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Scaling Research Efficacy in Supply Chain Management towards Industry 4.0 Automation

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ABSTRACT
With the advancement of various advanced technologies towards information access system using pervasive and ubiquitous computing, the field of Supply Chain Management (SCM) is yet not ready to adopt the latest technological system. The commercial usage of SCM is still limited to adoption of conventional Radio Frequency Tags and simple sensors with internal communication performed on internet system. However, the entry of cloud-computing has brought a significant revolution in the area of automation, which is expected to make the complete SCM process a ubiquitous one. There is a less focus on SCM process improvement in order to keep pace with faster changing dynamics of technologies, and this hypothesis is explored in proposed review work. This paper discusses recent studies being carried out in SCM, which proved that existing SCM system has many open-end limitations as well as significant research gap that is yet to be bridged in order to give SCM a shape of industry 4.0 standard

Keywords
Supply Chain Management, Review, Survey, Logistic, RFID, Sensor

1. INTRODUCTION
The standard definition of Supply Chain Management (SCM) states that it is the management of the flow of products/services right from the point of origination to end customer[1]. The flow includes various essential actors, e.g., consumers, suppliers, production, and distribution. With the changing time and inclusion of modern technologies, the demand of SCM has completely changed. SCM is not only about connecting all these actors together but to ensure reduced time gap between supply and demand with quality services. The so-called service quality is highly an abstract term that is governed by psychological demands of consumers that is highly dynamic in nature. But such forms of service quality can be now possible to be facilitated by the inclusion of different forms of technologies that offer ubiquitous features, e.g., cloud computing and Internet-of-Things (IoT) [2]. Hence, at present, apart from product/service to be delivered, what matters most is the exchange of precise information related to the process management in real-time. This is the key point for successful SCM. Another essential point in this regards is to design and develop a superior version of automation that can considerably save operation cost while retaining same or higher service quality. This could be possible by developing a model in adherence to present execution of automation trend called as Industry 4.0. This automation standard is all about an efficient exchange of information associated with any manufacturing technologies, and its building blocks are a cyber-physical system, IoT, cloud computing, and cognitive computing. However and whatever be the amount of advancement in technologies, there is a risk factor always involved in it. There are various forms of the latent risk factor, e.g., lack of precise and updated information, intermittent change of demands, absence of or improper log management of raw materials, natural disaster, attrition rate, etc. Another significant challenge in transforming existing SCM to what is actually demanded in industry 4.0 standard is an architecture that offers superior integration process with the highest level of flexibility in planning and execution [3]. After decades of research work carried out towards SCM, it has been seen that they are mainly application specific or they address a countable set of minor problems, whereas the major problems of well-architecture and robust SCM is still yet to come. Neither there is any such commercial application or framework in use in present-day nor is there any break-through research innovation in SCM till day. Therefore, this topic is worth doing the investigation to find out the impending factors and develop a slow and steady solution that can transform existing SCM to smart SCM with superior performance capable enough to meet the dynamic demands of the consumer in a futuristic time. Therefore, this paper reviews some of the recent work being carried out by existing researchers for measuring the scale of effectiveness in existing approaches. The organization of the paper is as follows: Section 1.1 discusses the background of SCM concerning various reviews carried out in existing system followed by the discussion of research problems in Section 1.2 and proposed solution in 1.3. Section 2 discusses about recent enhancing the operational performance associated with a supply chain management system followed by findings of the research survey in Section 3. The research gap from the existing approaches are discussed in Section 4. Finally, the conclusive remarks are provided in Section 5.

1.1 Background
At present, there have been multiple review-based studies being carried out towards exploring various approaches associated with SCM. Few researchers have discussed the usage of sophisticated mechanisms in order to deal with various forms of risk in SCM [4][5][6]. Such studies offer a good baseline of existing theories towards establishing an internal relationship of various entities involved in risk management system in SCM. There are also reported investigation towards evolving optimization techniques associated with risk management [7]. Such forms of investigation offer more edge of information towards exploring critical processes governing risk management. There are also investigations carried out towards data forms in

SCM [8] along with other forms of studies towards performance analysis [9]. Most recently, a review work has discussed about SCM system associated with production sector [10].

