Computers in Industry 144 (2023) 103788

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.sciencedirect.com/journal/computers-in-industry

When business processes meet complex events in logistics: A systematic mapping study

Belén Ramos Gutiérrez [a], Antonia M. Reina Quintero [a,*], Luisa Parody [b], María Teresa Gómez López [a]

[a] Dpto. Lenguajes y Sistemas Informáticos, Universidad de Sevilla, Spain
[b] Dpto. Métodos Cuantitativos, Universidad Loyola Andalucía, Spain

ARTICLE INFO

Keywords:
Logistics
Event-driven business process
Complex event processing
Business process
Systematic mapping study
Systematic literature review

ABSTRACT

Logistics processes are attracting growing attention because of the globalisation of the market. Its growing complexity and the need for reducing costs have provoked the seek of new solutions based on the processing of the complex events that the business processes produce. Event-Driven Business Process Management (EDBPM) is a discipline that studies the integration of business processes and complex events. The analysis of the maturity level of the approaches and gaps to point out future lines of research could help not only logistics organisations, but also academia. Logistics organisation could benefit from producing more environmentally friendly and optimal solutions in transport, and academia could benefit from revealing open problems. Thus, this study aims to identify current approaches, frameworks, and tools that integrate business processes and complex events in the logistics domain. To do so, we follow a systematic approach to do a mapping study that captures and synthesises the approaches, frameworks, and tools that integrate these two fields. As a result, 10,978 articles were gathered and 169 of them were selected for extraction. We have classified the selected studies according to several criteria, including the business process life cycle in which they are being applied, the business process modelling language, and the event process modelling language, among others. Our synthesis reveals the open challenges and the most relevant frameworks and tools. However, there is no mature enough framework or tool ready to be used in companies, and a promising research must provide solutions that cover all phases in the process life cycle.

1. Introduction

Product exchange and globalisation of the market have caused an increase in logistics processes as a key part of supply chain management. However, the rise in shipping rates and the cost of cargo containers, the increase in fuel cost, the lack of wooden pallets, the clogging of containers in port yards, or the low availability of storage make the logistics problem a global concern that Forbes has classified as much bigger than the pandemic (Broadman, 2021). To solve these problems, Information and Technology (I&T) is playing an important role in supply chain organisations, as stated in the Gartner report (Klappich et al., 2020). This report claims that "by 2023, 50% of global product-centric companies will invest in real-time transportation visibility platforms".

In this globalisation context, logistics processes might be very complex since they can choreograph various entities, including resources and time restrictions. Furthermore, the collaboration of various entities, which may be geographically distributed, generates an enormous number of events that are complexly related. As a consequence, the extraction of knowledge from logistics processes implies the analysis of the processes that choreograph the organisations that collaborate, and the analysis of single events to derive other events defined at a higher level of abstraction, known as complex events.

Traditionally, Business Process Management (BPM) and Complex Event Processing (CEP) are the two disciplines that face the problems related to business processes and complex events separately. However, recently, Event-Driven Business Process Management (EDBPM) (Ammon, 2009a) has emerged as a new discipline to integrate both, in such a way that the events generated through the BPM systems can be paralelly analysed by a CEP taking the advantages of both disciplines. On the one hand, Business Process Management (BPM) (Weske, 2012) is the most valuable corporate asset, and according to the Business Process Management Market Research Report (Future, 2021), the "BPM market is expected to grow to approximately USD $16 billion by

* Corresponding author.
E-mail addresses: brgutierrez@us.es (B. Ramos-Gutiérrez), reinaqu@us.es (A.M. Reina Quintero), mlparody@uloyola.es (L. Parody), maytegomez@us.es (M.T. Gómez-López).

https://doi.org/10.1016/j.compind.2022.103788
Received 21 January 2022; Received in revised form 22 September 2022; Accepted 24 September 2022
Available online 14 October 2022

2023". BPM represents an integration of technologies and methodologies that facilitates the modelling and deployment of process models by coordinating a set of activities choreographed to achieve the objectives of an organisation (Pérez-Álvarez et al., 2018). Complex Event Processing (CEP) (Luckham, 2012) refers to a set of concepts and principles for processing events and the methods for implementing those concepts. The advantages of integrating both BPM and CEP are widely known (Eyers et al., 2016), and have been considered in logistics (Ammon et al., 2008; Schiefer et al., 2007; Emmersberger et al., 2009), due to the complexity and heterogeneity of the systems and the types of events that are handled in this context. However, there is no comprehensive overview of the state of research on Event-Driven Business Process Management in the logistics context.

The aim of this paper is to analyse the state-of-the-art of EDBPM in the logistics context to understand how business processes and complex events are being integrated into logistics processes. To do so, we conducted a systematic mapping study that aims at giving an overview of the research area through classification and counting contributions in relation to the categories of that classification (Khan et al., 2019). The results of this mapping study are not only valuable for organisations because they can be aware of the most mature approaches, frameworks, and tools, but also for researchers because they reveal the gaps that can drive future research lines. Therefore, if an organisation with logistics management wants to leverage the level of digitalisation of its processes, our study can provide information on how many approaches, techniques, and tools exist to support the deployment of business processes through complex event processing in the logistics context.

The rest of the paper is structured as follows: Section 2 introduces the background needed to understand the analysis; Section 3 presents the related work; Section 4 details the method we used in our systematic mapping study; Section 5 presents the data extracted following the method previously mentioned; in Section 6, the research questions are discussed; in Section 7 the threads to validity are analysed; and finally, Section 8 draws conclusions.

2. Background

This section defines the concepts needed to fully understand this study according to the main areas of research that frame this work: logistics, business processes and complex events.

2.1. Logistics

The importance of supply chain management has increased drastically during the last decades, especially with the necessity of coordinating various entities. While supply chain is related to the more general actions related to coordinate and manage items and persons in an organisation, the term logistics is used to refer to the set of activities that describe the flow of items in a company or its interchanging between various of them. In this context, a **logistics system** (Ghiani et al., 2013) describes the activities that determine the flow of the materials and information among the facilities of the organisations that can be in different places. It includes the infrastructure, equipment, means and resources (including humans) necessary for performing the activities. The capacity of modelling (Bassil et al., 2004) and reasoning over these systems (Chow et al., 2005) can improve performance in real scenarios. For this reason, the advantages that business process management can offer make them prone to logistics systems.

2.2. Business processes

Business process management is a mechanism for modelling, observing and improving the activities developed in an organisation to achieve their goals according to a set of constraints that govern their behaviour (Gómez-López et al., 2015). Process modelling is the first step to understand how the activities performed by organisations, both manually and supported by information systems, are related. According to Weske (2012), a **business process**[1] is composed of a set of activities belonged from one or over one organisation. These activities are performed in a coordinated way to achieve a business goal. Thus, **business process management** (Dumas et al., 2013) gathers the techniques and methods to support the life cycle of business processes. Furthermore, according to Augusto et al. (2019), the business process life cycle is composed of different phases: identification, discovery, analysis, redesign, implementation, and monitoring and controlling.

For modelling business processes in the phases of the life cycle different languages can be used, both imperative and declarative. Thus, a **business process modelling language** is a language oriented towards the description of a set of rules to govern how the elements involved in a process can be combined (Dumas et al., 2013). One of the most widely used business process modelling language is BPMN (OMG, 2013), although others can be used, such as Petri-nets (van Hee et al., 2013), YAWL (Ter Hofstede et al., 2009), Declare (Pesic and Van der Aalst, 2006), BPEL (OASIS, 2007), GSM (Guard Stage Milestone) (Hull et al., 2010) and UML Activity Diagram (Force, 2001).

2.3. Complex events

The complexity of logistics processes is derived from the multiple entities that can be involved, the distribution of the processes, and the different levels of abstraction of the generated events. This complexity makes necessary the analysis of the single events produced to infer more complex actions. These complex actions are represented by more than one event, known as **complex events**.

In computer science, an event can be defined as "anything that happens, or is contemplated as happening" (Chandy et al., 2011). However, the definition of event varies depending on the context (BPM or CEP). From a business point of view, an **event** is an action or occurrence that affect the business, and that happens in a timestamp that may be handled and stored by a software system. Events can include attributes, such as time at which they happened, resources or location (Luckham, 2012). Furthermore, in the context of business processes, event logs used to be represented by using the XES standard (eXtensible Event Stream).[2] Event logs are formed of a set of traces that contains a sequence of events.

The term **complex event processing (CEP)** (Luckham, 2005) gathers a set of technologies to discover relationships between single events to infer the existence of relevant information, such as timing, causality, membership, or existence of patterns of behaviour or correlation (Schiefer and McGregor, 2004). To describe the type of events and the attributes they hold, we need an event model, and for processing them an event processing language is necessary. Thus, an **event model** is the mechanism for describing the events produced by the involved systems (Cugola et al., 2015), that includes a set of attributes At and a set of domains D for each attribute, $\{At_1; D_1, \ldots, At_n; D_n\}$. Whereas, an **event processing language (EPL)** is a high-level declarative language that permits defining functions to manage events within a data stream.

[1] There is a wide range of definitions of business process in literature (Davenport, 1993; Hammer and Champy, 1993; Johansson et al., 1993). We have chosen the definition proposed by Weske because it is the most recent and one of the most relevant taking into account the number of citations.

[2] https://www.xes-standard.org/.

The declarative capacity of the EPL facilitates the description of complex event conditions, event correlations, and the inclusion of possibly spanning time windows (Luckham, 2008).

The discipline that integrates business processes and complex events is named event-driven business process management. **Event-Driven Business Process Management (EDBPM)** (Ammon, 2009b; Goetz, 2010) combines both Business Process Management (BPM) and Complex Event Processing (CEP) techniques to support the actions performed in a business process that originates complex events. In this context, the BPM engine generates events during the execution of the daily processes, that are analysed by the CEP in a parallel way, with the objective to detect the relevant information. These events can also influence the execution or the process and give as result other events.

3. Related work

We consider as related work the secondary studies focused on the combination of complex events and business processes in the logistics context. Secondary studies are those studies that summarise and classify the published literature, in contrast to primary studies that present a primary work and are the focus of the analysis performed in secondary studies. Secondary studies in software engineering can be classified into surveys, systematic literature reviews, and systematic mapping studies.

A survey is a kind of secondary study that is not conducted systematically nor with a systematic protocol (Khan et al., 2019). On the contrary, systematic literature reviews and systematic mapping studies follow a systematic approach by following a systematic protocol. One of the fundamental differences between systematic literature reviews and systematic mapping studies is their goals (Kitchenham et al., 2010, 2015). While the goal of systematic literature reviews is to address very specific questions, systematic mapping studies aim at giving an overview of a research area through classification and counting contributions in relation to the categories of that classification (Khan et al., 2019).

None of the analysed secondary studies has been conducted as a mapping study and only a few analyse the integration of business processes and complex events in the area of logistics. To analyse these secondary studies, we have classified them into systematic literature reviews, surveys, and other secondary studies. The following subsections analyse in detail these groups of studies.

3.1. Systematic literature reviews

The research questions of systematic literature reviews are more focused compared to the questions proposed in mapping studies. We have found various systematic literature reviews focused on some aspects of the relationship between complex events and business processes (Krumeich et al., 2014; Amjad et al., 2018; Augusto, 2020). These studies explore how events drive the management of business processes (Krumeich et al., 2014), how business requirements can be modelled and validated with event-driven processes (Amjad et al., 2018), and the accuracy and efficiency of process mining in the context of event-driven processes (Augusto, 2020). However, these studies do not give an overview of how, within the life cycle of processes, events can be applied or affected, and of course, how their study can be applied to the field of logistics.

Falco (Jaekel, 2019) conducts a systematic review of the existing literature in the area of cloud logistics. He selects 83 studies and classifies them according to the meaning of the term "cloud logistics". However, the logistics encompasses much more than what is covered by the term cloud logistics, so this study is insufficient for answering the research questions we proposed.

3.2. Surveys

Surveys are another type of secondary study. In general, surveys are less rigorous than mappings and systematic literature reviews. We have found a set of surveys related to CEP, BPM, and logistics (Davidsson et al., 2005; Li, 2005; Fulop et al., 2010; Akila et al., 2016; Li et al., 2017; Dayarathna and Perera, 2018). As in some of the aforementioned studies, the surveys have not been conducted systematically, and as a result, neither the research questions nor the identified studies are explicit, so they are difficult to replicate.

