A Review on Industry 4.0 and Supply Chain Sustainability

A. Telukdarie
[1]Postgraduate School of Engineering Management
University of Johannesburg, South Africa
arnesht@uj.ac.za

S. Bag
[2]Postgraduate School of Engineering Management
University of Johannesburg, South Africa
218099351@student.uj.ac.za

Abstract

The concept of Industry 4.0 has bought a big change in business process management enabled through wireless sensors networks and advanced technologies. Industry 4.0 has lead to successful smart manufacturing, smart warehousing and smart logistics. These practices have direct and indirect effects on supply chain sustainability. This area is under researched and need focus from the research community. The aim of this paper is to systematically review prior literature in the field of Industry 4.0, Cyber Physical Systems, and supply chain sustainability. Further analysis is performed to view the publication trends, number of publications per year, author affiliation, top papers and highest number of citations. This will provide a clear picture and enable researchers' to draw a boundary for proposing future research directions.

Keywords:
Industry 4.0, Industrial Internet of Things, Literature Review, Sustainable supply chain

1. Introduction

Digital transformation is no more a choice to manufacturers in today's dynamic business environment and is rather an imperative for survival. The previous three industrial revolutions have witnessed significant improvement in firms' productivity. The past industrial revolutions had effect on the shop floor level only. Industry 4.0 is a more advanced concept and shifts productivity much more by involving support functions such as engineering [Schuh, 2013]. Under Industry 4.0 concept, factory personnel will be able to work with smart phones and tablets for running production and communication at all levels. Industry 4.0 has been instrumental in improving supply chain connectivity, which further enhances supply chain visibility. However, the dark side of all previous industrial revolutions has been the ignorance of social and environmental dimensions.

The first industrial revolution was driven by steam power that transformed lives of people. The second industrial revolution was driven by electricity and communication enabling just in time operations and production lines in the mid-1800s. The 20th century witnessed the third industrial revolution through introduction of information technology. However, the fourth industrial revolution is much

more advanced, which involves Cyber Physical Systems and can process data at super fast speed at a fraction of cost compared to previous applications. The fourth revolution has bought enhanced speed, increased visibility and cost economics beyond the imagination.

However, the burning problem confronting firms is the lack of a coherent strategy for managing total supply chain integration, all delivered through automation and enabled workflows. Poor management will lower efficiency and also lead to direct and indirect financial losses. Enhancing skills, changing the traditional organisation structure and change management are crucial under Industry 4.0 digitalisation without which it is not sustainable. Therefore, social, environmental and economic impact has certain crucial implications for the firm and need to be taken care through proper technological application and management. Existing literature does not show much evidence, which may prove that firms are focusing on these sustainability dimensions and thus opens up a research gap for further investigation.

The research objectives can be considered as: (i) to understand the research progress in the field of Industry 4.0 and its role in driving supply chain sustainability, (ii) to classify the literature and categorize them under various key themes, and finally (iii) provide food for thought to the research community.

The paper is divided into following sections. Section 2 provides a detailed strategy for conducting the systematic literature review; Section 3 presents the research framework; Section 4 provides the conclusion and managerial implications followed by a final section on limitations, unique contributions and directions for future research.

2. Literature Review

In this research study, the authors have adopted a Systematic Literature Review (SLR) methodology to study the concept of Industry 4.0 and Sustainable supply chain management. The list of papers is downloaded using Scopus (https://www.scopus.com) which is the largest abstract and citation database for academic reputed scientific research journals, books and conference proceedings. The systematic literature review methodology is adopted based on the guidelines advised by Tranfield et al. [Tranfield, 2003]. The key steps in the SLR are (i) Planning the strategy for conducting the literature review, (ii) Conducting the literature review and (iii) Reporting the findings from the literature review.

2.1 Planning the review of literature

The data is obtained from the Scopus database. Scopus consist of research papers from four fields, such as Life Sciences, Health Sciences, Physical Sciences and Social Sciences. This allows for conducting research studies in cross-disciplinary fields, which is one of the primary purposes for selecting the Scopus database in this research study.

The authors did not consider data from databases such as Web of Science, DBLP and WorldCat because more journals are present in Scopus.

This research study undertakes a novel attempt to combine two independent concepts, the first concept from the domain of Information Technology (Industry 4.0) and second concept from the domain of Business management (Sustainable supply chain). The keywords used to search the academic literature for these two concepts are provided in Table 1.

