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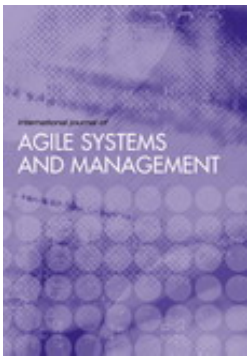

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Research agenda for supply chain management 4.0

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Research agenda for supply chain management 4.0

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Abstract: The purpose of this paper is to conduct a systematic review of the supply chain management 4.0 literature in the principal logistics and supply chain management journals, across an eight-year time frame. The selected journal papers are categorised on the basis of an analytical framework that contains keywords related to supply chain management and Industry 4.0. The systematic literature review indicates that supply chain issues from an industry 4.0 perspective are under-researched. Many technical issues are unexplained, and broader methodological factors as well as how the process can be managed in organisations are major gaps in the literature. Based on the literature review we argue that supply chain researchers need to understand the major developments taking place linked to Industry 4.0 and engage in research that fills the gaps.

Keywords: industry 4.0; supply chain; innovation; cybersecurity; readiness; sustainability.

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Australia (WA) Committee. He is also Supply Chain and Logistics Association of Australia (SCLAA) WA Committee. He has maintained a high quality of research throughout his academic career including international scholarly leadership in the areas of supply chain management and logistics, including being invited to be keynote speaker and to give public lectures at symposiums and international conferences in Indonesia, Malaysia, Vietnam, China, UK and Australia. From 2017 to now, published more than 46 refereed journal papers – including 23 papers in Q1-ranked in the SCImago and 22 papers in Q2-ranked in the SCImago, and 8 refereed conference papers. Furthermore, he has received research grants/awards adding up to over $1.85 million between 2010 and 2020.

Susan Standing completed her PhD in information systems at ECU in 2013 and was awarded the School medal for higher degree research. She has taught on a range of units at undergraduate and postgraduate levels and has been involved in research over many years. Research areas include: electronic marketplaces, innovation, e-health, and the sharing economy and transportation. She has published on these topics in A* and A ranked journals such as *Decision Support Systems, Industrial Marketing Management, Journal of Business and Industrial Marketing, Systems Research and Behavioral Science and Electronic Commerce Research*. She has also presented her work in leading international conferences in China, Singapore, Hungary and Malaysia. She has collaborated on international projects with researchers in Finland and the UK. Her recent work, on the sharing economy and transport trends, is funded by the Planning and Transport Research Centre (PATREC).

Prior to joining the School of Science in July2016, Naeem Janjua worked as a Post-Doctoral Fellow at UNSW Canberra and as a Research Associate at Curtin University. He received his MS in Information Technology from the National University of Science and Technology (NUST), Pakistan; and the PhD in Information Systems from Curtin University, Perth, Australia, in 2013. He has more than 5 years of experience in information system's design and development in various business environments. He is an Associate Editor for *International Journal of Computer System Science and Engineering (IJCSSE) and International Journal of Intelligent systems (IJEIS)*. He has published an authored book, a book chapter, and various papers in international journals and refereed conference proceedings. His areas of active research are knowledge representation and reasoning, enterprise knowledge management, cloud computing and IoT. He works actively in the domain of making informed business decisions (business intelligence) through the use of Web-based intelligent decision support systems.

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With research interests including national innovation strategies and the use of ICT to support organisational innovation, Craig Standing has also been the

recipient of ARC Linkage and Discovery grants and was a member of the ARC College of Experts between 2011 and 2013. He collaborates on research projects with members of the Centre for Innovative Practice and international academics from the UK, Denmark and Finland. Craig studied at Lancaster University, University of Manchester, and the University of Western Australia. He has published in the top 10 Information Systems journals and has presented at many international conferences. He has obtained significant research funds including the prestigious Australian Research Council Awards.

1 Introduction

Increased outsourcing of supply chain (SC) operations and use of digital technologies have facilitated global SC collaboration (Alaranta and Henningsson, 2008; Lambert and Cooper, 2000; Norta and Eshuis, 2010). However, the continuous drive towards lean business processes and efficient SCs have resulted in SCs becoming more vulnerable to operational risk, uncertainties and disruption (Daultani et al., 2015).

The role of accurate and timely information sharing, information quality, advanced digital technologies has become critical to overcome operational risks, uncertainties and disruptions, particularly in the manufacturing sector. The reason being, SC affects manufacturing companies in a variety of ways including the demand forecasting, inventory decision, production planning, scheduling/availability of raw materials/ components needed for production processes, determining costs and profitability of manufactured items, company infrastructure and ways in which companies interact with their stakeholders. To support these changes manufacturing companies have given critical attention to the use and sharing of information with trading partners with recent advancements in this direction (digital technologies) known as Industry 4.0.

Industry 4.0, referred to as the 'fourth industrial revolution', also known as 'smart manufacturing', encompasses the promise of a new industrial revolution – one that marries advanced manufacturing techniques with the internet of things (IoT) to create a digital manufacturing enterprise that is not only interconnected, but communicates, analyses, and uses information to further drive intelligent action back into the physical world (Gubbi et al., 2013; Jiang, 2017).

The design principles behind the concept of Industry 4.0 is to enable interoperability, virtualisation, decentralisation, realtime capability, service orientation and modularity (Hofmann and Rüsch, 2017). This involves employing Cyber-Physical systems (CPS), Internet of Things, Internet of Services, Internet of People and Internet of Energy as crucial building blocks, for example within Smart City design (Hermann et al., 2016). Some of the underlying protocols that enable these technologies include RFID in manufacturing (Lasi et al., 2014) and Internet (IP) for CPS interaction (Hermann et al., 2016) (Alippi, 2014). The vulnerabilities that exist in these protocols have been discussed in depth in the literature. Furthermore, there is a significant increased interest in the cyber security research domain with regard to discovering weaknesses in the underlying technologies and protocols that enable key building blocks (as previously mentioned) of Industry 4.0. Consequently, these vulnerabilities are inherited in the SCM4.0 technology ecosystem.

