration for human and cultural dynamics such as the intellectual capital which has not yet been extracted from the minds of employees or has not yet been generated due to knowledge gaps—intellectual capital management thus shares a common set of concerns with research interests associated with human resources, serious games, communities of practice, and learning management systems [46].

LS - Library Science

Library science is perhaps the earliest field to mature among the disciplines discussed here [47,48], and much like information management, separate from its relationship with knowledge management it has had both internal and external confusions regarding scope and ontology [29,47]. As of the 1970s, library science was roughly defined as the theory and practice of information selection, acquisition, organization, storage, and curation for "all-types of information-handling organizations" [47]. Due to the development of numerous other fields which have similar concerns, and the changing function of the library building in modern society, library science may be becoming an "island" in the knowledge base, evidenced by its lower degree of interdisciplinarity with other fields when compared with adjacent domains [29].

Term	**2-Character Abbreviation**	**Inclusion Search-String**	**Exclusion Search-String**
Command & Control	C2	(("C2" OR "C3" OR "C4") "Command and Control")	-"c2" -"c3" -"c4" -"Command and Control"
Supervisory Control and Data Acquisition	SC	"Supervisory control and data acquisition"	-"Supervisory control and data acquisition"
Knowledge Management	KM	"Knowledge Management"	-"Knowledge Management"
Data Fusion, Sensor Fusion, and Information Fusion	DF	("Data Fusion" OR "Sensor Fusion" OR "Information Fusion")	-"Data Fusion" -"Sensor Fusion", -"Information Fusion"
Information Management	IM	"Information Management"	-"Information Management"
Intellectual Capital Management	IC	"Library Science"	-"Library Science"

Table 1. Areas of research included in the bibliometric analysis, along with exact search-strings utilized.

Methods

This study was conducted in three parts: (i) collection preparation, (ii) data collection, and (iii) data analysis and visualization.

Collection Preparation

A list of domains with similar focus on and approaches to the production, management, allocation, routing, and synthesis of meaning and information was generated by considering co-occurrence of references to other domains within disparate definitions of knowledge and information management in relevant literature reviews, meta-analyses, and encyclopedias (see Table 1) [3,10,19,24–27,49,50]. Given that these areas are frequently discussed across both professional and academic disciplines [3], there was an expectation that much of the material would be contained in conference, working, and white papers, Google Scholar was chosen over Web of Science for this analysis as it has "far more comprehensive coverage" of these kinds of documents [51]. Due to Google Scholar's limitations on search-string size [52], this initial list and associated search commands had to be prioritized and pruned. The removed domains and the basis for their removal are described in the paragraphs below.

Records Management

Records management was a very good candidate for inclusion given both its subject matter focus [27] and an initial exploratory search indicating that over 62% of the records management literature was found to have keyword co-occurrence with other chosen domains (see Appendix A-1). However, it was removed on the basis that the aspects of records management that would place it as a domain of interest are often acknowledged to be part of the information management discipline [53–56].

Situation Awareness System

While the "situation awareness system" market was valued at over 18 billion USD as of 2019, it is primarily a market-research term that describes SCADA, intelligence fusion systems, command and control systems [57]. It was not included on the basis that exploratory searches indicated that it was of limited use in academic literature and that where it was used, it shared a reasonable overlap with larger and more impactful domains (see Appendix A-1).

ISR Systems

ISR (Intelligence, Surveillance, and Reconnaissance) systems also fall under this umbrella of common systems and was considered for inclusion, however, it was removed on the basis that less than 25% of the retrieved ISR literature was separated from the context of command and control systems and features of the command and control ecosystem [58,59] and that the total results associated with ISR systems only constituted 165 documents (see Appendix A-1).

Intelligence Fusion Systems

Intelligence fusion systems were removed on the basis that only 77 documents were retrieved via an initial exploratory search and thus not impactful enough to be included despite a high rate of co-occurrence with other domains (see Appendix A-1).

Bibliometrics, Scientometrics, and Informetrics

We did not include bibliometrics, scientometrics, or informetrics as a part of the study on the basis that they are more specifically concerned with metrics about the use of intellectual capital and knowledge products, rather than the facilitation of their use [60].

Creation of Search-Strings

Individual searches of every combination of domain-associated “Include” and “Exclude” search-strings (see Table 1) were found to be necessary due to limitations of Google Scholar search features and the potential for false positives and unintended overlap [52]. The inclusion or exclusion of each search-string set constitutes 27 - 1 permutations, as there was no reason to include an “all-excluded” query. A Python script was developed (see Appendix A-2) to produce the set of search-strings (see Appendix A-3).

Data Collection

Searches were implemented in Google Scholar using manual search based upon generated search-strings (see Appendix A-3). After each search, the number of total Google Scholar results for the search-string was noted.

Data Analysis and Visualization

Data analysis was performed using Google Sheets and Python and visualizations were done using Google Sheets and Gephi.

Visualization

Given past successes in the use of graph visualizations for communicating cross-domain collaboration and other relationships in past bibliometric analyses [61–63], the graph visualization and analysis tool Gephi was chosen as a basis for rendering and analyzing the relationships between Google Scholar search results. A Python script was developed (see Appendix A-2) to take the results of the data collection and convert it into "node" and "edge" files compatible with Gephi (see Appendix A 4-5). In the interest of making the network renderings presentable, the domains were each given 2-letter abbreviations (see Table 1). These node and edge files were used to generate additional versions of node and edge file pairings and imported into Gephi to render network visualizations (see Appendix A 7-9 and Appendix B, Supplementary Figures 1-3).

Numerical Analysis

Google Sheets was used to perform a regression analysis of the number of results, comparing linear, exponential, and logarithmic regressions with number of domains included as the independent variable (X-axis, from 1 to 6) and number of results as the dependent variable (Y-axis). Conditional formatting was used to generate a heatmap of one- and two-term search results (see Figure 2).

Results

A total of 127 searches were performed on Google Scholar on June 10th, 2021 (see Appendix A-6), covering all include and exclude combinations of the 7 domains and their search-strings described in Table 1. These domains are abbreviated to their respective 2-character abbreviations assigned in Table 1 within this section.

There were 57 queries, all with 2 or more include search-strings, that had zero results. Of the 69 queries with one or more result, 46 queries returned ten or more results. The search with the largest number of results was for IM alone (962,000).

In descending order of total citations, the domains were: IM, KM, LS, SC, C2, DF, and IC. In order of highest proportion of co-occurrence with other keywords (reflecting degree of integration across fields) to least, the domains were: IC (76%), DF (71%), KM (32%), C2 (30%), IM (28%), LS (29%), and SC (15%) (see Figures 3-9). Thus at least in this keyword-based search among areas, there is an indication that DF and IC have the fewest number of overall citations, but demonstrate the highest rate of co-occurrence with other keywords. In contrast, the relatively large body of literature related to IM and KM demonstrates an intermediate degree of co-occurrence with other domains, while the mid-sized body of literature related to SC demonstrates the lowest level of overall co-occurrence.

Among searches which included 3 domains, the highest-volume domain crossovers were KM-IM-LS (11,800 results), KM-DF-IM (1,820 results), KM-IM-ICM (1,560 results), C2-DF-IM (887 results), and C2-KM-IM (819 results). Among searches which included 4 domains, the highest-volume domain crossovers were C2-KM-DF-IM (273 results), KM-DF-IM-LS (89 results), KM-IM-IC-LS (78 results), and SC-KM-DF-IM (48 results). Among searches which included 5 domains, only 4 searches produced results: C2-SC-KM-DF-IM (6 results), SC-KM-DF-IM-LS (1 result), C2-KM-IM-IC-LS (1 result), and C2-KM-DF-IM-LS (1 result). No searches which included 6 or all 7 domains returned any results.

Figure 1 shows the distribution of the number of search hits (Y-axis) as a function of the number of included domains (X-axis). As expected, there was a monotonically decreasing number of returned searches as a function of the number of search-strings used. The drop-off in search results was more consistent with an exponential regression with negative exponent (R2=0.324) than a logarithmic regression (R2=0.177) or a linear regression (R2=0.096). Notably, the KM-IM co-occurrence edge is above the trend line of the overall regression (Figure 1), suggesting that these two keywords are deployed in main texts and bibliographies at a rate higher than expected. Anecdotally, the areas of KMS and IM are largely overlapping in scope, including many works explicitly linking, contrasting, or juxtaposing the two approaches (e.g. [64]).

