Role of Artificial Intelligence in Operations Environment: A Review and Bibliometric Analysis

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Abstract

Purpose - 'Technological Intelligence' is the capacity to appreciate and adapt technological advancements, and 'Artificial Intelligence' is the key to achieve persuasive operational transformations in majority of contemporary organizational set-ups. Implicitly, artificial intelligence (the philosophies of machines to think, behave, and perform either same or similar to humans) has knocked the doors of business organizations as an imperative activity. Artificial intelligence, as a discipline, initiated by scientist John McCarthy and formally publicized at Dartmouth Conference in 1956, now occupies a central stage for many organizations. Implementation of artificial intelligence provides competitive edge to an organization with a definite augmentation in its societal and corporate status. Mere application of a concept will not furnish real output until and unless its performance is reviewed systematically. Technological changes are dynamic and advancing at a rapid rate. Subsequently, it becomes highly crucial to understand that where have we reached with respect to artificial intelligence research. Present article aims to review significant work by eminent researchers towards artificial intelligence in the form of top contributing universities, authors, keywords, funding sources, journals, and citation statistics.

Design/methodology/approach - As rightly remarked by past researchers that reviewing is learning from experience, research team has reviewed (by applying systematic literature review through bibliometric analysis) the concept of artificial intelligence in this article. A sum of 1854 articles extracted from Scopus database for 2018-2019 (31st May) with selected keywords (artificial intelligence, genetic algorithms, agent based systems, expert systems, big data analytics, and operations management) along with certain filters (subject-business, management, and accounting; language-English; document-article, article in press, review articles; source-journals).

Findings - Results received from cluster analysis focus on predominant themes for present as well as future researchers in the area of artificial intelligence. Emerged clusters include Cluster 1: Artificial Intelligence and Optimization; Cluster 2: Industrial Engineering/Research and Automation; Cluster 3: Operational Performance and Machine Learning; Cluster 4: Sustainable

Supply Chains and Sustainable Development; Cluster 5: Technology Adoption and Green Supply Chain Management; and Cluster 6: Internet of Things and Reverse Logistics.

Originality/value - The result of review of selected studies is in itself a unique contribution and a food for thought for operations managers and policy makers.

Keywords: Artificial intelligence, operations management, network analysis, bibliometric analysis, systematic review

1. Introduction

Artificial Intelligence is the key to achieve persuasive operational transformations in majority of contemporary organizational set-ups. Implicitly, artificial intelligence (the philosophies of machines to think, behave, and perform either same or similar to humans) has knocked the doors of business organizations as an imperative activity (Aloini *et al*., 2018; Ammar *et al*., 2018; Schmidt and Hazır, 2019). Artificial intelligence, as a discipline, initiated by scientist John McCarthy (McCarthy et al., 2006) and formally publicized at Dartmouth Conference in 1956 (Moor, 2006), now occupies a centre stage for many organizations (Balugani *et al*., 2018; Sreedharan *et al*., 2018; Balugani *et al*., 2019; Kumar, 2019). Artificial intelligence forms a part of computer or computing science that generates expert systems, algorithms and programs (Aldasoro *et al*., 2019; Chen *et al*., 2019; Colicchia *et al*., 2019). The real purpose of artificial intelligence is to imitate human brain and perform decision making like human beings during various situations and circumstances (De Sousa Jabbour *et al*., 2018; Deshpande *et al*., 2018). Practically, it is the ability of a machine or equipment to think, learn, and act as humans. Although the concept of artificial intelligence was initiated in 1956, but it has gained momentum recently (Dolgui *et al*., 2018; Felfel *et al*., 2018; Garza-Reyes, 2018; Dolgui *et al*., 2019). Artificial intelligence is majorly known for its computing capabilities and power, data and genetic algorithms (Dubey *et al*., 2018a, 2018b, 2018c, 2018d; He and Yang, 2018). Artificial intelligence increases the ability of processors significantly. Availability of huge amount of data related to medicine, weather, defence and other similar areas with reduced data maintenance time and cost is the best example to be quoted (Nebl and Schroeder, 2011; Chaouch, 2018; Dubey *et al*., 2019a, 2019b). Artificial intelligence is categorised as narrow artificial intelligence and general artificial intelligence. The former deals with simple issues like organizing business events/calendars, resolving customer service enquiries. However, the latter handles complex issues like driving cars, robotics, and reducing language barriers (Breja *et al*., 2011; Choi *et al*., 2018; Dupont *et al*., 2018). Business creation by artificial intelligence is expected to touch $3.9 trillion in 2022, while it was $1.2 trillion in 2018, reported a increase of 70 percent from 2017 (Brown, 2013; Fatorachian and

Kazemi, 2018; Richards *et al*., 2019). Further, expert systems, agent based systems, big data analytics, and genetic algorithms are few other concepts that fall in close proximity of artificial intelligence (Gunasekaran, 2018; Ghadge *et al*., 2019; Gupta, 2019). Expert systems constitute one of the most essential aspects of artificial intelligence. It mimics the decisiveness of an expert human to solve complex issues and problems by applying reasoning and analytical abilities like computers (Keeble-Ramsay and Armitage, 2010; Hamdi *et al*., 2018; Hazen *et al*., 2018; Horng *et al*., 2018). Agent based systems, also known as agent-based models are computer-based models, which perform as autonomous agents. Such agents can work either in groups or individually towards assigned tasks. Groups may include organizations (Jeble *et al*., 2018; Jha *et al*., 2018). Big data denotes huge volume of data, and big data analytics is the management of such data. It does systematic organization of unorganized data that might be large and complex. The technique is extremely useful to avoid information asymmetry (Kazancoglu *et al*., 2018; Kumar *et al*., 2018; Kumar *et al*., 2019). Genetic algorithm is the process of optimization that is completely based on natural selection of resources. It relates itself with natural evolution process with an aim to select most suitable resources for productive activities (Laengle *et al*., 2018; Lu *et al*., 2018; Vouzas and Katsogianni, 2018; Luthra *et al*., 2019).

Operations management is a complex task involving managing of procurement, manufacturing, quality, logistics, and physical distribution. The complexity increases depending upon nature of business and scale of manufacturing operations (Mentzer *et al*., 2008). Operations managers face multiple challenges while managing operations. Major challenges include maintaining of manufacturing schedules, dispatch commitments in times of supply uncertainties, and challenges rising in managing of long and complex distribution networks (Hayes, 2002; Karlsson, 2003; Högström, 2011). Flexibility in production lines can switchover from one operation to another depending upon resource availability and such actions can be easily taken care through artificial intelligence enablement (Renzi *et al*., 2014). Artificial intelligent based machines have gained huge popularity in agriculture and food industry for proper segregation and selection of items; quick and accurate packaging has bought a revolutionary change in this digital age (Wauters *et al*., 2012). However, subject of artificial intelligence in the area of operations management is yet to mature; which necessitates more review and case based research studies to further extend the knowledge base.

Given above background, main objective of present article is to systematically review the existence of artificial intelligence and related domains in combination with operations management in the last two years of time. Specifically, research team aims to explore different combinations while keeping operations management as the common variable; identify the predominant themes related to artificial intelligence; discuss the future scope of recognised themes; and use of BibExcel and Gephi as unique contribution. The rest of the article is segmented into various sections covering literature review, research methodology and data statistics, data analysis, discussion, and conclusion.

2. Review of literature

Artificial intelligence includes every machine or equipment that uses computational abilities to work and perform like humans or replaces humans (Mishra *et al.*, 2018, 2019). Artificial intelligence is the process of manufacturing enabled by machines who can imitate human activities as original (Coleman, 2013; Chung, 2018; Hasuike and Mehlawat, 2018; Nguyen *et al.*, 2018; Nie *et al.*, 2019).

Pei *et al.* (2019) opine that artificial intelligence enables programs which when put into any computational device initiates thinking capability of machines. Contemporary, the trend of robotic cars is extremely evidenced. Such driverless cars are really gathering an attention from users due to highly technologically equipped design that can obey traffic rules, control speed, and several other similar functions without human intervention (Porselvi *et al.*, 2018; Prajogo *et al.*, 2018). In contrary to existing and expected benefits of artificial intelligence, Qiu *et al.* (2018) draws attention towards side effects of technology. The author further highlights dependability of humans on technology; and connects it with the notion that excess of everything is bad. Similarly, the speed at which humans are adopting tech-savvy life, it seems little dangerous (Karapetrovic, 2010; Liu *et al.*, 2018; Raut *et al.*, 2018; Raut *et al.*, 2019a, 2019b). In response, few eminent researchers comment that keeping distance with technology in present era is sheer foolishness. Technological interventions constitute a major portion of activities in daily routine of individuals (Ray, 2018). In the words of Ren *et al.* (2019), expert systems facilitates human like cognitive skills to perform simpler yet important aspects of human life. It acts like a human to solve analytical problems, mimics visual and speech issues, understands and removes language difficulties. Four main elements of expert systems cover knowledge base (explains the collection of facts, rules as desired from human experts), inference engine (talks about how to solve problems critically), scheduler (takes care of serials of a problem in question), and user interface (enables adequate interaction between various programs that run in parallel) (Petridis and Dey, 2018; Shibin *et al.*, 2018; Singgih *et al.*, 2018; Sheng *et al.*, 2019). Further, components of genetic algorithms highlight its importance (Stefanini et al., 2018; Tseng *et al.*, 2018). Firstly, this process creates an ambience of solution for a particular issue that matches with human brain. Secondly, it evaluates the sustainability of proposed solution. However, Van Gils *et al.* (2018, 2019) argues that genetic algorithms provide biased solution to the problems due to infinite nature of problems. Wang *et al*. (2018a, 2018b) elaborates agent based system as the process by which a bigger problem is dissected into smaller problem, which can be solved alternatively. It increases the problem solving capabilities of artificially designed systems enabling wider coverage. With this quality, agent based systems can provide solutions for not limited to customer relationship management, supply chain management, demand planning and forecasting, product development and penetration (Psomas *et al*., 2018; Yadav *et al*., 2018; Yao and Askin, 2019). Possibilities of successful implementation of artificial intelligence are largely dependent on big data (Yu *et al*., 2018, 2019). Everything revolves around information exchange and big data analytics facilitates management, analysis, and interpretation of data in desired format, thereby speeding the processes. Eventually, all these activities when combined together results in operational excellence by providing better management of operations (Zerbino *et al*., 2018; Zhou *et al*., 2018). Therefore, the present article aims to explore artificial intelligence and mentioned variables in combination with operations management through systematic literature review. The subsequent section shall discuss research methodology and data statistics.