The philosophy of supply chain initially was developed in 1963, when the practitioners were exploring the inter-relationships between the transportation functions and warehousing that were involved in physical distribution management. In order to reduce the inventory level by integrating these two functions, which is faster, more frequent, and more reliable transportation. Response times were shortened, and the accuracy of forecasts increased with faster warehouse handling and faster transportation. Warehouse locations were also optimised, which improved overall cost and service. Improved data communication and analysing techniques can increase the ability to make complex decisions. In the presence of electronic data interchange, worldwide communications, growing availability of computers, electronic data, and computerised decision support systems, more functions are added: manufacturing procurement, order management functions, and the integration of chain functions.

Now and in the future, the next stages of SCM will incorporate more functions such as marketing, customer service, and product development. This will be achievable through more advanced communication, adoption of more user-friendly decision support systems, and availability of shared information to all participants in the supply chain. IT makes SCM a continual development as it makes it possible to have information more accurately and frequently from all over the world, as well as the continual discovery of tools to aid the analytical process making it possible to deal with the supply chain's growing complexity

Undoubtedly, Industry 4.0 developments will bring profound impact and changes to supply chain and logistics management (SCLM). We refer to SCM in the new era of Industry 4.0 as "SCM 4.0". In SCM 4.0, the digital and autonomous linkages within and between companies become a focal point of SCM. However, little research has been done to address this critical topic, holistic literature review combining SCLM and industry 4.0, categorisation of industry 4.0 in a SCLM context, conceptual framework on the relationship between industry 4.0 and SCLM dimensions and little is known overall about the supply chain and logistics management impact of Industry 4.0. Hence, Industry 4.0 is a special challenge for businesses and supply chain, logistics and transportation managers.

To close this gap and create a foundation of the current research state, we conducted a systematic literature review (SLR), and thus evaluated Industry 4.0 impacts and changes to supply chain and logistics management, developed a comprehensive SCM 4.0 framework, and paid special attention to future research opportunities.

The aim of this study is to conduct a systematic analysis of the implications of Industry 4.0 in the supply chain by examining literature published in peer reviewed journals and conference proceedings between 2013 and 2020. The analysis will identify the focus of the previous studies and suggest future research directions.

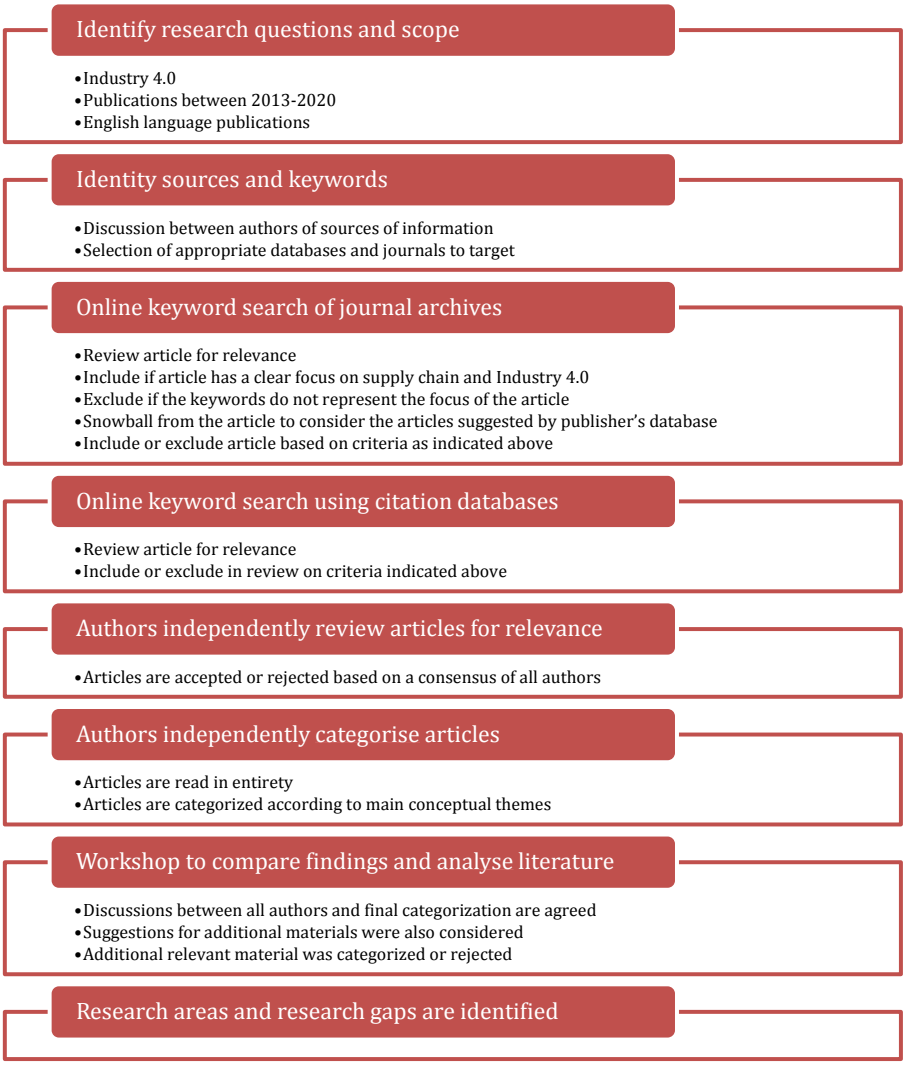
The remainder of the paper is organised as follows. The research methodology (including a conceptual framework) is described in Section 2. The study (SCM 4.0 themes) is presented in Section 3. The conclusion, contributions and limitation of study will be outlined in the last section.