Figure 2a shows a heatmap of the number of results for each domain searched alone excluding all other domains using their respective exclude search-strings (on the diagonal), and their co-usage (in the bottom triangle of the matrix) for each pair of domains, where darker cells reflect a larger number of total results per query. Figure 2b shows the proportion of citations from each target domain (row) that additionally reference another domain (column), where darker cells reflect a higher proportion of keyword co-occurrence. There was a significant degree of variation among terms in total number of solitary and co-occurrence, as well as the proportion of directed co-occurrence between the keywords of pairs of domains. The only domain pairing that was absent entirely was IC-SC, suggesting that these two are the most diverged or isolated from each other in terms of approaches, concerns, and ontology. In contrast, the large fields of IM and KM had a relatively high proportion of co-occurrence with other keywords, while among the smaller fields, DF-C2 displayed a higher proportion of co-occurrence than other pairings. In terms of directional co-occurrence, IC-KM had a higher rate of co-occurrence than any other field pairing, with nearly 60 percent of results associated with IC also being associated with KM.

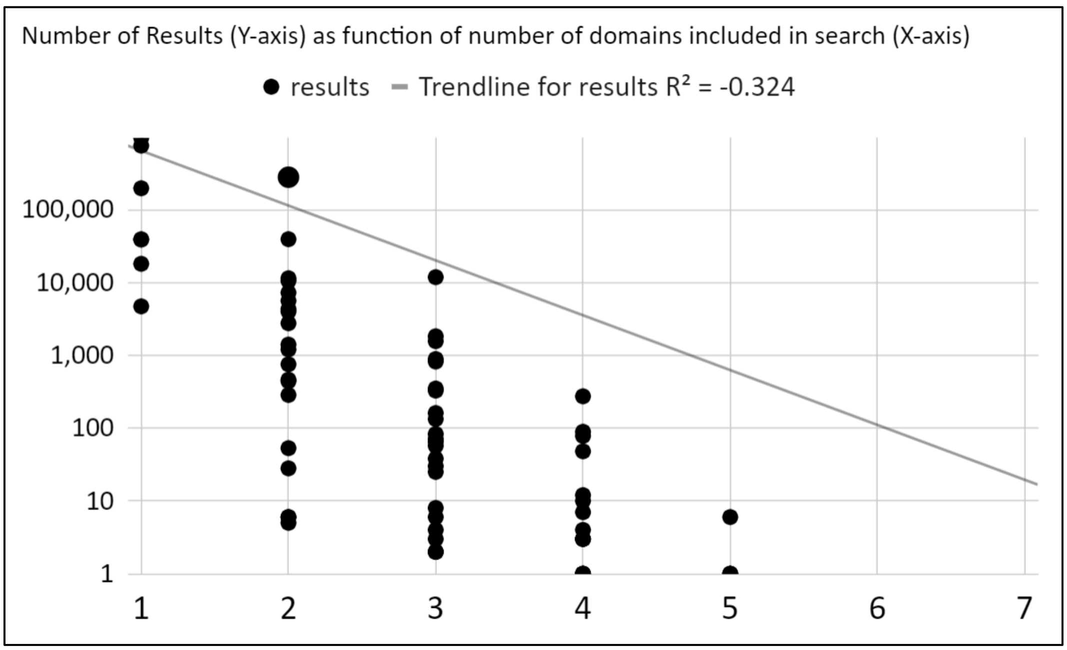

Figure 1. Relationship between number of domains included in search and number of Google Scholar results.

Figures 3-9 show targeted analyses centering each domain, with summary statistics and visual representations of the patterns of co-occurrence of keywords with other domains. Within Figures 3-9, subpanel A represents the proportion of co-occurrence and no co-occurrence with other domains within results associated with the subject domain broadly. Subpanel B represents the proportions of total results which had co-occurrence with specific other domains (so numbers will not sum to 100%). Subpanel C shows a weighted directed graph of the neighborhood around each keyword, in terms of the relative proportion of co-occurrences to and from each of the included keywords.

Broadly speaking, IM, KM, and LS were the most common domains overall, and appeared deeply intertwined. DF seems to be a bridge between these keywords (Figure 10), potentially because the practices and theories associated with it both support and draw support from a common class of systems of which LS, IM, and KM systems are a part. Visualization of the nominal (absolute) and relative percentage of co-occurrence among keywords (Figures 2-10 and Appendix B, Supplemental Figures 1-3) supported the trends broadly outlined above.

	IM	KM	LS	SCADA	C2	DF	ICM
IM	962,000						
KM	294,849	754,000					
LS	51,358	22,612	196,000				
SCADA	3,378	1,230	36	39,100			
C2	6,428	2,908	108	628	38,700		
DF	14,836	9,973	777	1,558	5,577	18,000	
ICM	1,936	7,295	128	0	14	17	4,690

a

	IM	*KMS*	*LS*	*SCADA*	*C2*	*DF*	*ICM*
IM		22.40%	3.90%	0.26%	0.49%	1.13%	0.15%
KMS	27.43%		2.10%	0.11%	0.27%	0.93%	0.68%
LS	19.86%	8.75%		0.01%	0.04%	0.30%	0.05%
SCADA	7.50%	2.73%	0.08%		1.39%	3.46%	
C2	12.49%	5.65%	0.21%	1.22%		10.84%	0.03%
DF	32.06%	21.55%	1.68%	3.37%	12.05%		0.04%
ICM	15.75%	59.34%	1.04%		0.11%	0.14%	

b

Figure 2. Heatmaps of (a) the total results associated with pairings of domains and (b) the percentage of total literature results associated with one domain (y axis) which had co-occurrence with another (x axis).

The bulk patterns discussed above and represented in the heatmaps in Figure 2 motivated a deeper analysis into whether the different domain keywords had distinct patterns of solitary and joint usage, potentially revealing patterns of disciplinary connectedness or isolation. A total of three Gephi files were generated from these initial files. The first, titled “Nominal Co-Occurrence”, was an undirected graph of 7 nodes and 27 weighted edges, where nodes represented the target domains, and edge weights represented the number of retrieved documents which included both terms (see Appendix B, Supplemental Figure 1). The second, titled

"Percentage Co-Occurrence", was a directed graph of 7 nodes and 40 weighted edges, where nodes represented the chosen domains, and edge weights represented the percentage of total documents associated with one domain that referenced another (see Appendix B, Supplemental Figure 2). The third, titled "Search-Strings as Nodes", was a directed multigraph of 65 nodes and 180 weighted edges, where nodes represented either chosen domains or the search-strings that were used to conduct searches (see Appendix A-3), and edge weights represented the number of documents associated with a domain and a search-string (see Figure 10 and Appendix B, Supplemental Figure 3). The search-strings for (i) KM-IM, (ii) IM-LS, and (iii) KM-IM-LS were removed from the "Search-Strings as Nodes" multigraph in the interest of visualization (see Figure 10). A histogram of this directed graph showed a range of edge weights representing the proportion of directed co-occurrence between pairs of domains, from almost 60% (IC->KM), to zero (see Figure 11).

