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Current Trends in Supply Chain Training Programs in the Context of Industry 4.0 Technologies*

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This systematic literature review attempts to identify current training and development (T&D) programs that have adopted Industry 4.0 technologies in the field of supply chain. It further endeavors to identify knowledge gaps and provide future research avenues to researchers. In this paper, we systematically reviewed the extant literature and included a total of 48 articles. The reviewed training and development programs are overall industry-need driven and focus mostly on training employees to apply new technology in the Industry 4.0 environment. However, the performance evaluation of the training and development programs are generally lacking. We also found that with a general rising trend in research interest about Industry 4.0 in supply chain workforce T&D around the globe, some regions such as Latin America are not actively engaged in this endeavor. We suggest supply chain organizations develop employees' technical skills and invest in training to embrace the change that Industry 4.0 has generated. Future researchers should consider filling the knowledge gaps this research identified on future workforce training and development in the wake of Industry 4.0.

Keywords: Industry 4.0; supply chain management; workforce; training and development

1. Introduction

A supply chain is defined as a connected series of organizations that distribute services or products from an original source to the point of consumption [1]. In the era of Industry 4.0, digital transformation has spread beyond the walls of organizations to encompass broader processes, functions, and industries of the supply chain [2]. The technology advancements such as autonomous robots, Internet of Things, automated sorting systems, cobots, hands-free wearables, data analytics, and other emerging technologies enable the supply chain industry to achieve greater productivity in the workplace [3–6]. As a result, new job roles have been emerging as well: data analysts, operations managers, supervisors, and network professionals within manufacturing and supply chain management.

While having yielded great benefits to the supply chain industry, the Industry 4.0 related advanced technologies and their systems have also been producing disruptive changes in the supply chain workforce [4, 7]. On one hand, the industry is adopting Industry 4.0 related technology, leading to the requirement for the workforce changing accordingly. On the other hand, organizations in this industry tend to fail to identify and hire qualified candidates, rendering increased challenges. Unfortunately, in the face of new technology, many businesses simply lay off unprepared workers [8]. But this practice is costly and most likely fails to effectively resolve the conflict between a prepared workforce and rapidly advanced technology [9].

Lacking talent capable of operating Industry 4.0 technologies is often cited as a barrier to Industry 4.0 implementation in the workplace [9–12]. Companies need workers who have the necessary industry-specific knowledge, as well as the skills to navigate the rapidly changing business and technological landscape. For these reasons, some scholars called for research to explore how to prepare the current workplace for Industry 4.0 through training and development (T&D) programs in supply chain [13, 14]. In this paper, we attempt to provide a

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systematical examination of the literature to understand what training programs are available for workforce development, and to address what future research and practice focus may be.

2. Purpose and Research Questions

In the wake of Industry 4.0, the field of supply chain needs to develop employees' engineering related skills and invest in T&D to embrace the change that Industry 4.0 has generated. The purpose of this systematic literature review is threefold. The first is to identify current training and development programs both in supply chain organizations and education institutions for the adoption of Industry 4.0. The second purpose is to pinpoint various areas of training that the supply chain industry needs to address. Lastly, this systematic review attempts to identify knowledge gaps and provide future research avenues to researchers interested in workforce training and development in the field of supply chain. To this end, the literature search range is from 2011 until late 2021 because the concept of Industry 4.0 originated in 2011 from a German government project [15]. Consequently, the research questions are as follows:

- What articles can be extracted from the literature regarding Industry 4.0 and supply chain workforce development?
- What are the characteristics of these publications in terms of published journal, publishing year, focus area, study region, research method, author connection, and co-occurrence networks of keywords?
- What T&D programs have been reported in terms of supply chain workforce T&D for Industry 4.0 in the existing literature?
- What areas of training still need to be addressed with regard to supply chain workforce T&D for the adoption of Industry 4.0?
- What research gaps can be identified in the extant literature that can be further explored?

For this purpose, this paper discusses the methodological contributions of current literature, offers future directions for supply chain workforce T&D researchers, and holistically presents knowledge gaps in the literature and thematically offers supporting information about the design of future training programs for engineering educators and trainers.

3. Methods

Following the guidelines in the Matrix Method for conducting systematic literature reviews [16], we used a three-step procedure to identify pertinent scholarly articles. First, we used four popular databases, ABI/Inform Complete, Business Search Ultimate/Business Search Complete, Web of Science, and EBSCO to identify articles in the literature for the initial literature pool generation. Second, Boolean search techniques were used and Industry 4.0 related key terms were selected (SeeTable 1). Third, we included papers using several eligibility criteria (See Inclusion and Exclusion section below). We employed an extensive list of search terms related to Industry 4.0. Given that we mainly focused on how to prepare the next generation workforce for Industry 4.0 in general, we used search terms such as "supply chain", "industry 4.0", "internet of things", "big data", "learning", "education", "training", "talent development", and others. Table 1 shows all the search terms we used.

3.1 Inclusion and Exclusion

First, we included articles that were written in English. Second, we limited the time frame to the period 2011–2021 because the term Industry 4.0 was coined in 2011. Third, we have excluded conference proceedings because high quality studies tend to be published in peer-reviewed journals [17]. Fourth, we ignored brief notes, introductions, editorials, professional commentaries and book reviews because they cannot be classified as published articles [17]. Last, we excluded those articles that focused on "data warehouse" and "non-human training (e.g., machine learning, statistical training, or robotic training). Table 2 provides inclusion and exclusion criteria for reviewing articles"

In order to answer our first research question, we followed the procedure of the Preferred Reporting

Table 1. Systematic description of the terms used in the search process

Key words	("warehouse OR "supply chain" OR "material handling") NOT ("data warehouse" OR "knowledge warehouse" OR "machine learning" OR "deep learning") AND (learning OR education OR "talent development" OR training) AND ("industry 4.0" OR "internet of things" OR blockchain OR digital OR connected OR sensor OR robotics OR "artificial intelligence" OR smart OR "big data")
Type of document	"article" AND "peer-reviewed"
Language	"English"
Database searched	ABI/Inform Complete, Business Search Ultimate/Business Search Complete, Web of Science, Scopus, and EBSCO
Publication year	2011–2021

Table 2. Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria
Written in English language	Conference proceedings
Publication date: 2011-2021	Brief notes and introductions
Peer-reviewed journal articles	Editorials
Contained search keywords	Professional commentaries
	Book reviews
	Articles focused on "data warehouse" or "non-human training (e.g., machine learning, statistical training, or robotic training)."

