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Supply chain traceability: a review of the benefits and its relationship with supply chain resilience

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ABSTRACT
There has been considerable recent growth in supply chain (SC) traceability research due to increased Industry 4.0 solutions and the potential of traceability systems to enable SCs to bounce back from a crisis, thereby having a long-term impact on firm/SC performance. However, to date, the relationship between SC traceability and SC Resilience (SCRes) has not been fully explored. Using a systematic literature review, this paper first provides a comprehensive state-of-the-art understanding of traceability to enable an appreciation of the inherent benefits of its implementation and its role in the improvement of SCRes. Building on this understanding, a conceptual framework is developed showing that there is a direct relationship between traceability benefits, such as improved risk awareness, and SCRes. The framework also demonstrates indirect relationships between these benefits and four enablers of SCRes: flexibility, velocity, visibility and collaboration. Finally, a future research agenda is proposed, including further development of this conceptual framework.

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KEYWORDS
Traceability; supply chain resilience; Industry 4.0; blockchain; risk awareness; literature review

1. Introduction

Supply Chains (SCs) have become increasingly complex in recent years resulting in a greater susceptibility to risks, turbulence and disruptions (Pettit, Croxton, and Fiksel 2013). Nearly 65 percent of companies experience at least one disruption a year, and 13 percent of the firms that faced a disruption in 2019 reported over €1million in losses (Business Continuity Institute 2019; Chang, Iakovou, and Shi 2020). The fourth industrial revolution (Industry 4.0) provides potential remedies for these issues. Specifically, it presents a timely paradigm shift for SC management especially with regards to technological innovations/digitalization that enhances an organization's capability of predicting future events and identifying and monitoring real-time events (Ivanov and Dolgui 2020). Industry 4.0 with its associated technologies such as Cyber-Physical Systems (CPS), 3 D Printing, Advanced Robotics, Artificial Intelligence (AI), Unmanned Aerial Vehicles (UAVs), Big Data Analytics (BDA), Blockchain, the Internet of Things (IoT), and Augmented Reality (AR) presents a platform that integrates and transforms SC management with increased end-to-end transparency and connectivity (Fatorachian and Kazemi 2021; Hopkins 2021; Mubarik et al. 2021). Kittipanya-Ngam and Tan (2020) identified efficiency, traceability, sustainability, legal culpability, and e-commerce as the main dimensions of this digitalization era.

Considering the consequences of a disruption on a firm, its SC, and subsequently on human health and safety (Bode et al. 2011; Ringsberg 2014; Stranieri, Orsi, and Banterle 2017), obtaining real-time information to identify and curb disruptions before the escalation of damages has become an important dimension expected of these emerging technologies (Granillo-Macías et al. 2020; Ivanov and Dolgui 2020). In particular, traceability systems have increasingly been considered to be an important tool to improve SC performance in relation to SC risk management because of its ability to obtain, update and transfer information in real time with minimal delays and errors (Ringsberg 2014; Stranieri, Orsi, and Banterle 2017). A robust traceability system has become necessary especially in customer-driven industries where consumer loyalty, trust, and confidence is gained through the assurance of the quality and safety of products (Montet and Dey 2018; Kittipanya-Ngam and Tan 2020). Coupled with the increased availability and accessibility of digital technologies, the demands for transparency and traceability among the SC actors continues to increase making it an effective capability to minimize production and distribution disruptions and further ensure the efficient tracking and tracing of potentially deficient batches in case of any recalls (Montet and Dey 2018; Kittipanya-Ngam and Tan 2020).

Given the link between the effective management of disruptions and traceability, and that both can potentially be supported by the digitalization era, it follows that traceability is an enabler of Supply Chain Resilience (SCRes) – as SCRes has been defined as an operational capability that enables a firm to prepare for, respond to and recover from a disruption/crisis to return to its normal operations' capacity or even to a better capacity (Brusset and Teller 2017). The role

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of traceability as an enabler of SCRes has been particularly emphasized in the context of food SCs (Van Rijswijk and Frewer 2008; Zhao, Liu, and Lopez 2017). Studies in other industries have also emphatically stressed the significance of real-time end-to-end monitoring across the SC as an enabler of SCRes. However, these studies have generally attributed this requirement to visibility (Jüttner and Maklan 2011; Pettit, Croxton, and Fiksel 2013; Mubarik et al. 2021) without an analysis of the role of traceability either in facilitating visibility or SCRes directly. To fully understand and appreciate the link between traceability and SCRes requires an encompassing definition of traceability that transcends beyond the tracking and tracing of products to include the generation, updating and transferring of information on: (1) product characteristics (such as weight and temperature); (2) energy and resource consumption; (3) batch quantity/size; and (4) production, transformation and distribution schedule and capacity (Karâa and Morana 2016; Marconi et al. 2017; Zhao, Liu, and Lopez 2017; Casino et al. 2020). Thus, this paper adopts this definition of traceability.

Research into the role of traceability dates back to the late 1990s where its impact on quality assurance in the European meat supply chain was examined (e.g. Simpson, Muggoch, and Leat 1998; Viaene and Verbeke 1998). Thereafter, a significant number of studies have been undertaken across various industries, including the recent resurgence due to the increased need in modern SC management operations in the Industry 4.0 era (e.g. Coronado Mondragon, Coronado Mondragon, and Coronado 2021; Casino et al. 2020; Kayikci et al. 2020). However, there remains a lack of consensus on the impact of traceability systems on SC performance, which hence affects the willingness of companies to adopt traceability systems voluntarily (Mai et al. 2010; Mattevi and Jones 2016). There have been notable literature reviews on specific themes of traceability, such as technology (Costa et al. 2013; Pournader et al. 2020; Wang, Han, and Beynon-Davies 2019) and legislation (Borit and Santos 2015); as well as reviews based on its relationship with other SC management concepts such as risk management (Ringsberg 2014) and sustainability (Garcia-Torres et al. 2019). There are also some reviews on the benefits of traceability and its impact on SC performance, but these reviews have been limited either to a particular industry, with a focus on food (Opara 2003; Dabbene, Gay, and Tortia 2014) or computers and software (Omar and Dahr 2017; Mustafa and Labiche 2017), or to a particular technology, with a focus on blockchain (Pournader et al. 2020; Feng et al. 2020) or RFID (Nambiar 2010; Costa et al. 2013). Thus, there is a need for a comprehensive review of the extant literature to integrate the benefits of traceability discussed across multiple industries and technologies. There is also a timely need to consider the relationship between the benefits associated with traceability and SCRes, as no literature reviews to date have explored this relationship.

This paper adopts a systematic literature review approach to address these gaps, and thereby address the following research question: *What are the benefits of the deployment of a SC traceability system emphasized in the literature, and how does the deployment of traceability enable/enhance the attainment of SCRes?* To fully appreciate the benefits of traceability and its relationship with SCRes, it is first necessary to summarize the current state-of-the-art understanding of traceability systems in terms of: the drivers/motivations, the evolution of technology; and the challenges/barriers that inhibit its implementation. This is necessary given that there is a clear link between these issues and the benefits achieved. For example, the choice and subsequent success of a traceability system is affected by: the reasons for its adoption, the functionality of available technologies and how the SC partners overcome any barriers to adoption. Thus, understanding these issues enables a deeper understanding of the benefits. A comprehensive understanding of the benefits in turn enables the development of an understanding of the relationship between these benefits and SCRes.

The rest of this paper is structured as follows. Section 2 outlines the methodology adopted for this study. Section 3 provides a descriptive summary of the identified literature, which includes the background information required to answer the research question in terms of traceability drivers, the evolution of technology and the barriers to implementation. Section 4 then discusses the findings in relation to the benefits of traceability. Section 5 explores the relationship between these traceability benefits and SCRes by further analyzing the issues raised in the literature. Section 6 provides a conclusion, identifies the research gaps and suggests potential future research directions.

2. Method

2.1. Systematic literature review (SLR)

An SLR was chosen for this study because of its ability to eliminate bias and improve thoroughness in identifying and selecting relevant studies (Tranfield, Denyer, and Smart 2003; Denyer and Tranfield 2009). Thus, the SLR approach ensures a comprehensive review of relevant studies thereby providing an important building block for the advancement of traceability knowledge. This is especially needed at this point in time given that evaluating the usefulness of SC digitalization in curbing SC disruptions is currently high on the research agenda. By collating existing literature into a rigorous and reliable format, this study informs academic researchers, practitioners and/or policymakers on the benefits of this important dimension of digitalization (Denyer and Tranfield 2009). It thereby enables firms to make informed decisions in terms of their investment choices around the digitalization of SC solutions, making effective use of their limited resources. Specifically, Durach, Kembro, and Wieland (2017) paradigm for conducting SLRs in SCM was adopted to meet the specific philosophical characteristics of SCM research. The stages are summarized in Figure 1 and described in turn below.

2.1.1. Stage 1: Define the purpose of the SLR

The purpose of the study has been stated above using the research question. In addition, the justification has also been

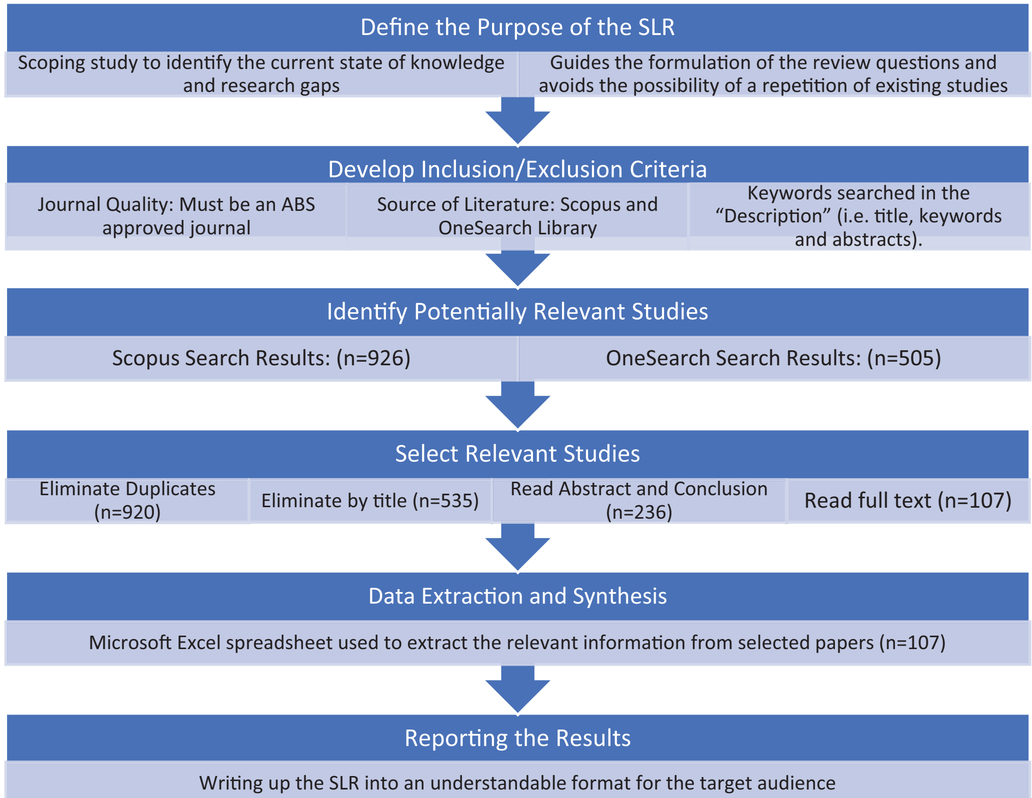

Figure 1. Systematic literature review process.

