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Research Article

Research Trends and Performance of IIoT Communication Network-Architectural Layers of Petrochemical Industry 4.0 for Coping with Circular Economy

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In the present era, many Petrochemical Industries (PIs) are driven energetically due to IIoT (Industrial Internet of Things) Communication Networks/Architectural Layers (CNs/ALs), abbreviated as $PI_{4.0}$-CNs/ALs. $PI_{4.0}$ fruitfully participated to achieve the Circular Economy (CE) by speeding the reutilization, recovery, and recycling of scrap materials by minimizing cost, unproductive operations, energy consumption, emission of flue gases, etc. Recently, it has been ascertained that the identification and measurement of Research Trends (RTs) of CNs-ALs help the $PI_{4.0}$ to build the future CE. In addressing the said research challenge, the objective of this research dossier is turned towards inculcating into future $PI_{4.0}$ researchers the RTs of CNs/ALs of $PI_{4.0}$, so that the researches can be organized over the very weak and moderately performing CNs-ALs to hike the future CE. To materialize the RTs of PI_4-CNs/ALs, the authors conducted the Systematic Literature Survey (SLS) focusing on $PI_{4.0}$-CNs/ALs, i.e., Internet of Things (IoTs), Cyber Physical System (CPS), Virtual Reality (VR), Integration (I), Data Optimization (DO), Enterprise Resource Planning (ERP), Plant Control (PC), Data and Analytics (DA), Network (N), and Information and Data Management (IDM). The authors searched three hundred two research documents, wherein two hundred seventy-five research manuscripts qualified as RQ_2. Next, the authors collected the DOIs/URLs corresponding to each CN-AL and explored the Sum of Digit Scoring System (SDSS) to summarize the DOIs/URLs of $PI_{4.0}$-CNs/ALs. The RTs of DO have been determined as excellent and stronger over 2007-2017 than residue CNs/ALs. Eventually, the authors advised scholars to focus on the research areas of very weak and moderately weak performing CNs/ALs in order to attain future CE.

1. Introduction

In the last decade, the demand from customers for customized products with the lowest prices thrust Production Systems (PSs) into more digitalized capabilities with an effort of minimizing the wastefulness of industries. This approach is called the Circular Economy (CE). The growth of the population also propelled industrialists to establish, expand, and integrate their business empires by incorporating different varieties of customized products with the least waste. This is another way to describe CE. Today's emergent demands of domestic oils and gas resources are stimulating the research communities towards devising appropriate means to monitor and evaluate the physical performance for saving energy, processes which are respected as CE as per [1, 2]. Firms adapt a technical and institutional framework for enrolling, recycling, and disposal monitoring systems to ensure utilization of waste oils and hazardous wastes with a huge public interest in developing CE [3, 4]. The employment of appropriate technology can radically reduce ecological pollution and wastes by improving connectivity, integration, and automation towards oil mill processors and allied systems for attaining CE [5, 6].

Today, it is necessary to react towards technological advancements and deployments for coping with the demand for liquid fuel, the shortage of crude oil, monitoring of liquid fuel routes, and the assessment of their life cycle's estimation for addressing CE as per [7, 8]. Industries ought to focus on stimulating the biomass means, technical routing, byproduct synergy, carbon capture features, system automation, scientific implications, feedback mechanisms, connecting nodes, etc. in industries for attaining global CE as per [9–11]. Additionally, the diverse varieties of emissions of offensive gases from production should be managed and monitored by developing national strategies, control systems, technology, etc., as they can cause irreparable loss, wastes, and commensurate costs to the society and to industrial plants [12, 13]. Accordingly, technological proximity and means need to evolve and be incorporated into a firm's system by modeling and integrating to build CE as per [14, 15]. An elevated level of connectivity, integration, and monitoring is evidently needed among business networks and is required for coping with the global CE, competition, and management of production costs as per [16, 17]. High-rank digitalization mechanisms, connecting technologies, and automation are needed at every corner of the organizational structure for attaining CE as per [18–20].

It is ascertained that the industry 4.0 revolution captured entire industries and markets around the world. Industry 4.0 is described in terms of automations, information exchangers, cloud storages and computing, cyber tech and physical systems, robotic self-navigation phenomena, big data analysis, and IoTs to add values in flexible and efficient PSs. Technological advancement, innovation, evolution, etc., are required for effective interconnection and communication among different manufacturing systems, which are demanding the critical exploration of industry 4.0 as per [21, 22]. The reactions of digital CNs/ALs are propelling the significant advancements in industry 4.0 structures and are assisting industry 4.0 for driving PSs with flexibility with least waste output. Industry 4.0 introduces electronic data feedback and an integrated digital medium system across the functional units of industry. Industry 4.0 stimulates the computerization, monitoring, automation, and setting up of wide CNs for predicting and self-diagnosing deployed manufacturing devices. Ennis et al. [23] reveals that the collaboration and integration among organizations are possible today due to industry 4.0. Oztemel and Gursev [24] stated that industry 4.0 can make PSs more capable for performing activities and achieving CE. Yuan et al. [25] suggested that industry 4.0's practices are the best for smart manufacturing and advised that industry 4.0 is a reliable and scalable platform (digitally operating hardware and software) to update the level of instrument technology for effective utilization of resources. Trotta and Garengo [26] and Maresova et al. [27] found that industry 4.0 is a complex and disruptive network, which helps the stakeholders of private and state companies to attain more revenue and develop the global CE.

It has been empirically investigated that Petrochemical Industries (PIs) have been counted as one of the significant sectors that fulfill the daily needs of society's people. Presently, PIs are leading and immensely expanding their business globally by producing chemical compounds and petroleum-based solvents such as paints, coatings, detergents, and adhesives. Nowadays, most of the PIs are emergently focusing on manufacturing beverage products, i.e., oil and gas refinery, vegetable and palm oil, petroleum oil, ethylene refinery, and ink and paint production for attaining a strong CE. [28–30]. A few PIs turn out ethane, ethylene, methane, and petrol to compensate for the daily needs of peoples. Today, PIs are engrossed into the industry 4.0 revolution or digitalization, which is called $PI_{4.0}$. The majority of $PI_{4.0}$ becomes sustainable and more lenient to flexible, agile, and lean manufacturing processes on account of digital transformation for attaining a strong CE. $PI_{4.0}$ overcomes the prohibitive issues related to production and monitoring of PSs with great digital network and capabilities, which help industries meet the challenges of market demands.

Investigations have shown that the Communication Networks/Architectural Layers (CNs/ALs) with $PI_{4.0}$ (which is abbreviated as $PI_{4.0}$-CNs/ALs), such as IoT, CPS, VR, I, and DO, build the PSs of PIs more lenient to CE and the market's demands. Therefore, the continuous digital advancement into CNs/ALs enabled $PI_{4.0}$ to meet the future market's demands. However, there is a need to map the RTs against CNs/ALs of $PI_{4.0}$ to identify the areas where CNs/ALs are still poor, weak, and not at all improved. This rationale diverts the attentions of the authors to quantify the RTs of $PI_{4.0}$-CNs/ALs. Gölzer et al. [31] argue that RT materialization is needed for a complete and detailed description of data processing requirements for all industry 4.0-based companies, to fully understand implications on IT-infrastructure and IT-solution-components. Van Tienen et al. [32] found that the digital advancement solution against CNs/ALs is a simplistic approach to improve industry 4.0 technologies and entrepreneurships and attain a high degree of CE. Groger [33] suggested that RT directions are useful for the successful implementation of industry 4.0, i.e., interdisciplinary research, specification of modular and reusable analytical services, appropriate tools, and organizational models and frameworks.

2. Literature Survey

The CNs/ALs augmented the convenience, handiness, and productivity across PIs due to intelligent interpretation of procured information and consequently aided the autonomous process [34, 35]. The apparent requirement for advanced digital technologies belonging to Internet of Things, cloud computing, information exchangers, etc., is embodying a novel paradigm and influencing countless aspects of the routine line of private and business users [36, 37]. Theoretical supports and academic researches provided the comprehensive pitch to be explored by smart industry 4.0 [38–40]. An assessment model was built in [41], and it was used to measure and gauge the industry 4.0 technologies by considering three dimensions such as factory of the future, people and culture, and strategy. The eight chief attributes, i.e., cloud computing, manufacturing execution system, e-value chains, additive manufacturing, IoTs and cyber physical systems, big data, and sensors and autonomous robots are suggested as "Factory of the Future" and implemented as the significant dimensions of industry 4.0. Accordingly, enablers of industry 4.0, interconnected nodes and medium, research questions, technical frameworks, distribution patterns, computation mechanisms etc., are respected as effectual patterns of industry 4.0 evolution [42–44].

A progressive elementary aspect can assist in visualizing, monitoring, and recovering the characteristics of a manufacturing system [45, 46]. The revolutionary concepts and creative tools are required to identify the significant enablers for future success of organizations [47, 48]. Multiple flow control mechanisms and flexibility in production, decision-making, and problem solving are needed for executing the production processes efficiently based on the operational models [49]; consequently, a novel operational model called the Internet Fulfillment Warehouses (IFWs) was devised in [50] for effectively optimizing the operational model of warehouses.

Internet is the key for technical innovation, and it possesses the capability to synchronize and optimize the static and dynamic constraints to enable the technical execution of industry 4.0 [51, 52]. Internet is presently serving as a novel operational configuration by linking smart apparatuses, machineries, and systems [53, 54]. Comprehensive integrated tools, models, strategies, policies, and techniques need to be integrated with industry 4.0 when tackling human resources [55, 56].

The authors adapted the internet-based research search engine [57] to accumulate databases related to research documents. The internet-based search engine has evidently been adapted in previous research works and has eliminated the drawback of the expert's panel and furcating schemes. The authors further conducted a Systematic Literature Survey (SLS) to recognize the momentous CNs/ALs of PIs and to quantify the RTs of $PI_{4.0}$-CNs/ALs. Matthew et al. [58] emphasized the failure detection analytics sensors to monitor the oil production failures in digitized oil fields. The research work suggested the use of thousands of sensors and gauges with equipment to map the physical and chemical characteristics of oil and gas extracted from underground reservoirs. John and David [59] proposed a simulation model to fruitfully analyze the dynamic magnitude of water and sand collected by extracting the oil from a pool of oil. An analysis was conducted to choose the optimum technology for coping with oil extraction challenges. Li et al. [60] proposed extensible X-3D software for building an interactive and dynamic virtual oil and gas pipeline system. The X-3D application was applied in designing a piping system to illustrate the virtual reality application in $PI_{4.0}$. Meng et al. [61] stated that IoT is a significant indicator for taking care of information technology and is respected as a crucial AL for executing industrial operations effectively. The authors demonstrated an IoT AL reference model to investigate IoT growth. A case study of a $PI_{4\cdot 0}$ is illustrated to reveal the research challenges and opportunities associated with IoT.

Hemant et al. [62] proposed an infeasibility driven evolutionary algorithm to resolve the efficiency evaluation problem of fifty-six oil pools under a single-level constraint variable. The authors have suggested to frame a multiobjective problem to define effective results and to eliminate the drawback of an earlier formulated objective. David [63] explained a key CNs/ALs of $PI_{4\cdot 0}$ proposed by the American National Standards Institute, the American Petroleum Institute, and Standard 780 to build security risk assessment methods for systematically identifying suitable measures and eliminating future threats. Parolini et al. [64] proposed a new Cyber Physical Index (CPI) for measuring the effects of a combined distribution of a Cyber Physical System (CPS) in a given data. A case study is conducted by the authors to demonstrate how the CPI indicates the potential impact of CPS control strategies and cyber cum physical control as well. Gholian [65] developed a mathematical model for establishing the optimized operational sequences for industrial load control operation. Yatin and Clifford [66] proposed a game theory algorithm to allocate the cybersecurity controls in the oil pipelines. The proposed algorithm assisted the oil pipeline cyber physical system to allocate the cybersecurity control teams around high-risk regions. Ahmed and Kim [67] described the Named Data Networking (NDN) with its applications in smart home communications for critically evaluating and defining the aspects to address the future challenges of NDN.

Robin and Chunyan [68] utilized the ERP (Enterprise Resource Planning) system and suggested its implementation over Continuous Auditing (CA) of oil refinery processes. It has been concluded that ERP increases the efficiency, fraud risk reduction, knowledge application, and credibility of the auditing team. Jeon et al. [69] proposed a specific plan to effectively implement ERP for controlling the shop floor of $PI_{4.0}$. In the proposed plan, an advanced MES is added for collecting, measuring, and analyzing shop floor controlling. Niggermann et al. [70] determined that data-driven approaches to analysis and diagnosis of CPSs are always inferior when compared with classical model-based approaches, constituted by experts. Trappey et al. [71] evaluated the critical international standards and intellectual property rights (associated with CPS patents) to benefit academic scholars and industry practitioners. Hassani et al. [72] focused on the evaluation of the significant innovations, technological drivers, and CNs/ALs of $PI_{4.0s}$. The authors searched the quantifiable and nonquantifiable impacts of innovation, technological drivers, and CNs/ALs that benefit $PI_{4.0s}$.