1.2 Research Problem

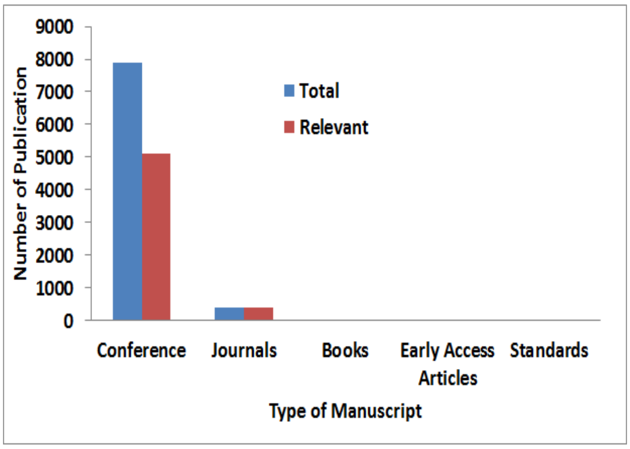
A review of the extant literature shows that most studies incline towards risk management in SCM as compared to any other research problems. There are also research studies towards knowledge-based management, collaborative operation, optimization methods, constraints, agent-based inclusive approach, the inclusion of some specific conventional method, etc. However, it would be interesting and useful to assess the advantages as well as limitation associated with existing approaches in the light of new trends in technology, such as industry 4.0. It has also been seen that there are various implementation work carried out in SCM, both using simulation, and experimental-based, where there is no report of any form of comparative analysis. There is an absence of any form of benchmarking systems in it. Hence, the significant research problem in this regard is to explore the level of effectiveness of existing approaches towards SCM. The next section outlines the proposed solution.

1.3 Proposed Solution

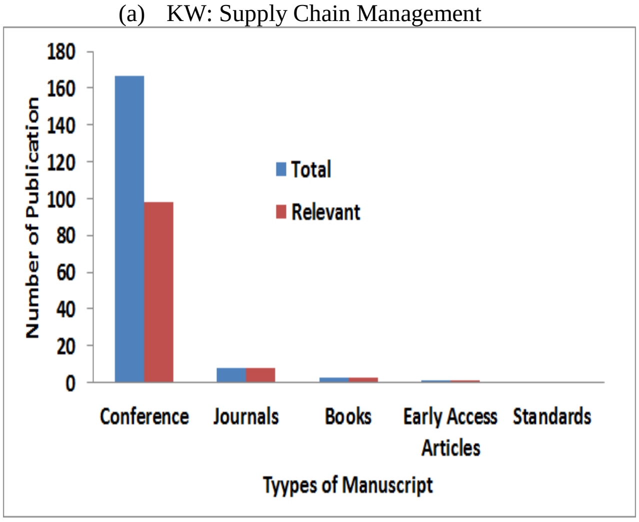
For an effective understanding or planning of a novel idea, it is required to identify the advantages that the existing approaches offer towards ensuring the better fit of SCM models in futuristic technologies. With the inclusion of cloud computing and industry 4.0 automation standard, it has been seen that existing research-based solutions are not oriented in this direction. This could be visibly understood by finding non-inclusion of the cyber-physical system in existing research approaches. Therefore, it is essential that along with advantages, there should be the thorough identification of limitations associated with existing approaches so that the viability of such limitations could be more identified and further investigated. This will offer the more comprehensive idea to develop a novel system. However, such design process of a novel system to upgrade SCM system will also be to identify the research gap existing in all the considered research work. There could be a good possibility of various factors leading to research gap in SCM however, the most critical one will be only considered for futuristic study formulation. The prime agenda of reviewing the existing study is to explore if the study has i) involved benchmarking as it could ensure its standard implementation on real-time test-bed with it, ii) involves complexity analysis that could ensure practicality of the presented approach, iii) inclusion of cyber-physical medium that could offer better assurance towards adherence on industry 4.0 automation standard, and iv) types of test-cases/environment being considered that could offer rich idea about targeted scope of applying the presented concept. Therefore, the proposed study assists in performing an exhaustive review of existing approaches towards SCM system. The next section briefs existing approaches.