Davidsson et al. (2005) presents a consistent view of the research efforts made in freight transportation and some work of traffic and transport of people, but the more generic aspects of logistics, such as the organisational part, external factors (traffic, weather, ...), or even the part of supply chain management are not included. Furthermore, they do not consider the role of CEP and BPs in logistics. In Li (2005), Li surveys the recent progress of event-driven applications and investigates their potential implications at the system and middleware levels. On the one hand, this study focuses on the military and intelligence community and the logistics is not included. On the other hand, activities are not contextualised within a business process. Fulop et al. (2010) examine the complex event processing and the related field of predictive analytic. The survey includes the terminology, research achievements, existing solutions, and open issues related to both areas. In Akila et al. (2016), Akila et al. analyse the techniques, challenges, and future directions of complex event processing over uncertain events. Lastly, Dayarathna and Perera (2018) summarise the latest cutting-edge work in 2018 done on event processing system architectures, event processing use cases, and event processing open research topics. In these three surveys, the focus is on events without considering business processes or logistics. Finally, Li et al. (2017) presents a variety of data-driven techniques and applications with a focus on computing system management.

3.3. Other secondaries studies

This group of studies includes secondary studies that cannot be formally classified as mapping studies, systematic literature reviews, or surveys. There are several points that differentiate the studies in this group from ours. Firstly, neither of the studies deals with the combination of CEP and BPM in the logistic context. Alias et al. (2016) focus on the combination of events with logistics, while Soffer et al. (2019) focus on the combination of events with processes. Secondly, the number of studies they analyse is considerably smaller than the number of studies we have considered in our mapping study. In addition, the rigour of such mappings precludes the exact replication of the studies.

The mapping study by Alias et al. (2016) aims at determining the updated status in 2016 of complex event processing and predictive analytics in the transportation and logistics sector. One of the major problems with this study is that it does not follow a formal method for conducting the mapping. Among other things, they do not specify exactly what terms have been used to perform the searches, making the replication of the study difficult. They identified 58 studies that are categorised into the areas of transport, logistics, and supply chain management. However, they do not mention any relation with the business process technology.

Soffer et al. (2019) focus on the challenges and opportunities for the combination of CEP and process mining. Although they illustrate and motivate the study through a logistics example, the focus of the study is not the logistics sector. Furthermore, in relation to replicability, they do not present the number of articles analysed, nor the sources used, nor what criteria they use to select the articles. Finally, as their research is focused on process mining, they do not cover the studies that are framed on the rest of phases of the business process life cycle.

Table 1
Research questions.

Id		Research question
RQ1	What are the demographics of the published studies?	
	RQ1.1	Which contributions were made over the years?
	RQ1.2	Which are the most influential researchers in the area and were are they from?
	RQ1.3	Which are the most influential studies?
	RQ1.4	Which are the top venues?
RQ2	What are the current trends in the area?	
	RQ2.1	What is the type of contribution made by the study?
	RQ2.2	Which are the application areas of the studies?
	RQ2.3	What type and which business process modelling languages are utilised?
	RQ2.4	What type and which event processing languages are utilised?
	RQ2.5	How is logistics covered in the studies?
	RQ2.6	Which are the event producers?
RQ3	What are the potential gaps in the area?	
	RQ3.1	Is event-driven business process treated in every phase of the process life cycle in a logistics context?
	RQ3.2	What are the challenges taken off in the field?

4. Method

The main purpose of our study is to analyse the state-of-the-art of integrating business processes and complex events in the logistics context. Our goal is to identify the current approaches, frameworks, and tools, their maturity level, and the areas not explored in depth to point out future lines of research. Thus, the principal objectives of this mapping study are as follows:

OBJ1: To synthesise the studies in the logistics domain with approaches related to event-driven business processes to provide insight into this area.

OBJ2: To investigate the trends in event-driven business processes in the logistics domain.

OBJ3: To reveal the gaps and foresee future directions of research.

To conduct the mapping study, we have followed the guidelines proposed by Kitchenham and Charters (2007), Kitchenham et al. (2015) and Kuhrmann et al. (2017) for performing systematic literature reviews in software engineering. And the guidelines for the use of snowballing by Wohlin (2014).

The review process consists of three main stages: planning, conducting, and documenting the review. Fig. 1 depicts these stages and the principal activities involved in each phase. The protocol is defined during the planning stage (phase 1), which includes assigning responsibilities and activities to the reviewers. The result of this stage is the protocol. The activities defined in the protocol are executed in the conducting stage (phase 2). These activities include identification, selection, assessment of the quality of primary studies, data extraction, and synthesis of the extracted data. Since phase 2 is the stage that comprises more activities, we have detailed it in Fig. 2 by means of a process specified with the BPMN notation (OMG, 2013). Fig. 2 describes the activities performed in Phase 2, in which the different search engines are searched. Duplicated studies are removed from the set of studies to be analysed. The rest of the studies are submitted for first screening and, if they are related to the objectives of the study, for a later careful read. After this analysis, the researchers discuss the selection to arrive at a consensus on possible doubts. The selected studies are used to perform a backward and a forward snowballing, that is, the studies that are included in the references and the studies that cite a selected study are included in the set of studies to be analysed. After that, each selected study is used to extract the required data, and its quality is assessed. Eventually, the extracted data is synthesised to facilitate later knowledge extraction. Finally, in phase 3, a report is produced to distribute the results.

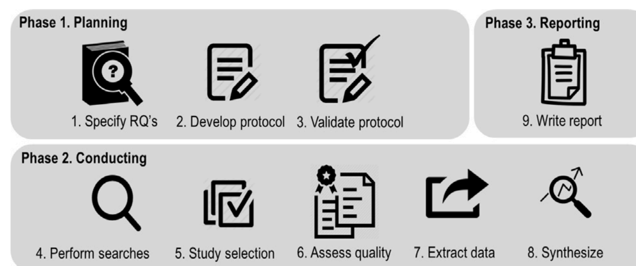

Fig. 1. Main stages for conducting the SMS according to Kitchenham and Charters (2007).

4.1. Research questions

The specification of the research questions is an essential part of the conduction of a systematic mapping study because they drive the entire review process (Kitchenham et al., 2015). As we have developed a mapping study, some research questions are broad and are concerned with classifying the literature. The questions are aligned with the three objectives mentioned previously. We have defined three broad fundamental questions (R1-R3) that are based on the categories of research questions identified by Khan et al. in Khan et al. (2019): demographics, current trends, and research gaps. Additionally, each question has been broken down into some secondary questions.

Table 1 lists the research questions addressed in this study. Question RQ1 belongs to the demographics category and aims to characterise the studies published in the area. This question has been broken down into sub-questions RQ1.1-RQ1.4. These subquestions will help us identify the number and frequency of publications, the most influential researchers and their countries, the most influential studies, and the top venues. Question RQ2 belongs to the category of current trends and aims to identify the nature of the existing work in the area. We have broken this question down into sub-questions RQ2.1-RQ2.6 that help us to identify the type of contributions, the application areas, the business process modelling and event processing languages, the logistics coverage, and the event producers. Finally, RQ3 belongs to the research gaps category and aims at the identification of gaps in the area. This question has been broken down into sub-questions RQ3.1-RQ3.2. The rationale behind these sub-questions is the identification of the process life cycle phases in which the approaches are framed, and the identification of the challenges in the area.

4.2. Search process

To collect the studies, we used a broad automated search followed by an automated backward snowballing and a later forward snowballing. Table 2 lists the digital libraries and search engines used as data

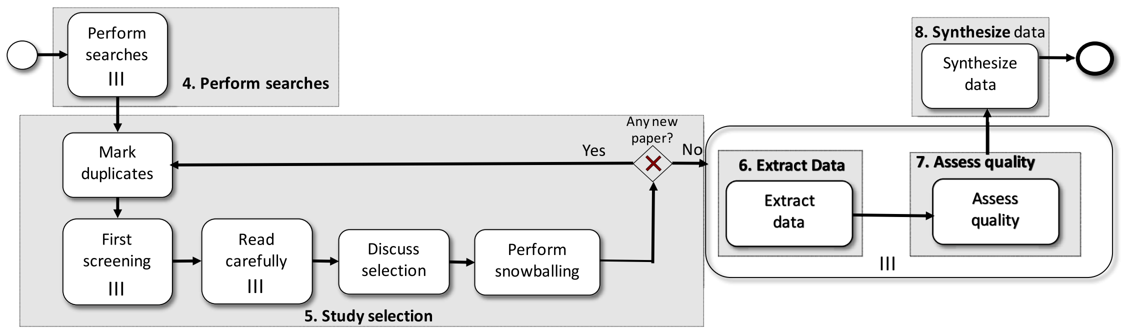

Fig. 2. Phase 2: Process definition for conducting the review.

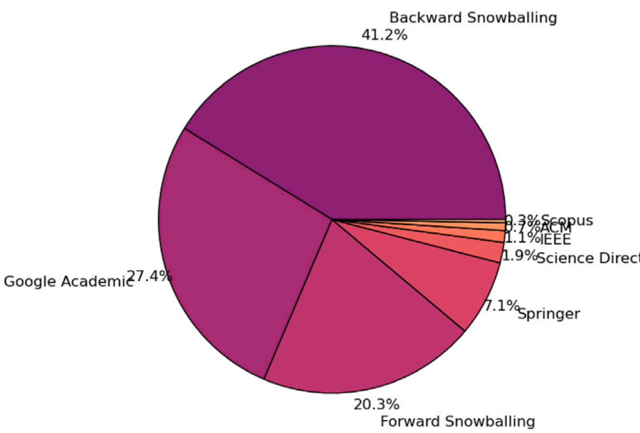

Fig. 3. Proportion of studies recovered in relation to the data source.

Table 2
Digital libraries and search engines employed as data sources.

Search engine	URL
ACM DL	http://dl.acm.org
Springer	http://www.springer.com
IEEE Xplore	http://ieeexplore.ieee.org
ScienceDirect	http://www.sciencedirect.com
Google Academic	http://scholar.google.es
Scopus	http://www.scopus.com

sources during the automated search process. Furthermore, to arrive at proper search strings, we have followed a "Trial-and-error Search", as recommended in Kuhrmann et al. (2017). The terms resulting from this approach are the following:

- "complex event" AND "business process" AND "logistics"
- "event-driven business process" AND "logistics"
- "complex event" AND "workflow" AND "logistics"

As our goal is to have an overview of how event-driven business processes are used in the logistics domain, we have selected the following keywords: complex event and business process. Furthermore, since the term workflow is used as a synonym of business process in this context (von Ammon, 2018), we have also included workflow as a search string.

The queries to collect the studies from the digital databases and search engines were executed in December 2020, and later, in March 2022, a second round has been carried out to update the searches. It deserves to be mentioned that the searches in ACM DL, Springer, IEEE Xplore, Science Direct and Scopus have been performed through the Web interface, while searches in Google Academic have been performed using *Publish or Perish*.[3] This tool returns a maximum of 1000 results for this search engine.

As search engines have different query syntaxes, the previous search strings must be rewritten for every search engine. Table 3 lists the query strings used in each search engine. Note that a Search ID identifies every search. This ID is automatically generated by the Start tool,[4] which is the tool that we have used as a support and helps us trace the origin of the recovered study.

Regarding snowballing, we have performed an automatic extraction of the references of the selected studies (the so-called backward snowballing) following a two-step approach: first, we have queried Crossref[5] with a Python-based script to extract references[6]; second, if the study is not indexed in Crossref, we have used GROBID (2008–2021) to extract the references directly from pdf files. The forward snowballing has been performed by querying Opencitations[7] with a Python-based script,[8] and has been complemented by manually querying Scopus.

As a result of the search process 10,978 studies have been found. Fig. 3 summarises the number of studies obtained from the data sources, as well as the number of studies obtained with the backward and forward snowballing process. Note that more than the 61% of the incorporated studies have been obtained thanks to the snowballing process.

4.3. Study selection

Once the studies have been recovered from the data sources, they are loaded into the Start tool, which helps us detect some duplicates (see the first activity in Fig. 2). As the tool only detects duplicates by checking the exact match of titles, some duplicates are marked manually. After that, an initial screening is performed based on title, abstract, and keywords.

