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Digital Supply Chain: Literature review and a proposed framework for future research

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ABSTRACT

Suppliers, partners, companies and dealers in supply chains do use, generate and share information with others. These associations lead to a multitude of challenges and opportunities within the supply chains. A Digital Supply Chain (DSC) is a smart, value-driven, efficient process to generate new forms of revenue and business value for organizations and to leverage new approaches with novel technological and analytical methods DSC is not about whether goods and services are digital or physical, it is about the way how supply chain processes are managed with a wide variety of innovative technologies, e.g. unmanned aerial vehicles, cloud computing, and internet of things, among others. Recent literature highlights the importance of DSC and many industrial researchers discuss its applications. This article reviews the state-of-the-art of existing DSC literature in detail from both academic and industrial points of view. It identifies key limitations and prospects in DSC, summarizes prior research and identifies knowledge gaps by providing advantages, weaknesses and limitations of individual methods The article also aims at providing a development framework as a roadmap for future research and practice.

1. Introduction

Digital technologies have profoundly altered the way people communicate and interact with their surroundings. Technological novelties and personal gadgets, such as mobile devices, personal computers, self-driving cars, drones, advanced television units, wearable devices, smartphones and smartwatches change the way how societies access and exchange information. These emerging new technologies affect every industry. Supply chains and logistics services are no exception. Nevertheless, many operations for producing and delivering goods or services to customers are being carried out independently in current organizational structures. Conventional supply chains consist of physical facilities scattered geographically to help establish and maintain transportation links among them. Supply chains can be defined as a series of interconnected activities that involve the coordination, planning and controlling of products and services between suppliers and customers. Many of these organizational structures are no longer self-sufficient due to technological developments. Digitalization has touched almost each and every aspect of human life all over the world, greatly affecting supply chain processes. According to market forecasts [1], 76% of global population have now access to internet with half of them actively using social media. Moreover, nine out of ten internet users make online purchases, 43% of companies make use of sophisticated big data analytics. Cloud storage is projected to hold about 37% of all generated data by 2020. In the same time horizon, 26 billion internet-connected "things" are expected to become operational. Digitalization has a disruptive transformation effect across industries, generating value and network effects. One day, people may even be able to dispatch fleets of vehicles with a simple handheld device. It may be possible to find out the contents of a cargo container with just a brief electronic glance. Before long, wearable computers on sleeves could be available. With possibilities abound, organizations become more aware of these potential developments and emphasize how DSC can add value to firms. Considering that the primary focus of organizations is to keep and strengthen their core competences in a competitive market, modern organizations should interact with their dealers through DSC processes for the production and delivery operations of their goods and services.

The DSC is in its infant steps, and the most of its potential for value creation remains unclaimed. Nonetheless, it has set supply chains and the logistics industry into a rapid change and a novel innovation path. In today's emerging digital model, data centers replace physical warehouses, bits replace the physical boxes,

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bandwidth replaces the physical trucks. There are shifts in channel management from conventional distribution centers to retailer services to broadband providers, to online, and directly to the customers. Within the DSC, there are many innovations, e.g. Augmented Reality (AR), Big Data (BD), Cloud Computing (CC), Robotics (R), Sensor Technology (ST), Omni Channel (OC), Internet of Things (IoT), Self-Driving Vehicles (SDV), Unmanned Aerial Vehicle (UAV), Nanotechnology (N) and 3D Printing (3DP), to name a few. Recent literature highlights the importance of DSC and many industrial researchers discuss its applications. Determining all potential benefits of different DSC implementations is a tedious task, as most of the benefit is not derived from the DSC itself but from the numerous solutions that arise from DSC implementations. Integration of DSC can provide various benefits to supply chains and logistics, which are addressed throughout this paper. The paper reviews the state-of-the-art within the context of DSC and introduces a framework proposition. It summarizes the past studies on the subject by critically consolidating and examining contributions of prior research. It starts with a discussion of the DSC literature to capture the conceptual and theoretical state of research to identify knowledge gaps in the literature, including the similarities and differences between the components of digitalization and their relation to the DSC. Our original contribution to DSC literature stems from our analysis of advantages, weaknesses and limitations of the published methodologies. The review also reflects the implications and inferences of DSC, challenges and success factors with a managerial perspective. The study presents a framework by synthesizing past knowledge, identifying important biases for the further development of DSC to help academics and practitioners in organizing, conceptualizing and conducting their research on DSC in the future.

The identification, realization and assessment of DSC requires a framework to build upon. Many benefits of digitalization in supply chains are still untapped, because crucial organizational transformations and their management are often neglected or postponed. Academic and industrial researchers have suggested several types of approaches to evaluate potential DSC possibilities, but little research has been conducted so far on how to construct a complete conceptual or theoretical DSC framework. In this paper, we intend to fill this research gap.

This literature review attempts to answer the question of 'How to integrate the existing importance of digitalization into supply chain or logistics?' The answer to this question involves the development of a framework that can be used in the identification, realization and assessment of benefits DSC can bring about. These discussions also include the similarities and distinctions of components and their relation to the problem statement, implications and inferences of DSC technologies, challenges and success factors. The section on managerial implications will separately discuss these overlapping issues and differences.

The study discusses the benefits of DSC transformation to guide researchers and industry experts in organizing, conceptualizing, and conducting their research on DSC of the future. Instead of presenting empirical results, the outcome of this extensive review aims to present a foundation for further research in this field. In this context, this study offers a development framework to capture, present and relate the digitalization in the supply chains. The main task of implementing and verifying DSC is to identify its critical stages, which is not only essential for supply chains to manage and function better (such as to fully transformed DSC), but is also functional or essential for a typical supply chain to catch the transformation path for DSC.

This article is organized as follows: the following section reviews and categorizes related publications (e.g. journal articles, theses, industrial reports, etc.) and explains the methodology adopted in this literature review. The third section discusses the concept of DSC, its definition, features and components to build a conceptual framework that is derived from existing literature. The fourth section describes the advantages and challenges of digitalization for supply chains and logistics. A DSC framework for development is constructed in the fifth section. The sixth section presents the managerial implications to discuss the limitations as well as possible directions for DSC. The final section contains the article's concluding remarks.

2. Review of literature on DSC

This review of journal articles and industrial reports is based on a classification methodology, which presents how the literature is approached as a basis for the conceptual and theoretical framework. First, the classification used in this literature review is explained and then the methodology of the literature review is introduced.

2.1. Method of study

Relevant publications are located with the help of a detailed online search with the objective to collect, organize, and synthesize existing DSC knowledge. Identified papers span several types of interrelated disciplines including marketing, management, operations management, management science, industrial engineering, and supply chain management. Due to the lack of precise key words defining the topic, we put substantial effort to sort academic and industrial journals by reviewing their titles, abstracts and manuscripts in the traditional and electronic library systems. Usually, this step can be carried out by targeting prominent journals and conferences. This is not the case for DSC since this recent phenomenon has emerged only a few years ago and related publication channels are still scattered. Using search queries in online databases is today the dominant method of identifying the most relevant papers. It is more practical and appropriate to focus on online databases rather than reviewing library collections for a literature review on DSC. Therefore, the following major online databases were targeted for the past six years: Elsevier's Scopus, Thomson Reuter's Web of Science, IEEE Xplore, ProQuest (ABI/INFORM), and ScienceDirect (Elsevier). This search indicated that the concept of DSC is still in its early years of research and development among academics, while it is widely recognized and discussed among practitioners. To include industrial reports, Google search engine is also used for a wider reach-out.

In this study, we review and classify relevant studies to gain insight on DSC. The overall review methodology for DSC papers is graphically presented in Fig. 1. Fig. 2 illustrates the significant findings by presenting a detailed summary in terms of types of DSC publication and its enablers. The literature sources are investigated in scientific databases and regular search engines which include books, peer and non-peer reviewed papers, industrial reports and white papers. The keywords were not predetermined before the search but they have gradually emerged during the extensive reading process that took place while drafting this study. The nomenclature lists the non-exhaustive keywords which is completed with the mentioned keywords and terms. Accordingly, this research captures the trends in the DSC literature by examining published academic articles and industrial reports, including DSC technologies, in order ensure that these papers are sufficiently investigated based on the year of publication, subject, objective or method. Considering the nature of DCS, however, it is quite a challenge to confine studies into specific categories. Considering this fragmented structure, the search in major databases is supported with Google Scholar search engine queries

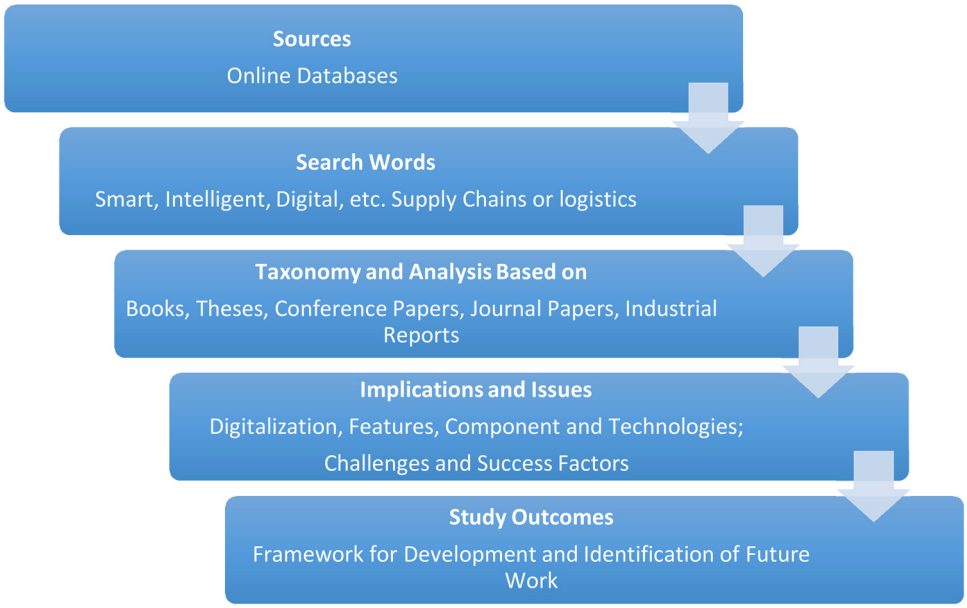

Fig. 1. Review Methodology.

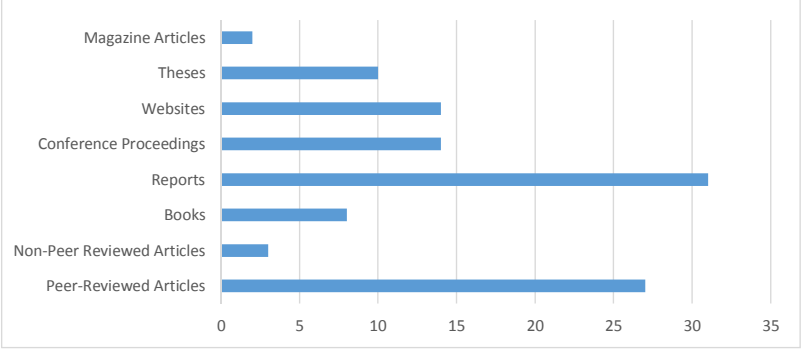

Fig. 2. Types of publication for DSC and its enablers.

to end up with a comprehensive bibliography of papers on DSC. The following section presents this comprehensive review.

Nomenclature

AR	Augmented Reality
BD	Big Data
CC	Cloud Computing
DSC	Digital Supply Chain
IoT	Internet of Things
N	Nanotechnology
OC	Omni Channel
R	Robotics
ST	Sensor Technology
SCOR	Supply Chain Operations Reference
SDV	Self-Driving Vehicles
UAV	Unmanned Aerial Vehicle
3DP	3D Printing

2.2. Academic literature on DSC

Today's customers are very aware, attached and knowledgeable about how to best use the latest digital technologies. The direction of technological focus is shifting from serving companies towards serving individuals. Such disruptions can lead to loss of market position to competitors if organizations do not act in a timely manner and improve their processes. This forces businesses to reconsider how they can transform their classical supply chain operations to better address the demands of the rising number of their now well-equipped customers.

Digitalization has started to receive much attention from organizations all over the world as it creates superior benefits to a wide range of companies. Our review on DSC literature signifies a gap between the theory and practice in supply chains. Currently there is a limited number of studies regarding DSC. As far as we know, there are no academic studies that explicitly focus on the DSC concept. There however, exists supply chain focused articles which discuss DSC technologies in terms of their applications. The following analysis supports this statement. According to the factors on which DSC literature has been reviewed, the spider diagram in Fig. 3 highlights that the focus of the study on DSC has primarily been on its enablers. Existing journal articles and conference papers related to DSC and its technologies that focus on supply chains are classified in Table 1. Table 2 then lists the master or doctoral theses related to DSC.

2.3. Published books on DSC

To the best of our knowledge, the DSC chapter in Managing Digital Enterprise book prepared by Xu [57] is one of the earliest books which substantiates the concept of DSC. The book is mainly about rapid development of digitalization, dramatic advancements

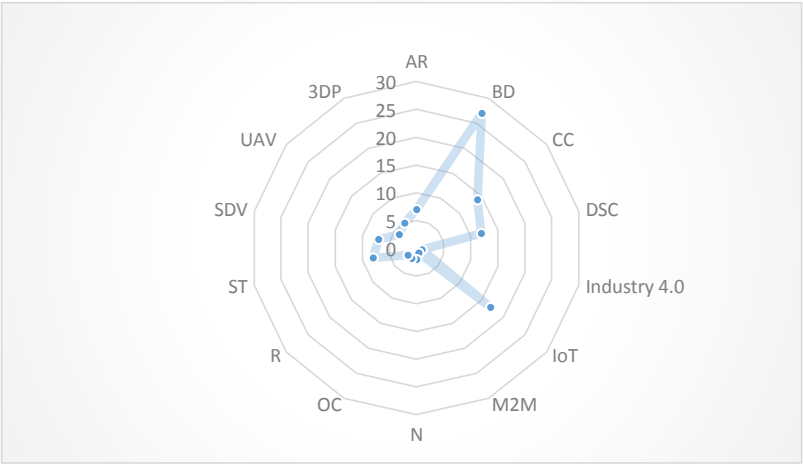

Fig. 3. Various subjects covered in selected journals.

in digital technologies and its strategic importance in organizations. There is also a dedicated chapter about DSC that comprehensively presents DSC in terms of digital enterprises, issues and success factors of DSC, emerging trends and future directions. Skilton [58] focuses on practical applications of new digital solutions and illustrates how companies can have a role in digital access and digital delivery while illustrating the DSC capability strategies. Sanders [59] attempts to provide a systematic framework for companies to display the implementation of BD analytics across the supply chain on how to turn data into intelligence and thus succeed to competitive advantages.

Another book that elaborates on the field of DSC is Digital Enterprise Transformation prepared by Uhl and Gollenia [60]. The authors published its new edition in 2016 [61]. These original and new editions are dedicated to the combination of transformation ability and novel digital skills to be developed. Again, one of its chapters is dedicated to DSC management, explaining the key features of supply chain management and the SCOR model. It also introduces 18 cases of supply chain management to assess digital cases on the SCOR model to position strategic effort-benefits portfolio.

A recently published book on DSC entitled "E-Logistics: Managing Your Digital Supply Chains for Competitive Advantage" authored by Wang [62] aims to capture the state-of-the-art developments in managing supply chains to gain competitive advantage. The book also investigates the emerging technological changes in e-logistics and considers what the future holds for this rapidly shifting and evolving field.

The latest book on DSC is authored by Editors Oswal and Kleinemeier [63]. This book presents an overview of digitalization, its impacts, drivers and objectives. It includes chapters on DSC management for the automotive supplier industry, digital business transformation and the effect of digital culture with its effect on supply chain organizations, etc. This book details the concept of DSC and its related technologies to enhance and improve supply chain management processes.