2 Methodology

An in-depth evaluation of supply chain concepts and Industry 4.0 is conducted using a systematic literature review based on a systems approach (Levy, 2006). This approach

consists of sequential steps including collection, know, comprehend, application, analysis, synthesis, and evaluation and is a key method used to manage knowledge diversity for a specific academic inquiry and structuring a field of research. A flow diagram of the process of literature research is shown in Figure 1.

Figure 1 Literature review and analysis procedure (see online version for colours)



In brief, we considered the following to identify papers:

i The review covers only publications in the form of peer-reviewed journal papers and peer-reviewed conference papers. Other publications will be excluded from being reviewed.

ii Journals published only in the English language will be considered.

The review process involves searching with keywords related to supply chain and Industry 4.0 and delimiting the results to only peer-reviewed journal papers and conference papers published in the main bibliographic databases between 2013 and 2020. Textbooks, book chapters, periodical reports, trade reports, magazine, dissertations and any other working papers will be excluded. The major bibliographic databases used in searching the relevant papers will be Business Source Premier (EBSCO Host), Emerald Insight, Science Direct (Elsevier), Scopus, Springer Link and IEEE Xplore. These databases are selected because of their wide coverage of supply chain technologies, industry 4.0 and cyber security topics and business contexts.

Online searches of academic databases were made to identify papers that contained keywords in the title, abstract or keyword list. All the relevant papers were downloaded into the citation management software Endnote 8.0. The Endnote library was shared between the authors to facilitate collaboration and the review of the literature. The following section explains the scope of the review and the necessity to include expertise across academic disciplines in reviewing the literature. A detailed method for conducting the literature review is given and a summary of the online search results are given.

Figure 1 shows literature review and analysis procedure.

2.1 Scope

Industry 4.0 has been a topic of research interest since it was formally conceptualised in 2011. There is a need to investigate its impact on academic work to identify areas of research and research gaps in order to suggest a research agenda for both academics and practitioners.

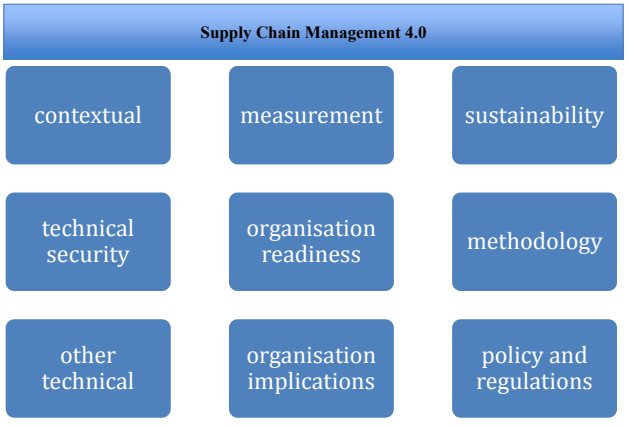
Industry 4.0 systems represent a convergence of organisational and operational systems that require strategic management and information communication technology. In the manufacturing sector robotics, artificial intelligence and 3D printing are changing the way goods are produced. Obtaining raw materials, manufacturing and delivering goods in changing production environments will continue to be a challenge. The supply chain is most efficient when management, organisational systems and information technology are integrated and focused on achieving strategic goals. In order to include recent, relevant literature in the area the time frame of the literature publication date was limited to 2013–2020. This allows for the most recent developments to be considered, accommodates the time lag between paper submission and publication (which can be significant), and acknowledges the foundational work cited in a paper. Many journals release papers online before they are published in hardcopy format, so the date extends beyond the present year (i.e., 2020). English language literature was the primary source of information.

2.2 A conceptual framework

Based on the comprehensive understanding of the systematics literature review from 2013 to 2020, we developed the conceptual framework of Supply Chain Management 4.0 (see Figure 2). This conceptual framework is useful to set an agenda for future avenues of research in Supply Chain Management 4.0.

There are 9 (nine) elements in Supply Chain Management 4.0: contextual; measurement; sustainability; methodology; organisation readiness; technical security; other technical, organisation implications and policy and regulations.

Figure 2 A conceptual framework (see online version for colours)



2.3 Expertise and sources of information

This research is a collaboration between authors from different academic disciplines, bringing together knowledge of computer science, artificial intelligence, machine learning, internet of things, (IoT), cyber security, strategic management, information systems, and supply chain and logistics management. Reviewing literature from these disciplines allows an integration of knowledge and provides a broader base from which to consider the impact of Industry 4.0 on the supply chain. The authors discussed the concept of industry 4.0 and the supply chain from these viewpoints and developed the research questions to explore the impact of industry 4.0 on the supply chain and identify research areas and gaps in the literature. Sources of literature for the review were online journals and academic databases. Online supply chain journals from the Australian Business Deans'Council (ABDC) list were the initial source of information providing a basis for the business and innovation aspects of Industry 4.0 and its relevance to supply chain management. After a relevant paper was identified in the journal, links to other papers suggested by the publisher's online database were investigated for significance. This occurred until the suggested references were repeated, inappropriate or no longer made. The search was expanded to the Scopus database and Google Scholar to include a wider range of literature from across more academic disciplines. Table 1 provides a summary of literature sources and search results. The authors have categorised the nine themes after analysing, synthesising and evaluating the literatures (127 papers).