given above by identifying existing literature reviews on SC traceability to avoid the repetition of studies. In summary, previous SLRs are limited to the consideration of benefits relating to specific industries only or a specific technology only. Hence the unique purpose of this study is to consider multiple industries and technologies, to develop a more comprehensive understanding of the benefits to guide researchers and practitioners in the future. In addition, this review is unique in exploring the relationship between traceability and SCRes.

2.1.2. Stage 2: Develop the inclusion and/or exclusion criteria

The criteria that determines whether a publication can provide information to answer the research questions was defined in advance of the actual literature search to avoid manipulating procedures based on the researcher's expectations (Tranfield, Denyer, and Smart 2003; Kitchenham and Charters 2007; Durach, Kembro, and Wieland 2017). Therefore, the literature sources, journal quality and search words were specified at this stage.

- *Literature Sources:* Scopus was the main search engine for this study because it is an up-to-date database of relevant journals. This was supplemented with the OneSearch Library, which also incorporates a range of major business and management databases such as EBSCOhost, SpringerLink, Science Direct, IEEE Xplore, Emerald Insight and Wiley Online Library. Despite the sophistication of each search engine, combining them widened the coverage and improved the search results.
- *Keywords:* The keywords were selected considering other terms that could be used to refer to traceability. Therefore, they were specified as: Trac* (trace, track, tracing, tracking, traceability etc.) OR Transparen* (transparent, transparency etc.) OR Visib* (visible, visibility etc.) OR Recall* (recall, recalls etc.) AND Supply Chain* (supply chain, supply chains etc.). The truncation symbol (*) ensured the inclusion of different endings to the search term. It is also noted that the keywords focussed entirely on traceability, with SCRes literature linked to traceability identified in this way. A search of the SCRes literature was also carried out, but this is not included here as it did not significantly add to the findings.
- *Journal Quality:* To ensure the quality and relevance of the search results, only studies published in Association of Business Schools (ABS) ranked journals were included. This meant that all studies were internationally peer-reviewed and published in English.

2.1.3. Stage 3: Identify potentially relevant literature

The search string 'Trac*' **OR** 'Transparen*' **OR** 'Visib*' **OR** 'Recall*' **AND** 'Supply Chain*' was entered into Scopus and OneSearch with the search directed to the 'Description' (i.e. title, keywords and abstracts). The searches retrieved 854 and 465 peer-reviewed articles from Scopus and OneSearch, respectively. Mendeley reference management software was used to keep a log of the retrieved articles and further manage the references cited.

2.1.4. Stage 4: Select relevant studies

The inclusion and exclusion criteria for this study involved passing the 1,319 (854 + 465) articles through screening stages to assess them individually for their relevance to the research question. With regards to inclusion and exclusion at each stage, the papers had to fit the definition of traceability as coined in the introduction above. This led to the removal of several papers because some of the keywords, such as 'transparency', 'visibility', 'tracking and tracing' and even 'traceability' did not necessarily refer to the type of traceability in question. Articles clearly addressing the role, purpose, impact or benefits of a traceability system or a specific traceability technology were selected. However, any such articles that were not related to supply chain management were excluded – such as on the use of blockchain in cryptocurrencies, or the use of RFID for race timing or attendee tracking. The stages followed were:

1. The articles were cross-checked to eliminate duplicates retrieved from multiple databases. This reduced the number of articles to 920 studies.
2. The articles were screened by their titles and keywords for their potential relevance – reducing the number of articles to 535 studies.
3. The abstracts and conclusions were read to determine their potential relevance, reducing the set further to 236 articles. To avoid excluding relevant articles, studies for which there was any doubt on whether or not to exclude them were retained and passed on to the final screening stage.
4. Finally, the remaining articles were fully read to determine their relevance.

107 articles were finally selected and passed on for extraction and analysis.

2.1.5. Stage 5: Data extraction and synthesis

This SLR used a Microsoft Excel spreadsheet to record and monitor the data obtained from the selected studies. This cataloguing also provides an audit trail to map the claims made in the SLR to the source of the evidence (Denyer and Tranfield 2009). The findings of the primary studies were then analysed and integrated to answer the research question.

3. Overview of the current state-of-the-art regarding SC traceability

3.1. Summary of literature – descriptive analysis

This section evaluates the descriptive characteristics of the selected papers to generate an overview of the selected sample to ensure consistency in the content analysis (Durach, Kembro, and Wieland 2017; Seuring and Gold 2012). Table 1 below provides a statistical summary of these characteristics to illustrate that the traceability literature is a vibrant research area with publications in highly ranked journals.

The SLR selected 107 papers dated between 1998 and 2021, of which 50 percent (54 papers) were published between 2016 and 2021, indicating that traceability related studies are still a significant research focus. Geographically, Europe accounted for most papers (44) whereas Africa and Oceania had the least research focus with 2 and 1 paper respectively. This indicates that studies on traceability have usually been centred on developed countries whilst developing countries have received little or no attention. This may be due to the relative level of consumer agitation and demands for traceability from the respective SCs.

The sample also exhibited a balance of qualitative and quantitative methods with case studies (37) representing the most used method whilst experiments (2) were the least used methods. 95 papers adopted a single method whereas only 12 papers adopted a mixed method.

Furthermore, 79 papers addressed the issues from a specific industrial perspective with the food industry accounting for most studies (45 papers), followed by studies carried out 'across industries' (11 papers). The healthcare industry also accounted for 5 studies whilst mining, leather, and the transport and aviation sectors had the lowest number of studies with 1 each. The dominance of the food industry can be attributed to an increase in societal attention because of the monetary and health implications of previous food scares and the test-runs of new technologies in the food SCs (Ringsberg 2014; Casino et al. 2020; Kayikci et al. 2020).

3.1.1. Adoption of theoretical lenses in the traceability literature

Only 16 of the 107 papers explicitly referred to the use of a theoretical lens, with one paper adopting 3 theoretical approaches, as shown in Table 2. This shows that studies in this area have not significantly considered a theoretical approach. However, 12 out of the 16 studies that did use a theoretical lens were published between 2016 and 2021, signalling an increasing drive towards the use of theories over the last 5 years. As shown in Table 2 below, resource-focussed theories account for 8 papers with the Resource Based View (RBV) being the most applied theory. This suggests a view of traceability systems as a unique resource controlled by a firm to gain competitive advantage. Beyond the resource focussed perspectives, Transaction Cost Economics (TCE) was also adopted in 3 papers to justify implementing traceability systems using Cost-Benefit Analysis (CBA), whereas stakeholder theory (2 papers) was used to indicate the drivers of traceability and their role in determining its adoption.

3.1.2. SC tiers studied in empirical papers

This study identified 5 tiers of the SC that served as the focus of data collection – consumers, traders (wholesalers and retailers), distributors, manufacturers/processors and suppliers. Only 19 out of the 64 empirical papers that were identified focussed on more than one tier, as shown in Table 3 below. Thus, empirical studies primarily focussed on a single tier, meaning the findings were generally limited to firm-based data and were not conclusive across the SC.

Table 1. Descriptive analysis of the literature.

Year period	Continents	Research methods	Industry of focus	Journals
Up-to-2000 (3)	Africa (2)	Action (3)	Across Industries (11)	British Food Journal (13)
2001–2005 (1)	Asia (23)	Case Study (37)	Automotive Manufacturing (3)	Supply Chain Management: An International Journal (12)
2006–2010 (19)	Europe (44)	Modelling (25)	Consumer Goods (2)	International Journal of Production Economics (10)
2011–2015 (30)	South America (3)	Simulation (3)	Electronics (2)	International Journal of Production Research (10)
2016–2021 (54)	North America (11)	Conceptual (13)	Fashion (3)	Journal of Cleaner Production (8)
	Oceania (1)	Experiment (2)	Food (45)	International Journal of Physical Distribution & Logistics Management (7)
		Lit. Review (13)	Forestry (3)	Industrial Management & Data Systems (7)
		Survey (25)	Healthcare (5)	Production Planning and Control (5)
			Leather (1)	Supply Chain Forum: An International Journal (5)
			Mining (1)	Computers in Industry (4)
			Service (2)	Production and Operations Management (3)
			Transport & Aviation (1)	Others (23)
Total = 107	Subtotal = 84	Total = 121*	Subtotal = 79	Total = 107

Notes: (*n*): *n* represents the number of studies; *some studies used more than one research method.

Table 2. The distribution of articles based on theoretical approaches adopted.

Theory	Count	Papers
Adoption Theories	2	(Karâa and Morana 2016; Kamble, Gunasekaran, and Arha 2019)
Agency Theory	1	(Resende-Filho and Hurley 2012)
Diffusion of Innovation Theory	1	(Karâa and Morana 2016)
Enactment Theory	1	(Oliveira and Handfield 2017)
Normal Accident Theory	1	(Skilton and Robinson 2009)
Resource Based View (RBV)	5	(Brofman Epelbaum and Garcia Martinez 2014; Timmer and Kaufmann 2017; Dubey et al. 2018, 2019; Agyabeng-Mensah et al. 2020)
Resource Dependency Theory	2	(Kamble, Gunasekaran, and Gawankar 2020; Agyabeng-Mensah et al. 2020)
Resource Orchestration Theory	1	(Bradley et al. 2018)
Stakeholder's Theory	2	(Karâa and Morana 2016; Timmer and Kaufmann 2017)
Systems Theory	1	(Fatorachian and Kazemi 2021)
Transaction Cost Theory	3	(Banterle and Stranieri 2008; Vo, Mainetti, and Fenies 2016; Stranieri, Orsi, and Banterle 2017)
Total Papers using Theory	15	

Table 3. Studies that focussed on two or more tiers.

