

Application of Semantic Web Technologies for Supporting Customer Relationship Management: a Systematic Literature Review

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Abstract: *The purpose of the present paper is to summarize the current state of the existing research on the application of Semantic web technologies in supporting customer relationship management. Its achievement includes providing answers to a set of research questions as a result of conducting a systematic literature review. A total of 44 scientific publications are identified as relevant to the topic and included in the review. Information is extracted from the selected literature sources, which is then summarized, systemized and analyzed according to the predefined research questions and finally reported. The conducted systematic literature review determines that the development of Semantic web technologies is provoked interest among researchers, as a result of which the advantages of using them for descriptions useful for various CRM purposes are investigated and practically confirmed. In addition to defining semantic models for descriptions supporting a variety of CRM activities and processes (such as customized products and services; supporting users of CRM systems; integrated offerings across channels; improved and innovative products and services; customer complaint management, etc.), various research works identify new approaches to support CRM, that can be achieved through the application of appropriate Semantic web technologies.*

The detailed study represented in this paper contributes to familiarization with the existing experience in the application of Semantic web technologies in supporting customer relationship management, as well as facilitates the discovery of trends and directions for future research. This is the reason for the expected interest from scientists whose research area cover the considered and similar fields; software engineers implementing CRM systems; data analysts exploring CRM domain.

Keywords: *Semantic web technologies, customer relationship management, systematic literature review.*

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1. Introduction

Customer relationship management (Techopedia, 2018) is defined as a strategy widely used by companies and organizations to store and manage their comprehensive data and interactions with current, past and potential customers. The purpose is to ensure that all organizational customer interaction functions (i.e. sales, marketing, technical support) are efficient and synchronized to ensure adequate and appropriate service to former and potential customers. Achieving this goal involves integrated information systems and technologies.

1.1. Customer relationship management and information technology

Since customer relationship management is based on customer data, it can be greatly facilitated and assisted by the use of information technology (Brito and Ramos, 2003; Bahrami et al., 2012; Orenga-Roglá and Chalmeta, 2016; Stefanov et al., 2023). By applying the appropriate information technologies, communication can be carried out with convenient channels such as e-mail, SMS (Short Message Service), etc.; collecting and analyzing customer data, discovering patterns in customer behavior that are useful for targeting profitable customers; receiving feedback in order to generate adequate recommendations, personalization of products and services.

1.2. Technologies for Semantic web

The implementation of the idea of Semantic web (Lassila & Hendler, 2001) leads to the development of Semantic web technologies. Standards designed to represent content are developed – the Resource Description Framework (RDF) (W3C, 2014), as well as RDF Schema (RDFS) (W3C, 2014b), the Web Ontology Language (OWL) (W3C, 2012) that allow for a comprehensive description of the content. The RDF standard provides possibilities for the semantic description of resources and their linked data in a way that is understandable to both machines and humans, with the option of using the XML (*eXtensible Markup Language*) format for representing the descriptions. The XML (W3C, 2008) and XML Schema (W3C, 2012b) standards are also included in the so-called Semantic web stack (Berners-Lee, 2000), which illustrates the architecture of the Semantic web, covering its syntactic level. One of the main advantages of using RDF/RDFS and OWL is the possibility of reusability and building on domain-specific ontologies already built by other developers. The SPARQL Protocol and RDF Query Language (SPARQL) (W3C, 2013) is intended for executing queries to

semantic data; the Semantic Web Rule Language (SWRL) (W3C, 2004) – for reasoning.

1.3. Problem statement

The CRM process consists of the four dimensions or phases (Ngai et al., 2009), (Guerola-Navarro et al., 2022):

- Customer identification with elements of target customer analysis and customer segmentation;

- Customer attraction, the element of which is direct marketing;

- Customer retention;

The elements of this dimension are one-to-one marketing, loyalty programs, complaints management.

- Customer development with elements of customer lifetime value, upselling/cross-selling, market basket analysis.

In (García-Crespo et al., 2010), possible benefits for CRM as a result of influence caused by application of social and Semantic web technologies are indicated, which are:

B1. Improved ability to target profitable customers;

Semantic web technologies provide opportunities for organizing and structuring feedback from customers, containing their opinions, recommendations, as well as analyzing the created dataset in order to target the appropriate customers. This advantage contributes to the implementation of the customer identification phase.

B2. Integrated offerings across channels;

Social technologies create and collect data, and the application of semantic technologies to them (mainly RDF representation and data retrieval queries) allows the construction of datasets containing offerings represented in a structured, ontology-based way that can be connected to customers and integrated into channels. In this way, the attraction of customers is supported.

B3. Improved sales force efficiency and effectiveness;

Customer feedback is essential to improve sales force effectiveness and efficiency, which in turn would have a positive impact on all CRM phases. Structuring and analyzing customer feedback can provide estimates of this effectiveness.

B4. Improved pricing;

B6. Customized products and services;

B7. Social branding;

It can affect customer attraction, retention and development.

B8. Improved customer service efficiency and effectiveness;

This benefit could have an impact on customer retention and development.

B9. Individualized marketing messages.

In the research area of knowledge representation, ontologies and semantic technologies not only use knowledge representation to personalize messages and make them individually oriented, but also enable the sharing and reuse of discovered knowledge elements inside messages.

A summary of the listed possible benefits and the different dimensions of CRM to which they relate is presented in Table 1.

Table 1. Correspondence between the possible benefits of applying social and semantic web technologies for CRM and the dimensions of CRM

Possible benefits for CRM	Dimensions of CRM
B1, B3	Customer identification
B2, B4, B5, B6, B8	Customer attraction
B3, B4, B5, B6, B7	Customer retention
B3, B4, B5, B6, B7	Customer development

Despite the growing importance of Semantic web technologies in various fields, including customer relationship management, there is a lack of a detailed systematic review of literature sources related to the subject under consideration. In the present paper, a comprehensive literature review is provided, which concerns the scientific publications related to the application of Semantic web technologies to support customer relationship management, the achievement of the expected possible benefits B1-B8, the identification of other realized benefits such as customer segmentation, improved products and services, support for users of CRM systems, etc. The papers found are classified according to the addressed potential benefits and according to the applied semantic web technologies. The results of the research conducted are summarized, systematized and analyzed to provide answers to a set of predefined research questions.

This paper is organized as follows. In section 2, existing reviews related to the topic under consideration are studied and the need for systematic literature review (SLR) is established, which addresses supporting customer relationship management through Semantic web technologies. Section 3 describes the research methodology. Section 4 provides and analyzes the results of the review.

2. Related work

On the one hand, there is an interest in research that summarizes existing knowledge and experience in the application of approaches and technologies from other fields such as data mining (Ngai et al., 2009); knowledge management (Khosravi and Hussin, 2016); data analytics (Gončarovs, 2017); big data analytics (Perera and Dilini Kulawansa, 2018), (Chen et al., 2019), (Sharma, 2020); implementation of big data for CRM from the point of view of international marketing (Del Vecchio et al., 2021); artificial intelligence (Ledro et al., 2022). In Soltani and Navimipour, (2016) research studies are studied and classified into the categories of E-CRM, knowledge management, data mining, data quality, and social CRM.

On the other hand, the application of Semantic web technologies in various domains is considered in systematic literature reviews such as cloud computing (Brabra et al., 2016); formal education (Jensen, 2017); distance learning (Bashir and Warrach, 2020); internet of things (Rhayem et al., 2020); bibliographic databases (Georgieva-Trifonova et al., 2020); big data modeling from analytics perspective (Georgieva-Trifonova and Galabov, 2021); healthcare (Bahalul Haque et al., 2022); software accessibility evaluation (Estrada-Martínez et al., 2022).

As a result from the conducted exploration, it is established a lack of a detailed and up-to-date systematic literature review focused on the use of Semantic web technologies to support CRM, which motivates the present study.