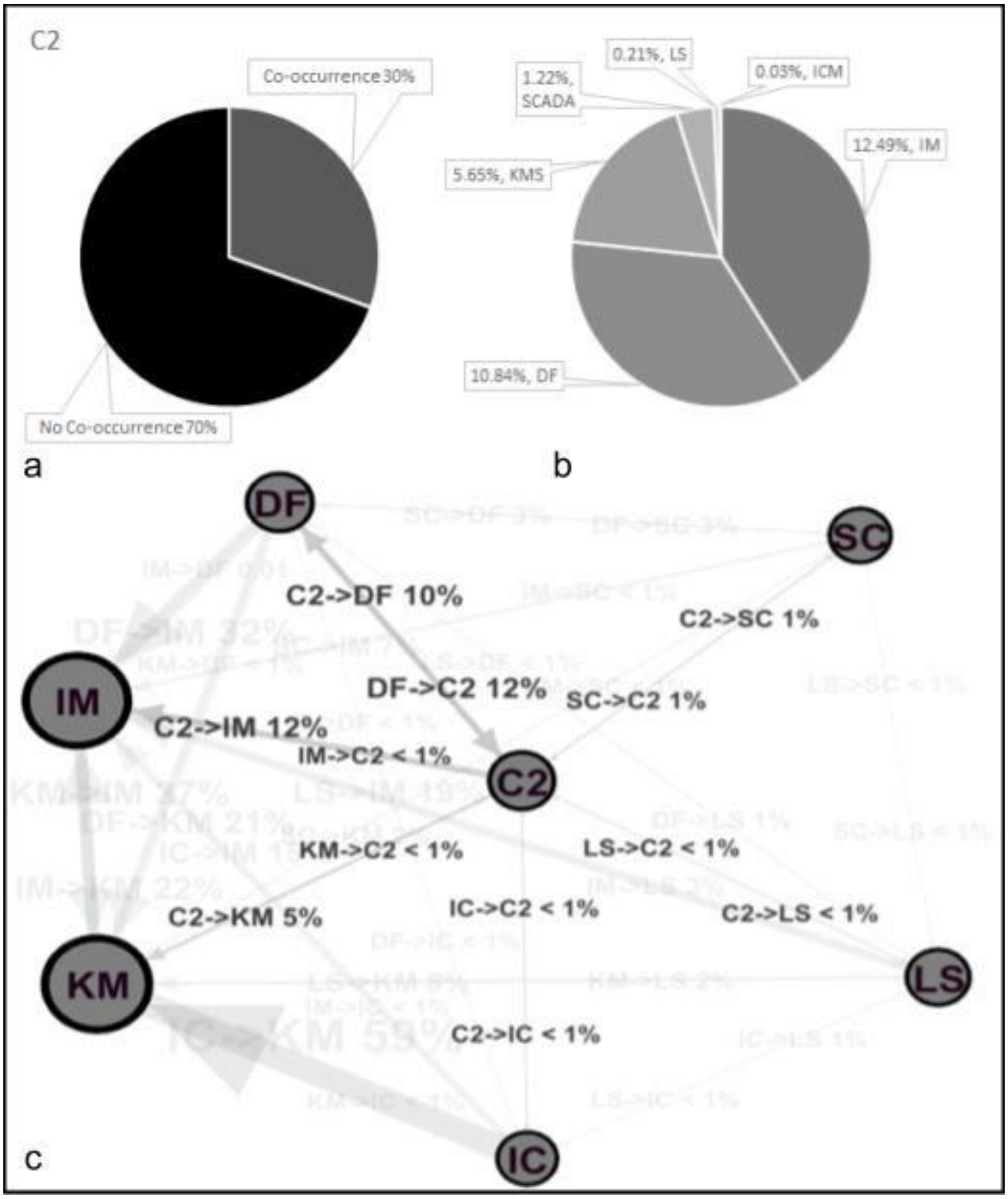

Figure 3. C2 (Command and Control)

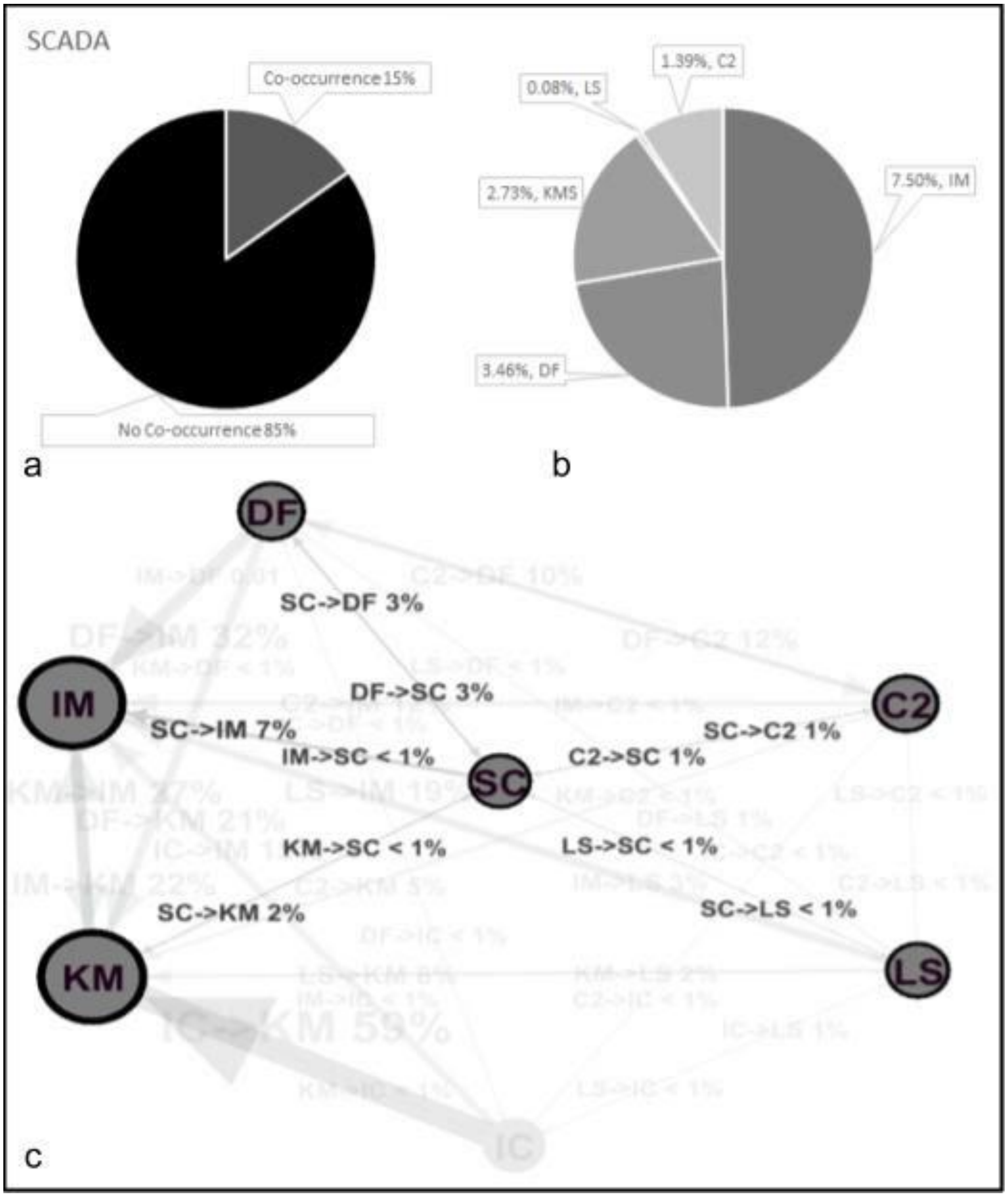

Figure 4. SC (SCADA)