Number of tiers	Count	Papers
2 Tiers	10	(Bottani, Montanari, and Volpi 2010; Canavari et al. 2010; Mai et al. 2010; Azevedo et al. 2013; Hinkka, Främling, and Tätilä 2013; Kumar, Heustis, and Graham 2015; Ringsberg 2015; Scholten and Schilder 2015; Sander, Semeijn, and Mahr 2018; Hoek 2019)
3 Tiers	5	(Kärkkäinen et al. 2007; Björk et al. 2011; Papert, Rimpler, and Pflaum 2016; Vanany et al. 2016; Wowak, Craighead, and Ketchen 2016)
4 Tiers	4	(Simpson, Muggoch, and Leat 1998; Brofman Epelbaum and Garcia Martinez 2014; Ringsberg and Mirzabeiki 2013; Gunawan, Vanany, and Widodo 2021)

Table 4. Distribution of empirical papers based on supply chain tier researched.

SC tier	No of papers
Consumers	1
Traders (wholesalers & retailers)	22
Distributors	14
Manufacturing/Processing	50
Suppliers	18

The distribution of papers across the tiers is summarized in Table 4 below. This table shows that most studies focussed on 'manufacturing/processing' whereas the end downstream tier 'consumers' had the least focus. The extant literature also confirms that there is a stronger incentive to implement traceability among upstream enterprises than among downstream firms (Ringsberg 2015).

3.2. Drivers/motivations to adopt traceability systems

The motivations/drivers (also referred to as incentives) of traceability systems are the forces that influence stakeholder interest in the implementation of traceability systems (Mattevi and Jones 2016). They can also serve as a yardstick against which the benefits of traceability can be measured to determine whether the desired goals for its implementation have in fact been achieved. It is therefore important to understand the various factors that drive the initial interest in order to appreciate the perceived benefits of traceability. The drivers identified in this SLR are summarized in Figure 2 below. This figure builds on the terminology used in the extant literature, fully collating the research to date, and thereby presents a novel holistic nomenclature that highlights the various drivers identified and their hierarchical relationships.

3.2.1. Internal factors

Internal factors are the motivations that stem out of a firm/SC's pursuit of improved effectiveness through the real-time exchange of information (Mattevi and Jones 2016). In turn, this improved effectiveness aims to lower transaction costs and risks associated with SC vertical interactions (Stranieri,

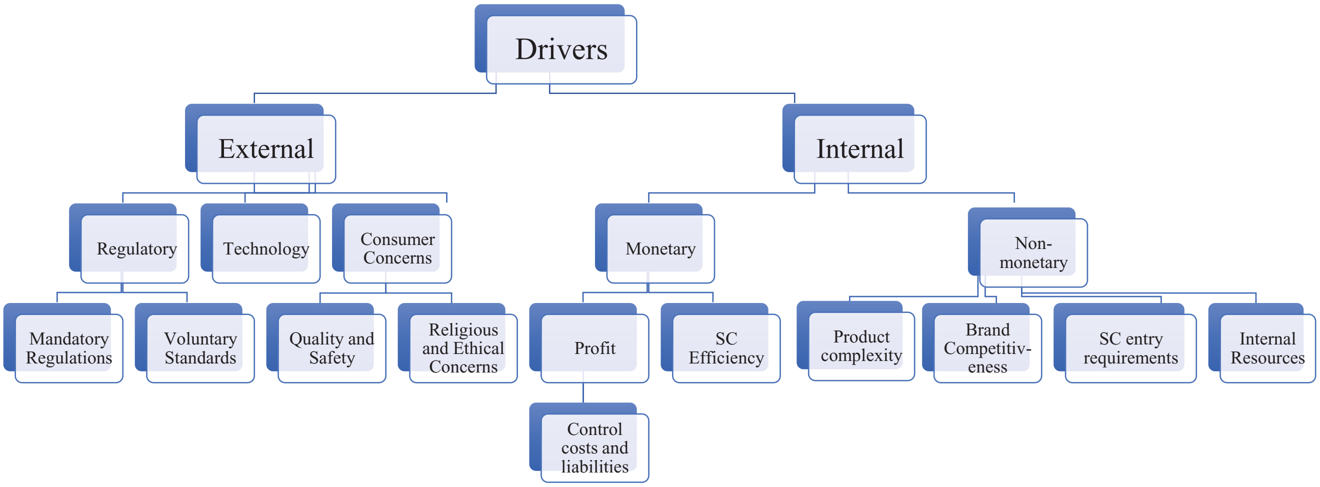

Figure 2. Categorization of the drivers/Motivations of traceability systems.

Cavaliere, and Banterle 2016). The internal factors were subcategorized as either monetary or non-monetary market incentives.

Non-monetary market incentives encompass the drivers that cannot be directly quantified economically and have no bearing on profit in the short-to-medium term (Stranieri, Cavaliere, and Banterle 2016). The literature points to firm and SC brand competitiveness, product complexity and SC entry requirements as the main non-monetary elements that drive traceability systems (Stranieri, Cavaliere, and Banterle 2016; Resende-Filho and Hurley 2012; Manos and Manikas 2010; Mai et al. 2010; Mattevi and Jones 2016). The most significant internal drivers were varied across studies depending on the nature of the sample of companies studied (Manos and Manikas 2010; Mattevi and Jones 2016) – for example, small-sized firms may not necessarily invest in traceability for long-term gains (such as to improve brand image or competitiveness). Traceability may also be driven by the dominant actors within the SC when they impose a traceability system on other actors as a SC entry requirement (Sun and Wang 2019; Heyder, Ludwig and Thorsten 2012; Canavari et al. 2010). For instance, food retailers such as ASDA, Morrisons and Walmart may require all suppliers to adopt a traceability system.

Monetary market incentives are the drivers that can be easily quantified economically within the firm and SC (Stranieri, Cavaliere, and Banterle 2016; Brofman Epelbaum and Garcia Martinez 2014; Canavari et al. 2010). Drivers in this category were either to increase firm profits or to improve SC efficiency (Stranieri, Cavaliere, and Banterle 2016; Brofman Epelbaum and Garcia Martinez 2014; Canavari et al. 2010). Firstly, increasing profits stands as a long-term driver which may be initiated by short-term drivers such as the desire to reduce costs and eliminate liabilities associated with SC failures, (e.g. the cost of recalls, financial penalties and damage to market share) (Mai et al. 2010; Stranieri, Cavaliere, and Banterle 2016; Kayikci et al. 2020). Secondly, companies consider the tracking and swift transmission of information among SC actors as a value-adding activity that impacts SC efficiency (Hinkka, Främling, and Tätilä 2013). Hence, firms that seek to improve operations and become more efficient are motivated to adopt traceability systems.

3.2.2. External factors

These are factors beyond the control of a firm and its SC partners that influence the adoption of traceability systems. They range from mandatory and imposed drivers, such as local and international regulations, quality and safety standards set by government and NGOs, through to voluntary standards (Manos and Manikas 2010; Donnelly, Mari Karlsen, and Dreyer 2012; Mattevi and Jones 2016); and also include technological advances and customer concerns, as summarized in Figure 2.

Mandatory regulatory drivers refer to requirements imposed on firms and SCs that do business within a geographical area – i.e. either locally (within a country) or internationally (within a continent) (Stranieri, Cavaliere, and Banterle 2016; Mattevi and Jones 2016). These enforcements to a large extent are aimed at ensuring the assurance of product quality and safety, and hence are usually limited to the minimum requirement of tracing one tier in both directions – i.e. 'one-up, one-down' traceability (Mattevi and Jones 2016; Vo, Mainetti, and Fenies 2016).

The global recognition and prestige attached to voluntary standards and certifications, such as the Codex Alimentarius Commission (CAC), the International Organization for Standardization (ISO), the Marine Stewardship Council (MSC), the Global Standardization Organization 1 (GS1), and the Global Good Agricultural Practices (GLOBALG.A.P.) also drives the implementation of traceability systems. That is, since firms seek certification by such bodies to assure SC partners and consumers of their adherence to the highest standards of operations, they are driven to comply with the requirements of these bodies, which includes the deployment of traceability systems (Ringsberg 2015; Mattevi and Jones 2016; Karâa and Morana 2016; Stranieri, Cavaliere, and Banterle 2016).

The user-friendliness, availability, effectiveness and other characteristics of traceability technology play a vital role in its implementation (Manos and Manikas 2010; Mattevi and Jones 2016; Kittipanya-Ngam and Tan 2020). Although traceability can be achieved without technology, to ensure the efficiency of the system and its ability to deliver information as quickly as possible, there is the need to integrate appropriate technology (Karâa and Morana 2016). Thus, as advances in technology are developed and become available, this can drive the adoption of either new or improved traceability systems.

Traceability systems are also driven by the need to address consumer concerns relating to health and safety, ethical and religious beliefs (Folinas, Manikas, and Manos 2006; Pouliot and Sumner 2008; Ringsberg 2015). In recent years, consumer purchase decisions have become increasingly based on the assurance that there is adequate information regarding the provenance of what they procure (Folinas, Manikas, and Manos 2006; Mai et al. 2010; Kayikci et al. 2020). Although traceability does not improve the quality and safety of a product *per se*, it assures consumers and other stakeholders of safety and quality given its effectiveness in swiftly recalling or withdrawing products during crises (Folinas, Manikas, and Manos 2006; Manos and Manikas 2010; Ringsberg 2015). Religious and ethical concerns of consumers also drive traceability adoption as, for example, consumers are interested in evidence of adherence to animal welfare certifications (Bumblauskas et al. 2020; Kittipanya-Ngam and Tan 2020).