3. Research methodology

The present study is based on the guidelines for systematic literature reviews proposed in Kitchenham and Charters (2007).

3.1. Research questions

RQ1. How many research papers on applying Semantic web technologies to support CRM are published by now? What is the distribution of publications found by year?

The aim is to study the research interest in the subject under consideration and its change over time, providing summarized information in a quantitative and substantive aspect.

RQ2. Which Semantic web technologies are used to support CRM?

RQ3. What CRM benefits does the implementation of Semantic web technologies aim to contribute and what Semantic Web technologies are used for them?

The purpose of the research questions RQ2 and RQ3 is to identify the addressed potential benefits from the perspective of CRM and the Semantic web technologies applied to them, to examine the trends for the most popular of them and to understand their specific purpose.

RQ4. What ontologies are created to support CRM? What is the specific purpose of their application?

The goal is to systematize the proposed ontologies that are implemented when applying Semantic web technologies to support CRM.

RQ5. What trends exist in the application of Semantic web technologies to support CRM?

The purpose of RQ5 is to find trends in CRM benefits that are targeted by applying Semantic web technologies; current issues discussed in the most recent publications, as well as the proposed solutions to them, which allow for future progress.

The information obtained in response to the defined research questions would be useful to researchers working in the considered and related fields; software engineers developing CRM systems; analysts of data from CRM activities. From RQ1-3, they can acquire knowledge about the existing interest in the considered topic, as well as in the specific Semantic web technologies and for what purposes they are applied; from RQ4-5 – about the proposed approaches, observed trends, directions for future work.

3.2. Search process

The search process includes manual search of the academic databases Scopus, Web of Science, EBSCO, ScienceDirect, SpringerLink, ACM Digital Library, IEEE Xplore, CiteSeerX, Google Scholar.

Search strings are derived based on the defined research questions. Synonyms, alternative spelling, construction of sophisticated search strings using the Boolean operators AND, OR are identified. An approach described in the methodology of Kitchenham and Charters (2007) is applied, where individual facets of the research questions are considered:

- Population: customer relationship management, CRM, customer relationship, client relationship, user relationship, CRM system;
- Intervention: semantic technology, semantic web, ontology, XML, eXtensible Markup Language, RDF, Resource Description Framework, RDFS, RDF Schema, OWL, Web Ontology Language, SPARQL, SPARQL Protocol and RDF Query Language, SWRL, Semantic Web Rule Language, linked data, triplet, triplestore, knowledge graph;

- Comparison: relational database, Structured Query Language, SQL, non-relational database, NoSQL, data mining, knowledge discovery, data analytics, data analysis, data analyst, data science, data scientists;
- Outcomes: target profitable customers, integrated offerings, improved pricing, customized products and services, improved customer services, individualized marketing messages, brand development, customer identification, target customer analysis, customer segmentation, customer attraction, direct marketing, customer retention, one-to-one marketing, loyalty programs, complaints management, customer development, customer lifetime value, upselling/cross-selling, market basket analysis.

Search strings are constructed by concatenating the keywords from one list of each facet with the Boolean OR operator, then concatenating the resulting expressions with the Boolean AND operator.

The defined inclusion and exclusion criteria are applied to the initially found publications. In addition, after the initial selection, the reference lists of the selected publications are reviewed. Besides, publication lists of authors found on their web pages, academic social network profiles (such as ResearchGate, Academia.edu, Mendeley, Google Scholar) are explored.

3.3. Inclusion and exclusion criteria

For the selection of the literature sources, the following criteria are defined for inclusion in the current SLR review:

- Publications relating to the application of Semantic web technologies;
- Publications where the issues addressed and applied Semantic web technologies refer to customer relationship management;
- Publications that represent articles in scientific journals, reports at scientific conferences, the full text of which is written in English, since scientists and practitioners most often use such publications to obtain information and disseminate new discoveries.

The exclusion of literature sources from this review is based on the following exclusion criteria:

- Reviews or surveys of research on applying Semantic web technologies to support customer relationship management;
- Duplicate publications of the same study. In such cases, only the fuller version of the study is included in the review;

- Publications that are not conference papers or journal articles (such as books, textbooks, book chapters, editorial notes, theses, dissertations) or whose full text is not written in English.

3.4. Quality assessment

The publications found after the keyword search are 201. Then, the defined inclusion and exclusion criteria are applied, as well as an additional study of the literature sources of the selected publications and lists of authors' publications is performed. A further 11 are discovered as a result of these activities. A final set of 44 publications is obtained, on the basis of which the conclusions set out in Section 4 are summarized.

The publication search process undertaken for the purposes of this review is summarized in Figure 1 using a PRISMA Flow diagram (Moher et al., 2009).

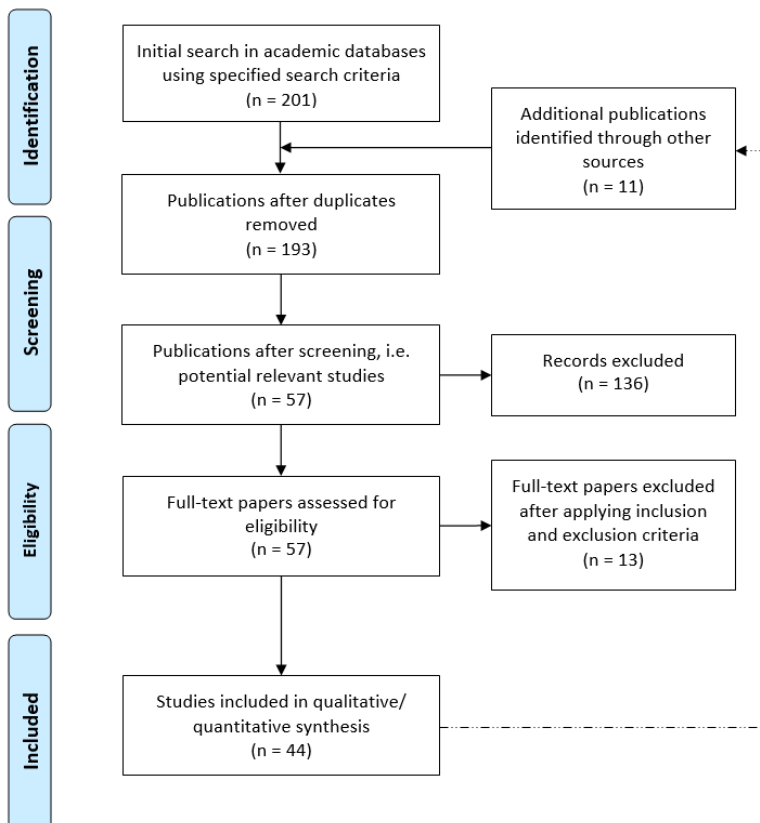


Fig. 1 PRISMA Flow diagram of the publication search process for the current SLR

The authors created the figures 1-6 and tables 1-4, according to the data collected in our study.

3.5. Data collection

The data extracted from each publication are:

- Bibliographic description – authors, title, journal or conference, year of publication, as well as annotation, keywords, conclusion;
- Main thematic scope;
- Applied or discussed semantic web technologies;
- CRM benefits that are targeted by applying Semantic web technologies;
- Ontologies created or used;
- Directions for future research work.

3.6. Data analysis

Data are represented in tabular, graphical or tabular form to reflect the following summary information:

- Diagram of the number of publications by year (fig. 2);
- Diagram of the number of publications on the most frequently applied Semantic web technologies (fig. 3);
- Table of the ontologies created and used in the studies under consideration, their purpose, as well as the Semantic web technologies applied to them (table 2);
- Table of the number of publications on Semantic web technologies (table 3);
- Table of the number of publications by addressed CRM benefits (table 4) and charts of the number of applied Semantic web technologies for the three most popular benefits (figs. 4, 5, 6).

