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Analysis and Synthesis of Theoretical and Practical Implications of Case Management Model and Notation

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Abstract: Case Management Model and Notation (CMMN) is a graphical notation used to model less predictable, highly flexible processes that may behave differently in each instance. It uses an event-centred approach and expands on what can be modelled with procedural modelling notations. Nearly a decade since the occurrence of CMMN, its practical use is questionable. We performed this research to identify possible reasons for this and to classify the potential advantages and disadvantages of CMMN. With the aforementioned objectives, we conducted a systematic literature review, which provided a broad insight into the state of the investigated object along with techniques for analysing qualitative data, coding, and successive approximation. From an initial set of 942 articles, 43 remain relevant. The results of the analysis and synthesis of the obtained data from relevant articles were generalised codes, which were used to explicitly answer the research questions. The results indicate that CMMN has good foundations in the declarative modelling approach and within the Case Management paradigm. Nevertheless, some issues were identified with the notation and elements of CMMN and with its complement—Business Process Model and Notation (BPMN).

Keywords: CMMN; Case Management; BPMN; declarative modelling; flexibility; visual language

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1. Introduction

Constant changes are a part of everyday life, despite the fact that we are often unaware of them. One great example is climate change, which is happening all around us, but we do not perceive it as impacting our lives. Constant changes occur in nature, between people, and in organisations where the production of a product or service is needed. To be able to respond to changes in the workflow, some kind of monitoring is required. This can be covered with the modelling of organisation workflows (or business processes).

There are many reasons why it makes sense to list processes, especially business processes, which bring value to organisations; for example: "ability to deliver improvements in organisational performance, regulatory compliance and service quality" [1]. The way people work in organisations has been changing throughout history, evolving from industrial to knowledge societies.

The assembly line principle was often used in the industrial age, focusing on routine functioning. However, nowadays, well-structured, highly predictable, pre-definable processes in organisations are covered with a systematic approach to manage business processes—Business Process Management (hereinafter referred to as BPM) [2–5].

In the current knowledge society, which emphasises the role of knowledge and knowledge workers, routine functioning is no longer appropriate to the same extent as before.

Nowadays, business processes are commonly less-structured and less predictable and may differ in each instance [3,4]. BPM is less applicable for unstructured business processes, which brought to light a new paradigm—Case Management [6].

Case Management (also Adaptive Case Management or Case Handling) is a paradigm for supporting flexible and knowledge-intensive business processes [6]. It was formed because of the shortcomings of BPM, a more restrictive paradigm, with some issues with the introduction of change [6].

Nevertheless, the transition from BPM to Case Management is far from optimal. BPM is still largely in use, according to the de facto standard of this field—Business Process Model and Notation (hereinafter referred to as BPMN) [7]. BPMN is well accepted and frequently used [7], but it is also quite complex, which is often referred to as its main weakness [8]. Some authors specify that BPMN is more appropriate for structured business processes and less for unstructured ones [9,10]. To fill the identified deficit, the consortium Object Management Group (OMG) published the first version (1.0) of the Case Management Model and Notation (hereinafter referred to as CMMN) specification [11] in 2014, a notation dedicated to unstructured, flexible business processes.

The main idea for CMMN was to complement BPMN with unstructured, flexible parts of the process, where BPMN demonstrated some shortcomings [8–10,12,13], and vice versa, BPMN can also complement CMMN [11].

However, findings from the literature indicate that CMMN "did not take off" as expected [12,14]. There could be several reasons for this, and we have identified two of them.

Firstly, in the paragraph above we mentioned BPMN, which is, first and foremost, a complement to CMMN. Nevertheless, BPMN can also be used with the modelling of unstructured business processes, which indicates that BPMN and CMMN can be competitors. Further, BPMN was published a few years before CMMN; but still, if we compare the frequency of the searching of the terms "CMMN" and "BPMN" on Google Trends [15], limited to the last five years and within a worldwide range, we can conclude that the average ratio between search terms is 1:20, in favour of BPMN. To summarize, CMMN is a good starting point within unstructured business processes, but it also has a well-trained and frequently used alternative.

Secondly, the current knowledge society introduced a new, less restrictive, and more adjustable approach to function in organisation. Nevertheless, there is still a significant amount of assembly line functioning, which makes sense since the transition (from one society to another) cannot be sudden. From this we can conclude that organisations are not yet completely ready to adopt a new way of functioning, and consequently, also notations like CMMN are less in use.

To identify other possible reasons for the non-intensive use of CMMN, we decided to investigate the current notation. Therefore, our research objectives are to classify the potential advantages and disadvantages of CMMN and to identify extensions, upgrades, or improvements for the CMMN, and finally, to find potential cases of practical use.

According to our understanding, CMMN impacts essential human functioning areas, like academic research and practical use within the industry. Therefore, the research objectives cover theoretical issues regarding CMMN, frequently processed by academics, and also practical issues, more associated with the industry. As this research is exploratory, the aim is to obtain a basic overview of the aforementioned issues related to CMMN. The most appropriate research method is thus a systematic literature review.

In preparing this review, we observed that, while CMMN has been addressed in various conceptual, technical, and empirical studies, the existing literature does not yet provide a coherent and consolidated understanding of the field. Most available works

concentrate on specific modelling challenges, limited use cases, or isolated comparisons with other notations, without offering a broader perspective. So far, and as far as we are aware, no comprehensive and methodologically grounded synthesis exists that brings together both theoretical insights and practical experiences related to CMMN. This lack of an integrated view limits the understanding of the notation's overall maturity, adoption patterns, and future potential. Our study aims to address this research gap by conducting a systematic literature review that covers a full decade of publications, thereby highlighting both current trends and open challenges in the field.

The remainder of this article is structured as follows. Section 2 reviews the theoretical background of related concepts. In Section 3, related work is presented. In Section 4, the research method is presented in details. The results of the given research are presented and discussed in Section 5. An important aspect—the validity of our research—is presented in Section 6. Finally, conclusions and implications for future work are presented in Section 7.

2. Theoretical Background

In this section, the relevant theoretical foundations of Case Management and CMMN are briefly presented.

2.1. Case Management

Case Management was first introduced in 2004 by authors van der Aalst, Weske, and Grünbauer [6], where they presented a new paradigm for business process support. They first called it Case Handling. Later on, the term Adaptive Case Management was introduced, abbreviated as ACM [16,17]. As emphasised in the introduction, Case Management was proposed because of some shortcomings of BPM, which was evidenced as too restrictive and not flexible enough [6,16].

The main concept of Case Management is a *case*. Numerous domains specify and manage cases: in medicine, law, social security, employment, etc., where each instance of a case can be different. The latter means that the set of activities executed within one case can differ in each instance of a case. Meanwhile, in workflow management systems, "an activity is considered to be atomic and either carried out or not" [6]. In contrast, Case Management offers a less rigid approach—activities are "chunks of work" [6], which are being manipulated by case/knowledge workers. They decide what is relevant in a particular case based on the knowledge they have about the whole case, an essential aspect in Case Management [6].

Business Artefacts

Case management is fundamentally data-centric. The business artefacts (or "business entities with lifecycles"), introduced in 2003 [18,19], ensures a tight connection between data and process, including information and lifecycle models. Declarative approaches, which are data-centric, have roots in the Event–Condition–Action (ECA) rules paradigm, which specifies the control of activities formally and derive from the concept of activity pre-conditions [16]. The declarative Guard–Stage–Milestone (GSM) model for business artefacts [20,21] derives from that work and provides the foundation for the CMMN core model [16].