3.2.3. Use of theory in understanding drivers

Karâa and Morana (2016), drawing from the theory of adoption and diffusion of innovation, suggest that despite the significance of technology, the adoption of traceability depends on a firm's internal readiness (as included under the heading of 'internal resources' in Figure 2). Thus, they confirm the role of internal management with the CEO as the 'champion' (Rogers, 2003, cited in Karâa and Morana 2016). Notwithstanding the sophistication of a technology, the CEO is still critical since he/she is an internal actor and can easily transcend his/her personality to encourage staff to adopt the technology. Timmer and Kaufmann (2017), based on Stakeholder and RBV theories, also asserted that the final decision on traceability systems depends on the internal motivations; thus, external stakeholder salience supplements the internal resources available.

Furthermore, the use of TCE theory highlights the monetary drivers of traceability. Stranieri, Orsi, and Banterle (2017) argued that traceability standards are a transaction governance mechanism adopted as a tool to reduce transaction costs (profits) and manage transaction risks (SC efficiency). Hence, a firm's perception about transaction risks determines the choice of traceability system, emphasizing that internal risk is positively related to the complexity of the traceability technology adopted. This perspective also highlights the risk of opportunistic behaviour by dominant SC actors and related inter-firm risk (Banterle and Stranieri 2008). Vo, Mainetti, and Fenies (2016) and Banterle and Stranieri (2008) added that the implementation of a traceability system directly impacts three transaction attributes as it: augments asset specificity; decreases the level of uncertainty; and augments transaction frequency.

3.3. Evolution and contribution of technology to traceability systems

The choice of traceability technology determines the breadth, depth and efficiency of a traceability system, and therefore is a critical aspect of the impact of traceability on SC performance (Banterle and Stranieri 2008; Manos and Manikas 2010). The evolution of traceability systems from paper-based to IT-enabled devices has enhanced the ability and efficiency of firms in collecting relevant information and keeping track (Banterle and Stranieri 2008; Manos and Manikas 2010; Kayikci et al. 2020). This evolution began in industries like pharmaceuticals and has now also been adopted in other industries such as food, thereby helping to: reduce the errors associated with manual handling; improve the transmission and analysis of large volumes of data; and improve tracking (Wilson and Clarke 1998; Manos and Manikas 2010).

From an RBV perspective, a firm's ability to create a valuable, rare, inimitable and non-substitutable resource from a traceability system, and hence to gain competitive advantage, depends on its embedded technology (Brofman Epelbaum and Garcia Martinez 2014). However, from the Resource Orchestration Theory (ROT) perspective, Bradley et al. (2018) argued that obtaining technology (resource) does not guarantee competitive advantage until it is effectively 'bundled' and 'leveraged'. Thus, effectively integrating technologies was more likely to improve traceability systems faster than simply adopting new technologies since users' attitude towards new technology is likely to affect its usefulness (Shou et al. 2021). This confirms the theoretical model developed by Kamble, Gunasekaran, and Arha (2019) based on the integration of three adoption theories – the technology acceptance model (TAM), technology readiness index (TRI) and the theory of planned behaviour (TPB) - which infers that the attitude of the traceability technology users towards its adoption is positively linked to its perceived usefulness, which is also influenced by its perceived ease of use.

Expanding on the identification and/or communication functions of traceability technology, as recognized by earlier literature (e.g. Brofman Epelbaum and Garcia Martinez 2014), Papert, Rimpler, and Pflaum (2016) identified six functional capabilities that a traceability technology may exhibit depending on its characteristics. Table 5 below assesses the identified technologies based on these functional capabilities.

The table confirms the evolution of technologies and an associated significant improvement in functional capabilities (George et al. 2019). New technologies do not always replace/wipe out existing technologies – instead both may remain as complements of each other, as seen in the case of RFID and barcodes.

Although no technology was limited to a product or industry (as shown in Table 6 below), some specific technologies are better aligned to certain products, based on their unique characteristics, that require particular functional capabilities (Papert, Rimpler, and Pflaum 2016; Musa, Gunasekaran, and Yusuf 2014). For instance, Isotopic and DNA-based technologies trace products using their unique composition of isotopes (elements) and molecules, hence they are mostly used in bio-products/industries such as agri-food and forestry (Saikouk and Spalanzani 2016; George et al. 2019). RFIDs do not require line-of-sight and can simultaneously identify multiple products, and hence can be effective

Table 5. Functional capabilities of traceability technologies.

Technology	Functions: Identification	Locating	Sensors	Communication	Data storage	Logic	Description/ Appraisal
Stable isotopic technology	x		x		x		• Uses the unique isotopic compositions of a product to determine its provenance and authenticity (Saikouk and Spalanzani 2016; George et al. 2019). • Complex to use for simple traceability since it requires laboratory tests to determine the provenance and the isotopic composition of products (George et al. 2019).
DNA-based tracers	x			x			• A sophisticated tool for product verification that certifies a product's origin and authenticity based on a DNA added to the product (Saikouk and Spalanzani 2016; George et al. 2019). • Useful for traceability in the food industry for the identification of organic crops, livestock against adulterated and genetically modified organisms (GMOs). • Not very effective with finished products composed of different raw materials with different origins (George et al. 2019).
Nano-capsules	x				x		• Generates unique codes as molecular prints that are merged into a product for identification and authentication (Saikouk and Spalanzani 2016). • Accommodates several codes, hence permits the effective reading of complex combinations.
Magnetic markers	x	x		x			• Fuses silica-coated magnetic particles into a product during its manufacturing, to help identify and convey secured information about a product along the SC (Saikouk and Spalanzani 2016). • Simple, safe, effective and generally a low-cost technology since the magnetic markers automatically generate a unique readable code for the product (Saikouk and Spalanzani 2016).
Barcode (1D barcode)	x			x			• An optical technology that uses horizontal bars to represent, identify and encode product information. • Read-only technology, i.e. data printed cannot be modified along the SC. • The scanner requires a relatively short direct line-of-sight to the barcode, hence time consuming. • Does not guarantee the authenticity of products because its limited information density is liable to duplication (Saikouk and Spalanzani 2016).
Matrix code (2D barcode)	x	x		x			• An optical technology that uses geometric patterns in two dimensions to represent, identify and store product information. • The codes represent data such as a product number, charge number, serial number, expiry date, etc. • 2D barcodes encode more information than a 1D barcode. • The simplicity, universality and low cost of barcodes explains its popularity despite its deficiencies (Musa, Gunasekaran, and Yusuf 2014). • Labels easily become unreadable since they are usually exposed to weather and other conditions that cause wear and tear (Kumar, Heustis, and Graham 2015).
Data logger		x	x	x	x		• Sensor-driven devices used to measure and store temperature profiles of a product along the SC (Papert, Rimpler, and Pflaum 2016). • The sensor records and saves temperature at defined intervals (communication and storage) but is unable to regulate extreme high or low temperature (logic) (Papert, Rimpler, and Pflaum 2016). • Lacks the basic function of identification unless merged with another technology.
RFID	x	x		x	x		• Referred to as the "next-generation barcode" because of its enhanced features. • Enables the simultaneous automatic identification of multiple objects without direct contact (Kumar, Heustis, and Graham 2015). • Saves cost with reusable tags instead of labels and stickers (Ringsberg and Mirzabeiki 2013). • Allows modification of product information as it moves along the SC (Gautam et al. 2017). • Despite its functional limitations, it can be easily integrated with other devices to enhance its functionalities (Papert, Rimpler, and Pflaum 2016). • The high investment required for its deployment is a disincentive for most SMEs (Karâa and Morana 2016). • RFID tags are subject to being cloned and counterfeited and security may be undermined since it runs on wireless networks (Azzi, Chamoun, and Sokhn 2019).
Wireless Sensor Network (WSN)	x	x	x	x	x	x	• Integrated sensors with embedded product logic that combines with RFID to enhance traceability communication to achieve real-time product monitoring along the SC (Yan et al. 2016; Papert, Rimpler, and Pflaum 2016). • Facilitates the outlay Internet of Things (IoT) – an intelligent system that has proven to be capable of realising all the six functional capabilities (Yan et al. 2016). • Relatively unpopular because its setup requires a completely new framework, hence new skills training, and configuration to align with existing legislations within the SC (Papert, Rimpler, and Pflaum 2016).

(continued)

Table 5. Continued.

Technology	Functions						Description/ Appraisal
	Identification	Locating	Sensors	Communication	Data storage	Logic	
Blockchain technology (BCT)	x	x	x	x	x	x	• A peer-to-peer (distributed) ledger technology that provides SC actors within a blockchain network with enhanced visibility and transparency of transactions, assets, stock items, etc. (Pournader et al. 2020). • Offers consistency and immutability of data, hence errors in records are minimised. • Reliable for product recalls because it facilitates the tracking of the origin of a product with accurate details of its journey from the producer to final consumer (Azzi, Chamoun, and Sokhn 2019). • Eliminates paperwork and expedites contract fulfilment and payment through smart contracts (Hald and Kinra 2019). • BCT interfaces are complex, hence requires some level of blockchain knowledge to fully appreciate its potential (Chang, Iakovou, and Shi 2020). • Excessive transparency may lead to powerful SC actors unduly monitoring and dominating surveillance to the detriment of the less powerful firms (Hald and Kinra 2019). • Its enhanced automation eliminates nearly all forms of human intervention, which has adverse effects on worker skills and competencies (Hald and Kinra 2019).

Notes: Identification: To determine the unique identity information about a product; Locating: to determine timely and accurate information about the position of a product; Sensors: to determine the current object and environmental-related status of the product; Communication: to assess and exchange product information among SC actors; Data storage: retention of product history and other information to facilitate information sharing in real-time; Logic: recognition of the critical events in the journey of a product (temperature fluctuations, quality issues, etc.).

for bulky products or palletized goods (Lee and Özer 2007; Kang and Lee 2013). The continuing demands of traceability from stakeholders mean that the system requires persistent enhancement through innovation to ensure that it is continuously able to record and disseminate the information required by authorized stakeholders.

To enhance the functionalities of traceability systems, an existing system may serve as a grounded technological framework that is integrated with other devices to upgrade its functions instead of switching to the adoption of an entirely new technology. RFID's dominance as an underlying technology is due to its ability to be integrated with other traceability technologies, such as DNA and barcodes, as well as sensory devices such as: Time Temperature Indicators (TTI); electronic data-interchange (EDI); the internet-of-things (IoT); and global positioning systems (GPS) (Mai et al. 2010; Musa, Gunasekaran, and Yusuf 2014; Bradley et al. 2018; George et al. 2019; Coronado Mondragon, Coronado Mondragon, and Coronado 2021). Therefore, RFID technology can be integrated with sensors to solve its lack of logic and sensor functionality (Papert, Rimpler, and Pflaum 2016). For example, in the case of RFID and TTI (Rf-TTI), TTI augments the underlying capabilities of RFID (i.e. identification, location, communication and data storage) with the ability to monitor temperature (sensor) and recognize fluctuations that impede quality (logic).