2. RECENT APPROACHES

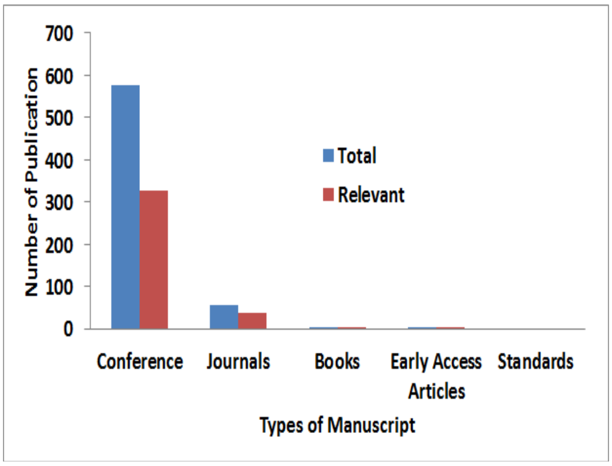
This section discusses about the existing research-based approaches carried out towards enhancing the operational performance associated with a supply chain management system. There is the total number of 412 Journals, 7,889 conference papers, 26 early access articles, five standards, 31 books, and three courses being published in reputed IEEE Xplore in last ten years. In order to have a comprehensive look at the research trend, the investigation was carried out to observe all possible direction where SCM was considered in direction with multiple research targets.



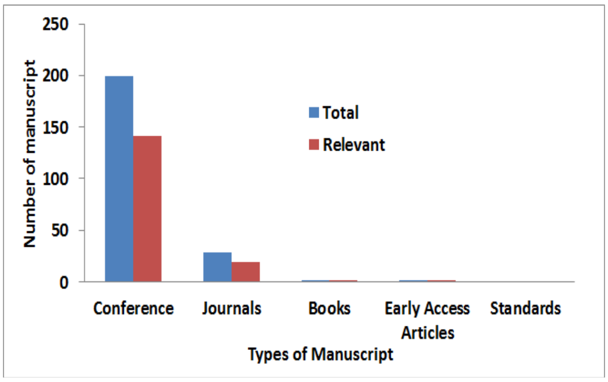
(a) KW: Supply Chain Management



(b) KW: Supply Chain management, Cloud



(c) KW: Supply Chain management, RFID



(d) KW: Supply Chain management, sensor

Figure 1 SCM Research Trend during 2008-2018

Fig.1 highlights that there are less than 5000 relevant research papers about SCM (Fig.1(a)) published in last decade with more focus on inclusion of RFID-based problems (Fig.1(c)). With the evolution of cloud computing, the research community has started including cloud-based approaches, however, there are absolutely no significant work in this direction as there are only less than 20 relevant journals towards cloud-based SCM (Fig.1(b)). Similar is also the trend of sensor-based study in SCM (Fig.1 (d)). Therefore, this section briefs about only the recent work carried out in last three years only.