The list of references for each theme above can be seen in Appendix 1.

3 Research agenda: SCM 4.0 themes

Although the literature on Industry 4.0 and the supply chain is growing it is, on the whole, an under researched area particularly when compared with the wealth of papers on Industry 4.0 alone. Effective supply chain management is critical to the operational and financial success of organisations and given that Industry 4.0 has obtained significant

attention both in the practitioner and academic communities we suggest that there is a dire need for further research on the implications of Industry 4.0 for SCM. Future research needs to be focused and concerned with addressing key problems and issues.

Table 1 Summary of literature sources and search results

Theme	*Description*	*Number of papers*
Contextual Factors	The implications of Industry 4.0 in the Supply Chain within certain contexts such as SMEs, particular industry sectors or countries	19
Measuring are the benefits of SCM 4.0	Methods to measure the benefits of SCM 4.0	10
Sustainability and SCM 4.0	Sustainability issues in SCM 4.0	8
Methodology	Methodology recommendations and frameworks related to implementing aspects of industry 4.0 in the supply chain	17
Organisational readiness for SCM 4.0	Frameworks to assess organisational readiness for SCM 4.0	6
Technical security	Technical security issues related to SCM 4.0	6
Technical – other	Technical issues related to SCM 4.0	11
Organisational implications	Organisational implications of SCM 4.0 including risk management and human resource implications	47
SCM 4.0 Policy and Regulation	Policies and regulations related to SCM 4.0	5
Total		127

Drawing upon the literature gathered for the systematic review we have identified a research agenda to guide future research work. This classification of research agenda items results from analysing the recommendations and suggestions for future research in the papers that met the criteria for inclusion in our sample frame.

3.1 Organisation readiness

Few of the papers written on SCM 4.0 examine the needs and requirements of organisations. It is unclear from the literature just how ready organisations are to embrace SCM 4.0 or the size of the task facing them. SCM 4.0 readiness studies need to be conducted that identify the barriers and challenges in implementing industry 4.0 principles in the supply chain. In recent study, the organisations should identify gaps related to skills required for Industry 4.0. Readiness studies also provide organisations with a map of where they are positioned on the implementation journey and what they need to do to move along the implementation continuum.

Readiness studies can examine a range of issues, including technical, skills and managerial factors and provide insights into the differences in readiness between countries, industry sectors and firm size.

3.2 Technical security and other technical issues

Industry 4.0 is largely underpinned by technological developments. Yet many of these technologies are still developing and not available in integrated solutions. The integration of technologies often requires the development of interfaces and systems to exchange data, analyse data, and maintain security. In addition, SCM 4.0 has several characteristics (in terms of technical issues/challenges), they are (Vogel-Heuser and Hess, 2018) : service orientation based on Cyber Physical Systems (CPS) and the internet of services; CPS and multi-agent systems making decentralised decisions; interoperability between machine and human and virtualisation of all resources; ability to flexible adaptation to changing requirements (cross-disciplinary modularity); Big data algorithm and technologies provided in real-time (real-time capability); optimisation of processes due to flexible automation; data integration cross disciplines and along the life cycle; and access to data securely stored in a cloud or distributed data storage (e.g., blockchain).

As Atasevena and Nairb (2017) revealed, supplier integration has a higher impact on performance in a broader sense compared to customer integration and internal integration. However, they have recommended that internal organisational processes to be aligned through integration before external integration (i.e., supplier integration for information sharing and collaboration) is considered.

Decision makers should consider the significant importance of information processing during supply chain integration to mitigate risks due to environmental uncertainty. SCRM has evolved over the years, following the seminal works by Kogut and Kulatilaka (1994) and Huchzermeier and Cohen (1996). According to the most significant literature produced within the SCRM field between 1994 and 2010 (Colicchia and Strozzi, 2012), a reactive risk management approach has been considered in the early years to address uncertain future events exposed to a single organisation. Significant natural disasters and the grim reality of terrorism (post World Trade Centre bombing in September 11, 2001) has shifted risk management to more proactive approach in later years towards considering disruption risks in addition to traditional operational risks (Kleindorfer and Saad, 2005), and across supply chain partners of multiple organisations consequent to globalisation. This is followed by broadening the view of addressing risk exposure due to supply chain vulnerabilities (cited from Trkman and McCormack (2009) and (Oehmen et al., 2009) caused by increasing complexity of networks of supply chains.

While this proactive risk mitigation is preferred in SCRM (Colicchia and Strozzi, 2012), there may be a need to rethink and revisit reactive risk mitigation approaches. As industry and context has evolved consequent to Industry 4.0, the challenges posed are different.

Thus, today we need to re-address the growing risks exposed in cyber due to heterogeneous integration of technologies and systems. We need to re-think the SCRM strategies.

A supply chain (SC) chain is the network of all the individuals, organisations, resources, activities and technology involved in the creation and sale of a product, from the delivery of source materials from the supplier to the manufacturer, through to its eventual delivery to the end user (Dong et al., 2014; Dudek, 2013). Today, SCs are characterised by increasing dynamicity which arises from the trends of the global economy, political situations, distribution of transport services and individual customer demands (Spekman and Davis, 2016). Additionally, the continuous drive towards lean business processes and efficient SCs have resulted in SCs becoming more complex and

vulnerable to operational disruptions. Managing operational disruptions is important as they have a significant impact on operational factors such as quality, delivery and cost of a service delivery (Spekman and Davis, 2016).