Table 1. Keywords used for searching relevant literature

Industry 4.0	Sustainable Supply Chain Management
"Industry 4.0"	"Sustainable supply chain"
"Industrial internet of things"	"Sustainable development"
"Embedded systems"	"Sustainable operations"
"Cyber physical system"	"Smart logistics"

Source: Authors' own compilation

The literature search process on Scopus database is conducted as an independent process by means of using 'or' operator for individual keyword and further the search output of the two concepts is combined by means of using 'and' operator. Table 2 provides detailed search syntax used in this study.

Table 2. Search Syntax

Source of Data collection	**Search Syntax**
Search Performed on Scopus on 22 Jan 2018 Website: https://www.scopus.com	((TITLE-ABS-KEY ("industry 4.0") OR TITLE-ABS-KEY ("industrial internet of things") OR TITLE-ABS-KEY ("embedded systems") OR TITLE-ABS-KEY ("cyber physical system"))) AND ((TITLE-ABS-KEY ("sustainable supply chain") OR TITLE-ABS-KEY ("sustainable development") OR TITLE-ABS-KEY ("sustainable operations") OR TITLE-ABS-KEY ("smart logistics"))) AND (EXCLUDE (PUBYEAR , 2018)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ip")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))

Source: Author's own compilation

The search process can be re-run on the Scopus website by simply copying and pasting the referred syntax under the advanced search option. However, the output may vary due to the constant updating of the digital database. The data was obtained on Monday, 22nd Jan, 2018 at 6.35 PM, South African time.

2.2 Conducting the literature review

This section details the classification of the research papers. The pie chart shows the range of research papers which is obtained after stage five in the paper search process. The authors found that maximum number of papers is published in the field of Engineering, second highest is Environmental, third highest is Computer science and followed by other eight categories.

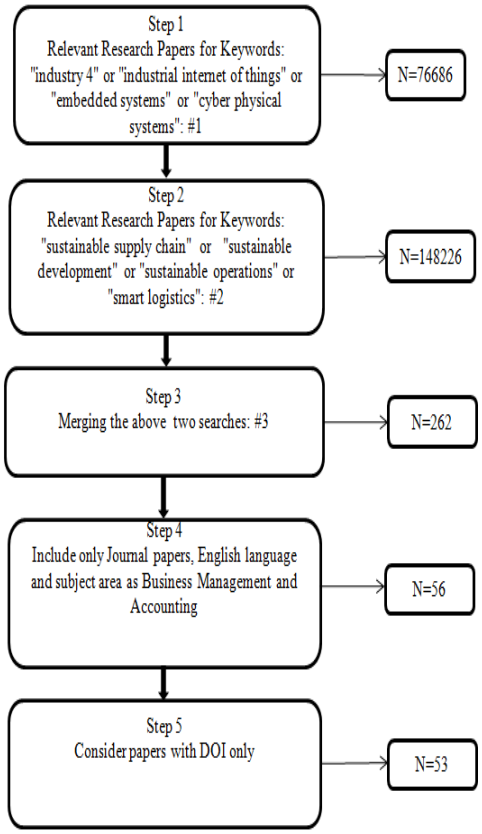

Figure 1. Steps for selecting the research papers for Literature review (Source: Authors' own compilation

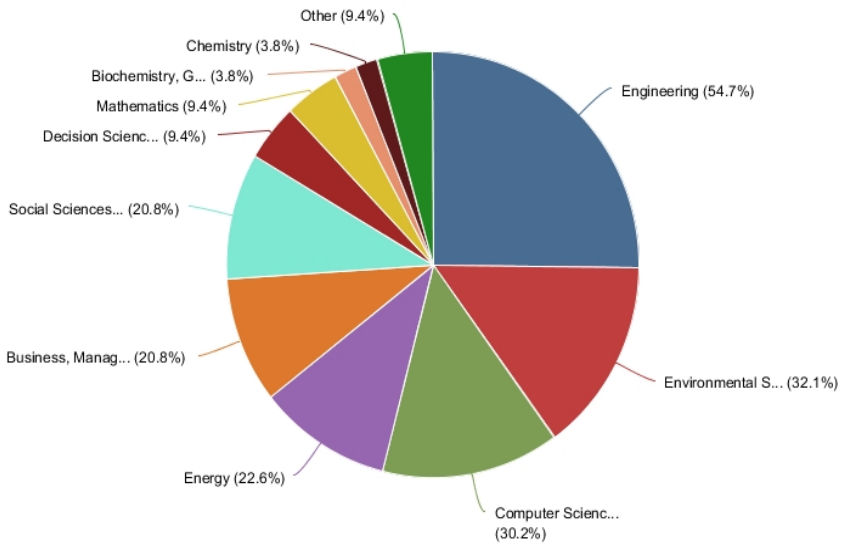

Figure 2. Range of research papers after stage five (Source: Authors' own compilation)

Figure 3 provides the publishing trend. Interestingly, the number of published papers increased from 2009 onwards and significantly in 2016. The authors' further identified the ten papers which attracted the highest number of citations and is tabulated in Table 3.