2.4. Industrial reports on DSC

The analysis of industrial reports is provided in this subsection. There is a gradual increase in the number of sectoral reports about DSC as new technological improvements emerge. IBM [64] predicted in its report that future supply chains would be smarter. They have identified the challenges and risks that supply chains will face and priorities that needed to be handled. As far as we know, one of the earliest reports about DSC is published by Capgemini Consulting [65], which introduced a digital transformation approach to supply chains to describe the deficits and benefits of digitally transformed supply chains. Their framework consists of DSC execution and strategy stages that in essence defines DSC as an approach to access extensive information and achieve greater collaboration. Accenture [66] is another consulting company that assessed the impact of digital technologies on supply chain management and offered new opportunities to unlock DSC's full potential. To enable DSC, they proposed the following four key attributes: Rapid, Scalable, Intelligent, and Connected. Another company, Supply Chain Insights, also published a report on DSC that sheds light on driving the DSC transformation in the industry [67,68]. Their report commences with a definition of digital organization and discusses the creation of a DSC strategy, then captures the highlights by conducting a questionnaire during the years 2013 and 2014. Their report aims to help supply chain managers to align their source, make and deliver strategies. ATKearney and WHU-Otto Beisheim School of Management united their forces to prepare a collaborative report about DSC [69]. They dedicated their study to the future role of DSC in a global and connected world. Their analysis indicated that managers of leading European companies expect the digital transformation in next three years to be traditional (information technology integration) rather than novel technological advances (e.g. 3DP, R, IoT, etc.). Monsanto farming company is among the pioneers investing in the DSC to bring new forms of revenue and business value to the farming market [70]. They have presented several examples to share how DSC are connected to better product and customer experience. Their own improvements made them the 35th top supply chain company in 2015, a significant improvement from 100s, according to Gartner's ranking for the last 11 years.

Bearingpoint [1] consulting company presented a report on trends in DSC management and digitalization's impact on supply chain as it transforms every industry. Their approach consists of prepare, assess, analyze and roadmap & governance steps. The Digital Supply Chain Initiative [71] gathered information from twenty-four top managers responsible for the world's largest supply chains. These executives forecast that the most significant transformation for organizations will occur over the next 5 years. This report provides a DSC implementation framework and roadmap to assist industry leaders, supply chains managers and any other specialists interested in leading-edge supply chains developments. These developments aim to transform supply chain organization by focusing on the customer, maximizing demand, decreasing supply chain costs and increasing organizations' revenues. The report's practical steps guide business managers

Table 1
Literature Review of DSC.

References	Subject	Objective	Method	Contribution
Tiwari et al. [2]	BD	This paper investigates BD in supply chains between 2010 and 2016 and provides insights to industries.	Review	This paper contributes by providing a guideline for academicians and practitioners in implementing BD in different aspects of supply chains.
Farahani et al. [3]	DSC	This paper provides 17 digital supply chain management cases for automotive supply chains using expert interviews to form the basis for the creation of the DSC.	Modeling	This paper contributes by providing a recipe for managers on how to bring innovations on a cohesive agenda.
Hofmann and Rüsch [4]	Industry 4.0	This paper sheds light on the topic of Industry 4.0 in the context of logistics management.	Modeling	This paper contributes by presenting core components of the Industry 4.0 to make the concept more understandable.
Merlino and Sproge [5]	AR	This paper explores the main technological changes and the most advanced cases in supply chain.	Review	This paper contributes as a review of the main technological factors impacting and transforming supply chain.
Majeed and Rupasinghe [6]	IoT	The paper derives a conceptual framework to enhance inbound and outbound operations in ERP for fashion apparel and footwear industries.	Modeling	This paper contributes by managing, optimizing and automating the operations in an ERP system through RFID technology.
Nguyen et al. [7]	BD	This paper reviews the BD within supply chain context to responds where and how BD has been applied.	Review	This paper contributes by proposing a novel classification framework that provides a full picture of current literature on BD.
Ben-Daya et al. [8]	IoT	This paper explores the role of IoT and its impact on supply chain through an extensive literature review.	Review	This paper contributes by covering important aspects of IoT in supply chain including its definition, main technology enablers and various supply chain processes and applications.
Korpela et al [9]	DSC	This paper investigates the requirements and functionalities of DSC integration.	Modeling	This paper contributes by offering cost effective supply chain integration.
Michel [10]	DSC	This paper compiles the knowledge of technology executives, consultants and supply chain analysts in the area of DSC and industry 4.0.	Review	This paper contributes by stating the six DSC trends using the studies of SC analysts, consultants and executives.
Scuotto et al. [11]	DSC	This paper presents the relationship among multiple buyers and suppliers in the context of DSC management.	Modeling	This paper contributes by underlining the use of information and communication technology using the service sector in Italy
Vanderroost et al. [12]	AR	This paper provides an extensive overview of computer systems that are used in the logistics of a food package's life cycle and that to a certain extent integrate novel technologies.	Review	This paper contributes by improving efficiency of logistics operations on food packages and encourages resolving the technical issues.
Büyüközkan and Göçer [13]	DSC	This paper proposes a novel MCDM approach to evaluate supplier selection process under DSC environment.	Case Study Supplier Selection	The paper contributes by proposing a novel framework combines the Interval Valued Intuitionistic Fuzzy Analytic Hierarchy Process to evaluate criteria weights and Additive Ratio Assessment methodology for alternative assessment procedure.
Büyüközkan and Göçer [14]	DSC	This paper approaches the supplier selection problem in a DSC environment by the help of an extension of Multi-Objective Optimization by Ratio Analysis.	Case Study Supplier Selection	This paper contributes by utilizing the interval valued intuitionistic fuzzy numbers and a group decision making approach for a suitable supplier selection in a DSC environment.
Tenkorang and Helo [15]	BD	This paper discusses the BD issues, trends and perspectives in supply chain management.	Review	This paper contributes by presenting an original literature review research and proposes a value-adding framework on BD II.
Gunasekaran et al. [16]	BD	This paper identifies the influence of connectivity and information sharing resources under the mediation effect of top management commitment on BD and supply chains.	Modeling	This paper conceptualizes the assimilation as acceptance, routinization, and assimilation stages.
Hazen et al. [17]	BD	This article presents a research by proposing an agenda based on a theory by reviewing the eight theories that can be used by researchers to examine and clarify the nature of BD analytics impact on supply chain sustainability.	Modeling	This paper contributes by enabling scholars and practitioners to understand how companywide BD and predictive analytics initiatives might impact measures of supply chain sustainability.
Kumar et al. [18]	DSC	This article examines the role of smart city in changing the nature and form of traditional supply chain using an integrative framework through a case study.	Case Study Manufacturing system	This paper contributes by developing an integrative framework for understanding the interplay between smart city and distributed manufacturing on supply chain design.
Papadopoulos et al. [19]	BD	This study presents a framework in that the BD is used for sustainability in disaster relief activities in the aftermath of 2015 Nepal earthquake.	Modeling	The article contributes to the literature on resilience in disaster supply chain by a framework using BD.
Wu et al. [20]	DSC	This review focuses on exploring the current status and remaining issues of smart supply chain management.	Review	This paper contributes by providing original and relevant guidance for researchers and practitioners on developing smart supply chains.
Wu et al. [21]	BD	This article presents a methodology using the fuzzy and grey Delphi to identify a set of reliable attributes and transform BD to a manageable scale to consider their impacts.	Modeling	This paper contributes by showing the greater influence of capacity and operations than other supply chain attributes.
Zhao et al. [22]	BD	This paper offers multiple objective optimization methodology for a green supply chain management scheme that minimizes the inherent risk occurred by hazardous materials using BD analysis.	Modeling	This study contributes in improvement of green supply chain management in three scenarios involving risk minimization and carbon emission in different orders.
Zhong et al. [23]	BD	This study examines the representative BD applications and reviews the current technologies, as well as models and algorithms are reviewed.	Review	This paper contributes to the academia and practitioners to get insights and observation of BD implementation in service and manufacturing sectors.
Wang et al. [24]	BD	This study reviews the literature on BD business analytics in logistics and supply chains management and explores the applications of BD in supply chain strategy and operation.	Review	This article stresses the significance of BD applications on logistics and supply chain management.
Cortés et al. [25]	IoT		Review	

Table 1 (*Continued*)

References	Subject	Objective	Method	Contribution
		This paper offers revisions and proposal of IoT applications in supply chain management and reviews the applications of IoT in supply chain management.		This paper contributes by stating the benefits of incorporating the IoT not only for gaining the better management and efficiency improvement.
Chen [26]	IoT	This case study designs the autonomous agent-based trace system using IoT architecture based on Fuzzy CM and fuzzy rule methods in products usage life cycles.	Case Study Agriculture Food Product	This paper contributes simulating food tracing complex system with imprecise relationships for agriculture food product.
Wamba and Akter [27]	BD	This review provides BD analytics for supply chain management literature using studies related to the areas within SCOPUS.	Review	This paper contributes to the literature by stating the near future transformation of supply chain management practices using the BD analytics.
Gnimpieba et al. [28]	IoT and CC	This study aims using IoT and CC technology for real time geo-positioning and tracing of goods and collaboration between involved players in a logistic process.	Modeling	This paper contributes by implying the information sharing aspect for interoperability and collaboration between involved actors in a logistic flow by introducing the IoT and CC technologies.
Gospic and Bakmaz [29]	M2M	This paper presents comprehensive survey on Machine to Machine (M2M) communications towards realization of smart logistics systems.	Modeling	This study emphasizes the specific properties of M2 M communications which are of importance for applications of M2 M systems in logistics services.
Hofmann [30]	BD	This study deals with BD potential on improving the various supply chain processes and aims elaborating BD characteristic with the greatest potential that mitigates the bullwhip effect.	Modeling	The paper contributes to the literature by operationalizing BD in the control engineering analyses.
Isasi et al. [31]	BD	This article aims to review the state-of the-art BD and business analytics applications in supply chains by means of bibliometric and systematic analysis.	Review	This paper contributes to the literature by identifying the key trends, challenges and knowledge gaps for BD.
Mehmood and Graham [32]	BD	This study uses Markov models for the integration of BD with city transport sharing in health care.	Modeling	This paper aims to contribute to the theory on BD and city operations by exploring how BD leads to progresses in transport capacity sharing.
Schoenherr and Pero [33]	BD	This article discusses the results of a large-scale survey on BD among supply chain management professionals and identifies major benefits and obstacles to predictive analytics.	Modeling	This paper intents to provide a timely assessment of BD, illustrate the future potential of BD, and motivate additional research on it.
Sebastian and Omera [34]	3DP	This paper examines the areas of the supply chains which is most likely to be disrupted by 3DP and identifies the key issues that must be addressed in a roadmap for future researches and practices.	Review	This paper contributes to the literature by pinpointing the necessity to mitigate the effects of disruption on future supply chain by 3DP.
Tan et al. [35]	BD	This study wishes to address analytic techniques by testing and developing an infrastructure using the deduction graph techniques for companies to combine their capability sets with other companies.	Case Study Eyeglasses Manufacturer	This study contributes by filling the gap on the lack of data analytics techniques to aid companies to gain competitive advantage and capture the potential of innovation.
Tadejko [36]	IoT	This paper describes some principles and characteristics of IoT, and briefly discusses the application of it in modern logistics. Some aspects of modern logistics related to the IoT technology is studied.	Review	This study contributes by introducing and presenting the current application areas of IoT and future prospects of this technology.
Zhong et al. [37]	BD	This study deals with a holistic BD methodology to excavate frequent trajectory from extensive RFID enabled shop floor logistics data with a number of innovations highlighted.	Modeling	This paper contributes by establishing a guide for end-users to carry out associated decisions.
Hazen et al. [38]	BD	This paper introduces the data quality problems in the context of supply chains management and proposes a methodology for monitoring and controlling data.	Theory	This paper contributes by a review of literature on BD in supply chain and hope to encourage interdisciplinary collaboration for controlling data.
Leveling et al. [39]	BD	This paper focuses on BD solutions dealing with supply chains by representing a key discipline for managing the increased collaboration.	Review	This paper present BD applications' classification and its potential benefits. And also, it outlines the general technologies of BD.
Rozados and Tjahjono [40]	BD	The investigations range from the fundamentals of BD, its taxonomy and the level of maturity of BD solutions.	Review	This study contributes to the literature by explore the role of BD in supply chains management
Wang and Liu [41]	IoT	This article introduces IoT related technologies and then analyzes the functions and utilities of IoT by means of production supply chain on applications of agriculture resources.	Modeling	This article contributes by building a model on Agricultural Means of Production Supply Chain using IoT technologies.
Bhargava et al. [42]	DSC	This study examines the challenges and approaches for secure collaboration among partners in DSCs.	Modeling	This study contributes by suggesting a novel approach relying on the usage of trust brokers and taint analyses.
Cirulis and Ginters [43] [41]	AR	This paper describes the basic elements of logistics and pays special attention to improvement possibilities in packaging, handling, storage and transportation phases.	Modeling	This study contributes to the literature by implying that AR technologies can improve the execution of logistics elements.
Ginters et al. [44]	AR	This paper presents an AR and RFID application for an outdoor environment combined logistic item visualization	Modeling	This study contributes improvement of logistics processes by use of AR RFID technologies in outdoor environment.
Waller and Fawcett [45]	BD	This paper describes possible applications of predictive analytics and BD in practice and provides examples of research questions, as well as examples that stem from management theories.	Theory	This paper contributes by proposing specific steps for interested researchers to research on the intersection of supply chain management and BD.
Sun [46]	IoT	This paper presents an approach using applications of RFID technology for logistics on IoT	Modeling	This study contributes by introducing RFID technology for logistics on IoT.
Wagenaar [47]	IoT	This research analyses the benefits the IoT has on supply chains through a literature study, and looks how these benefits can increase revenue within supply chain.	Review	This study contributes by increasing revenue in a supply chain and utilize new business models using IoT.

Table 2
Theses on DSC.