4. Results and discussion

As a result of our search, exploration, application of the defined inclusion and exclusion criteria, 44 publications are found and selected for the present review, whose research problems concern the application of Semantic web technologies to support CRM. In the following subsections, the obtained results are represented and discussed in accordance with the research questions formulated in subsection 3.1.

4.1. Distribution of publications by year

Research papers published between 2002 and 2022 are included in this SLR review. The beginning of the period can be explained by the exposition of the idea of Semantic Web in 2001 (Lassila & Hendler, 2001), gaining popularity of Semantic web technologies caused by the fact that RDF and OWL obtain the status of W3C Recommendation in 2004, the first edition of OWL 2 – in 2009, the second edition – 2012, SPARQL 1.0 – 2008, SPARQL 1.1 – 2013.

The process of searching for publications and collecting data from them for the purposes of the represented review are carried out until the end of 2022. For this reason, studies published later are not considered.

The distribution of publications by year is shown in Figure 3.

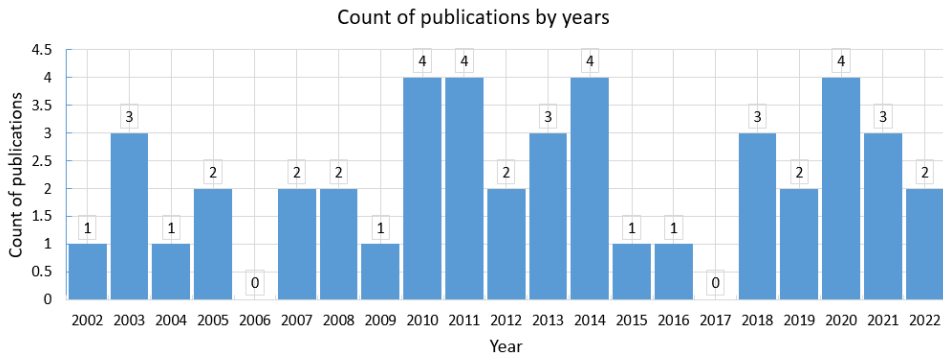


Fig. 2 Distribution of publications by year

From the distribution of publications by year, it can be concluded that the development of semantic web technologies leads to the maintenance of research interest in their application to support customer relationship management.

4.2. Applied Semantic web technologies to support customer relationship management

Figure 3 illustrates a summary of the number of publications included in this systematic literature review that apply the Semantic web technologies XML, RDF/RDFS, OWL, SPARQL, Linked data, SWRL, mentioned in section 1.2.

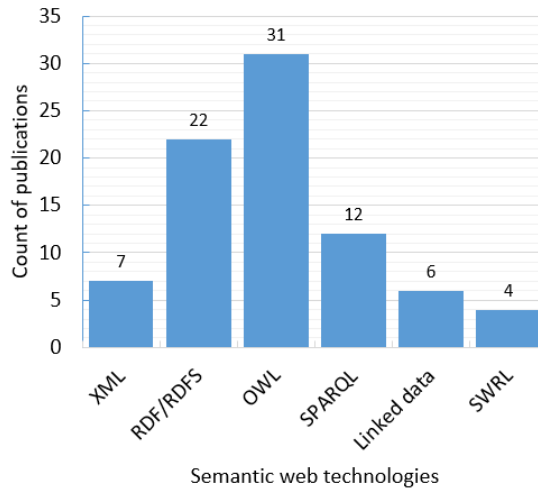


Fig. 3 Number of publications by applied Semantic web technologies

In addition, after exploring the selected publications, it is established that the following Semantic web technologies are used in them:

- WSDL (W3C, 2007);

The Web Services Description Language (WSDL) provides a model and XML format for describing Web services.

- SAWSDL (W3C, 2007b);

Semantic Annotations for Web Services Description Language (SAWSDL) is a standard for adding semantics to web service descriptions. The specification defines how to define semantic annotations by referencing semantic models such as ontologies.

- SHACL (W3C, 2017);

Shapes Constraint Language (SHACL) is a language for validating RDF graphs against a set of conditions that are also represented by RDF graphs. SHACL graphs can be considered as descriptions of data that satisfy the conditions specified in them. Therefore, SHACL descriptions can be used for purposes other than validation, including user interface construction, code generation, and data integration.

- SeRQL (Broekstra and Kampman, 2003).

Sesame RDF Query Language (SeRQL) is an RDF/RDFS query language developed as part of Sesame (now RDF4J). Unlike SPARQL, it does not have W3C submission or W3C recommendation status.

The use of XML, RDF/RDFS, OWL is related to building ontologies and knowledge bases for various purposes. Table 2 provides a

summary of the ontologies created and used in the reviewed studies. The purpose of the ontology in the research is indicated, as well as the applied Semantic web technologies both for creating the ontology and for extracting data from it, reasoning.

Table 2. Ontologies for the purposes of the studies under consideration

Ontologies	Publications	Purpose	Semantic web technologies
Customer complaint ontology	(Jarrar et al., 2003)	The created ontology aims to supporting the management of customer complaints.	XML, RDF
Customer Emotion Ontology	(García-Crespo et al., 2010)	An ontology that enables the classification of customer emotions is built, as well as an ontology that models the different aspects related to CRM. They are applied for the purposes of an approach that is based on extracting features from social networks and connecting them with user emotions in order to increase customer satisfaction.	OWL
Ontology for Customer eXperience	(Rehman Laghari et al., 2010)	An ontological model for customer experience is introduced. The goal is to provide an understanding of how the customer experience enhances the service provision.	SAWSDL
Ontology for Customer Knowledge Management	(Yan and Zha, 2010)	Ontology building is applied in the implementation of CKM (<i>Customer Knowledge Management</i>) strategy to enable automatic understanding and processing customer knowledge.	OWL
Customer preference ontology	(Cao et al., 2011)	The ontology is used for retrieving information when responding to requests according to customer requirements. Ontology-based retrieval is compared with traditional keyword retrieval.	XML, RDF/RDFS, OWL
Ontology for modeling user behaviour	(Razmerita, 2011)	It is used in the context of a knowledge management system (KMS) to support user activities based on their activity in the system and to provide personalized user support in the KMS.	RDF/RDFS
Customer demand ontology	(Wang and Zhou, 2014)	An ontology mapping between the customer demand ontology and the product configuration ontology is implemented to provide a scientific basis for pricing.	OWL

Ontology for opinion mining	(Alfrjani et al., 2016)	It is used to perform various information extraction tasks in order to improve products and services.	RDF/RDFS, OWL, SPARQL, Linked data
ONTARIS ontology (Ontology of Innovative Products and Services' Consumer Knowledge)	(Kudryavtsev et al., 2020)	ONTARIS ontology supports the design of innovative products and services; the design of a system of interaction between a company and a user.	RDF/RDFS, OWL
Ontology of products and/or services	(Baida et al., 2005)	An e-services ontology is applied to unify elementary e-services into bundles of e-services satisfying customer needs.	RDF/RDFS
	(Frasincar et al., 2009)	News ontology is used for personalized news services.	OWL, SPARQL
	(Pagoropoulos et al., 2014)	PSS (Product/Service-Systems) ontology provides a systematic collection of knowledge in the relevant field and facilitates the implementation of integrated solutions.	OWL
	(Chatwin and Sam, 2013)	Electronic Products Ontology is applied to extract semantic content based on user queries by analyzing user reviews of products.	OWL
	(Yılmaz and Alptekin, 2013)	An ontology of mobile operating systems is used for precise user segmentation to support vendors in offering a suitable product to the customer.	RDF, OWL
	(Ruijgrok et al., 2018)	An ontology for representing product assortments in web stores is implemented to facilitate users in finding their desired products.	OWL
Ontology GoodRelations for Describing Products and Services Offers	(Hepp, 2008)	The GoodRelations ontology allows describing the relationship between web resources; offerings made through these web resources; legal entities; prices; conditions. It is intended for the purposes of e-commerce in the commodity segment.	RDF/RDFS, OWL, SPARQL
Ontology of tourism offers /tourist knowledge	(Picot-Clémente et al., 2010)	This ontology supports dynamic adaptation of the offerings to customers.	OWL, SWRL, Linked data