Papert, Rimpler, and Pflaum (2016) noted that despite the desire for a technology that provides accurate and secure information, companies also consider its ease of adoption and alignment with their existing structure. Bradley et al. (2018) stressed the value of 'joint use' of newly adopted technologies with other technologies already in use, arguing that consistent use of such a 'bundled resource' is more likely to lead to long term successful traceability. Thus, as a technology meets the traceability needs over time, users become more accustomed to it and hence more willing to accept it (Musa, Gunasekaran, and Yusuf 2014; Kamble, Gunasekaran, and Arha 2019).

To override the loopholes of the Auto-ID based technologies, blockchain technology (BCT) and the Internet of Things (IoT) have emerged as essential underlying traceability technologies for the future, though some experts remain rather pessimistic about expectations being fulfilled (Tsang et al. 2018; Pournader et al. 2020; Wang, Han, and Beynon-Davies 2019). This advancement in technology, enhances the transparency and awareness of the SC and makes traceability more capable in exploring larger volumes of data quickly (Ivanov and Dolgui 2020; Shou et al. 2021). Despite some failed attempts to implement BCT in industry, it continues to have huge potential with some successful business cases (Pournader et al. 2020). Likewise, IoT presents an expanded system based on existing technology such as RFID, WSN, barcodes etc. (Coronado Mondragon, Coronado Mondragon, and Coronado 2021) that extends traceability beyond the functional capabilities into a network infrastructure that enables it to connect both virtual and physical objects (Tsang et al. 2018). It is therefore concluded that the potential ability of traceability systems to provide significant firm and SC

Table 6. Technologies adopted and the industrial contexts studied.

Technology	Industry (product)	Sources
Barcode	Food SC	(Vanany et al. 2016; Li et al. 2017)
	Forestry SC	(Saikouk and Spalanzani 2016)
	General SC	(Li 2013; Musa, Gunasekaran, and Yusuf 2014; Choi, Yang, and Cheung 2015; Dai, Ge, and Zhou 2015; Dai, Tseng, and Zipkin 2015)
Blockchain	Food SC	(Sander, Semeijn, and Mahr 2018; Behnke and Janssen 2020; George et al. 2019; Feng et al. 2020; Casino et al. 2020; Kayikci et al. 2020; Kittipanya-Ngam and Tan 2020)
	General SC	(Hald and Kinra 2019; Azzi, Chamoun, and Sokhn 2019; Chang, Iakovou, and Shi 2020; Hastig and Sodhi 2020; S. Kamble, Gunasekaran, and Arha 2019; Pournader et al. 2020; Saberi et al. 2019; Hoek 2019; Wang, Han, and Beynon-Davies 2019)
DNA-based Tech.	Forestry SC	(Saikouk and Spalanzani 2016)
IoT	Food SC	(Tsang et al. 2018; Coronado Mondragon, Coronado Mondragon, and Coronado 2021; Kittipanya-Ngam and Tan 2020)
	General SC	(Fatorachian and Kazemi 2021)
Isotopic Technology	Forestry SC	(Saikouk and Spalanzani 2016)
Magnetic Tracing	Forestry SC	(Saikouk and Spalanzani 2016)
Nano-Capsules	Forestry SC	(Saikouk and Spalanzani 2016)
RFID	Automotive	(Modrák and Moskvich 2012)
	Fashion SC	(Guo et al. 2015; Landmark and Sjøbakk 2017)
	Food SC	(Kelepouris, Pramatari, and Doukidis 2007; Mai et al. 2010*;Ringsberg and Mirzabeiki 2013; Yan et al. 2016; Gautam et al. 2017; Li et al. 2017)
	Forestry SC	(Björk et al. 2011; Appelhanz et al. 2016; Saikouk and Spalanzani 2016)
	General SC	(Spekman and Sweeney 2006; Attaran 2007; Lee and Özer 2007; Lee and Park 2008; Lee and Lee 2010; Hong, Kim, and Kim 2010; Cui et al. 2017; Dai, Ge, et al. 2015; Musa, Gunasekaran, and Yusuf 2014; Kang and Lee 2013; Li 2013; Shi et al. 2012)
	Healthcare (Hospital)	(Bradley et al. 2018)**
	Manufacturing SC	(Dai, Tseng and Zipkin 2015; Liukkonen 2015)
	Pharmaceutical SC	(Kwok et al. 2010; Papert, Rimpler, and Pflaum 2016)
	Retail SC	(Bottani, Montanari, and Volpi 2010)
WSN	Pharmaceutical SC	(Papert, Rimpler, and Pflaum 2016)
	Food SC	(Coronado Mondragon, Coronado Mondragon, and Coronado 2021)
Unspecified technologies		
Food Trak	Food	(Wilson and Clarke 1998)
Sanitel	Food	(Viaene and Verbeke 1998)

*-RFID + TTI.
**-RFID + EDI.

level benefits continues to expand as the technologies themselves continue to evolve.

3.4. Challenges/barriers to the adoption of traceability systems

Despite the remarkable improvements that firms and SCs desire from the implementation of traceability systems, and the capabilities of the technologies themselves, it is also worth noting that there are several challenges/barriers associated with technology adoption that may hamper the associated benefits. Thus, there can be a difference between expected and actual outcomes. The various challenges/barriers encountered in the implementation of traceability systems can be summarized in four categories, as previously applied to the categorization of the challenges associated with blockchain technology adoption identified by Saberi et al. (2019):

1. Challenges Internal to the firm (Intra-Firm);
2. Challenges Internal to the SC (Inter-Firm);
3. Technical/System Related Challenges; and,
4. External Challenges.

3.4.1. Intra-firm challenges

Implementing a traceability system usually involves a reconfiguration of the internal operations with new technology and new skill-sets, and hence there is a need for step-by-step guidelines prior to implementation (Manos and Manikas 2010; Guo et al. 2015). Obstacles to implementation are therefore likely to emanate internally from the firm's financial capacity and the attitude of both management and employees (Saberi et al. 2019). These include: financial constraints (Mattevi and Jones 2016; Accorsi et al. 2018; Kayikci et al. 2020); lack of management commitment (Guo et al. 2015; Saberi et al. 2019); employee resistance to change (Alfaro and Rábade 2009; Kwok et al. 2010); and the lack of required skill and expertise (Canavari et al. 2010; Saberi et al. 2019; Kayikci et al. 2020).

3.4.2. Inter-firm challenges

Efficient traceability systems harness inter-firm relationships to create value for stakeholders (Saberi et al. 2019). However, organizational differences and the individual rights of firms along the SC pose challenges to the implementation of traceability systems. Amongst these challenges are: ethical and privacy concerns due to a lack of trust among SC partners (Sanfiel-Fumero, Ramos-Dominguez, and Oreja-Rodríguez 2012; Hald and Kinra 2019; Chang, Iakovou, and Shi 2020; Shou et al. 2021); the uneven distribution of costs and benefits of the implementation (Mai et al. 2010; Sanfiel-Fumero, Ramos-Dominguez, and Oreja-Rodríguez 2012; Hinkka, Främling, and Tätilä 2013); and the reluctance of SC partners to sacrifice their internal policy for the advantage of the SC (Canavari et al. 2010; Gunawan, Vanany, and Widodo 2021).

Table 7. Benefits of traceability.

Category	Benefits of traceability	Example authors
Impact on crisis management	Improved monitoring and visibility	(Attaran 2007; Kher et al. 2010; Ringsberg 2014; Dubey et al. 2018; Kamble, Gunasekaran, and Arha 2019; Kayikci et al. 2020; Ivanov and Dolgui 2020; Kittipanya-Ngam and Tan 2020; Coronado Mondragon, Coronado Mondragon, and Coronado 2021; Sumukadas 2021)
	Efficient recall management	(Kher et al. 2010; Mai et al. 2010; Dai, Tseng, and Zipkin 2015; Kumar, Heustis, and Graham 2015; Bumblauskas et al. 2020; Casino et al. 2020; Kayikci et al. 2020; Sumukadas 2021)
	Assurance of product safety and quality	(Folinas, Manikas, and Manos 2006;Kher et al. 2010; Mattevi and Jones 2016; Sun and Wang 2019; Agyabeng-Mensah et al. 2020; Kayikci et al. 2020; Coronado Mondragon, Coronado Mondragon, and Coronado 2021; Shou et al. 2021)
	Eliminate counterfeiting and fraud	(Li 2013; Hald and Kinra 2019; Hastig and Sodhi 2020; Kayikci et al. 2020; Yao and Zhu 2020)
Impact on firm & SC performance	Reduced operations cost	(Mai et al. 2010; Modrák and Moskvich 2012; Appelhanz et al. 2016; Kurniawan et al. 2017; Bradley et al. 2018; Feng et al. 2020; Casino et al. 2020; Fatorachian and Kazemi 2021)
	Reduced risk of SC disruption – stockouts, inventory inaccuracy	(Jonsson and Mattsson 2013; Chang, Iakovou, and Shi 2020; Pournader et al. 2020; Ivanov and Dolgui 2020; Kamble, Gunasekaran, and Gawankar 2020; Kayikci et al. 2020; Kittipanya-Ngam and Tan 2020; Yao and Zhu 2020; Coronado Mondragon, Coronado Mondragon, and Coronado 2021; Fatorachian and Kazemi 2021; Shou et al. 2021; Sumukadas 2021)
	Real-time asset tracking	(Bradley et al. 2018; Hald and Kinra 2019; Fatorachian and Kazemi 2021)
	Enhanced SC trust and confidence (collaboration)	(Alfaro and Rábade 2009; Kumar, Heustis, and Graham 2015; Feng et al. 2020; Casino et al. 2020; Kittipanya-Ngam and Tan 2020)
	Improved reliability and security	(Li 2013; Bentahar, Benzidia, and Fabbri 2016; Casino et al. 2020; Kayikci et al. 2020; Fatorachian and Kazemi 2021)
	Improved brand image	(Banterle and Stranieri 2008; Kumar, Heustis, and Graham 2015; Saak 2016; Wowak, Craighead, and Ketchen 2016; Kayikci et al. 2020; Kittipanya-Ngam and Tan 2020; Coronado Mondragon, Coronado Mondragon, and Coronado 2021)
Impact on consumers & society	Improved retainment and attraction of new customers	(Marucheck et al. 2011; Appelhanz et al. 2016; Landmark and Sjøbakk 2017; Bumblauskas et al. 2020; Kittipanya-Ngam and Tan 2020)
	Evidence of sustainable/ ethical production/ sourcing methods	(Cousins et al. 2019; Saberi et al. 2019; Gunawan, Vanany, and Widodo 2021; Kittipanya-Ngam and Tan 2020)
	Improved reverse logistics and remanufacturing	(Rotunno et al. 2014; Dai, Ge, et al. 2015; Agyabeng-Mensah et al. 2020; Sumukadas 2021)

3.4.3. Technical/system related challenges

As traceability systems have evolved from paper-based systems to be more IT-enabled system, their implementation has also faced challenges that stem from the use of IT tools and systems (Saberi et al. 2019). Notable challenges under this category include: technological limitations in capacity and the availability of suitable technology (Bentahar, Benzidia, and Fabbri 2016; Wowak, Craighead, and Ketchen 2016; interoperability challenges (Musa, Gunasekaran, and Yusuf 2014; Chang, Iakovou, and Shi 2020; van Hoek 2019; Gunawan, Vanany, and Widodo 2021); depreciation of technology (Liukkonen 2015), and security challenges (D. Lee and Park 2008; Li 2013; Saberi et al. 2019; Azzi, Chamoun, and Sokhn 2019; van Hoek 2019).