Items for Systematic Reviews and Meta-analysis (PRISMA) to screen the literature [18]. The process is shown in Fig. 1. The initial search generated a total of 331 articles. We also checked the included articles' reference list, aiming to expand the literature pool. Thirty-four papers were added to our literature pool (not including duplicates). We created a publication pool with 365 articles. The first and second author served as evaluators and carefully screened the abstracts of those articles using the inclusion and exclusion criteria. Only if both evaluators decided the articles met the criteria, the whole text would then be downloaded. After further review, 86 articles were deleted because they focused on "data warehouse" and "non-human training." A case in point is [19] article which discussed a 3D Warehouse. In addition, articles with English titles and abstracts, but foreign language text were also excluded (n = 23). Further, we discarded 122 articles due to contents irrelevant to workforce training/education. For example, we excluded [20] paper because this article only focused on the development of an innovative method to accurately map rubber and palm oil plantations using fusion of Landsat-8, Sentinel 1 and 2 and did not mention workforce training/education as a purpose. We did not include 45 papers because their study contexts were not in the field of supply chain. For instance, [21] only examined the factors influencing knowledge management system adoption in small and medium enterprises, thus being ruled out for further examination. Moreover, we excluded other 41 papers because their content was not centered on Industry 4.0. Eventually, we created a literature pool with 48 papers published from 2011-2021.

3.2 Classification and Coding

To answer our research questions by synthesizing the literature and providing guidance for future researchers interested in developing the future workforce for the global connected supply chain,

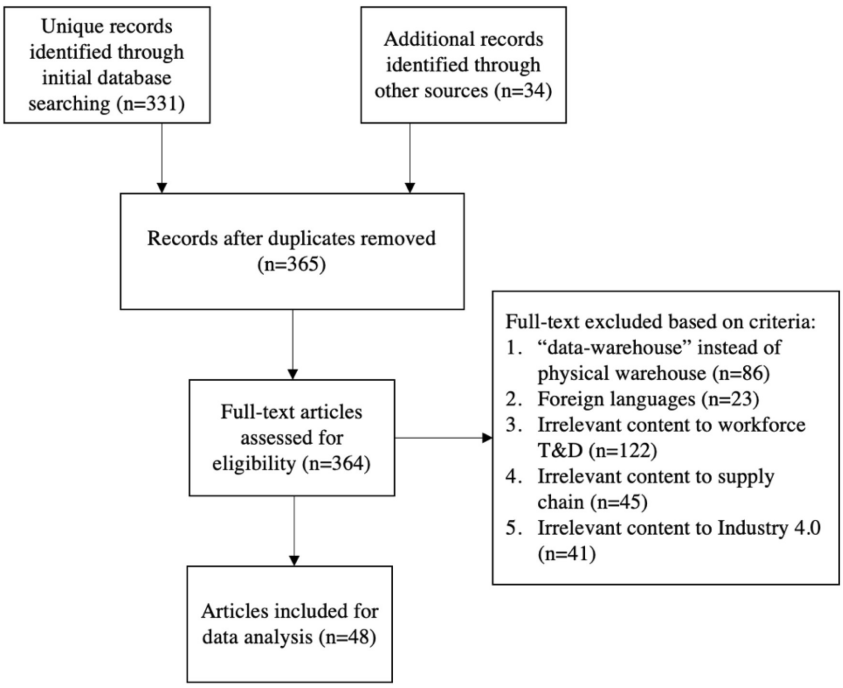

Fig. 1. PRISMA literature review flow chart.

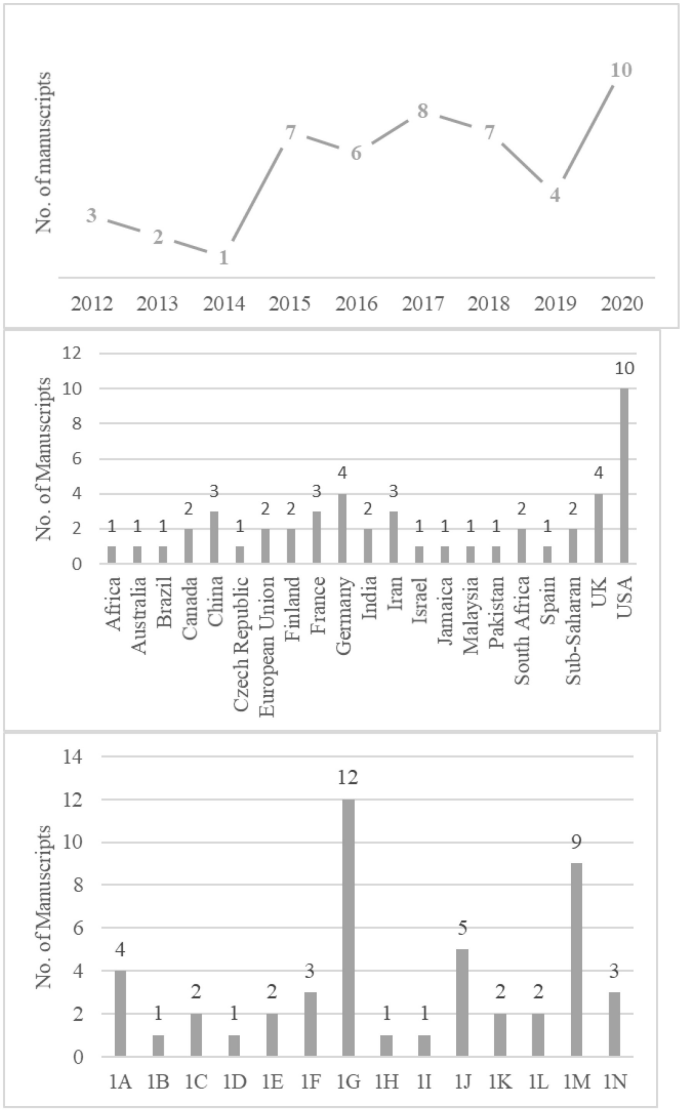

Fig. 2. Bibliometrics analysis panel charts – publication trend (top chart), targeted region (middle chart), and focused industry (bottom chart).