	(Pai et al., 2019)	An ontology is applied to recommend tourist knowledge in order to assist making the appropriate travel decision.	OWL
Ontology, which models the possible product compositions	(Ardito et al., 2011)	It models the possible product compositions that users can perform to support creating products that best meet their desires.	RDF, SeRQL
Product Configuration Ontology	(Haav and Maigre, 2018)	This ontology enables the construction of distributed product configurators that use semantic configuration models and validation of integrity constraints of individual configurations.	RDF, OWL, SPARQL, SHACL
Product Review Ontology	(Ali et al., 2020)	The analysis of online customer feedback is applied to identify key product attributes to be used in the product conceptual design phase.	RDF/RDFS, OWL, SPARQL
Online retail ontology	(Alaa et al., 2021)	It is applied to a recommendation method where ontological reasoning is performed.	OWL
e-Business Model Ontology	(Osterwalder and Pigneur, 2002)	The ontology is designed to the development of various useful tools for e-business management and requirements clarification.	XML
Ontology for Collaborative B2B Relationships	(Caliusco et al., 2004)	It supports the management of collaborative B2B relationships between trading partners.	XML, RDF/RDFS, OWL
Business Process Customization Ontology	(Liang et al., 2011)	This ontology is applied to customize service-based business processes using existing knowledge about web services and business processes.	RDF/RDFS, OWL, SWRL
Ontology of Brand Message	(Zailskaitė-Jakštė and Damaševičius, 2014)	The ontology describes the relationships between content variables (tone, theme, visual and audio aids, keywords, manner, promotion, addressing, URL) and publication features (channels, target users, timing, frequency, and message length). The aim is to provide an opportunity to understand and evaluate the features of the brand message published on social media.	OWL
PaaS (Platform-as-a-Service) ontology	(Bassiliades et al., 2018)	It is used to semantically annotate PaaS offering capabilities; requirements of the applications to be deployed. Through semantic matching and	RDF/RDFS, OWL, SPARQL, Linked data

		ranking, the best matching PaaS offering can be recommended to the application developer.	
Business Model Ontology	(Di Martino et al., 2021)	This ontology is used for representation of a business model. It allows definition of deductive rules for knowledge extraction and automatic ontology completion.	OWL, SWRL
SoNBO (Social Network of Business Objects) Ontology	(Blankenberg et al., 2022)	SoNBO is applied to the integration of information from multiple business information systems using a user-specific Enterprise Knowledge Graph, which represents a unique and valuable access to information that is dispersed in heterogeneous information systems (ERP/CRM) of the company.	RDF
CRM Ontology	(Gottgroy and Gottgroy, 2003)	CRM ontology supports managers in their activities to formally define customer segments, channels, etc. It contributes to communicative, comparable, analyzable and easily modifiable customer relationships.	XML
	(Osterwalder and Pigneur, 2003)	CRM ontology supports managers to optimize channels, improve customer acquisition and retention, sales, especially in the context of e-business.	XML
	(Lee et al., 2007)	CRM ontology describes the knowledge for planning CRM projects based on Capability Maturity Model Integration (CMMI).	RDF/RDFS, OWL
	(Damme et al., 2007)	It improves the process of creating knowledge about the customer in order to overcome the problem of unsatisfactory results when searching for customer information in CRM systems.	RDF/RDFS
	(Goy et al., 2008)	It is used in building web-based repositories of software solutions aimed at using web services and the Semantic web to support small and medium-sized enterprises. Reasoning techniques are applied to find possible matches between business requirements and software solutions.	OWL, WSDL
	(Magro and Goy, 2012)	O-CREAM-v2 ontology can find application in web-based repositories supporting the mediation of the supply and demand of CRM-related tools.	OWL

	(Tiryaki and Atalay, 2020)	CRM ontology enables automatic semantic interpretations of data received from various sources (such as sales process, service and call centre).	OWL, SPARQL, SWRL
	(Fernández-Cejas et al., 2022)	CRM ontology supports managers and information systems' specialists in the development and maintenance of applications.	OWL

The built ontologies can be classified as customer-oriented (preferences, opinions, behavior, etc.); product/service oriented (features, offers, configuration, reviews, etc.); orientation to business objects and processes. In Table 2, the three groups are marked with bold lines.

Table 3 contains a summary of the applied Semantic web technologies in the considered publications.

Table 3. Number of publications by Semantic web technologies

Semantic web technologies	Count of publications	Publications
XML	7	(Osterwalder and Pigneur, 2002), (Gottgtroy and Gottgtroy, 2003), (Jarrar et al., 2003), (Osterwalder and Pigneur, 2003), (Caliusco et al., 2004), (Smirnov et al., 2005), (Cao et al., 2011)
RDF/RDFS	22	(Jarrar et al., 2003), (Caliusco et al., 2004), (Baida et al., 2005), (Damme et al., 2007), (Lee et al., 2007), (Hepp, 2008), (Cao et al., 2011), (Ardito et al., 2011), (Liang et al., 2011), (Razmerita, 2011), (Wu, 2012), (Yilmaz and Alptekin, 2013), (Hladky and Maltseva, 2013), (Hladky et al., 2014), (Thakor and Sasi, 2015), (Alfrjani et al., 2016), (Bassiliades et al., 2018), (Haav and Maigre, 2018), (Kudryavtsev et al., 2020), (Ali et al., 2020), (Fensel et al., 2020), (Blankenberg et al., 2022)
OWL	31	(Caliusco et al., 2004), (Lee et al., 2007), (Goy et al., 2008), (Hepp, 2008), (Frasincar et al., 2009), (García-Crespo et al., 2010), (Yan and Zha, 2010), (Picot-Clémente et al., 2010), (Cao et al., 2011), (Liang et al., 2011), (Magro and Goy,

		2012), (Chatwin and Sam, 2013), (Yılmaz and Alptekin, 2013), (Hladky and Maltseva, 2013), (Wang and Zhou, 2014), (Zailskaitė-Jakštė and Damaševičius, 2014), (Hladky et al., 2014), (Pagoropoulos et al., 2014), (Thakor and Sasi, 2015), (Alfrjani et al., 2016), (Bassiliades et al., 2018), (Ruijgrok et al., 2018), (Haav and Maigre, 2018), (Deepak and Kasaraneni, 2019), (Pai et al., 2019), (Kudryavtsev et al., 2020), (Tiryaki and Atalay, 2020), (Ali et al., 2020), (Alaa et al., 2021), (Di Martino et al., 2021), (Fernández-Cejas et al., 2022)
SPARQL	12	(Hepp, 2008), (Frasincar et al., 2009), (Wu, 2012), (Hladky and Maltseva, 2013), (Hladky et al., 2014), (Thakor and Sasi, 2015), (Alfrjani et al., 2016), (Bassiliades et al., 2018), (Haav and Maigre, 2018), (Tiryaki and Atalay, 2020), (Ali et al., 2020), (Fensel et al., 2020)
Linked data	6	(Picot-Clémente et al., 2010), (Hladky et al., 2014), (Alfrjani et al., 2016), (Bassiliades et al., 2018), (Fensel et al., 2020)
SWRL	4	(Picot-Clémente et al., 2010), (Liang et al., 2011), (Tiryaki and Atalay, 2020), (Di Martino et al., 2021)
WSDL	1	(Goy et al., 2008)
SAWSDL	1	(Rehman Laghari et al., 2010)
SHACL	1	(Haav and Maigre, 2018)
SeRQL	1	(Ardito et al., 2011)

From the data represented in Figure 3, Tables 2 and 3, it stands out that the main application of Semantic web technologies to support CRM consists in building appropriate ontologies. SPARQL queries, Linked data, SWRL are mainly used to browse and extract data from them.