3.4.4. External challenges

This category of challenges refers to the challenges that arise from stakeholders and entities that do not directly economically benefit from a firm and its SC activities (Saberi et al. 2019). External bodies like government, industrial stakeholders and other NGOs have a critical role to play in ensuring the effectiveness of traceability systems, and hence when there is a lack of clearly defined governmental policy on traceability (Kwok et al. 2010; Chang, Iakovou, and Shi 2020; Saberi et al. 2019; Gunawan, Vanany, and Widodo 2021) and/or no unified industrial standard (Bentahar, Benzidia, and Fabbri 2016; Accorsi et al. 2018; Saberi et al. 2019), this lack of clarity will also act as a barrier to the successful implementation of traceability systems.

In conclusion, although firms expect to reap benefits from their investments in traceability systems, it is important to note that the challenges described above may hinder system effectiveness. It is therefore important to have an overview of these challenges and to be fully aware that these challenges are inherent not only at the adoption stage but also varied across the lifespan of the traceability system. It is also important to note that financial constraints, as identified as the principal impediment to the implementation of traceability systems (Kwok et al. 2010; Mattevi and Jones 2016), should not be limited to only the initial purchase cost but also include other aspects of implementation, such as the cost of staff training, skills upgrading, administrative and legal costs associated with information accessibility (Kayikci et al. 2020).

4. Benefits resulting from the implementation of traceability

As discussed above, a firm may be driven to adopt traceability by many factors which, to a large extent, determines the choice of traceability technology – i.e. either they adopt a basic or an advanced traceability system. Despite the unique advantages of these technologies, the benefits of the traceability system can only be fully obtained through the effective bundling and integration of the traceability resources (Bradley et al. 2018). The potential rewards firms desire from the implementation of traceability systems must sufficiently outweigh the challenges and barriers they must overcome to achieve them.

This section discusses the perceived benefits generated from the effective implementation of a traceability system. The papers reviewed here highlighted various qualitative and quantitative benefits, which were then classified based on the nomenclature of Mattevi and Jones (2016) – (1) impact on crisis management, (2) impact on firm/SC performance, and (3) impact on consumers/society. For each of these categories, novel sub-categories were then also developed, as summarized in Table 7. These benefits are discussed in turn below

4.1. Impact on crisis management

This category of benefits of traceability relates to the expediency and efficiency that traceability systems present to SC stakeholders in the event of a crisis/disruption (Mattevi and Jones 2016). Thus, it includes the combination of benefits that relate to: prevention of the crisis, 'containment' during the crisis, and quickly recovering from the crisis. As summarized in Table 7, dominant benefits include improved monitoring and visibility, given that traceability systems enhance the monitoring of the physical conditions (such as weight, temperature and texture) of a product in transit or storage (Mai et al. 2010; Ringsberg and Mirzabeiki 2013; Kumar, Heustis, and Graham 2015). In particular, traceability is essential for the visibility of 'long' SCs to inform on 'who made it', 'what was made', 'when it was made' and its real-time location (Tse and Tan 2012; Sumukadas 2021) which are essential during crisis management. In particular, a lack of visibility and control procedures will hinder effective decision making because detailed knowledge of what is happening at other parts of the SC is not available.

Product recalls represent a major crisis event for manufacturers and their SCs which have a negative bearing on shareholder value, a product's brand, firm profits and goodwill among customers (Donnelly, Mari Karlsen, and Dreyer 2012), especially in cases of mass media coverage. There is therefore a need for preparedness to swiftly withdraw defects from the market to minimize the impact (Kumar, Heustis, and Graham 2015). Product recall management is effective when it efficiently combines the identification of the problem, mitigation of the risk and learning from the recall (Marucheck et al. 2011; Casino et al. 2020). Researchers have asserted that identifying a problem requires the collaborative efforts of SC partners through sharing timely information on potential malfunction issues (Marucheck et al. 2011; Kumar, Heustis, and Graham 2015; Sumukadas 2021). Despite the assertion that a traceability system does not reduce the likelihood of a SC crisis (Resende-Filho and Hurley 2012), its role in controlling the consequences by enabling rapid recalls of harmful products cannot be overemphasized (Folinas, Manikas, and Manos 2006; Sumukadas 2021). For example, logistics information provided by traceability systems (such as batch quantity, origin, destination and dispatch date) ensures knowledge of the up-to-date location of a product to facilitate its swift withdrawal from the market (Folinas, Manikas, and Manos 2006; Ringsberg and Mirzabeiki 2013; Dai, Ge, et al. 2015; Kumar, Heustis, and Graham 2015).

Traceability systems also serve as a quality verification platform that firms can use to assure all concerned parties that the product has duly followed the right production procedures and hence is safe for usage (Folinas, Manikas, and Manos 2006; Sun and Wang 2019). In addition, it has the ability to curb counterfeiting and fraud by securing the integrity of the SC through effective monitoring and ensuring that the right information can be accessed by SC actors at the right time to verify the authenticity of the product (Li 2013; Hald and Kinra 2019; Hastig and Sodhi 2020). This role of traceability is particularly beneficial to the food, beverage and pharmaceutical industries where consumers' health and safety are paramount (Li 2013; Hastig and Sodhi 2020; Casino et al. 2020).

4.2. Impact on firm and SC performance

This category encompasses the perceived benefits to the operations of the immediate firm and its wider SC (Mattevi and Jones 2016). These benefits can be categorized as either internal to a firm or internal to the SC. Benefits in this category include reduced operations costs through a reduction in internal inefficiencies (e.g. shortages, stock errors, theft and shrinkages) and improved product recall management through the real-time exchange of logistics information (Modrák and Moskvich 2012; Appelhanz et al. 2016; Sumukadas 2021). In addition, the outputs of traceability, such as up-to-date information on inventories and the current capacity of SC partners (including suppliers, distributors, manufacturers and retailers), improve decision making at both the firm and SC level (Azevedo et al. 2013; Jonsson and Mattsson 2013; Scholten and Schilder 2015). This track-and-trace information creates a wider visibility that helps to anticipate potential disruptions in either production capacity, transport capacity or warehousing capacity at any of the tiers (Alfaro and Rábade 2009; Marucheck et al. 2011; Scholten and Schilder 2015). This helps SC firms to devise strategies ahead of a disruption and, in a worst-case scenario, to quickly recover from such disruptions using SCRes.

Traceability systems enhance the real-time tracking of assets, which facilitates the exchange and joint use of assets and resources for the mutual benefit of SC partners (Bradley et al. 2018; Hald and Kinra 2019). In the healthcare sector, for example, traceability has proven useful in the efficient tracking of expensive, durable and mobile equipment such as wheelchairs, infusion pumps, blood supplies and other materials such as pharmaceuticals, surgical trays and supplies. Thus, it aids in maintaining a high service level in the delivery of healthcare (Bradley et al. 2018; Hald and Kinra 2019).

Christopher and Lee (2004) argued that the quality of SC information is directly proportional to the level of trust and confidence in that SC. Traceability creates an efficient communication protocol that builds trust and confidence among SC actors and consumers, hence establishing long-term collaborative relationships among them (Alfaro and Rábade 2009; Kumar, Heustis, and Graham 2015; Feng et al. 2020; Sumukadas 2021).

Traceability technology also provides accurate point-of-sale data that can subsequently provide an effective avenue for the reconciliation of inventory records with actual inventories within the firm (Bottani, Montanari, and Volpi 2010; Hong, Kim, and Kim 2010; Fatorachian and Kazemi 2021). This level of traceability enhances reliability and security by facilitating the swift transfer of inventory information across the SC to decrease inventory errors and eventually mitigate the bullwhip effect in the SC (Bottani, Montanari, and Volpi 2010; Cui et al. 2017; Pournader et al. 2020). It also provides reliable transaction history for financial audits (Hald and Kinra 2019). Advanced traceability systems, in particular the blockchain, exhibit security features such as stability and immutability, hence, information on past transactions can be easily retrieved, thus ensuring fairness and trust, reducing corruption (Hald and Kinra 2019; Saberi et al. 2019).

Traceability systems also serve as a reliable platform to enhance brand competitiveness. When issues arise in the SC operations, notifying the concerned stakeholders such as government agencies, consumers, and SC partners is a very important step that can protect or destroy the firm's reputation (Kumar, Heustis, and Graham 2015; Wowak, Craighead, and Ketchen 2016). Traceability presents an effective communication approach that firms can use to reassure stakeholders that they are in full control of the situation (Banterle and Stranieri 2008; Kumar, Heustis, and Graham 2015; Wowak, Craighead, and Ketchen 2016). The ability to eliminate counterfeits also boosts the brand's reputation (Azzi, Chamoun, and Sokhn 2019) and builds customer confidence in the integrity of the SC.