After passing through the aforesaid literature survey, the authors built a research methodology and listed four Research Inquiries (RIs) to effectively grab the significance for commencing the research work. The four research inquiries and manuscript filtering/screening guidelines for quantifying the RTs against $PI_{4.0}$-CNs/ALs are framed. The authors reported a research approach and structure for successfully materializing the RTs and suggesting the future research challenges of $PI_{4.0}$-CNs/ALs to attain CE.

3. Research Methods and $PI_{4.0}$-CN/AL Contribution towards Building the CE

CE is motivated to eliminate several industrial wastes, i.e., idle times, waste materials, and emission of carbon gases (emissions can be minimized by enhancing the reusing,

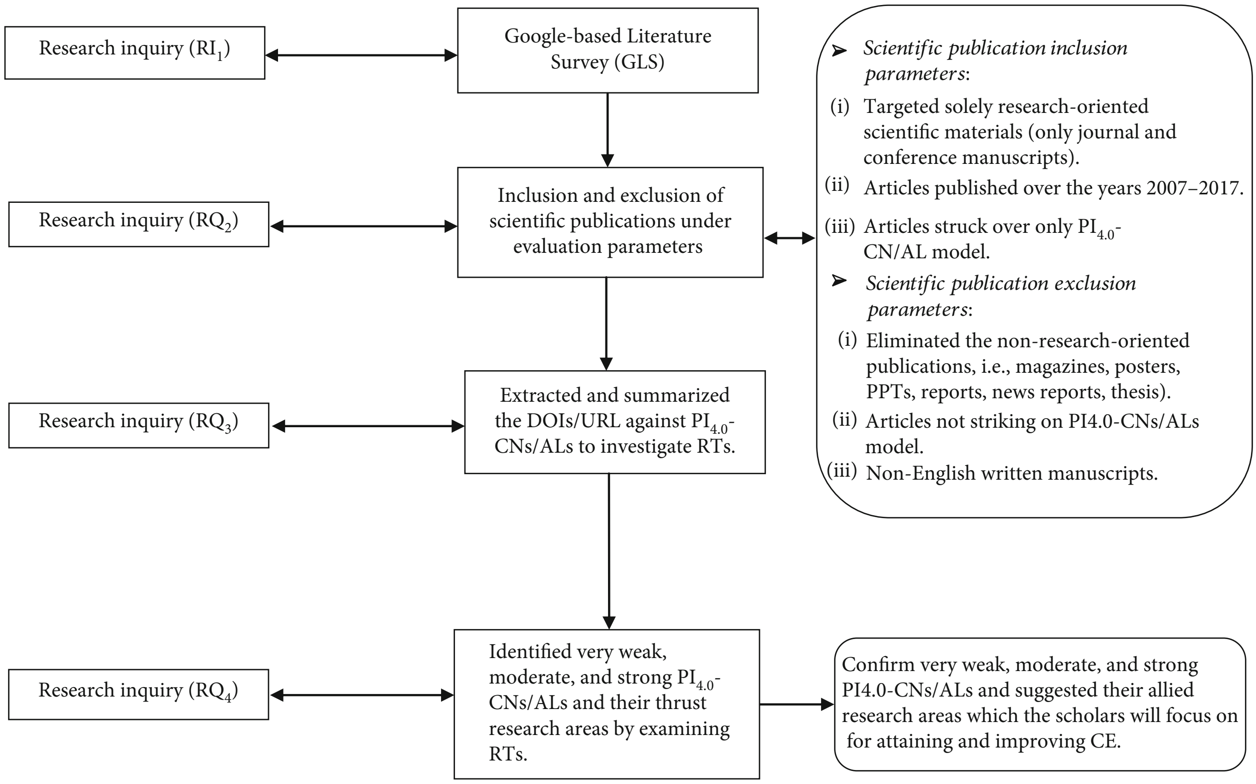

Figure 1: The structure of the proposed work.

repairing, refurbishing, remanufacturing, and recycling systems in production systems of companies). CE develops economic, natural, and social capital by addressing the three challenges of companies, i.e., concentrating on elimination of waste and pollution, recycling products and materials, and generating energy. In the present $PI_{4.0}$, CNs/ALs contribute towards balancing the advance of manufacturing and the reutilization, recovery, remanufacturing, and recycling (reverse manufacturing) of scraps/parts aiming at forming the CE of industries. CE improvement across $PI_{4.0}$ can be attained by enriching and advancing the CNs/ALs through identifying the RT levels. In the research forum presented in this study, the authors built and proposed a research method and four Research Inquiries (RIs) for quantifying the RTs of $PI_{4.0}$-CNs/ALs. The research structure is illustrated in Figure 1. The four RIs are shown below:

(i) *Research Inquiry (RI_1)*: How does research work address the most significant $PI_{4.0}$-CNs/ALs?

(ii) *Research Inquiry (RQ_2)*: What is the research policy to search the database of only scientific research-oriented documents against a framed $PI_{4.0}$-CN/AL model?

(iii) *Research Inquiry (RQ_3)*: How do we segregate the RTs corresponding to each $PI_{4.0}$-CN/AL?

(iv) *Research Inquiry (RQ_4)*: How do we recognize the very weak, moderate, and strong research areas of $PI_{4.0}$-CNs/ALs?

Table 1: Defined $PI_{4.0}$-CN/AL model.

Years	CNs/ALs corresponding to $PI_{4.0}$									
2007-2017	IoT	CPS	VR	I	DO	ERP	PC	DA	C/N	IDM

Table 2: The nomenclatures and description of struck over $PI_{4.0}$-CN/AL model.

PI4.0-CNs/ALs	Descriptions
(i) IoT	Internet of Things
(ii) CPS	Cyber Physical System
(iii) VR	Virtual Reality
(iv) I	Integration
(v) DO	Data optimization
(vi) ERP	Enterprise Resource Planning
(vii) PC	Plant Control
(viii) DA	Data and Analytics
(ix) C/N	Networking
(x) IDM	Information and Data Management

4. Research Inquiries (RQs) and Responses

4.1. Research Inquiry (RQ_1): How Does Research Work Address the Most Significant $PI_{4.0}$-CNs/ALs? From the Internet, the authors accessed Google, Yahoo, DuckDuckGo, and Ask.com, which are interdisciplinary scientific database

Table 3: The definition of $PI_{4.0}$-CNs/ALs.

	$PI_{4.0}$-CNs/ALs
IoT	It is a digital intelligence device enabling mechanical machines, computing devices, and humans to unite with each other. Information is transferred via IoT devices across the business societies.
CPS	It integrates computational algorithms with physical elements, i.e., robot and CNC of production system. CPS is a consistent synergy between hardware and software towards driving the efficient production systems.
VR	It demonstrates the practical experiments before commencing work in reality. VR passes the investigators through a phenomenon before conducting the same phenomenon in reality. ANSIS, CAD, POE, VERSA CAD, KEY-CAD, and AUTO-CAD assist the investigators/designers to realize the production before commencing the same in reality/practically.
I	It is a technique to increase the future business opportunities. It focuses on augmentation of the firm's capacity at the market, eliminates the transaction costs, and secures multiple vendors or distribution channels for the future.
DO	It deals with evaluation of the most excellent choice under cost and other business parameters. In case of DO, the business parameters are interpreted by simulations, models, decision support systems, and decision-making tools.
ERP	It is a computerized system, focuses on controlling the business operations such as customer orders and tracking, scheduling operations, reviews inventory records, and prepares the financial sheet related to production and marketing.
PC	It deals with storing and retrieving the input and output data via electronic signals for maintaining the production assets for future use.
DA	It deals with interpretation of the input and output digital data by exploring the vector machine algorithm, clustering algorithm, support, linear regression, logistic regression, artificial neural networks, and sensors to enable the production system to work without failures.
N	It interconnects the soft computing and peripheral devices with parent's identical devices. The cross-functional units of production systems are connected by networking.
IDM	It helps for simulating the data/information for planning, modeling, security control, conducting experiments, data analytics, and quality control purposes. It escalates the data sharing and fosters the information to other departments for use.

Table 4: Scientific publication research guidelines.

(i) Scientific publication inclusion parameters:
(a) Targets solely research-oriented scientific materials (only journal and conferences).
(b) Articles published over the years 2007-2017.
(c) Articles are searched, strike over evaluated $PI_{4.0}$-CN/AL model.
(ii) Scientific publication exclusion parameters:
(a) Eliminated the non-research-oriented publications, i.e., magazines, posters, PPTs, reports, thesis, synopsis, news reports, and short notes.
(b) Articles are not in line with $PI_{4.0}$-CN/AL model.
(c) False scientific articles, which are not found in English.

search engines. The authors fruitfully explored the Google (open) internet-based research database search engine to conduct SLS in addressing $PI_{4.0}$-CNs/ALs. The authors extracted and reviewed the research manuscripts. Eventually, the authors scrutinized the most significant $PI_{4.0}$-CNs/ALs based on architectural celebrity, fame, population, and identification in most of the research manuscripts. Tables 1 and 2 illustrated the nomenclatures of $PI_{4.0}$-CNs/ALs for addressing RQ_1. Table 3 reflects the definitions of all scrutinized $PI_{4.0}$-CNs/ALs. The research structure is illustrated in Tables 1, 2, and 3 and Figure 1.

4.2. Research Inquiry (RQ_2): What Is the Research Policy to Search the Database of Only Scientific Research-Oriented Documents against a Framed $PI_{4.0}$-CN/AL Model? In order to extract the scientific research documents against each CN/AL, the authors adopted inclusion and exclusion parameters. Non-research-oriented scientific materials, i.e., magazines, posters, ppts, reports, and news reports are excluded. Only conference and journal manuscripts are respected under the inclusion parameters. The reason to pursue only research-oriented scientific materials is that most of the non-research-oriented scientific materials illustrate the newspaper or represent unreliable, unreadable works and non-value-added research activities. Table 4 illustrates the list of inclusion and exclusion parameters to justify RQ_2.

Table 5: Searching of scientific research databases I and II.

The searching of scientific document database I	
IEEE Xplore	http://www.ieee.org/
ScienceDirect	http://www.sciencedirect.com/
Searching of scientific document database II	
Springer Link	https://link.springer.com/
ACM Digital Library	http://dl.acm.org/
Emerald Insights	http://www.emeraldinsight.com/

4.3. Research Inquiry (RQ_3): How Do We Segregate the RTs Corresponding to Each $PI_{4.0}$-CN/AL? Table 5 describes the

Table 6: Primary, secondary, and tertiary search on $PI_{4.0}$-CNs/ALs.

Primary search	Petrochemical industry
Secondary search	Paint production/industry
	Ink production/industry
	Glycol production/industry
	Oil/petroleum refinery production/industry
Tertiary search on oil production under aspects	Natural gases
	Coal
	Waste products
	Agriculture waste

Table 7: Evaluated scientific research documents/manuscripts considering exclusion parameters, full text, and primary search.

Search engines	Total documents found	Exclusion parameters	Full text	Primary search
Emerald Link	12	3	9	0
Springer Link	24	14	9	1
ACM Link	51	1	46	4
IEEE Xplore	100	1	69	30
ScienceDirect	115	8	71	36
Total documents	302	27	204	71

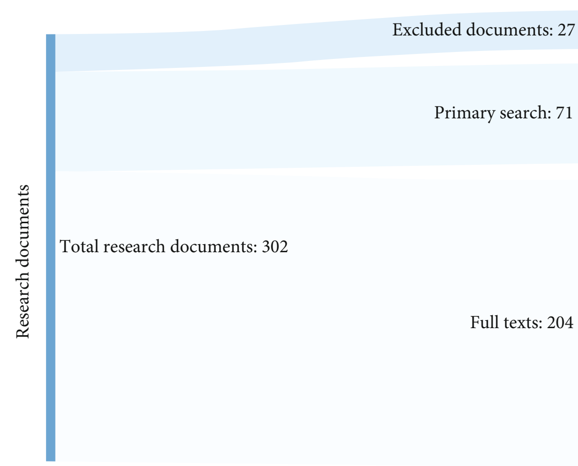

Figure 2: Sankey flow diagram.

specific research search engines [57], which are targeted in this research to store the relevant database and thus satisfying RQ_2. The authors collected only DOIs/URLs against $PI_{4.0}$-CNs/ALs over years 2007-2017. The authors explored primary, secondary, and tertiary protocols as discussed in Table 6 for searching research documents.

The authors applied the Sum of Digit (SD) technique to quantify the research manuscripts, published over the years 2007-2017. Table 7 summarizes the results against the scientific research databases I and II with respect to the exclusion parameters, full text search, and primary search. Figure 2 illustrates the database using the Sankey flow diagram, which shows the total research documents and its scattering record. Figure 3 reveals the total database of $PI_{4.0}$-CNs/ALs by bar chart. Figure 4 evaluates the research documents by PRISMA 2009 flow chart, which shows the research documents' refinery process (inclusion and exclusion documents) and the research documents to be considered for studied, quantitative, and qualitative analysis.

4.4. Research Inquiry (RQ_4): How Do We Recognize the Very Weak, Moderate, and Strong Research Areas of $PI_{4.0}$-CNs/ALs? The authors summarized the research documents with respect to each $PI_{4.0}$-CN/AL as discussed in RQ_3 to recognize the weakly, moderately, and strongly performing $PI_{4.0}$-CNs/ALs. The RT data are depicted in Tables 8–10 which exhibit the DOIs/URLs of research documents, existing under the exclusion parameters. The results and discussions are carried out in Section 5. Suggestions to improve the very weak and moderately performing $PI_{4.0}$-CNs/ALs are discussed in Section 5.1.