References	Subject	**Objective**	**Contribution**
Aktepe [48]	CC	This master thesis investigates the awareness of logistics companies regarding CC, their reasons for preferring or not preferring the usage of CC and benefits and risks of CC for logistics companies. In this context, findings derived from the analysis of the data obtained via interviews with the logistics companies are evaluated in the context of technological, organizational and environmental issues.	This thesis contributes by enhancing the competition levels in the markets by integrating high technologies, CC, offers to the logistics companies.
Aviles [49]	CC	This doctoral dissertation aims to explore the advantages and outcome of strong collaborative relationships among organizations. The reliance on the internal relationship of organizations has amplified and become a principal strategy with the organizations compete as supply chains of multi-relationship. There are several contradictory views on cloud viability but supply chain collaboration may be facilitated by the logistics technologies in the cloud.	This dissertation contributes by stating that maintaining collaborative relationships provide value-added capabilities that logistics organizations require in order to remain competitive and be successful in some cases strengthen by the use of CC.
Kache [50]	BD	This doctoral dissertation focuses on one exemplary under-represented area of research, concerning the role and value of information in supply chains in general, and the implications of BD on information usage at corporate and supply chain level in particular. Thus, taking the digital business transformation perspective, a key focus is addressed on BD analytics and the value of information in supply chains.	This dissertation provides a thorough overview of the current state of research in supply chain management, outlining a range of under-represented research areas as identified through a review of literature reviews.
Torğul [51]	IoT	This master thesis presents a closed loop supply chain to meet the demand of the sales and collection centers for both remanufactured and new products. Manufacturers have refurbishing, disassembly and disposal options for assessment of returned products.	This thesis contributes to the literature by providing a mixed-integer linear-programming approach for a single product which is totally modular.
Aikaterini [52]	IoT	This master thesis proposes investigation of connected services extent that could be used in the downstream automotive supply chain as a long term viable solution. Opportunities and challenges is identified by door-to-door perspectives concerning the different stakeholders among the supply chain.	This thesis contributes to the literature by illustrating the opportunities in automotive industry by the advances in IoT and BD.
Gantzia and Sklatinioti [53]	CC	This master thesis aims to investigate benefits and challenges perceived by the cloud providers and third-party logistics firm technology users and which cloud services are used in the third-party logistics industry. Thesis has focused on the assessment of three third-party logistics firms and three cloud providers to grasp the picture in complete.	This thesis contributes that Software as a Service and more precisely, transportation administration software, as the most prevailing cloud-based system applied in the third party logistic industry.
Pang [54]	IoT ST	This doctoral dissertation investigates the technologies and architectures of the IoT for these two applications as so-called Food-IoT and Health-IoT respectively to resolve a series of research problems about the wireless sensor Network architectures, device architectures and system integration architectures.	This dissertation contributes to the literature by presenting the so-called Business-Technology Co-Design, to resolve an essential challenge in research on the IoT.
Keller [55]	IoT ST	This doctoral dissertation evaluates the distribution center in Unna, Germany for RFID enabled outgoing goods processing. In this case scenario, distinguishing the tracked RFID tagged pallets loaded onto trucks and other pallets also in range of the reader is necessary.	This dissertation contributes by identifying meaningful attributes and addresses those weaknesses by means of a machine learning based approach.
Li and Lu [56]	IoT	This doctoral dissertation examines how the organizational changes in Small and Medium Enterprises is influenced by the IoT and research how Small and Medium Enterprises manage the changes in this IOT era. Finally, to help the Small and Medium Enterprises, thesis suggests strategy developments to make successful organizational changes.	This dissertation contributes by examining how IoT influences the organizational changes in small and medium sized enterprises and how they manage the changes in IoT era.

to better comprehend game-changing technologies that affect all supply chain organizations and to gain overview of key differences between traditional and digital supply chains.

Bain & Company Consulting focused on the intangible benefits of a DSC [72]. Accordingly, the latest digital transformation shaped intangible assets, things like intellectual property or customer relationship of a company, rather than its tangible assets. They offer solutions as applying various digital technologies across DSC to deliver powerful ways for organizations. Rakowski [73] presented the latest technology trends in her article to emphasize that supply chains go digital. She suggests that the future of technology will drive a new wave of productivity by digitalization of key organization and financial processes and collaboration will increase and thus fuel innovation so that organization will be run simpler with blurred lines and smarter procurements. Cerasis [74,75] also prepared reports on the future of supply chains to know how the technology is transforming different industries. EY [76] prepared another report on DSC from the perspective of BD to notify companies to act as soon as possible to focus on BD to preserve their competitive edge. The Boston Consulting Group described the advantages of DSC in three key paths [77]. It suggests possible ways to address performance gaps, innovate business processes and disrupt supply chain strategies. These ways include applying digital technologies, such as advanced analytics to calculate the optimal inventory level and forecast future demand more accurately, rather than applying cumbersome conventional approaches.

The present and future state of digital transformation in supply chains is analyzed in the reports of GT Nexus and Capgemini Consulting [78,79]. Their key findings from the survey with 337 leading executives from several global supply chain organizations suggest that 75% of executives deem DSC to be “important or very important”, 50% say DSC is “very important”, 33% of respondents are “dissatisfied” with the progress so far, while only 5% are “very satisfied”. They accept that key technology enablers are identified but have not been widely used. They also expect dramatic changes to occur within next five years.

DHL runs series of trend research on logistics about creating value [80–91]. These reports on AR, BD, UAV, Low Cost ST, SDV, IoT, OC, 3DP and R in Logistics inspire novel strategies and innovation in the logistics industry. Strategy& global team also prepared a series of reports on digitalization of supply chain organizations

[92–95]. However, there are not any companies that have yet succeeded in truly building DSC, and DSC applications remain limited. The experts predict that in the next five-to-ten-years many industries will be implementing DSC and tremendous changes to take place.

2.5. Advantages, weaknesses and limitations of DSC literature

It is important to highlight that the identified 109 articles influenced the results of this study reported in Section 2 (Figs. 2–3). In some circumstances, the paper under review will still be utilized to describe the results and to gain a better understanding of the topic. In this section, the advantages, weaknesses and limitations of the published methodologies are presented, which could correlate the papers in order to find future trends, identify knowledge gaps, synthesize past knowledge, identify important biases and to find common features among various studies. We decided to build Tables 1 and 2 with the names of the authors, year of publication and the reference number as columns. Listed in the rows, the subject indicates the literature's inclusive focus, objective clarifies the goal of the research paper; method identifies the methodology used in the paper while the contribution involves the goal of literature's contribution statement with its clear and concise focal points. These characteristics have been nominated based on authors' expertise in the field and the relevant studies. Books and industrial reports are synthesized to identify important biases by narrating their findings so that short, specific and precise knowledge gaps could be extracted from these statements.

When the relevant literature on DSC is consolidated and examined thoroughly, they exhibit certain advantages to the readers. These utilized advantages describe the roadmap for establishing the DSC framework in the following sections based on the overview of the content, scope, and findings of selected literature. On the other hand, academics and practitioners have defined DSC from diverse perspectives (Section 3.1). It is easily comprehensible that so far, there is no unanimously adopted definition on the concept of DSC. These diverse definitions of DSC create a complexity for researchers to compile a general description that is acceptable by the majority. The key fundamental principles of existing DSC literature have significant limitations when establishing DSC framework. Based on the papers in this research category, following sections utilize and identify the key limitations and prospects in DSC, summarize prior research to identify knowledge gaps by providing advantages, weaknesses and limitations of individual methods and introduce a development framework as a roadmap for future research and practice.

3. Digital Supply Chain (DSC)

The network between companies and their suppliers built for production and distribution of a specific product is defined as a supply chain. It represents the necessary steps taken to deliver a product or service to customers. According to supply chain council, these steps can be managed with the help of the SCOR model that consist of the Plan, Source, Make, Deliver, Return processes. Management of supply chain is a significant process since optimized supply chains will lead to lower costs and faster production cycles. However, traditional supply chain has lack of certain attributes that are needed in today's and tomorrow's business requirements. The traditional supply chain consists of a series of largely discrete, siloed steps. Transforming a traditional supply chain into DSC breaks down these walls so that the chain turns into an integrated system that runs flawlessly. DSC is not about whether the products or services are physical or digital, it is the way how supply chain is managed.

An increasing number of senior executives have started to support and get involved with organizations' digital initiatives since more and more of them have realized the importance of digitalization on their corporate performance and hence the competitive advantage of the corporation. In a recent study [96] involving 850 senior executives representing the full range of industries, regions and firm sizes, 31% of CEOs of the participant organizations personally sponsored their digital initiatives in 2013 while the same figure was 23% in 2012. Supply chain operations face a common confrontation. Detailed information about supply chain operations is held locally, which in turns creates functional, organizational, and cultural storage points. This situation undermines the effective and efficient collaboration among distinctive sections of the supply chain processes while increasing the possibility of complications evolving at later stages, and thus limits the options for response [66]. Many different companies from diverse sectors are investing profoundly on digitalizing their business operations and their supply chains. Take major logistics service providers such as DHL, for example, which monitors and reports on the trends that could have an impact on the logistics industry in the future. DB Schenker, another logistics service provider, is investing in a digital mobility lab. Airlines with strong cargo operations, such as THY, Lufthansa and Emirates expand their paperless e-freight offerings with data cleaning for customers. Monsanto, an agriculture company, is investing on ST to digitalize farming operations. Global retailers Amazon and Alibaba have invested in drones and R for handling and delivery of goods. The following subsection summarizes several definitions of DSC taken from different sources.

3.1. Definitions of DSC

There are several definitions of DSC in literature. The ones that are found throughout this research are presented in this article with a chronological order. The definition that reflects articles' view on DSC is also presented at the end of this subsection.

Capgemini Consulting [65] states that traditional supply chain relies on a mixture of electronic processes and paper-based documentations. The organizational structures are often illustrated by functional and geographical silos which are reluctant to share information openly, leading to a sub-optimal performance. DSC, on the other hand, has the capability of making widespread information available, superior collaboration and communications across digital platforms, resulting in enhanced reliability, agility and effectiveness.

Bhargava et al. [42] state that DSC is composed of those systems (e.g. software, hardware, communication networks) that support interactions between globally distributed organizations and orchestrates the activities of the partners in supply chains. These activities include buying, making, storing, moving and selling a product.

Accenture Consulting [66] proposes that digitalization has the potential to transform supply chains by making services more valuable, accessible and affordable. Accordingly, a different perspective is needed for digital technologies to create new supply chain opportunities. Organizations should reimagine their supply chains as a digital supply network that not only unites physical flows of products and services, but also talents, information and finance. In an abstract sense, people and data, as well as materials, products and supplies, must travel together across the extended enterprise.

According to Kinnet [70], DSC is an intelligent, value driven network that leverages new approaches with technology and analytics to create new forms of revenue and business value.

The analysis of the report prepared by A.T. Kearney and WHU-Otto Beisheim School of Management [69] defines DSC as the best-fit technologies that support and synchronize supply chain processes – including warehouse and transportation systems,

Radio Frequency Identification (RFID), advanced picking technologies, and innovative planning and scheduling systems to quickly alleviate areas of "pain," such as waste in the supply chain, in a world where demand is volatile and risks are high.

The Digital Supply Chain Initiative [71] describes the DSC as a customer centric platform that captures and maximizes the utilization of real-time information emerging from variety of sources. They suggest that DSC enables demand stimulation, sensing, matching and management in order to have an optimized performance and minimized risk.

According to Rouse [97], DSC is a supply chain whose foundation is built on Web-enabled capabilities. Many supply chains use a mix of paper-based and IT-enabled processes. A true DSC goes far beyond this hybrid model to fully capitalize on connectivity, system integration and the information-producing capabilities of "smart" components.

Cecere [68] defines DSC as a process that uses new technologies to define processes to sense, respond and orchestrate bi-directionally from market to market (from the channel to supplier networks). The processes move at the cadence of the market.

This analysis shows that there are several different definitions of DSC. However, all of them share unifying common concepts. The definition of DSC, in our view, is an intelligent best-fit technological system that is based on the capability of massive data disposal and excellent cooperation and communication for digital hardware, software, and networks to support and synchronize interaction between organizations by making services more valuable, accessible and affordable with consistent, agile and effective outcomes. Therefore, the objective of this review is to propose integrated approaches for building an effective DSC structure.

3.2. Features of DSC

Most of the world's successful organizations have excellence in their supply chains, and some even argue that the competition among organizations is competition among their supply chains. For instance, the two largest supermarket chains in Australia, Woolworths and Coles, are competing head-to-head with their global chains in terms of high agility with greater service and cost productivity. Another example is iPad's supply chain: its semiconductors are manufactured in three countries, the assembly is done in a different country, the monitors are brought in from another set of countries, whilst the design and branding is done in the U.S. where the Apple Inc. is headquartered [57]. Supply chains are evolving and turning into something novel. The days when a classical supply chain only moves goods from one place to another is now over. Nowadays, supply chains require a significant size of complex activities all of which need to be coordinated and tracked. Thus, digitalization enables the evolution of the next generation of supply chains offering both flexibility and efficiency. Since digital solutions are disrupting traditional supply chains, there are some distinct features associated with virtually every DSC. These distinct advantages are compiled into the following eleven main features that DSC aim to achieve;

Speed: The speed at which goods are delivered is central for both suppliers and those involved in DSC. Not only do organizations desire to get the stock as soon as it is needed, but those working within DSC want to be able to move more in a shorter period of time. This ability to react quickly to demand is going to be one of the most important pillars of a DSC as organizations look for new ways to get product delivery quickly. For instance, Amazon (Prime Air) and Google (Project Wing) both test drones for delivery systems to get packages to customers in 30-min or less to break the illusive delivery barrier. It may be seen as science fiction for the moment, but DSC will make it real that this kind of speed will be accomplished [1,66,98].

Flexibility: Digitalization in supply chains implies the need for operational agility with ease in adaption to changing circumstances. This does not describe how items are delivered, but defines the way how to react to problems within supply chains. For example, political instability in Syria, diseases like the West African Ebola epidemic or natural disasters such as earthquakes can be devastating. Nevertheless, predicting such events or taking suitable measures and reacting efficiently and effectively can minimize disruptions in supply chains. This is the case for traditional supply chains, but DSC has the ability to accomplish this almost instantaneously by efficiently using the information collected and modelled [94,98].

Global connectivity: The internet has made the world a smaller place. Organizations need to deliver goods and services throughout the world quickly. This necessitates a truly global supply chain to enable organizations not only to deliver, but also to ensure reaction at local level. If a certain product made in Europe is demanded in the United States, it will be inefficient to have it fetched all the way from Europe to United States at the exact instant it is needed. It would take a lot of time and potential loss of revenue. Thus, DSC establishes a way to build effective global hubs to locally supply goods and services, instead of carrying them across the world for a sole order [94,98].

Real-time inventory: DSC provides the means to ensure that the stock on hand is sufficient, but not excessive, to meet the demand. DSC makes warehouse management more efficient and monitors stock levels continuously with the help of arrays of sensors or via other advanced technologies. While customer behavior changes rapidly, the supply always needs to meet the demand. Consumers can place orders anytime from anywhere, thus stock at hand should be monitored in real time. This does not mean the same amount of inventory should be kept at every distribution center. It in fact means that buying trends and future demand for goods and services shall be recognized in advance to make informed decisions. DSC provides these means required for advanced analytics [94,98].

Intelligent: New generation technological enablers provide smart products that are equipped with enough computing power so that self-learning and autonomous decision-making could be enabled based on defined algorithms. DSC encompasses this feature that allow improved decision making, automated execution and abets innovations in operations [98,99].

Transparency: In a transparent supply chain, links in the chain do comprehend and act according to other links' behaviors and needs. In case of lack of transparency, the orderly flow within supply chain will inevitably be disrupted somewhere. DSC can enable companies to act transparently and be better prepared to disruptions by anticipating, modeling the network, creating what-if scenarios and adjusting the chain instantaneously to changing conditions [94].

Cost-effective: Digital technologies are essentially reducing the cost in almost every area. Initial investment costs can be high for novel technologies with a decline over time. DSC is essentially a cost-effective way for organizations, not just because of its utilization of technological enablers but also because the process how the supply chain is managed with DSC creates cost efficiency for organizations.

Scalability: Scaling supply chains up or down according to the required circumstances often creates a colossal struggle for organizations. When classical supply chains are integrated with digitalization, however, scalability becomes less of an issue. This brings easier optimization and duplication of processes and simpler spotting of anomalies and errors [98,99].

Innovative: Excellence in DSC is a key feature so that DSCs are always open for a change. The world is being swamped with novel technologies at a seemingly faster rate than ever before. DSC

should always look for new ways to incorporate these innovations into processes to remain competitive and ensure excellence in supply chain. Todays' innovations are becoming tomorrows' idle, inactive, dead technologies. Some examples include the evolution of TVs from black and white to smart TVs or changes from paper and pen to smart glasses in warehouses management for optimized picking. Technologies inevitably change, it is in the genes of innovation. Information becomes the basis for a commercial enterprise which has not changed in thousands of years. People who feel that today's BD is just an improvement of past information trends are as mislead as if they were to claim that a stone tablet is essentially identical to a tablet computer or an abacus is a same thing as a supercomputer [100]. These are just a few of the many examples of innovative approaches to DSC across various functions.

Proactive: DSC imposes proactive actions to prevent potential disruptions. This can be made possible not only through troubleshooting, but also by identifying latent issues in advance through research. It demands a substantial amount of knowledge and planning to coordinate these problems. DSC offers proactive solutions to anticipate issues prior to their occurrence, an effective analytics framework and operational intelligence to satisfy digitally enabled consumers.