4.3. Impact on consumers and society

The third category of benefits extend beyond firm and SC improvements to address consumer expectations and positively impact society (Mattevi and Jones 2016). For example, traceability acts as a driver for trust among consumers who might be willing to pay more for safer products – especially for food and pharmaceuticals (Alfaro and Rábade 2009; Mattevi and Jones 2016). Thus, for concerns related to ethics, health and safety, and religious beliefs, consumers have become increasingly interested in knowing the source and composition of what they consume, hence the ability of traceability systems to provide such evidence retains existing and attracts new customers (Marucheck et al. 2011; Bumblauskas et al. 2020). For example, the continuous monitoring of drug distribution and sales helps ensure patients' safety through the early detection of counterfeiters (Rotunno et al. 2014).

Mattevi and Jones (2016) added that traceability has a positive impact on the environment by providing evidence of the ethical and sustainable sourcing of materials. In particular, Pournader et al. (2020) and Saberi et al. (2019) contest that sustainable logistics and SC operations are one of the most anticipated benefits of traceability data. Saberi et al. (2019) opined that blockchain traceability presents an avenue to promote social SC sustainability by ensuring adherence to human rights, including fair and safe working conditions. They hinted that since data cannot be modified without the consent of authorized actors, any unethical practices by individuals, firms or governments can easily be detected to ensure that corrupt individuals are held accountable.

Moreover, traceability helps manage returns in situations of unfit products and recyclable artefacts. The efficiency with which these reverse logistics activities are carried out goes a long way towards instilling consumer confidence and minimizing the risk of lost sales (Rotunno et al. 2014; Dai, Ge, et al. 2015). Traceability information also helps to reduce the direct and indirect costs associated with reverse logistics since there is verifiable information on the location of the product and its safe handling procedures (Rotunno et al. 2014; Agyabeng-Mensah et al. 2020).

4.4. Attaining the full potential of a traceability system

Notwithstanding the enormous benefits that can be derived from the implementation of traceability systems, these benefits may be preceded in the short-term by a significant increase in operational expenses (Bradley et al. 2018) and relationship friction among SC actors (Shou et al. 2021; Sumukadas 2021).

Moreover, the benefits are not wholly reliant on the level of investment (Resende-Filho and Hurley 2012) as it may be more advantageous to make relatively inexpensive complementary improvements to an existing traceability system than to adopt a new, more sophisticated and hence more expensive system. In addition, it is important to note that the gathering of tools and systems does not guarantee the desired benefits unless these resources are effectively bundled and integrated (Bradley et al. 2018). That is, despite the varying capabilities of the technologies, they only act as enablers of the traceability system, thus attaining the full benefits of traceability will require a focussed integration of other elements – such as user skills and resource layout.

Despite literature claims that traceability is an enabler of inter-firm trust and confidence, it is also important to note that empirical findings suggest the presence of opportunistic behaviour in the implementation of traceability (Shou et al. 2021), as firms are more likely to implement traceability systems to mitigate their internal risks than the external risks in the SC (Stranieri, Orsi, and Banterle 2017). Thus, larger brands may be more likely to exert pressure on smaller firms to meet stringent traceability demands to harmonize their vertical transactions (Stranieri, Orsi, and Banterle 2017). Therefore, some of the potential benefits within the SC are not always realized.

5. Traceability as an enabler of SCRes

The benefits of traceability, especially under the category of crisis management, highlight some key points that guide the discussion on the role of traceability as an enabler of SCRes. Although literature has aligned SCRes with temporary SCs established in response to a disaster, such as a hurricane, earthquake or famine (Johnson, Elliott, and Drake 2013), any potential or actual disruption to the flow of goods, materials, services or related information in the 'normal' SC may also require SCRes (Scholten and Schilder 2015). SCRes represents an essential part of the broader perspective of business continuity planning that addresses the stance that most threats to business survival lie outside the focal firm (Kurniawan et al. 2017). Firms in a SC are vulnerable to risks emanating

Table 8. SCRes as a benefit of traceability.

Benefit of traceability	SCRes enabler	Definition of enabler
Direct relationship		
Improved risk awareness and pro-activeness Improved consumer trust and confidence	Traceability	SC capability used to advance SC transparency and visibility by providing traces of the provenance, location, status, composition etc. through all stages of production, processing and distribution (Kelepouris, Pramatari, and Doukidis 2007; Timmer and Kaufmann 2017).
Indirect relationship		
Improved monitoring of events and risk identification	Visibility	Timely knowledge of the identity, location and status of operating assets transiting through the SC (Johnson, Elliott, and Drake 2013).
Real-time tracking and exchange of information	Flexibility Velocity	Flexibility refers to the ease with which a SC can alter its operations to cope with changes in market situations or any other unexpected event (Jüttner and Maklan 2011; cited in: Scholten and Schilder 2015)
Improved reliability and security		Velocity refers to the speed with which a SC can respond to and recover from an unexpected disruption (Scholten and Schilder 2015; Johnson, Elliott, and Drake 2013).
Improved trust and confidence among SC actors	Collaboration	The capability of inter-organizational interactions to plan and execute SC operations to achieve common goals (Scholten and Schilder 2015).

from their lack of control over the dynamic environment in which they operate, resulting in coordination problems that lead to supply and demand inconsistencies (Kurniawan et al. 2017). Hence, appropriate strategies are needed to explore the sources of risks and potential solutions that improve the responsiveness of SC operations to consumer demand. In this context, this section discusses both the direct and indirect relationships between traceability and SCRes by analogising the themes related to the benefits identified from the traceability literature to the key theoretical constructs surrounding SCRes. As discussed and summarised in Table 8, this paper thus builds on the identified benefits *vis-à-vis* the dominant enablers of resilience – flexibility, velocity, visibility and collaboration (Scholten and Schilder 2015), which are key theoretical constructs in the SCRes literature.

5.1. Direct impact on SCRes

The prevalence of internal and exogenous risks has major implications for the performance of SCs, hence the management of risks remains a core issue in establishing resilience in SCs (Ringsberg 2014). Risks cannot be fully eliminated due to increasing SC complexity, hence firms must devise strategies to efficiently control the impact and rate of disruptions (Stranieri, Orsi, and Banterle 2017). Within a competitive industry, exogenous risks are inherent in the presence of substitutes and the frequent safety and quality regulatory interventions that have several implications for customer quality preferences, leading to demand uncertainties.

Traceability helps acknowledge the provenance of products, the authenticity of its raw materials/composition/ingredients and the sustainability and ethical adherence of the production process (Timmer and Kaufmann 2017; Stranieri, Orsi, and Banterle 2017). This helps firms gain market recognition that impacts strongly on consumer preferences. Thus, the implementation of a traceability standard that assures consumers of quality and safety helps to avoid disruptions in demand.

Traceability as a risk identification tool presents an avenue to develop a proactive and holistic approach to manage a SC crisis. The pursuit of SCRes seeks to ensure that a disruption at one node of the SC does not impede the entire system (Musa, Gunasekaran, and Yusuf 2014). Traceability technologies such as blockchain and IoT enhance the relay of real-time event notifications which enhance the pro-activeness of other SC partners in the event of a disruption at any node in the SC (Oliveira and Handfield 2017; Ivanov and Dolgui 2020). Improving traceability systems thus helps uncover potential vulnerabilities inherent at any stage of the SC and prepare a response and recovery strategy in advance (Timmer and Kaufmann 2017).

Furthermore, counterfeiting and fraud along the SC may be considered SC disruptions that require SCRes to control their occurrence and impact. Traceability enables the attainment of SCRes in this regard by providing an audit trail of the provenance and authenticity of products that can be verified at the various tiers to limit the likelihood of counterfeits (Chang, Iakovou, and Shi 2020). Traceability supports the early detection of deviations or potential deviations to alert all stakeholders of potential disruptions and as well, develop measures to curb it (Ivanov and Dolgui 2020).

5.2. Indirect impact on SCRes

Traceability also plays an indirect role by enhancing other enablers of SCRes. The analysis below focusses on the indirect relationship between traceability and the dominant formative elements of SCRes captured in the literature – i.e. flexibility, visibility, velocity and collaboration (Johnson, Elliott, and Drake 2013; Scholten and Schilder 2015).

Flexibility enables SCRes by ensuring that resources are easily redeployed to quickly adapt operations in the event of a disruption, whereas velocity contributes to this by ensuring that adaptation or recovery occurs at a fast pace. Ensuring flexibility and velocity in SCs requires close relationships between SC actors to facilitate timely information flow on any changes, such as those related to delivery schedules and equipment availability (Johnson, Elliott, and Drake 2013). Continuous monitoring and real-time tracking facilitated by traceability systems enhances SC responsiveness (flexibility and velocity) to disruptions (Sumukadas 2021). Moreover, these improvements in reliability and security also lead to consistency in the performance of SC partners, thus building trust and confidence among them (Shou et al. 2021). This facilitates swift access to information and support during a crisis by eliminating the need for new formal contractual negotiations as all parties are confident that any monetary liabilities will be harmoniously resolved (Johnson, Elliott, and

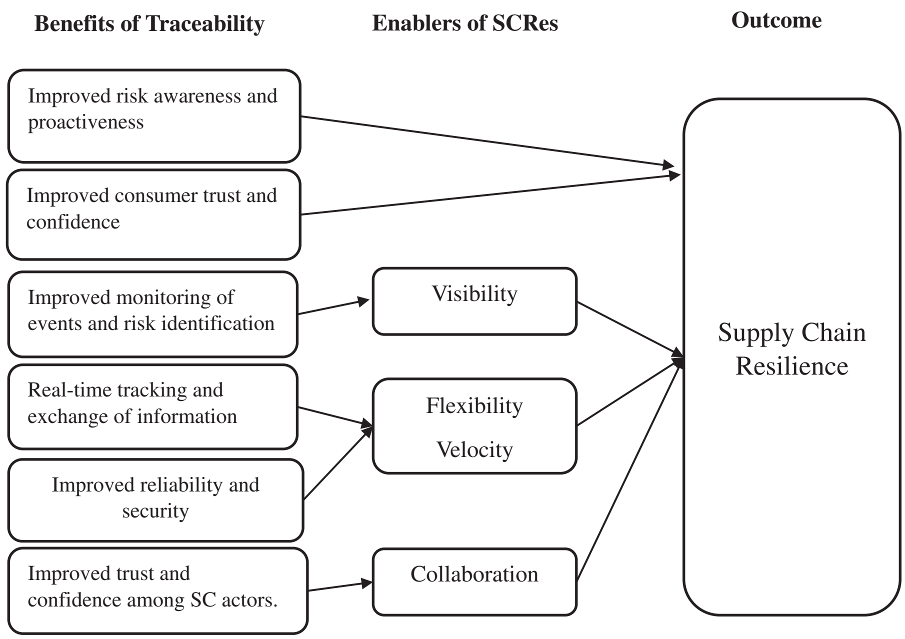

Figure 3. Proposed framework with traceability as a direct & indirect enabler of SCRes.