5. Result and Discussions

The line charts are presented in Figures 5–7 which illustrate the RTs. The results are briefly articulated as follows:

(a) $PI_{4.0}$-DO-CN/AL: the total number of RMs (Research Manuscripts) has been found (fifty-five) in the case of DO-CN/AL. The RTs have been found consistent and stable more than twice, i.e., 2007-2009 and 2013-2015, respectively. It has been proven that the RTs from 2013 to 2015 are stronger than those from 2007 to 2009. Next, the RTs have been found with strong acceleration over 2016-2017. As a result, the RTs of DO have been traced as more credible than the residue of all CNs/ALs

(b) $PI_{4.0}$-N-CN/AL: the total number of RMs has been found (fifty) in the case of N-CN/AL. The RTs have been found excellent in 2016. In addition, the RTs have also been observed stable over 2008, 2010, and 2017 with six to eight RMs, but the RT of 2016 could not be accessed. As a result, the RTs of N have been traced to be slightly less than those of DO-CNs/ALs

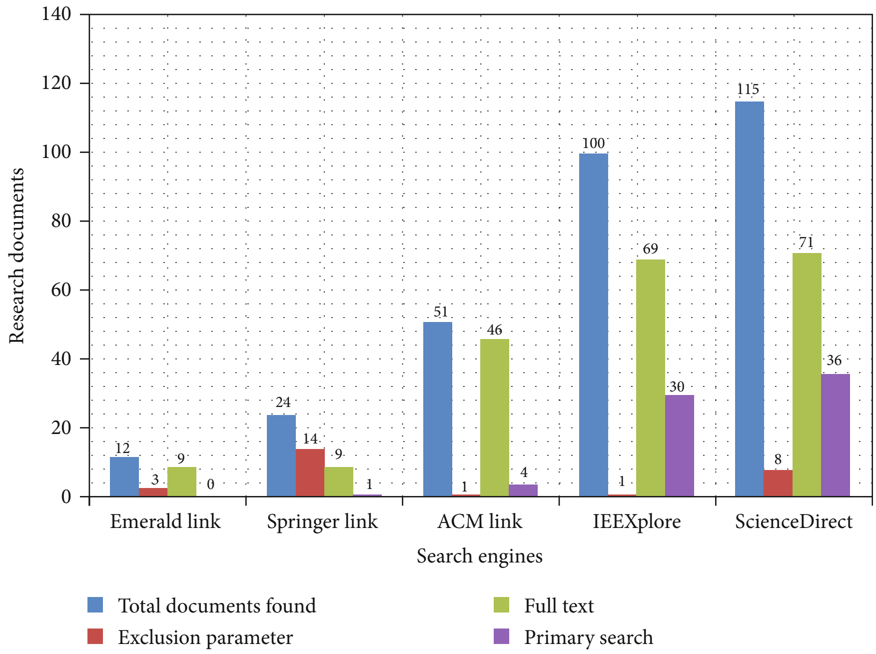

FIGURE 3: Total database of $PI_{4.0}$-CNs/ALs.

(c) $PI_{4.0}$-DA-CN/AL: this layer reserved forty-one RMs. The research has no sound from 2007 to 2008. Later, RTs have been found constant from 2009 to 2012 excluding 2011 which reflected only four RMs. RTs over 2013-2017 have been found stronger (wherein 2016 and 2017 seem to be the most significant years). As a result, the RTs of PC have been found lesser than those of N and DO

(d) $PI_{4.0}$-PC-CN/AL: this layer reserved thirty-three RMs. The RTs have been found constant over the years 2007-2014. RTs are slightly accelerated over 2015-2017. As a result, the RTs of PC have been found prosier than N, DO, and DA

(e) $PI_{4.0}$-IoT-CN/AL: this CN/AL stands with twenty-two RMs. The RTs illustrated upward and downward slopes throughout 2010-2015. However, RTs have been found strong for over two years (2016 and 2017). As a result, this layer RT has been found inferior to that of DO, N, DA, and PC

(f) $PI_{4.0}$-VR-CN/AL: the total number of RMs has been found (twenty-two). The RTs are continuously upward and downward over 2010-2017. The RTs have been found the same over the years 2007, 2010, 2013, and 2015. RTs resonate with a good sound for over two years (2012 and 2016). As a result, the RTs of DO, N, DA, PC, and IoT have been found superior to that of VR

(g) $PI_{4.0}$-I-CN/AL: this AL stands with only twenty RMs. The RTs have been observed with no sound/null or hardly with one RM over the years 2007-2014. The RTs highly accelerated over 2015-2017 in comparison with 2010-2014. As a result, the RTs of DO, N, DA, PC, IoT, and VR have been found superior to that of I

(h) $PI_{4.0}$-CPS-ERP-IDM-CNs/ALs: all said, ALs seemed to be without sense to the researchers. The RTs are the same in terms of RM publications. The researchers must focus on CPS-ERP-IDM-CNs/ALs to make the smart $PI_{4.0}$ for the future. As a result, the RTs of CPS, ERP, IDM have been found at the level of the same RTs, but inferior to that of DO, N, DA, PC, IoT, VR, and I

After identifying as well as discussing the RTs of $PI_{4.0}$-CNs/ALs, the authors focused on suggestions, provided by published articles in improving the very weak and moderately performing $PI_{4.0}$-CNs/ALs, linked to CE. The authors present Section 5.1, which directs the scholars towards conducting research over very weak performing $PI_{4.0}$-CNs/ALs such as CPS-ERP-IDM and subsequently focusing on the moderately weak performing $PI_{4.0}$-CNs/ALs such as N, DA, PC, IoT, VR, and I.

5.1. Suggested Research Areas to Be Focused for Improving the Very Weak Performing $PI_{4.0}$-CNs/ALs Such as CPS-ERP-IDM. Asongu and le Roux [73] and Miksa et al. [74] focused on the information and communication system and advised scholars to focus on information technology to enable effective communication systems in IT sectors. The presented research suggests that future scholars should focus on electronic devices, security risks, wireless monitoring control, knowledge and big data management, maintenance systems, and smart manufacturing architectures for improving the future performance of $PI_{4.0}$-IDM-CN/AL and CE.

Robin and Chunyan [68] investigated the ERP system of oil and gas industries in Houston and analyzed the RTs and

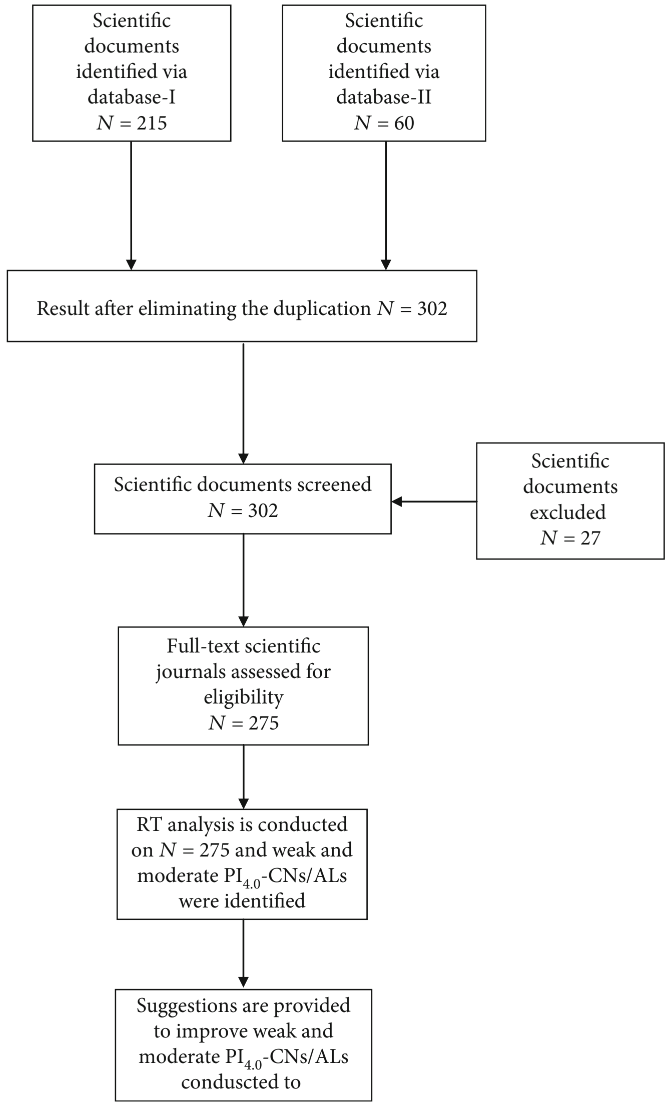

Figure 4: Evaluation of research documents by PRISMA 2009 flow chart.

Table 8: Evaluated scientific research manuscripts include full text and primary search.

Years	Full text and primary search results									
	IoT	CPS	VR	I	DO	ERP	PC	DA	N	IDM
2007	0	0	1	0	1	1	2	0	1	0
2008	0	0	2	1	1	0	0	0	7	0
2009	1	0	2	0	1	0	2	1	3	0
2010	0	0	1	1	5	1	1	1	6	0
2011	1	0	4	0	2	0	1	4	4	1
2012	0	0	2	1	2	1	2	1	1	0
2013	1	0	1	1	4	3	2	3	4	3
2014	0	0	2	0	4	1	2	3	4	2
2015	0	2	1	4	4	1	4	5	1	0
2016	8	5	5	6	10	1	8	12	9	3
2017	11	4	1	6	21	2	9	10	10	2
Sum = 275	22	11	22	20	55	11	33	40	50	11

RTs of models, mathematical modeling, and applications of algorithmic techniques under I_4 structures. The authors advised scholars to focus more towards path planning, machine learning process, and ERP software benefits for enhancing the future performance of $PI_{4.0}$-ERP-CN/AL.

Mbohwa and Sahu [75] suggested that researchers should work on cyber physical security risk, cybersensor nodes, application of CPS principles, and polymorphic wireless receivers to improve the future performance of $PI_{4.0}$-CPS-CN/AL and CE.

5.1.1. Suggested Research Areas to Be Focused for Improving the Moderately Weak Performing $PI_{4.0}$-CNs/ALs Such as N, DA, PC, IoT, and VR, I. Lu [42] suggested that scholars should focus on such areas as development of models and data modeling, application of techniques/methods/algorithms, fuel market integration, integration of biofuel filtration, new technology, the best decision styles, and design integration and vertical integration in order to improve the future performance of $PI_{4.0}$-I-CN/AL and CE.

Table 9: Tabulation of URL/DOI of research manuscripts associated with exclusion parameters.

Years	
	Application of ACM Library research search engine
2011	[doi: https://dl.acm.org/citation.cfm?id=2348214]
	Application of Springer research search engine
2007	[doi: https://link.springer.com/chapter/10.1007/978-0-387-73659-4_4] [doi: https://link.springer.com/chapter/10.1007/978-3-319-54969-9_4]
2009	[doi: https://link.springer.com/chapter/10.1007/978-1-4419-1017-2_29]
2010	[doi: https://link.springer.com/chapter/10.1007/978-3-642-59268-3_3]
2013	[doi: https://www.springer.com/gp/book/9789814451697] [doi: https://www.springer.com/gp/book/9781447129202]
2015	[doi: https://www.springer.com/gp/book/9783319145280] [doi: https://www.springer.com/gp/book/9783319165301] [doi: https://link.springer.com/referenceworkentry/10.1007/978-3-319-14529-7_28] [doi: https://www.springer.com/gp/book/9783540788362]
2016	[doi: https://link.springer.com/chapter/10.1007/978-3-319-48725-0_14] [doi: https://link.springer.com/chapter/10.1007/978-1-4842-2047-4_2]
2017	[doi: https://link.springer.com/chapter/10.1007/978-3-319-57078-5_54] [doi: http://www.springer.com/978-3-319-45254-8]
	Application of Emerald research search engine
2011	[URL: http://www.emeraldinsight.com/doi/full/10.1108/S0195-6310%282011%290000028008]
2014	[URL: http://www.emeraldinsight.com/doi/full/10.1108/S1571-502720140000027016]
2017	[URL: http://www.emeraldinsight.com/doi/full/10.1108/S1571-502720170000030003]
	Application of IEEE Xplore research search engine
2017	[doi: 10.1109/HASE.2017.23]
	Application of ScienceDirect research search engine
2014	[doi: 10.1016/B978-0-12-397022-0.00002-9]
2015	[doi: 10.1016/B978-0-12-420114-9.00003-4] [doi: 10.1016/B978-0-12-800939-0.00024-3] [doi: 10.1016/B978-0-12-800037-3.00016-9]
2017	[doi: 10.1016/B978-0-12-809272-9.00042-6]
2017	[doi: 10.1016/j.ijhydene.2017.09.158] [doi: 10.3182/20100908-3-PT-3007.00058] [doi: 10.1016/B978-0-12-804642-5.00004-9]

Nazari et al. [76] advised researchers to follow up areas such as technological aspects, virtual reality architectures, analytical simulation or virtual testing of oil dynamic aspects and application of software model development, fault monitoring and diagnostics, Java-based toolkit, proportions, virtual line process monitoring, virtual reality-based education program, analytical simulation for parameter optimization, and data sharing to social network websites for escalating the future performance of $PI_{4.0}$-VR-CN/AL and CE.