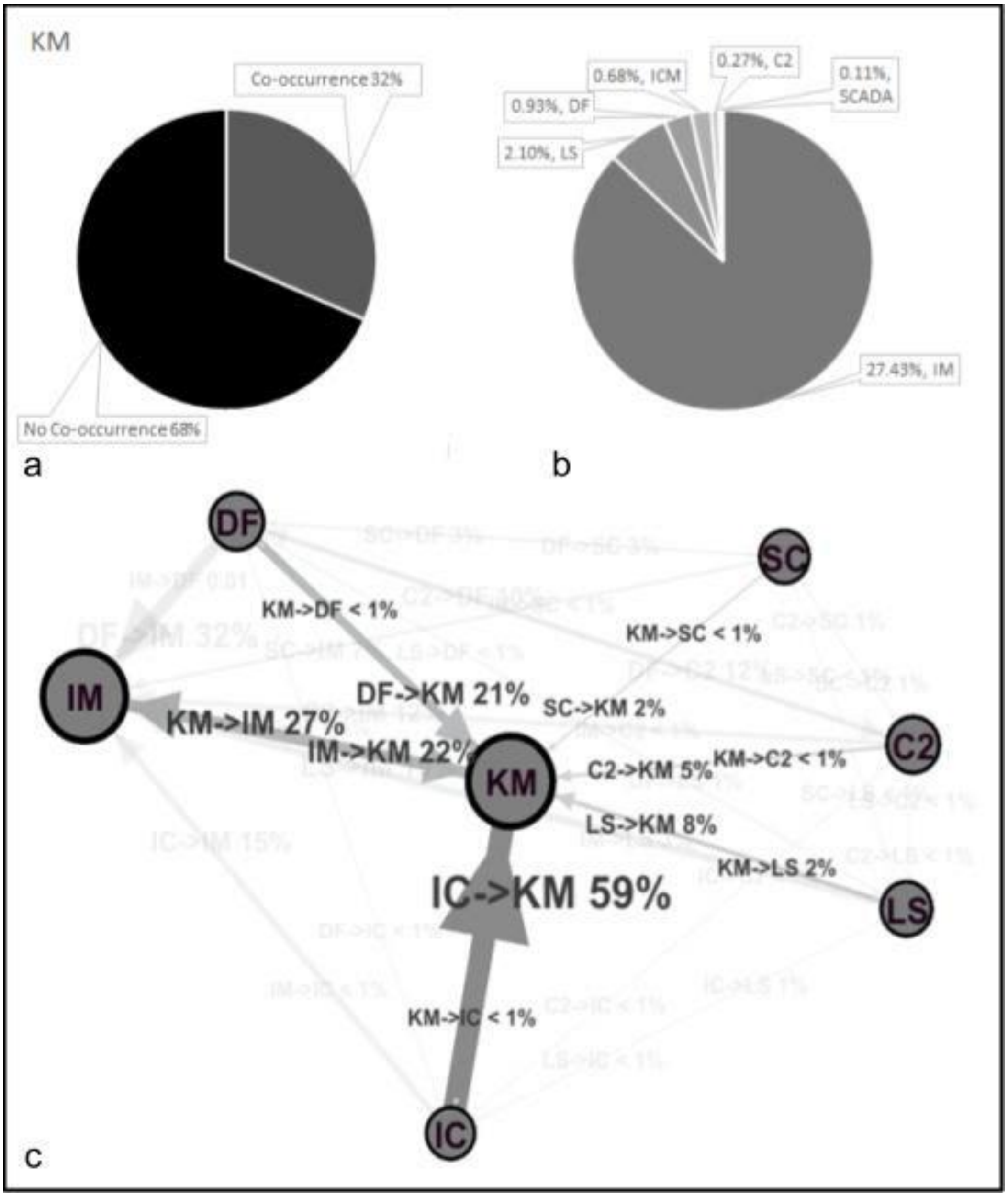

Figure 5. KM (Knowledge Management)

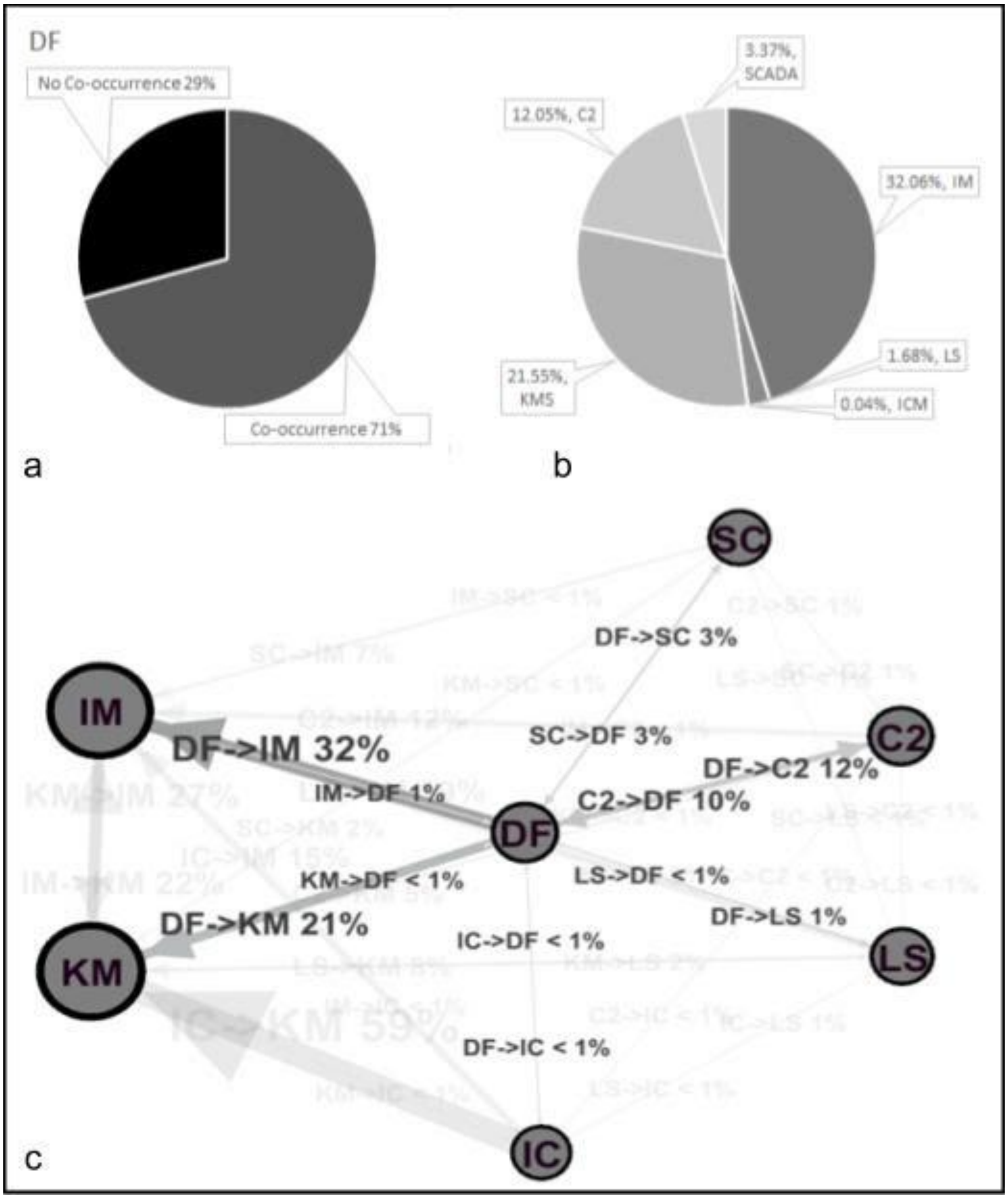

Figure 6. DF (Data, Information, and Sensor Fusion)

