A Systematic Literature Review on Ontology-driven Business Intelligence Components

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Abstract: This research undertakes a systematic literature review to explore the integration and application of ontologies within Business Intelligence (BI) components across a variety of domains. Ontologies, as formal representations of knowledge, have emerged as a key enabler in enhancing the functionality and intelligence of BI systems, particularly in the era of big data and digital transformation. The objective of this study is to analyze how ontologies are designed, implemented, and utilized to improve data integration, semantic interoperability, and system adaptability. The review draws upon data sources from Scopus, IEEE Explore, Science Direct, and Google Scholar, ensuring a rigorous and comprehensive coverage of relevant literature. Following a structured selection process based on inclusion and exclusion criteria, 27 peer-reviewed articles published between 2011 and 2024 were identified as meeting the quality and relevance standards for this study. The selected studies reveal that ontology-driven BI components offer several advantages, including the unification of heterogeneous data sources, improved semantic clarity, and enhanced reasoning capabilities for decision support. Moreover, ontologies contribute significantly to the flexibility and scalability of BI systems, facilitating the development of context-aware and domain-specific analytical tools. Despite these advantages, the review also highlights persistent challenges, such as difficulties in managing large-scale ontologies, real-time processing limitations, and organizational resistance to adoption due to complexity and integration costs. By synthesizing the existing body of knowledge, this review not only consolidates the current understanding of ontology-driven BI but also provides a conceptual framework for future research. It emphasizes the need for innovative approaches that address identified limitations and align ontology development with dynamic organizational requirements. The findings serve as a valuable resource for both researchers and practitioners, offering strategic insights into the design and deployment of advanced BI solutions. Ultimately, this study contributes to the evolving discourse on intelligent decision-making systems by bridging theoretical perspectives with real-world applications.

Keywords: Business intelligence components, Ontology integration, Ontology-based BI, Ontology-driven BI, Organizational knowledge management

1. Introduction

The creation of actionable knowledge to support business decision-making and strategic development is no longer an unattainable goal, particularly when considering the significant advancements in technology over the past two decades (De Oliveira and Rodrigues, 2021).

In the era of big data and digital transformation, organizations are increasingly relying on Business Intelligence (BI) systems to support data-driven decision-making. Traditional BI systems, however, often struggle with semantic heterogeneity, data integration challenges, and a lack of contextual understanding, especially when dealing with diverse, distributed, and unstructured data sources (Matar, Al-Jaber, & Matar, 2024). Nonetheless, traditional BI frameworks often face challenges in seamlessly integrating, analyzing, and interpreting diverse data sources, which restricts their flexibility and scalability. To overcome these obstacles, ontology-driven solutions have emerged as a promising approach, offering a semantic foundation that improves data integration, enhances contextual understanding, and supports advanced reasoning capabilities in BI systems (Moussas, Hafiane, & Achaba, 2024). To address these challenges, ontology-driven approaches have emerged as a promising paradigm, enabling the formal representation of domain knowledge and facilitating semantic interoperability across heterogeneous systems (Zhuoxun Zheng et al., 2022). Ontologies provide a shared vocabulary and structure for conceptualizing and integrating data, thereby enhancing the adaptability, reusability, and reasoning capabilities of BI frameworks. This has led to growing academic and industrial interest in the integration of ontologies with BI platforms, particularly within contexts such as healthcare, finance, manufacturing, and smart cities (Hussain, Al-Turjman and Sah, 2021).

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Despite the potential benefits, the adoption of ontology-driven BI components remains fragmented, with varying methodologies, tools, and frameworks reported in the literature. Additionally, while some studies have examined the role of ontologies in knowledge representation and semantic reasoning, few have systematically explored how ontology-driven BI systems contribute to knowledge sharing, reuse, and organizational learning. A systematic synthesis of existing research is critical to identify trends, evaluate technological advancements, and uncover gaps in the current body of knowledge. Previous studies have explored aspects of ontology-driven BI in isolation, such as data warehousing or semantic querying (Taelman, R et al., 2018), but a comprehensive review of the components, domains, and technologies underpinning ontology-driven BI is lacking.

Given the growing but fragmented body of research on ontology-driven approaches in Business Intelligence, a comprehensive synthesis is essential to consolidate current knowledge and guide future developments in the field. While previous studies have provided valuable insights into specific components—such as ontology modeling, semantic querying, and data warehousing—these efforts have remained largely domain-specific and disconnected. As a result, there is still no unified understanding of how ontology-driven BI systems are conceptualized, implemented, and applied across diverse organizational contexts. This fragmentation not only limits cumulative knowledge but also obscures the methodological and technological evolution of ontology-driven BI research. Therefore, a systematic and integrative review is required to bring coherence to the field by mapping existing findings, clarifying interrelationships among BI components, and identifying emerging patterns. Addressing this gap justifies the adoption of a Systematic Literature Review (SLR) approach, which offers a rigorous and transparent framework to evaluate the state of the art, synthesize theoretical and empirical contributions, and propose future research directions.

To address this gap, this study conducts a Systematic Literature Review (SLR) following the methodology proposed by Kitchenham et al. (2009). Review explicitly focused on ontology-driven Business Intelligence (BI) components, understood as BI elements whose design, integration, and analytical capabilities are guided by ontological models. Specifically, the study examines the evolution of research on ontology-driven BI components, the approaches and technologies employed in their design and implementation, the domains in which such components have been applied, and the evidence reported regarding their benefits, limitations, and operational characteristics. Together, these analytical dimensions define the scope of the review and provide a structured basis for synthesizing current knowledge on ontology-driven BI components and their interrelationships.The remainder of this paper is organized as follows: Section 2 outlines the research methodology employed for the systematic review. Section 3 presents the descriptive and thematic analysis of the reviewed studies. Section 4 discusses the main findings, emerging trends, and research challenges. Finally, Section 5 concludes the paper with recommendations for future work.