Eco-friendly: Supply chains have a certain level of impact on the environment. If DSC does not place enough emphasis on environment, it might lead to business disruption due to negative press, environmental laws or public awareness, to name a few. Finding a traditional supply chain with eco-friendly practices in every single stage is a daunting task. Next-generation DSC can be able to extend eco-friendly process capabilities.

3.3. Components and technologies of DSC

Several executives struggle simply to stem the tide without making any profound change in their organizations when they face with a fundamental change. Others look for new ways to jump ahead of the curve. It can be observed that notable companies are trying to digitalize their supply chain operations. From sensors and cloud services to nanotech and BD, several technologies drive DSC trends. There are many significant digitalization trends that could be applied in a supply chain to greatly improve the future. With the help of several reports published by consulting firms and other academic researches on DSC, eleven different digitalization technologies will be explored in this study. These eleven areas are explained in Table 3.

4. Benefits, challenges and research gaps on DSC

Whether they are small or big organizations, companies need to look at developing some type of digital organization capabilities

Table 3
DSC Technologies.

DSC Technologies	Description	DSC Challenges in Supply Chain
AR [43,88]	AR is described as the extension of physical reality by adding layers of computer generated information to the real environment. Information in this context could be any kind of virtual object or content, including text, graphics, video, sound, haptic feedback, Global Positioning Systems (GPS) data, and even smell.	The challenges AR in DSC include social acceptance, addressing privacy, and profitability for businesses to use it. Other challenges include optimized picking operations and virtual testing of new supplier parts and packages to reduce distribution of physical sample products.
BD [24,82]	BD is an evolving term that is used to describe any large amount of structured, semi-structured or unstructured data that has a potential to be mined for information.	For millions of shipments made every day, their origins and destinations, sizes, weights, contents, and locations, etc. are all tracked across global delivery networks. But does this data tracking fully exploit value?
CC [66,69]	CC delivers a network of virtual services so that users can access them from anywhere in the world on subscription at competitive costs.	DSC, enabled by the CC, have clear challenges which, together, drive unprecedented visibility, insights and flexibility while operating rapidly and at scale. Losing the control over the data that was previously housed on internal servers and/or computer hard drives, safety of the data on the web and service outages situations are also some challenges.
R [69,85]	R technology in Logistics is a branch of engineering that involves the conception, design, manufacture, and operation of R.	Challenges on R includes it is not the speed of development, but the fear humans, governments and regulators have towards the technology. Flexibility, automated systems to have the ability to keep up with changing demands, or worries on robots taking over all the jobs and whether they are secure.
ST [86]	ST is essential for robust detection and filling status, product quality, packaging quality, equipment status in a wide range of field conditions.	Real-time analysis of data originating from sensors. Improved transaction efficiency due to ubiquitous process control and factory optimization. Necessity of deploying extensive and expensive infrastructure in geo-location.
OC [81]	OC is a multi-channel approach to sales that seeks to provide the consumers with a seamless shopping experience whether the consumers is shopping online from a desktop or mobile device, by telephone or in a bricks and mortar store.	Direct sales to users and consumers with smaller lot sizes and different central and regional warehouse needs.
IoT [83]	IoT refers to the everyday objects that feature an IP address for internet connectivity allowing them to send and receive data, and so communication occurs between these objects and other network devices and systems.	The use of unique identifiers for various types of assets among different industries on a global scale, seamless interoperability for exchanging sensor information in heterogeneous environments, establishment of trust and ownership of data and overcoming privacy issues.
SDV [87]	SDV is a vehicle that is capable of sensing its environment and navigating without human input.	To achieve a vehicle capable of driving itself, four basic interdependent functions are required. These are navigation, situational analysis, motion planning, and trajectory control. Beyond technological capability, some key challenges include regulatory pressures, public acceptance, and liability.
UAV [101]	UAV is an aircraft with no pilot on board, commonly known as a drone. UAVs can be remote controlled aircraft or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems.	The regulatory environment, privacy concerns, and integration into existing networks are substantial challenges for UAV. In addition to the tangible (and technically controllable) challenges of congested airspace and inherent risks, there is another, less defined area of concern in the public domain.
N and 3DP [69]	N is the engineering of functional systems at the molecular scale and 3DP, also known as additive manufacturing, refers to various processes used to synthesize a three-dimensional object.	To successfully implement N and 3DP in logistics requires strong collaboration, along with high levels of participation between different players and competitors within the supply chain, and a common willingness to invest.

since organizations will compete on supply chains in global level ultimately. For global organizations, the DSC is the key for organizations' long-term growth and success. Some good examples are Google, Amazon, and Apple; each of them has ventured many areas in addition to their core business and have leveraged the advantages of hardware, software, networks, and the large user base and the collected large amount of data from the large user base. For instance, Amazon, the largest digital retailer, has ventured into digital services, software services, CC, mobile phones, e-readers, tablets, payments, television, media, entertainment, and other areas [57]. A great deal of time and effort of academics and industry managers are diverted to these activities. Indeed, there are many things that still need to be done in order to search for better supply chain structures and strategies. Lean supply and lean manufacturing systems together with world-class manufacturing, and continuous improvement concepts (Kaizen), are all examples of developments that have been born out of these concerns [102]. DSC, on the other hand, could be the way to improve and get better supply chain structures and strategies. Following sections review the challenges and benefits of DSC.

4.1. Challenges and issues of implementing DSC

Various problems can occur along the supply chain. Xu [57] defines the primary challenges to building DSC as gathering all required data from many disparate sources and ensuring the accuracy of that information and developing a software architecture and platform that can use the data to manage and execute the supply chain. Since the length of chain involves internal and external partners, it will be slow and prone to errors. Moreover, existing large amounts of inventory may not be able to meet the demand, logistics infrastructure can be insufficient and the quality of goods can be hard to control. Some of these identified challenges for DSC are presented as follows:

- Lack of planning: Deficiency of proper demand plan and guidelines and tools [57,94].
- Lack of collaboration: Deficient collaboration with external associates and deficient input from internal functions [1,57,71,76].
- Wrong demand forecast: Inaccurate over optimistic forecasts for demand, inventory, production and other data [57,103,104].
- Lack of information sharing: Companies' reluctance on information sharing [57,92].
- Silver bullet chase: The belief that everything will be fine [57,102].
- Lack of knowledge: Deficiency of supply chain management training and skills [57,102].
- Agility and Flexibility: Lack of required flexible and agile supply chain management [1,57,102,104,105].
- High volatility: Lack of knowledge and skills in dealing with volatility in supply chain management [57,76,102].
- Over confidence on suppliers: Relying on certain suppliers in certain parts of the globe [57,102].
- Lack of integration: Deficient view on the integration of digital and non-digital supply chain management [1,57,76,102].

4.2. Success factors for DSC

The core benefit of DSC is its ability to bring out the capacity of extraordinary performance in customer satisfaction. The DSC enables the creation of products and services designed with more accurate information about customer needs, built with efficiency and has locations with a quick and easy access of true customers. The performance measurement in DSC is also very important. This measure could be examined by ability of filling of orders till due day, delivery time, supplier reliability, chain cost or delays, among many others. Despite the many benefits of digitalization in supply chains, only a handful of early industry adopters have integrated it as a core process. One exception to this is in the farming industry; Monsanto leads digital revolution on the world's oldest industry. According to a recent study, more than one third of 2000 respondents have started implementing digitalization in their supply chains, and fully 72% expect to have done so within five years [94]. Some of the reasons why DSC adoption has been slow are the lack of awareness among workforce and stakeholders about digital means and the lack of required skills across employees and stakeholders. Therefore, the widespread adoption of DSC will depend on the realization of these critical success factors as follows:

- Real-Time Visibility: Dynamic, secure and interactive visibility across the entire supply chain will improve the management of DSC [67,72,78,102,106].
- Continuous collaboration: Capabilities are harmonized within and beyond physical boundaries to increase collaboration between involved actors of the supply chain [78,102,106].
- Alignment of suppliers: Aligning the interest of all the firms in the supply chain with your own to create incentives for better performance and developing trust (alignment) [57,66,69,78].
- Integration: Building the integration of digital and non-digital supply chains so that a unified and whole view of inventory across the firm can be achieved [57,66,69].
- Shared information: DSC allows easier information sharing on sales forecast and production data [57,66,67,69,78,102].
- Highly evolved operating models: Product and service functions can be altered easily to meet customers' changing demands [66,98,106].
- Adopting advanced analytics and analytics tools: Advanced data analysis improves decision making. Gaining better understanding and forecasting of the demand and solve previously unsolvable and even unknown problems along the supply chain. (e.g., BD and Data Analytics, etc.) [57,66,98,106].
- Automated execution: Seamless human-machine interactions increase operational efficiency [65,66,69,73,78,79,106].
- Enhanced and accelerated innovation: Digital supply chains inspire and abet innovations in designs, operations and customer relationships [57,66,67,69,106].
- Maximum efficiency: Seamless integration of people, processes and technology [66,73].
- Organizational flexibility: Digital plug-and play capabilities make it easier to configure and re-configure [65–67].
- Personalized experiences, Customer-centricy: Channel-centric supply networks support customized products and services [1,57,66,69,98,106].
- Enhanced responsiveness: Better information and sophisticated analytics can help accelerate responses to competitors' moves, technology shifts, and changing demand and supply signals [57,66,67,69,78,98,106].
- Proactive prevention: Decision support systems driven by predictive analytics can strengthen adaptability and reliability [57,66,98,106].
- Last mile postponement: Swiftly repurposing organizational assets assists on ensuring the supplies are aligned with evolving demands [57,66,98,106].

4.3. Research gaps on DSC

One of the main objective of this study was to provide a literature review on DSC research. Our search identified 105 relevant papers. The literature review also showed that very few

studies were actually conducted on DSC (see Tables 1 and 2) but most of them were conducted on its enablers that focus on supply chains. The distribution of papers found have been presented and discussed. The literature review showed that while there is a constant increase of papers published on the topic since 2010 (e.g., from 2 papers (1%) published in 2010 to 30 papers in 2016 (28%), and 10 articles (10%) by Dec 2, 2017), the clear majority of studies are still 'industrial reports' (see Fig. 2). Therefore, more research on DSC is needed to be done by journals. Indeed, no articles were identified among these outlets that is recognized as cutting edge study. More significantly, papers should focus on the development framework to transform, implement and adopt digitalization in the context of supply chains.

Thus, this section provides a number of observations regarding the applicability of digitalization in supply chains and identify the gaps in the literature with respect to the potential of DSC in helping address DSC benefits and challenges. Despite the recent interest in the DSC trend due to its colossal potential and disruptive nature, studies that address DSC benefits and challenges are still in their early stages. As mentioned in the introduction, DSC offers unprecedented advantages to all aspects of the supply chains, providing automation to better collaboration, all enabled by technologies like supply chain visibility, big data analytics, and the cloud, etc. Therefore, DSC enables supply chains to respond to the edge of the competition to transform digitally. Current studies are still short of unlocking this potential. There are only piecemeal literatures in isolated areas with inadequate effort that addresses the entire DSC concept, as evidenced by the literature analysis in Tables 1 and 2. Based on our classification of the literature on DSC, we found that studies are still confined to isolated areas of their enablers. Although we did not focus on the implementation of DSC in our review, it is worth noting that there is not many research in the implementation phase of DSC.

There are several research gaps in the current literature dealing with DSC that can be identified from the current review. These gaps can be summarized as follows:

- Lack of development frameworks that provide guidance for DSC adoption in a context with clear guidelines and roadmaps. These would aid in guiding managers as to which stages and where in supply chains would managers deploy DSC, given that supply chains may be at different steps of the DSC implementation. In addition, development frameworks would provide assistance in changing the management practices within the supply chains.
- Lack of tools and technologies that address supply chain problems in an DSC environment. DSC is different from that of a typical supply chain. Decisions in an DSC context requires new tools and technologies that take into account digitalization environment, such as the abundance of BD generated from ST and IoT. DSC will affect maintenance, quality, inventory management, production planning and procurement, among other issues.
- There are numerous barriers to the implementation of DSC from both managerial and technological perspectives. There's rather a significant change happening throughout the world. Organizations are at the edge of a competition to transform their supply chains digitally [78]. Thus, DSC challenges and issues addresses in Subsection 4.1 need to be unlocked by the help of DSC success factors derived from extant literature. There is not much studies on how to deal effectively with these.

Keeping in mind the derived knowledge from the literature on DSC, we resume this study by pointing out a need of a framework for developing DSC. In the following section, we use all the knowledge gathered from the surveyed literature to establish this state-of-the-art novel framework.

5. Framework for developing DSC

Successful supply chains operate with a clear vision, using frameworks and roadmaps that define the way forward. The extant literature is summarized into three main stages and their sub goals. The synthesized literature is then utilized in developing the roadmap which further paved the way towards designing the development framework for DSC. Hence, this section presents a framework for developing DSC. Fig. 4 displays the framework in a visual structure based on a review of the literature.

By compiling a formal definition of DSC that is valid for all organizations, an approach could be proposed to build an effective DSC structure. The features, components and technology enablers, challenges and success factors for developing the framework are identified by reviewing the DSC literature as presented in detail at the earlier sections. The taxonomy and review of available literature on DSC is accomplished by considering major challenges, success areas and enabling components and technologies with the objective of managing and developing an effective DSC. Further classification of the related literature is aimed at helping both academics and practitioners to identify the key features and success factors for effective operation and development of DSC. Indeed, DSC increasingly allows supply chains to become an integral part of decision making and strategic planning. To this end, organizations can leverage and develop DSC to complement different facets of their strategy and more effectively target their specific needs.

Keeping in mind the insight on the DSC literature and proposed framework for the development of DSC arises the question of how it can be suitably implemented and verified in a typical supply chain. Every supply chain will have a slightly different set of digital development goals with different priorities. In addition to rethinking and redesigning entire supply chains, the key desired digital evaluation objectives for supply chains often map the areas of ***Digitalization***, ***Technology Implementation*** and ***Supply Chain Management***, which are vital steps for organizational alignment. The main decomposition of the DSC development framework is thus clearly defined.

By utilizing this framework, most of the supply chain managers will be familiar with the basic DSC approach: assessing the supply chains' current digitalization state, establishing a vision for technology implementation, and developing a transformation road map for supply chain management in a DSC environment. Elaboration of these areas, their decompositions and establishment of their structure is the essence of DSC's implementation in a typical supply chain. Therefore, three main decompositions and their structure will be elaborated next. The major issues and challenges that need to be addressed are discussed using the attributes used to categorize and review the literature. Although implementation and verification of DSC in a typical supply chain needs more comprehensive research focusing merely on these steps. The findings of this study will be of interest to supply chain managers and companies opting for digitally enabled organizations and fully transformed DSC. The details of the DSC decomposition are presented in below subsections and the framework for developing DSC is displayed in Fig. 5.