2.2. CMMN

With the introduction of Case Management, a need for standardisation in this field emerged, and in 2014 the consortium OMG released the first version (1.0) of CMMN [11,22]. CMMN belongs to the declarative business process paradigm, where the main focus is on capturing the regulations and directives of the organisation and additionally presents a

balance between flexibility and support [23]. Therefore, CMMN is suitable for capturing knowledge-intensive, flexible processes [11].

CMMN can provide a standardised way to model and manage a case. It contains a set of elements, graphically presented on Figure 1 and described bellow, according to [11].

- *Case Plan Model* is the outermost element, within which the whole case is presented and defined.
- *Task* is a central element that defines a single action, a unit of work that needs to be performed. There are different types of task: *Non-Blocking Human Task* (i.e., Manual Task), *Blocking Human Task* (i.e., User Task), *Case Task*, *Process Task*, and *Decision Task*.
- *Case File Item* is an element that defines data (e.g., document, file) required for case processing.
- *Stage* may be considered as an "episode" or a "phase" of one case. Elements, like Tasks with Connectors, can be united within one Stage element.
- *Milestone* represents an achievable target, defined to enable the evaluation of progress of the case.
- *Event Listeners* is an element that waits for an event in a case to trigger other elements, like Tasks or Stages. There are two different types of Event Listeners: *Timer Event Listener* and *User Event Listener*.
- *Sentry (Sentries)* is a combination of an "event and/or condition". It is not a stand-alone element; it needs to be part of the Case Plan Model, Stage, Task or Milestone. It is graphically represented with a rhombus: *Entry Criterion* (for entry condition) with a white rhombus and *Exit Criterion* (for exit condition) with a black rhombus (Figure 1).
- *Connectors* can be used to visualise dependencies between elements but do not have associated execution semantics.

An essential characteristic of CMMN is its ability for discretionary implementation (for Tasks and Stages), which enables the introduction of a higher degree of flexibility into business processes in general. This flexibility is one of the defining features of CMMN, enabling knowledge workers to tailor process execution at runtime. One example of such use is the *Discretionary Task*, shown in Figure 1.

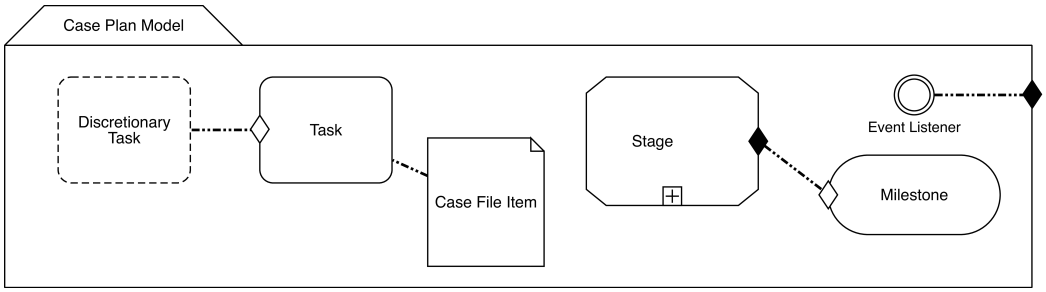


Figure 1. Basic elements of CMMN.

Furthermore, Figure 1 clearly shows all of the elements of CMMN mentioned above. The Case Plan Model encompasses all elements and is presented by a "folder" shape. The Discretionary Task is presented with a rectangle shape with dashed lines, and it is connected to a regular Task, which has an Entry Criterion, marked with a white rhombus. The Task is later connected to the Case File Item, depicted by a "document" shape with a broken upper right corner. The Element Stage, depicted by a rectangle shape with angled corners, includes an Exit Criterion, marked with a black rhombus. At the end, the elements Milestone (rectangle shape with half-rounded ends) and Event Listener (circle shape with double line) are contained.

The execution aspect of CMMN involves the use of specialised software components known as execution engines to interpret and enact CMMN models, managing case lifecycles,

executing tasks and events, integrating with external systems, and providing monitoring and analytics capabilities.

3. Related Work

Although CMMN has been the subject of various conceptual and technical discussions since its introduction in 2014, only a limited number of literature reviews have specifically focused on this notation or on the broader domain of modelling flexible and unstructured processes. Most existing reviews are either exploratory in nature or focus on the comparative analysis of different modelling paradigms.

For example, Marin et al. [8] presented an early evaluation of the complexity of CMMN by applying method complexity metrics. Their study offered useful insights into the cognitive load of using CMMN but did not attempt to synthesise the broader state of research or practical use. Similarly, Slaats [24] provided a comprehensive overview of declarative and hybrid process discovery approaches, where CMMN was included as one of several declarative modelling languages. However, the focus of that work was mainly on process discovery and not on notation-level evaluation or practical implications.

Other works, such as those by Routis et al. [12,25–27], provided empirical evaluations of CMMN usage in collaborative processes and discussed user perceptions of the notation. While these studies contribute valuable empirical insights, they are generally limited in scope and do not adopt a systematic review methodology. Additionally, comparisons between CMMN and alternative notations such as BPMN, DMN, Declare, or DCR Graphs have been made in various articles (e.g., [9,10,28,29]), but these usually address specific use cases, domains, or modelling aspects.

To our knowledge, there is no comprehensive systematic literature review that synthesises both the theoretical discussions and practical applications of CMMN over the entire period since its publication. Our work aims to fill this gap by providing an updated, methodologically rigorous review, covering articles from 2014 to 2024, and offering a detailed synthesis of CMMN's advantages, limitations, extensions, and degree of practical adoption. This positions our research as a relevant contribution to the ongoing discourse on flexible process modelling and the role of declarative approaches in business process management.

4. Research Method

The systematic literature review (hereinafter referred to as SLR) is a research method where identification, evaluation, and interpretation of all available, relevant research articles are performed [30]. Relevant articles are gathered based on research questions determined at the beginning of the research process. Guidelines to conduct SLR in the field of software engineering were defined in [30] and represent the basis for our research.

According to [30], SLR has been implemented in three phases: planning, conducting, and reporting. In the planning phase, several activities were executed: identification of the need for SLR, proposal for the implementation, formation of research questions and research protocol. In the conducting phase, research questions have been dissected, a search string was tested for suitability, relevant research articles have been collected, and quality assessments have been made. Further on, with data synthesis, key findings from relevant research articles have been exposed. Finally, in the reporting phase, the method of dissemination was determined and the final report was created [30].

Each step proposed in [30] was discussed, and later on thoughtfully included or excluded from our research process, according to the characteristics of our research.

A desktop application to assist in performing SLR (and gathering articles), called Parsifal [31], was used. Parsifal was composed based on guidelines from [30] and therefore

very suitable to work with. Some steps of SLR, i.e., evaluation and data synthesis, have been processed manually (with Microsoft Excel).

In the following subsections, further details of our research are given, i.e., the research questions, search strings and digital libraries, the inclusion and exclusion criteria, the search process and evaluation, and finally, the data analysis.

4.1. Research Questions

To formulate research questions, we considered the research objectives and research gap, both presented in Section 1, and PICOC criteria, presented in Table 1. We formulated the following research questions:

1. (RQ 1) What are the reported advantages and disadvantages of CMMN?
2. (RQ 2) What extensions, upgrades, or improvements for CMMN exist?
3. (RQ 3) Is CMMN used in practice?