3. Research methodology and data statistics

Exhaustive review of selected articles significantly contributes towards the existing body of literature. Systematic literature reviews are highly dependent on suitable selection of keywords. It is a step wise process involving five stages i.e. screen, assemble, organize, draft, and finally presentation of results (Tatham *et al*., 2017). Similar process has been adopted in the present work to identify different themes based on selected keywords, followed by prediction of future scope of work with reference to artificial intelligence.

3.1 Primary keywords and search results

In the beginning, research team proceeded with random selection of certain keywords that includes “artificial intelligence”, “genetic algorithms”, “expert systems”, “agent based systems”, and “big data analytics”. In the next step, each of these keywords is merged with “operations management”, and various combinations comprising (1) artificial intelligence AND operations management, (2) genetic algorithms AND operations management, (3) expert systems AND operations management, (4) agent based systems AND operations management, (5) big data analytics AND operations management. Artificial intelligence is a technique to replace human involvement. This work presents how this technique has been advantageous especially to operational excellence (Richards *et al*., 2019). Systematic literature reviews are pursued by selecting one of the available databases. Most popular online databases include SCOPUS, Web-of-Science, and Science Direct. Research team has selected Scopus database for present piece of work. Attributable reason is the plausibility of highest number of articles published in almost 22000 journals (Emerald, Taylor and Francis, Wiley, Elsevier, and Springer) in comparison to other online databases (Web of Science with 14000 journals approximately). Majority of available articles belong to various disciplines (business management and accounting, econometrics, social sciences, information systems, decision sciences, materials science etc.). Abstraction of articles from Scopus resulted in 5390 articles towards each respective combination i.e. artificial intelligence AND operations management (1681), genetic algorithms AND operations management (1445), expert systems AND operations management (1026), agent based systems AND operations management (963), big data analytics AND operations management (575). This extraction covers published articles from 2018-2019 (until 31 May). Further, research team focuses the category of fully published articles and articles in press excluding book chapter, editorial, and conference articles. Comprehensive allocation of articles with respect to selected keywords is shared below (refer to Table 1). Identified articles provide information related to contributing author(s), publication year, article source, article affiliation, and abstracts of articles.

Table 1: Primary Search Results

Keywords	Search Results (No. of Articles)
Artificial Intelligence AND Operations Management	1681
Genetic Algorithms AND Operations Management	1445
Expert Systems AND Operations Management	1026
Agent Based Systems AND Operations Management	963
Big Data Analytics AND Operations Management	575
Total	5390

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

3.2 Refining of initial results

Next step proceeds with the refinement of primary search results by applying certain filters (Subject-business, management and accounting; Language-English; Source- journals). A figure of 1854 articles i.e. artificial intelligence AND operations management (684), genetic algorithms AND operations management (443), expert systems AND operations management (345), agent based systems AND operations management (246), big data analytics AND operations management (134) is generated (refer to Table 2) in RIS format. Articles without DOI are excluded from the study. The present work purely focuses on artificial intelligence and its close connection with other related terms. Eventually, research team shall discuss identified clusters in the upcoming sections.

Table 2: Filtered Results

Keywords	Search Results (No. of Articles)
Artificial Intelligence AND Operations Management	686
Genetic Algorithms AND Operations Management	443
Expert Systems AND Operations Management	345
Agent Based Systems AND Operations Management	246
Big Data Analytics AND Operations Management	134
Total	1854

Source: Scopus Database; 2018 to 2019 (31 May) and Authors' Own Compilation

3.3 Descriptive statistics

Descriptive statistics explains concentration of articles as yearly publication, journal-wise publication, affiliation-wise publication, top 10 countries, subject classification, and top 20 funding sponsors based on information received from Scopus database related to artificial intelligence and its allied domains. Foremost description is about yearly publication of articles on artificial intelligence (refer to Table 3 and Figure 1). A huge contribution is evidenced in the year 2018 (1028), followed by 2019 (826; until 31st May 2019). Recorded figures denote wide interest of author(s) to research and contribute towards artificial intelligence.

Table 3: Yearly Publication (Artificial Intelligence)

Year	Number of Articles
2019*	826
2018	1028

Source: Scopus Database; 2018 to 2019* (31st May) and Authors' Own Compilation

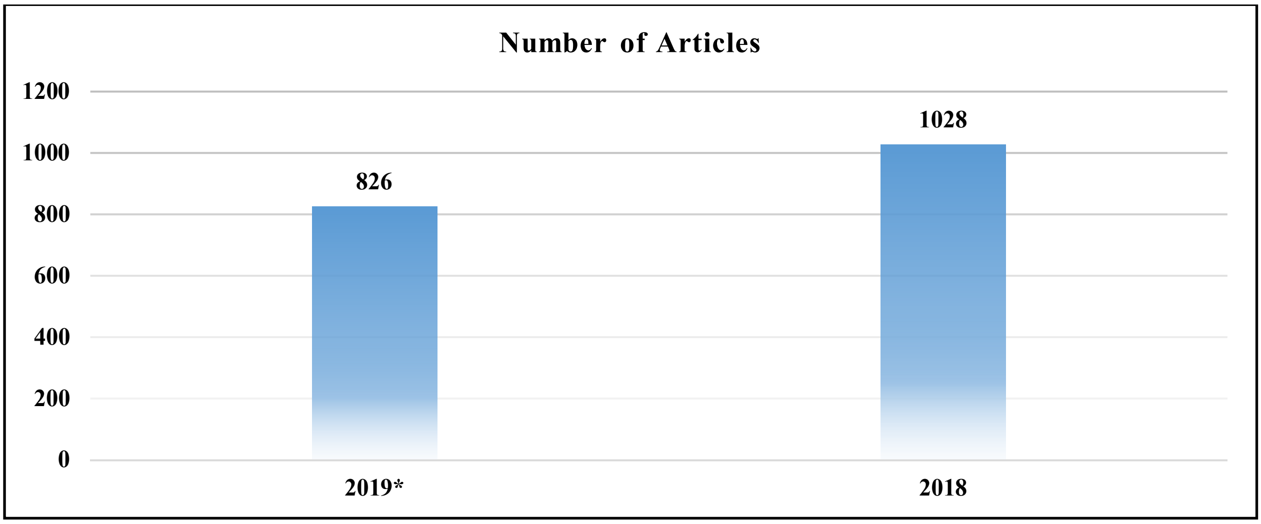

Figure 1: Distribution Trend of Published Articles

With respect to journal-wise contribution of articles, research team has presented a list of top 20 journals who publish articles based on artificial intelligence in last two years of time. The information shall prove extremely useful for researcher(s) who are working towards artificial intelligence, and for other interested groups. Most popular journals considering work related to artificial intelligence include common journals are IJPR (156), JCP (153), IJSAEM (95), IJPE (76), BM (59), and the list continues (refer to Table 4 and Figure 2).

Table 4: Journal-Wise Publication (Artificial Intelligence)

Journal Title	Number of Articles
International Journal of Production Research (IJPR)	156
Journal of Cleaner Production (JCP)	153
International Journal of Systems Assurance Engineering and Management (IJSAEM)	95
International Journal of Production Economics (IJPE)	76
Benchmarking: An International Journal (BM)	59
Transportation Research Part E: Logistics and Transportation Review (LTR)	37
International Journal of Services and Operations Management (IJSOM)	34
Omega: The International Journal of Management Science (OM)	33
Production Planning and Control (PPC)	30
Production and Operations Management (POM)	27
International Journal of Supply Chain Management (IJSCM)	22
Technological Forecasting and Social Change (TFSC)	21
Decision Support Systems (DSS)	16
Industrial Management and Data Systems (IMDS)	15
International Journal of Logistics Management (IJLM)	14
Business Process Management Journal (BPMJ)	13
Journal of the Operational Research Society (JORS)	12
International Journal of Productivity and Performance Management (IJPPM)	11
International Journal of Quality and Reliability Management (IJQRM)	11
International Transactions in Operational Research (ITOR)	11