The initial screening of the 3450 studies obtained as a result of the automatic searches in digital databases is undertaken by all researchers. The screening of the 7528 obtained with backward and forward snowballing was also undertaken by all researchers.[9] We kept a full record of the researchers who conducted the initial screening of the study. Table 4 lists the inclusion and exclusion criteria used in the review. Note that some of these criteria are de facto standards, as noted in Kuhrmann et al. (2017).

As a result of the screening, 621 studies have been selected. These studies have been thoroughly reviewed by all researchers. Note that the researcher who performed the screening of one study is not in charge

[3] https://harzing.com/resources/publish-or-perish.
[4] http://lapes.dc.ufscar.br/tools/start_tool.
[5] https://www.crossref.org/.
[6] https://github.com/reinaqu/bibreferences.
[7] https://opencitations.net/.
[8] https://github.com/reinaqu/snowballing-opencitations.
[9] See Section 7 to see who did what.

Table 3
Search queries employed in the different search engines.

Source	SearchIDs	Search string
ACM DL	SEARCH0	[Full Text: "complex event"] AND [Full Text: "business process"] AND [Full Text: logistics]
	SEARCH6	[Full Text: "event-driven business process"] AND [Full Text: logistics]
	SEARCH7	[Full Text: "complex event"] AND [Full Text: workflow] AND [Full Text: logistics]
Google Scholar	SEARCH5	"complex event"+"business process"+ logistics
	SEARCH16	"event-driven business process"+ logistics
	SEARCH17	"complex event"+"workflow"+ logistics
IEEE Xplore	SEARCH3	((("Full Text & Metadata":"complex event") AND "Full Text & Metadata":"business process") AND "Full Text & Metadata":logistics)
	SEARCH10	(("Full Text & Metadata":"event-driven business process") AND "Full Text & Metadata":logistics))
	SEARCH11	((("Full Text & Metadata":"complex event") AND "Full Text & Metadata":workflow) AND "Full Text & Metadata":logistics)
Science Direct	SEARCH2	"complex event"+"business process"+ logistics
	SEARCH12	"event-driven business process"+ logistics
	SEARCH13	"complex event"+"workflow"+ logistics
Springer	SEARCH1	"complex event"+"business process"+ logistics
	SEARCH8	"event-driven business process"+ logistics
	SEARCH9	"complex event"+"workflow"+ logistics
Scopus	SEARCH4	TITLE-ABS-KEY ("complex event" AND "business process" AND logistics)
	SEARCH14	TITLE-ABS-KEY ("event-driven business process" AND logistics)
	SEARCH15	TITLE-ABS-KEY ("complex event" + "workflow" + AND logistics)

Table 4
Exclusion and inclusion criteria.

Criteria	Description
Exclusion	The study is not written in English. It is a proceeding book.[a] It is an index or a table of contents, not a book chapter. It is an editorial. It is not a paper, but the slides of a presentation. It is a call for paper, not a paper. It is an encyclopaedia entry, not a paper. It is an extended abstract. The study occurs multiple times in the result set. The study is not accessible electronically. It is the result of an importation error. Title, keyword list, and abstract make explicit that the paper is NOT related to logistics, business processes, or complex events.
Inclusion	Title, keyword list, and abstract make explicit that the paper is related to logistics, business processes and complex events.

[a]This criteria helps to avoid duplicates due to the behaviour of some search engines, which returns two results when searching for a study: one that refers to the single study, and another one that refers to the whole book of the proceedings in which the paper was published.

of reading it carefully and extracting the information of that same study. Furthermore, if one reviewer has doubts about the acceptance or rejection of a study after a thorough review, another researcher reviews that study, and the final decision on the acceptance of that study is taken in a voting workshop in which all researchers are involved. That is, we have followed an approach similar to the alternative approach proposed in Kuhrmann et al. (2017).

Once a study is selected for extraction, a backward snowballing of the references included in the study and a forward snowballing of the papers that cite the study is made. As Start does not work properly with the references obtained through snowballing, we have set up a procedure to add the references to the tool and to maintain the traceability of the snowballing process. On the one hand, the references/citations obtained automatically from a study are included in a BibTex/RIS file that is loaded in a new search session in Start. The session has as a keyword the *id* of the study that includes the references. On the other hand, we have used a spreadsheet to annotate the *id* of the search session, the *id* of the study, and the number of references recovered.

As a result of the selection, 169 studies are collected. Subsequently, their quality is assessed as explained in Section 4.4, and the relevant information is extracted for our mapping study (see Section 4.5). Fig. 4 shows a diagram and a Start screenshot that summarises the results obtained during the three principal activities carried out in the review stage: identification, selection, and extraction.

Table 5
Assessment of Intrinsic IQ.

Category	Intrinsic IQ output
J1 ∨ C1	HIGH
J2 ∨ C2	MEDIUM
J3 ∨ C3 ∨ O1 ∨ O2 ∨ O3	LOW

4.4. Quality assessment

The quality assessment of the studies has been carried out in parallel with the data extraction activity, because, as in Varela-Vaca and Reina Quintero (2021), we have used an Information Quality framework (Wang and Strong, 1996) to assess the studies. The quality assessment depends on the type of publication and the quality of the venues and the amount and completeness of the extracted data. The framework (Wang and Strong, 1996) defines four dimensions of Information Quality, namely: Intrinsic, Contextual, Representational, and Accessibility. Information Quality (IQ) can be measured regarding one or several dimensions depending on the extracted attributes. As the format of the data and the access to information are irrelevant in our context, we measure only Intrinsic and Contextual IQ.

Intrinsic IQ (Wang and Strong, 1996) measures the accuracy, objectivity, believability, and reputation of the data for the task at hand. Thus, to measure this dimension, we take into consideration the type of publication, the venue, and the ranking of the venue, and as a result, a value is obtained based on a three-point Likert scale with HIGH, MEDIUM, and LOW values. On this scale, HIGH is the best result, and LOW is the worst result. To calculate the value, first, the study is classified into one of the categories shown in Fig. 5, and then the value is obtained according to the category (Journal, Conference/Workshop or Others), as shown in Table 5. Afterwards, to obtain the value of the Intrinsic IQ, we have to look after the category in Table 5, and return the associated value. For example, if the category of the paper is J1 or C1, then the value is HIGH.

Contextual IQ (Wang and Strong, 1996) measures the amount of data and the completeness of the extracted data. To obtain this measure, we have defined a questionnaire composed of Yes/No questions (see Table 6). In relation to the number of Yes and Noes, we have defined the metric depicted in Eq. (1) that returns a value on a scale of [0-1]. The contextual IQ is defined based on a three-point Likert

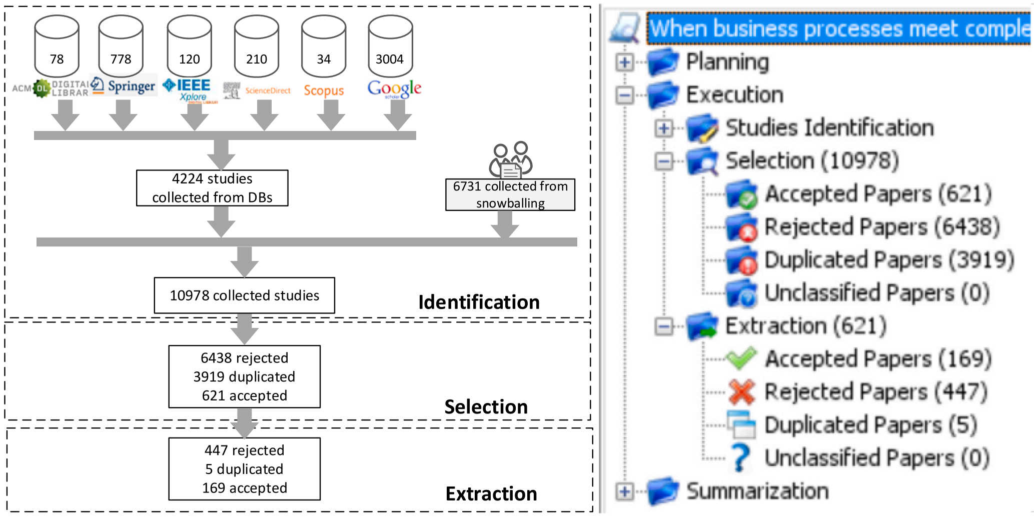

Fig. 4. Summary of the results.

$$study = \begin{cases} Journal & \begin{cases} J1: & Journal\ indexed\ as\ Q1\ or\ Q2\ in\ the\ ISI\ WoK\ and/or\ Scimago\ Journal\ rankings. \\ J2: & Journal\ indexed\ as\ Q3\ or\ Q4\ in\ the\ ISI\ WoK\ and/or\ Scimago\ Journal\ rankings. \\ J3: & Journal\ not\ indexed\ in\ the\ ISI\ WoK\ nor\ Scimago\ Journal\ rankings. \end{cases} \\ Conference/Workshop & \begin{cases} C1: & Conference\ indexed\ as\ Class\ 1\ or\ Class\ 2\ in\ the\ SCIE\ Conference\ ranking. \\ C2: & Conference\ indexed\ as\ Class\ 3\ in\ the\ SCIE\ Conference\ ranking. \\ C3: & Conference\ not\ indexed\ in\ the\ SCIE\ Conference\ ranking. \end{cases} \\ Others & \begin{cases} O1: & Book\ chapters. \\ O2: & arXiv\ papers. \\ O3: & Technical\ report,\ Phd\ thesis,\ Msc\ thesis\ and\ others. \end{cases} \end{cases}$$

Fig. 5. Classification of a study based on the type and quality of the venue.

scale with HIGH, MEDIUM and LOW values, in which HIGH is the best result and LOW is the worst result. We calculate the Contextual IQ value according to the criterion defined in Table 7. As stated in Even et al. (2010), data quality assessment cannot be defined in a general way because it is context dependent and, as a consequence, must be defined by domain experts. As our context differs from Varela-Vaca and Reina Quintero (2021), we maintain the same level of granularity as them, but we use different thresholds. Note that they present a multivocal mapping study that includes information from the grey literature, which requires a higher level of extracted data to classify a study with a high level of contextual IQ. In our case, a study with fewer than four extracted data has a low Contextual IQ, a study with seven or more extracted data has a high Contextual IQ; otherwise, the study has a medium Contextual IQ.

$$m_{Completeness} = \frac{|Number\ of\ answered\ questions|}{|Total\ number\ of\ questions|} \quad (1)$$

Finally, the quality of a study is determined based on the level of quality obtained in the two dimensions, that is, intrinsic and contextual. We consider the study acceptable when the HIGH or MEDIUM quality level is obtained in both dimensions. The study is rejected when both quality dimensions have a LOW value.

4.5. Data extraction and synthesis

The data extraction process has two stages: first, the data are extracted; and second, the extracted data are reviewed. All researchers are involved in the data extraction process. The researcher who selects a study for extraction is responsible for extracting the data from that study. If the researcher in charge of the extraction has doubts about the extraction of certain labels, we discussed them at a later meeting in which all researchers were involved. Data revision is made in parallel with data synthesis, because of inconsistencies, and errors are better detected at this point.

Table 6
Yes/No questions included in the quality questionnaire.

ID	Yes/No question
QA01	Could the type of contribution be extracted?
QA02	Could the application area be extracted?
QA03	Could the logistic coverage be extracted?
QA04a	Could the type of business process modelling language be extracted?
QA04b	Could the business process modelling language be extracted?
QA05a	Could the type of event processing language be extracted?
QA05b	Could the event processing language be extracted?
QA06	Could the event producer be extracted?
QA06	Could the process life cycle phase be extracted?
QA07	Could the challenge be extracted?

Table 7
Assessment of Contextual IQ.

Metric	Values	Contextual IQ
$m_{Completeness}$	>0.66	HIGH
$m_{Completeness}$	(0.33,0.66]	MEDIUM
$m_{Completeness}$	0.33≤	LOW

Data extraction is performed using three different tools: a Publication Form, a form that provides the Start tool with common information about publications, such as title, authors, and so on; an Extraction Form, a customised form created in the Start tool with data about the specific domain of the literature review; and an Excel Datasheet, to store information that has been obtained automatically, such as the

Table 8
Type of data extraction form and alignment of extraction fields with research questions.