With the first research question (RQ 1), we want to become acquainted with the current advantages and disadvantages of CMMN, associated with its syntax, quality characteristics, and any other relevant aspects. With the second research question (RQ 2) we want to identify all relevant existing improvements of CMMN, any existing reported extensions, or any kinds of upgrades. Our intention with the third research question (RQ 3) is to determine to what extent CMMN is used in practice.

Table 1. PICOC criteria.

Criteria	Answers
Population	Business analysts, researchers
Intervention	CMMN
Comparison	Where applicable, compared to BPMN
Outcomes	Insight into advantages, disadvantages, extensions, upgrades, or improvements and practical use of CMMN
Context	All available, existing scientific articles

4.2. Search String and Searched Space

The search string was focused on the considered technology, CMMN, namely: ("cmmn" OR "case management model and notation"). The search string relates to Intervention (PICOC criteria in Table 1) and was composed of the notation's full name, its abbreviation, and expected operator OR between them. The same query was applied across all selected digital libraries, with minor syntax adjustments as required by individual platforms.

The search string is relatively general and simple; nevertheless, we expect to gain all available scientific articles related to this topic. We are also well aware that every article that contains some kind of reference to CMMN could be a relevant source. It also makes sense to point out that a smaller set of articles is generally expected to be identified for CMMN.

Later on, the following digital libraries were included in our research: ACM Digital Library (abbr. ACM) [32], IEEE Xplore Digital Library (abbr. IEEE) [33], Web of Science (abbr. WoS) [34], ScienceDirect (abbr. SD) [35], Scopus (abbr. Sc) [36], and SpringerLink (abbr. SL) [37]. We considered the most relevant digital libraries for the IT field, referred to in [30].

The digital libraries used additionally provide different search options. In all mentioned digital libraries, our defined search string was used consistently. We also used additional options, if possible, e.g., time intervals, type of publication (book, journal, etc.), or specific databases within the selected digital library. Since most search engines of the chosen digital libraries have the result sorting option, we sorted by relevance.

4.3. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were composed according to the research questions. The criteria were composed and applied to titles, summaries, and keywords. If it was impossible to determine whether or not an article was suitable, a complete review of the content was made. The criteria are also in accordance with the research questions, presented in Section 4.1.

The inclusion criteria covered the following: (1) general articles about CMMN; (2) articles proposing extensions, upgrades, or improvements of CMMN; (3) articles presenting the use of CMMN; (4) articles presenting a comparison of CMMN and other notations.

The exclusion criteria covered the following: (1) articles unrelated to CMMN; (2) inaccessible articles; (3) articles mentioning CMMN only indirectly; (4) articles older than 2014, when CMMN was first published; (5) grey literature; (6) non-English articles.

4.4. Search Process and Evaluation

Within our SLR, a manipulation with gathered initial articles was performed. The search process was conducted by two researchers, where the initial articles of the first researcher were compared to sampled articles by the second researcher. The evaluation of initial articles was performed in the following four phases: (1) pre-evaluation, (2) first evaluation phase, (3) second evaluation phase, and (4) third evaluation phase. In each evaluation phase, irrelevant articles were eliminated based on corresponding conditions for every phase. Evaluation of initial articles is described in detail in Section 5.

4.5. Data Analysis

The evaluation of initial articles was conducted by considering relevant information (or attributes) from each article. Attributes are classified into four attribute groups, altogether presented in Table 2. The first attribute group is called Basic information, where attributes Title, Authors, Source, Type of source, Year of publication, Researchers, and Domain are contained. For some attributes, possible values are not defined (attributes Title and Authors), while others do have their stock of value (attributes Source, Type of source, Year of publication, Researchers, and Domain). The other attribute groups included are Analysis of content, Interpretations of results, and Other.

Table 2. Attributes of initial articles.

Attribute	**Possible Values**
Basic information	
Title	-
Authors	-
Source	journal title, conference name, book title
Type of source	journal, conference, book chapter, thesis
Year of publication	2014–2024
Researchers	academics, business people, both
Domain	general article OR article about extensions OR articles about use OR articles about several notations, including CMMN
Analysis of content	
Purpose	-
Problem description	-
Proposed solution	-

Table 2. *Cont.*

Attribute	Possible Values
Interpretations of results	
Discussions	-
Further work	-
Other	
Notes	-
Subjective assessment	excellent, very good, good, poor, very bad

5. Outcomes and Interpretation

5.1. Analysis of All Initial Articles

In the *pre-evaluation phase*, the total number of identified initial articles was 942, of which 226 passed the relevance threshold (according to the topic). The distribution of articles, according to each digital library and each evaluation phase, is presented in Table 3.

Table 3. Results of evaluations.

	Input	Pre	First	Second	Third
ACM	151	31	2	2	2
IEEE	199	20	2	1	0
WoS	91	52	21	18	9
SD	14	12	8	8	4
Sc	125	61	34	27	19
SL	362	50	15	12	9
Total	942	226	82	68	43

The pre-evaluation was followed by the first evaluation phase, where the inclusion and exclusion criteria were considered. Firstly, we identified and eliminated 67 duplicates. Secondly, 71 articles did not meet the given criteria (see Section 4.3) and were also eliminated from the research, resulting in 82 relevant articles for the first evaluation phase.

In the second evaluation phase, seven articles were excluded because of the inadequacy of the content, according to the research questions, discovered within the metadata of each article (title, keywords, and abstract). An additional seven articles were eliminated because of technical unavailability. This evaluation phase concluded with 68 relevant articles, representing income to the final third evaluation phase, where the research questions were considered again, but now covering the complete content of each article. This resulted in the exclusion of 25 articles, which did not answer any of the given research questions. There were 43 articles (presented in Table 4) left for further analysis and synthesis of the gathered data, which can serve to provide more credible answers to research questions.

Table 4. Relevant articles.

#	Ref.	Author(s)
S1	[13]	Allah Bukhsh et al.
S2	[3]	Auer et al.
S3	[38]	Benzarti et al.
S4	[39]	Bruno
S5	[40]	Bruno

Table 4. *Cont.*

#	Ref.	Author(s)
S6	[41]	Bule and Polančič
S7	[28]	Carvalho et al.
S8	[42]	Carvalho et al.
S9	[43]	Castellanos et al.
S10	[44]	Fred A. Cummins
S11	[45]	Czepa et al.
S12	[46]	Ferreira et al.
S13	[47]	van Gaal et al.
S14	[48]	Gonzalez-Lopez and Pufahl
S15	[49]	Herzberg et al.
S16	[50]	Holz et al.
S17	[29]	Jalali
S18	[51]	Jalali
S19	[52]	Junger et al.
S20	[22]	Kocbek Bule et al.
S21	[14]	Kurz et al.
S22	[53]	Lantow
S23	[8]	Marin et al.
S24	[54]	Marin et al.
S25	[55]	Marrella et al.
S26	[56]	Mei et al.
S27	[57]	Milani et al.
S28	[58]	Nešković et al.
S29	[59]	Nikolaidou et al.
S30	[60]	Nova Arévalo and González
S31	[61]	Ozturk Yurt et al.
S32	[62]	Plebani et al.
S33	[12]	Routis et al.
S34	[25]	Routis et al.
S35	[26]	Routis et al.
S36	[27]	Routis et al.
S37	[63]	Ruiz Herrera and Sánchez Díaz
S38	[64]	Shahrah and Al-Mashari
S39	[24]	Slaats
S40	[65]	Sprovieri and Vogler
S41	[66]	Sprovieri et al.
S42	[10]	Wiemuth et al.
S43	[9]	Zensen and Küster

5.2. Analysis Relevant Articles

In this section, we present a descriptive analysis of the 43 relevant articles identified during the third evaluation phase. The aim is to provide an overview of their temporal distribution, publication types, conference fields, and research focus.