we focused on finding existing workforce T&D programs and identifying future training needs. In particular, we coded reviewed articles' publication year, publication outlets, sample regions, targeted industries, and research methods. We also conducted bibliometric analysis to map the network of author collaboration and keywords of reviewed 48 articles and presented the networks in two figures (Figs. 4 and 5). For the categories of targeted industry, sample regions, and research methods, they consisted of several classifications. To facilitate understanding, we used number and letter codes to classify the articles (see Appendix C)

4. Results

4.1 Descriptive Analysis

First, reviewing the 48 published papers, there is an upward trend in publication numbers from year 2011 to 2020 with fluctuation. While 2014 witnessed only one paper relevant to the Industry 4.0 T&D in supply chain, there were 10 papers published in the year 2020 associated with this topic.

Second, there are 28 articles that specified their research sampling countries. The other 20 articles did not provide any information about their research targeted regions. Those 20 articles are mainly conceptual/literature review papers, which either propose an Industry 4.0 related advanced technology, review them, or provide implications with regard to how they are applicable to improve the training efficiency in supply chain workforce development. For those articles (n = 20) that do not explicitly state their targeted countries, we identified their first author's affiliation as their sampling countries. There are five papers focusing on the

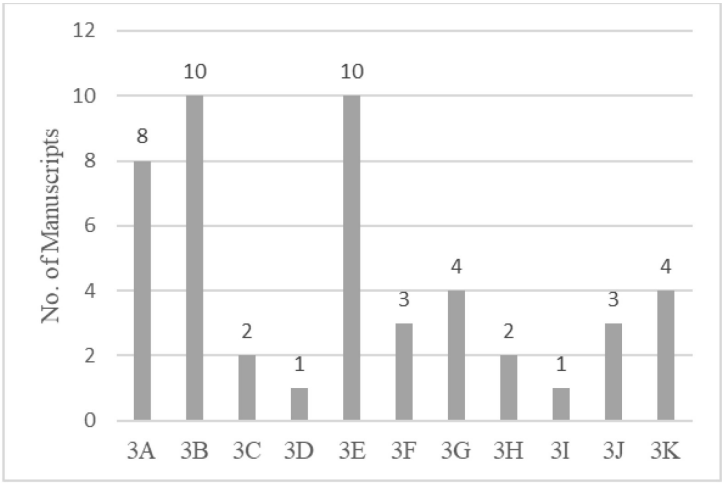

Fig. 3. Research methods. Note: See the Appendix A for codes.

United States and five led by the first author who is from an institution in the United States. Germany and the UK are the second most studied regions (n = 4 respectively).

Third, of those 48 assessed papers, 12 of the papers were focused on educational institutions. One example is the study by [22] focused on the design and development of an auction game that is based IoT technology for Chinese colleges and universities. A total of 12 articles did not specify which industry they focused on, and instead, discussed the implications of Industry 4.0 on business and management in various industries which are related to supply chain. The rest of the papers covered ten other industries such as agriculture (n = 4), assembly (n = 1), construction (n = 2), fashion (n = 1), government (n = 2), health systems (n = 3), humanitarian (n = 1), management (n = 5), pharmaceutical (n = 2), hospitality (n = 1), and manufacturing (n = 2). For instance, van Hoek et al. (2013) identified the Supply Chain Management (SCM) skill development priorities in manufacturing firms and found out how the structural properties of the supply chain translate into demand for SCM skills in manufacturing firms.

The 48 reviewed articles were published in 46 different journals, representing a wide variety of audiences interested in this research topic. Among these journals, 29 are indexed in SCI and SSCI (2019) with the impact factors (2019) ranging from 0.529 (International Journal of Engineering Education) to 8.519 (Trends in Food Science and Technology). Appendix B shows the publication outlets of the reviewed articles and impact factors (if any).

4.1.1 Research Methods

For empirical studies, the most popular research method is case study. There are eight papers that used the case study method to introduce training programs [23], evaluate programs [24], or simply assess the needs for more training programs to bridge the gap between the current situation and future requirements in the workforce because of Industry 4.0 [25]. There are 10 conceptual papers that used extensive but not exhaustive literature reviews to support arguments and made propositions or suggestions for future work regarding integrating Industry 4.0 into the field of supply chain. Specifically, [26] reviewed the literature and evaluated the role of blockchain in cybersecurity and protecting privacy. The author went on to propose the possible implications for regulation and policy and suggested more training was needed for future stakeholders. Five papers were literature reviews. There are some papers that used surveys (n = 4), traditional qualitative research methods (n = 2), or model proposal techniques (n = 4) to answer their research questions. The distribution of research methods is offered in Fig. 3.

4.1.2 Network Visualization

We used VOSviewer version 1.6.13 software to conduct bibliometric analysis to map the network of reviewed 48 articles. VOSviewer is a tool that construct, visualize, and explore bibliometric networks. The produced network provides a visual map that represents the authors' collaborations and key research topics identified by authors (i.e., keywords). It can assist us to detect the research gaps and thus providing opportunities for future studies. First, we mapped the collaboration networks among authors from our reviewed articles (Fig. 4). In total, 158 authors were involved in the reviewed 48 articles. On average, each publication has 3.29 authors. However, Fig. 4 shows no collaboration among research groups, meaning that