Tool	Extracted data	RQ
Publication form	Publication title	RQ1.1, RQ1.2, RQ1.3
	Publication authors	RQ1.1, RQ1.2, RQ1.3
	Publication venue	RQ1.4
	Publication year	RQ1.1
Excel datasheet	Citations of the publication	RQ1.3
	Author's countries	RQ1.2
Extraction form	Type of contribution	RQ2.1
	Application area	RQ2.2
	Type of business process modelling language	RQ2.3
	Business process modelling language	RQ2.3
	Type of event processing language	RQ2.4
	Event processing language	RQ2.4
	Logistic coverage	RQ2.5
	Event producer	RQ2.6
	Process lyfecycle phase	RQ3.1
	Challenge	RQ3.2

citations of a publication or the author's country. Table 8 lists the extracted data, the tool in which the data is stored, and the research questions that can be answered using the extracted data.

Regarding the synthesis, we employ an approach based on both qualitative and quantitative methods to analyse the data. We use a qualitative approach when we are interested in questions about "what" and "how". To complement this qualitative analysis, we used descriptive statistics to discuss frequency and distribution.

4.6. Replication package

To strengthen the replicability of our review, we have published a bundle with all the artefacts and the final results of our study in url.[10] This bundle includes a Jupyter notebook with all generated graphics and some additional information, such as the raw numbers behind the graphics or the concrete studies under the different classifications made in the paper; three GitHub repositories, one with the Python code behind the graphics generation, and two with the Python-based scripts we have used to query Crossref[11] and Opencitations[12]; and the datasets used in the study (Ramos-Gutiérrez et al., 2021). Furthermore, the selected studies can be accessed online by following the information reported in a separate Selected Studies section in the Appendix included as supplementary material.

5. Data extraction results

The review process has been conducted from December 2020 to March 2022. During this process, we developed the protocol, identified and selected primary studies, performed data extraction and synthesis, and reported the results. All researchers participated in the entire process, as explained in Section 4.

5.1. Primary studies

Our set of primary studies is composed of 169 studies. For space reasons, the selected studies are listed in the Appendix as a table which is ordered by year and type of venue. The table shows the reference, the title, and the venue. Fig. 6 shows the percentage of studies by type of publication. As can be observed, almost half of the studies (46.2%) have been published in conferences; more than a quarter of the studies (26%) have been published in journals, and only 18.3% of the studies have been published in workshops. This demonstrates that the field is quite mature.

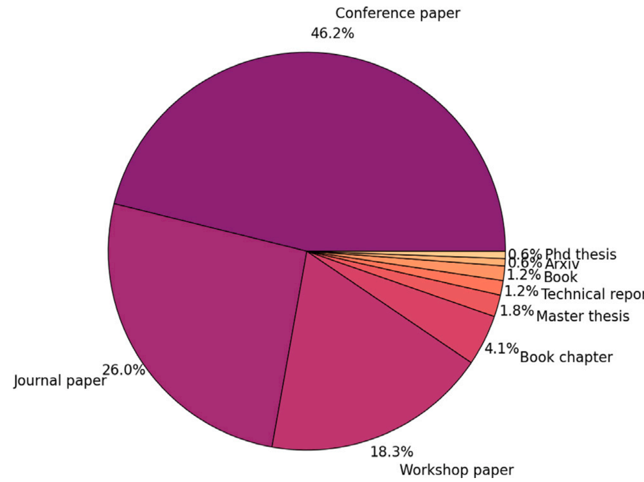

Fig. 6. Percentage of publications per type.

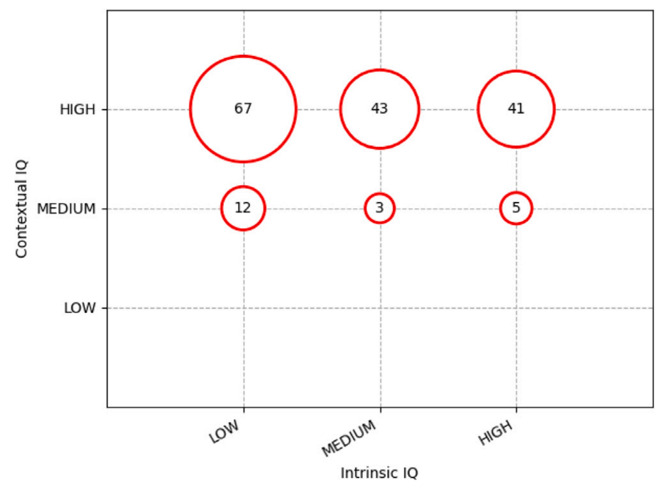

Fig. 7. Studies quality assessment.

5.2. Study quality assessment

The quality of each study has been determined by calculating the Intrinsic and Contextual IQ measurements (see Section 4.4). Fig. 7 shows a summary of the quality measurements. The figure depicts two dimensions, Contextual IQ and Intrinsic IQ, in a bubble chart. Each dimension can have the values LOW, MEDIUM, and HIGH. A bubble represents the number of studies that have the values depicted on the X and Y axes, respectively. Therefore, there are 41 studies that have HIGH Intrinsic and Contextual IQ; 43 studies that have a Medium Intrinsic IQ and a High Contextual IQ; and 67 studies that have a Low Intrinsic IQ and a High Contextual IQ. In summary, 151 out of 169 studies have a HIGH Contextual IQ, which means that in more than 89% of the studies the data can be extracted. Finally, it also deserves to be noticed that there is no study with Low Intrinsic and Contextual IQ, so no study has been rejected for quality reasons.

6. Discussion of research questions

In this section, we discuss the research questions by synthesising the results obtained from the collected studies.

RQ1. What are the demographics of the published studies?

This research question helps identify the number and frequency of publications, the top researchers in the area, the top countries, the

[10] http://www.idea.us.es/when-bp-meet-ce-in-logistics-a-sms/.
[11] https://www.crossref.org/.
[12] https://opencitations.net/.

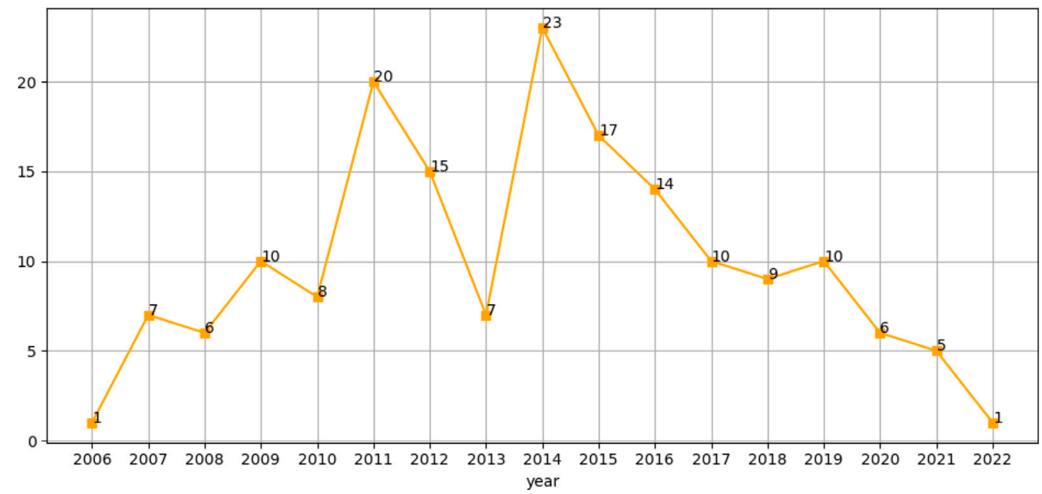

Fig. 8. Number of publications per year.

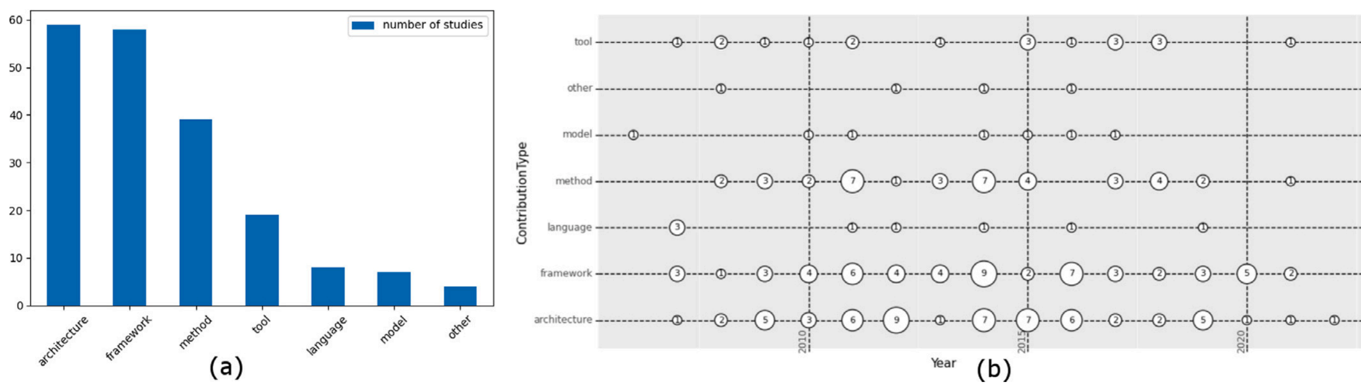

Fig. 9. (a) Proportion of type of contribution, and (b) Number of studies per contribution type and year.

most influential studies, and the top venues. For space reasons, this section is mainly focused on the discussion of RQ1.1. However, details on questions RQ1.2-RQ1.4 (authors, leading countries, most influential studies, and leading venues) are provided in the Appendix.

The goal of RQ1.1 is to provide information on the number and frequency of publications over time. The rationale behind this question is to analyse trends, such as the maturity of the field. Fig. 8 shows the number of relevant studies extracted in our review per year. As can be observed, the year with the highest number of publications is 2014, with a total of 23. Since 2014, the number of publications has been decreasing until 2018. This implies that event-driven business processes in logistics were an emerging research topic in 2007–2014. Afterwards, the number of publications has decreased until 2018, when it began to increase. Since then, it has started to decrease again in the years of pandemics (2020 and 2021).

RQ2. What are the current trends in the area?

This research question helps identify the nature of existing work in the area. The following subsections discuss the questions RQ2.1-RQ2.4, because they are the ones that allow us to obtain more interesting conclusions. The reader interested in RQ2.5 and RQ2.6 can consult the Appendix.

RQ2.1. What is the type of contribution made by the study?

This question aims to identify the nature of the work in the area. As in Petersen et al. (2008), the categories were determined by carefully reading the studies. It should be noted that there are studies that produce more than one type of contribution. For example, the study (Linden et al., 2013) proposes an architecture and a framework. Fig. 9(a) shows the proportion of types of contributions, and Fig. 9(b) shows the distribution of contributions per type and year. Architecture is the most frequent type of contribution (59 out of 169 studies contribute with an architecture), although the number of studies that contribute with a framework (58 out of 169) is also important. Unfortunately, most of the proposals that contribute with frameworks, tools and architectures do not offer a definitive version of their solution. In fact, many of them propose solutions that are still under development or are purely conceptual (24.5%), proofs of concept (10.7%) and prototypes (19.8%) (see the Appendix). Furthermore, most of the approaches that provide more details on the implementation of their solutions do not make their software publicly available (19.1%) and only 9.9% of the studies propose the integration of well-known commercial tools (see Fig. 10). Finally, all these proposals have one thing in common: they focus on the design or development of prototypes and software tools for academia; none of them constitutes a solution close to being a commercial solution applicable in industry.

RQ2.2. Which are the application areas of the approaches?