4.3. Benefits for customer relationship management

Table 4 summarizes the data on the number of publications by addressed CRM benefits.

Table 4. Number of publications by CRM benefits addressed

Benefits for CRM	Count of publications	Publications
Customized products and services	11	(Smirnov et al., 2005), (Frasincar et al., 2009), (Picot-Clémente et al., 2010), (Razmerita, 2011), (Ardito et al., 2011), (Cao et al., 2011), (Chatwin and Sam, 2013), (Deepak and Kasaraneni, 2019), (Haav and Maigre, 2018), (Pai et al., 2019), (Alaa et al., 2021)
Integrated offerings across channels	5	(Baida et al., 2005), (Hepp, 2008), (Pagoropoulos et al., 2014), (Bassiliades et al., 2018), (Fensel et al., 2020)
Improved ability to target profitable customers	1	(Di Martino et al., 2021)
Individualized marketing messages	1	(Zaïlskaitė-Jakštė and Damaševičius, 2014)
Improved pricing	1	(Wang and Zhou, 2014)
Improved sales force efficiency and effectiveness	1	(Hladky et al., 2014)
Improved products and services	2	(Alfrjani et al., 2016), (Ali et al., 2020)

Innovative products and services	1	(Kudryavtsev et al., 2020)
Customer complaint management	2	(Jarrar et al., 2003), (Thakor and Sasi, 2015)
Customer segmentation	1	(Yılmaz and Alptekin, 2013)
Supporting users of CRM systems	11	(Osterwalder and Pigneur, 2002), (Gottgtroy and Gottgtroy, 2003), (Osterwalder and Pigneur, 2003), (Caliusco et al., 2004), (Damme et al., 2007), (Yan and Zha, 2010), (García-Crespo et al., 2010), (Wu, 2012), (Tiryaki and Atalay, 2020), (Blankenberg et al., 2022), (Fernández-Cejas et al., 2022)
Supporting CRM projects	1	(Lee et al., 2007)
Integration of information in a CRM system	2	(Hladky and Maltseva, 2013), (Tiryaki and Atalay, 2020)
Description of business processes	2	(Goy et al., 2008), (Magro and Goy, 2012)
Personalization of business processes	1	(Liang et al., 2011)
Social branding	1	(Zailskaitė-Jakštė and Damaševičius, 2014)

From the data represented in Table 4, it can be concluded that each of the listed CRM benefits B1-B8 is addressed in at least one study selected for the systematic literature review.

Furthermore, as a result of the detailed consideration of the publications included in this study, the following addressed benefits for CRM are identified in addition to those listed in section 1.3:

B1. Improved products and services;

Customer feedback allows companies to understand the strengths and limitations of their products and services and improve them. Such valuable information is contained in the opinions expressed by those customers who have purchased the products/services and expressed their experience in the form of text reviews. Opinion mining (Alfrjani et al., 2016) aims to automatically analyze opinions expressed as free text and can be assisted by appropriate representation of user opinions using Semantic web technologies. Improving products and services is beneficial in both attracting and retaining customers.

Ali et al. (2020) outline the analysis of online customer feedback to identify key product attributes in order to use them in the product conceptual design phase. The analysis can be applied to determine critical customer needs and preferences to improve the design of new versions of a product.

B2. Innovative products and services;

In (Kudryavtsev et al., 2020), the creation of an ontology of user knowledge for innovative products and services is proposed. Its main aim is to support the design of innovative products and services; the facilitation of research activities and the integration of research data.

B3. Customer complaint management;

In (Jarrar et al., 2003), an ontology-based approach for managing and maintaining multilingual online customer complaints is described. For this purpose, an ontology is built, which allows representing the basic knowledge about the domain of customer complaints; it provides extensibility of the complaint platform.

Thakor and Sasi (2015) focus on building an ontology model to identify the departments or sections of the office that have problem areas related to customer dissatisfaction in postal services. For this purpose, shared content on social media is analysed.

B4. Supporting CRM projects;

In (Lee et al., 2007), a CRM ontology is proposed that describes knowledge for planning CRM projects on the basis of CMMI (Capability

Maturity Model Integration). The proposed ontology can be applied to build a CRM system based on CMMI project planning for business applications.

B5. Description and personalization of business processes;

In (Magro and Goy, 2012), CRM ontology O-CREAM-v2 (updated and extended version of O-CREAM – Ontology for Customer Relationship Management) is proposed for describing CRM processes and for specifying the functionality of CRM applications. In addition, the use of OWL-based ontologies allows ARNEIS (Advanced Repository for Needs of Enterprises and Innovative Software) (Goy et al., 2008) to apply reasoning techniques to find possible matches between business requirements and software solutions.

Liang et al. (2011) represent a conceptualization of service-based business process customization according to the inconsistencies found in their business process description documents. For this purpose, OWL-BPC (Business Process Customization) ontology is proposed and reasoning is applied.

B6. Supporting users of CRM systems;

Supporting collaborative B2B relationships (Calusco et al., 2004) is achieved by analyzing the integration of XML-based standards with an ontology to describe the meaning of information and knowledge exchanged between trading partners for the joint execution of business processes.

Marketing and new product development in co-creative environments (García-Crespo et al., 2010) is based on extracting knowledge from social networks through user emotion analysis methods in order to implement appropriate CRM strategy to maximize customer satisfaction.

The Customer Relationship Ontology (Gottgroy and Gottgroy, 2003), (Osterwalder and Pigneur, 2002), (Osterwalder and Pigneur, 2003) is defined in order to support managers. In (Damme et al., 2007), an integrated visual approach is proposed, where users themselves can participate in the process of creating an ontology of the CRM domain.

Yan and Zha (2010) analyze the necessity to build an ontology when implementing a CKM (Customer Knowledge Management) strategy.

Wu (2012) proposes a decision automation platform for CRM system based on AllegroGraph triple repository.

B7. Integration of information in a CRM system;

In (Hladky and Maltseva, 2013), the integration of information needed for the purposes of the CRM process using linked data is proposed.

Tiryaki and Atalay (2020) describe an ontological approach that enables automatic semantic interpretations of data obtained from different sources (such as sales process, service and call centre). Based on the

proposed approach, a tool is developed that can combine data from different CRM systems in a common format and make customer-oriented interpretations of these data.

B8. Customer segmentation (Yılmaz and Alptekin, 2013).

Among the most popular addressed benefits by applying Semantic web technologies are customized products and services; supporting users of CRM systems; integrated offerings across channels. Figures 4-6 illustrate the number of publications that examine them by applied Semantic web technologies.

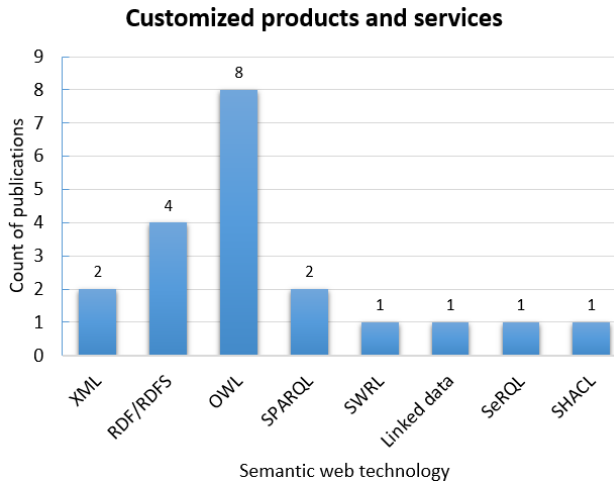


Fig. 4 Number of publications that apply Semantic web technologies to achieve customized products and services

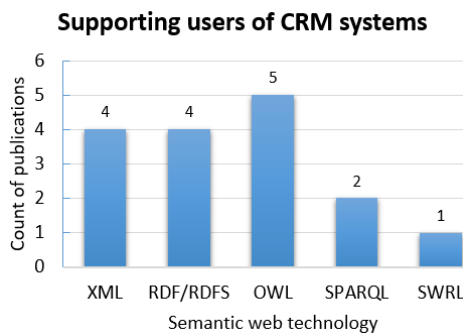


Fig. 5 Number of publications that apply semantic web technologies in order to supporting users of CRM systems

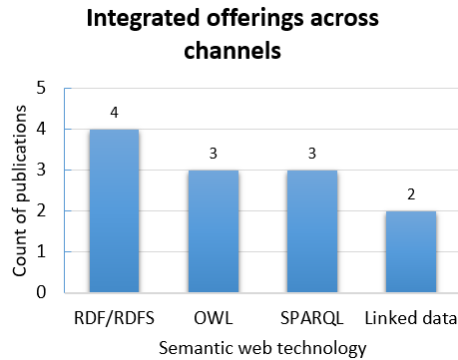


Fig. 6 Number of publications that apply semantic web technologies to achieve integrated offerings across channels

From Figures 4-6, it is observed that RDF/RDFS, OWL are the most applied Semantic web technologies for the three research objectives related to supporting CRM.