5.1. Digitalization

Being a DSC does necessarily not mean having the latest digital technologies. It is mostly about aligning digital initiatives with supply chain objectives and adopting a digital methodology to realize the untapped potential of existing resources and capabilities resulting in a higher level of performance [65]. By examining the extant literature on DSC, we have seen that DSC process often begins with ***Digitalization***. Supply chains need to be clear about

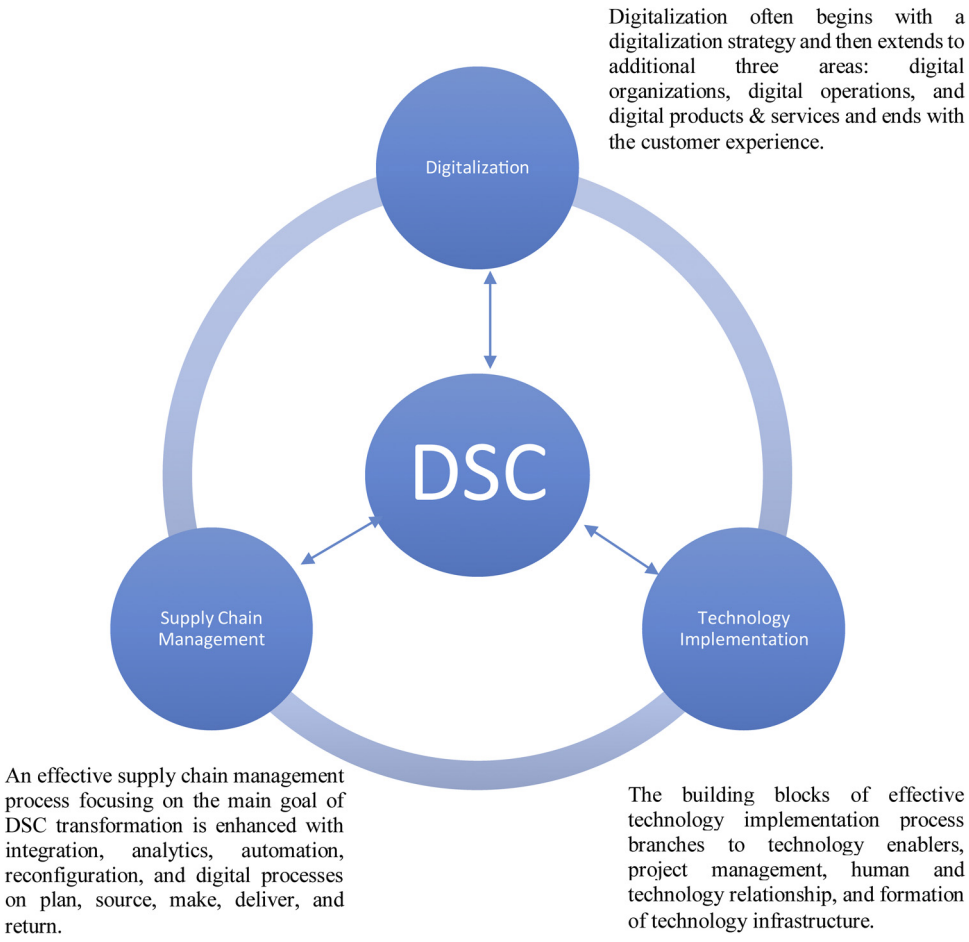

Fig. 4. A framework for the development of DSC.

their digitalization policy and focus on improving their digitalization capabilities they are going to build. It is not only important to survive the digitalization megatrend but also to use it to their advantage [107].

By establishing the first stage of DSC, we can further decompose the digitalization stage which commences with ***Digitalization Strategy***. This process then extends to additional three areas: ***Digital Organizations & Culture***, ***Digital Operations*** and ***Digital Products & Services***. It then ends at customers by improving the service levels and ***Digital Customer Experience*** to know them better [108]. Thus, the goal of an effective digitalization process can be decomposed into five distinctive sub-goals, each of which presenting the stages of the digitalization process. They are dependent on the successful execution of the respective methodologies. The framework for the digitalization of DSC is presented in Fig. 6.

The ***Digitalization Strategy*** is an important step. Supply chains would focus solely on solving current problems if they lack crucial strategic instruments. This results in a failure to generate continuous gains for their stakeholders. But most likely supply chains don't have a clear digital strategy. This situation has built an untenable condition for many supply chains, considering that digital technology is increasingly interwoven into the very fabric of most establishments and organizations. Newest digital technologies provide an opportunity to enhance how supply chains compete and create a foundation for outperforming rivals near and far [109,110]. As further decomposition of digitalization stage is followed, digitalization is branched into ***Digital Goal Setting***, ***Digital Strategy Formulation***, and ***Digital Strategy Implementation***. Defining ***Digital Goal Setting*** is an important step that decides on what digital strategy wants to achieve in and separates what's important from what's irrelevant, or a distraction in digitalization based on successful achievement of these goals. The ***Digital Strategy Formulation*** process refers to the process of selecting the best fitting objective in realization of supply chains' goals and so accomplish its vision [111]. The ***Digital Strategy Implementation*** addresses the questions of "how, when, where, and who" to reach the intended objectives and goals, thus focusing on the entire supply chain.

The ***Digital Organization & Culture*** is the second stage in digitalization. When all digital thinking individuals and organizations come together, common intelligence on digitalization can be reached. Nowadays the discussion is about consumers being digitalized, who demand novel digital products and services each passing day. First, there is a need for highest level (c-level) executives who understand and grasp this transformation notion. Executives who define their organizations' digital vision, mission, planning and aims need to promote digital managers and employees. Further decomposition of digital organization & culture is reduced to ***Analysing of the Current Organization & Culture, Digital Organization & Culture Management and Transform into Digital Organization & Culture.*** Organizational culture is like an employee's attitude and is a strong determining factor in its adaptability. If the established culture resists to change, the result will be a divided organization: one part moving into the future, the other part clinging to the traditional past, leading to delays for the much needed transformation [112]. Thus, first step is assessing the current situation of organization and culture in terms of its

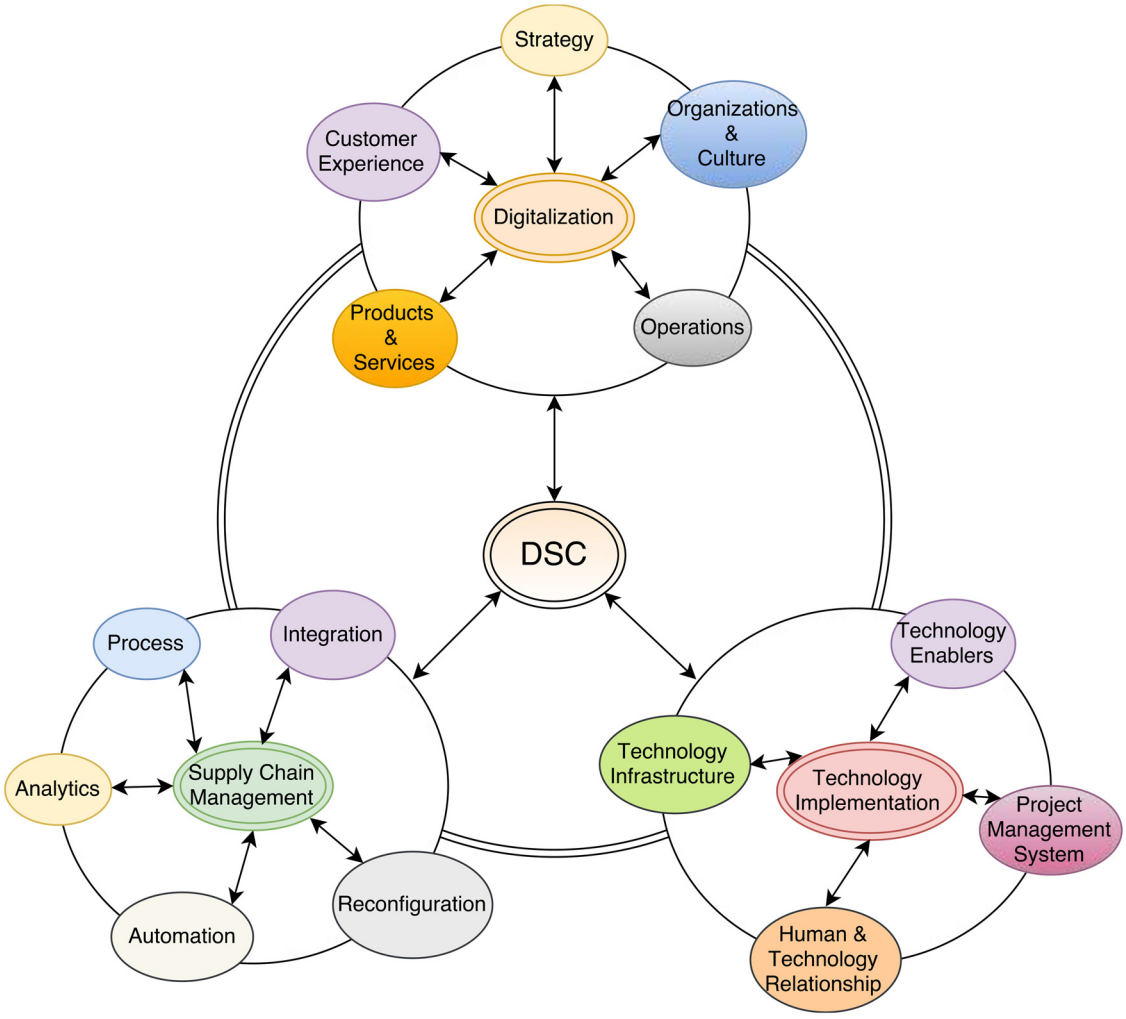

Fig. 5. Integration framework for the development of DSC.

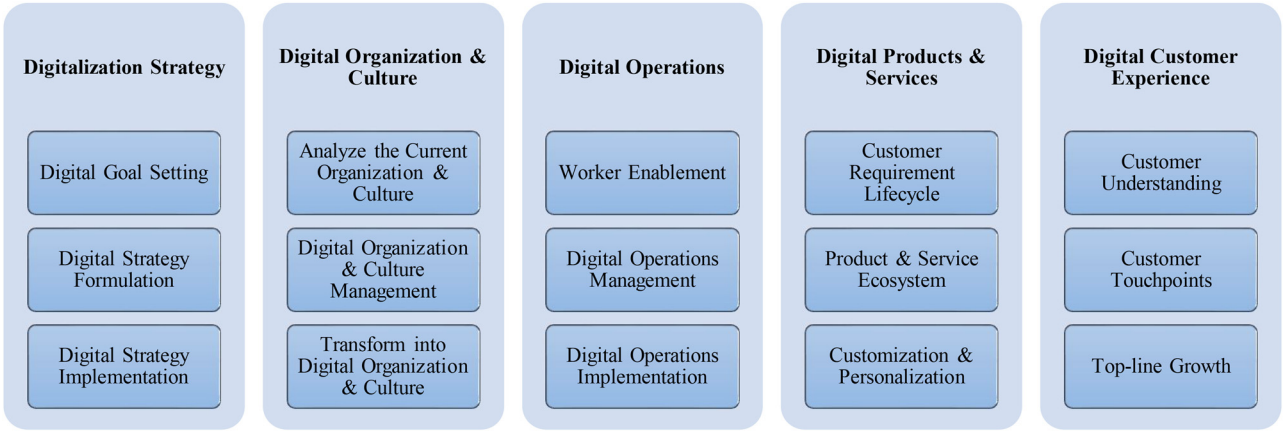

Fig. 6. Decomposed framework for the digitalization of DSC.

digitalization aspects. After this analysis is done, digitalization has to be managed and fully transformed into DSC. In today's digital era, change happens at tremendous speeds. Supply chains need to analyze and rethink their organizational structure in order not to fall behind in the competition. Organizations will lose their business to competitors if they cannot keep up and respond rapidly. It is decisive, therefore, to implement a digital organization strategy and initiate the digital evolution sooner rather than later and develop a digital organizational structure. Built on this foundation, supply chains can develop their own digital vision, design new digital organizational models and decide on acquiring strategies for the necessary skills and capabilities of digitalization [108].

Some key things must happen to achieve digital transformation as a part of ***Digital Operations***. Advanced digital solutions, powered by the BD, CC, etc. and supported by IoT or ST, etc., can expand supply chain processes in numerous ways. For instance, BD can assist in-bound logistics to run more smoothly by tracking the movement of goods and services; CC can be useful in creating uniform business processing platforms; and mobile technologies can support people to perform their work anywhere, anytime and on any device [113]. Supply chains should be able to evolve at the same pace and adapt more swiftly to continuous, instant and prompt changes. Supply chains also need to support workers' freedom and flexibility to work anywhere, anytime, and on any device, to improve their performance and apply the decided strategy [108]. "**Worker Enablement, Digital Operations Management and Implement Digital Operations**" attributes are defined in digital operations stage. ***Worker Enablement*** could be described, in essence, as the virtualization of individual level work. It separates the work process from the location of the work with the accumulative usage of email and digital communication and collaboration tools, etc., employees can now communicate with costumers or colleagues who might have never met face to face or in areas they have never been. ***Digital Operations Management*** is where transactional systems offer managers deeper knowledge of a specific product, region and consumers, allowing decisions to be taken on actual data and not on assumptions. It makes it possible to compare status across several areas and adjust capacities, thus making it possible to take better decisions about how to manage performance and prioritize. ***Implement Digital Operations*** strategy differs from operations management. There are two perspectives on implementing operations strategy such as: Structure and System Implementation, and Monitor and Improve Implement Operations. This establishes the efficient set of operations strategies. Implement Operations is totally different from employees and operations management. This step finalizes the digital operations stage.

Almost every successful supply chain has put novel digital products and services to its center. At the same time, service design practices expand by the ubiquity of digitalization. The rhythm and structure of the customer experience has been changed by this wave of new ***Digital Products & Services*** [114]. This stage is further decomposed into ***Customer Requirement Lifecycle, Product & Service Ecosystem, and Customization & Personalization***. The gap in the long-term service experience is bridged and effectively extended to the lifetime of the customer relationship by the digital products and services. The second attribute in which the digital services or products are woven into the ecosystems of other services and products to be more viable. Thus, services and products comprise a broader services and brand experiences. Customization & Personalization are the building blocks of novel digitally-enhanced products and services. This makes it possible to deliver individual experiences to large numbers of groups.

The ***Digital Customer Experience*** is not a guesswork. It is rather about the exploration of customers, their behaviors, their personalities and expectations. DSC can only develop when executives are armed with this information. Developing DSC requires a transformation of the entire customer experience. Several ways in which DSC is transforming customer experience include: social media exploration in understanding customer dissatisfaction and satisfaction, use of digital media for brand promotion, online community building to build loyalty with clients, making products that improve branding in lifestyle communities, structuring analytical capabilities to get to know customers more in detail, technology usage to improve communication in-person sales, integration of customer purchase data to offer better and personalized sales and customers services, etc. [113]. ***Customer Understanding*** is where organizations are starting to take full advantage of former investments in system to gain in depth understanding of analytics based segmentations, market segments, specific geographies, and socially informed knowledge. ***Top-Line Growth*** is where organizations are applying digitalization to enhance in-person sales discussions, improve predictive marketing and streamline customer processes. ***Customer Touchpoints*** are where organizations services can be enhanced drastically by digital initiatives, provide customer services, cross channel coherence and self-service.

5.2. Technology implementation

The Technology Implementation process differs from Digitalization process given that this goal focuses on the successful implementation acquired by the DSC efforts. Technology implementation process leverages technology enablers in the DSC. These key technologies – some mature, some emerging – now serve as the foundational building blocks in the new DSC ecosystem. Taking a holistic view across all these enablers can help maximize business benefits and unlock new forms of value in the coming years. Introducing technological change into an organization presents a different set of challenges. In a market that is increasingly driven by technological enablers, supply chains need to implement the hottest innovative solutions to keep their competitive edge and access new opportunities in fresh markets. This is an ongoing process to keep supply chains up-to-date, but this also takes a certain time. Thus, it branches to Management Process, Human and Technology Relationship, the Formation of Technology Infrastructure, and Technology Enablers. These goals are the building blocks of effective ***Technology Implementation*** process. Fig. 7 present the decomposed framework for the technology implementation of DSC

Technology implementation requires ***project management***. Every implementation methodology should include a detailed description of which tasks need to be accomplished and which equipment need to be acquired during the implementation period. This sophisticated planning helps a DSC to anticipate costs, avoid delays and minimize disruptions in work processes that are caused by previously used technologies. Workforces can also benefit from team work during the implementation and evaluation [115].