Meng et al. [61] and Celia and Cungang [77] proposed that scholars should focus on research areas such as IoT application to digital manufacturing, programming for production plans, IoT-based intelligent sensor systems, IoT architectures, IoT thinking and principles, supervisor control and data acquisition, operational analysis by IoT software, smart network applications and IoT simulators, and applications of programming in order to improve the future performance of $PI_{4.0}$-IoT-CN/AL and CE.

Mraz et al. in 2017 advised scholars to work on the development of bench and site acceptance testing techniques, mathematical modeling, development of architectures for improving plant production and control, safety and controlling of operations in oil refineries, web servers and database information systems, internet technological design, monitoring technologies, energy controlling, multiagent systems, discharge and architecture loss control system, control systems for accidents and failures, scheduling programming, design and application of physical or soft controllers, improvement in industrial network, algorithm/programming configuration of plant system, modeling of hybrid internet and intranet, monitoring the gasification processes, plant control principles and advanced technology design, and application of physical controllers for improving the future performance of $PI_{4.0}$-PC-CN/AL and CE.

Ahmed and Kim [67] advised scholars to concentrate on such techniques as smart network, application for

Table 10: Tabulated list of DOI/URL related to primary search and full text database.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
		PI_4-IOT	
2013	[doi:10.1007/978-3-642-38427-1_113]	Focuses on safety management by using Java web technology as well as structured query database programming technology.	Java web technology
2017	[doi:10.1109/JSYST.2017.2700268]	Focused on industrial intelligent sensing ecosystem (IISE) by using wireless sensor networks.	IoT-based intelligent sensors system
2016	[doi:10.1016/j.cie.2016.08.008]	Focused on mathematical programming to enable the firm to determine the better production plans.	Programming for production plans
2016	[doi:10.1016/j.eswa.2014.08.006]	Identified the importance of innovation and technology in the petroleum and petrochemical industry.	Innovation and technology
2009	[doi:10.1145/1324892.1324935]	Direct annotation of program code in digital production of ink.	Programming
2016	[doi:10.1145/2897839.2927393]	Physically plausible oil paint simulator implemented on mobile hardware to be used to teach novice painters.	Simulator application
2017	[doi:10.1145/3131542.3140269]	Digital painting frame through IoT talk.	IoT application to digital manufacturing
2017	[doi:10.1145/2936744.2936750]	Focused on real watercolor and acrylic painting software.	Operational analysis by IoT software
2016	[doi:10.1108/JFC-04-2016-0021]	Demonstrated types of internal control weaknesses and its impact that leads to fraud activities in an oil and gas company.	Internal control and IoT
2012	[doi:10.1109/GreenCom.2012.46]	Tested behavior of things under internet web service architecture.	Internet web service architectures
2013	[doi:10.1109/GreenCom-iThings-CPSCom.2013.410]	Focused on information technology of petroleum enterprises.	IoT-based intelligent sensors system
2016	[doi:10.1109/LATINCOM.2016.7811564]	Focused on industrial wireless networks.	IoT-based intelligent sensors system
2016	[doi:10.1109/WARTIA.2014.6976401]	Wireless sensor networks in measuring temperature of oil.	IoT-based intelligent sensors system
2017	[doi:10.1109/ICRAMET.2017.8253173]	Wireless sensor used in monitoring oil and gas infrastructures, i.e., pipelines.	IoT architectures
2017	[doi:10.23919/ICACT.2017.7890184]	IoT-based architecture is proposed for oil and gas industries to collect quick data from connected objects.	IoT architectures
2017	[doi:10.1002/9781119173601.ch31]	Illustrated human-machine interface, industrial control system by internet web service architectures.	IoT architectures
2017	[doi:10.1109/ICRAMET.2017.8253159]	Intelligent IoT accompanied by smart objects for reliable and efficient monitoring of oil and gas wells.	IoT-based intelligent sensors system
2017	[doi:10.1109/ICCNEA.2017.111]	Focused on node microcontroller and main design software module to control petroleum well fuel pumps.	IoT-based intelligent sensors system
2017	[doi:10.1109/ICBDA.2017.8078802]	Suggested a few important IoT architectures for monitoring the wells of oil field.	IoT architectures
2017	[doi:10.1109/IACC.2017.0078	Appraised oil and gas purchasing order by IoT devices.	IoT devices
2016	[doi:10.1016/j.procs.2016.08.205]	Focused to monitor noise and vibration under crude oil pipeline in real time by the Internet of Things (IoT).	IoT architectures

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2016	[doi:10.1016/j.compchemeng.2016.03.006]	Focused on application of IoT thinking and principles towards conceptualizing smart factory in petrochemical industry.	IoT thinking and principles
2016	[doi:10.1016/j.chaos.2015.10.030]	Drafted the supervisor control and data acquisition architectures to help to drive the petrochemical industry.	Supervisor control and data acquisition
2017	[doi:10.1016/j.ifacol.2017.12.012]	Focused on the smart network applications for obtaining the smart equipment automation to outline a cyber physical automation network.	Smart network applications
		PI_4-CPS	
2016	[doi:10.1109/CYBER.2016.7574873]	Focused on polymorphic wireless cybersystem in automation technology for maintaining plant material quantity.	Polymorphic wireless cybersystem
2015	[doi:10.1145/2818427.2818443]	Articulated the CPS application and spatial user interface for collaborative petroleum well planning.	CPS application
2016	[doi:10.1145/2970030.2970032]	Proposed a game theory algorithm to allocate the cybersecurity controls in the oil pipeline cyber physical system.	Game theory algorithm
2016	[doi:10.1145/2966986.2980091]	Developed an intelligent cyberattack model to optimize the operational data of petroleum industry.	Development of cyber physical model
2016	[doi:10.1109/TCAD.2016.2584065]	Used computer in designing the petroleum CPS and built a new CPS framework to compute the petroleum well connectivity.	Development of cyber physical model
2017	[doi:10.1109/ICCAD.2017.8203865]	Build a cybersystem-based cross-entropy optimization technique to sense the oil leak in petroleum industry.	Cybersystem improvement by technique
2016	[doi:10.1016/j.chaos.2015.10.030]	Proposed a cyber physical network security risk assessment approach to control the problem of SCADA (supervisor control and data acquisition) network in oil and gas industry.	Cyber physical security risk
2017	[doi:10.1016/j.ifacol.2017.08.347]	Focused on CPS architecture standard to obtain the accessibility of process data for controlling production cost in oil and gas industry.	CPS architectures
2017	[doi:10.1016/j.cose.2017.04.005]	Suggested few practices based on multilevel CPS in the China Petrochemical Corporation (SINOPEC).	CPS architectures
2015	[doi:10.1145/2737095.2737727]	Used cybersensor nodes to monitor an area of petrochemical industry and suggested workers to wear safety equipment.	Cybersensor nodes
2017	[doi:10.1016/j.compchemeng.2016.12 .012]shift to cps	Suggested few references and working principles of a CPS towards the petrochemical industry. Moreover, investigated the construction practice of a multilayers CPS in the China petrochemical companies.	Application of CPS principles
		PI_4-VR	
2016	[DOI:10.1145/3013971.3013977]	Designed an interactive somatosensory cloth system by using virtual technology to avoid the fire accidents in petroleum industry.	Technological aspects
2014	[doi:10.1109/Dynamics.2014.7005657]	3D virtual model of equipment are built by CAD software based on data entry by petrochemical's technological processes.	Application of software for model development

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2012	[doi:10.3182/20120710-4-SG-2026.00182]	Focused on fault monitoring and diagnostics model for virtually observing the polymer reactor in a petrochemical plant.	Fault monitoring and diagnostics
2017	[doi:10.1016/j.ifacol.2017.08.1921]	Presented a Modelica-based software to simulate and develop a control of cyber physical systems in petrochemical industry.	Application of software for model development
2007	[doi:10.1145/1281500.1281523]	Described the functionality and architecture of SATIN (a Java-based toolkit) that embraced a generalized architecture to knob pen input to ink industry.	Java-based toolkit
2008	[doi:10.1145/1477862.1477899]	Developed a 3D visualization model of oil spill under consideration to tidal hydrodynamic model in oil refinery industry.	Application of software for model development
2009	[doi:10.1145/1559764.1559794]	Developed an extensible 3D software for constructing an interactive and dynamic virtual of oil and gas pipeline system.	Application of software for model development
2009	[URL: https://dl.acm.org/citation.cfm?id=1655363]	A simulation is conducted to virtually test the dynamic proportions of oil, water, and sand of heavy oil.	Analytical simulation to conduct virtual test
2011	[doi:10.1145/2087756.2087770]	Explained an effectual technology, which visually simulates the ink diffusion process.	Technological aspects
2011	[doi:10.1145/2071639.2071645]	Designed an architecture based on web-flex technology to build and monitor the virtual image of oil well.	Technological aspects
2011	[URL: https://dl.acm.org/citation.cfm?id=2025782]	Proposed the sensors to assist the virtual monitoring of processes of lubricating oil.	Virtual line process monitoring
2007	[doi:10.1109/MCG.2007.141]	Discussed about the execution of oil recovery projects over the past 10 years without using the concept of virtual reality architectures.	Virtual reality architectures
2008	[doi:10.1109/ICALIP.2008.4590213]	Focused on an interactive and virtual reality-based education program to make the safety in oil field operations.	Virtual reality-based education program
2010	[doi:10.1109/CCIE.2010.163]	Suggested to conduct the virtual experiment/simulation to optimize the parameters vs. sucker-rod pumping in oil field.	Analytical simulation for parameters optimization
2013	[doi:10.1109/NAVCOMP.2013.23]	Stated the virtual-mixed reality technique for data acquisition considering automation and maintenance systems of oil and gas industry.	Technique to improve virtual reality
2014	[doi:10.1109/SVR.2014.27]	Stated about the required future skill of professionals for building the 3D model of an offshore oil platform.	Application of software for model development
2015	[doi:10.1109/EuMC.2015.7345837]	Focused on hybrid three-dimensional inkjet additive manufacturing technique for the production of massive ink.	Technique to improve virtual reality
2016	[doi:10.1109/ETFA.2016.7733633]	A model hybrid technique is proposed for virtual process monitoring in oil production industry.	Virtual line process monitoring
2016	[doi:10.1109/SVR.2016.38]	A desktop virtual collaborative bridge between users and trainers for constructing the 3D of an offshore oil platform is presented.	Application of software for model development
2016	[doi:10.1109/PCICEurope.2016.7604641]	Focused on virtual testing, plant design, and training of systems based on simulation tools for conforming automation in the processes of oil plants.	Analytical simulation by software

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2016	[doi:10.1109/MCG.2016.60]	Stated that VR is boon for multiple areas of oil industry and provides immense visualization in diverse working environments, online monitoring, and analysis.	Analytical simulation by software
2011	[doi:10.1016/j.pubrev.2011.04.006]	Shared the gulf coast oil spill images through the social network website to make the audience aware with crisis of oil spill of gulf coast.	Data sharing to social network website
2012	[doi:10.1016/j.aasri.2012.06.030]	Conducted their research on oil extraction engineering based on virtual reality and explained that production data query, information and display is possible due to virtual reality technology.	Application of software for model development
		PI_4-I	
2013	[doi:10.1109/ICCA.2013.6564943]	A data integration model is developed to calculate the oil flow in petrochemical units.	Development of framework and data modeling
2015	[URL: https://dl.acm.org/citation.cfm?id=2857190]	Presented the data structure technique for integrating the oil spill production.	Application of techniques/methods/algorithms
2015	[doi:10.1145/2791060.2791067]	Product line engineering model is proposed for typical subsea production systems for the utilization of oil and gas production fields.	Development of framework and data modeling
2015	[DOI 10.1134/S207020511507014X]	Discussed about the perspective of the chemical engineering architectures to protect and integrate the petroleum-refining units.	Architectures for improving plant production
2016	[DOI 10.1007/s11356-015-6034-x]	Integrated biofuel filtration and presented biofiltration process for tertiary treatment of oil refinery wastewater. It is suggested that integration of advanced oxidation processes is best for oil refinery and for reducing the wastewater.	Integration of biofuel filtration
2012	[DOI 10.1108/17506221211216553]	Focused upon the integration of wood fuel trade and market integration between the Sweden and Estonia and found that their fuel markets are still far away from fully developed.	Fuel market integration
2016	[DOI 10.1108/EMJB-11-2015-0055]	Investigated the architectures, which can influence the development and integrate of embryonic oil and gas industry of Cyprus. The work explored numerous forces and factors influencing the development of said industry.	Focuses to architectures for improving plant production
2016	[DOI 10.1108/IJQRM-02-2015-0026]	Proposed a practical approach by integrating reliability centered maintenance technique considering the idea of reliability, availability and maintainability in performing the maintenance in the oil offshore industry.	Application of techniques/methods/algorithms
2016	[doi:10.1155/2016/31598]	Presented the cluster of integrated principles for reconfigurable smart factory and developed an integrating IoT technology to address the technical challenges of smart industry.	Integration principles
2017	[DOI 10.1108/JSTPM-07-2016-0011]	Analyzed factors/architectures for integrating the agro-food-energy-biochemical system in Thailand.	Architectures for improving plant production
2017	[DOI 10.1108/IJOPM-02-2016-0089]	Examined the importance of organizational structure and supply chain integration for improving the operational performance of oil and gas (O&G) industry. The work discussed about the academic and practical donations of operations management and organizational studies under oil and gas supply chain architecture.	Development of model and data modeling