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

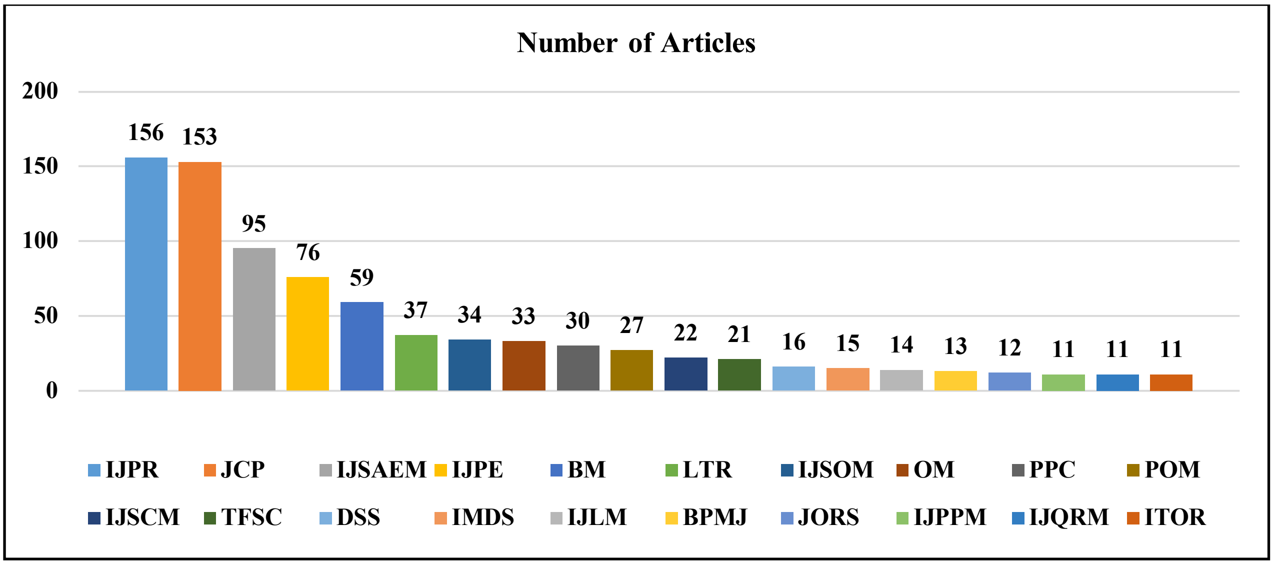

Figure 2: Journal-Wise Publication

Affiliation-wise segregation of articles presents an interesting statistics for researcher(s) and academician(s). This section shares list of topmost universities globally that are highly contributing towards research outputs in the area of artificial intelligence. Most active universities include UT (25), HKPU (20), IITR (20), UP (16), IITD (13), and sequence goes on (refer to Table 5 and Figure 3). This analysis can be a revelation for rest of other institutions because research in technological upgradations is on high demand across the world.

Table 5: Affiliation-Wise Publication (Artificial Intelligence)

University/Institute Name	Number of Articles
University of Tehran (UT)	25
Hong Kong Polytechnic University (HKPU)	20
Indian Institute of Technology Roorkee (IITR)	20
University of Plymouth (UP)	16
Indian Institute of Technology Delhi (IITD)	13
Indian Institute of Technology Kharagpur (IITK)	10
National Institute of Industrial Engineering (NIIE)	10
Montpellier Business School (MBS)	10
Ministry of Education China (MEC)	9
University of Kent (UK)	8

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

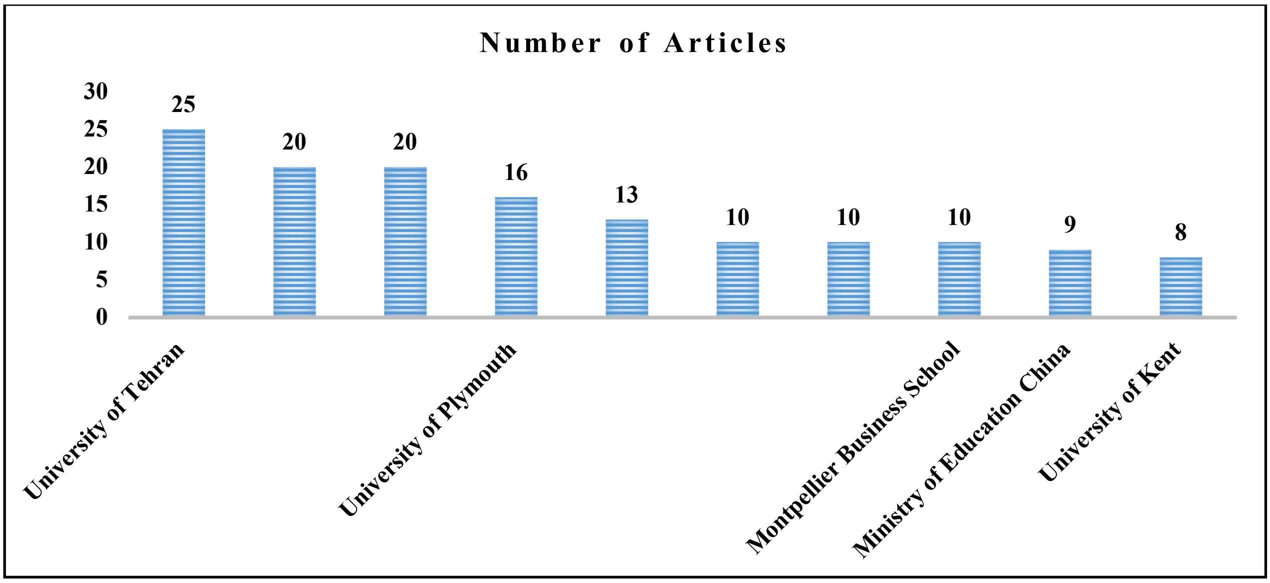

Figure 3: Affiliation-Wise Publication

Every country feels concerned about economic growth and development, which is to some extent related to research oriented activities. Growth in research output is one of the main signals of progress for almost every country. Technological developments are happening at an express rate globally, and it becomes deadly need of every country to match with technological competition. The list of top 10 countries, which contribute or/are working towards artificial intelligence in the last two years of time is shared below. Top most countries are India (364), United States (352), China (275), United Kingdom (197), Iran (146), and for rest Table 6 and Figure 4 can be consulted. The present analysis is a revelation for other countries that are lagging behind in this race.

Table 6: Top 10 Countries (Artificial Intelligence)

Country	Number of Articles
India	364
United States	352
China	275
United Kingdom	197
Iran	146
France	83
Italy	82
Germany	78
Australia	75
Brazil	66

Source: Scopus Database; 2018 to 2019 (31 May) and Authors' Own Compilation

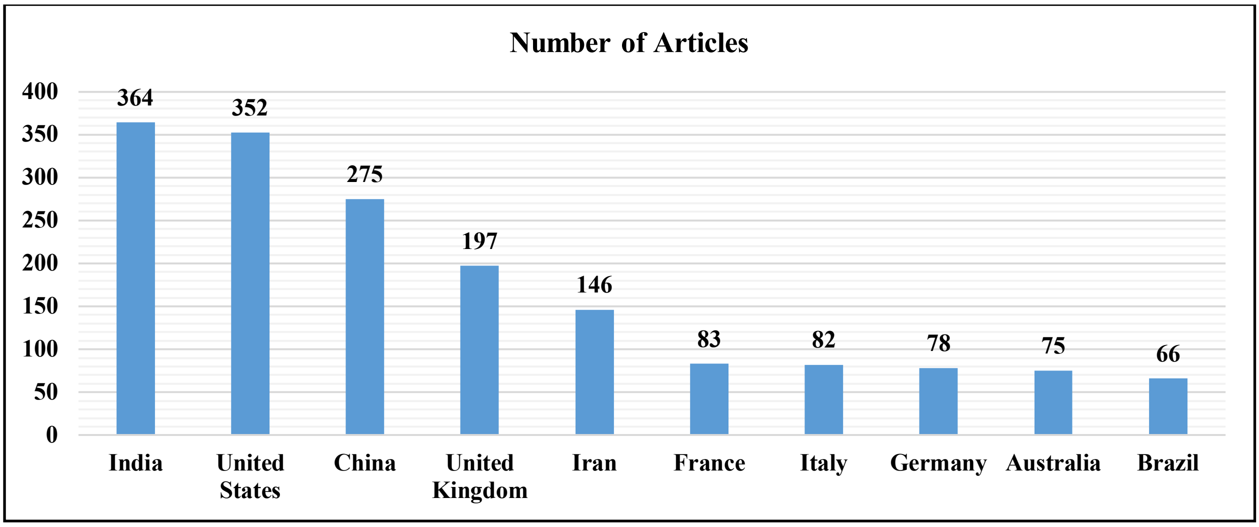

Figure 4: Country-Wise Publication

Technology has touched almost every aspect of human life, be it personal or professional. The field of education is no exception. Diverse subjects one-way or the other connects themselves with technology. This section demonstrates number of publications in various subjects in combination with artificial intelligence. The aspect of artificial intelligence is covered most in business, management, and accounting (1854), engineering (903), decision science (861), computer science (312), social sciences (212), and rest subject areas can be referred from Table 7 and Figure 5.