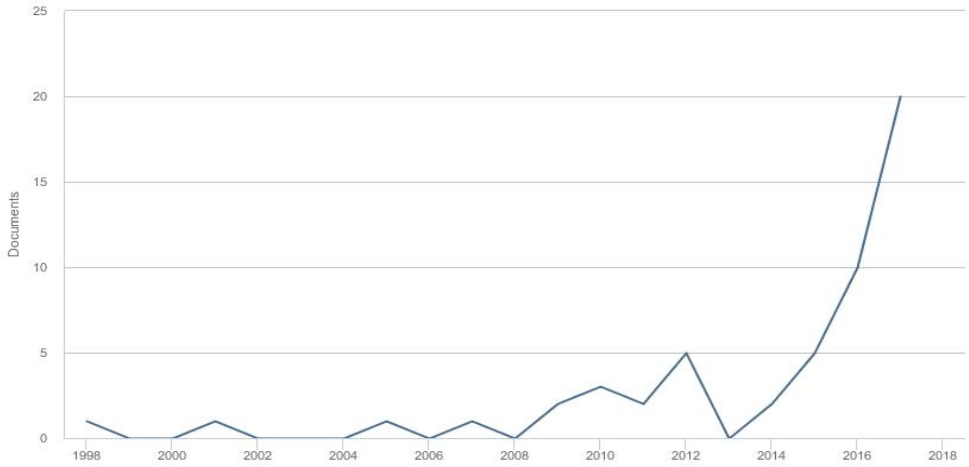

Figure 3. Number of research papers published per year (Source: Authors' own compilation)

Table 3. Ten top papers which attracted max citations and corresponding author's affiliation

Sl No.	Author(s), Year	Corresponding Author's Affiliation	Citations
1	Buchholz et al., [Buchholz, 2009] (2009)	Department of Forest and Natural Resources Management, State University of New York, College of Environmental Science and Forestry, One Forestry Drive, Syracuse, NY 13210, USA	205
2	Banerjee et al., [Banerjee, 2012] (2012)	School of Computing, Informatics, and Decision Systems Engineering , Arizona State University (ASU), Tempe, AZ, USA	149
3	Moser et al., [Moser, 2012] (2010)	C. Moser and L. Thiele are with the Computer Engineering and Networks Laboratory, Swiss Federal Institute of Technology (ETH) Zurich, Gloriastr.35, CH-8092 Zuerich, Switzerland	93
4	Gupta et al., [Guptha, 2011] (2011)	Impact Lab, School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, Tempe, AZ, USA	64
5	Franken et al., [Franked, 2012] (2012)	Institute of Health Policy and Management, Erasmus University, Rotterdam, Netherlands	51
6	Scognamiglio et al., [Scognamiglio, 2014] (2014)	AdR1 Dipartimento Agroalimentare, IC-CNR Istituto di Cristallografia, Via Salaria Km 29.3, 00015 Monterotondo Scalo, Rome, Italy	44
7	Leary et al., [Leary, 2012] (2012)	Department of Mechanical Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, UK	41
8	Wang et al., [Wang, 2015] (2015)	Department of Electrical and Computer Engineering, Michigan Technological University, Houghton	33
9	Aylott et al., [Aylott, 2010] (2010)	School of Biological Sciences, University of Southampton, UK	28
10	Bolton & Hannon, [Bolton, 2016] (2016)	Science, Technology and Innovation Studies, School of Social and Political Science, University of Edinburgh, Old Surgeons' Hall High School Yards, Edinburgh EH1 1LZ, UK	24

2.3 Reporting the findings from the literature review

The key points which emerge from the review of existing literature are as follows:

- Industry 4.0 or the fourth industrial revolution integrates core technologies such as IoT, Cyber physical systems and cloud computing. Industry 4.0 has enabled firms' advancement by significantly enhancing the productivity and efficiency.
- The literature review brings out some interesting facts and figures which will be helpful for the research community. Although there has been studies in all domains but limited studies exist in the area of managing supply chain network through smart technologies.
- Smart supply chain is an emerging form of logistics systems, integrating resources and capabilities with wireless sensors and actuators to collect data and process data for business decision making [Kusiak, 2017]. Such real-time information sharing aids in right decision support and enhanced profitability [Lee, 2017].
- From stage 5 of the review, the researchers' identify 53 research papers, which focuses on both Industry 4.0 and Sustainability. However, only 10 papers out of 53 papers actually focuses on smart manufacturing/production system, smart warehouse management system, smart logistics and sustainability. Most of the previous research works ignored one the important dimensions of sustainability i.e. Social dimension. None of the papers provided a holistic framework on smart supply chain network design under Industry 4.0 concept.
- This area has been under researched and the gaps in the existing literature opens new research avenues for future researchers. Future study must explore Industry 4.0 and sustainable supply chain network design from both technological and management perspective.

This study provides food for thought to future researchers. New research studies are required to explore the risk management strategies in supply chain network under the control of Industry 4.0. It would be interesting to see the effect of supply chain connectivity on information sharing and finally on supply chain visibility.

3. Research Framework

The reseach includes a reseach framework as developed to proposition the research hypothesis, refere to Figure 4.

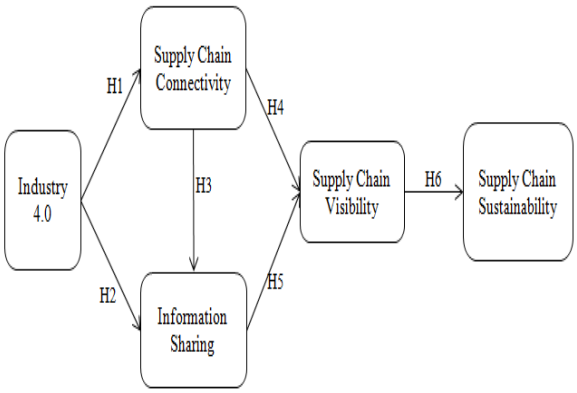

Figure 4. Research framework (Source: Authors' own compilation)

4. Conclusion

The study provides a clear picture on prior research works related to Industry 4.0 and supply chain sustainability. Further, a framework is proposed which can be tested by collecting data through survey

methodology. The design of smart warehousing, smart logistics and smart production systems through technology enabled automation is a major learning compared to past studies. Most importantly, the safety, security and sustainability parameters must be remembered while designing IIOT architecture in context to industrial systems. Change management, training and up grading of manpower is vital for meeting Industry 4.0 demands. The better managers know Industry 4.0 requirements, the better they are ready for adopting Industry 4.0 technologies in the supply chain network. Industry 4.0 enables supply chain connectivity and information sharing, the key to supply chain visibility which further leads to supply chain sustainability.

4.1 Limitations, unique contributions and future research directions

The only limitation of the study is the data, which has been obtained from the Scopus database which is dynamic and changes every second. However, the current study provides an overview of the number and nature of studies conducted in the field of Industry 4.0 and Sustainable Supply chain management. Future research work can be conducted to perform an empirical survey to test the model in a South African context and validate it through multiple case studies.

References

Schuh, G., Potente, T., Wesch-Potente, C. and Hauptvogel. A., Sustainable increase of overhead productivity due to cyber-physical-systems, In Proceedings of the 11th Global Conference on Sutainable Manufacturing – Innovation Solutions, pp. 332–335, 2013.

Tranfield, D., Denyer, D., & Smart, P., Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, Vol. 14, pp. 207–222, 2003.

Buchholz, T., Rametsteiner, E., Volk, T. A., & Luzadis, V. A., Multi criteria analysis for bioenergy systems assessments. Energy Policy, Vol. 37, No. 2, pp. 484-495. DOI: 10.1016/j.enpol.2008.09.054, 2009.

Banerjee, A., Venkatasubramanian, K. K., Mukherjee, T., & Gupta, S. K. S., Ensuring safety, security, and sustainability of mission-critical cyber–physical systems. Proceedings of the IEEE, Vol. 100, No. 1, pp. 283-299. DOI: 10.1109/JPROC.2011.2165689, 2012

Moser, C., Thiele, L., Brunelli, D., & Benini, L., Adaptive power management for environmentally powered systems. IEEE Transactions on Computers, Vol. 59, No. 4, pp. 478-491. DOI: 10.1109/TC.2009.158, 2010

Gupta, S. K., Mukherjee, T., Varsamopoulos, G., & Banerjee, A., Research directions in energy-sustainable cyber–physical systems. Sustainable Computing: Informatics and Systems, Vol. 1, No. 1, pp. 57-74. DOI: 10.1016/j.suscom.2010.10.003, 2011.