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2008	doi:10.1109/WGEC.2008.51]	Proposed integrated architectures and a decision support structure defining the oil production management system.	Architectures for improving plant production
2010	[doi:10.1109/CEE-SECR.2010.5783168]	Proposed computer integrated manufacturing model for greater flexibility and data integration under each unit for progressing the process of oil and gas company.	New technology
2017	[doi:10.1109/ICUAS.2017.7991525]	Integrated small unmanned aerial system (sUASs) under ICT for inspecting network components and to minimize the time for repair multiple oil and gas pipeline.	ICT
2017	[doi:10.1109/ICAICT.2016.7991832]	An integrated architectural model is proposed to analyze the big business transaction data of oil and gas industry.	Architectures for improving plant production
2015	[doi:10.1016/j.aap.2015.08.016]	Recognized best decision styles based on health, safety, environment, and ergonomics program of large oil refinery.	Best decision styles
2016	[doi:10.1016/j.ejor.2016.01.034]	Developed a model/framework for crude oil scheduling in an integrated terminal-refinery system under vague supply chain.	Development of model and data modeling
2016	[doi:10.1016/j.ijggc.2015.12.018]	Integrated and designed the optimal operations in oxy fuel plant under time-varying electricity prices.	Design integration
2017	[doi:10.1016/j.landusepol.2017.08.020]	Examined the fundamental query in relation to agro commodity value chains and stressed on the vertical integration of petrochemical plants.	Vertical integration
2017	[doi:10.1016/j.jclepro.2017.03.105]	Proposed a multiobjective mathematical model to integrate the up- and midstream components of crude oil supply chain along with environmental indicators.	Development of model and data modeling
		PI_4-OD	
2010	[doi:10.1109/ICMSS.2010.5578485]	Developed the high-level architecture simulation to support the distributed interactive simulation of petrochemical industry.	High-level architecture simulation
2010	[doi:10.1109/MED.2010.5547645]	Used the theoretical knowledge of automatic control systems and a few principal characteristics of petrochemical process to optimize the ethylene reactor in the petrochemical industry.	Theoretical knowledge
2016	[doi:10.1109/ECC.2016.7810423]	Optimized the operation of the global refinery H_2 network by operational management of hydrogen networks.	Operation management by hydrogen H_2 networks
2017	[doi:10.1109/TENCON.2016.7848003]	Introduced strategy based on evolutionary algorithms to efficiently tackle the single-level production planning.	Evolutionary algorithms application
2010	[doi:10.1016/j.ces.2009.10.015]	New industrial tools and techniques to solve the optimization problems of petrochemical process are demonstrated.	Illustration of industrial tools and techniques
2012	[doi:10.1016/j.eswa.2012.02.165]	Artificial intelligence, concepts, methodologies, decision-making tools to solve the optimization problems of petrochemical process are presented.	Artificial intelligence application
2013	[doi:10.1016/B978-0-12-382165-2.00109-4]	Implicated analytical techniques, i.e., infrared spectroscopy, Raman spectroscopy to help to further distinguish and differentiate the samples of paint.	Infrared spectroscopy application

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2017	[doi:10.1016/j.jclepro.2016.07.078]	Proposed cogeneration as the most significant optimization channel to reduce the energy consumption and greenhouse gas emission.	Illustrated the cogeneration application
2017	[doi:10.1016/j.jece.2017.04.003]	Proposed regenerated spent catalyst scheme to a petrochemical styrene unit to eliminate the phenol from an industrial phenolic effluent.	Regenerated spent catalyst scheme application
2017	[doi:10.1016/j.compchemeng.2016.11.020]	Applied a multiperiod mixed integer nonlinear programming to optimize the production planning of refinery and the ethylene unit simultaneously of a petrochemical industry.	Multiperiod mixed integer nonlinear programming
2017	[doi:10.1016/j.jclepro.2016.10.168]	Applied group decision-making algorithms for evaluating sustainable industrial building for petrochemical projects.	Group decision-making algorithms
2017	[doi:10.1016/J.ENG.2017.02.011]	Discussed about few elementary principles and key technologies for optimal production of oil in the process industry.	Highlighted few elementary principles
2017	[doi:10.1016/j.apenergy.2017.04.007]	Developed novel virtual sample generation technique by using Monte Carlo and particle swarm optimization algorithms to enhance the precision of energy efficiency analysis based on small data set for a petrochemical process.	Virtual sample generation application
2017	[doi:10.15439/2017F365]	Proposed an evolutionary modeling technique to optimize the lean operations and to recognize the future industry 4.0 models.	Evolutionary modeling technique
2017	[doi:10.1016/j.jenvman.2017.03.065]	Developed petrochemical industry architectures model to optimize the air pollutant filtration technologies.	Development of architectures model
2010	[doi:10.1145/1864349.1864360]	Stressed on identifying digital technologies to enables the petrochemical process effective.	Digital technologies
2010	[URL: https://dl.acm.org/citation.cfm?id=2433724]	Used retrospective optimization (RO) algorithm to search well location and optimizing the well load under uncertainty.	Retrospective optimization algorithm application
2013	[doi:10.1162/EVCO_a_00064]	Applied an infeasibility driven evolutionary algorithm towards optimizing the fifty-six problems of a well reservoir.	Infeasibility driven evolutionary algorithm application
2013	[URL: https://dl.acm.org/citation.cfm?id=2676117]	Implemented a dynamic simplex interpolation algorithm for searching the oil well under uncertain data.	Dynamic simplex interpolation algorithm application
2014	[doi:10.1145/2597917.2597956]	Applied the artificial network combined with genetic algorithm for predicting and set optimal price of international crude oil produced by a petrochemical firm.	Artificial network with genetic algorithm application
2015	[URL: https://dl.acm.org/citation.cfm?id=2874937]	Proposed a merged energy optimization model for estimating the energy cost in oil sectors.	Development of energy optimization modeling
2017	[doi:10.1145/3059336.3059360]	Utilized genetic algorithm for efficient production and procurement of biofuel to complete the demands of countless users under multiple factors.	Genetic algorithm applications
2007	[doi:10.1109/ICIT.2006.372715]	Established the multiobjective scheduling optimization model for scheduling the crude oil vessel operations considering minimization of total time.	Scheduling optimization modeling
2008	[doi:10.1109/IJCNN.2008.4634275]	Implemented neural networks technique to analyze the behavior of an oil production system and to determine the optimal values of gas injection rate and oil rate lifted from a production system.	Neural network technique application

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2009	[doi:10.1109/IJCNN.2009.5179056]	Implemented the neural networks, linear and sequential programming to analyze the behavior of an oil production system to find the optimal values of gas injection rate and oil rate in a two-oil-well system.	Neural networks and linear and sequential programming application
2013	[doi:10.1109/CICN.2013.139]	Optimized the sale process and designed a business process reengineering scheme for effectively implementing customer relationship management in China lubricant enterprise.	Fixed-sale process scheme
2017	doi:10.1109/BigData.2017.8258496]	Developed a petroleum analytics learning machine for optimizing the Internet of Things-related problems of oil field in refinery petroleum system.	Petroleum analytics learning machine
2017	doi:10.1109/BigData.2017.8258055	Proposed novel network architectures to help predict the steam capacity of oil reservoir.	Novel network architectures
2011	[doi:10.1016/j.compchemeng.2011.01.030]	Proposed an integrated multilevel simulation for solving the crude oil loading and unloading scheduling problems.	Integrated multilevel simulation technique
2011	[doi:10.1016/j.powtec.2011.08.030	The grinding brass particle manufacturing process variables are optimized for paint and pigment industry.	Optimize process variables
2012	[doi:10.1016/j.jlp.2012.06.002]	Developed a risk and condition-based maintenance to predict the time to provide maintenance to an oil transfer station.	Condition-based maintenance predict
2014	doi:10.1016/j.jlp.2014.04.002]	Demonstrated the fault tree analysis approach to estimate the failure rate of a piping system of a process industry considering the chance of failure data.	Fault tree analysis approach
2014	[doi:10.1016/S1570-7946(06)80348-2]	Proposed an integrative optimization technique for evaluating the refinery operations of petrochemical plants	Integrative optimization to refinery operations
2014	[doi:10.1016/j.biortech.2016.04.077]	Evaluated the optimum bio gas production from solid-state oil palm biomass under waste solids contents by considering total solids (TS) contents, feedstock to inoculum (F : I) ratios and carbon to nitrogen (C : N) ratios.	Optimum biogas and oil production
2015	[doi:10.1016/j.ejor.2015.03.002]	Demonstrated a dynamic programming technique to solve multiperiod multiproduct optimization problem of refinery petroleum system.	Dynamic programming technique
2015	[doi:10.1016/j.proche.2015.10.022]	Proposed a list of architectures to evaluate the relative efficiency of the distillation unit flow sheets in refinery petroleum system.	Identified architectures
2015	[doi:10.1016/j.egypro.2015.07.724]	Performed the modeling of biomass residual optional fuels and suggested it as a potential alternative fuel and valuable chemical feedstock. Two-level factorial design of experiment is used for predicting the optimal condition for maximizing the biooil content in it.	Biomass modeling
2016	[doi:10.1016/j.trpro.2016.02.045]	Established a mixed integer linear programming model to evaluate the location for setup a waste cooking oil system in China under both economic and environmental concern.	Mixed integer linear programming model
2016	[doi:10.1016/j.jclepro.2016.01.033]	Developed gas emission optimization modeling to help to recognize the best gas mitigation technology with minimum cost.	Gas emission optimization modeling

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2016	[doi:10.1016/j.partic.2016.04.001]	Implicated response surface technique to optimize the variables of fish oil refinery process for improving fish oil encapsulation efficiency.	Optimized fish oil refinery process
2016	[doi:10.1016/j.lwt.2016.02.025]	Response surface technique towards optimizing the encapsulation of coffee oil production under multiple process variables is presented.	Coffee oil optimization
2016	[doi:10.1016/j.cjche.2016.04.050]	Implemented a particle swarm optimization algorithm for solving the scheduling problem of numerous light load oil well simultaneously under demand variables.	Particle swarm optimization algorithm for scheduling
2016	[doi:10.1016/j.indcrop.2016.06.017]	Optimized the process variables of oil recovery from moringa seeds by using central composite rotatable technique.	Optimized variables of oil recovery
2016	[doi:10.1016/j.proeng.2016.06.509]	Optimized the multiple parameters of methanol castor oil for the synthesis of fatty acid methyl ester (FAME).	Optimized multiple parameters
2016	[doi:10.1016/j.compchemeng.2016.03.028]	Proposed a model towards finding the optimal configuration of oil production firm and the energy infrastructure.	Configuration of oil production
2016	[doi:10.1016/B978-0-444-63428-3.50365-9]	Conducted the thermodynamics and economic analysis to find the optimum operating conditions for two actual crude oil distillation units	Optimized variables of crude oil distillation units
2017	[doi:10.1016/j.seppur.2017.04.044]	The response surface technique for optimizing the multiple deodorization parameters for chemical refining of seed oil is presented.	Optimized multivariables of oil production
2017	[doi:10.1016/B978-0-444-63965-3.50210-5]	Applied a subjective data analysis technique for optimizing the planning and scheduling operations of crude oil refineries.	Subjective data analysis technique
2017	[doi:10.1016/j.jclepro.2017.04.161]	Utilized a central composite factorial design technique to set up an experimental plan for processing variables of mortar mixtures and used to mix byproduct oil of oil refinery industry.	Central composite factorial design
2017	[doi:10.1016/j.jclepro.2017.06.240]	Implemented a response surface methodology technique for optimizing the coagulation and flocculation of paint composed by wastewater.	Response surface technique application
2017	[doi:10.1016/j.marpolbul.2017.09.012]	Applied an advanced oil spill modeling upon an offshore oil spill model to search the allocation of response crews for cleaning up an offshore oil spill.	Advanced oil spill modeling
2017	[doi:10.1016/j.molliq.2017.09.007]	Applied the Taguchi experimental design and emulsification technique to determine the appropriate variables for fast manufacturing of garlic essential oil nanoemulsions.	Taguchi experimental design application
2017	[doi:10.1016/j.fuel.2017.07.115]	Stated that the integration of technologies with advanced feed-stocks system helps to meet the future environmental criteria and optimizes the process variables of oil industry.	Optimized the process variables
2017	[doi:10.1016/j.rser.2016.08.053]	Conducted the systematic literature reviews on the biooil supply chains and suggested the echnoeconomic models, which assisted in optimizing the upstream forest biomass to biooil supply chains.	Biooil supply chains
2017	[doi:10.1016/j.jclepro.2016.11.077]	Utilized the central composite design for optimizing the process variables of palm oil mill.	Central composite design