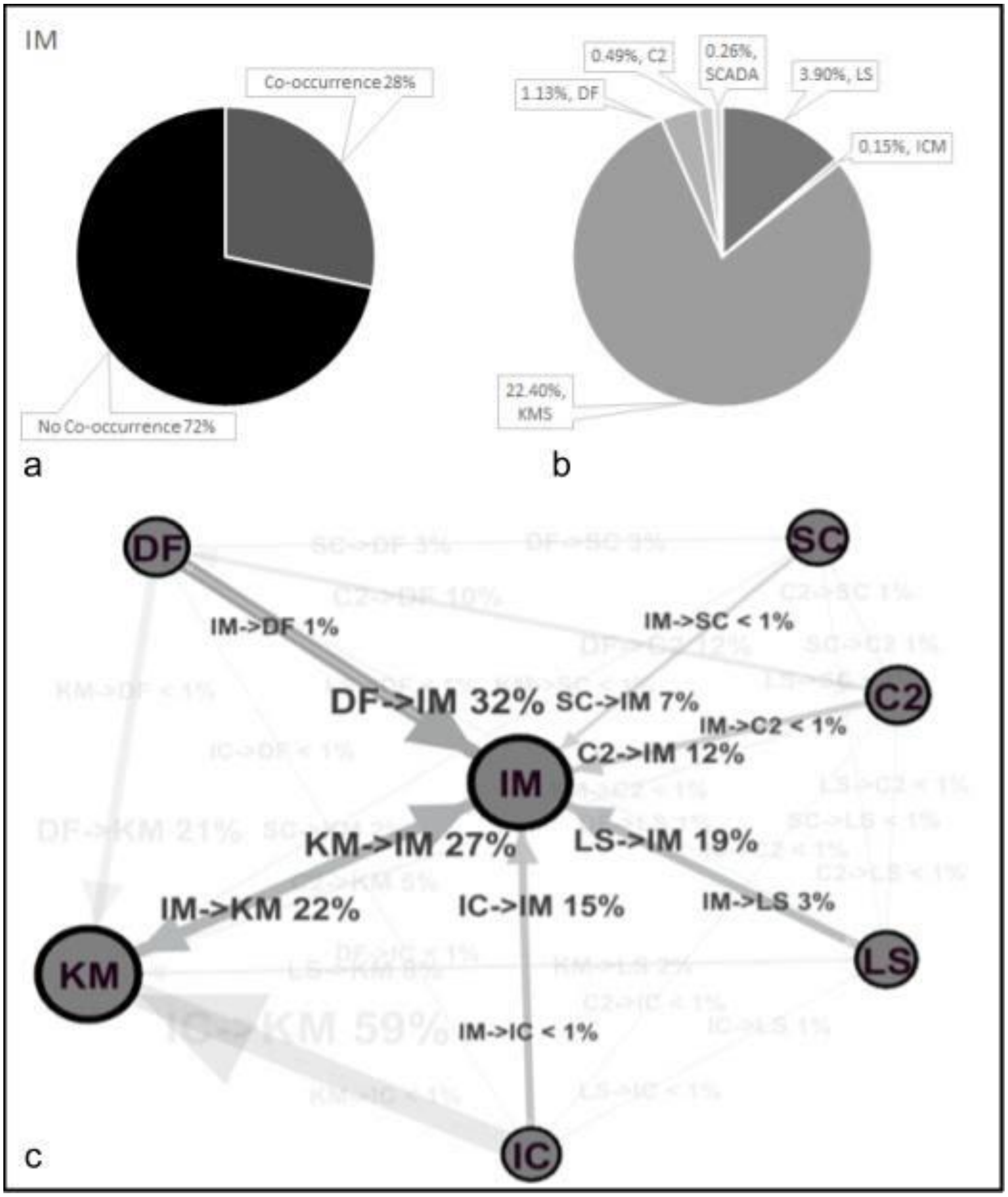

Figure 7. IM (Information Management)

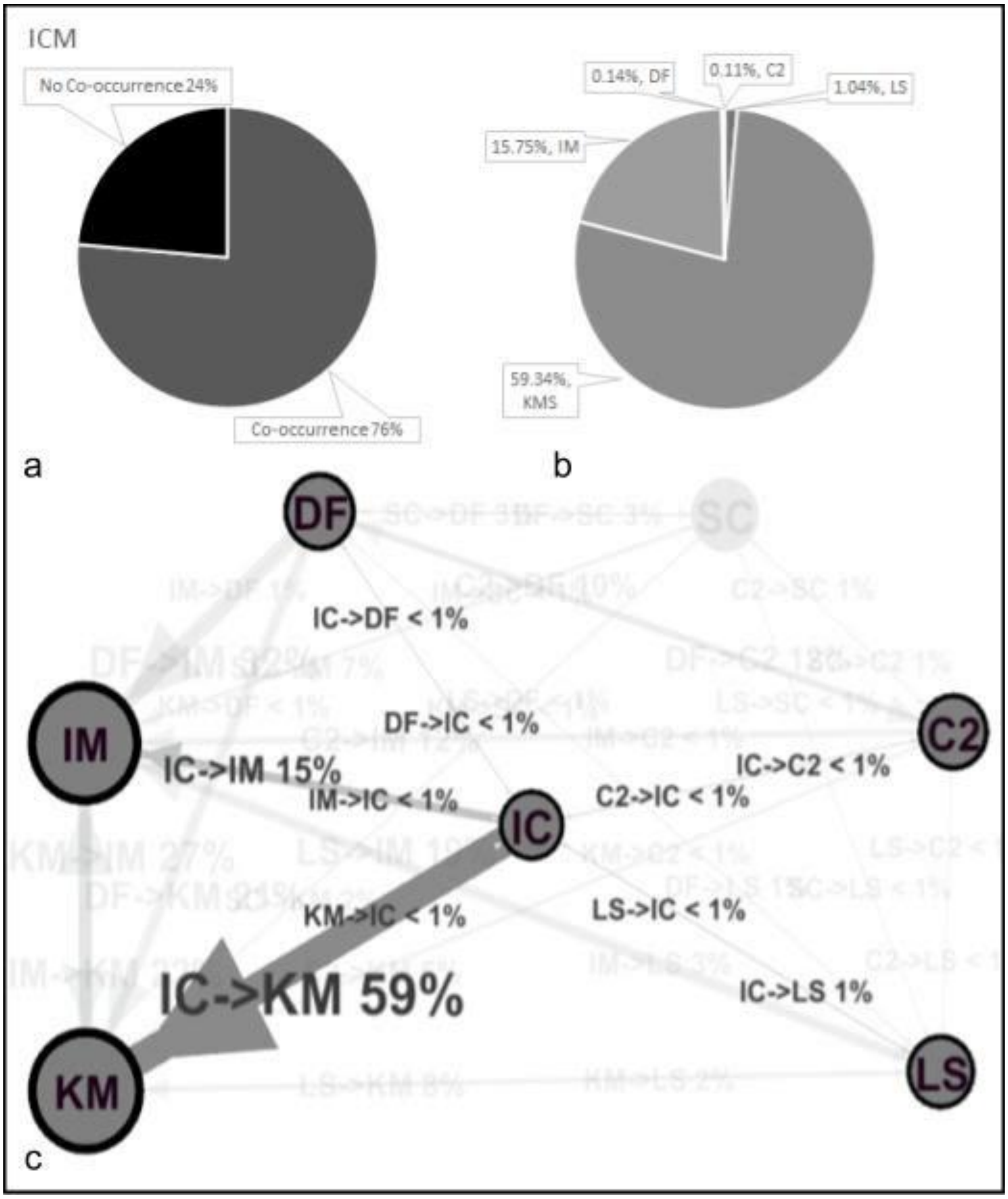

Figure 8. IC (Intellectual Capital Management)

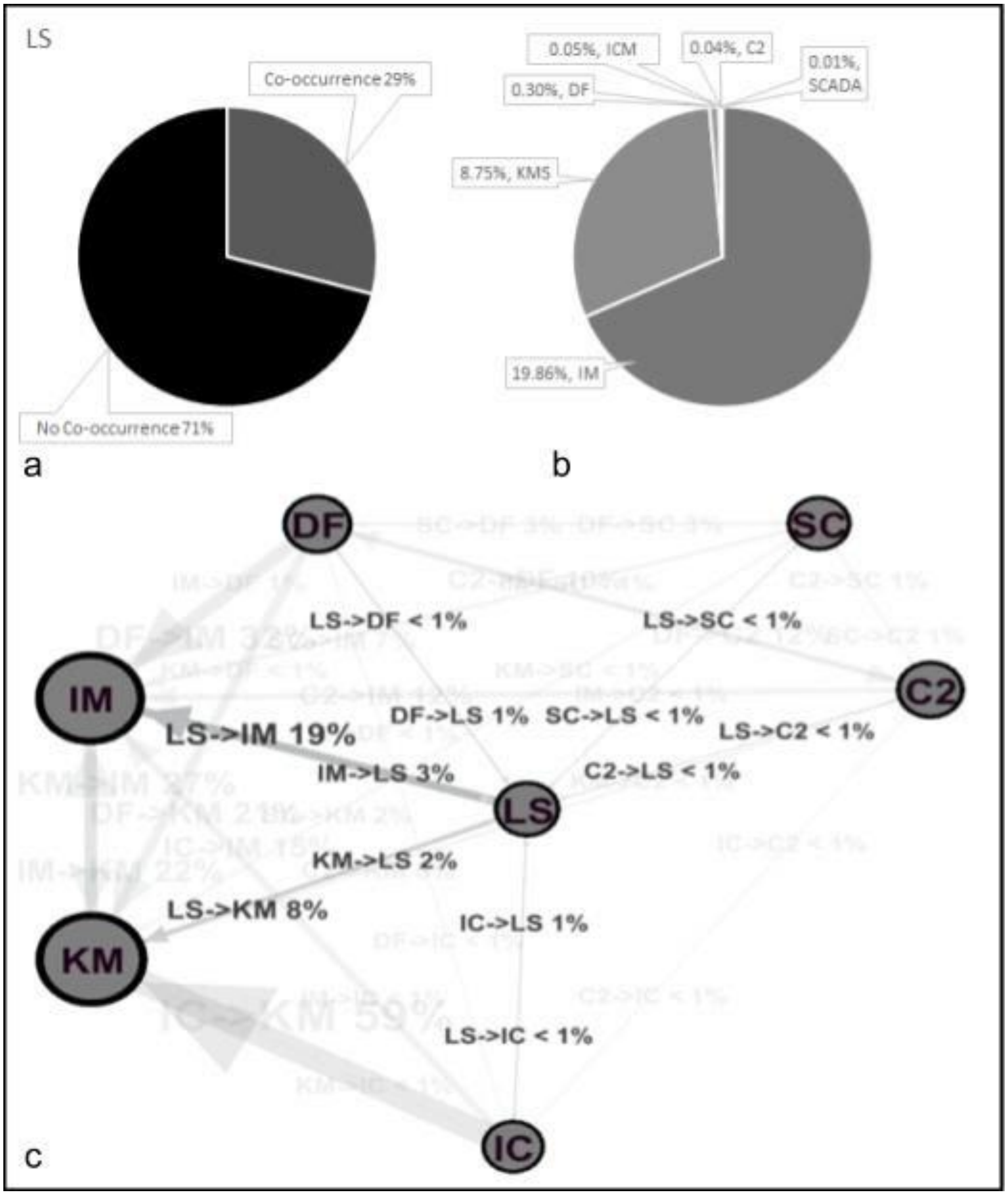

Figure 9. LS (Library Science)