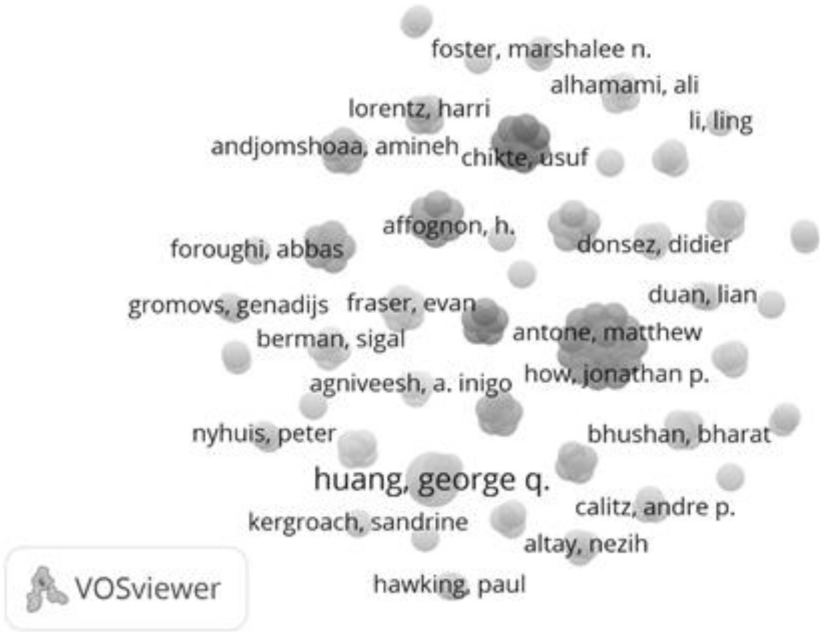

Fig. 4. Visualization networks of author collaborations.

each author retrieved from the reviewed articles only published once regarding Industry 4.0 T&D programs in supply chain. The size of the cluster represents the number of collaborators on one project. For example, the largest cluster in Fig. 4. represents the largest group of researchers with 16 authors on one publication [27].

The network visualization of all keywords (n = 251) is presented in Fig. 5. VOSviewer generated four clusters. Cluster 1 points to technology in supply chain. Keywords in this cluster consist of big data, design, internet, logistics, and supply chain management. Cluster 2 primarily refers to challenges and barriers in training. Keywords

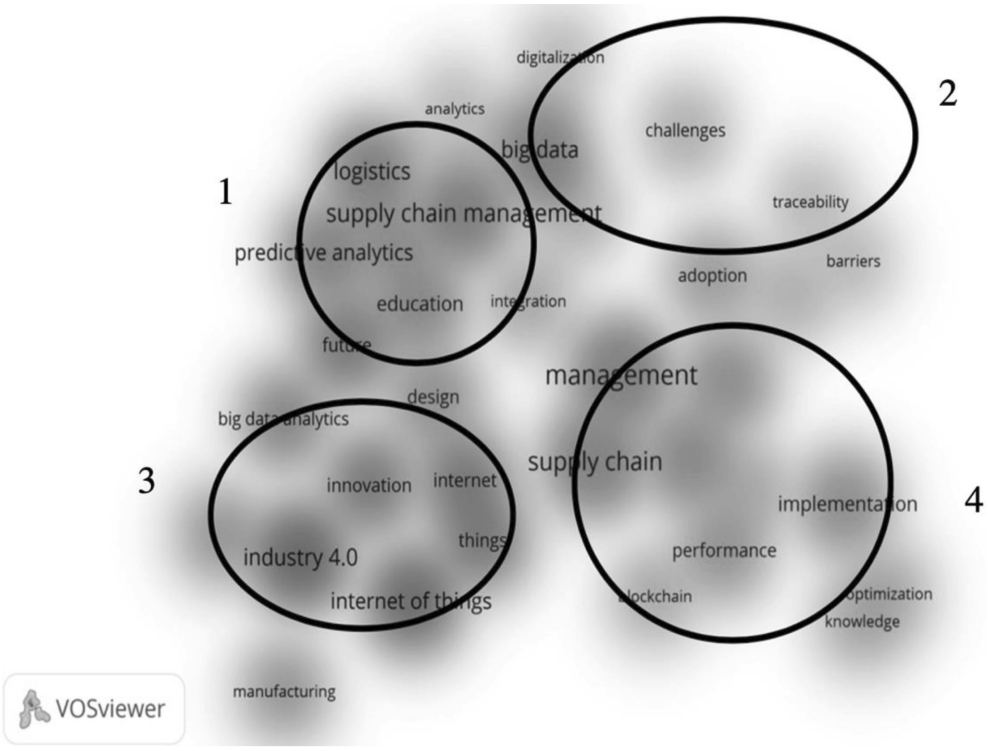

Fig. 5. Co-occurrence networks of all keywords.

include challenges, barriers, analytics, digitalization, and information. Cluster 3 is mainly related to future technology, which contains keywords such as industry 4, internet of things, innovation, and future. Cluster 4 represents the keywords pertaining to technology management and training in supply chain, including supply chain, implementation, performance, knowledge, impact, and barrier analysis.

4.2 Existing Available Training Programs

4.2.1 Training Programs in Corporations

Through reviewing the coded literature, we identified five papers that introduced Industry 4.0 related training. It is worth noting that despite a lack of industry-wide training and development about Industry 4.0 in supply chain, some industry-leading companies are implementing pioneering training programs to prepare the workforce. For corporations, researchers offered possible training programs for business settings from a business perspective [28]. However, most of them mainly proposed a learning/training model or reported the findings from the implementation of a newly enacted technical training framework or model. For example, Schallock et al. [29] studied a German learning factory and reported on their production system for the Industry 4.0 environment. The reported training/learning programs served as a sustainable approach to prepare employees with change management skills, decision making, and innovation capabilities. Training content, purpose and evaluation method of reviewed programs are listed in Table 3.

4.2.2 Educational Programs in Universities

In addition to the identification of the training programs/models/frameworks, we also found seven papers that proposed new educational modules with detailed program descriptions in the context of higher education. For instance, [34] focused on the system level of the supply chain environment. They introduced a designed game of using a combination of IoT technologies and RFID, aiming to educate students for each supply chain echelon, such as manufacturing and other key principles in global SCM. The authors claimed that the game created a smart pedagogical environment for Teaching by Examples and Learning by Doing which has improved the effectiveness of both learning and teaching from the perspectives of both tutor and students. Detailed coding categories are presented in Table 4.