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
		PI_4-ERP	
2013	[doi:10.1109/MIS.2013.112]	Developed and simulated the human resource-based model for assisting the human resource planning problem under a large petrochemical industry.	Development of models and mathematical modeling
2017	[doi:10.1109/AIM.2017.8014250]	Path for the firefighter robots in large petrochemical environments is planned by way of feeding big computation memory in firefighter robots.	Path planning
2010	[doi:10.1145/1785414.1785448]	Discussed few benefits of ERP software to evaluate the drilling location of oil well.	ERP software benefits and application
2013	[doi:10.1162/EVCO_a_00064]	Utilized the genetic algorithms technique to estimate the optimal quantity of gas rejected from each well for obtaining the maximize amount of oil extracted. Moreover, developed a model to help to generate a plan for future problems related to gas injection.	Technique and application to improve ERP capability
2017	[doi:10.1145/3166094.3166096]	Demonstrated the applications of machine learning process for modeling and increasing the precision of planning and economy for digital oilfield processes.	Machine learning process
2013	[doi:10.1109/SBESC.2013.10]	Illustrated the resource planning technique, which established the connectivity and served the information between the two oil and gas refineries.	Technique and application to improve ERP capability
2014	[doi:10.14257/ijca.2014.7.3.36]	Applied ERP to analyze the cloud computing data for providing the rapid technological advancements to industry.	ERP to analysis the cloud computing data
2016	[doi:10.1109/ICIMTech.2016.7930329]	Stated the benefits of ERP for managing the operational performance of palm oil plantation companies.	ERP software benefits and application
2007	[doi:10.1016/j.enpol.2006.01.028]	Investigated an ERP stochastic dynamic growth evaluation model to find out the corruption level in oil supply chains.	ERP modeling and evaluation
2012	[doi:10.1016/j.phpro.2012.02.319]	Proposed geographical/surface model based on information technology to improve the ERP capability of petroleum engineering technologies.	Technique-based modeling to improve ERP capability
2015	[doi:10.1016/j.compchemeng.2015.05.013]	Applied chemical process based on neural network model for predicting the faults in chemical process. Furthermore, the same network assisted in planning the factors to diagnose the further faults.	Development of models and mathematical modeling
		PI_4-PC	
2009	[doi:10.1109/CCDC.2009.5194695	Discussed few connections of web servers and database information system to add value for controlling the petrochemical plant process globally.	Web servers and database information system
2010	[doi:10.1109/ICCAE.2009.64	Proposed the mathematical model of micro-electronic-mechanical systems based on temperature sensor to sense the temperature of the petrochemical industry.	Development of models and mathematical modeling
2011	[URL:http://ieeexplore.ieee.org/document/6017826/]	Prepared a list of significant factors to control the engineering projects related to South African petrochemical industries.	Architectures for improving plant production
2013	[doi:10.1109/IcConSCS.2013.6632017]	Proposed an internet technology-based reactor design to enhance the efficiency of chemical processes.	Internet technology in design

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2016	[doi:10.1109/PCICON.2015.7435127]	Suggested petrochemical plants to embark towards monitoring technologies to enhance the reliability factors and to diminish the total installed costs of electrical trace heating systems.	Monitoring technologies
2017	[doi:10.1109/ADCONIP.2017.7983838]	Focused on the measurement methods/techniques and models specifically to control the advanced processes of industrial processes.	Method/technique/approach application to control plant
2015	[doi:10.1016/j.jlp.2013.10.009]	Discussed few factors to recognize the significant security practices and measures for controlling the systems of petrochemical industrial	Architectures for improving plant production
2017	[doi:10.1016/j.jprocont.2017.11.005]	Discussed few merits of exergy-based fault detection method over energy-based detection scheme. Moreover, the characteristics of exergy-based fault detection model are discussed to petrochemical processes.	Energy controlling
2012	[doi:10.1145/2401603.2401685]	Proposed multiagent systems to enable the multiobjective simulation of offshore oil and gas production.	Multiagent-based multiobjective simulation
2007	[URL: https://link.springer.com/chapter/10.1007/978-3-540-73435-2_17]	Applied the neural-based techniques for injecting the optimal ink from nozzle during its production.	Method/technique/approach application to control plant
2007	[DOI:10.1007/s11434-007-6007-7]	Discussed a few oil and gas discharge and controlling architectures for accumulating oil in Sichuan Basin area.	Development of architectures
2009	[doi:10.1007/s11814-009-0264-x RAPID COMMUNICATI	Focused on loss control management system to enhance the safety and green management in the petrochemical industries.	Loss control system
2014	[doi:10.1134/S1064230714030095]	Proposed a mathematical model to oil refinery system to eliminate the organic acids from oil fractions.	Development of models and mathematical modeling
2015	[URL:10.1007/s10556-015-0038-8]	Proposed an advance electrochemical technique for controlling the process parameters of processing liquids in oil industry.	Methods/techniques/approach application to control plant
2016	[doi:10.1134/S0020168517140072]	Discussed few features to be considered during evaluating the analytical techniques for analyzing the catalysts of the petrochemical industry.	Methods/techniques/approach application to control plant
2016	[doi:10.1108/JFC-04-2016-0021	Demonstrated numerous types of internal weaknesses in architectures by empirical research that leads to fraud activities in an oil and gas company.	Architectures for improving plant production
2017	[doi:10.1108/02656710610664613	Developed a model by integrating the accidents and failures to assess the chances of accidents and failures in oil and gas production activities.	Modeling to control accidents and failures
2012	[doi:10.1109/ICCSE.2012.72]	Presented a technique by amalgamating fuzzy and signal strength indicators to improve the reliability of the system and to diminish the handoff overheads at same time.	Method/technique/approach application to control plant
2013	[doi:10.1109/PESMG.2013.6672710]	Proposed mathematical models to evaluate the operational sequences for controlling industrial load.	Development of models and mathematical modeling
2014	[doi:10.1109/ICRA.2014.6907329]	Discussed about two scheduling problems related to the logistics of crude oil. Theoretical modeling-based scheduling indictors are formulated to control and to solve logistic problem of crude oil.	Scheduling programming
2015	[doi:10.1109/ICMECH.2015.7083966]	Proposed a design of electronic controller for controlling the air flow arrangement in ventilation and air-conditioning systems in the paint industry.	Design and application of physical or soft controllers

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2015	[doi:10.1109/RTSI.2015.7325158]	Improvement in industrial network of an oil refinery to result improved performance and more flexible connectivity and integration with the commercial network is presented.	Improvement in industrial network
2017	[doi:10.1109/CDC.2017.8263957]	Compared the distributed extremum algorithm with data-driven optimization methods to assess the effectiveness of distributed extremum algorithm for solving gas-lifting problem in oil production is presented.	Algorithm/programming
2017	[doi:10.1109/TIMA.2017.8064814]	Presented a design of decentralized system to efficiently control the configuration of petrochemical industry.	Configuration of plant system
2017	[doi:10.1109/TSMCC.2007.897339]	Focused on an application of hybrid petri internet for modeling the crude oil operations for controlling the oil refinery process.	Hybrid internet for modeling
2017	[doi:10.1109/MIAS.2017.2739827]	Developed bench and site acceptance testing technique for assessing the safety and controlling of operations in oil refinery.	Method/technique/approach application to control plant
2016	[doi:10.1016/j.measurement.2013.08.032]	Combined a new gas injection technique with zero dimensional reactor for monitoring the gasification processes, i.e., fuel conversion, composition, during oil refinery.	Monitoring of gasification processes
2016	[doi:10.3182/20130902-3-CN-3020 .00143]	Proposed few plant control principles to improve the capacity of the produced water treatment (PWT) in offshore oil and gas production processes.	Plant control principles
2016	[doi:10.1016/j.jclepro.2015.11.023]	Proposed an expert-based mathematical model for determining the optimal synergy between the location of fixed refineries and mobile refineries via considering a few factors, i.e., capital, transportation, and operational costs.	Development of models and mathematical modeling
2016	[doi:10.1016/j.proeng.2016.07.627]	Developed an evolutionary algorithm for controlling the quality of ink with respect to three concerns, i.e., microgeometry parametric analysis, analyzing the coverage, and the strength.	Algorithm/programming
2016	[doi:10.1016/j.jenvman.2016.07.027]	Proposed a membrane filtration technology to minimize the oil refinery hazardous matters, which affects the onsite pilots in petrochemical paints.	Technological advancement
2017	[doi:10.1016/j.cej.2017.08.081]	Developed a 3D Fe foam technique to extract the water from oil as wastewater with oil content results in pollution.	Method/technique/approach application to control plan
2017	[doi:10.1016/j.oceaneng.2017.11.052]	Demonstrated a modified Smith fuzzy controller to control the temperature of oil-replenishing apparatuses in case of deep-sea hydraulic system. PI_4-DA	Design and application of physical or soft controllers
2017	[doi:10.23919/CISTI.2017.7975733]	Conducted the simulations by Aloha software to analyze and recognize responsible factors, physically affecting the operations of petroleum-refining process.	Data analysis by simulations
2011	[doi:10.1016/j.ress.2011.07.010]	Presented a literature report and conducted statistical analysis on all the incidents of Greek petrochemical industry from 1997 to 2003. Few factors are highlighted with remedies to avoid future accidents.	Literature review
2013	[doi:10.1016/j.jclepro.2011.11.052	Suggested three kinds of technologies and strategies, i.e., wait and see, in-process focused, and all round strategies to be used by further industries for diminishing GHG emissions.	Technologies and strategies

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2014	[doi:10.1016/j.psep.2013.03.002	Developed a model based on resilience engineering practices accompanied by data envelopment analysis technique to assess the behavior of resilience engineering in petrochemical plant.	Resilience-based modeling
2015	[doi:10.1016/j.psep.2014.05.001	Applied fuzzy fault tree analysis technique to evaluate the significant hazards, i.e., fire, toxic gas, and explosion, of petrochemical process industry.	Application of technique/methods to analyze process
2015	[doi:10.1016/j.jlp.2015.06.002	Applied the data envelopment analysis technique on resilience engineering for determining the managerial factors in a petrochemical plant	Application of technique/methods to analyze process
2016	[doi:10.1016/j.atmosenv.2016.07.006	Utilized strategies to analyze the upshots of volatile organic compounds on the gigantic petrochemical complex.	Application of strategies
2016	[doi:10.1016/j.esd.2016.07.006	Measured the performance of a Thailand upstream petrochemical industry with respect to several factors, i.e., energy, environmental, and economic cost.	Performance measurement
2016	[doi:10.1016/j.infrared.2016.03.018	Implemented data envelopment analysis technique to a process engineering-based model for analyzing the performance of process engineering petrochemical plant.	Application of technique/methods
2017	[doi:10.1016/j.jclepro.2017.12.005	Proposed the mathematical programming by mass integration of equations to minimize the wastewater production in the Brazilian petrochemical industry.	Programming
2017	[doi:10.1016/j.energy.2017.01.091	Proposed ideas and principles to enhance the efficiency of waste oil by bending hydrogen recovered by enriched biodiesel. The application of proposed waste oil is presented for driving the compression ignition engine.	Ideas and principles
2017	[doi:10.1016/j.applthermaleng.2016.12 .081]	Explored a machine learning integrated interpretative structural model for analyzing the energy and carbon emissions and estimating the green improvements in petrochemical systems.	Machine learning integrated
2013	[doi:10.1016/j.apergo.2013.02.003]	Analyzed the compatibility of standardized procedures of oil refinery plant by control room and suggested few guidelines for ease of examining the actual extent of sociotechnical systems (STS) of oil refinery plant.	Standard principles and procedures
2011	[URL: https://dl.acm.org/citation.cfm?id= 2431718]	Applied a multiattribute utility approach to evaluate the best port tanker operations under oil spill risk parameters.	Application of technique/methods
2012	[URL: https://dl.acm.org/citation.cfm?id= 2430216]	Proposed oil refinery simulation models for investing right money for expanding oil company's business swiftly and accurately.	Simulation models
2014	[doi:10.1145/2576768.2598319]	Applied fuzzy system programming on genetic programming for building fuzzy classification model to identify the seismic patterns and the rock types in any regions without opening oil wells.	Fuzzy classification modeling
2015	[doi:10.1145/2695664.2695891]	Developed accident-based model of offshore oil industry to analyze the safety and accidental risk in offshore oil industry.	Accident-based model
2016	[doi:10.1145/2948992.2949006]	Insights of evolutionary algorithms approach are illustrated towards tackling the oil and gas industry. Eventually, it resulted in the shifting of the interest of geosciences community to algorithm applications towards maintaining oil and gas fields.	Application of evolutionary algorithms