Supply chain visibility (SCV) refers to an ability of SC trading partner to collect and analyse distributed data, analyse and generate specific recommendations, and match insights to strategy. It can be decomposed into inventory, demand, and logistics visibility based on the information available and is important for SC management. Several SC collaboration practices, such as the Vendor Managed Inventory, Just In Time, Efficient Consumer Response, Continuous Replenishment and Accurate Response, Collaborative Planning, Forecasting and Replenishment (CPFR) that have been suggested in the literature focus on better planning through tight processes integration and sharing the forecasting information among the SC trading partners (Sheffi, 2002). However, modifications to the customer orders (at the customer's request), resource unavailability's from suppliers and machine breakdown all drive the system away from any existing predictive schedule. Additionally, in these approaches, databases and data warehouses were designed to store, query and manipulate static data concerned with looking at what happened in the past and try to predict the future.

Information technology (IT) has enabled suppliers, manufacturers, logistics service providers and retailers to benefit from SCV gained by digitising their businesses. Internet of Things (IoT), a new IT revolution, provides a paradigm shift in getting SCV. It is a novel concept that results from the connection of physical objects to the software systems with help of sensors and actuators giving rise to IoT enabled SC. The data emitted from sensors is collected and analysed in real-time by a specialised software known as complex event processing (CEP) engines (Bearzotti et al., 2012; Bodendorf and Zimmermann, 2005; Vlahakis et al., 2018). The CEP is enabling technology for industry 4.0, smart logistics, smart cities, smart manufacturing, smart grid, building and home automation, and wearables, healthcare etc. (Aniello et al., 2011; Bonino et al., 2015; Naqishbandi et al., 2015). It comprises of various sensors (sources) and actuators (sinks) technologies connected by wired and wireless sensor networks to the computing systems.

CEP is concerned with the detection of real-time complex events that are of a particular business interest. A complex event can be perceived as a composition of various simpler events (e.g., sensor readings, elementary changes, updates etc.) that happens satisfying different temporal, and causal relationships to be notified to sink, which act as event consumer that may trigger time-critical actions or support the planners in decision making process. The current state of the art CEP engines are designed to deal with the specific problem of defining new (higher level) events starting from primitive events (raw data) and doesn't provide support to integration of events coming from different heterogeneous sources. As a result, the complex events coded and detected by current CEP engines are not expressive enough to capture and reason with complex situations such as situation awareness where time-critical actions are not only triggered by an individual event, but rather events also coming from different sources, integrated through additional contextual knowledge to infer new pieces of knowledge to detect and classify a situation of interest. To overcome the issue of information heterogeneity, CEP researchers need to step back and learn from another stream of research in Artificial Intelligence known as the Semantic Web (Margara et al., 2014).

The Semantic Web research focuses on how meaning can be attached to the data so that data can be understood, shared, reasoned and integrated by machines without human intervention (Janjua and Hussain, 2012). Use of semantics in CEP means annotating sensor events streams with contextual knowledge, thus serves as a meta-data to linkages between distributed events streams (Margara et al., 2014). Contextual knowledge is critical to correctly interpret the distributed events information that could otherwise be interpreted in a number of ways by a CEP engine. The modelled and codified contextual knowledge for a certain domain is known as ontology (Janjua, 2014). Ontologies are the core of the Semantic Web and provide a formal and explicit specification of a certain domain. They use a combination of classes, and their relationships or properties, instances and axioms are defined in some formal language. The W3C has proposed two ontology languages for representing knowledge on the Semantic Web. The first one is RDFS, based on XML and logic programming, which is a lightweight ontology language. The second language is OWL, which is based upon description logic and provides constructs for cardinality restrictions, Boolean expressions and restrictions on properties. OWL ontologies come in three species: Lite, DL, and Full, ordered in increasing expressivity.

Thereby, CEP engine using ontologies can reason with various annotated sensors events streams to deduce new or implicit knowledge, discover significant (and erroneous) events/situations and answer complex queries.

3.3 Contextual issues

Further research is needed on how SCM 4.0 will impact in sectors outside of manufacturing and in small and medium enterprises. What is possible or desirable is likely to be mediated by the context and so further research is needed to shed light on the differences in requirements that stem from the context. Moeuf et al. (2017) argue that SMEs often lack the resources to effectively adopt new frameworks such as Industry 4.0 and that SMEs typically need a lot of convincing about whether the benefits will outweigh the costs. There is little research that examines Industry 4.0 in relation to the service sector (Shamim et al., 2017). The service sector is facing many pressures and many of the concepts driving industry 4.0 are highly relevant. Supply chain processes interweave products and services and so Indutsry 4.0 needs to take the integration of products and services into account. Many service sectors sare aiming for real-time service delivery through automation and digitisation but service sectors lacks guidance from an Industry 4.0 perspective.

In term of contextual issue, the recent study has researched to address these issues providing knowledge and frameworks for guiding the formulation of digital transformation strategies and for enabling transparency across supply chains through the integration of Internet of Things, IoT, and translating it into actual business value (Colli, 2020).

3.4 Methodological issues

Industry needs guidance on how to implement SCM 4.0 and its components. This can take the form of methodologies and techniques that can help decision making related to what needs to be implemented, where and when. Industry 4.0 is a high level framework and what is lacking are methods to support the transition process. A Deloitte (2018)

survey of executives found that they understand the changes associated with Industry 4.0 but are uncertain about how to go about achieving the benefits. In other words, there is a conceptual gap in relation to implementing the high level changes that are forecast. Industry 4.0 methodologies should include strategic planning approaches so that organisations can be guided in developing a plan for the future. There is also a need for more specific methodologies that steer the development and implementation of technologies.

Recent studies, the research methods being used to examine the SCM 4.0 using a survey on control theory applications to operational systems; and benchmarking healthcare supply chain by implementing industry 4.0 using a fuzzy-AHP DEMATEL.