Regarding training evaluation methods, there are eight articles that not only described the possible training programs, models, and frameworks for workforce development, but the evaluation process of the reported industry-based training and development programs. For example, using structural equation modelling, [30] confirmed the positive association between a Cloud-based Enterprise Resource Planning (CERP) program and firm performance. A total of seven articles reported the effectiveness of those educational courses. [22] employed a quasi-experimental design to focus on a SMART u-learning system that integrated IoT technologies to simulate the real business life experience. In terms of student evaluation of the program, they asked students to reflect on their learning experience after each session and filled out a pre/post-questionnaire. This evaluation design aimed to assess students' understanding of the background knowledge that was related to the trading mechanism in supply chain management. In another study, The University of Hong Kong shows quantitative improvements of a learning supply chain (LSC) smart pedagogical environment [34].

Table 3. Training programs for Industry 4.0 in supply chain

Training content	Training purpose	Program evaluation method
Cloud-based Enterprise Resource Planning [30]	Increase data availability across supply chain	Market/operation performance
A service-oriented and multi-layer architecture in the RFID context [31]	Increase the dynamicity and flexibility in the data collection layer, the protocol flexibility introduced in the intermediate layer, and the web service-oriented object naming service.	N/A
An online learning enterprise learning management system for the architecture of information products adapted for the e-learning organization [32]	Practice employees' logistics skills, systems engineering, and interpersonal skills	N/A
Big data analysis and Internet of Things sensor tracking location [33]	Improve truck driver safety driving habit	Longitudinal observation
Robotic forklift [27]	Use robotic forklift in warehouse/storage facilities in the military setting.	Both qualitative (interview) and quantitative (survey) measures of program effectiveness

Table 4. Educational programs for Industry 4.0 in supply chain

Training content	Training purpose	Program evaluation method
Smart ubiquitous learning methods [22]	Improve students learning effectiveness in auction education	Survey: pre-post questionnaire-motivation, usefulness, satisfaction, and ease of use
Advertising-Supply Chain Management simulation [35]	Improve undergraduate business students learning advertising with team-based simulation game.	Survey feedback on Team Experience, Team Effectiveness, and Overall Feedback
A curriculum structure based on systems thinking [1]	Increase student learning effectiveness in the context of Industry 4.0	
Four workshops of RFID/BIM/lean-PHP; prefabrication housing production [36]	Enhance student learning experience and effectiveness in the RBL-PHP simulates the process of PHP by integrating a platform with lean construction	Survey instruments
A lab design-Integrated Manufacturing Technology [37]	Integrated Manufacturing Technology produced products help teach advanced manufacturing-related topics to students in regular semesters	N/A
A smart pedagogical environment: the RFID-enabled Learning Supply Chain uses RFID technology, wireless communication standard, and service-oriented architecture to create a smart environment- simulation games-of the supply chain [34]	Produce graduates who can work not only as part of a team, but also have the necessary entrepreneurial skills to identify potential opportunities for organizations in minimizing the logistics cost	Time spent on games
A Learning Factory in relation to Production Planning and Control [38]	Facilitates improved production planning and control and allows production to be monitored using logistic models which utilize recorded operating data.	N/A

Note. Article ID numbers are in parentheses.

4.3 Future Training Needs Identified from the Literature

We identified 37 papers that concerned the lack of readiness of the current workforce in supply chain management. These papers pinpointed the need of training the workforce on Industry 4.0 advanced technologies but did not further suggest appropriate training programs to develop the workforce. Twenty-two papers suggested that certain industry specific trainings are needed. For example, [39] encouraged Iranian organizations to offer training and development opportunities for employees about the Internet of Things (IoT) solutions and applications. The author listed "cannot find right suppliers" as a major reason that current Iranian organizations lack IoT related training. Similarly, [40] studied the applicability of robotics in the construction industry in the European Union. There are many challenges including fragmented supply chain and lack of training to prepare workers who are capable of operating robots. Five articles argued the importance of having skillset training for employees in general without mentioning the specific training programs for employees. For example, [41] recognized that in the era of Industry 4.0, companies not only need to provide specific technical trainings, but also soft skill competence trainings. See the list in Table 5 with focused locations of these papers.

There are ten papers encouraging educational institutions to prepare students for the wake of Industry 4.0 as they are the future workforce from the module and structural perspectives. A case in point, [14] proposed an integration of Industry 4.0 into the educational modules in central Baltic Sea region. Waller and Fawcett [64] focused on educational structure and proposed two paths for graduate studies in supply chain management to prepare a future workforce in data science.Table 6 provided detailed coding results regarding training needs assessment.

5. Knowledge Gaps and Future Directions

From the literature, we identified both existing available training and educational programs and future workforce training needs for the supply chain industry. In this section, we focus on the knowledge gaps in workforce training and development in the field of supply chain and subsequently propose future research avenues to researchers and practitioners who are interested in this field.

First, synthesizing these 48 relevant articles, there is a rising trend with fluctuation in the number of the articles from 2011 to 2021 regarding Industry 4.0 and workforce training development in supply chain. While the research topic is gaining interest, one of our major concerns is where these studies were published, in which industries, and using which research methods. These 48 reviewed papers were published in 43 journals across different fields,

Table 5. Specific training programs needed in the Industry 4.0 literature

Needs area	Focused location
Industry 4.0 technology in general [1, 28, 39, 42–48]	Sub-Saharan Africa; Germany; Iran; Czech Republic; USA; India; Malaysia
HRM technology [49];	Brazil
Innovation, knowledge management, learning skills [50];	UK
Managerial skills [41];	Germany
Sustainability [4];	UK
Knowledge culture [51]	India
AI [28];	
Big data [40, 52, 53];	USA; European Union; France
Blockchain [26, 54-56];	USA; Spain; Iran; South Africa
Building information modeling [57];	UK
Cobots [58];	Africa
Decentralization of using point-of-care in health-related testing [59];	UK
Human-oriented designs – a learning factory [38];	Germany
Supply chain management skills [60];	Finland
Smart energy city [61];	European Union;
Stock Visibility Solution of medicines [62];	South Africa
Raspberry Pis and Arduino (small, simple and low-priced computers) in combination with sensor networking system [63]	Sub-Saharan Africa