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2011	[URL: http://ieeexplore.ieee.org/document/5936957/]	A rotor dynamics analysis on the monitored vibration data of induction motors to control refinery process in petrochemical industry is demonstrated.	Vibration monitoring
2014	[doi:10.1049/cp.2014.0534]	Advised the petrochemical industry to adapt the International Electrotechnical Commission 61850 protocols for fast analysis of data, controlling, and monitoring functions.	International Electrotechnical Commission 61850 protocols
2015	doi:10.1109/SIEDS.2015.7117014	Analyzed that how rail transformation system besides other logistic systems facilitates the expanding of oil refineries and compensates the need of current domestic oil system.	Exploration of logistic system for oil industry
2015	doi:10.1109/IEOM.2015.7093724	Advised petrochemical industry to preserve the general management cum technical architectures to avoid the chances of failure and accidents.	General management and technical architectures
2016	[doi:10.1109/INDUSCON.2016.7874501]	Proposed a simulation model to generate the online schedule of ships. The prepared schedule is compared with a schedule referred by hybrid technique implemented on a ship scheduling model.	Simulation model
2009	[doi:10.1016/S1570-7946(09)70302-5]	Developed a software to simulate and analysis the mass balance data of reconciliation process of oil refineries.	Simulate software
2010	[doi:10.1016/j.enpol.2009.11.021]	Applied the life cycle price approach to analyze a municipal solid waste incineration power plant project considering the acquisition, maintenance, fault, and operating costs.	Application of technique/methods
2011	[doi:10.1016/j.desal.2010.07.059]	The feasible processes out of three such as regeneration, reuse, and recycling are evaluated by considering three factors, i.e., the water hardness, suspended solid, and chemical oxygen demand for minimizing the waste water consumptions.	Analysis feasibility of processes
2013	[doi:10.1016/j.jclepro.2013.02.021]	Implemented a data envelopment analysis technique to fruitfully evaluate the energy efficient practices to be implemented in the vegetable oil production industry.	Application of technique/methods
2014	[doi:10.1016/j.jlp.2014.05.006]	Applied hybrid approach constituted by combining ANN, fuzzy, and regression techniques to estimate the project completion time for oil refineries.	Application of technique/methods
2016	[doi:10.1016/j.procs.2016.08.205]	Designed and proposed an antitheft system to block the stealing of crude oil during loading to tankers and trains under different scenarios	Antitheft system application
2016	[doi:10.1016/j.retrec.2016.07.005]	Proposed a descriptive statistical method under an econometric model to analysis the financial load of oil refinery firm and suggested improvement in annual income of Delta Air Line logistic system.	Application of technique/methods
2016	[doi:10.1016/j.jenvman.2016.04.056]	Advised the oil and gas industry to maintain the future supply chain under key four supply chain functions, i.e., production management, supplier management, product stewardship, and logistics management.	Operation management
2016	[doi:10.1016/j.proeng.2016.07.087]	Worked to utilized chemical and mineral additives for advancing the quality of the concrete, which are supported by oil refinery waste. Their simulation results prove that the byproduct produced by oil refinery industry can be treated as an additive material for producing the concrete materials.	Simulation model

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2016	[doi:10.1016/j.ijggc.2015.12.019]	Demonstrated technoeconomic analysis by considering six setups of carbon capture for defining the most economic setup pertaining to the implementation of future MEA carbon capture plant.	Technoeconomic analysis
2017	[doi:10.1016/j.rser.2016.10.026]	The previous price of oils is analyzed and the impacts of numerous factors on it are examined. It is concluded that the recent thrust in oil prices have not created any chief impact on renewable energy sectors.	Price (economic) analysis
2017	[doi:10.1016/j.jclepro.2017.03.222]	Applied stochastic frontier analysis on the true fixed effect model to estimate the production efficiencies of ten largest oil companies of world.	Stochastic frontier analysis
2017	[doi:10.1016/j.eswa.2017.06.014]	Proposed a functional network intelligent clustering system for grouping and predicting the pressure-volume-temperature properties of black oil.	Functional network intelligent clustering system
2017	[doi:10.1016/j.applthermaleng.2017.03.051]	Developed and implemented a novel DEA model to compute the energy and environmental efficiency for reducing the carbon dioxide emissions in case of ethylene industries.	Data envelope system modeling
2017	[doi:10.1016/j.ress.2017.05.036]	Proposed a novel human factor analysis based on the classification system model for the oil and gas industry to categorize the accidents of oil and gas industry.	Human practice analysis
2017	[doi:10.1016/j.egypro.2017.03.1766]	Conducted systematic review based on two hundred fifty manuscripts related to carbon capture and storage (CCS) technology. A technoeconomic analysis to find the optimum CCS technology for reducing the emission of CO_2 from iron and steel, cement, and oil-refining industries is presented.	Technoeconomic analysis
2017	[doi:10.1016/B978-0-12-803581-8.00848-1]	Demonstrated the application of structural integrity analysis to finalize the offshore structures, mobile drilling units and pipelines for oil extraction field.	Applications of structural integrity analysis
2017	[doi:10.1016/j.jngse.2016.12.028]	Conducted literature survey in the field of energy sectors to define historical strategies/policies. For the same information is extracted and observed by expert panel opinions to project potential alternative in futures.	Literature survey report
2017	[URL:https://dl.acm.org/citation.cfm?id=2348214]	PI_4-N Proposed a theoretical model with a simulation technique to identify the best strategy for petrochemical logistic network.	Models and simulation technique for logistic network
2013	[doi:10.1109/ICICES.2013.6508345]	Analyzed numerous critical parameters, i.e., temperature, current, viscosity, and pressure on sensor networks for controlling the refinery industry.	Sensor networks to the refinery
2008	[doi:10.1109/ICINIS.2008.184]	Compared Zigbee technology with wireless communication technology under petrochemical industry application field and it is concluded that wireless network technology ought to be substituted by Zigbee technology.	Zigbee technology

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2008	[doi:10.1109/ICCCE.2008.4580831]	Applied neural network technique for forecasting the demand of spare parts in process industries. The results of applied neural network are compared with results refereed by two conventional techniques. The neural network technique is declared suitable for forecasting the demand of spare parts for all process industries.	Applications of techniques to network problems
2008	[doi:10.1109/PICMET.2007.4349385]	The significant network architectures that helped to bring the innovation in Japan petrochemical industry are highlighted.	Network architectures
2009	[doi:10.1109/CCDC.2009.5194695]	Discussed about the advantage of miniadapter network for creating the evident communication mechanism between web server application and control program.	Miniadapter network
2010	[doi:10.1109/IEEM.2011.6117941]	Proposed the network topology evaluation technique for recognizing the root causes of an output and input signal variability in petrochemical industry.	Network topology technique
2011	[URL:http://ieeexplore.ieee.org/document/5936960/]	Suggested fault current limiter network to avoid the power breaking causes due to short circuit for advancing network applications under industrial domain.	Fault limiter network
2016	[doi:10.1109/MCOM.2016.7588225]	Proposed a wireless sensor network based on object identification technique to detect the toxic gas field in large scale petrochemical plants.	Object identification technique
2017	[DOI:10.1109/ICCChinaW.2015.7961605]	Demonstrated the application of wireless sensor networks system towards monitoring CO_2 concentrations in equipment in large scale petrochemical plants.	Application for monitoring processes
2017	[doi:10.3390/app7101072]	Organized few relevant literature surveys under context of IoT networking, monitoring, and controlling and suggested future researchers to focus on IoT networking control.	Networking monitoring and controlling
2017	[doi:10.1109/IIAI-AAI.2017.164]	Proposed text mining network for benchmarking the green performance indicators in petrochemical industries. The evaluated indicators helped to maintain the pollution-free environment in petrochemical industry.	Mining network
2009	[doi:10.3182/20090712-4-TR-2008.00128]	Proposed a mathematical model for the design of an optimal network for connecting the multisite petrochemical systems under uncertain data.	Models and mathematical modeling
2012	[doi:10.1016/j.ssci.2010.02.024]	Proposed a model that has included factors at multilevel network to materialize the quality of equipment under uncertainty for petrochemical industry.	Models and mathematical modeling
2017	[doi:10.1016/j.energy.2017.10.017]	Proposed a cosine similarity learning network to help to predict the effectual process parameters for petrochemical systems.	Cosine similarity learning network
2008	[doi:10.1145/1385989.1386002]	Suggested to introduce thousands of sensors and gauges with equipment to map many physical and chemical characteristics of oil and gas starting from underground reservoirs to oil distribution channels.	Deployment of sensors and gauges on equipment
2010	[doi:10.1145/1878022.1878023]	Proposed a novel fusion-driven routing solution towards improving the coverage, connectivity, privacy, and security in multimedia wireless sensor networks.	Network privacy and security

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2010	[doi:10.1145/1795194.1795204]	Proposed a lightweight geographic opportunistic network technique to solve the routing problem in complex strip network during monitoring oil pipelines.	Network improvement technique
2014	[doi:10.1145/2684103.2684105]	Illustrated the applications of a multiagent-based model on oil refinery network node for eliminating the communication link breakdown problems on forward networking.	Multiagent and network nodes
2011	[doi:10.1007/s11814-011-0087-4]	Reviewed two techniques, i.e., water pinch technology and mathematical optimization programming, and applied them to set up a petroleum plant network.	Network improvement techniques
2007	[doi:10.1109/ICCA.2007.4376830]	Proposed a downhole permanent sensor network for monitoring the temperature and pressure of oil wells.	Sensor network for monitoring
2015	[doi:10.1109/INFRA.2008.5439574]	Proposed a bunch of benchmarking strategies to evaluate a three network model of an oil refinery supply chain.	Models and mathematical modeling of network
2008	[doi:10.1109/ICSMC.2008.4811576]	Conducted comparison between integrated neural network, Gaussian mixture model and Markov model for monitoring the bushing condition of motors used in the petrochemical industry.	Neural network, Gaussian, mixture, and Markov modeling
2008	[doi:10.1109/ETFA.2008.4638521]	Suggested few principles to locate the wireless sensor network in Gullfaks offshore oil and gas in the North Sea.	Principles of networking
2008	[doi:10.1109/SENSORCOMM.2008.111]	Suggested that the designs of wireless sensor nodes must be based on ultrasound and infrared light to be deployed on offshore oil and gas fields.	WSN nodes
2009	[doi:10.1109/WFCS.2010.5548624]	Illustrated the utilization of wireless sensor network (WSN) technologies to onshore oil well monitoring and the network simulator (NS-2) is suggested for monitoring the onshore oil wells.	Technologies and network simulators
2010	[doi:10.1109/AINA.2010.18]	Prepared a report under the application extent of WSN applications to oil and gas operations, refineries, petrochemicals, and underwater development platforms.	WSN applications
2010	[doi:10.1109/AINA.2010.175]	Specific focuses on the security issues surrounding WSNs of oil and gas industry is highlighted and suggested to use sensors for advancing safety and operational performance.	Network privacy and security
2013	[doi:10.1109/TCST.2013.2288519]	Advised the outliers of the wireless sensor networks to be implicated for robust design in oil refinery application.	Outlier design of WSN
2013	[doi:10.1109/MCOM.2013.6495774]	Illustrated few applications of ultrawide band sensor networks to oil and gas extraction fields.	Ultrawide band WSN
2013	[doi:10.1109/ICIT.2013.6505902]	Developed mathematical modeling by considering evident characteristics of wireless channel to evaluate oil and gas refinery plants.	Models and mathematical modeling of network
2014	[doi:10.1109/JIOT.2014.2313459]	Standard techniques and procedures of plant designers are illustrated, which considered the wireless network coverage, deployment and layout evaluation.	Technologies and network procedures
2014	[doi:10.1109/PCICBRASIL.2014.6968883]	Analyzed the online partial discharge scheme for monitoring the condition of high voltage networks in oil and gas industry.	Voltage networks

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2014	[doi:10.1109/RoEduNet-RENAM.2014 .6955302]	Proposed an intelligent agent-based network to preserve and escalate the network performance in oil industry.	Intelligent agent network
2016	doi:10.1109/ICRAMET.2016.7849577]	Illustrated the application of wireless sensor networks for monitoring the oil and gas linkages.	WSN for monitoring
2016	doi:10.1109/AUS.2016.7748070]	Applied RBF neural networks modeling for mapping the depth of pipeline.	Models and mathematical modeling of network
2016	[doi:10.1109/ICSGRC.2015.7412475]	Proposed a novel cascade forward neural network to segregate the quality of agar wood oil with respect to grades.	Novel cascade neural network
2017	[URL: http://ieeexplore.ieee.org/ document/7944830/]	Critical nodes of networks are ranked in order to save energy of the group-based IWSNs (industrial wireless sensor networks) working in oil and gas fields.	Multiagent model to network nodes
2010	[doi:10.1016/j.psep.2010.06.004]	Proposed an advanced approach, i.e., security risk factor table (SRFT) and a stepped matrix procedure (SMP) for assessing the security networks for oil and gas industry.	Network improvement techniques and network privacy
2011	[doi:10.1016/j.jlp.2011.05.011]	Applied strong network principles to rank the oil and gas industries among other industries, i.e., IT, electricity.	Network principles
2011	[doi:10.1016/j.resconrec.2011.02.004]	Implemented integer linear programming technique on an industrial byproduct exchange network to maximize the refinery's profit and to reduce the byproduct generated by palm oil industry.	Network improvement techniques
2016	[doi:10.1016/j.worlddev.2011.07.012]	Proposed evident models to analyze the processes of three local oil palm production networks in Indonesia.	Models and mathematical modeling of network
2016	[doi:10.3182/20130522-3-BR-4036.00010]	Applied multiagent system consists of statistical process control technique to monitor the oil production system, which sends alerts as necessary.	Multiagent system network
2016	[doi:10.1016/j.physa.2014.06.055]	Proposed weighted oil trade network models by exploiting the trading data of 2002 to 2011 for estimating the oil trading in communities, cities, and countries.	Weighted oil trade network
2016	[doi:10.1016/j.jclepro.2014.01.019]	Suggested that the palm oil manufacturing units should boot up sensor network for effectively satisfying globally rising future perspectives palm oil demand.	Intelligent sensor network application
2016	[doi:10.1016/j.egypro.2016.12.036]	Build a production system-oriented network model to estimate the international oil trading.	Models and mathematical modeling of network
2017	[doi:10.1016/j.rcim.2016.12.007]	Proposed integrated oil pipeline monitoring and incident reduction system, which can effectively monitor the data of oil carrying pipelines to avoid accidents.	Network for monitoring and incident reduction
2017	[doi:10.1016/j.apenergy.2017.10.051]	Proposed a network-based mathematical model to assist in manufacturing hydrogen by using biogas supply chain to be used in oil industry.	Models and mathematical modeling of network
2017	[doi:10.1016/j.exis.2017.04.007]	Implemented sensor network to search the Vietnamese upwelling area during monsoon under normal conditions as the best choice for producing oil wells.	Intelligent sensor network application

Table 10: Continued.