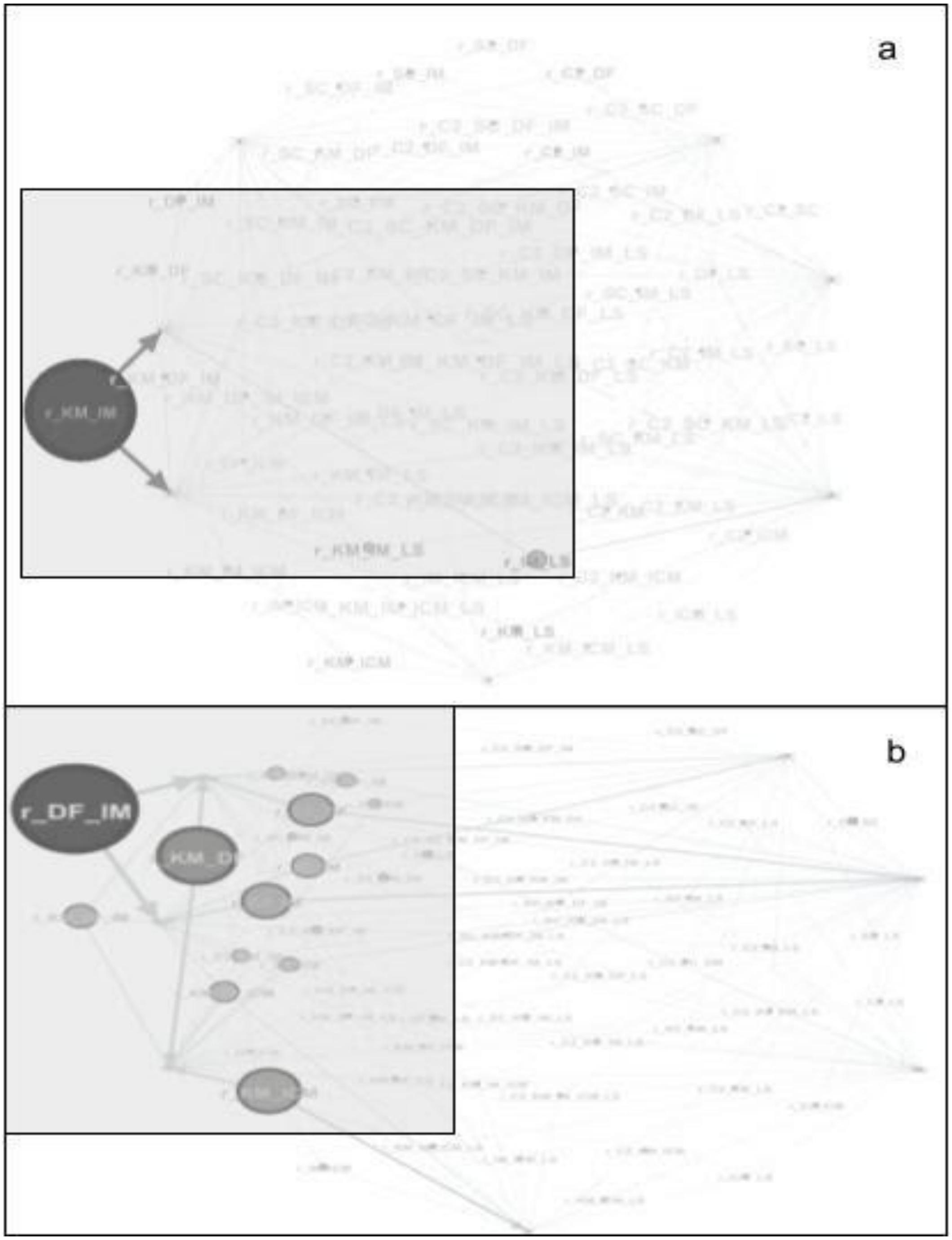

Figure 10. Gephi rendering of the "Search-Strings as Nodes" graph (see Appendix B, Supplemental Figure 3) before and after removing KM-IM, IM-LS, and KM-IM-LS search-string nodes for visualization purposes.

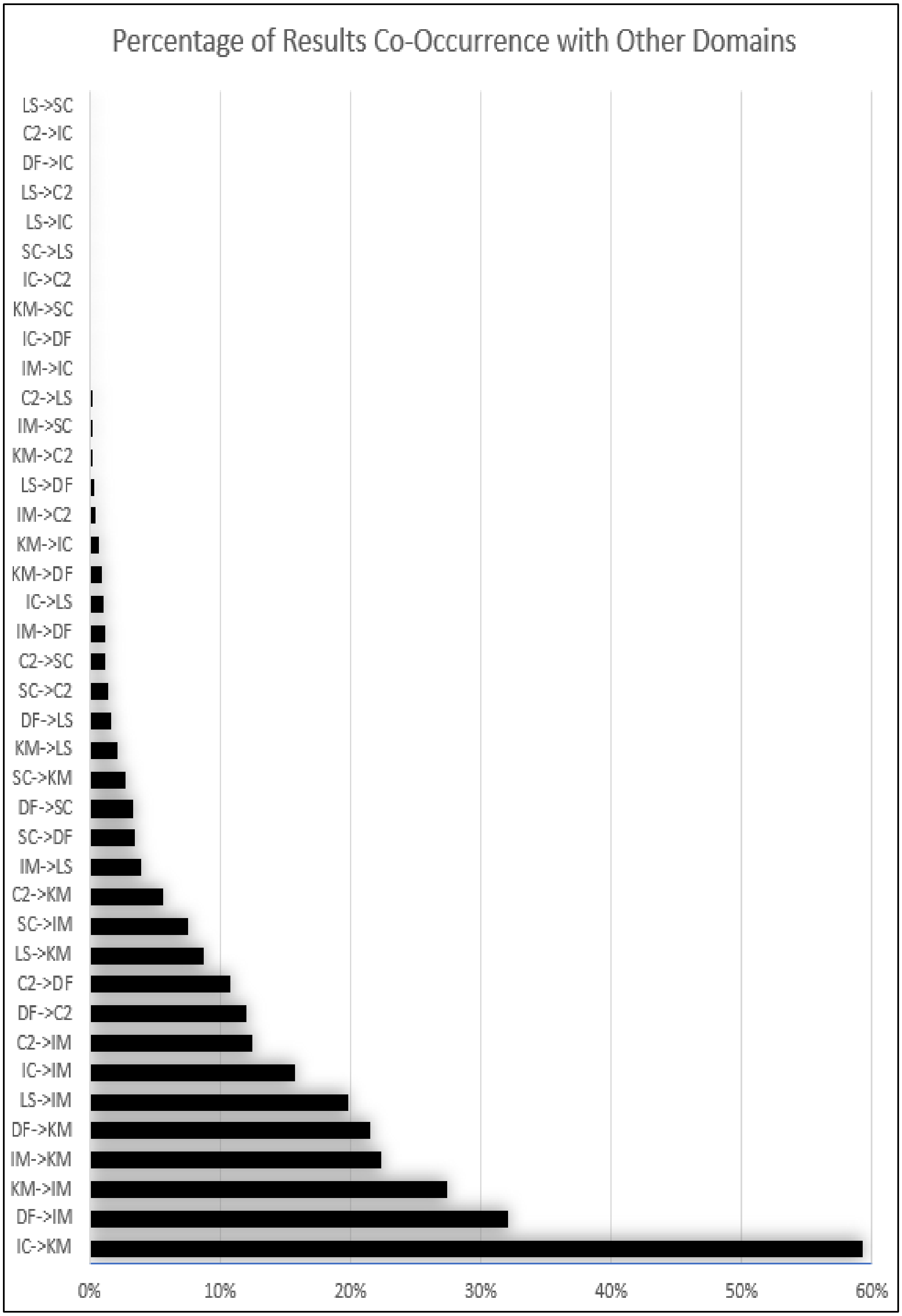

Figure 11. Percentage of results associated with one domain which had a co-occurrence of keywords with another domain.