Table 6. Specific educational programs needed in the Industry 4.0 literature

Needs area	Focused location
Big data [9]	USA
Industry 4.0 in general [14, 65];	Finland; Canada
Data analysis [66];	USA
Proposed two graduate program tracks [64]	USA

indicating a wide recognition of the intersection of Industry 4.0 and supply chain future workforce readiness issues across different disciplines (e.g., management, economics, and healthcare). In terms of targeted research regions, most studies were conducted in developed countries, such as the US, Germany, and UK. It is worth noting that only one paper was led by authors from the Latin American region – Brazil and there are no particular studies focusing on the population or the countries in that region. This may be explained by the current situation of the labor cost and human resources in Latin America. These countries appear to have a concentration of employment with lower wages and lower cost of human resources turnover as compared to more developed regions [67]. Thus, there is a great potential for research in training the Industry 4.0 workforce in developing countries [49, 68].

Second, there is no unifying framework for the development of this research topic – workforce T&D regarding supply chain in the context of Industry 4.0 from the results of our bibliometrics analysis using VOSviewer. As aforementioned, the collaboration clusters among authors are scattered evenly, indicating potential opportunities for researchers in the field of supply chain to collaborate on the topic of the impact of Industry 4.0 on workforce T&D with other authors from other fields. This situation suggested that researchers are still at an exploratory stage in regard to this research topic about Industry 4.0 T&D in supply chain [69]. Additionally, we found that researchers recognized the needs for training the workforce from various contexts (e.g., industries and countries), and different training/educational programs have been proposed and evaluated. There is a divergent research pattern [70].

Third, as shown in Fig. 5, training, development, or education is not a major research cluster even though we purposefully gleaned literature using these terms. Reviewing the 48 articles, we found the majority of them recognized the importance of the adoption of Industry 4.0 related technologies to the workplace and confirmed the possible performance improvement that Industry 4.0 technologies may produce. Many also critically pointed the need for T&D to prepare the workforce for the wake of Industry 4.0. Nevertheless, the emphasis on the necessity of sophisticated T&D programs and the strategic role of T&D in the workforce preparation have not been the main focus of the reviewed papers. For future researchers, interdisciplinary research between supply chain and human resources are needed because Industry 4.0 technologies are well understood and applied in the workplace by certain industry leaders and human resources professionals can design and implement T&D programs that are centered on those technologies to prepare the workforce.

Fourth, regarding the existing training programs, no dominant themes are found. Training programs and educational modules seem to suggest that any Industry 4.0 technologies such as big data and IoT sensors [33] and robotic forklift [27] are beneficial to workforce development. However, we distill key points from reviewing the 48 articles. The performance-based evaluation process is prevalently missing from the reported industry-based training and development programs, which is common considering that industry-based on-the-job training programs are often offered without measuring its relationship with performance improvement [45, 65]. Nonetheless, an evaluation of training programs' effectiveness adds internal validity of the reported training methods. The systematic way of collecting and analyzing outcome data serves the purpose of improving programs by judging their effectiveness. Therefore, future researchers should not only consider reporting the evaluation results of the program, such that practitioners can purposefully adopt the strengths of the programs and minimize the weaknesses to prepare the future workforce but also correlate the program results with organization's performance goals. For example, [30] used structural equation modelling to examine the effectiveness of the proposed cloud-based enterprise resource planning on market performance. Additionally, offering the evaluation results produces opportunities for future researchers and practitioners to improve the previously proposed training programs. Examining published articles, their evaluation is outcome oriented, by which they only investigated the program performance [27]. Although this is the most common evaluation method, nevertheless, the process and the content of the training programs should also be evaluated. After all, as [71] suggested that program evaluation is "the process of determining the merit, worth, or value of something, or the product of that process" (p. 2). Based on the lack of focus on program process and its overall evaluation, future researchers should emphasize more on the process and content evaluation rather than the outcome.

Last, the articles that proposed training programs for the workforce training and development are overall industry-need driven. Only seven papers focused on the educational setting and introduced new methods. With the rapid changing needs of the supply chain industry, educators in the formal setting have recognized the needs and proposed plans to prepare the workforce as educators have the responsibility to prepare the next generation of world leaders [31, 34]. Educators develop u-learning systems, smart environments, learning factories, simulation games (Ad-SCM), and other new ways of teaching to ultimately create a smart pedagogical environment for Teaching by Examples and Learning by Doing (TELD). The findings of those studies confirmed the importance of activities that integrate Industry 4.0 technologies but also stimulate and motivate students' learning interests, improving their understanding. For example, with IoT, the ubiquitous computing system can offer instant and ongoing instructions to students [22]. Thus, these studies shed lights to other academic institutions about how to design educational programs that timely incorporate Industry 4.0 technologies and effectively improve student learning to better prepare them for the future.

We must acknowledge that the lack of training needs assessment in the reported industry-based training programs may be due to the fact that the nature of such reports is less frequently published as articles; educational institutions often report their courses to certain government agency. Rarely can we see publications introducing formal educational programs for workforce preparation in academic journals. For example, in the state of Texas, some courses that focus on connectivity and using information for automation aspects of the warehouse operations exist and are offered in community colleges (e.g., CETT 1x49 – Digital Systems); this course trains students to analyze and troubleshoot digital systems. A database of courses is available from the state of Texas's Higher Education Coordinating Board's (THECB) Workforce Education Course Manual (WECM) through their Career & Technical Education/Workforce Initiatives (Website: http://board.thecb.state.tx.us/apps/WorkforceEd/wecm/). However, assessing the courses and their content, to the best of our knowledge, there are no courses, certificates or program that will train for the multi-disciplinary skills needed for the workforce. We thus further suggest researchers to not only focus on the needs of the future workforce, but also develop the components of the course especially from a curriculum development standpoint, offering constructive suggestions for educators across all educational levels to collectively contribute to workforce training and development.