Table 7: Subject Classification (Artificial Intelligence)

Subject	Number of Articles
Business, Management and Accounting	1854
Engineering	903
Decision Sciences	861
Computer Science	312
Social Sciences	212
Environmental Science	183
Energy	175
Economics, Econometrics and Finance	168
Psychology	58
Mathematics	43
Arts and Humanities	33
Physics and Astronomy	6
Agricultural and Biological Sciences	3
Materials Science	3
Medicine	1
Multidisciplinary	1

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

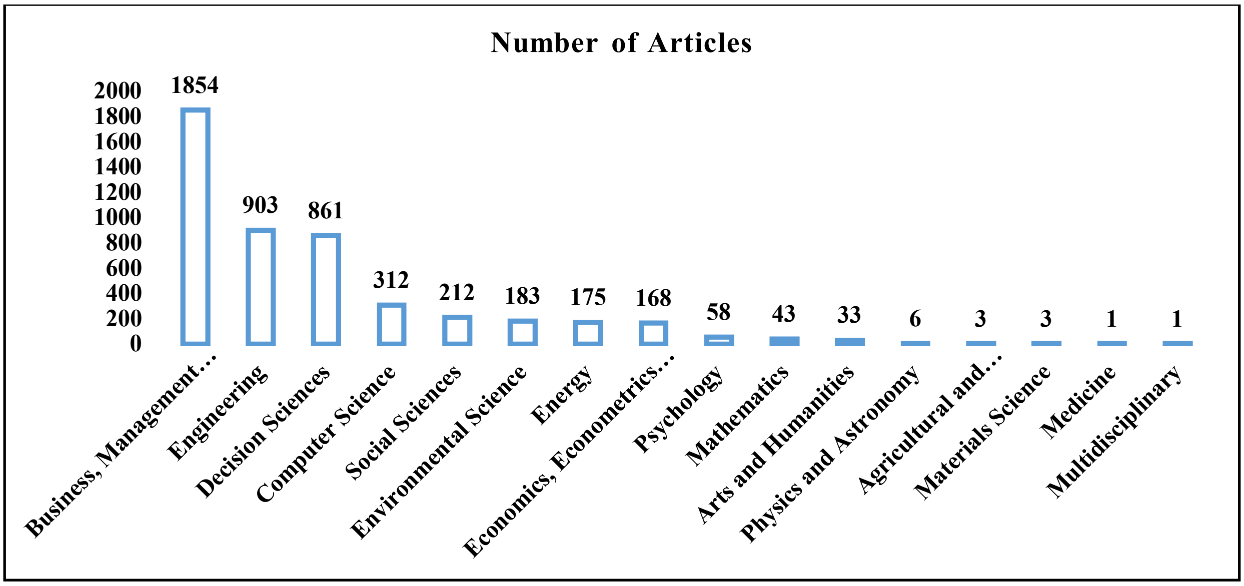

Figure 5: Subject-Wise Publication

Funded research is most awaited aspect for researchers and academicians. The plausibility of getting a research funding is a big achievement for institutions. The results confirm that many foundations, institutions, and sponsors are funding research related to artificial intelligence in the form of research projects, consultancy projects, doctoral and post-doctoral academic fellowships, and other related activities. In last two years, organizations that have provided funding include National Natural Science Foundation of China (159), National Council for Scientific and Technological Development (27), Fundamental Research Funds for the Central Universities (24), Coordination for the Improvement of Higher Education Personnel (22), National Science Foundation (16), and the list goes on (refer to Table 8 and Figure 6). The results can guide future researcher(s) to approach for funding.

Table 8: Top 20 Funding Sponsors (Artificial Intelligence)

Funding Organization	Number of Articles
National Natural Science Foundation of China	159
National Council for Scientific and Technological Development	27
Fundamental Research Funds for the Central Universities	24
Coordination for the Improvement of Higher Education Personnel	22
National Science Foundation	16
Humanities and Social Science Fund of Ministry of Education of China	12
National Aerospace Science Foundation of China	12
China Postdoctoral Science Foundation	11
Engineering and Physical Sciences Research Council	11
Hong Kong Polytechnic University	11
Natural Sciences and Engineering Research Council of Canada	11
European Commission	10
Sao Paulo Research Foundation (FAPESP)	9
Natural Science Foundation of Guangdong Province	9
Foundation for Science and Technology	8

China Scholarship Council	7
National Research Foundation of Korea	7
Ministry of Science, Innovation and Universities	6
Ministry of Science and Technology Taiwan	6
Research Grants Council (University Grants Committee)	6

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

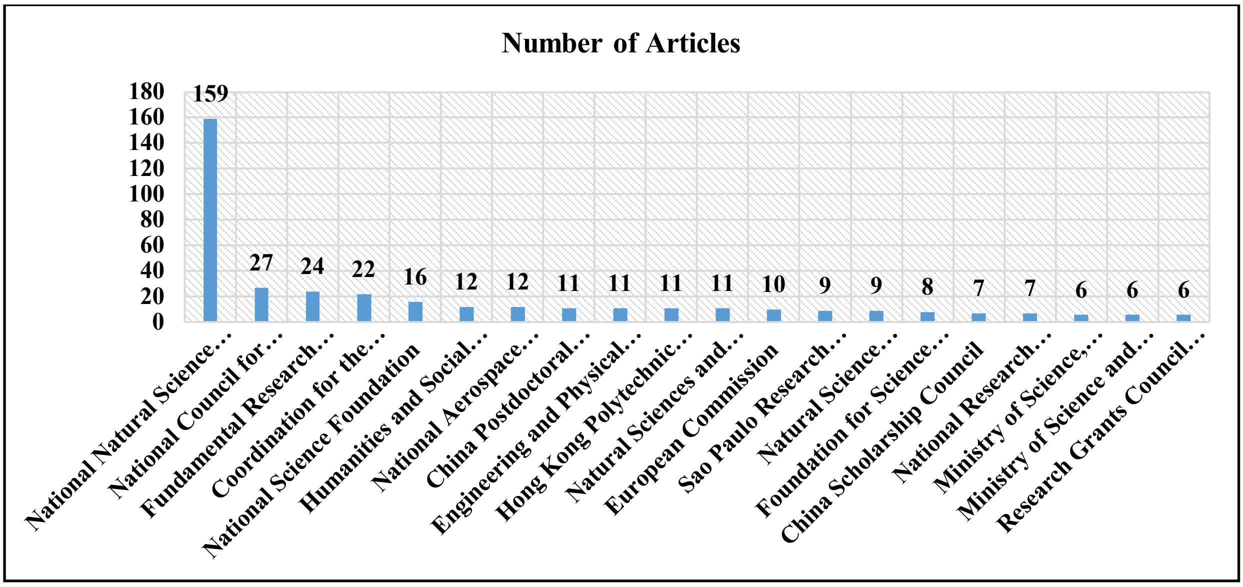

Figure 6: Funding Sponsor-Wise Publication

4. Data analysis and findings

This section covers citation analysis of collected data from Scopus. The research team adopts two ways to conduct citation analysis i.e. bibliometric analysis and network analysis. The former is carried out with BibExcel software. It provides results related to author(s) and keyword statistics. This software features to handle huge volumes of data and further creating a file, which can be used/transferred to other software like Pajek, Gephi, and Excel (Persson and Schlichter, 2015). Network analysis is performed by putting file generated from BibExcel to Gephi. It enables results in the shape of citation analysis and co-citation analysis. Cluster analysis is a content-based analysis. Alike BibExcel, Gephi takes an edge over other similar software like Pajek and VOSviewer. It facilitates innovative visualizations in various colourful forms.

4.1 Bibliometric analysis

Bibliometric analysis is possible with different available software like Publish or Perish and HistCite. However, BibExcel entails wide acceptance. It features to analyse data received from either Web of Science or Scopus or any other similar software. The present study aims to analyse and interpret huge volume of data for systematic review, for which, BibExcel is most suitable. This software takes an edge over other software because it can produce file in .Net format, which is further analysed in Gephi. The future researcher(s) are advised to consult Paloviita (2009) and Persson and Schlichter (2015) for better understanding of this software. The following subsections shall discuss about keyword statistics, author influence, and most commonly used search words with respect to artificial intelligence.

4.1.1 Author influence

In the world of growing competition, the research on artificial intelligence is on peak. Similarly, academics are also researching in this area to maximum. A record of top 10 author(s), who are working towards this domain and have produced good number of articles (Table 9 and Figure 7) towards artificial intelligence are Gunasekaran, A. (16), Dubey, R. (12), Mangla, S.K. (11), Childe, S.J. (10), and Garda, B.B. (10). The work contributed can be a good source of reference for future researchers.

Table 9: Top 10 Authors (Artificial Intelligence)

Author	Number of Published Articles
Gunasekaran, A.	16
Dubey, R.	12
Mangla, S.K.	11
Childe, S.J.	10
Gardas, B.B.	10
Luthra, S.	09
Pant, M.	09
Papadopoulos, T.	09
Kant, R.	07
Narkhede, B.E.	07