The aim of this research question is to identify the areas within the logistics sector in which the approaches are applied. The application areas have been obtained from Alias et al. (2016). They include maritime transport, air transport, multimodal transport, general transport, manufacturing, foodstuffs, transshipment, chemical and pharmaceuticals, retail, and others. After carefully reading the studies, we have classified the use cases, running examples, or descriptions they present according to the areas of application previously mentioned. Note that a study can be associated with more than one area of application. As

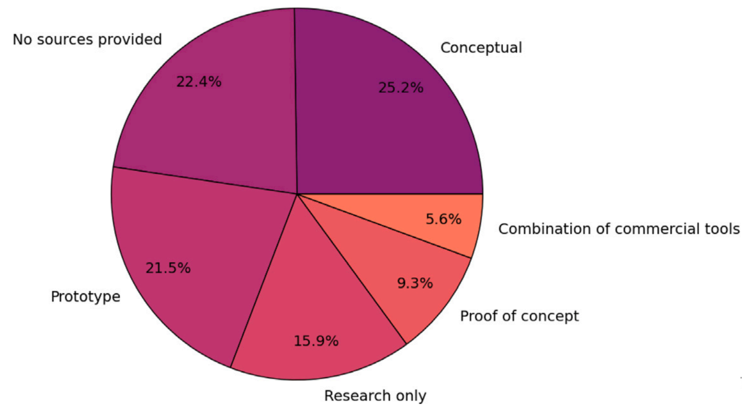

Fig. 10. Proportion of studies that contribute with frameworks, tools and architectures by feature.

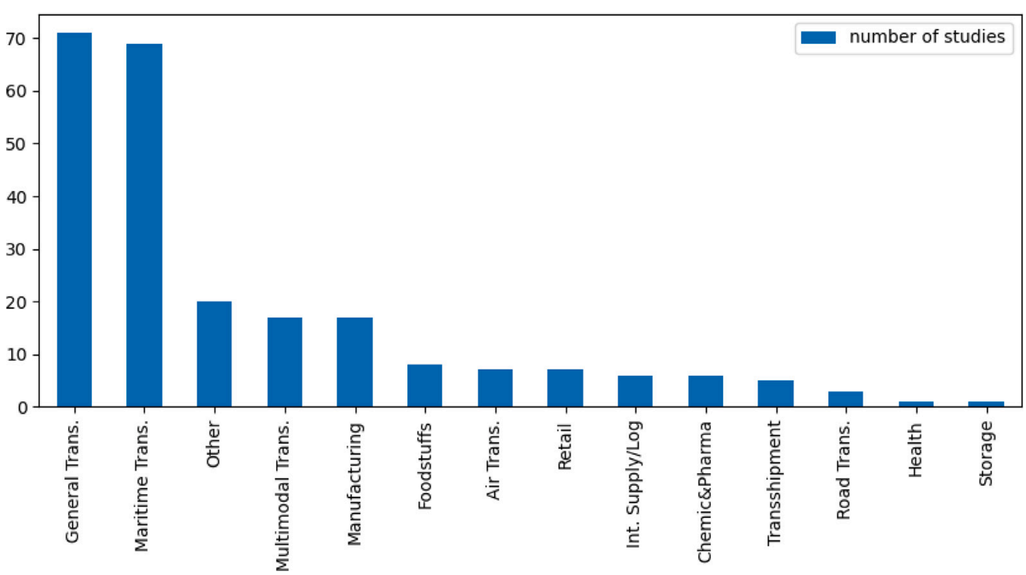

Fig. 11. Number of studies that cover the different domains.

shown in Fig. 11, the top areas of application are *general transport* and *maritime transport* with 71 and 69 studies, respectively. The third area is *other*, a hodgepodge of minority domains, such as military, art, and industry 4.0.

RQ2.3. What type and which business process modelling languages are utilised?

The rationale behind this question is to classify and identify the business process modelling languages utilised in the different studies. Each language has been classified according to its imperative or declarative nature. According to Fahland et al. (2009), imperative process modelling languages focus on the continuous changes of the process' objects, whereas declarative process modelling languages focus on the logic of the actions and objects of a process. Note that sometimes we have extracted the modelling language nature, even though the paper does not mention the concrete modelling language. For example, the study (Mousheimish et al., 2016) does not mention any concrete modelling language; however, we are able to infer the declarative nature of the language. Fig. 12 shows the proportion of business process modelling languages according to their nature. The 89.2% of the business process modelling languages have an imperative nature, and only the 10.2% of them have a declarative nature.

Regarding modelling languages, we have found 31 different ones. Fig. 13 shows a bar graph with the number of studies per modelling language. For clarity purposes, the graph only includes the business

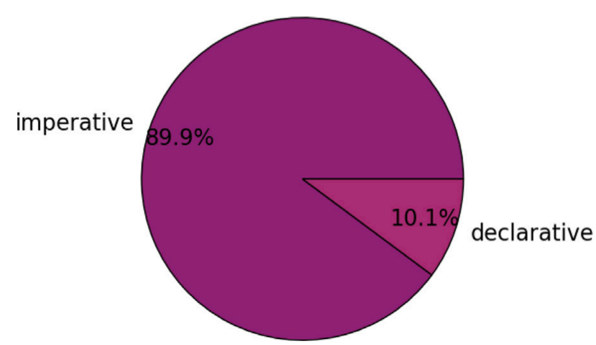

Fig. 12. Studies per business process modelling language type.

process modelling languages that have been mentioned in more than one study.[13] BPMN (Business Process Modelling Notation) (OMG, 2013) is by far the winner of the ranking (with 78 studies). BPEL (Business Process Execution Language) (OASIS, 2007) occupies the second place in the ranking (with 14 studies), while Petri Nets (van Hee et al., 2013) occupies the third place (with 11 studies). Finally, note that a study could mention more than one modelling language.

[13] For the reader interested in the ranking of all the languages, see the Appendix.

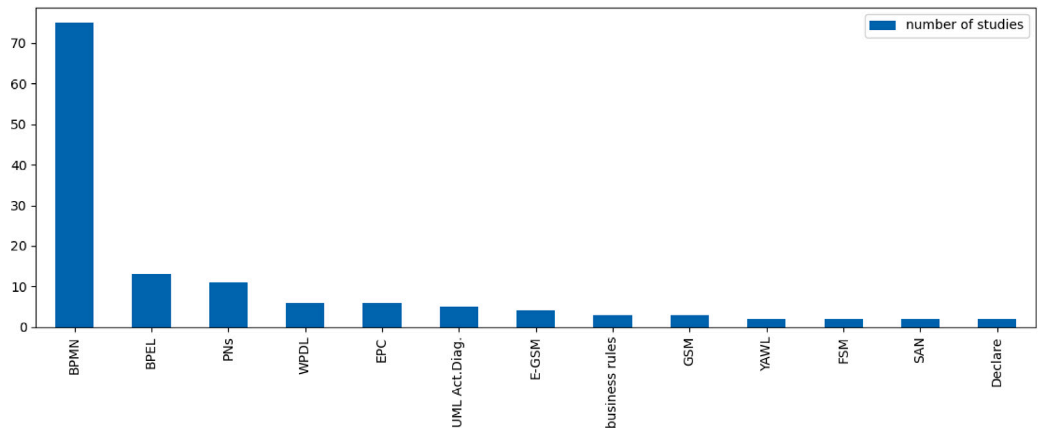

Fig. 13. Modelling languages: PNs = Petri Nets; SAN = Situation-Action-Network; FSM = Finite State Machine.

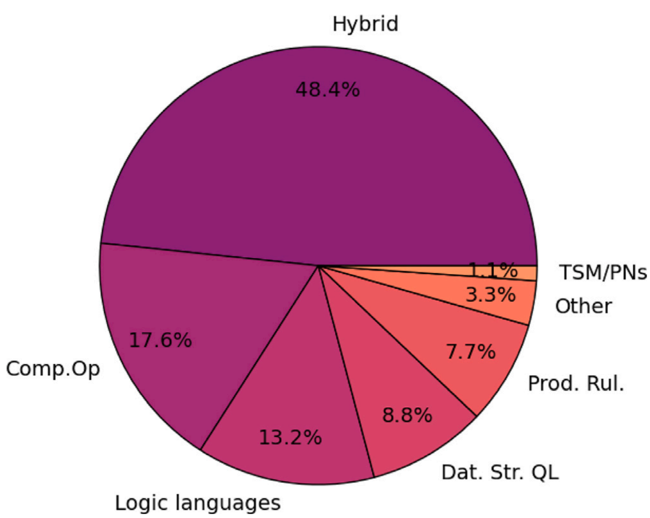

Fig. 14. Studies by event processing language style. Comp. Op. = Based on composition operators; Prod. Rul. = Production rules; Dat. Str. QL = Data stream query language; TSM/PNs = Timed stated machines/Petri nets.

RQ2.4. What type and which event processing languages are utilised?

The rationale behind this question is to classify and identify the event processing languages utilised in the different studies. Each language has been classified according to the five language styles for CEP enumerated in Eckert et al. (2011): languages based on composition operators, data stream query languages, production rules, timed state machines, logic languages, and hybrid approaches.

Languages based on composition operators define complex events using composition operators, such as conjunction of events or a sequence of events. Data stream query languages are usually based on SQL, where events are represented as tuples that flow in data streams, and queries are evaluated on these data streams. Production rules are not really query languages, but they provide a flexible way of implementing event queries. They relate event occurrences to facts, and event queries are expressed as conditions on these facts. Timed-state machines are a formalism in which a system that reacts to events is represented as a graph. Nodes are the states of the system, and edges represent events with associated temporal conditions that change the system state. The state machine implicitly defines the complex events. Logic languages define event queries through logic formulas. Finally, hybrid approaches introduce pattern matching into data stream query languages. Fig. 14 shows a pie chart of the distribution of studies per language style. More than 45% of the studies employ hybrid languages. This could be related to the fact that, by far, the most widely used event processing language is Esper (EsperTech Inc., 2006), which is a hybrid language.

Regarding event processing languages, we have found 33 different languages. Fig. 15 shows a bar graph with the number of studies per language. The graph only includes the event processing languages that have been mentioned in more than one study.[14] EsperTech Inc. (2006) is by far the most widely used EPL, with 31 studies. ECA Rules (Berndtsson and Mellin, 2009) are used in 10 studies. Finally, the third place in the ranking is occupied by SPARQL (W3C, 2013) and event calculus (Shanahan, 1999), with 7 studies each.

RQ3. What are the potential gaps in the area?

This research question helps identify potential gaps in the area. The following subsections discuss the secondary questions in which we have broken it down.

RQ3.1. Is event-driven business process treated in every phase of the process life cycle in a logistics context?

The rationale behind this question is to classify approaches along the life cycle of the process, which, as stated in Leitner and Rinderle-Ma (2014), "has proven to be a viable method to gain a holistic view". As introduced in Section 2, there are different phases in a process life cycle (Dumas et al., 2013): process identification, process discovery, process analysis, process redesign, process implementation, and process monitoring. Fig. 16(a) shows the distribution of studies per phase in the life cycle and Fig. 16(b) shows the distribution of studies per phase and year. One study can cover more than one phase. For example, the study (Mousheimish et al., 2016) covers the phases of analysis and monitoring.

Monitoring and analysis are the phases covered more by the studies. In fact, 43.1% and 33.1% of the studies cover these phases. The redesign phase is treated in 17.7% (30 out of 169) studies. The implementation and discovery phases are covered by 20 and 16 studies, respectively, and, finally, the least covered phase is the identification, with only 8,2% of the studies. Finally, regarding the holistic view, it deserves to be mentioned that only one study (Conforti et al., 2013) covers all the phases.

Regarding the distribution per year of the studies, it can be seen that there are some phases such as monitoring and design that maintain a constant flow of publications over the years. However, there are others, such as identification and implementation, with important publication gaps. It is also interesting to note that the number of publications has decreased drastically in the last two years, in which only the

[14] For the reader interested in the ranking of all the languages, see the Appendix.