Table 1 Summary of Existing Literatures Published in 2015

Reference	Problem Focused	Methodology	Advantage	Limitation
Matta.et.al [11]	Decision formulation for product variety.	Numerical Analysis.	-Shorter processing time.	Doesn't discuss about computational complexity
Chli.et.al [12]	Developing real-time SCM	-Loopy belief propagation (LBP) Method.	-Good performance without being affected by the ongoing change of properties	Lack of Benchmarking
Zhang.et.al [13]	Uncertainty problems	-Linear Matrix Inequalities (LMIs) methods.	-Stability of the discrete-time switch fuzzy system.	Outcome-dependent on the static rule system
Xiao.et.al [14]	-Developing two supply chain models. -Issues of product variety and pricing.	-Game theory.	-cost saving, ensure high quantity.	-includes computational complexity for higher problems
Sabbagh .et.al [15]	-Modeling target system, Identify the threats and Analyse countermeasure.	Delphi method.	-Ensure security	The highly iterative process, do not support real-time applications
Jiang.et.al [16]	Decision making in a coordinative way.	-Genetic algorithm. -Lagrange multiplier method. -Nash bargaining model.	-Low elasticity of retailer -Can stimulate more product demand	-includes computational complexity for higher problems
Ramkumar.et.al [17]	Developing sustainability into the supply chain?	-Multi-criteria decision making (MCDM) method. -Decision Making Trial and Evaluation Laboratory (DEMATEL) method.	Improve sustainability in the supply chain.	Outcome-dependent on Static prototyping parameters
Shahriari.et.al [18]	-To improve the business competitiveness of supply chains.	-Decision support system (DSS). -Online analytical processing (OLAP).	-Online real-time qualitative measurements on the product, process & procedures.	Doesn't support distributed data aggregation process in SCM
Raj.et.al [19]	To give a quantitative measurement of resilience, regarding recovery time.	Cox-PH model.	-Good coverage of different perspective in SCM	Narrowed test-cases considered to validate the outcome
Chan.et.al [20]	-To enhance the operational efficiency of SCM	-Quick response system (QRS). -Radio Frequency Identification (RFID) system.	-Faster processing -Information updating process is working.	-outcome confined to the single case study
Haykin.et.al [21]	-To allocate the spectrum dynamically. -To improve spectral efficiency.	Cognitive radio networks for spectrum supply chain networks	-Market-driven regime. -Allow analysis of both equilibrium and transient behavior.	No benchmarking, no complexity analysis

Table 2 Summary of Existing Literatures Published in 2016

Reference	Problems Focused	Methodology	Advantage	Limitation
Lowe.et.al [22]	Scheduling problem in SCM	mixed-integer programming	-flexible scheduling	Doesn't consider all entities of SCM
Mogre.et.al [23]	Risk mitigation	Decision support systems (DSSs). Analytic network process (ANP).	Simplified Risk Management	-outcome confined to the single case study
Ali.et.al [24]	Security incorporation in SCM application	Experimental Approach	Good balance between security & operation	-Doesn't address all adversaries
Skudlarek.et.al [25]	Security incorporation in SCM application	Experimental Approach	Supports tracking and provisioning of chips.	-Doesn't address all adversaries
Qi.et.al [26]	Security incorporation in SCM application (RFID).	Digital Signature Scheme	-Supports privacy and non-repudiation	-Doesn't support compliance with all security standards
Chiu.et.al [27]	Affect of channel leadership on performance	-Good Analytical model	-supports better information symmetry.	-The theoretical model with less evidence of practical validation
Fan.et.al [28]	Capability enhancement	Supply chain risk (SCR) information processing system.	Supports existing automation	-doesn't involve complete automation process
Qi.et.al [29]	RFID-Security measures	Ciphertext Policy-Attribute Based Encryption (CP-ABE). Security analysis.	Effective data accessibility & control mechanism	-doesn't discussion data complexity
Lajimi.et.al [30]	-Monitoring of dynamic risk	Failure mode and effects analysis (FMEA) method.	Asses the delay risk with this operations.	-outcome confined to transportation problems only
Wang.et.al [31]	Hybrid formation of SCM	Meta-analysis methods.	Effective monitoring of vulnerable areas	Dependent on Static prototyping parameters
Liu.et.al [32]	Security incorporation in SCM application	Scout method.	To build up the security of the supply chain.	Iterative method-leads to the complexity
Choi [33]	Incorporate optimization -risk management	Sensitivity analysis.	Simplified base design	Doesn't involve cyber-physical system
Zhang.et.al [34]	Capital constraint and loss aversion on operational decisions in supply chains.	Supply Chain Finance (SCF)	The analysis shows that the optimal operational decisions of both manufacturer and retailer are related to their initial capital and financing decision.	Doesn't involve cyber-physical system -No Benchmarking -No complexity analysis