Figure 2 shows the distribution of relevant articles by year of publication, covering the period from 2014 to 2024. The number of articles fluctuated over the years, with the highest number published in 2016 and 2018. This trend may indicate initial research momentum following the release of the CMMN specification, and a renewed interest around 2018, potentially linked to methodological or tooling developments.

Figure 3 presents the distribution of publication types. The majority of the selected articles were published in conference proceedings (27), followed by journal articles (14), and a small number as book chapters (2). This suggests that research on CMMN is still somewhat emerging and exploratory in nature, with findings being shared in venues with shorter publication cycles.

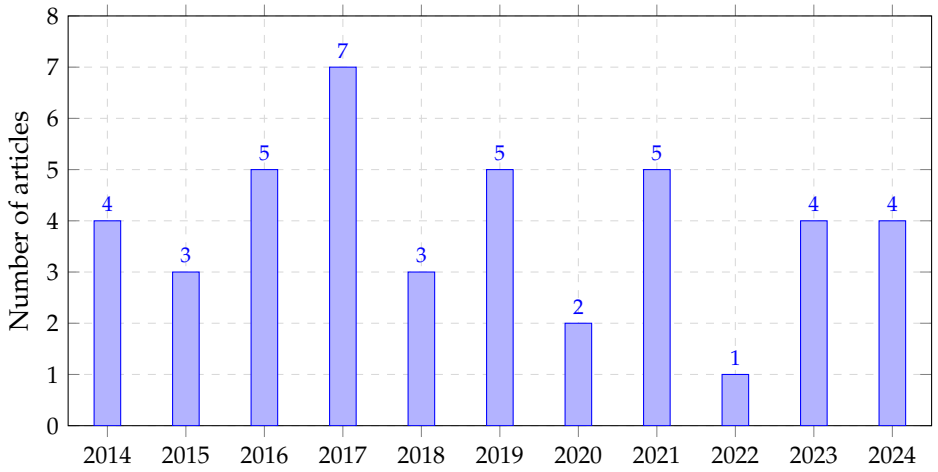


Figure 2. Distribution of relevant articles by year of publication.

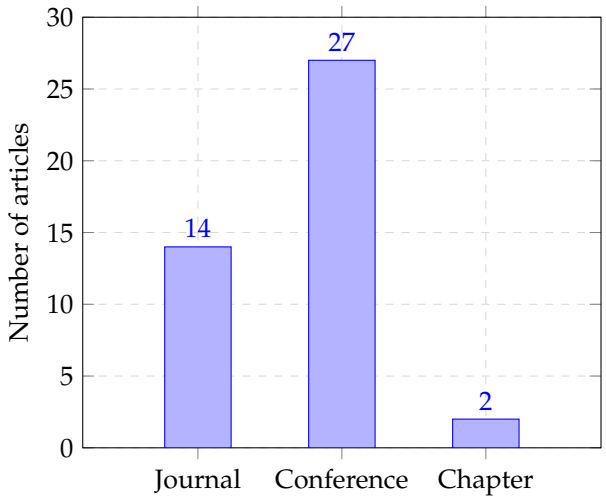


Figure 3. The distribution of relevant articles by publication type.

To further understand the disciplinary background of the research, Figure 4 shows the distribution of conference fields. We categorized conferences based on their thematic scope and found that most CMMN-related articles were presented in the fields of Business Process Management (BPM) and Information Systems (IS), with fewer contributions from the Enterprise Modelling and Mixed/Other domains. This supports the view that CMMN research is closely linked to ongoing discourse in process modelling communities.

Finally, Figure 5 illustrates the classification of articles based on their domain of content, i.e., their research orientation. The distribution shows a relatively even split between general/conceptual articles and those focused on practical use (14 each). Additionally, eight articles addressed extensions or improvements to the CMMN notation, while seven articles explored its use in comparison or integration with other modelling notations. This classification provides insight into the types of contributions present in the literature and serves as a foundation for the synthesis presented in the next section.

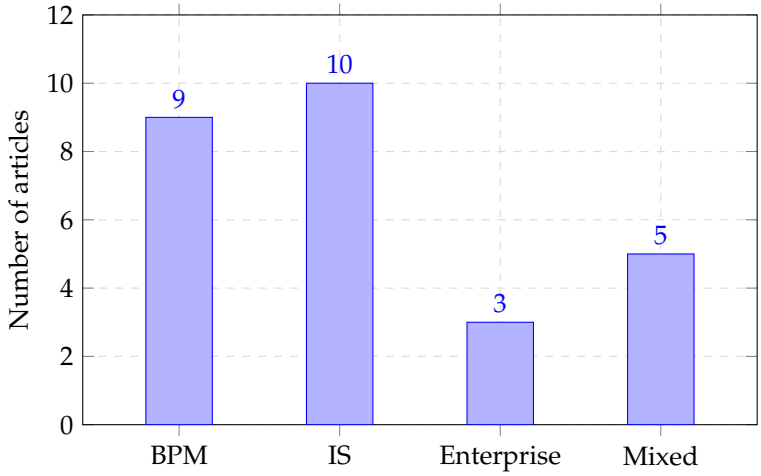


Figure 4. The distribution of relevant articles by conference field.

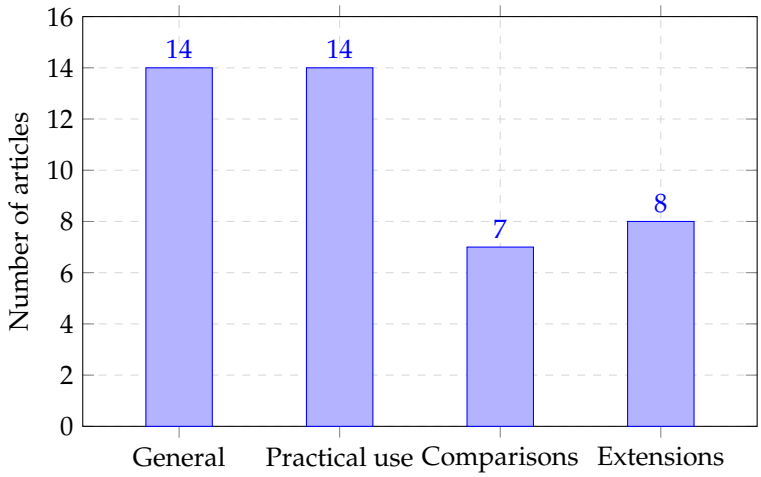


Figure 5. The distribution of relevant articles by domain of content.

5.3. Synthesis of Relevant Articles

To obtain more explicit answers to research questions, further analysis and especially synthesis of the gathered data was required. Here we used coding and successive approximation techniques for analysing the qualitative data gained from relevant articles, according to [67].

Firstly, when performing coding, raw data were collected from relevant articles, and initial codes emerged. Initial codes are "tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study" [67]. In our case, the identified initial codes varied in length, and the majority of them were sentences or paragraphs. Later on, we established seven categories, which were generated from our research questions. The categories were (1) advantages, (2) disadvantages, (3) interesting facts, (4) extensions, (5) use in practice, (6) other notations, and (7) flexible processes, all referring to CMMN. All initial codes were placed into one of these categories. Later on, 16 concepts were created out of these categories. When reviewing the data for the second time, the main focus was to identify concepts that grouped together and also to find possible relations between identified concepts. Out of 16 concepts, we assembled four groups of concepts, shown in Table 5. Within the first group of concepts, called Syntax, concepts mainly refer to concrete syntax, except for the concept Metamodel, which is referring to abstract syntax. In the second group, all five of the identified concepts refer to the quality characteristics of CMMN. Concerning CMMN, some codes

regarding non-routine work and knowledge workers were identified, which are also grouped together. The last group of concepts unites concepts referring to experiences in use. All concepts are in equivalent positions within their group, or in other words, no hierarchy was identified between concepts.