Discussion

Here we performed keyword-driven searches on the Google Scholar database to assess the fragmentation and connection within the literature related to knowledge management (Table 1). We traced out broad trends in keyword occurrence, and co-occurrence, and used graph visualization to investigate the relationships among domains.

As a result of this exploratory analysis, an interesting pattern was found. Namely, that many papers directly motivated the transition between the use of one included area and another (see Table 1), or between included areas and other areas not initially considered or known. For example from business intelligence to information management [65], information technology to information management [66], information management to knowledge management [21,67], knowledge management to “interaction management” [68], knowledge management to “knowledge services" [69], knowledge management to “learning management” [70,71], “information resources management” to knowledge management [67], and knowledge management to records management [72].

Other relevant areas were discovered during searches that were not included or considered for inclusion in the target keywords in Table 1. Several significant areas are described in the paragraphs below.

Decision Support Systems

“Decision support systems” were found to be discussed alongside or as a feature of, adjacent to, or a complement to knowledge management and C2 systems [33,73,74]. Decision support systems are generally defined as a system which increases the quality of decision making and related processes primarily by aiding in the curation, synthesis, creation, and sharing of information with consideration for user and organizational dynamics [75]. Decision support systems had not been initially considered as a candidate for inclusion but should be in similar research in the future. The volume of decision support systems literature was comparable to that of knowledge management, information management, or library science and only ~6% of decision support systems results had co-occurrence of keywords with areas included in this study (see Appendix A-1).

Learning Management Systems

“Learning management systems” were found to be discussed alongside or as a feature of, adjacent to, or a complement to knowledge management [71,76,77], SCADA systems [78,79], and intellectual capital management [70,77,80]. Learning management systems are generally expected to assist in learning, knowledge gap handling, and management of learner data and include features such as personalized search and curriculum, rapid assessment of the state of the knowledge and progress of users, intellectual capital management features such as attribution and plagiarism detection within resources and generated content, curation and recommendation of resources and relevant problem scenarios, and reference management [81]. An exploratory search showed that 13% of the returned learning management results had a co-occurrence of keywords with this study's selected domains (see Appendix A-1), and many of the top resources (sorted by relevance) returned on this search were concerned specifically with the similarity and opportunity for synergy between learning management and these other domains [40,70,76].

Business Intelligence Systems

"Business intelligence systems" were found to be discussed alongside or as a feature of, adjacent to, or a complement to SCADA [82,83], knowledge management and information management [84–88], and decision support systems [88]. Business intelligence systems are defined as systems which help reduce the impact of cognitive overload and increase the quality of business decisions by providing situational awareness and curation, access, and synthesis of relevant intelligence products [89,90]. An exploratory search showed that the volume of business intelligence literature is comparable with that of knowledge management, information management, and literature management and an exploratory search showed only ~6% of business intelligence results having a co-occurrence of keywords with this study's selected domains (see Appendix A-1).

Information resources management

"Information resources management" was found to be discussed alongside or as a feature of, adjacent to, or a complement to knowledge management [67,91,92], information management [67], intellectual capital management [93], and SCADA systems [94], as well as other areas that are related but not included in this study, such as records management [95] and document management [92]. Information resource management was originally coined as a term by a US Presidential commission and intended to be an area concerned with the design, creation, collection, analysis, use, sharing and curation, storage, and retrieval of information, records, and knowledge. An exploratory search showed ~60% of information resources management results having a co-occurrence of keywords with this study's selected domains (see Appendix A-1).

Document management

"Document management" was found to be discussed alongside or as a feature of, adjacent to, or a complement to knowledge management [24], information management [24], learning management [96,97], information fusion [98,99], intellectual capital management [100], library science [101], and SCADA systems [102–105]. Document management is generally concerned with the collection, use, sharing, retention and storage, security and governance, retrieval, and identification of attributes associated with documents and records [106,107]. An exploratory search showed ~18% of document management results having a co-occurrence with keywords within this study's selected domains (see Appendix A-1). Surprisingly, despite having a nearly identical definition and scope to the area of records management, only ~8% of the results associated with document management had keyword co-occurrence with records management (see Appendix A-1).

There were several limitations to this study. As stated in the Introduction, an unknown amount of relevant literature may be unavailable due to it being classified by a government, or regarded as proprietary information by industry. Other limitations were related to the use of Google Scholar for performing searches. First, Google Scholar may provide results based on false positives and false negatives in keyword recognition, sometimes due to problems associated with the digitization or indexing of the document (e.g., spaces within a keyword or keywords being separated by line or page) [108]. Second, the keyword proportion in any database at any single time may not be reflective of the relative accessibility of this information to any specific researcher from the past or now [51,52,108]. Third, Google Scholar does not provide affordances to separate a positive recognition of the keyword in a text from a positive recognition of the keyword in the titles within cited works in a text—the ability to do so would have allowed for a more nuanced picture of the fragmentation and connection between various domains. Fourth, Google Scholar search results can vary, sometimes significantly, based on a variety of both known and unknown factors [108]. Fifth, temporality of results was not considered given that affordances for considering time of publication in conducting searches were restrictive for a manual search, that it is "not an infrequent occurrence" for Google Scholar to index dates incorrectly [109], and that Google Scholar provides no affordance for downloading the results of a search. Therefore, our estimates of usage and co-occurrence may not capture recent or contemporary trends in each area.

Conclusion

There appears to be an archipelago of partially-connected "islands" in the knowledge management space. The state of the literature indicated by the exploratory analysis conducted suggests a need for synthesis across these domains and areas of expertise so that each domain can benefit from research in others and reduce the likelihood of redundant work. However, the path towards this synthesis is unclear. In the face of this uncertainty, we conclude not with a single answer, but a set of potential avenues of synthesis and driving questions. Several approaches for this synthesis present themselves, some of which we present here as the beginning steps:

Restoring prominence of an existing keyword. Rehabilitation of an appropriate extant keyword could be attempted. knowledge management or information management for example could be restored as a central keyword around which all others could be reorganized. A conference or working group could be assembled to facilitate synthesis of the existing literature and wider adoption of the new framing. A compendium detailing the use and scope of these many terms could be written to serve as a common resource.

Creation of a new keyword. A new keyword or search-string could be generated to tag works related to information storage, search, and presentation. This keyword could be used within documents, or applied as an annotation to existing documents, reflecting the relevance of the document for knowledge management. A new synthetic keyword or string might be proposed as a tag for any kind of work broadly in the domains of Table 1, such as a novel emoji or hashtag such as #9jt05kw690j ("information" with each key shifted up and to the right one position on a QWERTY keyboard). Alternatively, a new term could be generated that describes or scopes the common set of challenges, approaches, and concerns of these various fields without necessarily intending to replace any of the extant ontologies. However, any of these approaches would have to be done with consideration for achieving wide adoption in order for them to be useful rather than further contribute to divergence among fields.

Encouraging interdisciplinary communities of practice. A longer-term approach may be to socially connect various domains of expertise with broader communities of practice and encourage interdisciplinary collaboration. This would connect networks and projects across silos and allow for synthesis and integration of terms and resources in a sustainable and organic manner.

New tools. Computable documents, computable ontologies, and low-cost distributed knowledge management tools could enable next generation indexing, annotation, and semantic tagging of digital artefacts that would allow users to search not just for syntax but for meaning and use of syntax, and could do so across languages [110–113]. This kind of search would reduce the impact of diverging ontologies and increase situational awareness of the literature. Further, tools of this kind would help index non-academic resources and have value in handling challenges outside of the academic space, such as cognitive security in civil society, education, and journalism [12,114].

Awareness. Increased recognition of the similarity of challenges, approaches, and concerns across fields on its own could set the stage for synthesis and integration across fields. At this time, no results are provided for any search including all of the included domains within this study, let alone all of the other similar domains found during exploratory searches.