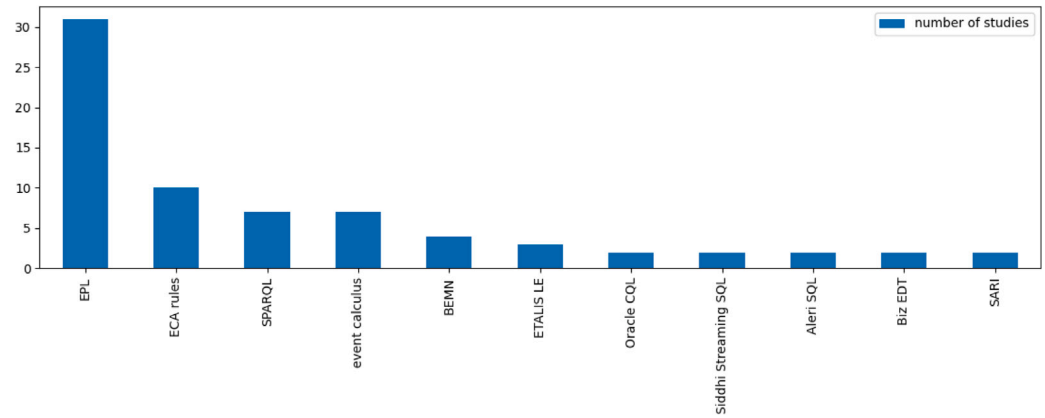

Fig. 15. Event Processing Languages: EPL = Esper Event Processing Language; BEMN = Business Event Modelling Notation; EPN = Event Processing Network; ETALIS LE = ETALIS Language for Events; Biz AL = Business Aware Language.

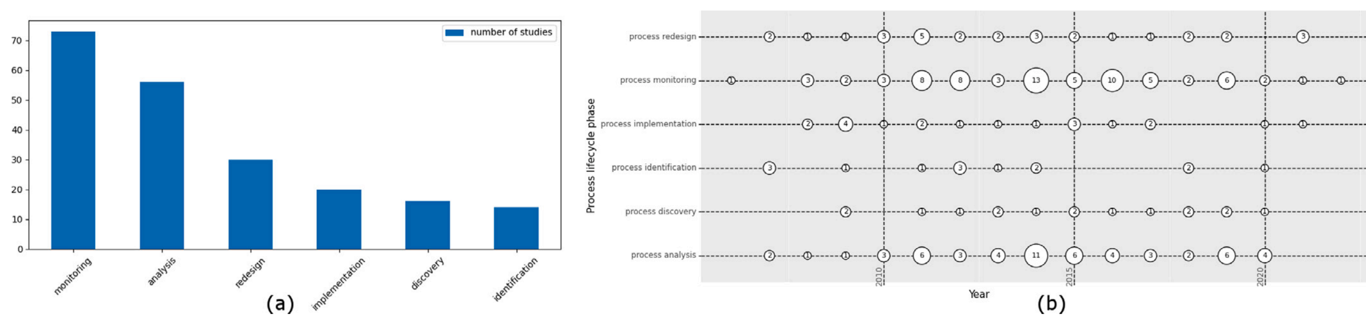

Fig. 16. (a) Number of studies per phase along the process life cycle, and (b) Number of studies per phase in the life cycle and year.

implementation, monitoring, and redesign phases have been covered by the studies. This situation could be due to the COVID pandemic or to a lack of interest in the field.

RQ3.2. What are the challenges taken off in the area?

The rationale behind this question is to identify which of the challenges in the area have been faced. To classify the challenges, we have taken as basis the challenges identified in the Dagstuhl Seminar 16341 on "Integrating Process-Oriented and Event-Based Systems" (Eyers et al., 2016), whose goal was to outline the research challenges in this field. The group of challenges reported in the seminar is listed in Table 9. The table contains an id and a brief description of the topic of the challenges in the group. Fig. 17(a) shows the percentage of studies that address the group of challenges, while Fig. 17(b) shows the distribution over the years of the number of studies per challenge. Note that a study can face more than one challenge.

The most beaten-off challenges are by far those of the `CH08-Integrated Platforms for BMP & CEP` group with 33.7% (57 out of 169) of the studies. The second place in the ranking (with 39 studies) is the `CH03-Automatic Event-based Monitoring of Processes` group. The third place is occupied by the `CH01-Event Models for BPM` group, with 27 studies. In the lowest part of the ranking are the challenges of the groups `CH11-Event Data Quality`, `CH06-Abstraction Levels: placed. Processes versus Event`, `CH10-Optimisation Opportunities`, `CH02-Compliance, Audit, Privacy and Security`, with 3, 5, 7 and 7 studies, respectively.

The lowest part of the ranking could point out areas that need further research. Thus, if we check if the three main challenges identified in Eyers et al. (2016) for CH11 have been addressed, we can conclude that: no proposal has yet addressed enrichment of process models with the specification of the quality of events yet; only one proposal focusses on making better decisions based on the quality-aware process, and very few approaches focus on defining sources of uncertainty, assessing the quality of events, and translating them into a process-oriented specification.

Regarding the four challenges identified in CH06, none of the analysed proposals addresses the problem of handling unexpected events, and only one of them mentions how to manage integration problems. Furthermore, the analysis of the abstraction levels of processes and events is very limited, and in almost all studies, the relationship of events with process models is established through event logs that represent the input of process discovery algorithms.

In relation to the eight challenges identified in CH10, it should be noted that most of the studies focused on the use of CEP to detect/predict/improve processes at run-time. Only two studies focus on resource allocation for event-driven architectures. But there are three challenges that are not addressed in the identified studies: how information extracted from processes can help optimise complex event processing; distributed query of event streams to improve the performance of BPM; and having a language to handle BPM and CEP that is expressive enough to deal with users (from the point of view of business processes) and, at the same time, efficient for evaluation (from the point of view of CEP).

Finally, of the five challenges identified in CH02, only the one related to information access control and the automation of compliance validation has been addressed. Therefore, challenges such as the processing of audit logs, the use of process models to express policies in event-based systems, and the application of SLAs to CEP engines remain open.

In addition to this, Fig. 18 represents the proportion of proposals that address a given challenge within each phase of the process lifecycle. This helps us to know what type of challenges have been addressed in each of the phases. Thus, it can be seen that CH06 is not addressed in the monitoring phase, leaving open the area of process model and event abstraction analysis within monitoring. In the analysis phase, all

Table 9
Challenges categories.

Id	Challenge category description
CH01	**Event Models for BPM**: This group of challenges is related to how events can be used to process instance adaptation, how the change of event states can influence process instances and how processes can help to give context to events.
CH02	**Compliance, Audit, Privacy and Security**: The challenges in this group are related to the exploitation of CEP to processing audit logs, and BPM tools to express policies in event-based systems and take benefit of the richer access control of BPM.
CH03	**Automatic Event-Based Monitoring of Processes**: This group of challenges are related to the automatic discovery of event patterns to business process monitoring, to monitoring events to guide process adaptation and to use process information to guide the monitoring adaptation.
CH04	**Patterns and Models for Communication**: This group of challenges are related to how the effects of the communication model impose by event-based middlewares are explicitly reflected in process models.
CH05	**Choreographies and Inter-Process Correlation**: This group of challenges is related to the extension of choreography languages to deal with advanced event-based concepts, and to enable the analysis of the information flow between processes.
CH06	**Abstraction Levels. Processes versus Events**: As process models usually follow a top-down approach, whereas event processing follow a bottom-up approach, the challenges in this group are related to find the adequate level of abstraction for a concrete modelling goal and to deal with conflicts in large-scale systems integration.
CH07	**Context in Events and Processes**: The challenges in this group are related to the representation of context, both in processes and in event patterns, to the scoping of context and to the relation of processes and context at runtime.
CH08	**Integrated Platforms for BPM & CEP**: The challenges in this group are related to the integration of BPM and CEP platforms, which also involve the development of a unified model for events and processes.
CH09	**Distributed Processes & The Role of Events**: The challenges in this group are related to event loss, to misdetection of complex events, to analysis of stream events in real time, to deal with privacy in the context of event and processes handled in a centralised or distributed sources.
CH10	**Optimisation opportunities**: The challenges in this group are related to the exploitation of BPM to improve event processing, and the other way around, the exploitation of CEP methods to improve processes.
CH11	**Event Data Quality**: The challenges in this group are related to making explicit uncertainties, to make business models aware of data quality and to how this quality-aware model influences decision making.
CH12	**From Event Streams to Process Models and Back**: The challenges in this group are related to automate the generation of CEP rules from business process monitoring, to use CEP constructs for process mining, to enrich the expressiveness of process models with CEP constructs and to execute business processes via CEP rules.

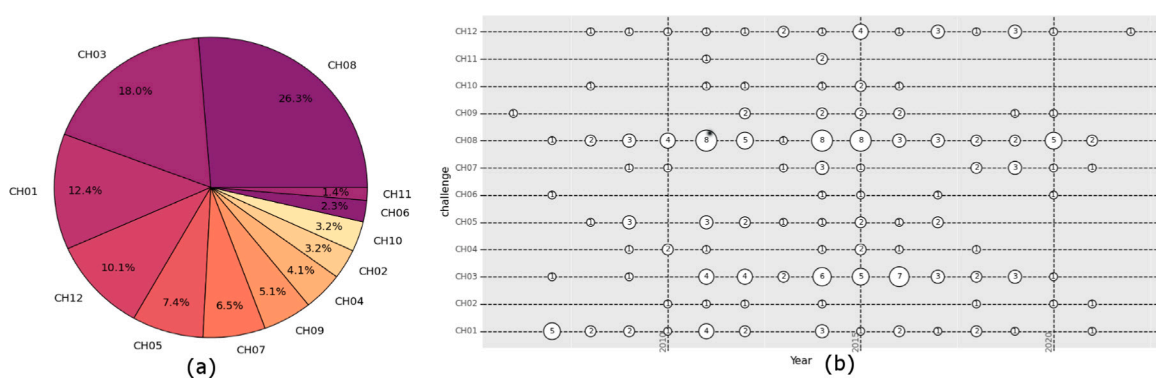

Fig. 17. (a) Percentage of challenges by number of studies, and (b) Number of studies per challenge and year.

the challenges are covered, while in the implementation phase, CH10 and CH11 are not addressed.

At the redesign phase, CH02, CH06, CH09 and CH11 are not addressed, which indicates that issues such as compliance, levels of abstraction, distributed processes and event quality needs further research. Finally, there are still many challenges open in the identification and discovery phases (CH04, CH06, CH07, CH09, CH10 and CH11).

7. Threats to validity

To ascertain the validity of the results obtained in our mapping study, we have used as a checklist the list of threats to validity proposed by Wohlin et al. (2012). As standardised in software engineering, we will introduce threats to validity by grouping them into the four categories proposed by Cook and Campbell (1979): construct, internal, external, and conclusion validity.

The threats in **construct validity** are concerned with generalising the results of the experiment to the concept or theory behind it (Wohlin et al., 2012). There are two kinds of threat in this category: design threats that are related to the design of the experiment and social threats that are concerned with the behaviour of the subjects and the experimenters.

Some design threats that could affect the validity of this study are related to the suitability of the research questions, the inclusion and exclusion criteria defined to select the primary studies, and the classification scheme used for data extraction. To mitigate the threat related to the research questions, we follow the guidelines proposed in Kitchenham et al. (2015), Kuhrmann et al. (2017) and Petersen et al. (2015) to design our research questions, and we use some of the research questions that are most frequently addressed by systematic mapping studies (Khan et al., 2019). The inclusion and exclusion criteria threat is also mitigated by using the standard inclusion and exclusion criteria proposed in Kuhrmann et al. (2017). In relation to the categorisation scheme, we faced this threat by using taxonomies and categorisations published in relevant references to classify the selected primary studies. Finally, it also deserves to be noticed that we have carefully documented the whole process using the Start tool.