Table 5. Groups of concepts and corresponding concepts.

Groups of Concepts	Concepts
Syntax	Elements, Control-flow, Data, Execution, Progress in process, Roles, Metamodel
Quality characteristics	Applicability, Complexity, Expressibility, Simplicity, Understandability
Declarative aspect	Knowledge workers, Non-routine work
Experiences in use	Companions, Vendors

Secondly, when performing successive approximation, initial codes were verified once again. As a result, we acquired a set of generalised codes, which represent a more general form of the initial codes. Therefore, every generalised code corresponds to one initial code and also has the belonging concept. We assume that generalised codes, combined with initial codes and corresponding concepts, present a good foundation for answering research questions.

The described process of our qualitative analysis and synthesis is also presented graphically, with a BPMN diagram, in Figure 6, where, after a start event (named "Start of data analysis (SLR concluded)"), two sub-processes are included (named "Coding" and "Successive Approximation"), consistently with the techniques used. The process ends with an end event (named "End of data analysis"). In the sub-process "Coding", activities like "Establishing initial codes", "Establishing categories", "Placing initial codes to categories", etc. are used to represents all performed steps. Meanwhile, data objects, such as "43 relevant articles", "3 research questions", "Initial codes", etc. are used to represent input or output documents. Similar presentation of the process is also performed in the sub-process "Successive approximation". It is important to note that both of these sub-processes were carried out manually, with the support of Microsoft Excel, which provided a flexible environment for organizing, categorizing, and refining qualitative data.

5.4. Answers to Research Questions

This research aimed to provide some basic conclusions regarding the state of CMMN. In Table 6, columns represent research questions (RQ 1.1, RQ 1.2, RQ2, RQ3), and rows represent relevant articles (S1 to S43). Some of the research questions are also divided into generalised codes, presented in Section 5.3, which, as already stated, presents a good foundation for answering the research questions. The codes are as follows: (A1) CMMN is promising, (A2) The combined use of CMMN and BPMN is favourable, (A3) Alternatives and complementary notations exist, (A4) Use of the hybrid approach is favourable, (D1) Control flow is challenging, (D2) Data modelling capability has weak support, (D3) Roles are poorly defined, (D4) Lack of execution support, (U1) Elements, (U2) Discretionary elements, which help to highlight optional work, (U3) Its early adoption stages by industry vendors, (U4) Complexity.

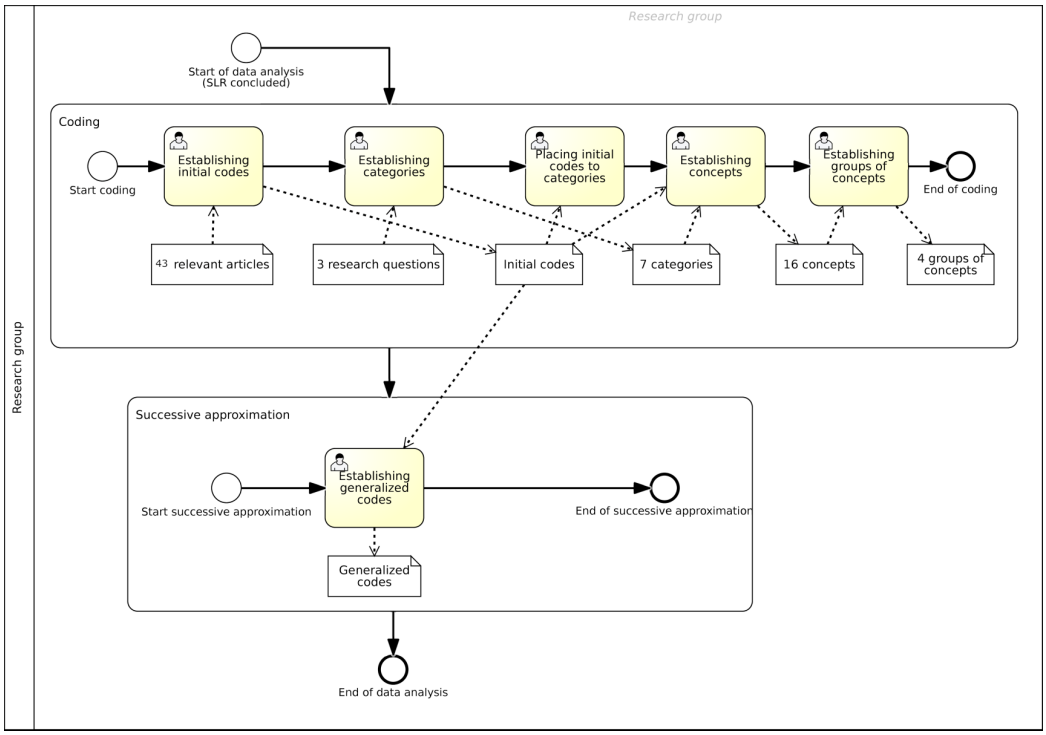


Figure 6. Process of qualitative analysis and synthesis, presented in a BPMN diagram.

Table 6. Answers to research questions.

	RQ 1.1				RQ 1.2				RQ 2		RQ 3		
	A1	**A2**	**A3**	**A4**	**D1**	**D2**	**D3**	**D4**		**U1**	**U2**	**U3**	**U4**
S1	✓	✓		✓	✓	✓	✓				✓		
S2		✓											
S3	✓												
S4					✓		✓		✓	✓			
S5					✓	✓	✓		✓	✓			
S6						✓			✓				
S7			✓			✓							
S8		✓											
S9	✓	✓	✓									✓	
S10													✓
S11					✓				✓				
S12	✓												
S13	✓				✓								
S14						✓							
S15	✓						✓						
S16	✓					✓	✓						✓
S17			✓										
S18	✓						✓			✓			
S19		✓											
S20										✓			
S21							✓	✓					
S22		✓	✓										
S23		✓	✓										✓
S24										✓			
S25	✓					✓			✓	✓			
S26													✓
S27							✓			✓			
S28	✓								✓				

Table 6. *Cont.*

	RQ 1.1				RQ 1.2				RQ 2		RQ 3		
	A1	**A2**	**A3**	**A4**	**D1**	**D2**	**D3**	**D4**		**U1**	**U2**	**U3**	**U4**
S29								✓					
S30	✓												✓
S31	✓												
S32						✓	✓		✓				
S33	✓	✓						✓	✓				
S34						✓		✓					
S35	✓							✓					✓
S36	✓												
S37			✓	✓									
S38	✓		✓								✓	✓	
S39				✓									
S40									✓	✓			
S41								✓					
S42		✓	✓										
S43		✓			✓	✓	✓			✓	✓		

In Table 6, we explicitly ticked (✓) relevant articles that contain answers for a particular research question (with the corresponding generalized code). On the foundations of all collected knowledge gained from articles, associated analysis, and synthesis of the data, we can provide answers to the research questions.