Driving questions for ongoing research:

- How can we search, read, and cite across fields to make better knowledge management decisions?
- How can connecting communities, skill sets, and understandings across fields lead to better performing systems?
- How can uncirculated or currently unindexed literature resources from industry and government be safely and respectfully indexed, queried, and quantified?
- How can we synthesize the requirements of systems associated with the many domains concerned with

creating, sharing, integrating, storing, attributing, accessing, searching, and curating digital information?

- How can systems with heterogeneous datasets and domain-specific information be provided for users from different backgrounds and areas of expertise, without cognitive overload?

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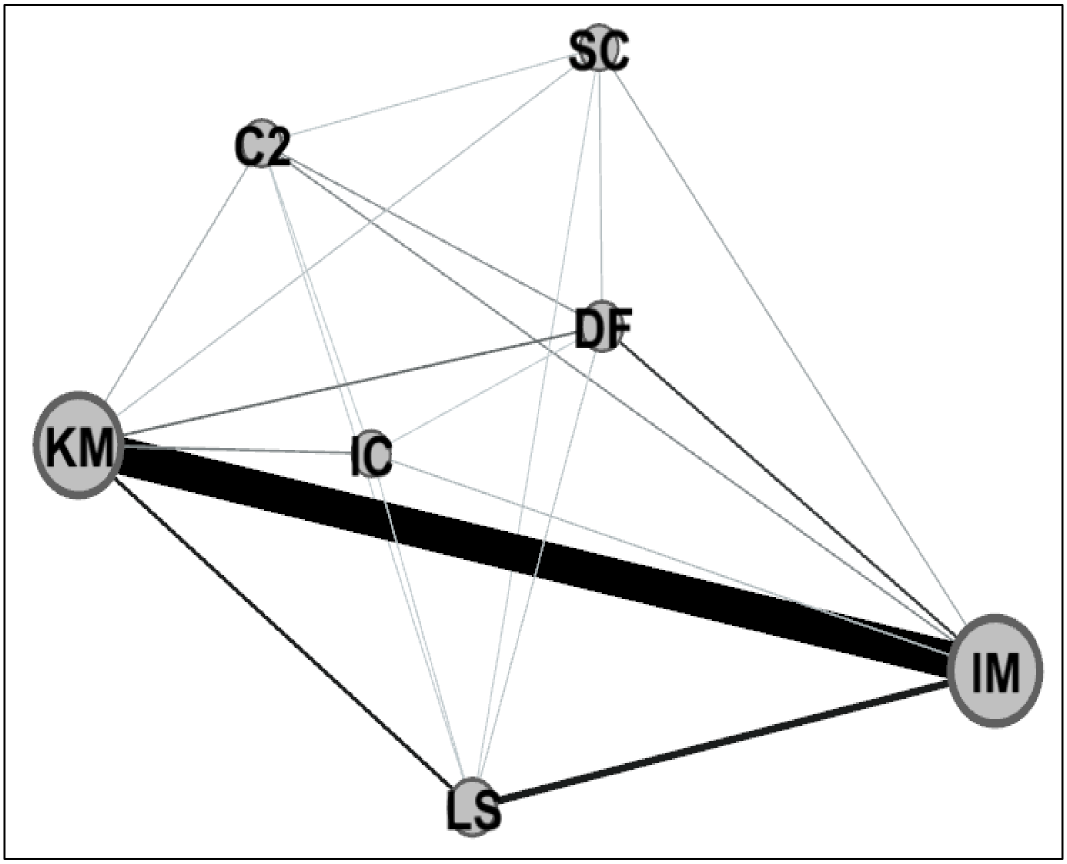
Appendices

Appendix A. Supplemental Files

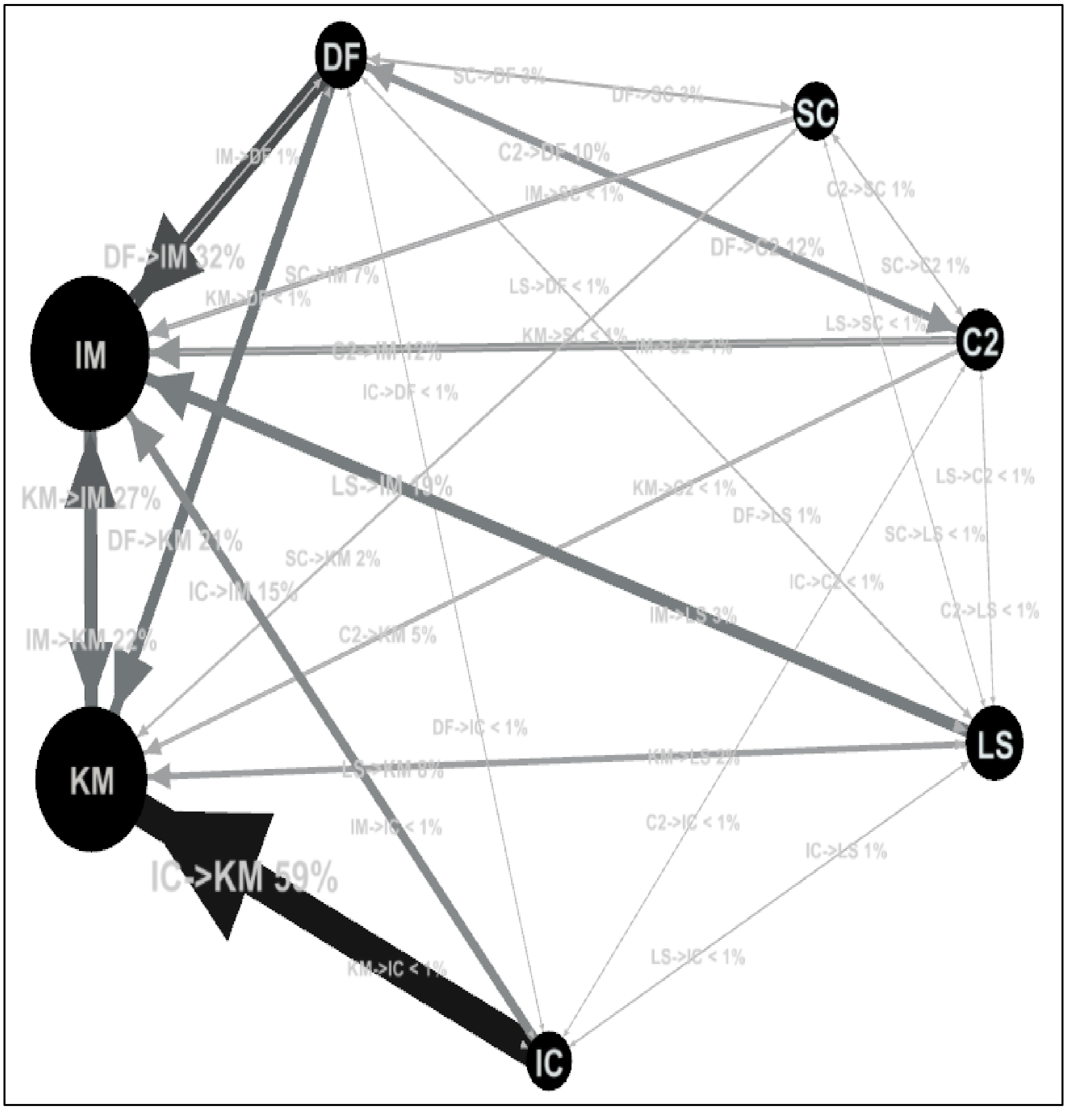
All files available at https://github.com/Cordes-RJ/KMA

ID	Name
A-1	Additional Searches
A-2	Python Script
A-3	Python Outputs - Search-Strings
A-4	Python Outputs - Edges
A-5	Python Outputs - Nodes
A-6	Results
A-7	Folder - Gephi - Nominal Co-occurrence
A-8	Folder - Gephi - Percentage Co-occurrence
A-9	Folder - Gephi - Search-Strings as Nodes

Appendix B. Supplemental Figures



Supplemental Figure 1. Gephi Rendering: Nominal Co-Occurrence



Supplemental Figure 2. Gephi Rendering: Percentage Co-Occurrence

Supplemental Figure 3. Gephi Rendering: Search-Strings as Nodes (KMS-IM-LS connections removed for visualization)