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

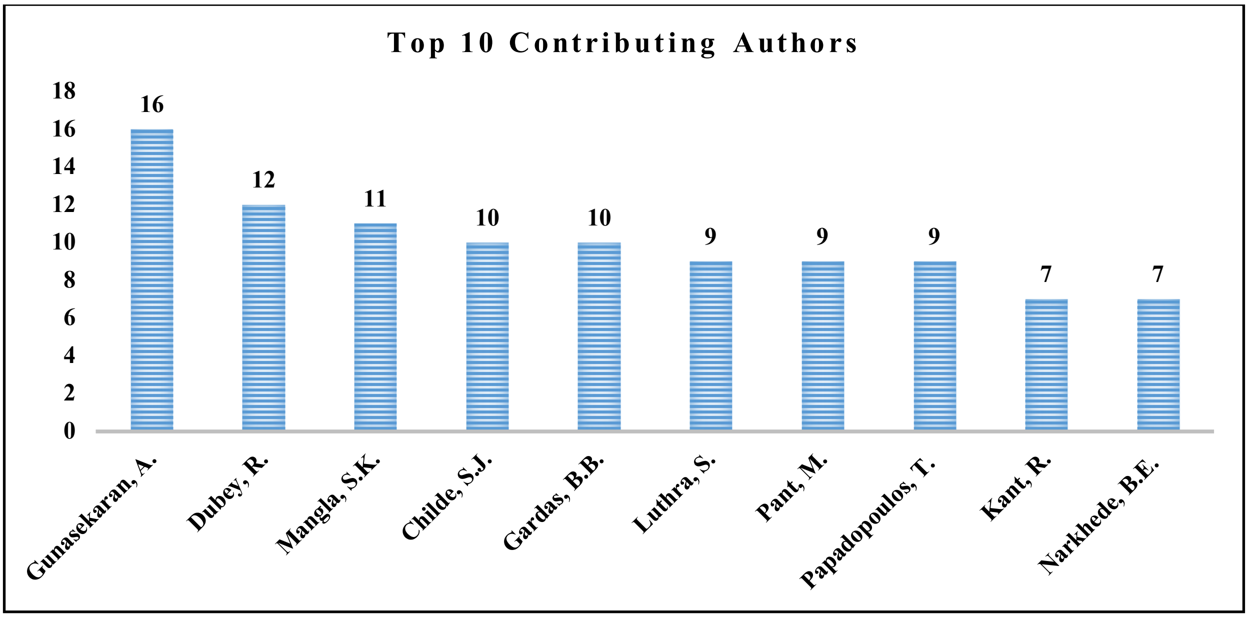

Figure 7: Top 10 Contributing Authors towards Artificial Intelligence

4.1.2 Keyword statistics

Keywords constitute one of the major aspects of search engines. Selection of correct keywords is extremely important for higher number of citations. The list of most searched keywords when artificial intelligence is the main keyword is given below. Analysis shows frequency occurrence of top listed keywords. The term artificial intelligence has been noticed most in combination with supply chain management (186), decision-making (177), sustainable development (119), sustainable supply chains (92), and information management (79). Table 10 and Figure 8 discuss the main list.

Table 10: Top 10 Keywords (Artificial Intelligence)

Word	Frequency
Supply Chain Management	186
Decision Making	177
Sustainable Development	119
Sustainable Supply Chains	92
Information Management	79
Artificial Intelligence	76
Product Development	73
Operations Management	71
Multiobjective Optimization	65
Reverse Logistics	53

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

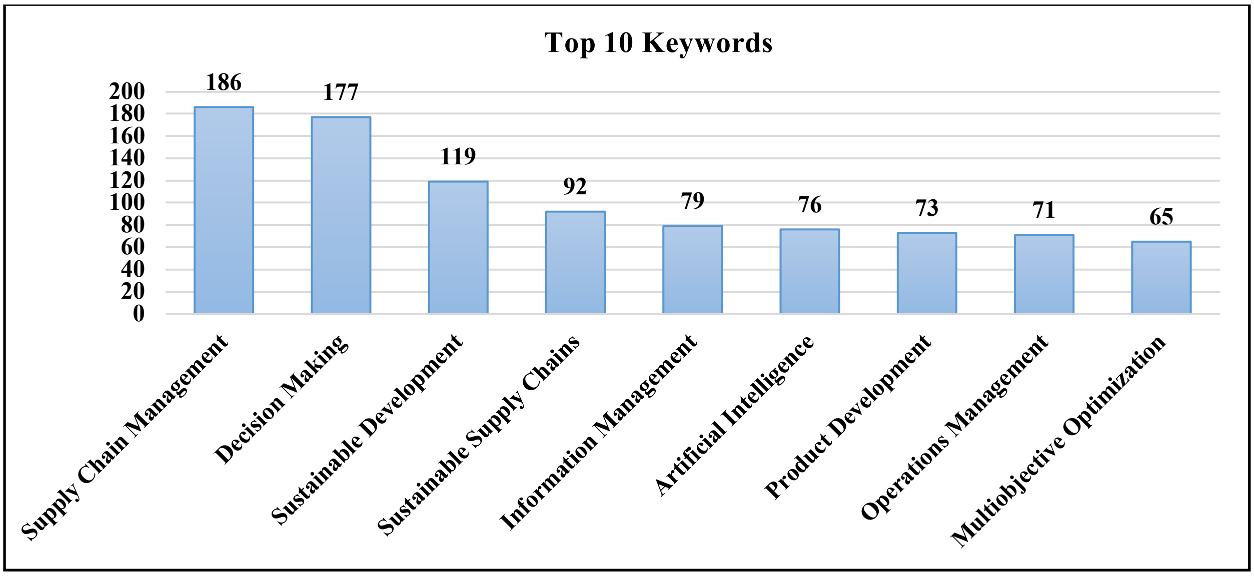

Figure 8: Top 10 Keywords

4.1.3 Most commonly search words

Apart from keywords, a category of commonly search words is also considered important to understand the popularity of a particular topic, here, it is artificial intelligence. This relates to the general search carried out in this domain of knowledge (Table 11 and Figure 9). Majorly searched words are information systems (130), optimization (92), green supply chains (78), project management (61), and big data (47).

Table 11: Top 10 Commonly Used Search Words (Artificial Intelligence)

Word	Frequency
Information Systems	130
Optimization	92
Green Supply Chains	78
Project Management	61
Big Data	47
Automation	35
Industrialization	23
Industry 4.0	20
Sustainability	15
Energy Utilization	14

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

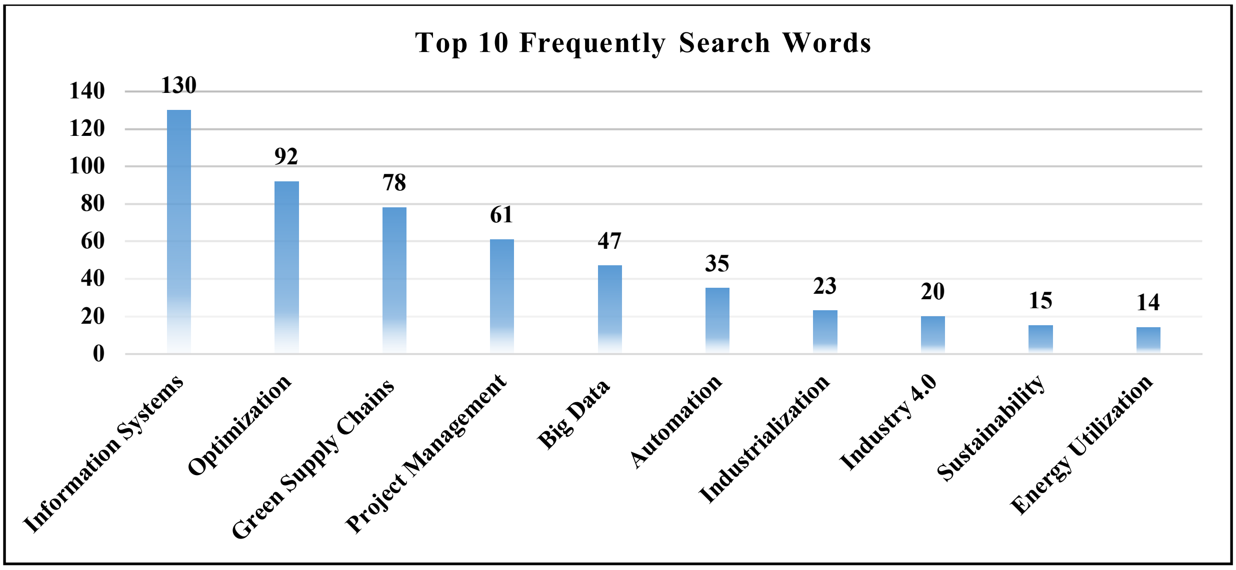

Figure 9: Top 10 Frequently Search Words

4.2 Network analysis

Network analysis is core presentation of citation matrix for selected area of study i.e. artificial intelligence. A review of citation analysis allows interested parties to understand what work is happening and is widely acceptable by audiences. Citation analysis provides an impression about credibility of published work, and same can be trusted by knowing citation patterns of the work. As per research team understanding, Gephi is the suitable tool to analyse the .Net file generated from BibExcel. It produces results in the form of citation analysis, PageRank analysis, co-citation analysis, and cluster analysis (Bastian *et al.*, 2009). Gephi produces interesting visualizations showing nodes and edges (Gephi, 2013). Nodes reflect published articles and edges show citation links.

4.2.1 Citation analysis

The purpose of citation analysis is to understand and review work of contributing authors towards particular topic of study. It facilitates ranking and significance of work published in various journals of repute. Frequency of citations for every respective article can be analysed through network analysis. The mentioned process identifies most influential work and its acceptance among readers. In this article, the research team identifies top 10 authors based on the citation analysis of last two years of time (refer to Table 12 and Figure 10). Zhou *et al.* (2018) is leading the race with 155 citations. The article presents basics of artificial intelligence and its relation with operations management. The next in sequence is Dolgui *et al.* (2018), Mishra *et al.* (2018), Tseng *et al.* (2018), Kumar *et al.* (2018), Pie *et al.* (2019), Gunasekaran *et al.* (2018), Hmadi *et al.* (2018), Ren *et al.* (2019), and Dubey *et al.* (2018) with 85, 47, 38, 30, 29, 26, 19, 16, and 9 citations respectively. The contributed work areas include artificial intelligence, internet of things, optimization, machine learning, sustainable development, and green supply chain management.

4.2.2 PageRank analysis

Citation analysis allows us to understand the credibility of a particular work. Similar to citation analysis, there are few other techniques that confirm the popularity of article. PageRank analysis is one such technique. PageRank presents the number of visits of a reader on a particular web page. It shows familiarity of work in search engines by using suitable keywords. It enables researchers to gauge significance of an article based on the findings of web keyword searches (Mishra *et al.* 2018).