4.4. Trends in the application of Semantic web technologies to support CRM

From the aggregated data resulting from studying the publications examined in the present systematic review, the following trends are noticeable:

- Expanding the scope of the addressed CRM benefits;
Researchers are identifying new CRM benefits that can be achieved through the application of appropriate Semantic web technologies.

- Expanding the scope of applied Semantic web technologies.
Research interest is directed towards various relevant Semantic web technologies. The development of the Semantic web technologies themselves, as well as the tools for their usage and application, contribute significantly to this trend.

In addition to the most popular addressed CRM benefits, the following ones stand out as current (i.e. examined in recent studies): improved / innovative products and services, integration of information in a CRM system.

Possible perspectives for future research are aimed at the complex application of Semantic web technologies in order to achieve more comprehensive CRM solutions.

5. Conclusion

As a result of the systematic literature review, the following conclusions can be summarized regarding the current state of research concerning the application of Semantic web technologies to support CRM:

- The advantages of using Semantic web technologies to support CRM are researched and practically confirmed;
- Semantic models (including ontologies) for descriptions related to customers, products/services, business objects and processes are defined;
- Datasets are created in accordance with the defined semantic models;
- Approaches are applied to extract data from the created datasets by applying Semantic web technologies for queries, rules for reasoning, including in combination with data mining algorithms;
- Opportunities to develop more comprehensive solutions that address a combination of the mentioned CRM benefits are outlined as a key direction for future research.

References

- Alaa, R., Gawish, M., & Fernández-Veiga, M. (2021). Improving recommendations for online retail markets based on ontology evolution. *Electronics*, 10(14). DOI: 10.3390/electronics10141650.
- Alfrjani, R. Osman, T., & Cosma, G. (2016). A new approach to ontology-based semantic modelling for opinion mining. In *Proceedings of the 18th International Conference on Computer Modelling and Simulation*, pp. 267-272. DOI: 10.1109/UKSim.2016.15.
- Ali, M. M., Doumbouya, M. B., Louge, T., Rai, R., & Karray, M. H. (2020). Ontology-based approach to extract product's design features from online customers' reviews. *Computers in Industry*, 116. DOI: org/10.1016/j.compind.2019.103175.
- Ardito, C., Barricelli, B. R., Buono, P., Costabile, M. F., Lanzilotti, R., Piccinno, A., & Valtolina, S. (2011). An ontology-based approach to product customization. In: *Costabile, M.F., Dittrich, Y., Fischer, G., Piccinno, A. (eds) End-User Development. IS-EUD 2011. Lecture Notes in Computer Science, 6654*. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-21530-8_9.
- Bahalul Haque, A. K. M., Arifuzzaman, B. M., Siddik, S. A. N., Kalam, A., Shahjahan, T. S., Saleena, T. S., Alam, M., Islam, R., Ahmmed, F., & Hossain, J. (2022). Semantic web in healthcare: A systematic literature review of application, Research Gap, and Future Research Avenues. *International Journal of Clinical Practice*, 2022. DOI: 10.1155/2022/6807484.

- Bahrami, M., Ghorbani, M., & Arabzad, S. M. (2012). Information Technology (IT) as an improvement tool for customer relationship management (CRM). *Procedia - Social and Behavioral Sciences*, 41, 59-64. DOI: 10.1016/j.sbspro.2012.04.008.
- Baida, Z., Gordijn, J., Sæle, H., Akkermans, H., & Morch, A. Z. (2005). An ontological approach for eliciting and understanding needs in e-Services. In: Pastor, O., Falcão e Cunha, J. (eds) *Advanced Information Systems Engineering. CAiSE. Lecture Notes in Computer Science*, 3520. Springer, Berlin, Heidelberg. DOI: 10.1007/11431855_28.
- Bashir, F. & Warraich, F. N. (2020). Systematic literature review of Semantic Web for distance learning. *Interactive Learning Environments*. DOI: 10.1080/10494820.2020.1799023.
- Bassiliades, N., Symeonidis, M., Gouvas, P., Kontopoulos, E., Meditskos, G., & Vlahavas, I. (2018). PaaSport semantic model: An ontology for a platform-as-a-service semantically interoperable marketplace. *Data & Knowledge Engineering*, 113, 81-115. DOI: 10.1016/j.datak.2017.11.001.
- Berners-Lee, T. (2000). Semantic web vision, semantic web vision. *XML2000 conference*. <https://www.w3.org/2000/Talks/1206-xml2k-tbl>.
- Blankenberg, C., Gebel-Sauer, B., & Schubert, P. (2022). Using a graph database for the ontology-based information integration of business objects from heterogenous Business Information Systems. *Procedia Computer Science*, 196, 314–323. DOI: 10.1016/j.procs.2021.12.019.
- Brabra, H., Mtibaa, A., Sliman, L., Gaaloul, W., & Gargouri, F. (2016). Semantic web technologies in cloud computing: A systematic literature review. In *Proceedings of the IEEE International Conference on Services Computing*, 744-751. DOI: 10.1109/SCC.2016.102.
- Brito, C. M. & Ramos, C. (2003). The impact of information technologies on customers relationships management. In *Proceedings of the 19th IMP Conference*, Lugano.
- Broekstra, J. & Kampman, A. (2003). SerQL: A second generation RDF query language. In *Proceedings of SWAD-Europe Workshop on Semantic Web Storage and Retrieval*, available at: <https://www.w3.org/2001/sw/Europe/events/20031113-storage/positions/aduna.pdf> (accessed 20 July 2023).
- Caliusco, M. L., Galli, M. R., & Chiotti, O. (2004). Ontology and XML-based specifications for collaborative B2B relationships. *CLEI Electronic Journal*. 7(1). DOI: 10.19153/cleiej.7.1.5.
- Cao, D., Li, Z., & Ramani, K. (2011). Ontology-based customer preference modeling for concept generation. *Advanced Engineering Informatics*. 25(2), 162-176. DOI: 10.1016/j.aei.2010.07.007.