3.5 Measuring the benefits and the business case for SCM 4.0

A number of papers express that the benefits of SCM 4.0 need to be clear before organisations will go down that path. Hence, studies are required that measure and evaluate the benefits of SCM 4.0 and that provide a financial and non-financial business case for adoption.

An Industry 4.0 readiness assessment tool by Warwick University (WMG, 2018) uses a measurement scale that includes: key performance indicators that are unaligned with Industry 4.0 to business metrics that are centered around Industry 4.0 objectives. Financial investment is examined from the perspective of breadth of investment such as Industry 4.0 investment in one business area, multiple areas or across the entire business. A KPMG report (KPMG, 2017) on Industry 4.0 stresses the importance of measuring the benefits in relation to the cost of goods, order lead times and inventory levels.

Performance measurement is a management tool aimed at improving a company's performance (Bititci et al., 2012). It is "… a process of collecting, computing and presenting quantified constructs for the managerial purposes of …monitoring, improving organisational performance…" (Elg and Kollberg, 2009, p.410) and comparing with desired level of performance for effective control and follow up (Melnyk et al., 2014, p.173). It can provide decision making framework and tools supporting delivery of strategically aligned goals (Moreira and Tjahjono, 2016, p.2345; Laihonen and Pekkola, 2016, p.560). As stated in (Ferreira et al., 2012, p.673) to be successful, supply chain partners need to continuously monitor and evaluate each other's performance.

Supply chain performance measurement systems (SCPMS) is defined as "...a set of metrics used to quantify the efficiency and effectiveness of supply chain processes and relationships spanning multiple organisations…" (Maestrini et al., 2017, p.301; Maestrini et al., 2018 (a), p.934). It has potential to facilitate inter-organisational collaboration, improve communication between SC partners enhancing understanding of joint targets (Aki and Otto, 2018). The research in SCPM has potential to improve SC performance.

There has been an increased call for further research on SCPMS (Bititci et al., 2012). The improving access to technology supporting performance measurement and monitoring is also behind the recent increased research interest in this area as stated in Maestrini et al. (2017). Among others, a sample of some of the recent publications in SCPM or PMS in supply chain management is summarised in Table 2.

Table 2 Previous studies on SCPMS

Author/year	*Description*
Chalyvidis et al. (2013)	Using Supply Chain Interoperability to measure of Supply Chain Performance
Cunha et al. (2017)	To understand the influence of Supply Chain Governance on Supply Chain Performance
Jamal et al. (2017)	Internet of Things (IoT) and its potential impact on Supply Chain Performance Measurement
Laihonen and Pekkola (2016)	To examine the effectiveness of supply chain performance measurement systems: a case study
Maestrini et al. (2017)	Supply chain performance measurement systems: A systematic review and research agenda
Maestrini et al. (2018a)	To measure supply chain performance using a lifecycle framework and a case study
Melnyk et al. (2014)	Current state and future direction of Performance measurement and management
Mishra et al. (2017)	Green supply chain performance measures: A review and bibliometric analysis
Moreira and Tjahjono (2016)	To measure performance systems in order to support decision making in supply chain at beverage industry as a case study
Dalenogare et al. (2018)	This research contributes by discussing the real expectations on the future performance of the industry when implementing new technologies, providing a background to advance in the research on real benefits of the industry 4.0

According to Maestrini et al. (2017, p.301) supply chain performance measurement systems can be split into:

- Supplier performance measurement systems which are focused on the upstream side of a SC. They target the supplier- buyer dyad.
- Operational performance measurement (internal performance system focused on intra organisational performance).
- Customer performance measurement system (external and downstream focused).

Most existing literature on performance measurement is focused on intra firm performance (operational performance measurement systems) than inter firm. However, in the recent past there has been a shift resulting is increased interest on inter firm performance measurement systems (also known as SCPMS) (Aki and Otto, 2018; Maestrini et al., 2018a; Hald and Ellegaard, 2011).

A significant portion of the literature on SCPMS is concentrated on supplier performance measurement systems (SPMS). However, a significant gap still exists within Supplier performance measurement systems hence the call for further research on these (Maestrini et al., 2017). The proposed research is therefore partly a response to this call. It will consequently contribute towards filling this gap by aiming to contribute to the understanding of supplier performance measurement systems. Supplier performance measurement system are discussed further in the following section.

Maestrini et al. (2018b) stated that companies (buyers) are increasingly dependent on their suppliers for value creation, thence the criticality of measuring and monitoring performance upstream of the supply chain. This is the role played by supplier performance measurement systems.

Supplier performance measurement systems are defined as a "…set of metrics measuring the efficiency and effectiveness of suppliers' actions and the goodness of the relationship with them" (Hald and Ellegaard, 2011, p.890; Maestrini et al., 2017, p.301). Their main use is to support decision making by the buyer (Hald and Ellegaard, 2011). They are used by a buyer to identify and select the best suppliers, monitor their performance and support continuous improvement (Luzzini et al., 2014).

The view that these SPMS support continuous improvement is premised on the understanding that buyers communicate results of these performance measurement systems suppliers. This would allow the supplier to better meet the buyer expectations and therefore improve performance. In fact, Maestrini et al. (2018 (b)) stated that it is not enough to measure the right thing, but rather it is important to use the results of these to motivate for improved performance. In the agribusiness SC, there is poor information flow from buyers to suppliers, in fact there is no transparency across the supply chain (MLA, 2017). It is therefore questionable whether suppliers in general and specifically in Industry 4.0 benefit from these performance measurement systems.

Maestrini et al. (2018a) stated that most existing research on inter firm performance measurement systems are focused on the views of a single company (the buyer) neglecting other supply chain participants such as the suppliers. This is a gap that the proposed research aims to contribute to. This will be achieved by concentrating on the views of both suppliers and the buyers.