Years	DOI/URLs	Literature surveys and their focused research realms	Focusing research area
2017	[doi:10.1016/j.psep.2017.08.015]	Proposed a fuzzy Bayesian network technique based on fuzzy data for analyzing the risk of failure under production system of process-based oil and gas industries.	Fuzzy-technique-based network
2014	[doi:10.1109/PCICEurope.2014.6900060]	PI_4-IDM Intelligent electronic devices applications under petrochemical plants are highlighted. It is concluded that intelligent electronic devices helped the petrochemical companies in monitoring, controlling, metering, protecting, communicating, etc.	Implementation of electronic devices
2013	[doi:10.1016/j.jlp.2013.10.012]	Proposed a model to analyzes the data of all security risk practices under petrochemical infrastructure and operations.	Security risks
2011	[doi:10.1145/2068816.2068828]	Proposed a cellular data technology to communicate information from oil field area to other locations.	ICT
2013	[doi:10.1145/2529975]	Applied ginseng algorithms to build a wireless monitoring system for monitoring and controlling the production practices in oil refineries, chemical plants, and factories.	Wireless monitoring control
2013	[URL: https://dl.acm.org/citation.cfm?id=2557686]	Designed an intelligent response information system to be deployed on oil logistic fields for the purpose of circulating information into each unit of industry under unexpected situations.	Intelligent information
2016	[doi:10.1145/3080845.3080849]	Proposed intelligent production architectures for evaluating oil wells after analyzing the data collected from past literature surveys.	Intelligent ICT
2016	[doi:10.1108/JKM-07-2016-0262]	Established the connection between knowledge management and big data for modeling the case of oil and gas industries in order to improve the decision-making power of industry.	Knowledge and big data management
2016	[doi:10.1108/ITP-08-2016-0198]	Proposed software package to analyze the operational issues concerned towards improved performance, innovation and continuous improvement in oil and gas organizations.	ICT software package
2014	[doi:10.1109/TENCON.2013.6719046]	Proposed a radio frequency identification-based patrol management system for petrochemical industry for enhancing the efficiency and capacity of maintenance system	Maintenance system
2017	[doi:10.1016/j.techfore.2017.09.021]	Illustrated local factors related to the application of information communication technology for safely operating petroleum industry.	ICT
2017	[doi:10.1016/J.ENG.2017.02.012]	Demonstrated smart manufacturing attempts for connecting oil-refining and petrochemical sector into information-driven environment. A cluster of few factors are identified to model future smart chemical and petrochemical manufacturing processes.	Smart manufacturing architectures

monitoring processes, models as well as mathematical modeling, sensor network for monitoring, WSN applications, network privacy and security, network principles and intelligent agent network, sensor networks to the refinery, ZigBee technology problems, network architectures, mini adapter network, network topology technique, fault limiter network, object identification technique, mining network models and mathematical modeling, cosine similarity learning network, deployment of sensors and gauges on equipment, network privacy and security, multiagent and network nodes, neural network, Gaussian implication, mixture and Markov modeling, principles of networking, WSN

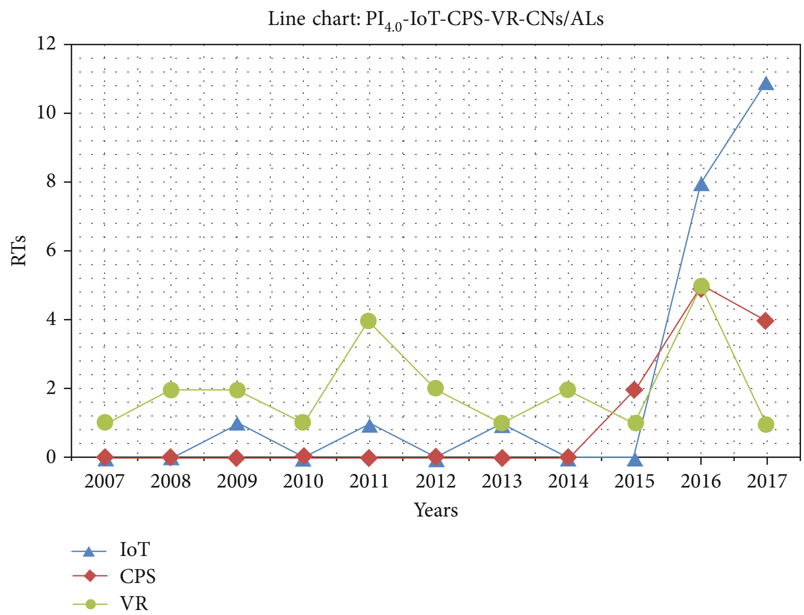

Figure 5: Representation of RTs vs. CNs/ALs-$PI_{4.0}$-IoT-CPS-VR.

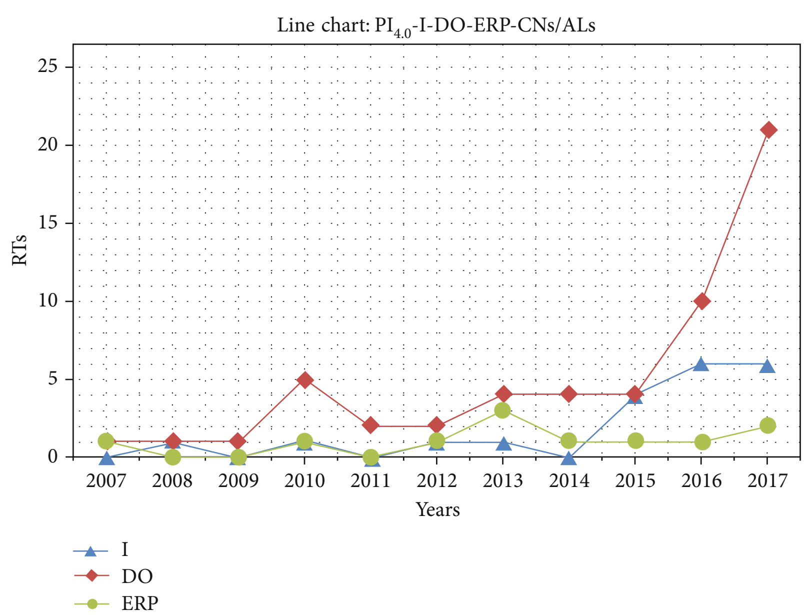

Figure 6: Representation of RTs vs. CNs/ALs-$PI_{4.0}$-I-DO-ERP.

nodes, technologies and network simulators, outlier design of WSN, ultrawide band WSN, technologies and network procedures, voltage networks, novel cascade neural network, multiagent model to network nodes, multiagent system network, weighted oil trade network, intelligent sensor network application, network for incident reduction, and fuzzy-technique-based network in order to enrich the future performance of $PI_{4.0}$-N-CN/AL and CE.

Triantafillou [78] emphasized to scholars the importance of focusing on areas such as technologies and strategies, resilience-based modeling, application of strategy performance measurement, programming, machine learning integration, standard principles and procedures and application of techniques/methods and fuzzy classification modeling, accident practice-based model development, application of evolutionary algorithms, analysis-based vibration monitoring, international electrotechnical commission protocols, benefits of logistic system for oil industry, literature survey report, general management, technical architectures, feasibility analysis of processes, antitheft system application, production management, stochastic frontier analysis, functional network intelligent clustering system, data envelope

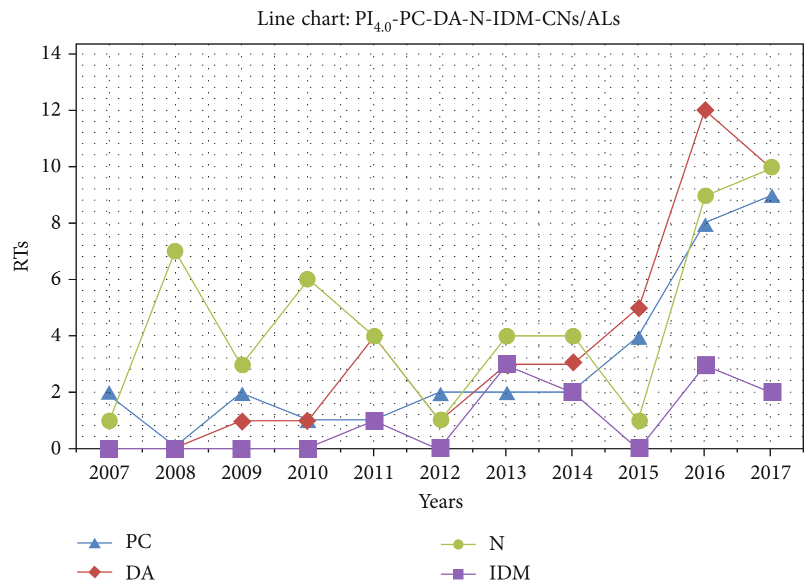

Figure 7: Representation of RTs vs. CNs/ALs-$PI_{4.0}$-PC-DA-N-IDM.

system modeling, human practice analysis, and applications of structural integrity analysis to augment the future performance of $PI_{4.0}$-DA-CN/AL and CE.

Agrifoglio et al. [36] stimulated the scholars to focus on areas such as the effects of digital technologies on optimization of multiple operations, high-level architecture simulation, theoretical knowledge, operation management by hydrogen networks, illustration of industrial tools and techniques, infrared spectroscopy applications, illustration of cogeneration applications, regenerated spent catalyst scheme applications, and group decision-making algorithms to improve the future performance of $PI_{4.0}$-IDM-CN/AL and CE.

6. Managerial Implication/Research Values for Scholars

The presented research work suggested the moderate and very weak performing research areas corresponding to $PI_{4.0}$-CN/ALs. This work advises researchers to accept as a research gap the very weak performing research areas of $PI_{4.0}$ and to focus on them to enhance the future performance of $PI_{4.0}$-CNs/ALs, linked to CE. The research work also provides a new research methodology to $PI_{4.0}$ researchers for materializing the future RTs of $PI_{4.0}$ under multiple/different CNs/ALs. Researchers can avail the same methodology to address the future RTs and improve CE. The work has iconic value if it can be conducted without using any bibliographic software tools.

7. Conclusions

Investigation has shown that strong CNs/ALs lead a vital role in driving the processes of PIs at a faster and quicker rate. Machine learning, big data analysis, signal analysis of sensors, machine to machine virtual interaction, and mechanical automation thrust $PI_{4.0}$ to turnout the standard/predicted outputs for attaining CE. Strong CNs/ALs aid $PI_{4.0}$ in controlling the quality of refined beverage items, escalating green practices, and stimulating the overall sustainable traceability of PSs. In the presented research forum, the authors built a $PI_{4.0}$-CN/AL model by gratifying RQ_1 and archiving 302 research documents on conducting SLS over 2007-2017; however 275 were respected under the inclusion parameters to represent the RTs of the CN/AL model by satisfying RQ_2. Later, the RTs of the presented CN/AL model materialized by addressing RQ_3. It has been concluded that the RTs of a particular DO is dazzling among defined $PI_{4.0}$-CNs/ALs. The DO-RT has been found with consistent acceleration and momentum. RTs of residue CNs/ALs are expressed in descending orders, i.e., N>D>A>PC>IoT/VR>I>CPS/ERP/IDM (discussed in Section 5). The authors also bifurcated RTs under two aspects, where N>D>A>PC>IoT/VR>I are introduced under moderately weak performing research areas/CNs/ALs, whereas CPS/ERP/IDM are introduced under very weak performing research areas/CNs/ALs.

In continuation of above, the authors suggested which areas the scholars should focus on to reform and amend the RT's level of moderate and very weak performing CNs/ALs (discussed in Section 5.1) thus hiking and improving CE. The research work can aid future scholars with methodology to materialize the RTs of any interdisciplinary research area and topic focusing on CE. The presented CN/AL model also assists $PI_{4.0}$ researchers and managers to explore the same model for investigating and mapping the performance of $PI_{4.0}$ by using expert's opinion/subjective data with focus on CE aspects.

Data Availability

Highlights: this work proposes a novel method to measure and identify the growths and trends of IIoT communication networks for petrochemical companies

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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