Table 3 Summary of Existing Literatures Published in 2017

Reference	Problems focused	Methodology	Advantage	Limitation
Sun.et.al [35]	by-product reuse -synergy formation cost.	Game theoretical model.	Promote by-product synergy formation.	-Cannot design complex processes
Huang.et.al [36]	Decision making in SCP process for the maximized profits.	Bayesian analysis.	Effective correlation of demand for successive periods – the better process of estimation errors.	No evidence to prove it real-time operation

Huang.et.al [37]	Clone process detection in SCM	Double-Track Detection (DTD). Clone detection mechanism.	The simplicity of the clone detection mechanism produces its independency on the structure of supply chains and thus makes it universally usable.	No benchmarking
Zhang.et.al [38]	Control Bullwhip Effect in Uncertain Closed-Loop Supply Chain with Hybrid Recycling Channels.	Fuzzy robust control method. Simulation analysis.	cost of the closed-loop supply chain lowers	The outcome depends on static rulesets
Tsao.et.al [39]	Improving RFID design of a supply chain network	Continuous approximation (CA) method.	Effective identification of any problems	Doesn't include complete cyber-physical system
Li.et.al [40]	Optimizing the supply chain and extending its value.	Cluster analysis method.	It will give a result to effective and efficient for data supply chain retrieval.	Doesn't include complete cyber-physical system
Son.et.al [41]	Analyses the gaps between the degrees of dependence perceived by the two parties	Bi-perspective Group Decision	Can be utilized to redesign and improve communication and decision-making processes of the system.	Doesn't include complete cyber-physical system
Gao.et.al [42]	the difference in bullwhip effects in online and offline retail supply chains	bullwhip effect	-supports effective analysis of bullwhip effect.	Less cost effective design
Lu.et.al [43]	Security incorporation in SCM application	a survey-based methodology using questionnaire	Simple quantification of security approaches	No robust solution of security yet found
Du.et.al [44]	To lower the impact of the demand fluctuation on the supply chain.	RFID and Multi-Agent technology.	Can improve the feasibility of the construction plan and facilitate dynamic adjustment in order to achieve full production and minimize the inventory and delay for the assembler.	Doesn't include complete cyber-physical system
Chen.et.al [45]	Cost management in SCM	Lingo 12.0 and Microsoft Excel 2010.	The simple design process of distribution strategy	Narrowed computational modeling
Zhou.et.al [46]	Green supply chain design.	Mathematical model.	tariff imposition policy	Doesn't include complete cyber-physical system
Xiao.et.al [47]	Cost management in SCM	game theory	Symmetric outsourcing decreases	Cannot solve complex problems
Liu.et.al [48]	To understand the integrated operations in the construction supply chain (CSC)	a hybrid genetic algorithm with the fuzzy-random method	→considering of uncertain rush orders and delay times can be vital for optimum CSC	The outcome depends on static rulesets

			performance	
Ewen.et.al [49]	planning and control processes	MIMAC simulation	Simplified accessibility to information	Doesn't include complete cyber-physical system
Wang.et.al [50]	To examine the differences in performance between two seemingly very similar markup pricing policies in two supply chains that compete in a market with two substitutable products.	Game theory	→equilibrium pricing strategy depends on the level of supply chain-to-chain competition	Iterative process--includes higher response time

Hence, it can be seen that there are various cadres of research-based approaches towards cloud-computing with diversified focus on different problems associated with it. The study also shows very less inclusion of latest trends and technologies that could contribute to internal process management in SCM.

3. FINDINGS OF REVIEW

This is the first phase of the proposed research work where different approaches of SCM have been studied from research journals published in last decade. It could be found that there are serious implementations associated with big data analytics or cloud in improving SCM processes. It has been found that there are work carried out in SCM for i) developing a decision-based framework for risk management, ii) incorporating security feature in individual processes in SCM, iii) cost-based study approach for identifying return-of-investment, iv) explicit monitoring based approaches towards specific events, v) agent-based approaches, etc.