Human and technology relationship is another goal of effective technology implementation process. People and technology go hand-in-hand. The human evolution has made technology evolve, which helps people to be more adaptable. People need social interactions for their survival and technology plays a pivotal role in this. The human dependency on technology is growing at an exponential rate. In the coming decades technology will dominate the way humans interact [116]. Using novel technological means could be counterproductive if the workforce is not fully prepared to operate and take control of new resources. Therefore, proper training and adaptation of human and technology is a priority. The human and technology relationship should also include ***user training, interaction and collaboration*** sub-goals in order to be effective [117].

Almost all novel technologies create a different set of risks and new types of vulnerabilities. The technology implementation process should take these into account and define the necessary steps to establish the ***technology infrastructure***. Defining the nature of the infrastructure during the implementation process can also help better define the technological requirements and priorities [118,119]. Formation of a technology infrastructure is especially important for any supply chain looking to move to the next level by taking the steps needed to transform digitally. If a company wants to shift out of survival mode and take the next step towards becoming a big successful company, the technology infrastructure is needed to support this growth [120].

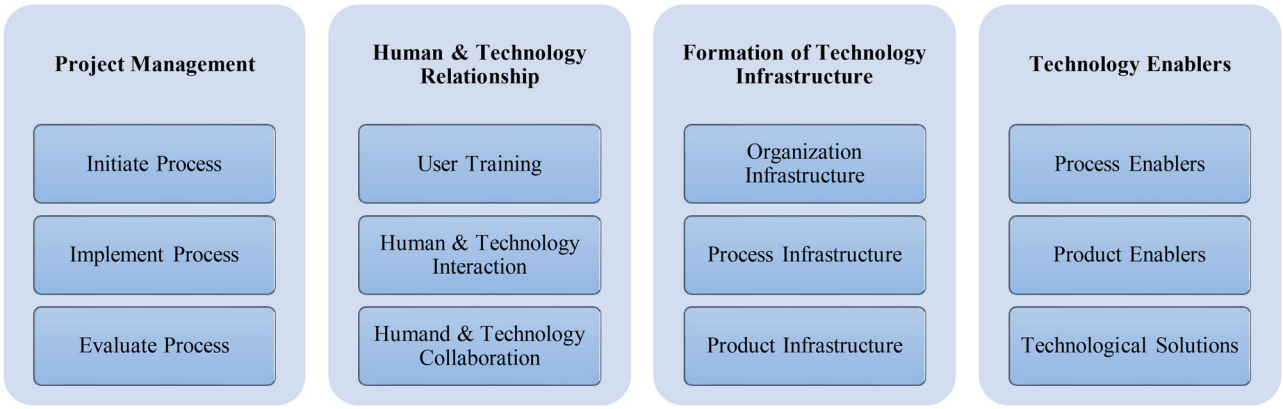

Fig. 7. Decomposed framework for the technology implementation of DSC.

The last goal in a technology implementation process is defining the technology enablers. Depending on the nature of the organization, these can be a need to support the achievement of the organization's strategy, enable implementation within appropriate timescale, or identify alternative ways for a new technological niche. After determining desired requirements, the basic strategy shall be defined to achieve the intended goals [121].

5.3. Supply chain management

Redesigning a supply chain system to achieve a set of strategic objectives involves making a series of complex decisions over time. Making these decisions in a way that supports supply chains' high-level objectives requires an understanding of how detailed design issues affect the interactions among various components of a supply chain system [69]. This consecutive goal of development for DSC is an effective ***supply chain management*** process which focuses on the main goal of DSC transformation. This process is enhanced with digitalization and technology implementation. ***Integration, Automation, Reconfiguration, Analytics and Process*** goals and their sub-goals are determined given that supply chain management process follows a course and each step depends on its antecedent. Fig. 8 presents the decomposed framework for the supply chain management of DSC.

Few authors have considered ***supply chain integration*** through multiple stage constructs. Different stages are used to characterize the supply chain integration concept. Sahin and Robinson [122,123] proposed the degree of information sharing and decision-making coordination as two major stages of supply chain integration at the operational level. Lee outlined three different stages of supply chain integration: information integration, coordination and resource sharing and organizational relationship linkage. Bagchi [124] categorized supply chain integration into five interrelated stages: information sharing and communication across the supply chains, collaboration and shared decision making with network partners, collaboration leading to risk, cost and gain sharing, sharing of skills, ideas and institutional culture and organization [125]. A truly integrated supply chain does more than just cost reduction. It also creates value for organizations, their partners, and their shareholders. ***Information sharing*** is the foundation for the integration. The next dimension is the ***coordination and resource sharing***, then comes the ***organizational linkages*** which enable sharing of risks, costs, and gains [126].

Automation is something that should be further embraced, not feared. Accuracy is critically important for the supply chain as small mistakes can have large impacts for the entire organization. Additionally, with goods and services crossing many borders, supply chain managers must keep compliance and regulation on top of their agenda [127]. Thus, it branches into ***Robotic Technologies, Process Automation and Intelligent Processes.*** Automation is an intelligent organizational process that delivers responsiveness and agility which is created as an outcome of effective usage of robotics technology. Through automation, supply planning, forecasting, sales, connection, replenishment, manufacturing, distribution activities and procurement, etc. become seamlessly automated and straight forward processes.

Many organizations have reconfigured their supply chain during the last decade. The most prominent drivers behind this trend have been global competition, increased focus on market

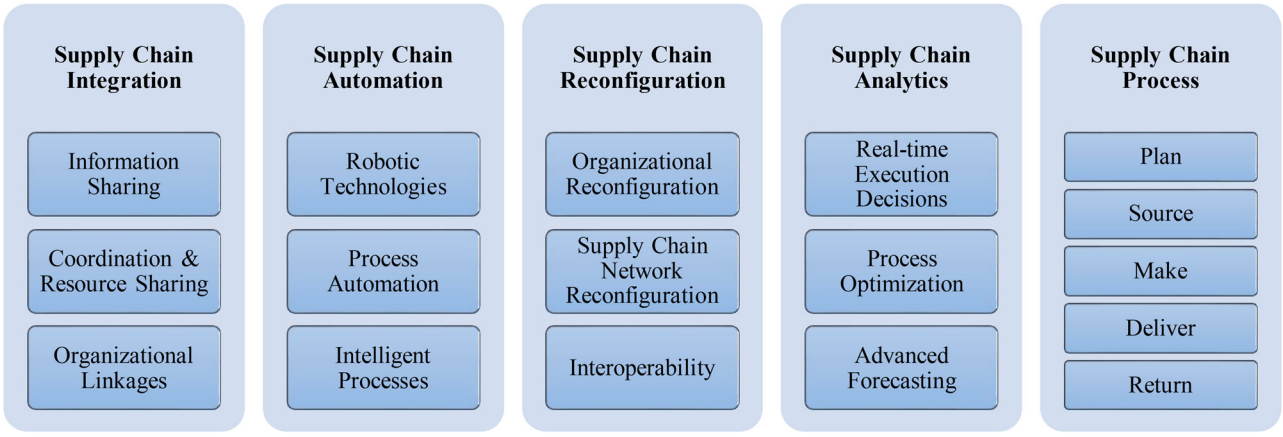

Fig. 8. Decomposed framework for the supply chain management of DSC.

requirements, advances in information and communication technology, and development in international freight transport systems [128]. Digital requirements also force organizations to reconfigure their supply chains. Therefore, ***supply chain reconfiguration*** process is decomposed into three sub-goal: ***Organizational reconfiguration***, which is needed to change the structural boundaries of the organizations, ***Network reconfiguration***, which is needed to minimize the risk in supply chain under integrated digital technology, and ***Interoperability***, which enables discoverability and interaction in the supply chains and is capable of improving the supply chain performance in the presence of risk.

In classical supply chains, standard reporting is commonly made via spreadsheets. Such practices are not sufficient to achieve competitive advantage. Supply chains that use data for inventory planning and forecasting across their distribution networks can acquire additional advantages from advanced analytics [69]. ***Supply Chain Analytics*** is also decomposed into three sub-goals: ***Real-Time Execution Decisions***, which gives a competitive edge, ***Process Optimization***, which allows effective and efficient reaction, and ***Advanced Forecasting***, which makes the process more accurate, reliable, and less costly.

The Supply Chain Operations Reference (SCOR) model was developed by the Supply Chain Council with the help of seventy of the world's leading manufacturing companies. The SCOR model is a management tool used to address, improve, and communicate supply chain management decisions within a company, its suppliers and customers [129]. It helps to explain the processes along the entire supply chain and provides a basis for how to improve those processes. It has been described as the most promising model for strategic decision making in supply chains [130]. ***Supply Chain Process*** focuses on five areas of the supply chain: ***plan, source, make, deliver, and return.*** These areas repeat again and again along the supply chain.

6. Managerial implications

"Digital Supply Chain" is one of latest hottest buzzwords in the industry. Specialists proclaim that digitalization will revolutionize logistics industry and supply chain management. Current investment in technology suggests DSC's importance; supply chain executives expect DSC to bring substantial economic benefits. Supply chain in itself is a business, rather than a department within a business and digital enterprises rely on DSCs [131]. Organizations with DSC and highly digital operations can expect 4.1% annual efficiency gains while boosting revenue by 2.9% per year [94]. Companies cannot opt-out digital transformation and expect to survive. A recent study by MIT and Capgemini attaches significant competitive advantage to companies that are on the leading edge of this transformation. Those companies that do have a strong vision perform the best, while laggers are already declining [132]. Still, some practitioners fear that the importance of DSC is exaggerated and perceives it as a little more than an extension of conventional logistics and supply chains structure. Studies and research from supply chain point of view to digitalization is lacking, like many other popular topics. There are very few publications that discuss the challenges of using DSC, or better yet, that explore the opportunities for new practices and theories that DSC might bring about. In fact, there is practically no consistency in defining DSC, categorizing its aim, or establishing its function in supply chain management.

This study poses some questions here which stem from a need to better understand the role of digitalization in supply chains. It reviews DSC approaches from both academic and industrial points of view. Agile Elephant consulting firm defines digital transformation as the process of shifting organizations from legacy approaches to new ways of working and thinking using digital, social, mobile and emerging technologies. This involves a change in leadership, different thinking, encouragement of innovation and new business models, incorporating digitalization of assets and an increased use of technology to improve the experience of organizations' employee, customer, supplier, partner and stakeholder [133]. 75% of retailers and manufacturers describe online data as a key for effective supply chains, but most of them still insist on sharing the information via fax and phone [134]. This small example shows that there still exists a huge gap between what organizations expect to have of DSC and their preparedness for participation. The study then extends to understanding how closely scientific views correspond to definitions of DSC. Further, it is discussed how supply chain executives use DSC to expose DSC's technology enablers and key success factors. These key enablers and success factors described here suggest that DSC makes services more valuable, accessible and affordable with consistent, agile and effective outcome in supply chain structure. The key here is digitalization, which offers both flexibility and efficiency. Apart from the apparent hype around DSC, it is mostly argued solely from the eye of the customers. However, this is only a part of the story. As it progresses from strategy to execution, it is quite significant for organizations to concretely target DSC outcomes. Consequently, the goal is set as digitalization for supply chains since the main goal of the development framework is to provide guidelines for successful DSC management. Thus, the adoption of the development framework can help supply chains transform to a technology driven DSC and to keep up with the industry in terms of performance improvement. To move the innovative concept of DSC in the complex environment of the supply chains towards new frontiers, further efforts in practice and science are indispensable.

The purpose of this study is to provide an insight to the DSC through investigating existing DSC literature in both academic and industrial world and, therefore, to identify the appropriate factors and means to propose a new development framework. Since the inevitable trend of digitalization in all areas of business and daily life, DSC have been the prominent to avoid rigidity or inefficiency and to achieve competitive advantages. This is a focused literature review prepared after analysing 105 articles related to the DSC. The academic literatures are analysed based on research subject, objective, methods and their contribution to the academia. Then reviewed result is presented to establish foundation for the development framework for DSC. The review reveals that: several problems in current DSC literature have been identified as profound non-existence of DSC framework; the reviewed papers' identification of eleven main features of DSC, their components and technologies, ten DSC challenges and fifteen DSC success factors; increasing the significance of specific guidance or integrated methodologies on need of DSC in supply chain literature. Then, a comprehensive DSC development framework has been developed. To the best of our knowledge, this is the first focused study that reviews the DSC in detail, comparing the outcome of the analysis, identifies current DSC literature problems and gaps, new DSC trends and shifts in the way that DSC are evaluated and typical supply chains are transformed into DSC proposing a new holistic DSC development framework. In addition, it identifies future research trends. Hence, the primary aim of our research agenda in Fig. 1 is to develop the state of practice development framework by applying a systematic literature review and analysis in this paper. Thus, the authors believe that this review and classification provides valuable insight for academics and practitioners about the importance of DSC which can then be adapted, explored and expanded for transforming supply chain organizations. In addition, the ways information and technology are consumed and delivered through CC, BD, and IoT, etc. are transforming how organizations compete. If any supply chain organization wants to survive and compete with others, they

should implement digitalization in their supply chains and become a DSC. In conclusion, the presented framework can be employed as a strategic assessment instrument by academics and practitioners to measure their supply chain performance in a DSC environment, and/or the development framework can be further stretched to creating a novel DSC structure from scratch. Consequently, the next step would be to implement the proposed framework in a typical supply chain with real requirements; which would provide a better comprehension of the limitations and further modifications required for the refinement of this framework.

6.1. Discussion on DSC concept

Digitalization has touched upon all aspects of organizations. SC and logistics are no exception. Today, an emerging worldwide trend in supply chain management is a focus shift from the classical supply chain to DSC. Technological means such as IoT, CC, BD etc. empower organizations to transform their existing 'traditional paper-based' or 'hybrid combination of technology' supported processes of SC structure into collaborative digital models with higher flexibility, agility, and openness. Unlike existing SC structures, which have resulted in rigid organizational configurations, inaccessible data and fragmented relationships with partners, DSC enables process automation, flexibility and digital management for corporate assets. Examples of this trend are visible in various technologies such as RFID, GPS and ST. In a supply chain, the aim is to get the right item, at the right time, in the right place, in the right quantity, in the right condition, and at the right (low) cost. This could be accomplished with DSC to address today's customer demands.

Selecting the most suitable technological solutions and reaping the maximum benefits of the digital means requires supply chains to internalize digitalization as an integral part of their overall operations methodology and their organizational structure. Localized, detached initiatives, and rigid silo-based operations pose severe threats to competitiveness in an increasingly digital world. Authors believe that a comprehensive approach to digital evolution of supply chain starts with a digitalization and technology implementation process which will set the direction for DSC management to reach its goal. Having DSC will not only enable any organization to grasp the untapped potential of their existing capability, but also to achieve higher performance and ultimately create greater value. The next generation supply chains must be stronger and more agile. They must be able to have the right people and skill sets, processes, and tools in the right places to drive efficiency and effectiveness. To achieve these objectives, supply chains must work on initiatives that will prepare them for the digital era. Meanwhile, technologies such as CC, BD and IoT will be adopted by more and more supply chain managers. Opinions and insights of this review can be used by academics and practitioners for applying digitalization notions in supply chains and logistics. Hence, researchers and business managers can extend this area of research by upgrading and transforming the classical supply chain understanding into a DSC. Based on the review and findings of this study, we recommend future research in the implementation of DSC industry application. All other aspects of DSC should also be examined with real data, especially implementation of development framework, as well as digital transformation of a specific industry application.