Franken, M., le Polain, M., Cleemput, I., & Koopmanschap, M., Similarities and differences between five European drug reimbursement systems. International Journal of Technology Assessment in Health Care, Vol. 28, No. 4, pp. 349-357. DOI: 10.1017/S0266462312000530, 2012.

Scognamiglio, V., Arduini, F., Palleschi, G., & Rea, G., Biosensing technology for sustainable food safety. Trends in Analytical Chemistry, Vol. 62, pp. 1-10, 2014.

Leary, J., While, A., & Howell, R., Locally manufactured wind power technology for sustainable rural electrification. Energy Policy, Vol. 43, pp. 173-183. DOI: 10.1016/j.enpol.2011.12.053, 2012.

Wang, Z., Song, H., Watkins, D. W., Ong, K. G., Xue, P., Yang, Q., & Shi, X., Cyber-physical systems for water sustainability: challenges and opportunities. IEEE Communications Magazine, Vol. 53, No. 5, pp. 216-222, 2015.

Aylott, M. J., Casella, E., Farrall, K., & Taylor, G., Estimating the supply of biomass from short-rotation coppice in England, given social, economic and environmental constraints to land availability. Biofuels, Vol. 1, No. 5, pp. 719-727, 2010.

Bolton, R., & Hannon, M., Governing sustainability transitions through business model innovation: Towards a systems understanding. Research Policy, Vol. 45, No. 9, pp. 1731-1742. DOI: 10.1016/j.respol.2016.05.003, 2016.

Kusiak, A., Smart manufacturing. International Journal of Production Research, pp. 1-10. DOI: 10.1080/00207543.2017.1351644, 2017.

Lee, C. K. M., Lv, Y., Ng, K. K. H., Ho, W., & Choy, K. L., Design and application of Internet of things-based warehouse management system for smart logistics. International Journal of Production Research, pp. 1-16. DOI: 10.1080/00207543.2017.1394592, 2017.

Banerjee, A., & Gupta, S. K., Analysis of smart mobile applications for healthcare under dynamic context changes. IEEE Transactions on Mobile Computing, Vol. 14, No. 5, pp. 904-919. DOI: 10.1109/TMC.2014.2334606, 2015.

Appendix A: All Papers Downloaded

Table A1. Papers downloaded

DOI: 10.1109/MCOM.2015.7105668	DOI: 10.1002/2015WR017342
DOI: 10.1016/j.ifacol.2017.08.1808	DOI: 10.1002/sres.985
DOI: 10.1016/j.ifacol.2016.12.203	DOI: 10.1108/17410381211253317
DOI: 10.1080/02533839.2017.1362325.	DOI: 10.1002/geot.201700050
DOI: 10.1115/1.4035063	DOI: 10.1016/j.trd.2017.05.001
DOI: 10.1145/2505767	DOI: 10.1016/j.jclepro.2005.09.002
DOI: 10.1016/j.trac.2014.07.007	DOI: Doi:10.5937/jaes14-11664
DOI: 10.1080/15568318.2017.1300716	DOI: 10.1016/j.enbuild.2017.03.068
DOI: 10.1177/1063293X16672508	DOI: 10.1080/17452007.2016.1178628
DOI: 10.1109/TAC.2017.2743678	DOI: 10.4155/bfs.10.30
DOI: 10.3390/w7105224	DOI: 10.1057/s41303-016-0030-1
DOI: 10.1016/j.technovation.2003.10.005	DOI: 10.1007/s10661-011-2491-y
DOI: 10.1007/s00254-008-1665-6	DOI: 10.1080/13504509809469972
DOI: 10.1080/00207543.2017.1401237	DOI: 10.1109/TII.2016.2605624
DOI: 10.1016/j.promfg.2017.02.053	DOI: 10.1007/s11265-015-1092-3
DOI: 10.1016/j.jclepro.2017.05.186	DOI: 10.1002/int.21866
DOI: 10.1080/08982110108918665	DOI: 10.1680/jurdp.15.00027
DOI: 10.3390/s17020372	DOI: 10.1109/MIS.2011.98
DOI: 10.1007/s11227-016-1937-y	DOI: 10.1016/j.jclepro.2017.11.094
DOI: 10.1016/j.eiar.2015.09.006	