6. Limitations of the Literature Review

We made several key contributions and provided future research directions to the field; however, there are some limitations. First, we limited our literature search to peer-reviewed journal articles. This exclusion criterion may have excluded significant work from conference proceedings or some relevant studies. Second, despite some recent literature reviews included articles published in other languages such as German or Spanish [49], we only reviewed English literature. Considering

industry 4.0 originated in Europe, the exclusion of other languages limits the scope of our understanding of this topic. Finally, we can only identify 48 articles that discussed Industry 4.0 and workforce T&D in this literature review. If there were more studies on this topic, we would obtain more in-depth understanding of the impacts of Industry 4.0 on workforce T&D. It is expected that more studies regarding workforce T&D programs will be available in the literature to offer recommendations or guidelines for us to develop the workforce in the time of Industry 4.0.

7. Conclusion

In conclusion, Industry 4.0 presents industry-wide challenges and rich opportunities to workforce training and development in supply chain. New technology generates challenges that render drastic changes in organizational culture, systems, and strategy and new training and educational programs ought to be designed to prepare the workforce. The review has demonstrated that there is an increasing number of researchers are interested in how to effectively improve the workforce readiness through training and development from various disciplines.

Our objectives were three-fold. First, we identified training and development programs in both organizations and education institutions regarding Industry 4.0. Second, we found various areas of training that the supply chain industry needs to address. For example, some regions are not actively engaged in the Industry 4.0 discussion (e.g., Latin America). Further, this literature review shows that interdisciplinary research collaborations between supply chain and human resources investigators are needed because a successful improvement of workforce readiness requires strategically designing and implementing T&D programs with the intricate Industry 4.0 technologies as the core content. Future researchers should not only focus on the evaluation results of the program, but also should evaluate the process and content of the programs, and eventually study the associations between program results and organizational performance. Lastly, this systematic review identified knowledge gaps and provided future research avenues to educators interested in workforce training and development in the field of supply chain. Future educators could further develop class components especially from a curriculum development perspective.

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Appendix A

Classification and codes used in the study

Category	Classification	Code
(1) Research targeted industry	Agriculture	1A
	Assembly	1B
	Construction	1C
	Fashion	1D
	Government	1E
	Health systems	1F
	Higher education	1G
	Hospitality	1H
	Humanitarian	1I
	Management	1J
	Manufacturing	1K
	Pharmaceutical	1L
	Supply chain	1M
	Various industries	1N
(2) T&D Focus	Training needs assessment	2A
	Training program	2B
	Training program evaluation	2C
(3) Research method	Case study	3A
	Conceptual paper	3B
	Content analysis	3C
	Delphi study	3D
	Literature review	3E
	Mixed methods	3F
	Program proposal	3G
	Qualitative research	3H
	Quasi-experimental	3I
	SEM	3J
	Survey	3K

Appendix B

Publication outlets

Journal title	Impact factor
Societies	0.529
International Journal of Engineering Education	0.611
Systems Research and Behavioral Science	0.731
Intelligent Automation & Soft Computing	0.79
International Health	1.664
Journal of Stored Products Research	1.954
Management Decision	1.963
Telecommunications Policy	2
Annals of Operations Research	2.284
Technology in Society	2.414
Human vaccines & immunotherapeutics	2.619
Energies	2.702
Computer Communications	2.766
Total Quality Management & Business Excellence	2.922
Annual Review of Resource Economics	2.978
Journal of Business Logistics	3.171
Journal of Business Logistics	3.171
Journal of Management in Engineering	3.269
Journal of Retailing and Consumer Services	3.585
IEEE Access	4.098
Supply Chain Management: An International Journal	4.296
Journal of Field Robotics	4.345
Process Safety and Environmental Protection	4.384
Journal of Business Logistics	4.697
Energy Policy	4.88
California Management Review	5
The International Journal of Logistics Management	5.212
Computers & Education	5.627
Trends in Food Science & Technology	8.519
Foresight and STI Governance	N/A
Higher Education, Skills and Work-Based Learning	N/A
IEEE International Symposium on Ethics in Engineering, Science and Technology (ETHICS)	N/A
Industrial and Commercial Training	N/A
International Journal of Fashion Design, Technology and Education	N/A
International Journal of Information Systems and Supply Chain Management	N/A
International Journal of Management and Sustainability	N/A
Journal of Global Operations and Strategic Sourcing	N/A
Journal of Management Analytics	N/A
Journal of Operations and Supply Chain Management	N/A
Procedia CIRP	N/A
Revista de Stiinte Politice	N/A
SA Journal of Human Resource Management	N/A
Technological and Economic Development of Economy	N/A
The Learning Organization	N/A
Transport Problems	N/A
Worldwide Hospitality and Tourism Themes	N/A