The existing technique towards big data analytics has associated advantages with respect to various individual processes in SCM; however, it is also associated with limitations too as there is the large number of data origination points in SCM. The identified problems in the existing system are as follows viz. i) Majority of existing literature has not considered many cases from SCM sector. The data arriving from SCM sector is highly complex in comparison to other forms of bigger data. Such problems are less addressed in existing literature, ii) Existing system introduces big data analytics with more focus on applying mining operation and very less focus on performing the processing operation on the top of it. Majority of the processing is left of existing software frameworks, which already has reported pitfalls, and iii) There are no research attempts where the data before storing over cloud undergoes processing in order to eliminate problems. Moreover, there is the integrated system which offers mitigation procedure for data variety, data uncertainty, and data speed in existing literature. Existing literature has found to good evidence that SCM processes have been investigated towards disruptive innovation or towards the most frequently spoken industry 4.0 standards.

Hence, the problem statement of the proposed study can be stated as – "*It is a computationally challenging task to design an integrated framework that can handle the complexity of Big Data in SCM without mitigating the problems of data complexity and adherence to industry 4.0 automation standards*". Therefore, in order to improve the existing system, there is need of a novel mechanism as well as an architectural-based approach for redefining SCM for suiting the present and upcoming dynamic needs of consumers.

4. RESEARCH GAP

Following are the outcomes obtained after reviewing the existing approaches on Supply Chain management system

- *Subjective pros & cons*: At present, the majority of the existing research work towards SCM has both beneficial features as well as limiting features. The beneficial features include the development of advanced control mechanism, enhancing security system, incorporating green features, etc. The limiting features will include: i) the solution is offered to specific components or operation in SCM, ii) narrowed scope of involvement of advanced sensing technologies, iii) less number of validation on the collaborative framework. Finally, all these pros and cons are highly subjective to local scale of SCM deployment and almost null on the global scale.
- *Ignorance towards involving cyber-physical system*: Inclusion of cyber-physical system is one of the first steps towards the adoption of the futuristic automation system, e.g., industry 4.0. There are almost zero standard frameworks or model or any evidence of standard research manuscript to highlight the involvement of cloud in automating the sophisticated process of SCM. Until and unless, there is the presence of highly distributed cloud-based control algorithms, existing SCM cannot be molded for industry 4.0 automation standard.
- *An unexplored hidden challenge in data complexity*: In SCM, there are different forms and types of data being generated from different operations involved in it. With the inclusion of sensors and RFID over mobile networks, there is a generation of a specific form of data that offers the potential challenge in order to perform an advanced analytical operation on it. With the evolution of cloud, storage is never a problem, but potential challenge arises as such data of SCM cannot be stored in conventions storage centers. Such data are characterized by heterogeneity and ambiguity that poses an impediment towards applying any existing mining approaches. This area is completely unexplored.
- *No research towards disruptive innovation in SCM*: from the evolution of 1st industry implementation of SCM till now, there has been absolutely any research for

promoting disruptive innovation in SCM. A closer look into commercial market products and research centers shows that automated vehicles, drones, artificial intelligence, and Internet-of-Things are slowly gaining pace and could be positively assisting in creating disruptive innovation in SCM. However, these are very much infancy stage of research with the slow pace of improvement on the factors to give birth of disruptive innovation in SCM.

5. CONCLUSION

This paper presents a discussion of the existing state of SCM and attempt has been made to understand the current position of research work of SCM towards its effectiveness level. After reviewing the existing approaches, it is clear that there are very less number of relevant studies where problems associated with SCM system has been actually addressed. The existing system is more specific on solving problems related to a particular component of SCM and less on the overall process. This will mean more inclination towards local problems in the highly scattered way and very less to global problems. This results in non-applicability of any existing approaches towards molding SCM in the direction of industry 4.0 automation standard. After knowing the limitation and research gap, it is found that there is a need to design and develop a novel architecture where it is feasible for using SCM to incorporate every feature of industry 4.0 standards. Hence, the future research direction will be to evolve up with a novel architecture where the SCM internal processes will be integrated with all the novel components responsible for giving the shape of industry 4.0 automation standard.

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