5.4.1. RQ 1: What Are the Reported Advantages and Disadvantages of CMMN?

With RQ 1, the aim was to identify the advantages, and also the disadvantages, of CMMN. For more explicit answers, we performed synthesis of the data, with the following results. The identified advantages and disadvantages are given bellow in generalised codes (given in Section 5.4), followed by explicit answers obtained from relevant articles and, additionally, by a paragraph where the factual statements are interpreted in light of information external to SLR.

(A1) CMMN is promising. "The interest in CMMN is increasing" S35–[26] and "CMMN is attractive since it promises an increased level of expressibility for modelling of evolving business processes" S1–[13]. It "introduces an additional degree of flexibility as declarative languages rely on an open-world assumption, thus leaving room for supporting situations that cannot be planned at design-time." S25–[55]. "CMMN model can be used in more specific and realistic scenarios" S38–[64].

The findings above do not coincide completely with the results on Google Trends, when exploring CMMN (search terms on trends.google.com: cmmn, Worldwide, 2004-present, All categories, Web search). We can highlight that the demand has been more or less even since publication. CMMN also has a solid foundation in well established Case Management (introduced in [6]), which is covering knowledge-intensive business processes and is resolving some open challenges of existing Workflow Management. Current work approaches adapted slowly to the knowledge workers, which are in the centre of the business processes and determine the activity sequence according to their expertise and/or knowledge. To formally record such a business process, a notation like CMMN fits perfectly S3–[38].

(A2) Combined use of CMMN and BPMN is favourable. CMMN was primarily designed to complement BPMN S42–[10], S23–[8], S33–[12]. Many claim that the combined use of BPMN and CMMN has major benefits for business process modelling and that this combination is the most optimal possible S43–[9], S22–[53], S42–[10], S2–[3], S1–[13], S8–[42], S19–[52]. It is hard to determine who has a leading role. On one hand, we have

supporters of BPMN, where CMMN has a minor role in fixing the deficits of BPMN S42–[10]. On the other hand, supporters of CMMN agree that flexibility in business processes is crucial, which is harder to achieve with only BPMN S43–[9], S23–[8].

It is a fact that many processes in organisations are not exclusively procedural or declarative—i.e., commonly we can find a combination of both paradigms, structured and unstructured parts of processes. Considering the year of first release of BPMN, we can assume that BPMN has a great advantage over CMMN, arising from a longer period of existence, disregarding other existing advantages. Nevertheless, possible opportunities to cover unstructured parts of processes are still pending for CMMN. An open question remains: if the modelling of processes truly requires two independent, yet related modelling languages, or if these could be resolved with an extension of one of the languages.

(A3) Alternatives and complementary notations exist. Beside BPMN, the most frequently used notation in combination with CMMN is DMN S42–[10]. In S37–[63], the authors stated that CMMN along with DMN are very suitable approaches to obtain a flexible model adapted to context-driven response processes. There are also traces of other notations, more precisely SBVR S22–[53], ConDec S7–[28], EPC S23–[8], UML Activity diagram S23–[8], Statecharts S38–[64], and DCR S17–[29].

With BPMN, which has a long period of existence, a good coverage of process concepts, a rich collection of researchers, many vendors available, etc., we can still identify weak points or possible opportunities for improvements, which can be associated with numerous extensions proposals [68]. The latter can also be supplemented with alternative or complementary notations. Naturally, it requires additional knowledge of the new notation, but the missing gap can be filled. The above examples can be transferred to other notations, where complementary use may fulfil requirements.

(A4) The use of a hybrid approach is favourable. From the last two paragraphs, we can assume that shared use of multiple notations or the so-called hybrid approach makes a lot of sense, because "many processes in organisations do not neatly fall in one category or the other, they contain both flexible and rigid parts" S39–[24]. In S1–[13], the authors state that "more than half of business processes are unstructured and unpredictable in nature". The hypothetical integration of BPMN, CMMN, and DMN specifications, to build the hybrid model, S37–[63], would be a logical consequence.

Nevertheless, one very important question that remains is the degree of compatibility of notations appropriate for hybrid use. In cases where compatibility is not guaranteed, analysts can face learning challenges, because of structural and visual differences of languages, issues related to tool support, or readability. Still, there are examples of the successful hybrid use of notations [69].

(D1) Control flow is challenging. In S5–[40], the authors detected "difficulty to figure out what the actual flow of activities" is. It is especially difficult to understand the model when the modeller has some prior knowledge about imperative sequence flows or notations of this type S43–[9]. In CMMN, so-called "seamless modelling" S11–[45] can be quite a mental leap. In some cases, connectors are still used; also, sentries can help to "lead the way". "Routing and control-flow without the use of connectors and sentries can be difficult to understand" S43–[9]. Some authors also state that "the combination of connector and sentries provides poor readability" S1–[13].

Here we would like to emphasise that modellers most importantly have to be aware of both approaches, and additionally of their differences, advantage, and disadvantages. In this way, modellers will be able to appropriately use imperative notations with structured parts and declarative notations with unstructured parts of processes.

(D2) Data modelling capability has weak support. Despite the fact that the Case File Item is an important element of CMMN, findings from our research state that "CMMN

provides a very limited view on data" S1–[13], "with no restrictions about the format and the nature of the represented data" S32–[62]. Additionally, "it is unclear how the intricacies of a Case File and the Case File Items contained can be included in the model" S43–[9]. Consequently, it "requires improvement on semantics for Case Files" S34–[25]. Similar conclusions regarding data in CMMN were also given in S25–[55], S14–[48], S7–[28], and S5–[40].

CMMN is data-centric. According to the identified limitations with data capability, this indicates options for further research and upgrades of existing element. One of the options is to better refine the existing element, which would be capable of carrying different types of data, like relational databases, unstructured data, media files, etc.

(D3) Roles are poorly defined. CMMN does not have any visual presentation for user roles, which are defined only semantically S1–[13]. However, there is one exception: "the modeller can assign roles to human tasks" S21–[14]. In the future, vendors are expected to map users to tasks or roles using proprietary mechanisms S21–[14]. Poorly defined roles are also exposed in S43–[9], S5–[40], S21–[14], S15–[49], S32–[62], S4–[39], and S27–[57].

That roles are important within modelling testifies to the fact that, with BPMN, pools and lanes are one of the first elements used when making a model. The absence of visual element for roles in CMMN is disturbing, as the content of processes often determines roles. The introduction of a new visual element could be an easy additive, in terms of artefacts for activities, or by introducing lanes, as in BPMN.

(D4) Lacks execution support. "While CMMN seems ideal for modelling cases in a declarative manner in design-time, it provides no guidance on how to represent a running case, e.g., a way to ensure that case models could be executable" S33–[12]. "The lack of effective execution support of important notation elements, such as sentries and discretionary items, limits applicability of CMMN" S34–[25], S35–[26]. Nevertheless, "meta-model allows monitoring the execution status of the case as well as all tasks and stages" S21–[14]. In light of this, some suggestions for extensions appeared in S33–[12] and S41–[66].

This disadvantage also offers opportunity. With good execution support and a multitude of executions available, machine learning (with characteristics and previously performed cases) can determine the highest probability of performing the following steps.

5.4.2. RQ 2: What Extensions, Upgrades, or Improvements for the CMMN Exist?

With RQ 2, the aim was to identify any existing extensions, upgrades, or improvements for CMMN. Detailed answers can be found in all relevant articles, as presented in Table 6. Our synthesis of the gathered data showed that some improvements would be welcome, especially if we proceed from identified disadvantages.