In PageRank analysis, it is assumed that article A is cited by several authors who have contributed towards other articles T1,…, Tn. The equation is provided below, which explains d as damping factor that denotes portion of continuous random citations. The value of damping factor (d) stays between 0 and 1. The character C (Ti) in equation denotes number of times other articles are cited by article Ti. Accordingly, PageRank of article A i.e. PR (A) is calculated by following formula:

$$PR(A) = \frac{(1-d)}{N} + d\left(\frac{PR(T_1)}{C(T_{1)}} + \cdots + \frac{PR(T_n)}{C(T_{n)}}\right)$$

Further, if C (Ti) = 0, then PR(Ti) is segregated into number of articles instead of C(Ti). Value of damping factor is a controversial issue. However, a value ranging between 0.50 to 0.85 is acceptable. The values of PageRank analysis of topmost articles by different authors are shared below (refer to Table 12). These contributions can serve a big source of reference for future scholars.

Table 12: Top 10 Articles Based on PageRank Analysis (Artificial Intelligence)

Author (year)	**PageRank**	**Citation**
Zhou *et al*. (2018)	0.000748	155
Dolgui *et al*. (2018)	0.001243	085
Mishra *et al.* (2018)	0.000831	047
Tseng *et al.* (2018)	0.000653	038
Kumar *et al*. (2018)	0.000150	030
Pei *et al*. (2019)	0.000567	029
Gunasekaran *et al.* (2018)	0.000742	026
Hamdi *et al*. (2018)	0.000256	019
Ren *et al*. (2019)	0.000454	016
Dubey *et al*. (2018)	0.000225	009

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

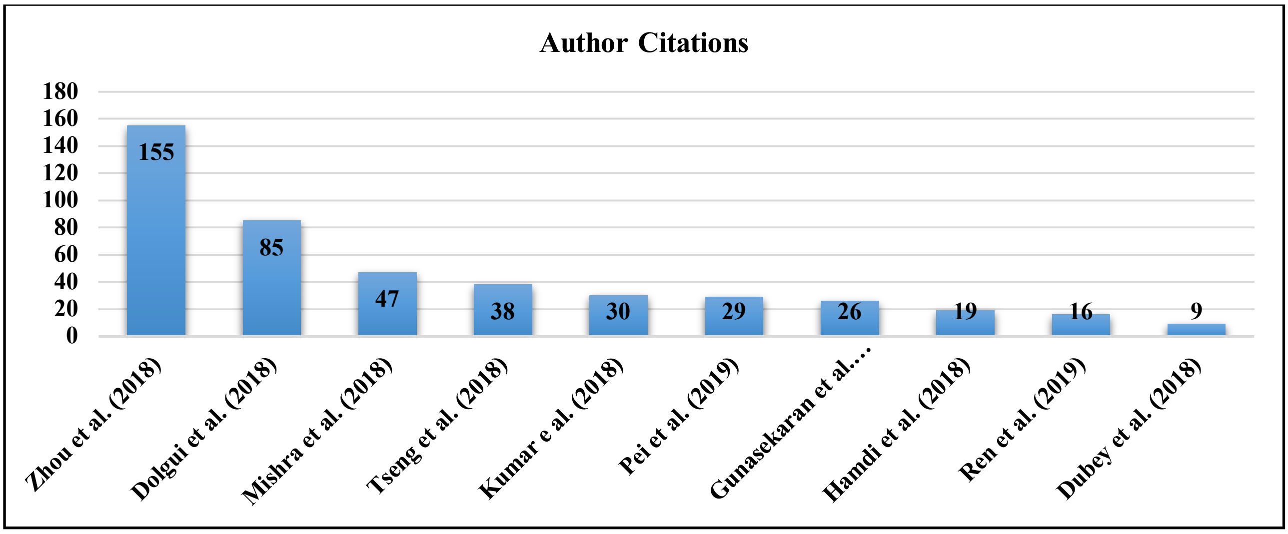

Figure 10: Top 10 Cited Articles

4.2.3 Co-citation analysis

The concept of co-citation analysis is slightly different to understand and interpret. It denotes citation matrix of authors, domains, journals, and keywords in on go. Research team decides application of co-citation analysis, as it can be applied on various combination, for example authors and domains, journals and keywords. However, this article has considered all plausible combinations.

Application of co-citation analysis on authors reveals its societal association or interconnectivity of work among authors; whereas its application on journal publications provides an analytical composition of particular domain of knowledge, here it is artificial intelligence. Research team explains sequence followed i.e. firstly, .NET file received from BibExcel with 962 nodes is forwarded to Gephi, post which a non-identifiable random map or image is generated. In second step, image is experimented in a layout 'Force Atlas' that delivers an interesting network of co-cited articles. Gephi application facilitates a researcher with a wide variety of layouts comprising of nodes (962) and edges (2315). Nodes are dots (big and small) and edges are connecting threads between nodes.

However, 'Force Atlas' is the most popular and recommended network presentation. The ideal situation is that edges appeal whereas nodes repel each other. Finally, nodes of articles with strong attraction meet at centre of layout, and nodes with less attraction settle themselves at borders of the structure. The Force Atlas layout of present work on artificial intelligence can be referred closely (refer to Figure 11). The combination of nodes and edges eventually provides various themes/clusters that are discussed in subsequent sections.

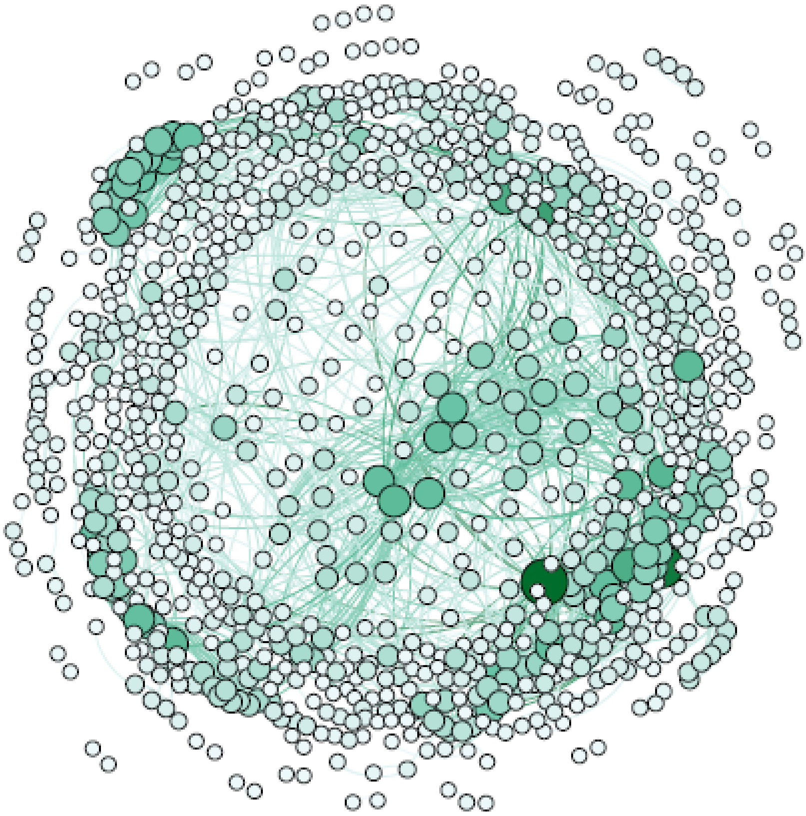

Figure 11: Force Atlas Layout of 962 Nodes and 2315 Edges

4.2.4 Cluster analysis

Data clustering denotes combining of articles with identical characteristics. Put differently, it is a process of bringing together articles of same domain at one place. The present work has carried out data clustering by using network analysis through Gephi. Placement of nodes and edges denotes process of cluster analysis. The dense linked nodes represent a particular cluster and differentiate it with the other connected nodes and clusters. Gephi provides method to understand density by modularity index application that ranges between −1 and +1, and is derived by applying Louvain algorithm.

The formula for modularity index is shared as under:

$$Q = \frac{1}{2m}\sum_{ij}\left(A_{ij} - \frac{k_i k_j}{2m}\right)\delta(c_i\,, c_j)$$

Where;

A_{ij} denotes weight of edges laying between nodes $i \& j$; k_i represents summation of edges weight that are attached to node i as $k_i = \sum_j A_{ij}$; c_i belongs to arm of vertex i; $\delta\ (u,\ v)$ equals to 1 if $u = v \& 0$; $m = (1/2) \sum_{ij} A_{ij}$