Regarding social threats, this mapping study could suffer from the experimenter expectancy; the experimenters can bias the results of the study based on their expectancies from the experiment. To mitigate this threat, each study is analysed by at least two researchers. For example, if a researcher is responsible for the selection of a study in the selection stage, a different researcher is responsible for the data extraction of that study. If unclear questions arise about a concrete study, a third researcher breaks the deadlock. In addition, some results of selection

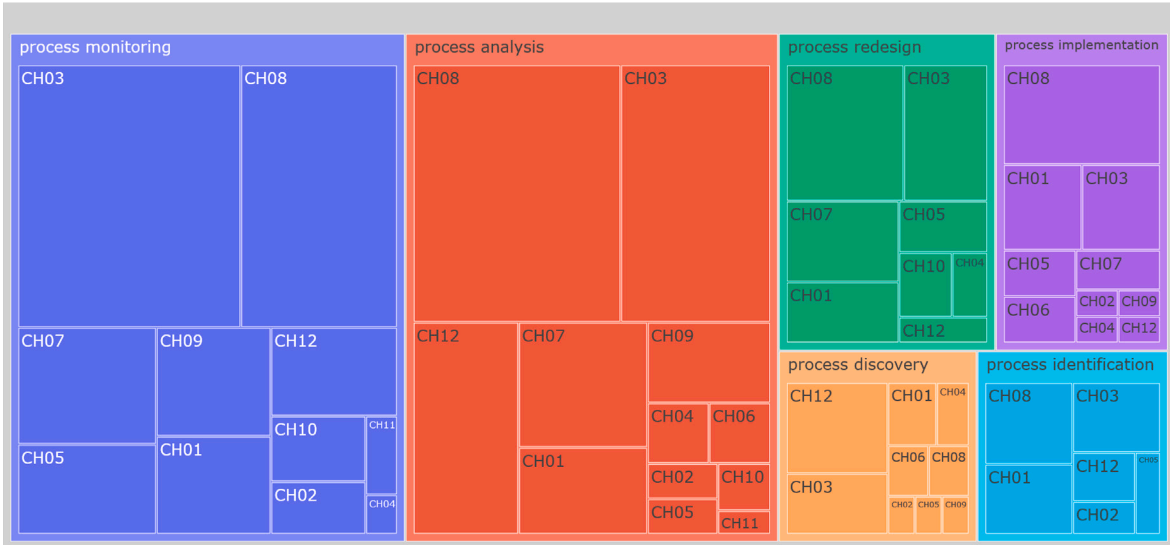

Fig. 18. Relationship between challenges and process lifecycle phases.

and extraction were discussed by the four researchers in weekly meetings. Furthermore, the different tasks have been assigned as follows: The four authors have classified the studies. The first screening and careful reading have not been performed for the same researcher in the same paper. Regarding the rest of the activities involved in the study selection, Author 2 was in charge of collecting studies from data sources (search engines and snowballing).

Internal validity checks the reliability of the results of a study in terms of how well the study is conducted. To face this kind of threat, we have followed a systematic approach (Kitchenham and Charters, 2007; Petersen et al., 2008). On the one hand, we performed a formal automatic search in six different online digital databases and search engines that are the most commonly used in other systematic mapping studies (Khan et al., 2019). On the other hand, an automatic backward and forward snowballing process has been included to incorporate the references included in selected studies. Finally, in relation to the bias that could be introduced by applying the inclusion/exclusion criteria, it has been partially faced due to the fact that different researchers test the decision of the researcher who has been responsible for the study at a previous stage.

The threats in **external validity** are concerned with the condition that limits the possible generalisation of the results and the interest of other people outside the review. To mitigate the threats in this category, we have prepared a bundle with all datasets produced during our analysis and we have publicly available the scripts that we used to synthesise the extracted data (see Section 4.6). Hence, researchers who wish to replicate or extend our material have all the material at their disposal. However, a threat that remains in this study is related to access to the whole set of selected studies. Although our institution maintains subscriptions to every digital library we have queried in this study, there may be researchers who have no access to those libraries.

Finally, **conclusion validity** is related to drawing the correct conclusions and to being reproducible for other researchers. In this mapping study, all graphs, charts, and tables are generated from datasets. On the one hand, datasets are publicly available, and, on the other hand, the Python scripts used to generate them are also available in a GitHub repository[15] and as a Jupyter notebook. Hence, our results are completely traceable. Data from primary studies have not only been extracted carefully (as explained in Section 4.5), but have also been reviewed by at least two different researchers. Another point that could threaten validity is the scheme used to score the quality of the studies. To mitigate this threat, a framework commonly used in the field of data quality has been used.

8. Conclusions

Logistics processes are receiving substantial mainstream attention because of the recent logistics crisis. These processes involve the choreography of various entities and produce an enormous number of complex events. The analysis of the state-of-the-art of event-driven business management approaches in logistics can help not only organisations with logistics management that want to leverage the level of digitalisation of their processes, but also researchers to foresee new opportunities of research by revealing open problems. However, there are no secondary studies focused on the analysis of approaches that integrate business processes and complex events in the logistics domain. To bridge this gap, this paper reports the results of a systematic mapping study that analyses and classifies the selected studies according to different criteria, such as the type of contribution they provide, their area of application, the logistics coverage, the business process modelling language they used to model processes, the event processing language they used to process complex events, the process life cycle they cover, and the open challenges. The main conclusions of this study can be drawn from the perspectives of companies and academia.

From the company's point of view, it is important to count on a variety of mature frameworks and tools that support the deployment of a solution in a real scenario. However, after analysing all selected articles, we can state that there is no framework or tool that companies can apply directly to manage the integration of business processes and complex event processing in logistics environments. More than 51% of the proposed solutions are proofs of concept, prototypes, or solutions entirely oriented toward academic research, which makes their application to a real scenario difficult. For this reason, companies must develop made-by-measure solutions for adapting the technologies they use to manage processes for taking the advantages that complex event processing could provide. This means that most of the proposals are still open for further analysis, improvement, and extension. In particular, it could be interesting to continue improving those tools that cover various phases of the life cycle to cover all phases.

From the academic point of view, the most interesting findings are those related to the less mature areas, because they could provide opportunities for new research lines. Regarding the phases of the life cycle, only 5% of the studies cover the discovery phase and approximately

[15] https://github.com/reinaqu/reportingslroo.

the 7% cover the identification phase. There is also a lack of approaches that cover the entire life cycle from the first phase to have a holistic view. In relation to business process modelling languages, only slightly more than 11% of the studies use a declarative language style. This is important in those cases in which the application of the government regulations describe the order of the actions allowed or prohibited, but not always specify the exact sequence. An example of this kind of regulation in the logistics context is ''before the entrance of a boat into a port, security documentation should have been verified''. Finally, there still are some challenges that remains open, above all those ones related to event data quality (CH11), abstraction levels (CH06), optimisation opportunities (CH10), and compliance, audit, privacy and security (CH02). For example, we have found that no proposal has yet addressed the enrichment of business process models with the specification of the quality of events or that there is a lack of approaches that deal with the processing of audit logs or translation of laws into security policies in this context.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

We have share data in mendeley and github through respective links.

Acknowledgements

This work has been funded by the projects AETHER-US (PID2020-112540RB-C44/AEI/10.13039/501100011033), COPERNICA (P20_01224), METAMORFOSIS (US-1381375) and FEDER funds through programme Interreg V-A España-Portugal (POCTEP) 2014–2020.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.compind.2022.103788.

References

Akila, V., Govindasamy, V., Sandosh, S., 2016. Complex event processing over uncertain events: Techniques, challenges, and future directions. In: ICCPEIC. pp. 204–221. http://dx.doi.org/10.1109/ICCPEIC.2016.7557198.

Alias, C., Rawet, V.L., Neto, H.X.R., do Egypto Neirão Reymão, J., 2016. Investigating into the prevalence of complex event processing and predictive analytics in the transportation and logistics sector: Initial findings from scientific literature. In: MCIS. University of Nicosia / AISeL, p. 2.

Amjad, A., Azam, F., Anwar, M.W., Butt, W.H., Rashid, M., 2018. Event-driven process chain for modeling and verification of business requirements-A systematic literature review. IEEE Access 6, 9027–9048. http://dx.doi.org/10.1109/ACCESS.2018.2791666.

Ammon, R.v., 2009a. Event-driven business process management. In: Liu, L., Özsu, M.T. (Eds.), Encyclopedia of Database Systems. Springer US, Boston, MA, pp. 1068–1071. http://dx.doi.org/10.1007/978-0-387-39940-9_577.

Ammon, R.V., 2009b. Event-driven business process management. In: Encyclopedia of Database Systems.

von Ammon, R., 2018. Event-driven business process management. In: Liu, L., Özsu, M.T. (Eds.), Encyclopedia of Database Systems. Springer New York, New York, NY, pp. 1399–1403. http://dx.doi.org/10.1007/978-1-4614-8265-9_577.

Ammon, R.v., Emmersberger, C., Springer, F., Wolff, C., 2008. Event-driven business process management and its practical application taking the example of DHL.

Augusto, A., 2020. Accurate and Efficient Discovery of Process Models from Event Logs (Ph.D. thesis). University of Melbourne and University of Tartu, Melbourne.

Augusto, A., Conforti, R., Dumas, M., Rosa, M.L., Maggi, F.M., Marrella, A., Mecella, M., Soo, A., 2019. Automated discovery of process models from event logs: Review and benchmark. IEEE Trans. Knowl. Data Eng. 31 (4), 686–705. http://dx.doi.org/10.1109/TKDE.2018.2841877.

Bassil, S., Keller, R.K., Kropf, P.G., 2004. A workflow-oriented system architecture for the management of container transportation. In: Business Process Management. In: Lecture Notes in Computer Science, vol. 3080, Springer, pp. 116–131. http://dx.doi.org/10.1007/978-3-540-25970-1_8.

Berndtsson, M., Mellin, J., 2009. ECA rules. In: Liu, L., Özsu, M.T. (Eds.), Encyclopedia of Database Systems. Springer US, Boston, MA, pp. 959–960. http://dx.doi.org/10.1007/978-0-387-39940-9_504.

Broadman, H.G., 2021. Global supply chains' crisis is much bigger than the pandemic; the transformation they're undergoing is the cure.

Chandy, M.K., Etzion, O., von Ammon, R., 2011. 10201 Executive summary and manifesto – event processing. In: Chandy, K.M., Etzion, O., von Ammon, R. (Eds.), Event Processing. In: Dagstuhl Seminar Proceedings (DagSemProc), vol. 10201, Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl, Germany, pp. 1–60. http://dx.doi.org/10.4230/DagSemProc.10201.1.

Chow, H.K.H., Choy, K.L., Lee, W.B., Chan, F.T.S., 2005. Design of a knowledge-based logistics strategy system. Expert Syst. Appl. 29 (2), 272–290. http://dx.doi.org/10.1016/j.eswa.2005.04.001.

Conforti, R., Rosa, M.L., Fortino, G., ter Hofstede, A.H.M., Recker, J., Adams, M., 2013. Real-time risk monitoring in business processes: A sensor-based approach. J. Syst. Softw. 86 (11), 2939–2965. http://dx.doi.org/10.1016/j.jss.2013.07.024.

Cook, T.D., Campbell, D.T., 1979. Quasi-Experimentation: Design & Analysis Issues for Field Settings. Houghton Mifflin Company.

Cugola, G., Margara, A., Matteucci, M., Tamburrelli, G., 2015. Introducing uncertainty in complex event processing: model, implementation, and validation. Computing 97 (2), 103–144. http://dx.doi.org/10.1007/s00607-014-0404-y.

Davenport, T., 1993. Process Innovation: Reengineering Work through Information Technology. Harvard Business School Press, Boston.

Davidsson, P., Henesey, L., Ramstedt, L., Törnquist, J., Wernstedt, F., 2005. Agent-based approaches to transport logistics. In: Klügl, F., Bazzan, A.L.C., Ossowski, S. (Eds.), Applications of Agent Technology in Traffic and Transportation. In: Whitestein series in software agent technologies and autonomic computing, Springer, pp. 1–15. http://dx.doi.org/10.1007/3-7643-7363-6_1.

Dayarathna, M., Perera, S., 2018. Recent advancements in event processing. ACM Comput. Surv. 51 (2), 33:1–33:36. http://dx.doi.org/10.1145/3170432.

Dumas, M., Rosa, M.L., Mendling, J., Reijers, H.A., 2013. Fundamentals of Business Process Management. Springer Publishing Company, Incorporated.

Eckert, M., Bry, F., Brodt, S., Poppe, O., Hausmann, S., 2011. A CEP babelfish: Languages for complex event processing and querying surveyed. In: Helmer, S., Poulovassilis, A., Xhafa, F. (Eds.), Reasoning in Event-Based Distributed Systems. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 47–70. http://dx.doi.org/10.1007/978-3-642-19724-6_3.

Emmersberger, C., Springer, F., Wolff, C., 2009. Location based logistics services and event driven business process management. In: IMC. In: Communications in Computer and Information Science, vol. 53, pp. 167–177. http://dx.doi.org/10.1007/978-3-642-10263-9_15.

EsperTech Inc., 2006. Pluto: The 'other' red planet. https://www.espertech.com/esper/, Accessed: 2021-11-24.