Drake 2013). In addition, since traceability ensures the availability of the right type of information at the right time, it expedites preparation for, response to and recovery from a disruption, thereby improving SC velocity (Scholten and Schilder 2015). Thus, there are several factors that lead to improved velocity when using an appropriate traceability system.

Timely information sharing among SC partners is vital to achieve the required level of SC visibility (Christopher and Lee 2004). Greater visibility is considered an antecedent of SCRes because it facilitates the identification and understanding of market events, with increased access to relevant information, thus enabling firms to manage potential risks and reduce the adverse effects of the disruption (Brandon-Jones, Squire, and Van Rossenberg 2015). To achieve visibility and subsequently create SCRes, a firm must be able to track and trace the right information to assist in anticipating disruptions (Scholten and Schilder 2015). This capability is enhanced by the ability to continuously track inventory in storage and transit and monitor their conditions (Ivanov and Dolgui 2020), which is facilitated by traceability systems.

Collaboration also facilitates inter-firm interactions and the exchange of real-time information among SC actors (Scholten and Schilder 2015) with the aim of jointly planning before, during and after a SC disruption to reduce its impact (Johnson, Elliott, and Drake 2013; Scholten and Schilder 2015; Sumukadas 2021). However, 'collaboration must be nurtured' (Sumukadas 2021, p.6). This is dependent on the commitment, trust and confidence among SC stakeholders which is enhanced by the assurance of reliability and security of information shared among SC actors (Johnson, Elliott, and Drake 2013; Scholten and Schilder 2015). Trust refers to the good intent and genuine concern of SC partners for one another, which reflects confidence in the capacity and reliability of each other (Johnson, Elliott, and Drake 2013).

5.3. Framework showing traceability as an enabler of SC resilience

Based on integrating the traceability literature with the key theoretical constructs from the SCRes literature, it is concluded that traceability systems can be explored as a SC capability that both directly enables SCRes and further indirectly enhances the attainment of the other enablers of SCRes. This relationship is illustrated in the proposed framework in Figure 3. This does not represent a cause-and-effect relationship, but rather a conceptual representation of how traceability can be linked to SCRes both directly and indirectly. Further empirical research is needed to investigate the strength of each link and the likelihood of a simultaneous fulfilment of more than one link from a traceability system.

6. Conclusions and research gaps

6.1. Summary of findings

Traceability has become an increasingly important research topic in recent years. The urgent need for quality and safety, especially in food and pharmaceutical SCs, coupled with recent evaluations of new technologies predicted to have a major impact on traceability, have significantly contributed to this increased research attention. As captured in the research question, this study sought to provide a comprehensive overview of the benefits of traceability systems as identified in the literature and further explain the relationship between traceability and SCRes. To answer this research question, this SLR first highlighted the current state-of-the art in the traceability literature, both by using descriptive analysis and by discussing three of the key themes identified: drivers, technology evolution and barriers to adoption. Key points raised under these themes included:

- Despite the relevance of external drivers, such as mandatory regulations, the ultimate decision to adopt a traceability system depends on internal motivations either to: meet the demands of the product; control excessive costs of failure (profit); or to improve SC performance.

- There is no wholly overriding traceability technology – all technologies have their strengths and weaknesses, and some perform better than others in some industries due to specific product characteristics. Nonetheless, it is concluded that, in the future, there should be less focus on developing new technological systems and instead more focus on creating a more universally accepted system that enhances interoperability globally.
- The challenges to the implementation of traceability can be categorised as either intra-firm, inter-firm, technical or external. Financial constraints are a key hurdle faced in the implementation of traceability systems, and these can be encountered in different forms at different stages of traceability implementation, such as: the cost of technology (hardware and software); cost of staff training; and legal costs associated with information accessibility.

Secondly, this SLR has summarized the benefits of traceability systems under three categories – impact on crisis management, impact on firm and SC performance, and impact on consumers and society, providing detailed sub-categories, as summarized in Table 7. This study further emphasized that the benefits of the implementation of traceability may be preceded by a significant increase in operational costs in the short-term and by inter-firm relationship friction. It is also concluded that the tools and technologies only act as enablers of traceability and require an effective integration with other resources to fully attain the desired benefits. In addition, it is important to note that the use of incentive-based contracts or contingent payments (i.e. where a 'principal' pays an 'agent' based on their ability to meet the quality and safety standards agreed) is persuasive in ensuring adherence to quality and safety requirements (Resende-Filho and Hurley 2012). However, these contingent payments are likely to lead to adversarial buyer-supplier relationships where the most influential tier may be overly opportunistic. Process traceability is therefore recommended to ensure the continuous monitoring of the production process, modifying potential threats at source to avoid the wasted production and distribution of compromised products.

Thirdly, this study explored the benefits of traceability that enhanced the attainment of SCRes. Building on the detailed benefits specified in Table 7, it is concluded that the following have a relationship with SCRes: improved risk awareness and pro-activeness; improved consumer trust and confidence; improved monitoring of events and risk identification; real-time tracking and exchange of information; improved reliability and security; and, improved trust and confidence among SC actors. These benefits either directly enable the development of SCRes or have an indirect impact through other known enablers of SCRes – flexibility, velocity, visibility and collaboration. As summarized in Table 8 and Figure 3, these results advance understanding of the traceability-SCRes relationship and set the tone for further empirical research that seeks to validate this relationship. Previous studies have focussed on identifying strategies that enable SCRes, whilst this study has added emphasis on how to implement these strategies to successfully overcome the associated barriers.

6.2. Managerial implications

From a managerial perspective, this study increases practitioner awareness of the challenges and potential benefits associated with traceability systems, which are essential considerations in making strategic decisions. It addresses the opportunities inherent in various technologies to aid an objective cost-benefit analysis in selecting technologies thus guiding traceability-related SC initiatives. This study also offers valuable insights for both practitioners on the importance of building trust and confidence in SC relationships to maintain shared values among all SC actors.

Moreover, the study provides a justification for investment in digitalization in response to the increased susceptibility of SCs to disruptions by outlining the various benefits of traceability that help improve both the proactive capacity to prevent a disruption and the reactive capacity to respond appropriately after experiencing a disruption. Specifically, traceability increases a firm's ability to monitor real-time events and obtain, update and transfer information quickly among SC partners to ensure a responsible partner takes the required action.

6.3. Research gaps and future research recommendations

The study identified the following broad gaps in the literature to steer future research.

- The literature differed on the most important driver of traceability because of the varying complexity of the SCs studied and, to some extent, the theoretical lens adopted. To objectively determine the significance of the drivers and gain a better understanding of them, it is proposed that future studies consider the complexity of the SCs by focussing on cases from similar industries to gain literal replication, and/or contrasting industries to gain theoretical replication.
- Unlike mandatory traceability, voluntary standards are likely to result in a restructuring of existing relationships because of the amount of information that must be shared among SC partners. Future research should explore the level of information firms are willing to share with partners and the potential benefits of stipulating boundaries on the demands for information that partners should realistically request from others.
- Further research is needed to compare the effectiveness of alternative technologies, given that to date the comparisons in the literature have considered technologies that were at different stages of implementation, with some still being tested in specific industries. Surveys to compare the effectiveness of technologies at similar operational levels (such as according to years of adoption) are therefore recommended to better assess their potential

for SC traceability. Case study research is also needed to analyse receptiveness towards advanced traceability and hence find effective implementation strategies for emerging technologies.

- In contrast to traceability as an enabler of inter-firm trust and confidence, from a TCE perspective, Stranieri, Orsi, and Banterle (2017) concluded that firms are more likely to implement traceability systems to mitigate their internal risks than to mitigate external risks in the SC. Further research is needed to explore strategies that jointly address these objectives and mitigate opportunistic behaviours in the SC.
- Notwithstanding the capacity of traceability systems to improve risk awareness by identifying risk sources along the SC, a comprehensive understanding of the relationship between traceability and SCRes is missing from the literature. Although it is explicitly mentioned in a few studies on food SCs, traceability has either been ignored or merged with other enablers in studies of other industries. As highlighted in Section 5 above, traceability plays a significant role as an enabler of SCRes both directly and indirectly. Future empirical research is needed to verify these insights, thereby extending understanding beyond the purpose of traceability for monitoring and identifying risks to also consider its impact on developing vulnerability mitigation strategies.
- The lack of a unified traceability standard obstructs the effectiveness of traceability since the various systems have different data manipulation attributes, creating compatibility problems. Survey research is recommended to understand the effects of this lack of standardisation on SC relationships and whether or not this blocks the entry of new potential partners.
- Attaran (2007) asserted that restricting traceability systems to regulatory requirements (compliance) because of the cost of technology may hinder the returns on investment (ROI) expected, suggesting a linkage between financial constraints and the level of traceability adopted. Further empirical investigation is needed to assess this assertion along with the severity of the other challenges identified in the literature. For example, case study research is recommended to investigate how an awareness of the challenges expected in the deployment of traceability systems can facilitate strategic decisions and subsequently determine the level of traceability to adopt.

6.4. Limitations

Despite rigorous efforts to ensure the validity of our findings, the study has some limitations. Firstly, there is potential for bias and subjectivity, as commonly attributed to literature reviews (Durach, Kembro, and Wieland 2017). This study relied on papers published in ABS recognized journals compiled from the OneSearch Library and Scopus with a predefined search string. Hence, there is a possibility that some relevant articles were omitted because of the specified scope of the search strategy. However, the authors attempted to neutralize this limitation by adopting a comprehensive, transparent and systematic process, as described in Section 2, where the bounds placed on the sources of literature was justified as being necessary to ensure that only high quality articles were screened for inclusion. Secondly, this study was based on the viewpoints of other researchers, and hence the conclusions are limited to the scope of knowledge presented in the literature. This hindered the exploration of SC traceability as an enabler of SCRes because empirical investigation was beyond the scope of this study. However, the framework and conclusions lay the conceptual foundations for future empirical studies that develop this promising line of enquiry further.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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