6.2. Limitations and further research trends

This review paper is a state-of-the-art study within the given field of research on DSC. Thus, it summarizes prior research on DSC, critically consolidates and examines the contributions of past research. However, this paper has a number of limitations. The following areas summarize these potential limitations:

- Collated documents in this literature review are based mainly on findings from academic journals or industrial reports (See Fig. 2). The inclusion of additional academic journals in the future can enhance this review's findings.
- The findings of this review are based on the search of mentioned databases by providing the input keywords. Since search is very sensitive to these keywords, studies which have slightly different inputs may be left out.
- It is significant to illuminate that, in this paper, a systematic literature review methodology has been applied in which each database is searched separately and the collected documents are selected just before the analysis steps. A different approach can be used for collating these documents found in databases.
- The review period spanned over the last 6 years (2002–2017). We deem this is demonstrative of the related literature on methodologies for DSC. Even though the findings are not exhaustive, we consider that they are comprehensive as they cover many highly ranked academic journals.
- The illustrated DSC framework aims at deploying the integration among digitalization, technology implementation and supply chain management. We have not included the further decomposition of the DSC model, since it is out of scope of our research.

Not forgetting the aforementioned limitations, the following future research trends on DSC are based on an elaborate literature review as well as the past working experience of authors. Further analysis of these suggestions can generate novel knowledge and robust theories in the area. Therefore, the following areas are proposed:

- This study recommends further research into industrial real-case applications for the proposed DSC framework, which is illustrated in Fig. 4.
- Companies from different industrial backgrounds have their own methodologies for DSC, depending on their specific purpose of using novel digital technologies. Therefore, key trends for future DSC necessitates a distinct roadmap for each to improve the digital transformation of its DSC tasks. The presented classification can, therefore, be further enhanced to inform both academic and practitioners by making sub-frameworks for each industry.
- Digitalization will transform the way supply chains operate. In order to suitably implement and verify the development framework, presented stages should be followed and assessed in a typical supply chain.
- Even though the advantages and limitations of DSC have been discussed at an academic level, further enhancements are still required in several areas of DSC in order to provide a robust, reliable and flexible solution for practical implementation of DSC into industrial real-case applications.
- Furthermore, the benefits and challenges of DSC can be explored to better understand the feasibility and effectiveness of the proposed framework.
- Finally, the components and technologies of DSC can be integrated to other existing supply chain related studies in both academic publications and industrial reports.

DSC is very far from deploying its full potential, and, as noted in this research, there are a number of areas that require immediate attention.

7. Concluding remarks

This study deals with the digitalization of supply chains, a topic of great interest both for practitioners and researchers. It is well-

written and organized in a consistent structure which helps to highlight the main proposal, based on an approach for the development of a DSC. The results of this study aim to answer the questions such as what the current state of DSC is in the academic and industrial studies, as well as what the DSC future developments look like, and how the existing importance of digitalization can be integrated into supply chain or logistics, etc. In order to describe the state-of-the-art of within the DSC field, a summary of the papers is provided, knowledge gaps in the given research stream is identified and the characteristics of past research are consolidated. In addition to this extensive discussion on future trends on DSC, a DSC framework is developed according to the advantages, weaknesses and limitations of existing DSC literature. It intends to fill the gap of past studies regarding the construction of a complete conceptual or theoretical framework. The proposed framework aims at identifying the features, components and technology enablers, challenges and success factors for developing a DSC. Hence, the present review and framework can provide insights to both academicians and practitioners in their application of DSC. In terms of future research of this study, the three main stages of DSC are integrated into the development framework. Further research is needed to evaluate and assess the relative prominence of the framework stages, to be implemented and verified in a typical supply chain.

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References

[1] S. Penthin, R. Dillman, Digital SCM, www.bearingpoint.com, Germany, 2015.
[2] S. Tiwari, H.M. Wee, Y. Daryanto, Big data analytics in supply chain managementbetween 2010 and 2016: Insights to industries, Comput. Ind. Eng. 115 (2018) 319–330, doi:http://dx.doi.org/10.1016/j.cie.2017.11.017.
[3] P. Farahani, C. Meier, J. Wilke, Digital supply chain management agenda for the automotive supplier industry, Shap. Digit. Enterp., Springer International Publishing, Cham, 2017, pp. 157–17210.1007/978-3-319-40967-2_8.
[4] E. Hofmann, M. Rüsch, Industry 4.0 and the current status as well as future prospects on logistics, Comput. Ind. 89 (2017) 23–34, doi:http://dx.doi.org/10.1016/j.compind.2017.04.002.
[5] M. Merlino, I. Sproģe, The augmented supply chain, Procedia Eng. 178 (2017) 308–318, doi:http://dx.doi.org/10.1016/j.proeng.2017.01.053.
[6] M.A.A. Majeed, T.D. Rupasinghe, Internet of things (IoT) embedded future supply chains for industry 4.0: an assessment from an ERP-based fashion apparel and footwear industry, Int. J. Supply Chain Manag. 6 (2017) 25–40.
[7] T. Nguyen, L. ZHOU, V. Spiegler, P. Ieromonachou, Y. Lin, Big data analytics in supply chain management: a state-of-the-art literature review, Comput. Oper. Res. (2017), doi:http://dx.doi.org/10.1016/j.cor.2017.07.004 ISSN 0305-0548 (http://www.sciencedirect.com/science/article/pii/S0305054817301685).
[8] M. Ben-Daya, E. Hassini, Z. Bahroun, Internet of things and supply chain management: a literature review, Int. J. Prod. Res. (2017) 1–24, doi:http://dx.doi.org/10.1080/00207543.2017.1402140.
[9] K. Korpela, J. Hallikas, T. Dahlberg, Digital supply chain transformation toward blockchain integration, Proc. 50th Hawaii Int. Conf. Syst. Sci. (2017) 4182–4191. http://hdl.handle.net/10125/41666.
[10] R. Michel, The evolution of the digital supply chain, Logist. Manag. (2017) 1.
[11] V. Scuotto, F. Caputo, M. Villasalero, M. Del Giudice, A multiple buyer–supplier relationship in the context of SMEs' digital supply chain management, Prod. Plan. Control. 28 (2017) 1378–1388, doi:http://dx.doi.org/10.1080/09537287.2017.1375149.
[12] M. Vanderroost, P. Ragaert, J. Verwaeren, B. De Meulenaer, B. De Baets, F. Devlieghere, The digitization of a food package's life cycle: existing and emerging computer systems in the logistics and post-logistics phase, Comput. Ind. 87 (2017) 15–30, doi:http://dx.doi.org/10.1016/j.compind.2017.01.004.
[13] G. Buyukozkan, F. Gocer, An extention of ARAS methodology based on interval valued intuitionistic fuzzy group decision making for digital supply chain, 2017 IEEE Int. Conf. Fuzzy Syst., IEEE (2017) 1–6, doi:http://dx.doi.org/10.1109/FUZZ-IEEE.2017.8015680.
[14] G. Buyukozkan, F. Gocer, An extension of MOORA approach for group decision making based on interval valued intuitionistic fuzzy numbers in digital supply chain, 2017 Jt. 17th World Congr. Int. Fuzzy Syst. Assoc. 9th Int. Conf. Soft Comput. Intell. Syst., IEEE (2017) 1–6, doi:http://dx.doi.org/10.1109/IFSA-SCIS.2017.8023358.
[15] R. Addo-Tenkorang, P.T. Helo, Big data applications in operations/supply-chain management: a literature review, Comput. Ind. Eng. 101 (2016) 528–543, doi:http://dx.doi.org/10.1016/j.cie.2016.09.023.
[16] A. Gunasekaran, T. Papadopoulos, R. Dubey, S.F. Wamba, S.J. Childe, B. Hazen, et al., Big data and predictive analytics for supply chain and organizational performance, J. Bus. Res. 70 (2017) 308–317, doi:http://dx.doi.org/10.1016/j.jbusres.2016.08.004.
[17] B.T. Hazen, J.B. Skipper, J.D. Ezell, C.A. Boone, Big data and predictive analytics for supply chain sustainability: A theory-driven research agenda, Comput. Ind. Eng. 101 (2016) 592–598, doi:http://dx.doi.org/10.1016/j.cie.2016.06.030.
[18] M. Kumar, G. Graham, P. Hennelly, J. Srai, How will smart city production systems transform supply chain design: a product-level investigation, Int. J. Prod. Res. 54 (2016) 7181–7192, doi:http://dx.doi.org/10.1080/00207543.2016.1198057.
[19] T. Papadopoulos, A. Gunasekaran, R. Dubey, N. Altay, S.J. Childe, S. Fosso-Wamba, The role of Big Data in explaining disaster resilience in supply chains for sustainability, J. Clean. Prod. 142 (2017) 1108–1118, doi:http://dx.doi.org/10.1016/j.jclepro.2016.03.059.
[20] L. Wu, X. Yue, A. Jin, D.C. Yen, Smart supply chain management: a review and implications for future research, Int. J. Logist. Manag. 27 (2016) 395–417, doi:http://dx.doi.org/10.1108/IJLM-02-2014-0035.
[21] K.-J. Wu, C.-J. Liao, M.-L. Tseng, M.K. Lim, J. Hu, K. Tan, Toward sustainability: using big data to explore the decisive attributes of supply chain risks and uncertainties, J. Clean. Prod. 142 (2017) 663–676, doi:http://dx.doi.org/10.1016/j.jclepro.2016.04.040.
[22] R. Zhao, Y. Liu, N. Zhang, T. Huang, An optimization model for green supply chain management by using a big data analytic approach, J. Clean. Prod. 142 (2017) 1085–1097, doi:http://dx.doi.org/10.1016/j.jclepro.2016.03.006.
[23] R.Y. Zhong, S.T. Newman, G.Q. Huang, S. Lan, Big Data for supply chain management in the service and manufacturing sectors: challenges, opportunities, and future perspectives, Comput. Ind. Eng. 101 (2016) 572–591, doi:http://dx.doi.org/10.1016/j.cie.2016.07.013.
[24] G. Wang, A. Gunasekaran, E.W.T. Ngai, T. Papadopoulos, Big data analytics in logistics and supply chain management: certain investigations for research and applications, Intern. J. Prod. Econ. 176 (2016) 98–110, doi:http://dx.doi.org/10.1016/j.ijpe.2016.03.014.
[25] B. Cortés, A. Boza, D. Pérez, L. Cuenca, Internet of things applications on supply chain management, Int. J. Comput. Electr. Autom. Control Inf. Eng. 9 (2015) 2204–2209.
[26] R.-Y. Chen, Autonomous tracing system for backward design in food supply chain, Food Control 51 (2015) 70–84, doi:http://dx.doi.org/10.1016/j.foodcont.2014.11.004.
[27] S. FossoWamba, S. Akter, Big data analytics for supply chain management: a literature review and research agenda, Lect. Notes Bus. Inf. Process. (2015) 61–72, doi:http://dx.doi.org/10.1007/978-3-319-24626-0_5.
[28] Z.D.R. Gnimpieba, A. Nait-Sidi-Moh, D. Durand, J. Fortin, Using internet of things technologies for a collaborative supply chain: application to tracking of pallets and containers, Procedia Comput. Sci. 56 (2015) 550–557, doi:http://dx.doi.org/10.1016/j.procs.2015.07.251.
[29] N. Gospic, B. Bakmaz, Machine-to-Machine communications toward smart logistics systems, 2nd Logist. Int. Conf., Belgrade (2015) 191–196.
[30] E. Hofmann, Big data and supply chain decisions: the impact of volume, variety and velocity properties on the bullwhip effect, Int. J. Prod. Res. 7543 (2015) 1–19, doi:http://dx.doi.org/10.1080/00207543.2015.1061222.
[31] N.K.G. Isasi, E.M. Frazzon, M. Uriona, Big data and business analytics in the supply chain: a review of the literature, IEEE Lat. Am. Trans. 13 (2015) 3382–3391, doi:http://dx.doi.org/10.1109/TLA.2015.7387245.
[32] R. Mehmood, G. Graham, Big data logistics: a health-care transport capacity sharing model, Procedia Comput. Sci. 64 (2015) 1107–1114, doi:http://dx.doi.org/10.1016/j.procs.2015.08.566.
[33] T. Schoenherr, C. Speier-Pero, Data science, predictive analytics, and big data in supply chain management: current state and future potential, J. Bus. Logist. 36 (2015) 120–132, doi:http://dx.doi.org/10.1111/jbl.12082.
[34] S. Mohr, O. Khan, 3D printing and its disruptive impacts on supply chains of the future, Technol. Innov. Manag. Rev. 5 (2015) 20–24. http://timreview.ca/article/942.
[35] K.H. Tan, Y. Zhan, G. Ji, F. Ye, C. Chang, Harvesting big data to enhance supply chain innovation capabilities: an analytic infrastructure based on deduction graph, Int. J. Prod. Econ. 165 (2015) 223–233, doi:http://dx.doi.org/10.1016/j.ijpe.2014.12.034.
[36] P. Tadejko, Application of internet of things in Logistics–Current challenges, Int. Soc. Manuf. Serv. Manag. Eng. 7 (2015) 54–64, doi:http://dx.doi.org/10.12846/j.em.2015.04.07.
[37] R.Y. Zhong, G.Q. Huang, S. Lan, Q.Y. Dai, X. Chen, T. Zhang, A big data approach for logistics trajectory discovery from RFID-enabled production data, Int. J. Prod. Econ. 165 (2015) 260–272, doi:http://dx.doi.org/10.1016/j.ijpe.2015.02.014.
[38] B.T. Hazen, C.A. Boone, J.D. Ezell, L.A. Jones-Farmer, Data quality for data science, predictive analytics, and big data in supply chain management: an introduction to the problem and suggestions for research and applications, Int. J. Prod. Econ. 154 (2014) 72–80, doi:http://dx.doi.org/10.1016/j.ijpe.2014.04.018.