In S5–[40], "an extension to CMMN in which stages represent states of information items" is proposed. One other given extension "enables the features of assignments to be inferred from the case process model" S4–[39]. In S40–[65], the authors proposed to "introduce the concepts of antecedents and consequences" into the meta-model. In S32–[62], the authors came up with an extension concerning Case File Items and tasks, where the connection between them would be annotated with the actions performed on the data. There is also some extension proposed in S33–[12], related to executable models. The collection of extensions is very much diverse. Mainly they spring from perceived disadvantages, as presented earlier in this section.

Figure 7 presents a minor extraction from the UML class diagram-based conceptual model of CMMN. Classes where extensions are proposed are marked grey, and additionally, notes with relevant articles are appropriately added. More specifically, in articles S25–[55], S28–[58], and S32–[62], extensions related to the Case File Item are proposed. Further, articles S11–[45], S32–[62], and S40–[65] are dealing with extensions related to class

CMMNEdge, which is covering connectors in CMMN. The highlighted suggestions are consistent with two identified disadvantages from Section 5.4. Other articles that are also proposing extensions related to a certain class are given in the class diagram notes beside every relevant class (Figure 7).

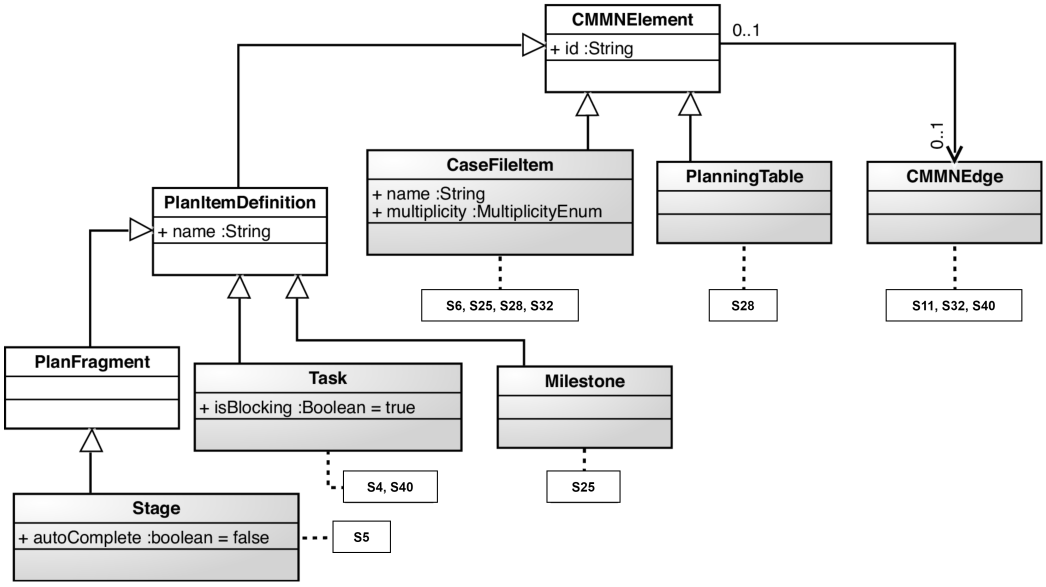


Figure 7. UML class diagram-based conceptual model of CMMN classes where extensions have been proposed.

5.4.3. RQ 3: Is CMMN Used in Practice?

With RQ 3, the aim was to become acquainted with the use of CMMN in practice. Detailed answers can be found in all relevant articles, covered in Table 6.

Firstly, we aimed to discover the use of CMMN at the lowest level—with notation elements (U1) and their characteristics. Some difficulties were already exposed within answers to RQ 2, mainly according to poorly defined data capabilities and roles. The use of roles in CMMN is almost completely absent, which is frequently pointed out as a problem. Some minor shortcomings also appeared with the element Case File Item, which covers the data aspect in CMMN. The modeller can "link Case File Items to Sentries, Milestones, and events" S43–[9], the format of data that can be stored within this element remains indeterminate.

"An advantage in terms of communication and events are milestones, where the overall progress of the process can be explicitly conveyed" S43–[9]. Some authors S25–[55] suggest alternative milestones that "can be defined to improve the level of resilience of CMMN models". Another very important part of CMMN are discretionary elements (U2), which help to highlight optional work and aid flexibility S43–[9], S38–[64], S18–[51]."The discretionary tasks and stages provide a better understanding of which tasks can be skipped during process execution" and can be compared to ad hoc sub-processes of BPMN S1–[13]. In S20–[22] and S24–[54], evaluations of CMMN elements are extensively presented. In S27–[57], the authors pointed out one missing aspect, more precisely, "CMMN does not provide a way to represent an external system".

Some authors emphasise that CMMN "is still in its early adoption stages" (U3) S38–[64], although quite a few years have passed since its creation (in 2014). Some also expose its complexity (U4) S10–[44], S35–[26], although it is "less complex than BPMN 1.2" S23–[8]. In S29–[59] and S36–[27], the potential of CMMN to support knowledge-intensive processes is exposed.

Secondly, we also wanted to briefly determinate, based on relevant articles and other relevant literature, how CMMN fared against other notations for the declarative modelling approach, like GSM, Declare, and DCR.

Guard–Stage–Milestone (GSM) is one of the alternatives for declarative modelling, but in the literature it is more frequently presented as an approach or a framework [20,21]. Similarly to CMMN, GSM also enables analysts to capture the control flow logic of business processes and identify dependencies, constraints, and decision points within the process flow. While there are about 850 hits in general for CMMN in Google Scholar, the GSM approach has only 600, which somehow makes sense, since it is more established as a approach rather than a notation, and as a result, it is most likely less used.

Another alternative to CMMN is Declare (or Declare/ConDec), which describes a set of constraints applied to activities; additionally, the control flow and the ordering of the activities are determined implicitly [70]. Beside a possible connection to a ProM framework, there are no noticeable known tools for Declare [71,72].

A quite widespread declarative modelling notation, as publicity reported in Google Scholar, is the Dynamic Condition Response Graph (DCR Graph). Here, processes are represented as a network of nodes and directed arcs. Nodes represent activities or states, while arcs represent dependencies or constraints between them [73]. A good foundation in the context of research articles led to a more extensive use in practice, for example [74,75].

6. Threats to Validity

As with any SLR, our research is subject to several potential threats to validity. We have addressed the following key categories of validity threats: selection bias, data extraction and interpretation bias, and temporal bias. Below, we discuss how these threats were considered and mitigated during the design and execution of our research.

Selection bias may occur if relevant articles are unintentionally excluded from the review, either due to search strategy limitations, database constraints, or researcher decisions during screening. To reduce this threat, we defined precise inclusion and exclusion criteria (Section 4.3) aligned with our research questions (Section 4.1) and the PICOC criteria (Table 1). The search process was conducted systematically across six digital libraries relevant to the field of information systems and software engineering (Section 4.2), which were selected based on recommendations from existing SLR guidelines [30]. Furthermore, the search string (Section 4.2) was formulated to be very general, inclusive, and applied consistently across all libraries.

To further minimize subjectivity, the selection and evaluation of articles were conducted by two researchers independently. Initial selections were compared, and in case of disagreements articles were discussed and decisions reached through consensus. The multi-stage evaluation process (pre-evaluation, first, second, and third evaluation phases) (Section 4.4 and Table 3) also served as a quality control mechanism, filtering out irrelevant or low-quality studies in a structured and transparent way. This layered approach significantly reduced the likelihood of accidental exclusion of important articles.