Aki and Otto (2018) state that there is no clarity in the role of SPMS in supporting purchaser-supplier collaboration. While Chalyvidis et al. (2013) stated that successful implementation of supply chain collaboration is restricted by inadequate SCPMS. By extension, supplier- buyer collaboration is impacted by poor supplier performance measurement systems. Unsymmetrical power between buyer and supplier also inhibiting collaboration (Hingley et al., 2015).

Performance measurement can be viewed from "…life cycle perspective including design, implementation, use and review." (Aki and Otto, 2018, p.121). Most research on SPMS is focus on the design (such as metrics to use), with some research on implementation whilst the review and use aspects have been poorly investigated (Maestrini et al., 2018b).

There is a substantial number of publications on different aspects of SPMS to date. Some of the recent (past 4 years) publications are listed in Table 3.

3.6 Organisational implications

A number of papers express that the organisation impact and human resources skills on supply chain in general. Hence, studies are required that investigate supply chain competencies either functional, relational, managerial or behavioural. In addition, further study is needed to develop, understand, assess the frameworks, business models, reference models and maturity models for industry 4.0 implementation with focus on technology, people and processes.

Table 3 Previous studies on supplier performance measurement

Author/year	*Description*
Dey et al. (2015)	Strategic supplier performance evaluation at UK manufacturing organisation using case study approach
Ming-Chang et al. (2014)	Reexamining supply chain integration and the supplier's performance relationships under uncertainty
Aki and Otto (2018)	Prerequisites for performance measurement supporting purchaser-supplier collaboration
Maestrini et al. (2018b)	The impact of supplier performance measurement systems on overall business performance
Luzzini et al. (2014)	To design vendor or suppliers' evaluation systems based on empirical approach

Moreover, it is essential that the study may focus on how to develop the skills, capabilities and competencies required for Supply Chain Management 4.0. One of the success factors in organisation is driven by the capabilities and competencies of its manager or leader in this specific area. They represent a unique discipline responsible for supporting the global network of delivering products and services across the entire supply chain, from raw materials to end customers. Armstrong (1998) suggests that competency describes what people need to be able to do to perform their jobs well. The competency is defined as a demonstrated ability including knowledge, skills, and attitudes to perform a task successfully according to the standards (Porasmaa and Kotonen, 2010). While Hitt et al. defined competency as a combination of resources and capabilities within an organisation (Hitt, 2011; Hitt et al., 2007). In other words, competencies refer to skills or knowledge that leads to superior performance (Richey et al., 2007). These are formed through an individual/organisation's knowledge, skills and abilities and provide a framework for distinguishing between poor performances through to exceptional performance.

As above mentioned, therefore further study is needed to develop and assess the determinants of competency for supply chain managers in the context of Industry 4.0. According to the literature, there are several determinants of competency below:

1 *Leadership*: is a process of social influence in which one person can enlist the aid and support of others in the accomplishment of a common task. Leadership is organising a group of people to achieve a common goal (Daud et al., 2011). Leadership has three attributes – formalisation, flexibility and measurement (Bowersox and Daughtery, 1992).

2 *People management*: people management encompasses the tasks of recruitment, management, and providing ongoing support and direction for the employees of an organisation (Chun and Yanping, 2006).

3 *Teamwork and communication*: teamwork and communication is a taken-for- granted human activity that is recognised as important once it has failed (Schulz, 2008). This includes coordinating with others

4 Change management is an ability of transitioning individuals, teams and organisations to a desired future state.

5 *Negotiation*: is a systematic coordination of all aspects of the procurement process. Including bids, price negotiations, assuring proper quantities and specifications, shipping and delivery (Simanjuntak, 2007).

6 *Project management*: a wide range of industry sectors now make use of projects and see the effective delivery of projects as a key driver in their organisational performance (Shepherd and Atkinson, 2011).

7 Transportation and distribution management is related to the responsibility for managing the flow of goods, information and people between a point of origin and a point of consumption in order to meet the requirements of consumers (Chow, 1998)

8 *Analytical*: is the ability to visualise, articulate, and solve both complex and uncomplicated problems, understand concepts, creativity and make judgement and decisions based on available information.

9 Managing results focuses on results in every aspect of management.

10 *Continuous improvement*: is an ongoing effort to change the quality of products or services.

11 *Creating and maintaining corporate social responsibility (CSR)*: describes as commitment of business to contribute to sustainable economic development working with employees, their families, the local community, and society at large to improve their quality of life, in ways that are both good for business and good for societal development. (Ciliberti et al., 2008)

12 *Cultural awareness*: is an ability to understand and admit the key cultural differences in various areas, such as: communication and cognitive flexibility styles, concepts of time and punctuality, negotiation strategies, and behavioural differences (Lynch, 2012). Some others aspects include emotional intelligence and service orientation.

13 Hardware and software knowledge is the ability to operate hardware and software related to the specific activity – creating and editing documents, spreadsheets, graphic, internet, etc.

14 *Information handling knowledge*: is the organisation of and control over the planning, structure and organisation, controlling, processing, evaluating and reporting of information activities in order to meet client objectives and to enable corporate functions in the delivery of goods and services (Apics, 2009; Gammelgaard and Larson, 2001).

Recent study by Ivanov and Dolgui (2021), this research is about to design and implementation of the digital twins when managing disruption risks in SCs. The results of this study contribute to the research and practice of SC risk management by enhancing predictive and reactive decisions to utilise the advantages of SC visualisation, historical disruption data analysis, and real-time disruption data and ensure end-to-end visibility and business continuity in global companies.