[39] J. Leveling, M. Edelbrock, B. Otto, Big data analytics for supply chain management, IEEE Int. Conf. Ind. Eng. Eng. Manag., IEEE (2014) 918–922, doi: http://dx.doi.org/10.1109/IEEM.2014.7058772.
[40] I.V. Rozados, B. Tjahjono, Big data analytics in supply chain management: trends and related research, 6th Int Conf. Oper. Supply Chain Manag, Bali, 2014.
[41] X. Wang, N. Liu, The Application of Internet of Things in Agricultural means of production supply chain management, Adv. Mater. Res. 6 (2014) 2304–2310. http://www.scientific.net/AMR.926-930.4118.
[42] B. Bhargava, R. Ranchal, L. BenOthmane, Secure information sharing in digital supply chains, 2013 3rd IEEE Int. Adv. Comput. Conf. (2013) 1636–1640, doi: http://dx.doi.org/10.1109/IAdCC.2013.6514473.
[43] A. Cirulis, E. Ginters, Augmented reality in logistics, Procedia Comput. Sci. 26 (2013) 14–20, doi:http://dx.doi.org/10.1016/j.procs.2013.12.003.
[44] E. Ginters, A. Cirulis, G. Blums, Markerless outdoor AR-RFID solution for logistics, Procedia Comput. Sci. 25 (2013) 80–89, doi:http://dx.doi.org/10.1016/j.procs.2013.11.010.
[45] M.A. Waller, S.E. Fawcett, Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management, J. Bus. Logist. 34 (2013) 77–84, doi:http://dx.doi.org/10.1111/jbl.12010.
[46] C. Sun, Application of RFID technology for logistics on internet of things, AASRI Procedia 1 (2012) 106–111, doi:http://dx.doi.org/10.1016/j.aasri.2012.06.019.
[47] J. Wagenaar, The impact of the Internet of Things on revenue in supply chains, 17th Twente Student Conf IT, Netherlands, 2012.
[48] Ç. Aktepe, Lojistik işletemelerinde bulut bilişim uygulamalarının değerlendirilmesi, Dokuz Eylül Üniversitesi, 2015, 2018.
[49] M.E. Aviles, The Impact of Cloud Computing in Supply Chain Collaborative Relationships, Collaborative Advantage and Relational Outcomes, Georgia Southern University, 2015.
[50] F. Kache, Dealing with Digital Information Richness in Supply Chain Management–A Review and a Big Data Analytics Approach, University of Kassel, 2015, 2018. http://www.uni-kassel.de/upress/online/OpenAccess/978-3-86219-926-6.OpenAccess.pdf.
[51] B. Torğul, Nesnelerin İnterneti ile Kapalı Döngü Tedarik Zinciri Optimizasyonu: Yeni Bir Model Önerisi, Selçuk Üniversitesi, 2015.
[52] M. Aikaterini, Impact of IoT Enabled Service Solutions in the Downstream Automotive Supply Chain, KTH University, 2014.
[53] D. Gantzia, M.E. Sklatinioti, Cloud Computing in the 3PL Industry, Jönköping University, 2014.
[54] Z. Pang, Technologies and Architectures of the Internet-of-Things (IoT) for Health and Well-being, KTH – Royal Institute of Technology, 2013.
[55] T. Keller, Mining the Internet of Things: Detection of False-Positive RFID Tag Reads Using Low-Level Reader Data, University of St. Gallen, 2011.
[56] X. Li, Y. Lu, University of GAVLE, Strategy Development of SMEs in the Internet of Things era: Case Study on Chinese Enterprises, 2010.
[57] J. Xu, Managing Digital Enterprise, Atlantis Press, Paris, 2014, doi:http://dx.doi.org/10.2991/978-94-6239-094-2.
[58] M. Skilton, Building the Digital Enterprise, Palgrave Macmillan, UK, London, 2015, doi:http://dx.doi.org/10.1057/9781137477729.
[59] N. Sanders, Big Data Driven Supply Chain Management: A Framework for Implementing Analytics and Turning Information Into Intelligence, Northeastern University, 2014. http://books.google.com.au/books?hl=de&lr=&id=-b2LAwAAQBAJ&oi=fnd&pg=PR6&dq=customer+driven+supply+chain&ots=RNP3I_URAY&sig=GO6InXDjMpl95Upqa-_Rqvmz-cQ.
[60] A. Uhl, L.A. Gollenia, Digital enterprise transformation: a business-Driven approach to leveraging innovative IT, in: A. Uhl, L.A. Gollenia (Eds.), Digit. Enterp. Transform. A Business-Driven Approach to Leveraging Innov. IT, Ashgate Publishin, Ltd., 2014, pp. 1–306.
[61] A. Uhl, L.A. Gollenia, Digital Enterprise Transformation: A Business-Driven Approach to Leveraging Innovative IT, Routledge, 2016.
[62] Y. Wang, E-logistics: Managing Your Digital Supply Chains for Competitive Advantage, Kogan Page, 2016.
[63] G. Oswald, M. Kleinemeie (Eds.), Shaping the Digital Enterprise, Springer International Publishing, Cham, 2017, doi:http://dx.doi.org/10.1007/978-3-319-40967-2.
[64] IBM, The Smarter Supply Chain of the Future, 2009.
[65] M. Raab, B. Griffin-Cryan, Digital Transformation of Supply Chains: Creating Value–When Digital Meets Physical, (2011) .
[66] S. Raj, A. Sharma, Supply Chain Management in the Cloud, (2014) . https://www.accenture.com/tr-en/insight-supply-chain-management-cloud.
[67] L. Cecere, Digital Supply Chain Insights on Driving the Digital Supply Chain Transformation, (2014) .
[68] L. Cecere, Embracing the Digital Supply Chain, Supply Chain Shaman, (2016) February, http://www.supplychainshaman.com/demand/demanddriven/embracing-the-digital-supply-chain/. (Accessed 15 October 2016)..
[69] B. Schmidt, C.M. Wallenburg, S. Rutkowsky, L. Einmahl, I. Petersen, F. Klötzke, Digital Supply Chains: Increasingly Critical for Competitive Edge, (2015) .
[70] J. Kinnet, Creating a Digital Supply Chain: Monsanto's Journey, SlideShare, 2015, pp. 1–16 http://www.slideshare.net/BCTIM/creating-a-digital-supply-chain-monsantos-journey. (Accessed 28 April 2016).
[71] The Digital Supply Chain Initiative, Digital Supply Chains: A Frontsite Flip, Sanya, China, 2015.
[72] P. Guarraia, G. Gerstenhaber, M. Athanassiou, P.-H. Boutot, The Intangible Benefits of a Digital Supply Chain, (2015) .
[73] E. Rakowski, TechTrends 2016, Part II: The Supply Chain Goes Digital, (2015) .
[74] Cerasis, The future of supply chain, logistics & manufacturing: How technology is transforming, 2015. http://cerasis.com/.
[75] Cerasis, Why Supply Chain Leaders Are Using Big Data Analytics, 2015. http://www.industryweek.com/supply-chain-big-data.
[76] EY, Digital supply chain: it's all about that data, 2016.
[77] A. Ganeriwalla, G. Walter, L. Kotlik, R. Roesgen, S. Gstettner, Three Paths to Advantage with Digital Supply Chains, (2016) .
[78] CapGemini, Infor, GTNexus, The Current and Future State of Digital Supply Chain Transformation, 2016. http://www.gtnexus.com/resources/papers-and-reports/current-and-future-state-digital-supply-chain-transformation.
[79] GTnexus, The Internet of Things Supply Chain, GT NEXUS. (2016) 1–6.
[80] DHL Customer Solutions & Innovation, Fair and Responsible Logistics. A DHL perspective on how to create lasting competitive advantage, (2015) 1–40. http://www.dhl.com/en/about_us/logistics_insights/dhl_trend_research/fair.html.
[81] D. Kraemer, Omni-Channel Logistics A DHL perspective on implications, DHL Cust. Solut. Innov. (2015)
[82] M. Jeske, M. Grüner, F. WeiB, Big Data in Logistics, (2013) .
[83] J. Macaulay, L. Buckalew, G. Chung, Internet of Things in Logistics, DHL Cust. Solut. Innov., (2015) , pp. 1–27.
[84] M. Heutger, M. Kuckelhaus, Unmanned Aerial Vehicle in Logistics, (2014) .
[85] T. Bonkenburg, Robotics in logistics, (2016) .
[86] K. Richter, O. Poenicke, Low-Cost Sensor Technology, (2013) .
[87] DHL Trend Research, Self-Driving Vehicles in Logistics, DHL Cust. Solut. Innov. (2014). http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_self_driving_vehicles.pdf.
[88] H. Glockner, K. Jannek, J. Mahn, B. Theis, Augmented Reality, DHL Cust. Solut. Innov., (2014), doi:http://dx.doi.org/10.1145/2656433.
[89] DHL Trend Research, Key Logistics Trends in Life Sciences 2020 +, 2013.
[90] N. Bubner, P. Bodenbenner, J. Noronha, Logistics Trend Radar, (2016) .
[91] M. Kuckelhaus, P.M. Yee, 3D Printing and the Future of Supply Chains, (2016) . http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_trendreport_3dprinting.pdf.
[92] G. Nowak, J. Maluck, C. Sturmer, J. Pasemann, The Era of Digitized Trucking: Transforming the Logistics Value Chain, (2016) .
[93] E. Alvarez, S. Pillsbury, M. Strom, M. Kinder, Connect and Optimize. The New World of Digital Operations, (2016) .
[94] S. Schrauf, P. Berttram, Industry 4.0: How Digitization Makes the Supply Chain More Efficient, Agile, and Customer-focused, Strategy, (2016) . http://www.strategyand.pwc.com/reports/industry4.0.
[95] R. Geissbauer, R. Weissbarth, J. Wetzstein, Procurement 4.0: Are you ready for the digital revolution? (2016) .
[96] B. Brown, J. Sikes, P. Willmott, Bullish on Digital: McKinsey Global Survey Results, Insights Publ., 2013 August, http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/bullish-on-digital-mckinsey-global-survey-results. (Accessed 15 October 2016).
[97] M. Rouse, Digital Supply Chain, Search Manufacturing ERP.com, (2016) 30 March, http://searchmanufacturingerp.techtarget.com/definition/digital-supply-chain?vgnextfmt=print. (Accessed 15 October 2016).
[98] G. Hanifan, A. Sharma, C. Newberry, The Digital Supply Network: A new paradigm for supply chain management, (2014) .
[99] J. Bechtold, A. Kern, C. Lauenstein, L. Bernhofer, Industry 4.0 – The Capgemini Consulting View: Sharpening the Picture beyond the Hype, (2014) .
[100] K. Cukier, Big data and the future of business, in: Turner (Ed.), Reinventing Co. Digit. Age, BBVA, 2015, 2018, pp. 37–51.
[101] M. Heutger, M. Kuckelhaus, Unmanned Aerial Vehicle in Logistics, (2014) .
[102] T. Hines, Supply chain strategies: customer-driven and customer-focused, (2004) .
[103] P.L. Carter, Robert M. Monczka, Gary L. Ragatz, Supply Chain Integration: Challenges and Good Practices, (2009) .
[104] R.G. Richey, T.R. Morgan, K. Lindsey-Hall, F.G. Adams, A global exploration of big data in the supply chain, Int. J. Phys. Distrib. Logist. Manag. 46 (2016), doi: http://dx.doi.org/10.1108/IJPDLM-05-2016-0134.
[105] D.H. Nabben, 12 Trends that are shaping the future of logistics, Digit. Supply Chain, (2016) http://www.supplychaindigital.com/logistics/3610/12-Trends-that-are-Shaping-the-Future-of-Logistics. (Accessed 4 September 2016).
[106] Accenture, Big data analytics in supply chain: hype or here to stay? Accent Glob. Oper. Megatrend Study (2014) 1–20.
[107] Strategy&, Digital strategy and capabilities to win in a digitized world, Strategy&. (2016). http://www.strategyand.pwc.com/global/home/what-we-think/digitization/digital-strategy-capabilities. (Accessed 15 October 2016).
[108] Q. Corver, G. Elkhuizen, A framework for digital business transformation, Cognizant (2014) 1–10. https://www.cognizant.com/InsightsWhitepapers/a-framework-for-digital-business-transformation-codex-1048.pdf.
[109] K.J. Cohen, R.M. Cyert, Strategy: formulation, implementation, and monitoring, J. Bus. 46 (1973) 349–367.
[110] A.K. Srivastava, Modeling strategic performance factors for effective strategy execution, Int. J. Product. Perform. Manag. 62 (2013) 554–582, doi:http://dx.doi.org/10.1108/IJPPM-11-2012-0121.
[111] J. Pradabwong, C. Braziotis, J.D.T. Tannock, K.S. Pawar, Business process management and supply chain collaboration: effects on performance and competitiveness, Supply Chain Manag. An Int. J. 22 (2017) 107–121, doi: http://dx.doi.org/10.1108/SCM-01-2017-0008.
[112] A. Harshak, B. Schmaus, D. Dimitrova, Building a digital culture: How to Meet the Challenge of multichannel digitization, (2013) .

[113] Anastasia, Digital Transformation: What, Why And How, Business, Strateg. Technol. May 1 (2015). https://www.cleverism.com/digital-transformation-what-why-how/. (Accessed 15 October 2016).
[114] Nurun, Digital Product & Services, Nurun Website. (2016). http://www.nurun.com/en/what-we-do/digital-products-services/. (Accessed 15 October 2016).
[115] J.T. Yee, S.C. Oh, Background and introduction, Technol. Integr. to Bus, Springer, London, London, 2013, pp. 1–22, doi:http://dx.doi.org/10.1007/978-1-4471-4390-1_1.
[116] P. Daugherty, No TitleBlending humans and technology in the workforce, Computerweekly.com. (2015) June. http://www.computerweekly.com/opinion/Blending-humans-and-technology-in-the-workforce. (Accessed 15 October 2016).
[117] J. Oyekan, V. Prabhu, A. Tiwari, V. Baskaran, M. Burgess, R. Mcnally, Remote real-time collaboration through synchronous exchange of digitised human–workpiece interactions, Future Gener. Comput. Syst. 67 (2017) 83–93, doi:http://dx.doi.org/10.1016/j.future.2016.08.012.
[118] A. Najmi, H. Shakouri, G.S. Nazari, An integrated supply chain: a large scale complementarity model for the biofuel markets, Biomass Bioenergy 86 (2016) 88–104, doi:http://dx.doi.org/10.1016/j.biombioe.2016.01.010.
[119] B. Klievink, Understanding public-private collaboration configurations for international information infrastructures, Lect. Notes Comput. Sci, Springer, Cham, 2015, pp. 170–180, doi:http://dx.doi.org/10.1007/978-3-319-22479-4_13.
[120] M. Townsend, Priorities for building organizational infrastructure, Mass High Tech. J. New Engl. Technol. 24 (2006) 9740.
[121] E.O. Ibem, S. Laryea, Survey of digital technologies in procurement of construction projects, Autom. Constr. 46 (2014) 11–21, doi:http://dx.doi.org/10.1016/j.autcon.2014.07.003.
[122] F. Sahin, E.P. Robinson, Flow coordination and information sharing in supply chains: review, implications, and directions for future research, Decis. Sci. 33 (2002) 505–536, doi:http://dx.doi.org/10.1111/j.1540-5915.2002.tb01654. x.
[123] F. Sahin, E.P.J. Robinson, Information sharing and coordination in make-to-order supply chains, J. Oper. Manag. 23 (2005) 579–598, doi:http://dx.doi.org/10.1016/j.jom.2004.08.007.
[124] P.K. Bagchi, B. Chun Ha, T. Skjoett-Larsen, L. Boege Soerensen, Supply chain integration: a European survey, Int. J. Logist. Manag. 16 (2005) 275–294, doi:http://dx.doi.org/10.1108/09574090510634557.
[125] R. Alfalla-Luque, C. Medina-Lopez, P.K. Dey, Supply chain integration framework using literature review, Prod. Plan. Control. 24 (2013) 800–817, doi:http://dx.doi.org/10.1080/09537287.2012.666870.
[126] H.L. Lee, Creating value through supply chain integration, Supply Chain Manag. Rev. 4 (4) (2000) 30–36.
[127] R. Barratt, How automation is changing the supply chain, Supply Demand Chain Exec. (2016) https://www.sdcexec.com/warehousing/article/12267524/how-automation-is-changing-the-supply-chain (accessed October 15, 2016).
[128] O.W. Lemoine, T. Skjoett-Larsen, Reconfiguration of supply chains and implications for transport, Int. J. Phys. Distrib. Logist. Manag. 34 (2004) 793–810, doi:http://dx.doi.org/10.1108/09600030410571365.
[129] S.C. Counsil, SCOR Model, Supply Chain Oper. Ref. Model. (2004). http://www.supply-chain.org.
[130] Z.D. Turhan, O. Vayvay, S. Birgun, Supply chain reengineering in a paint company using axiomatic design, Int. J. Adv. Manuf. Technol. 57 (2011) 421–435, doi:http://dx.doi.org/10.1007/s00170-011-3296-4.
[131] S.F. DeAngelis, Digital enterprises rely on digital supply chains, Enterra Solut. (August) (2015) http://www.enterrasolutions.com/2015/08/digital-enterprises-rely-on-digital-supply-chains.html. (Accessed 15 October 2016).
[132] J. Bradach, T.J. Tierney, N. Stone, Delivering on the promise of Digital Transformation, Harv. Bus. Rev. 27 (2014) 275–284.
[133] A.E. Consultancy, What Is Digital Transformation, (2015) http://www.theagileelephant.com/what-is-digital-transformation/. (Accessed 15 October 2016).
[134] N. Tepper, Companies want digital supply chains, but many are slow to act, (2016) b2becommerceworld.com. April 12. https://www.b2becommerceworld.com/2016/04/12/companies-want-digital-supply-chains-many-are-slow-act. (Accessed 15 October 2016).