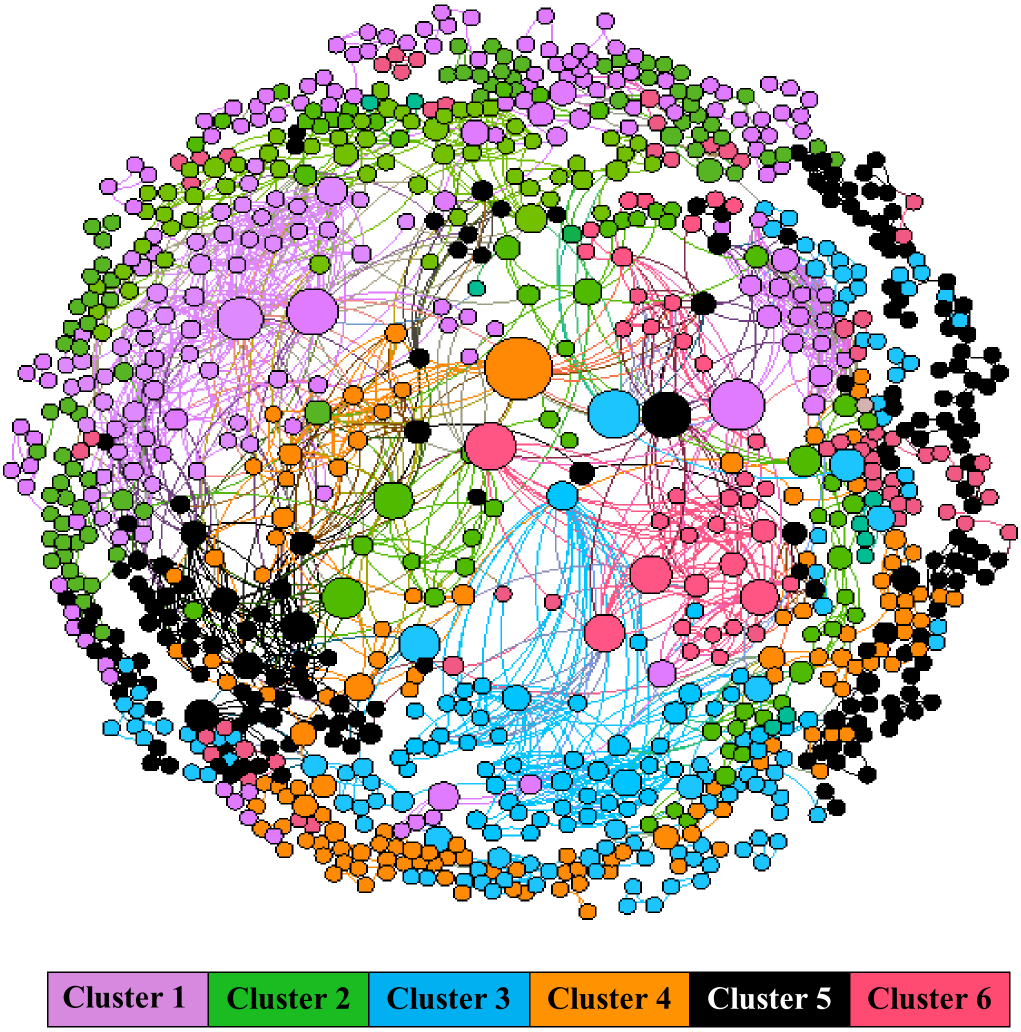

Figure 12: Force Atlas Structure of Six Clusters

The formula shared above has been used and applied to 962 nodes and 2315 edges, which have in turn resulted into six clusters (refer to Figure 12). Value received for modularity index is 0.189 due to presence of strong connectivity among nodes representing various clusters. Various clusters are very well identifiable because thickness of nodes is significant for each cluster. Further, linkages through edges confirm interconnectivity of various clusters (Mishra *et al*. 2019). Analysis confirms that articles, which are cited/ referred jointly, represent same domain of study and as strong co-citation status. The co-citation PageRank analysis reveals a larger figure of articles in each cluster (Mishra *et al*. 2018). Research team has discussed summary of articles in each cluster (refer to Table 13).

The received articles from Scopus database categorised into various clusters (Cluster 1: Artificial Intelligence and Optimization; Cluster 2: Industrial Engineering/Research and Automation; Cluster 3: Operational Performance and Machine Learning; Cluster 4: Sustainable Supply Chains and Sustainable Development; Cluster 5: Technology Adoption and Green Supply Chain Management; Cluster 6: Internet of Things and Reverse Logistics) are discussed in subsequent paragraphs. Each cluster explains a different theme related to artificial intelligence. Research team also discusses an interesting phenomenon i.e. interconnection between various clusters (refer to Figure 12 for pictorial view).

Table 13: Cluster Classification: Economic Development and South Africa

Cluster number and label	Current research	Future research suggestions
Cluster 1: **Artificial Intelligence and Optimization**	Conceptualization of artificial intelligence and optimization. Identifies connection between artificial intelligence and optimization. (Dubey *et al*., 2018; Gunasekaran *et al*., 2018; Nguyen *et al*., 2018; Shibin *et al*., 2018; Dubey *et al*., 2019a, 2019b, 2019c; Kumar *et al*., 2019; Raut *et al*., 2019a, 2019b)	Longitudinal studies for in-depth analysis are recommended to understand that how artificial intelligence can lead to optimization especially across sectors/industries.
Cluster 2: **Industrial Engineering/Research and Automation**	Explains basic relationship between industrial engineering/research and automation. (Aloini *et al*., 2018; Balugani *et al*., 2018; Dubey *et al*., 2018a, 2018b; Jeble *et al*., 2018; Porselvi *et al*., 2018; Zerbino *et al*., 2018; Van Gils *et al*., 2018, Balugani *et al*., 2019; Van Gils et al., 2019)	Contemporarily, automation is the key. Not only industrial engineering, rather future research can be very well directed towards how automation proves advantageous for other sectors/industries.
Cluster 3: **Operational Performance and Machine Learning**	Discusses bigger picture of operational performance and machine learning in terms of investment that can lead to better industrialization. (Dubey *et al*., 2018; Fatorachian *et al*., 2018; Horng *et al*., 2018; Lu *et al*., 2018; Qiu *et al*., 2018; Singgih *et al*., 2018; Yu *et al*., 2018; Gupta *et al.,* 2019; Pei *et al*., 2019; Yu *et al*., 2019)	Significant existence and need of machine learning cannot be denied. How machine learning connects itself with latest technology and eventually to operational performance is a big question to be answered.

Cluster 4:		
Sustainable Supply Chains and Sustainable Development	Elaborates a strong association between sustainable supply chain and sustainable development. (Dolgui *et al*., 2018; Dubey *et al*., 2018; Dupont *et al*., 2018; Kazancoglu *et al*., 2018; Mishra *et al*., 2018; Prajogo *et al*., 2018; Stefanini *et al*., 2018; Wang *et al*., 2018; Dolgui *et al*., 2019; Mishra *et al*., 2019)	A deep thought towards other factors that might lead to sustainable development is recommended. Merely, supply chain sustainability cannot address/fulfil the aim of sustainable development goals shared by United Nations Development Programme.
Cluster 5:		
Technology Adoption and Green Supply Chain Management	This cluster identifies an interesting theme that how technology adoption can lead to green supply chain management practices. (Ammar *et al*., 2018; Deshpande *et al*., 2018; Feng *et al*., 2018; Hamdi *et al*., 2018; Ray, 2018; Raut *et al*., 2018; Gardas *et al*., 2019; Ghadge *et al*., 2019; Nie *et al*., 2019; Yao and Askin, 2019)	Sustainable development is one of the important aspects that contribute towards betterment of every segment of human living. In fact, the need to explore 'GREEN' while addressing sustainable development is highly desired.
Cluster 6:		
Internet of Things and Reverse Logistics	Another significant result of this work is the relationship between internet of things and reverse logistics. (De Sousa *et al*., 2018; Hazen *et al*., 2018; Kha *et al*., 2018; Laengle *et al*., 2018; Wang *et al*., 2018; Yadav *et al*., 2018; Chen *et al*., 2019; Colicchia *et al*., 2019; Luthra *et al*., 2019; Sheng *et al*., 2019)	Research team recommends exploring the connection among internet of things, reverse logistics, and circular economy. Positive acceptance of technology is possible only when it contribute towards economic, social, and environmental sustainability.

Source: Scopus Database; 2018 to 2019 (31st May) and Authors' Own Compilation

Cluster 1 deal with theoretical background of artificial intelligence and its relation with optimization. If there is no optimization or optimal utilization of technological techniques, here, artificial intelligence, then whole concept of technology goes for a toss. Cluster 2 discusses how industrial engineering/research is affected by automation. Automation is main focus in the age of fourth industrial revolution. No matter whatsoever field an individual is connected with, but an essence of automation is highly expected. Cluster 3 hangs out with a deep connect with operational excellence and role of machine learning. Operational activities/issues consume maximum time and energy in various organizations. Role of artificial intelligence in smart decision making is need of this hour. Cluster 4 handles sustainable development through sustainable supply chains. Although, sustainable development is dependent upon several other parameters, but as per the results received from present analysis sustainable supply chains constitutes a major portion of sustainable development. Cluster 5 confirms strong association between technology adoption and green supply chain management. Importance of supply chain management in present tech-savvy set-ups is realised from its recurring appearance in other clusters as well. The learning and further adoption of technology is highly desirable. Lastly, Cluster 6 conveys existence internet of things and reverse logistics. This is really a unique theme emerged from this article. Reverse logistics is another way of reaching sustainable development. The forthcoming discussion section shall discuss about future directions of research with respect to each cluster.