Appendix C

ID	Author/s	Title	Year	Targeted region	Industry	T&D Focus	Research method
1	Calitz, A.P., Poisat, P., & Cullen, M.	The future African workplace: the use of collaborative robots in manufacturing	2017	Africa	1K	2A	3C
2	Gama, K., Touseau, L., & Donsez, D.	Combining heterogeneous service technologies for building an Internet of Things middleware	2012	France-Author affiliation	1G	2B	3G
3	Saadé, R. G.	Exploring the e-supply chain of information products.	2012	Canada-author affiliation	1G	2B	3G
4	Saxena Arora, A.	The "organization" as an interdisciplinary learning zone: Using a strategic game to integrate learning about supply chain management and advertising.	2012	USA	1G	2B,2C	3A
5	van Hoek, R., Wagner, B., Lorentz, H., Töyli, J., Solakivi, T., & Ojala, L.	Priorities and determinants for supply chain management skills development in manufacturing firms.	2013	Finland	1M	2A	3K
6	Waller, M. A., & Fawcett, S. E.	Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management.	2013	USA-author affiliation	1N	2A	3B
7	Zhong, R. Y., & Huang, G. Q.	RFID-enabled learning supply chain: A smart pedagogical environment for TELD	2014	China	1G	2B,2C	3A
8	Duan, L., & Xiong, Y.	Big data analytics and business analytics	2015	USA-author affiliation	1J	2A	3E
9	Naveh, G., Even, A., Fink, L., & Berman, S.	Information Technology Education in a Digital Factory Learning Environment	2015	Israel	1G	2B,2C	3B
10	Peeling, R. W.	Diagnostics in a digital age: an opportunity to strengthen health systems and improve health outcomes.	2015	UK-author affiliation	1F	2A	3B
11	Schoenherr, T., & Speier-Pero, C.	Data science, predictive analytics, and big data in supply chain management: Current state and future potential	2015	USA	1G	2A	3K
12	Schön, A., Streit-Juotsa, L., & Schumann-Bölsche, D.	Raspberry Pi and Sensor networking for African health supply chains	2015	sub-Saharan Africa	1F	2A	3G
13	Seitz, K.F. & Nyhuis, P	Cyber-Physical production systems combined with logistic models – a learning factory concept for an improved production planning and control	2015	Germany-author affiliation	1G	2B	3B
14	Walter, M. R., Antone, M., Chuangsuwanich, E., Correa, A., Davis, R., Fletcher, L., ... & Teller, S.	A Situationally Aware Voice-commandable Robotic Forklift Working Alongside People in Unstructured Outdoor Environments	2015	USA-author affiliation	1M	2B,2C	3F
15	Dregger, J., Niehaus, J., Ittermann, P., Hirsch-Kreinsen, H., & ten Hompel, M.	The digitization of manufacturing and its societal challenges: a framework for the future of industrial labor	2016	Germany/author affiliation	1G	2A	3B
16	Njoroge, A. W., Affognon, H., Mutungi, C., Rohde, B., Richter, U., Hensel, O., & Mankin, R. W.	Frequency and time pattern differences in acoustic signals produced by Prostephanus truncatus (Horn)(Coleoptera: Bostrichidae) and Sitophilus zeamais (Motschulsky)(Coleoptera: Curculionidae) in stored maize	2016	sub-Saharan Africa	1A	2A	3F
17	Pfeiffer, S	Robots, Industry 4.0 and humans, or why assembly work is more than routine work	2016	Germany-author affiliation	1B	2A	3A
18	Sanders, N. R.	How to use big data to drive your supply chain	2016	USA	1N	2A	3A
19	Vaduva-Sahhanoglu, A. M., Calbureanu-Popescu, M. X., & Smid, S.	Automated and Robotic Construction-a Solution for the Social Challenges of the Construction Sector	2016	European Union	1C	2A	3B
20	Valmohammadi, C.	Examining the perception of Iranian organizations on Internet of Things solutions and applications	2016	Iran	1N	2A	3K
21	Gromovs, G., & Lammi, K.	BLOCKCHAIN AND INTERNET OF THINGS REQUIRE INNOVATIVE APPROACH TO LOGISTICS EDUCATION	2017	Finland	1G	2A	3E
22	Kergroach, S.	Industry 4.0: new challenges and opportunities for the labour market	2017	France-Author affiliation	1M	2A	3B
23	Kong, X. T., Chen, G. W., Huang, G. Q., & Luo, H.	Ubiquitous auction learning system with TELD (Teaching by Examples and Learning by Doing) approach: A quasi-experimental study	2017	China-author affiliation	1G	2B,2C	3I
24	Kshetri, N.	Blockchain's roles in strengthening cybersecurity and protecting privacy	2017	USA-author affiliation	1J	2A	3B

Appendix C. *continued.*

ID	Author/s	Title	Year	Targeted region	Industry	T&D Focus	Research method
25	Li, X., Shen, G. Q., Wu, P., Fan, H., Wu, H., & Teng, Y.	RBL-PHP: simulation of lean construction and information technologies for prefabrication housing production	2017	China	1G	2B,2C	3A
26	Mosannenzadeh, F., Di Nucci, M. R., & Vettorato, D.	Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach	2017	European Union	1E	2A	3A
27	Shamim, S., Cang, S., Yu, H., & Li, Y.	Examining the feasibilities of Industry 4.0 for the hospitality sector with the lens of management practice	2017	UK-author affiliation	1H	2A	3H
28	Ding, B.	Pharma Industry 4.0: Literature review and research opportunities in sustainable pharmaceutical supply chains	2018	UK-author affiliation	1L	2A	3E
29	Gupta, S., Qian, X., Bhushan, B., & Luo, Z.	Role of cloud ERP and big data on firm performance: a dynamic capability view theory perspective	2018	France-Author affiliation	1J	2A,2B,2C	3J
30	Hopkins, J., & Hawking, P.	Big Data Analytics and IoT in logistics: a case study	2018	Australia-author affiliation	1M	2B,2C	3A
31	Mohelska, H., & Sokolova, M.	Management approaches for Industry 4.0–the organizational culture perspective	2018	Czech Republic	1J	2A	3K
32	Prasad, S., Zakaria, R., & Altay, N.	Big data in humanitarian supply chain networks: A resource dependence perspective	2018	India	1E	2A	3A
33	Wang, B., & Ha-Brookshire, J. E.	Exploration of Digital Competency Requirements within the Fashion Supply Chain with an Anticipation of Industry 4.0	2018	USA-author affiliation	1D	2A	3C
34	Weersink, A., Fraser, E., Pannell, D., Duncan, E., & Rotz, S.	Opportunities and challenges for Big Data in agricultural and environmental analysis	2018	Canada	1A	2A	3E
35	Kamilaris, A., Fonts, A., & Prenafeta-Boldú, F. X.	The rise of blockchain technology in agriculture and food supply chains	2019	Spain-author affiliation	1A	2A	3E
36	Liboni, L. B., Cezarino, L. O., Jabbour, C. J. C., Oliveira, B. G., & Stefanelli, N. O.	Smart industry and the pathways to HRM 4.0: implications for SCM	2019	Brazil-author affiliation	1J	2A	3E
37	Rajabion, L., Khorraminia, M., Andjomshoaa, A., Ghafouri-Azar, M., & Molavi, H.	A new model for assessing the impact of the urban intelligent transportation system, farmers' knowledge and business processes on the success of green supply chain management system for urban distribution of agricultural products	2019	Iran	1A	2A	3J
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