3.7 Sustainability issues

Existing research on Industry 4.0 does not cover sustainability parameter. Future research is to provide a set of propositions regarding which behavioural factors contribute to the

intention and decision to implement sustainable supply chain management (SSCM) 4.0. Sustainable supply chain management (SSCM) is defined as the set of managerial practices that involves the flow of information and capitals among organisations along the supply chain, considering economic, environmental and social requirements in all stages of the chain including product-lifecycle. Partner's cooperation is essential to achieve the intended level of economic, environmental and social requirements, to enhance competitiveness and comply with customer's demands (Gupta, 2011; Linton et al., 2007; Seuring, 2008).

By using a behavioural theory to predict the implementation of the environmentally sustainable innovation, the foundation of the future research is that SSCM implementation is determined largely by the organisation's intention to implement SSCM. Likewise, the future study will propose that there are several antecedents which affect managerial intention within an organisation in implementing SSCM. There are many factors, both internally and externally, which may influence the organisational intentions and decisions. Thus, the future research will focus on factors which may influence organisational intention towards implementing SSCM.

In order to establish relevant proposition, the future research is able to look at the definition and the background of the selected behavioural theory, the theory of planned behaviour (Ajzen, 1988, 1991; Ajzen and Fishbein, 1980; Ajzen and Madden, 1986; Madden et al., 1992; Montano, 2008). Secondly, the definition and components of sustainable supply chain management will be examined. The topic of sustainable supply chain has been growing among scholars in the past decade, however not many research utilise the theory of planned behaviour. This paper will conclude with the proposition and the agenda for future research on the implementation of sustainable supply chain management 4.0.

Recent study by Li et al. (2020), this research is to explore how digital technologies influence economic and environmental performance in the new era of Industry 4.0. The results indicate that digital supply chain platforms mediate the effects of digital technologies on both economic and environmental performance and that the mediating effects are enhanced under a high degree of environmental dynamism.

3.8 SCM 4.0 policy and regulation

Existing research on supply chain management policy and regulation are limited. Future research is to examine the role of policy and regulation in particular country to support the effectiveness and efficiency of supply chain management 4.0 (in particular Worksafe regulation). The emergence of the Industry Internet of Things (IIoT) promoted new challenges in logistic and supply chain policy and regulation.

In terms of transportation and freight logistics future research, with the new analytical tool, together with improved transport data, will allow researchers to consider future research better planning and investment decisions, and inform changes to transport policy settings. In addition, it will allow to improve the use of targeted government policy levers and regulation where appropriate.

In order to pursue eco-friendliness, which is one target of Industry 4.0, the recent research conducted by Ma et al. (2020), the research is to examine the coordination mechanism in a three-echelon cold supply chain including supplier, TPLSP, and retailer under cap-and-trade regulation.

For Australian perspective, with Industry 4.0, the future research will allow to identify the trend data which indicates whether policy/regulation changes, infrastructure and investment decisions or major technology initiatives. That is, researchers need to be able to measure the impact of trend of Industry 4.0, investments or changes in policy as we implement the National freight and supply chain strategy.

4 Conclusion, contributions and limitation of study

This paper has the aim of reviewing the literature on supply chain and logistics management and Industry 4.0. The convergence of technologies and the need for frameworks to guide organisations has promoted the use of Industry 4.0 as a roadmap for the future research. While, the supply chain and logistics management literature is growing, the systematic literature review (SLR) found the supply chain to be an under researched area in relation to Industry 4.0 which is surprising considering the importance of supply chain developments to the economy. The results of the SLR highlight a range of technical issues (i.e., cyber security, Internet of Things, artificial intelligence/machine learning, sensor/robotics, supply chain analytics/big data), sustainability that need further research as well as methodological guidance on how supply chains can transition to the Industry 4.0 paradigm.

The results of this paper can assist researchers and practitioners to better understand supply chain and industry 4.0 and also helps to identify a research agenda. It identifies key issues in SCM 4.0 research and calls for future research. Calls for future research include supply chain cyber security, supply chain digitalisation and transformation, supply chain recovery and resilience, supply chain 4.0 policy and regulations, sustainability supply chain 4.0.

Setting a research agenda for SCM 4.0 will help researchers and practitioners research focus on critical issues surrounding supply chain and industry 4.0 (contextual, measurement, sustainability, organisation readiness, methodology, technical security, other technical, organisation implications, policy and regulations).

The systematic literature review for SCM 4.0 sets a research agenda and calls for future empirical testing. Practitioners will benefit from the conceptual framework presented here by better understanding approaches to SCM 4.0 particularly in readiness, contextualisation, implications, sustainability, policy and regulations. In addition, practitioners can use our findings to guide industry 4.0 investment decisions.

In the final section, we discuss the paper's limitations. First, this paper is systematic literature review (SLR). The findings depend on the inclusion criteria applied and databases leveraged. We collected the published papers from 2013 to 2020. The published papers are written in English. We excluded the textbooks, book chapters, periodical reports, trade reports, magazine, dissertations and any other working papers. The major bibliographic databases used in searching the relevant papers are only limited to Business Source Premier (EBSCO Host), Emerald Insight, Science Direct (Elsevier), Scopus, Springer Link and IEEE Xplore.

Although we believe that we detected all relevant contributions, it is still possible that some studies may have been missed. However, we are convinced that additional papers would not undermine this study's clear results.

Second, since this paper is SLR, we did not test the relationships' strengths from the conceptual framework in this study. Nevertheless, the current framework covers all

dimensions for future research opportunities. We therefore call for empirical validation/ verification.

Third, this paper did not consider the impact of Industry 4.0 on supply chain risk, uncertainties (particularly during and post COVID-19).

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Appendix 1

Contextual Factors

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