5. Discussion of findings

Comprehensively, to researchers' knowledge and understanding, present article serves unique contribution towards existing body of literature with reference to artificial intelligence and its related areas. Undoubtedly, mere application of a concept will not furnish real output received until and unless its performance is reviewed systematically. Technology means change and change is never constant. It becomes important to explore, understand, and discuss about present status of artificial intelligence and future scope of work. Although, research team could locate literature in connection to artificial intelligence, but combination of selected keywords (artificial intelligence, genetic algorithms, agent based systems, expert systems, big data analytics, and operations management), followed by format of analysis (BibExcel and Gephi) has not been found in consulted articles. Keeping in mind received findings; research team understands and initiates few observations for similar researches in future. Firstly, requirement of longitudinal studies is recommended across various industrial set-ups. The process of prolonged period of studies shall allow researchers and interested parties to pursue critical analysis, where both good and bad aspects of artificial intelligence can be assessed. In short run, everything looks beneficial but in long run, negative consequences come into picture. Secondly, automation is the buzzword. It is worthwhile to mention that none of the sectors/industries is untouched from this phenomenon. Presently, automation is considered as one of the priorities across different corporate entities, and artificial intelligence provides main stream for automation. However, present findings are more inclined towards supply chain management domain. Research team proposes to explore other sectors/industries (medicine, education, banking, agriculture etc.) with respect to automation. Thirdly, operational excellence serves as root of success contemporarily. Research team initiates to understand the concepts of operational efficiency and machine learning in connection to skill development. Lack of desired skills is contributing negatively to industries in particular and societies largely. In the race to achieve big, real growth and development is going for toss. Adoption of artificial intelligence is sincerely in demand, but required skills are missing among implementers. Fourthly, sustainable development is the essence of every industry/sector/country. Whatsoever is the initiative, it revolves around sustainability. Put differently, a sustainable set-up enjoys wider acceptability. However, apart from supply chain processes, sustainability is dependent on many other factors. Hence, research team proposes to consult and assess artificial intelligence from the perspective of 17 Sustainable Development Goals 2030 (for example goal 9 and 11 covering industry, innovation, and infrastructure; sustainable cities and communities) shared by United Nations Development Programme. How artificial intelligence and its allied domains are contributing towards sustainable development is a big question to be answered. Fifthly, technology adoption of technology is not difficult; rather choosing right approach for its implementation is a challenge. Results of this work indicate technology adoption and green supply chain management. The future researches can focus and investigate if adoption of artificial intelligence is contributing towards sustainable development. Lastly, a very interesting contribution from research team is the combination of internet of things and reverse logistics. Every effort is rewarding only if it can be related to economical upliftment, and artificial intelligence is not an exception. Research team would like to bring in the concept of circular economy combined with internet of things and reverse logistics. Technological sustainability is the talk of town, and circular economy can very well address this peculiarity.

5.1 Theoretical contributions

Theoretically, this article discusses about artificial intelligence that who has contributed, what has been explored, what are strengths and weaknesses of existing work, and other similar issues. The identification of clusters and themes is yet another uniqueness of this article. The interconnection between various clusters like Cluster 1 Artificial Intelligence and Optimization and Cluster 2 Industrial Engineering/Research and Automation conveys that technology and optimization must go hand in hand. Cluster 3 Operational Performance and Machine Learning and Cluster 6 Internet of Things and Reverse Logistics explain that operational performance and technology share same platform. Cluster 4 Sustainable Supply Chain and Sustainable Development and Cluster 5 Technology Adoption and Green Supply Chain Management discusses about sustainable development in the era of Industry 4.0 and technology adoption. It is very important to understand that technological benefits can be derived only in the presence of adequate skills and knowledge. The interdependence of various clusters proves that focussing on one theme is not enough. Rather, all the connected areas or issues must be considered collectively and most important point is to understand these linkages.

5.2 Managerial contributions

The article delivers some meaningful insights for managers and policy makers to understand utility of artificial intelligence in their respective domain of knowledge and work. Firstly, increased technological involvements in any form (artificial intelligence, internet of things, chat bots) are decreasing manual skills of the people, which are affecting employment creation for manual activities. Secondly, managers must assess themes delivered by this article, as what has happened and what can be further planned to escape technological ailments and increase advantageous situations leading towards sustainable development. The interconnectivity of various themes/clusters is a revelation for policy makers. The question that arises here is that whether artificial intelligence is providing uniform benefits across sectors/industries/countries. Managers must target to conduct surveys and identify whether this technological enhancements are contributing towards betterment or destruction activities. A deep thought is required to understand if there is a real contribution of artificial intelligence towards organization, and if this concept is hindering the growth and development of intellectual capital. The policy makers must consider each cluster for analysis in its own capacity as its future scope.

6. Conclusion

Overall, article contributes a significant piece of work to existing body of knowledge with reference to artificial intelligence. Research team targeted data in the form articles, published only from credible journals. Due to dynamic evolution of technology, present article considers articles published in last two years of time. The inferences are drawn based on articles extracted from Scopus database. Research team has discussed findings in previous section in length. It gives a good food for thought for academicians, industrialists, managers, policy makers, and other similar groups to use this information for betterment of nation.

Rapid and unexpected changes at technological front in this era of fourth industrial revolution are providing new challenges and opportunities globally (Telukdarie *et al*., 2018) which are creating sustainability related concerns (Bag *et al*., 2018). Industry 4.0 technologies such as big data play a critical role in operational excellence (Bag *et al*., 2020a, b). Artificial intelligence is not a new concept but its application in managing operations in manufacturing industry is not widely practiced. However, there is great scope of artificial intelligence application in managing manufacturing operations (Dwivedi *et al*., 2019). Doing something in a smart way involves making smart decisions. Machine learning comprises of learning from data from real world and further summarizing into a precise mathematical description for decision making. Doing something smart from whatever is learnt from data is artificial intelligence. Precise observation from real world is data and computer programs learn about environment from the data to do smart things. Various tools are used in artificial intelligence starting from simple regression modelling tools to advanced tools such as deep learning (advanced computer vision).

Operations management involves strategic level, operational level and tactical level decision making (Van Gils *et al*., 2018, 2019).

Strategic level decisions involve product and services design, quality management, process and capacity design, process layout and product layout design, level of automation, material handling equipment selection, managing human resources and logistics and supply chain management.

Design of product and services related challenges involves difficulty in getting access at site for measurement of dimensions and gathering right data, delay in drawing approval from customer, delay in drawing approval from design department, non availability of data with design team for considering design for environment and non availability of data for designing of services in this volatile business environment. Quality management related challenges involves difficulty in managing non conformances, difficulty in managing quality rejects, difficulty in implementing digital quality management systems, challenges in quality related record keeping and improper storage of quality related data and knowledge gap among quality control personnel. Process and capacity design related challenges involve dealing with capacity constraint and difficulty in stabilizing manufacturing process for new products. Process layout and product layout design related challenges involve design related challenges for creating effective process layout and product layout. Level of automation related challenges involve difficulty in implementing advanced level automation and difficulty in selecting the right set of technologies Material handling equipment selection related challenges involve lack of information, lack of technical knowledge and lack of funds. Managing human resources related challenges involve knowledge gap among existing workforce and improper selection and recruitment. Logistics and supply chain management related challenges involve designing supply chain network, warehouse location decisions, supplier selection problems, lack of supply chain visibility and lack of supply agility, adaptability and alignment.

Operational level decisions involve batching, job assignment, workforce allocation, workforce level, inventory control and vehicle routing.

Batching related challenges involve difficulty in estimation of correct batch size. Job assignment related challenges involve difficulty in matching skills and time for assigning jobs to workers. Workforce allocation related challenges involve how many labourers to hire to complete a job and utilization of labourers. Workforce level related challenges involve issues in workforce planning. Inventory control related challenges involve difficulty to determine economic order quantity, problems in vendor inventory management, stock becoming obsolete with technological advancements and difficulty in managing various stock keeping units. Vehicle routing related challenges involve determining optimal set of routes for a fleet of vehicles and scheduling of vehicles.

Tactical level decisions involve managing day to day operations such as purchasing and supply management, manufacturing and logistics.

Purchasing and supply management related challenges involve delay in material supply, delay in services, lack of forecast and poor planning, overstocking and under stocking of raw material, poor communication and poor vendor follow-ups and managing frequent price increases. Manufacturing related challenges involve machine breakdowns and production losses, poor planning and inability to load machines, unavailability of material handling equipment during machine loading and unloading, bottleneck in production line and labour union related problems.

Logistics related challenges involve timely non- availability of vehicles, difficulty in tracking of vehicles in transit and delay in unloading of large number of incoming vehicles.

In smart factory manufacturer wants to smartly manage production operations using automated robots and further control entire operations. There, final decision involves controlling of multiple production lines, digital quality management, automated packaging and dispatch in an effective manner. So, in the first step machine learning can be useful to learn from the available real world data and in the second step decision making. Several decisions such as (what is manufacturing service level agreements for repeat or conversion orders; which production line to use; what raw material must be used; which group of machines should be used; how much pressure, temperature, curing time must be selected for individual product manufacturing; whether slow cooling or fast cooling is required; assembly process; painting specifications; assembly requirements; quality control plan; packaging selection etc.) are involved in manufacturing operations. Operations managers and data scientists are going to infer lot from data what is called machine learning. This learning from data and summarizing in mathematically precise ways to make decision is artificial intelligence. Deep learning is a specific machine learning tool that has proved to be very useful. Irrespective of the tools managers are going to use; ultimately they are going to learn about the real world and then the learning could be summarized in precise mathematical ways to make smart decisions in the field of operations management. To the best of researcher's knowledge, none of the consulted studies could confirm the use of the use of bibliometric and network analysis for systematic literature review of artificial intelligence. Various themes have emerged from this review which will be beneficial for future researchers.

6.1 Limitations of the study and future research directions

Rationally, every research output is followed by certain limitations. Similarly, this article possesses some limitations. Firstly, keywords are selected at discretion of research team. However, proper care has been taken while selecting the keywords by keeping central focus purely on the theme of study. Secondly, future researches can consider other tools for analysis instead of BibExcel and Gephi, which may provide more number of clusters. Although the research team have provided six future research directions previously (refer table 13). However, additional future research studies may involve analysing practical challenges in manufacturing operations and propose models to fit the artificial intelligence in operations environment to solve problems. Future research can also explore key risks involved in application of artificial intelligence for managing operations in various sectors and industries. Privacy and security related aspects are a big concern in application of artificial intelligence and need to focus by future researchers to avoid any kind of project failures. In-depth real case study reporting can provide rich insights for both researchers and practitioners.

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