- Chatwin, C. R. & Sam, K. M. (2013). Ontology-based sentiment analysis model of customer reviews of electronic products. *International Journal of e-Education, e-Business, e-Management and e-Learning*, 3(6), 477-482. DOI: 10.7763/IJEEEE.2013.V3.282.
- Chen, M.-C., Hsiao, Y.-H., Chang, K.-C., & Lin, M.-K. (2019). Applying big data analytics to support Kansei engineering for hotel service development. *Data Technologies and Applications*, 53(1), 33-57. DOI: org/10.1108/DTA-05-2018-0048.
- Damme, C. V., Christiaens, S., & Vandijck, E. (2007). Building an employee-driven CRM ontology. In *the Proceedings of the LADIS Multi Conference on Computer Science and Information Systems (MCCSIS): E-society*, Lisbon, Portugal, pp. 330-334.
- Del Vecchio, P., Mele, G., Siachou, E., & Schito, G. (2021). A structured literature review on Big Data for customer relationship management (CRM): toward a future agenda in international marketing. *International Marketing Review*, 39(5), 1069-1092. DOI: 10.1108/IMR-01-2021-003.
- Deepak, G. & Kasaraneni, D. (2019). OntoCommerce: an ontology focused semantic framework for personalised product recommendation for user targeted e-commerce. *International Journal of Computer Aided Engineering and Technology*, 11(4/5), 449-466. DOI: 10.1504/IJCAET.2019.10020285.
- Di Martino, B., Branco, D., Cante, L. C., Venticinque, S., Scholten, R., & Bosma, B. (2021). Semantic and knowledge based support to business model evaluation to stimulate green behaviour of electric vehicles' drivers and energy prosumers. *Journal of Ambient Intelligence and Humanized Computing*, 13, 5715-5737. DOI: 10.1007/s12652-021-03243-4.
- Estrada-Martínez, F.J., Hilera, J.R., Otón, S., & Aguado-Delgado, J. (2022). Semantic web technologies applied to software accessibility evaluation: a systematic literature review. *Universal Access in the Information Society*, 21, 145-169. DOI: 10.1007/s10209-020-00759-y.
- Fensel, A., Akbar, Z., Kärle, E., Blank, C., Pixner, P., & Gruber, A. (2020). Knowledge graphs for online marketing and sales of touristic services. *Information (Switzerland)*, 11(5). DOI: 10.3390/info11050253.
- Fernández-Cejas, M., Pérez-González, C. J., Roda-García, J. L., & Colebrook, M. (2022). CURIE: Towards an ontology and enterprise architecture of a CRM conceptual model, business & information systems engineering. *Business & Information Systems Engineering*, 64, 615-643. DOI: 10.1007/s12599-022-00744-0.
- Frasincar, F., Borsje, J., & Levering, L. (2009). A semantic web-based approach for building personalized news services. *International Journal of e-Business Research*, 5(3), 35-53. DOI: 10.4018/jebr.2009082103.

- García-Crespo, Á., Colomo-Palacios, R., Gómez-Berbís, J. M., & Paniagua-Martín, F. (2010). Customer relationship management in social and semantic web environments. *International Journal of Customer Relationship Marketing and Management*, 1(2), 1-10. DOI: 10.4018/jcrrmm.2010040101.
- García-Crespo, Á., Colomo-Palacios, R., Gómez-Berbís, J. M., & Ruiz-Mezcua, B. (2010). SEMO: A framework for customer social networks analysis based on semantics. *Journal of Information Technology*, 25(2), 178-188. DOI:10.1057/jit.2010.1.
- Georgieva-Trifonova, T. & Galabov, M. (2021). Semantic web technologies for big data modeling from analytics perspective: A systematic literature review. *Baltic Journal of Modern Computing*, 9(4), 377-402. DOI: 10.22364/bjmc.2021.9.4.01.
- Georgieva-Trifonova, T., Zdravkov, K., & Valcheva, D. (2020). Application of semantic technologies in bibliographic databases: A literature review and classification. *The Electronic Library*, 38(1), 113-137. DOI: 10.1108/EL-03-2019-0081.
- Gončarovs, P. (2017). Data analytics in CRM processes: A literature review. *Information Technology and Management Science*, 20, 103–108. DOI: 10.1515/itms-2017-0018.
- Gottgroy, M. & Gottgroy, P. (2003). Ontologies, CRM, data mining: How to integrate?. *Transactions on Information and Communications Technologies*, 29, 307-316.
- Goy, A., Magro, D., & Prato, F. (2008). ARNEIS: a web-based intelligent repository of ICT solutions for e-business. In *Proceedings of the 10th International Conference on Information Integration and Web-based Applications & Services*, pp. 403–406. DOI: 10.1145/1497308.1497381.
- Guerola-Navarro, V., Gil-Gomez, H., Oltra-Badenes, R., & Soto-Acosta, P. (2022). Customer relationship management and its impact on entrepreneurial marketing: a literature review. *International Entrepreneurship and Management Journal*. DOI: 10.1007/s11365-022-00800-x.
- Haav, H.-M. & Maigre, R. (2018). A semantic model for product configuration in timber industry. In *Proceedings of the 13th International Baltic Conference on Databases and Information Systems*, pp. 143 – 158. DOI: 10.3233/978-1-61499-941-6-143.
- Hepp, M. (2008). GoodRelations: An ontology for describing products and services offers on the web. In: *Gangemi, A., Enzenat, J. (eds) Knowledge Engineering: Practice and Patterns. EKAW 2008. Lecture Notes in Computer Science, 5268*, Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-540-87696-0_29.
- Hladky, D., Maltseva, S., Ogorodnychuk, D., Drobyazko, G., Voigt, M., & Le Grange, J.J. (2014). Return on investment in linking content to CRM by applying the linked data stack. In: *Klinov, P., Mouromtsev, D. (eds) Knowledge*

- Engineering and the Semantic Web*. KESW 2014. Communications in Computer and Information Science, 468. Springer, Cham. DOI: 10.1007/978-3-319-11716-4_7.
- Jarrar, M., Verlinden, R., & Meersman, R. (2003). Ontology-based customer complaint management. In: Meersman, R., Tari, Z. (eds) On The Move to Meaningful Internet Systems 2003: OTM 2003 Workshops. OTM 2003. *Lecture Notes in Computer Science*, 2889. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-540-39962-9_63.
- Jensen, J. (2017). A systematic literature review of the use of Semantic Web technologies in formal education. *British Journal of Educational Technology*, 50(2), 505-517. DOI: 10.1111/bjet.12570.
- Hendler, J. & Lassila, O. (2001). The semantic web. *Scientific American*. 284(5), 34-43. <https://www.lassila.org/publications/2016/lassila-dickinson-semweb-lecture-2016.pdf>
- Hladky, D. & Maltseva, S.V. (2013). Linked data paradigm for enterprises: Information integration and value chain. *Business Informatics*, 2(24), 3-12.
- Khosravi, A. & Hussin, A. (2016). Using knowledge management to improve customer relationship management: A systematic literature review. *Journal of Soft Computing and Decision Support Systems*, 3(1), 36-43.
- Kitchenham, B. & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering*. Keele University and Durham University Joint Report, Tech. Rep. EBSE 2007-001.
- Kudryavtsev, D., Gavrilova, T., Smirnova, M., & Golovacheva, K. (2020). Modelling consumer knowledge: the role of ontology. *Procedia Computer Science*, 176, 500-507. DOI: 10.1016/j.procs.2020.08.052.
- Ledro, C., Nosella, A., & Vinelli, A. (2022). Artificial intelligence in customer relationship management: literature review and future research directions. *Journal of Business & Industrial Marketing*, 37(13), 48-63. DOI: 10.1108/JBIM-07-2021-0332.
- Lee, C.-S., Wang, Y.-C., Liu, W.-M., & Lin, Y.-C. (2007). CRM ontology based on CMMI project planning for business applications. In *Proceedings of the International Conference on Machine Learning and Cybernetics*, pp. 2941-2946. DOI: 10.1109/ICMLC.2007.4370651.
- Liang, Q., Wu, X., Park, E. K., Khoshgoftaar, T. M., & Chi, C.-H. (2011). Ontology-based business process customization for composite web services. in *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, 41(4), 717-729. DOI: 10.1109/TSMCA.2011.2132710.
- Magro, D. & Goy, A. (2012). A core reference ontology for the customer relationship domain. *Applied Ontology*, 7(1), 1-48. DOI: 10.3233/AO-2012-0102.

- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., & The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med*, 6(7), e1000097.
- Ngai, E.W.T., Xiu, L., & Chau, D.C.K. (2009). Application of data mining techniques in customer relationship management: A literature review and classification. *Expert Systems with Applications*, 36(20), 2592-2602, DOI: 10.1016/j.eswa.2008.02.021.
- Orenga-Roglá, S. & Chalmeta, R. (2016). Social customer relationship management: taking advantage of Web 2.0 and Big Data technologies. *SpringerPlus*, 5. DOI: 10.1186/s40064-016-3128-y.
- Osterwalder, A. & Pigneur Y. (2002). An e-Business model ontology for modeling e-Business. In *Proceedings of the 15th Bled Electronic Commerce Conference e-Reality: Constructing the e-Economy*, pp. 1-12.
- Osterwalder, A. & Pigneur Y. (2003). Modelling customer relationships in e-Business illustrated through the mobile industry. In *16th Bled Electronic Commerce Conference eTransformation*, Bled, Slovenia.
- Pagoropoulos, A., Andersen, J.A.B., Kjær, L.L., Maier, A., & McAloone, T.C. (2014). Building an ontology of product/service-systems: Using a maritime case study to elicit classifications and characteristics. In: *Camarinha-Matos, L.M., Afzarmanesh, H. (eds) Collaborative Systems for Smart Networked Environments*. PRO-VE 2014. IFIP Advances in Information and Communication Technology, 434. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-662-44745-1_11.
- Pai, M.-Y., Wang, D.-C., Hsu, T.-H., Lin, G.-Y., & Chen, C.-C. (2019). On ontology-based tourist knowledge representation and recommendation. *Applied Sciences*, 9(23). DOI: 10.3390/app9235097.
- Perera, W.K.R. & Dilini Kulawansa, K. A. (2018). A review of big data analytics for customer relationship management. In *Proceedings of the 3rd International Conference on Information Technology Research*, pp. 1-6. DOI: 10.1109/ICITR.2018.8736131.
- Picot-Clément, R., Cruz, C., & Nicolle, C. (2010). Contribution of semantic web on customer relationship management in e-Tourism. In *Proceedings of the International Symposium on Computing, Communication, and Control*, Singapore.
- Rehman Laghari, K., Ben Yahya, I.G., & Crespi, N. (2010). Towards a service delivery based on customer eXperience ontology: Shift from service to eXperience. In: *Brennan, R., Fleck, J., van der Meer, S. (eds) Modelling Autonomic Communication Environments*. Lecture Notes in Computer Science, 6473. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-16836-9_5.
- Razmerita, L. (2011). An ontology-based framework for modeling user behavior - A case study in knowledge management. *IEEE Transactions on Systems, Man,*

- and Cybernetics - Part A: Systems and Humans*, 41(4), 772-783. DOI: 10.1109/TSMCA.2011.2132712.
- Rhayem, A., Mhiri, M.B.A., & Gargouri, F. (2020). Semantic web technologies for the Internet of things: Systematic literature review. *Internet of Things*, 11. DOI: 10.1016/j.iot.2020.100206.
- Ruijgrok, P., Frasinca, F., Vandic, D., & Hogenboom, F. (2018). OntoNavShop: An ontology-based approach for web-shop navigation. *Journal of Web Engineering*, 17(3&4), 241-269.
- Sharma, S. (2020). Big data analytics for customer relationship management: A systematic review and research agenda. In: Singh, M., Gupta, P., Tyagi, V., Flusser, J., Ören, T., Valentino, G. (eds) *Advances in Computing and Data Sciences. Communications in Computer and Information Science*, 1244. Springer, Singapore. DOI: 10.1007/978-981-15-6634-9_39.
- Smirnov, A., Pashkin, M., Chilov, N., Levashova, T., Krizhanovsky, A., & Kashevnik, A. (2005). Ontology-based users and requests clustering in customer service management system. In: Gorodetsky, V., Liu, J., Skormin, V.A. (eds) *Autonomous Intelligent Systems: Agents and Data Mining*. AIS-ADM 2005. Lecture Notes in Computer Science, 3505. Springer, Berlin, Heidelberg. DOI: 10.1007/11492870_19.
- Soltani, Z. & Navimipour, N. J. (2016). Customer relationship management mechanisms: A systematic review of the state of the art literature and recommendations for future research, *Computers in Human Behavior*, 61, 667-688. DOI: 10.1016/j.chb.2016.03.008.
- Stefanov, T., Varbanova, S., Stefanova, M., & Ivanov I. (2023). CRM System as a necessary tool for managing commercial and production processes. *TEM Journal*, 12(2), 2023, 785-797. DOI: 10.18421/TEM122-23
- Techopedia. (2018). Customer Relationship Management (CRM). available at: <https://www.techopedia.com/definition/1459/customer-relationship-management-crm> (accessed 20 July 2023).
- Thakor, P. & Sasi, S. (2015). Ontology-based sentiment analysis process for social media content. *Procedia Computer Science*, 53, 199-207. DOI: 10.1016/j.procs.2015.07.295.
- Tiryaki, A. M. & Atalay, M. (2020). An ontology based approach for next generation customer relationship management systems. *International Journal of Applied Mathematics, Electronics and Computers*, 8(4). 282-288. DOI: 10.18100/ijamec.802695.
- Yan, Y. & Zha, X. (2010). Applying OWL to build ontology for customer knowledge management. *Journal of Computers*, 5(11), 1693-1699. DOI: 10.4304/jcp.5.11.1693-1699.

- Yılmaz, N. & Alptekin, G. (2013). An ontology-based data mining approach for strategic marketing Decisions. *In Proceedings of the 17th World Multi-Conference on Systemics, Cybernetics and Informatics*, pp. 1-6.
- W3C (2008). “Extensible Markup Language (XML) 1.0 (Fifth Edition)”, available at: <https://www.w3.org/TR/xml/> (accessed 20 July 2023).
- W3C (2012b). “W3C XML Schema Definition Language (XSD) 1.1 Part 1: Structures”, available at: <https://www.w3.org/TR/xmlschema11-1> (accessed 20 July 2023).
- W3C (2012). “OWL 2 Web Ontology Language”, available at: <https://www.w3.org/TR/owl2-syntax> (accessed 20 July 2023).
- W3C (2013). “SPARQL 1.1 Query Language”, available at: <https://www.w3.org/TR/sparql11-query> (accessed 20 July 2023).
- W3C (2014). “RDF 1.1 Concepts and Abstract Syntax”, available at: <https://www.w3.org/TR/rdf11-concepts> (accessed 20 July 2023).
- W3C (2014b). “RDF Schema 1.1”, available at: <https://www.w3.org/TR/rdf-schema> (accessed 20 July 2023).
- W3C (2004). “SWRL: A Semantic Web Rule Language”, available at: <https://www.w3.org/Submission/SWRL> (accessed 20 July 2023).
- W3C (2017). “Shapes Constraint Language (SHACL)”, available at: <https://www.w3.org/TR/shacl/> (accessed 20 July 2023).
- W3C (2007). “Web Services Description Language (WSDL)”, available at: <https://www.w3.org/TR/wsdl/> (accessed 20 July 2023).
- W3C (2007b). “Semantic Annotations for WSDL and XML Schema”, available at: <https://www.w3.org/TR/sawSDL> (accessed 20 July 2023).
- Wang, J. & Zhou, C. (2014). Research on ontology building and pricing of customized product. *In Proceedings of the 11th International Conference on Service Systems and Service Management*, pp. 1-5. DOI: 10.1109/ICSSSM.2014.6943404.
- Wu, S.-C. (2012). The CRM of tomorrow with semantic technology. *In: Lukose, D., Ahmad, A.R., Suliman, A. (eds) Knowledge Technology. Communications in Computer and Information Science*, 295. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-32826-8_5.
- Zailskaitė-Jakštė, L. & Damaševičius, R. (2014). Ontology of brand messaging domain in social media communication. *In Proceedings of the European Conference on Social Media*, pp. 584-593.