Data extraction and synthesis can be influenced by the researchers' interpretation of the content, especially when dealing with qualitative data. To mitigate this, we followed a structured data extraction process based on a clearly defined set of attributes (as shown in Table 2). The extraction process was also supported by the use of a specialized SLR tool (Parsifal), which ensured traceability and consistency in managing the selected literature. In the analysis phase, we applied coding and successive approximation techniques, which are well-established methods for qualitative synthesis. Initial codes were created based on content from the articles and then categorized into meaningful themes related to our research questions. The development of generalized codes further supported abstraction

and reduced the influence of individual researcher interpretations. Importantly, both researchers participated in the coding and synthesis stages, thus ensuring cross-validation and reducing the risk of one-sided interpretations. This triangulation approach enhanced the objectivity and reliability of our findings.

Temporal bias refers to the risk that the timing of the literature search may skew results—either by favoring older, more cited works or by missing recent developments. In our research, the literature search covered the entire period of CMMN's existence, from its formal publication in 2014 to the end of 2024. This provided a comprehensive overview of the evolution of the notation over time. Nonetheless, we acknowledge that relevant articles published after the cutoff date (end of 2024) were not included in our review. While this is a common limitation in SLR studies, we believe the selected timeframe adequately reflects the state-of-the-art at the time of writing and provides valid insights into the current theoretical and practical implications of CMMN.

Given the conceptual and exploratory nature of this review, formal procedures typically associated with quantitative systematic reviews, such as risk of bias assessment, evaluation of reporting bias, or certainty of evidence scoring, were not applied in the traditional sense. Instead, the review focused on interpretative synthesis through a structured qualitative approach. Care was taken to maintain consistency and transparency in coding and categorization, and the potential influence of subjectivity was addressed through iterative refinement and cross-validation among researchers. While some methodological elements recommended in broader review standards (such as PRISMA [76]) were not applicable in this context, we acknowledge their value and have aimed to align with their underlying principles where possible.

In summary, while these threats to validity are inherent to SLR methodology, the rigorous design of our review process, coupled with the use of established tools and collaborative evaluation procedures, has helped to reduce their impact and enhance the credibility of our conclusions.

7. Conclusions

In this article, we performed an SLR of CMMN, above all, to identify potential advantages and disadvantages, and also to find some cases of practical use. Using the aforementioned research method, we obtained 43 relevant articles, out of 942 articles, which were input to the pre-evaluation phase, followed by other evaluation phases (details in Table 3). Information credible for our research was collected according to relevant information (attributes), given in Table 2. Information was systematically analysed and a synthesis was made with two techniques for analysing qualitative data—coding and successive approximation [67]. We obtained highlights to offer answers to research questions (in Section 5.4).

As is evident, CMMN has been the subject of many theoretical types of research, where authors are dealing with its notation, its role within the declarative paradigm, and its relationship regarding other notations. There is considerably less available literature on the practical aspects of CMMN.

Almost a decade after its publication, we still cannot say that CMMN is generally used for unstructured business processes. According to information obtained from our research, the possible reasons for this can be related to its notation and elements, for example, poorly defined aspect of roles, weak data modelling capability, control flow challenges, and lack of execution support. We must also pay attention to the requirement for flexibility, which must be fulfilled in CMMN. On one hand, flexibility is essential for declarative notations, where less complex diagrams are expected. However, on the other hand, there has to be some guard for diagrams not to become too loose and empty.

Nevertheless, we can conclude that CMMN has a good foundation. Firstly, it is part of the declarative modelling approach, which is derived from the Event–Condition–Action (ECA) paradigm, and consequently also from the Guard–Stage–Milestone (GSM) approach. Secondly, CMMN is part of the Case Management paradigm, whose ability is to handle complexity and variability effectively, enabling organisations to achieve better outcomes, improve efficiency, and enhance customer satisfaction in dynamic and unpredictable environments. Based on this, there are enough possibilities for CMMN to demonstrate its potential.

7.1. Recommendations

Based on the findings of this SLR, several recommendations can be made to guide future research and practice regarding CMMN. First, there is a clear need to increase empirical validation, as many studies focus primarily on modelling constructs or proposed extensions while offering limited evaluation involving real users or organizations. Future work should therefore include case studies, experiments, or field applications—especially in comparative settings with other modelling notations. At the same time, there remains a noticeable imbalance between the conceptual contributions and documented practical applications of CMMN. Researchers and practitioners are encouraged to implement the notation across various domains, such as education, public administration, or legal processes, and to report on the experiences and insights gained. Addressing usability concerns is also crucial; several studies have highlighted tooling limitations, particularly regarding user-friendliness, modelling flexibility, and integration with BPMN or DMN. Enhancing tool support and providing clearer modelling guidelines may significantly improve adoption. In addition, the value of CMMN lies in its ability to complement other modelling approaches, and further investigation is needed into how it can be effectively integrated with notations such as BPMN, DMN, or other declarative languages at both conceptual and implementation levels. Finally, given that CMMN is especially suited for knowledge-intensive and flexible processes, its development and application could greatly benefit from cross-disciplinary collaboration, particularly in fields like healthcare, law, or public services, where new perspectives and use cases may emerge.

Together, these directions aim to foster a more balanced, practically grounded, and interdisciplinary research landscape for CMMN.

7.2. Limitations and Future Work

The following limitations should be considered when viewing the results of this work.

The search string used in this study was intentionally kept relatively simple and concise in order to maintain compatibility across various digital libraries. Nonetheless, adaptations to the syntax and structure of the query were necessary in several cases, depending on the specific search interfaces and constraints of individual digital libraries.

Furthermore, the search was limited to the most prominent and relevant digital libraries in the field of information technology, as recommended by [30], which may have excluded some potentially relevant publications indexed elsewhere.

Another constraint relates to restricted access to certain publications, as some full-text articles were not available due to subscription or institutional access limitations, potentially affecting the comprehensiveness of the dataset.

In terms of limitations associated with qualitative data analysis, the nature of the data—largely consisting of textual content extracted from academic articles—presents inherent challenges in terms of replicability and verification. Since interpretation and coding involve a degree of subjectivity, the results cannot be independently verified in the same manner as quantitative data. Although we applied established methods and involved

multiple researchers in key phases of analysis to mitigate these effects, we recognize this as a fundamental limitation of the qualitative approach adopted.

Another limitation concerns the recurrence of publications by the same author team among the selected sources. For instance, a group of studies (e.g., S33–[12], S34–[25], S35–[26], S36–[27]) originates from the same research group, which may introduce a degree of thematic or methodological alignment within the dataset. Although these papers were included based on clearly defined inclusion and exclusion criteria and were evaluated with equal methodological rigor, we acknowledge that such concentration may affect the diversity of perspectives.

Another important consideration is that this SLR includes articles authored by the same research team that conducted this review. Given our active involvement in the field of CMMN and our ongoing research contributions, this inclusion emerged naturally through the application of the predefined selection criteria. While we strived to apply the same objective methodological approach to all sources (regardless of authorship), we acknowledge that the presence of an author-related article may raise concerns regarding potential bias. To address this, the same rigorous evaluation and coding procedures were applied to all articles, and independent assessments were conducted by multiple researchers to minimize subjectivity. We have made this aspect transparent in both our methodology and in this section to support the credibility and integrity of the findings.

Our future work could expand this review by considering especially identified disadvantages and more practical aspects of CMMN. We find particularly interesting areas of potential integration of CMMN with other notations. Any future work will be carefully designed to build upon the present findings without duplicating them by exploring more specific research questions and employing an expanded analytical perspective, while ensuring a clear distinction from the current study.

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Conflicts of Interest: The authors declare no conflicts of interest.

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