Even, A., Shankaranarayanan, G., Berger, P.D., 2010. Evaluating a model for cost-effective data quality management in a real-world CRM setting. Decis. Support Syst. 50 (1), 152–163. http://dx.doi.org/10.1016/j.dss.2010.07.011.

Eyers, D.M., Gal, A., Jacobsen, H., Weidlich, M., 2016. Integrating process-oriented and event-based systems (Dagstuhl seminar 16341). Dagstuhl Rep. 6 (8), 21–64. http://dx.doi.org/10.4230/DagRep.6.8.21.

Fahland, D., Mendling, J., Reijers, H.A., Weber, B., Weidlich, M., Zugal, S., 2009. Declarative versus imperative process modeling languages: The issue of maintainability. In: Business Process Management Workshops. In: Lecture Notes in Business Information Processing, vol. 43, Springer, pp. 477–488. http://dx.doi.org/10.1007/978-3-642-01862-6_29.

Force, U.R.T., 2001. Omg unified modeling language specification, version 1.4 (final draft).

Fulop, L.J., Tóth, G., Rácz, R., Pánczél, J., Gergely, T., Beszédes, Á., 2010. Survey on Complex Event Processing and Predictive Analytics. Tech. Rep., University of Szeged, Department of Software Engineering.

Future, M.R., 2021. Business Process Management Market. Market Research Report.

Ghiani, G., Laporte, G., Musmanno, R., 2013. Introduction to Logistics Systems Management. In: Wiley Series in Operations Research and Management Science, Wiley.

Goetz, D.M., 2010. Integration of business process management and complex event processing.

Gómez-López, M.T., Gasca, R.M., Pérez-Álvarez, J.M., 2015. Compliance validation and diagnosis of business data constraints in business processes at runtime. Inf. Syst. 48, 26–43. http://dx.doi.org/10.1016/j.is.2014.07.007.

GROBID, 2008–2021. GROBID. arXiv:1:dir:dab86b296e3c3216e2241968f0d63b68e8209d3c https://github.com/kermitt2/grobid.

Hammer, M., Champy, J., 1993. Reengineering the Corporation: A Manifesto for Business Revolution. Harper Business.

van Hee, K.M., Sidorova, N., van der Werf, J.M.E.M., 2013. Business process modeling using Petri nets. Trans. Petri Nets Other Model. Concurr. 7, 116–161. http://dx.doi.org/10.1007/978-3-642-38143-0_4.

Hull, R., Damaggio, E., Fournier, F., Gupta, M., Heath, F.T., Hobson, S., Linehan, M., Maradugu, S., Nigam, A., Sukaviriya, P., et al., 2010. Introducing the guard-stage-milestone approach for specifying business entity lifecycles. In: International Workshop on Web Services and Formal Methods. Springer, pp. 1–24.

Jaekel, F., 2019. Systematic review of cloud logistics knowledge. In: Cloud Logistics: Reference Architecture Design. Springer Fachmedien Wiesbaden, Wiesbaden, pp. 191–256. http://dx.doi.org/10.1007/978-3-658-22837-8_5.

Johansson, H.J., McHugh, P., Pendlebury, A.J., Wheeler, W.A., 1993. Business Process Reengineering: Breakpoint Strategies for Market Dominance. John Wiley & Sons.

Khan, M.U., Sherin, S., Iqbal, M.Z., Zahid, R., 2019. Landscaping systematic mapping studies in software engineering: A tertiary study. J. Syst. Softw. 149, 396–436. http://dx.doi.org/10.1016/j.jss.2018.12.018.

Kitchenham, B.A., Budgen, D., Brereton, O.P., 2010. The value of mapping studies - A participant-observer case study. In: EASE. In: Workshops in Computing, BCS.

Kitchenham, B.A., Budgen, D., Brereton, P., 2015. Evidence-Based Software Engineering and Systematic Reviews, first ed. CRC Press, An optional note.

Kitchenham, B., Charters, S., 2007. Guidelines for performing Systematic Literature Reviews in Software Engineering. Tech. Rep. EBSE-2007-01, School of Computer Science and Mathematics, Keele University.

Klappich, D., Muynck, B.D., Aimi, G., Titze, C., Stevens, A., 2020. Cpredicts 2021: Supply chain technology.

Krumeich, J., Weis, B., Werth, D., Loos, P., 2014. Event-driven business process management: where are we now?: A comprehensive synthesis and analysis of literature. Bus. Process. Manage. J. 20 (4), 615–633. http://dx.doi.org/10.1108/BPMJ-07-2013-0092.

Kuhrmann, M., Fernández, D.M., Daneva, M., 2017. On the pragmatic design of literature studies in software engineering: an experience-based guideline. Empir. Softw. Eng. 22 (6), 2852–2891. http://dx.doi.org/10.1007/s10664-016-9492-y.

Leitner, M., Rinderle-Ma, S., 2014. A systematic review on security in Process-Aware Information Systems - Constitution, challenges, and future directions. Inf. Softw. Technol. 56 (3), 273–293. http://dx.doi.org/10.1016/j.infsof.2013.12.004.

Li, C.-S., 2005. Real-time event driven architecture for activity monitoring and early warning. In: Conference, Emerging Information Technology 2005. p. 4 pp.. http://dx.doi.org/10.1109/EITC.2005.1544382.

Li, T., Zeng, C., Jiang, Y., Zhou, W., Tang, L., Liu, Z., Huang, Y., 2017. Data-driven techniques in computing system management. ACM Comput. Surv. 50 (3), 45:1–45:43. http://dx.doi.org/10.1145/3092697.

Linden, I., Derbali, M., Schwanen, G., Jacquet, J., Ramdoyal, R., Ponsard, C., 2013. Supporting business process exception management by dynamically building processes using the BEM framework. In: EWG-DSS. In: Lecture Notes in Business Information Processing, vol. 184, Springer, pp. 67–78. http://dx.doi.org/10.1007/978-3-319-11364-7_7.

Luckham, D.C., 2005. The Power of Events - An Introduction to Complex Event Processing in Distributed Enterprise Systems. ACM.

Luckham, D., 2008. The power of events: An introduction to complex event processing in distributed enterprise systems. In: RuleML. In: Lecture Notes in Computer Science, vol. 5321, Springer, p. 3. http://dx.doi.org/10.1007/978-3-540-88808-6_2.

Luckham, D., 2012. Event Processing for Business. In: Organizing the Real-Time Enterprise, Wiley.

Mousheimish, R., Taher, Y., Zeitouni, K., 2016. The butterfly: An intelligent framework for violation prediction within business processes. In: IDEAS. ACM, pp. 302–307. http://dx.doi.org/10.1145/2938503.2938541.

OASIS, 2007. Web Services Business Process Execution Language Version 2.0. Tech. Rep., OASIS.

OMG, 2013. Business Process Model and Notation (BPMN), Version 2.0.2. Tech. Rep., Object Management Group.

Pérez-Álvarez, J.M., Maté, A., Gómez-López, M.T., Trujillo, J., 2018. Tactical business-process-decision support based on KPIs monitoring and validation. Comput. Ind. 102, 23–39. http://dx.doi.org/10.1016/j.compind.2018.08.001.

Pesic, M., Van der Aalst, W.M., 2006. A declarative approach for flexible business processes management. In: International Conference on Business Process Management. Springer, pp. 169–180.

Petersen, K., Feldt, R., Mujtaba, S., Mattsson, M., 2008. Systematic mapping studies in software engineering. In: EASE. In: Workshops in Computing, BCS.

Petersen, K., Vakkalanka, S., Kuzniarz, L., 2015. Guidelines for conducting systematic mapping studies in software engineering: An update. Inf. Softw. Technol. 64, 1–18. http://dx.doi.org/10.1016/j.infsof.2015.03.007.

Ramos-Gutiérrez, B., Reina Quintero, A., Parody Núñez, M., Gómez López, M., 2021. When business process meet complex events in logistics: A systematic mapping study", mendeley data. http://dx.doi.org/10.17632/xwy9djwnh4.1.

Schiefer, J., McGregor, C., 2004. Correlating events for monitoring business processes. In: ICEIS (1). pp. 320–327.

Schiefer, J., Roth, H., Suntinger, M., Schatten, A., 2007. Simulating business process scenarios for event-based systems. In: ECIS. University of St. Gallen, pp. 1729–1740.

Shanahan, M., 1999. The event calculus explained. In: Artificial Intelligence Today. Springer, pp. 409–430.

Soffer, P., Hinze, A., Koschmider, A., Ziekow, H., Ciccio, C.D., Koldehofe, B., Kopp, O., Jacobsen, H., Sürmeli, J., Song, W., 2019. From event streams to process models and back: Challenges and opportunities. Inf. Syst. 81, 181–200. http://dx.doi.org/10.1016/j.is.2017.11.002.

Ter Hofstede, A.H., Van der Aalst, W.M., Adams, M., Russell, N., 2009. Modern Business Process Automation: YAWL and its Support Environment. Springer Science & Business Media.

Varela-Vaca, Á.J., Reina Quintero, A.M., 2021. Smart contract languages: A multivocal mapping study. ACM Comput. Surv. 54 (1), 3:1–3:38. http://dx.doi.org/10.1145/3423166.

W3C, 2013. SPARQL 1.1 Query Language. Tech. Rep., W3C.

Wang, R.Y., Strong, D.M., 1996. Beyond accuracy: What data quality means to data consumers. J. Manage. Inf. Syst. 12 (4), 5–33. http://dx.doi.org/10.1080/07421222.1996.11518099.

Weske, M., 2012. Business Process Management - Concepts, Languages, Architectures, second ed. Springer.

Wohlin, C., 2014. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In: EASE. ACM, pp. 38:1–38:10. http://dx.doi.org/10.1145/2601248.2601268.

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M.C., Regnell, B., 2012. Experimentation in Software Engineering. Springer, http://dx.doi.org/10.1007/978-3-642-29044-2.

Belén Ramos Gutiérrez, (Phd. Student) Universidad de Sevilla, Dpto. Lenguajes y sistemas informáticos – Spain.

Belén Ramos-Gutiérrez is currently a Software Engineering and Technology Ph.D. Student at the University of Seville. Her research interests include process mining, data extraction, and optimisation for process mining techniques; and troubleshooting and decision support systems in industrial environments. She is also working as a predoctoral researcher with the University of Seville and collaborates on projects involving industrial aspects related to logistics-port and aeronautical environments. Her research goal is to improve and automate the extraction and processing of heterogeneous data from industrial environments for exploitation with process mining techniques.

Antonia M. Reina Quintero, (Assistant Professor) Universidad de Sevilla, Dpto. Lenguajes y sistemas informáticos – Spain.

Antonia M. Reina Quintero obtained her Ph.D. with honours in Computer Engineering from the University of Seville (2012). She has worked as a full-time lecturer at the Computer Languages and Systems Department from the University of Seville since 2000, although she also has worked as a computer engineer for a leading company in traffic control systems. Her current research is focused on advanced separation of concerns, Model-Driven Engineering applied to business processes, and systematic literature reviews in software engineering. She has participated in public research projects and prestigious conferences. She has published several high-impact papers.

Luisa Parody, (Associate Professor), Universidad Loyola Andalucía, Sevilla, Spain.

Luisa Parody studied Computer Engineering (including a minor in Systems Engineering) at the Universidad de Sevilla (Spain) and graduated with honours in July 2009. She then earned an M.Sc. Degree in Software Engineering and Technology(2010) and obtained her international Ph.D. with honours at the Universidad Sevilla (2014). Since 2018, she has been working as an associate professor at Dpto. Métodos Cuantitativos at the Universidad Loyola Andalucía. She belongs to the IDEA Research Group and has participated in several private and public research projects. She was nominated as a member of Program Committees, such as ISD and SIMPDA. She has participated in prestigious conferences and has published several high-impact papers.

María Teresa Gómez-López is a Full Professor at the University of Seville and the head of the IDEA Research Group (www.idea.us.es). Her research areas include Business Processes and Data management, and how to improve the business process models including better decisions and enriching the model with Data Perspectives. She has led several private and public competitive research projects and has published more than 30 articles in high-quality conferences and journals. She was nominated as a member of Program Committees, such as ER, BPM, EDOC, ISD or CAISE Doctoral Consortium, and she has given various keynotes or was invited speaker in international forums.