2. Literature Review

2.1 Ontologies and Semantic Technologies in Business Intelligence

Following the identification and screening phases of the SLR protocol, the reviewed studies consistently highlight the growing role of digital technologies in enhancing knowledge accessibility and usability within organizational contexts (Padeli, Pangil, & Kadir, 2025). Within Business Intelligence (BI), ontologies and Semantic Web Technologies (SWT) are repeatedly identified as core mechanisms for addressing semantic heterogeneity and interoperability challenges.

Studies such as Stănescu and Oprea (2025) demonstrate that ontologies enable formalized knowledge representation across disciplines, thereby supporting semantic integration and improved decision-making. At a foundational level, semantic standards such as RDF and OWL provide the representational infrastructure that underpins ontology-driven analytical processes. These findings establish ontologies as a recurring conceptual construct across the corpus of selected studies.

2.2 Taxonomy of Ontology-based and Ontology-driven BI Approaches

As recommended by Kitchenham's guidelines for SLRs, the included studies were subjected to a conceptual classification process to reduce heterogeneity and support analytical synthesis. This classification reveals a clear distinction between ontology-based and ontology-driven BI approaches.

Ontology-based BI studies typically employ ontologies as auxiliary semantic layers to support specific functions such as annotation, querying, or data integration, while retaining conventional BI architectures. In contrast, ontology-driven BI studies position ontologies as central design artifacts that guide data modeling, integration, reasoning, and analytical workflows.

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Comparative studies (Pérez-Rey et al., 2022; Fensel et al., 2020) illustrate this distinction and confirm that, although hybrid solutions exist, ontology-driven approaches represent a more transformative paradigm. Consistent with the objectives and research questions of this review, only studies explicitly adopting an ontology-driven perspective were retained for in-depth synthesis.

2.3 Synthesis of Ontology-driven BI Components: Approaches, Technologies, and Tools

In line with the data extraction and synthesis phases of the SLR, ontology-driven BI studies were further categorized according to the types of components, approaches, and technologies they propose. Multiple studies emphasize the role of ontologies in structuring Data Warehouse (DW) processes and analytical pipelines (Antunes, Cardoso, & Barateiro, 2022; Masmoudi et al., 2024).

Ontology-driven multidimensional modeling emerges as a recurring theme. Abelló, Romero, and Zubcoff (2020) propose an ontology-driven framework for multidimensional data modeling, while Nebot and Berlanga (2021) and Kämpgen, Harth, and Stadtmüller (2020) demonstrate how RDF- and OWL-based representations enhance OLAP flexibility and expressiveness. The synthesis of these studies reveals a diverse set of design approaches and implementation technologies, but also highlights methodological fragmentation and a lack of standardized design practices across ontology-driven BI components.

2.4 Application Domains of Ontology-driven Business Intelligence

To address external validity and applicability, the reviewed studies were classified by application domain, as recommended in evidence-based review methodologies. Supply chain management (SCM) represents the most frequently investigated domain. Choi et al. (2020) identify ontologies as a central research focus in SCM, while Ahmed and Ahmed (2018) and Hasan, Shamsuddin, and Azmi (2021) demonstrate their use in semantic alignment and risk management.

Beyond SCM, ontology-driven BI frameworks have been applied sporadically in other organizational and decision-support contexts. However, the distribution of studies across domains remains uneven, limiting the generalizability of empirical findings.

2.5 Empirical Evidence, Reported Benefits, and Limitations

Following Kitchenham's recommendation to assess strength of evidence, the selected studies were analyzed with respect to reported benefits and limitations. Empirical findings suggest that ontology-driven BI components improve semantic interoperability, analytical flexibility, and decision support, particularly in heterogeneous data environments.

Ontology-based integration and matching techniques (Osman, Ben Yahia, & Diallo, 2021; Euzenat & Shvaiko, 2020; Doan, Halevy, & Ives, 2020) are frequently cited as enabling mechanisms. However, several limitations recur across studies, including ontology scalability (Gómez-Pérez, Fernández-López, & Corcho, 2021), evaluation complexity (Uschold & Gruninger, 2021), and insufficient standardization of ontology development processes (Guarino, Oberle, & Staab, 2020).

2.6 Scalability, Performance, and Usability Considerations

Performance-related aspects—particularly scalability, computational complexity, and usability—were explicitly examined during the synthesis phase due to their relevance to real-world deployment. Keet and Ławrynowicz (2021) identify reasoning complexity as a major barrier in large-scale ontologies and propose lightweight semantic models as a potential mitigation strategy.

Despite these contributions, the review reveals a notable lack of empirical evaluation of ontology-driven BI systems in large-scale or real-time environments, indicating a significant gap between conceptual development and operational validation.

2.7 Synthesis of Research Gaps and Research Questions

Although research on ontology-driven Business Intelligence (BI) has expanded considerably, several important limitations remain. The literature lacks a comprehensive synthesis of how ontology-driven BI components have been conceptualized and how they have evolved over time, leading to fragmented perspectives and underdefined conceptual boundaries. In addition, existing studies rely on heterogeneous methodological approaches, technologies, and tools, with limited consensus regarding standardization, which constrains comparability and cumulative knowledge building.

Furthermore, while numerous ontology-driven BI frameworks have been proposed, their application remains uneven across domains, and robust empirical evidence demonstrating their practical benefits and limitations is still scarce. Finally, critical issues related to scalability, performance, and usability—particularly in large-scale or real-time environments—are insufficiently examined, raising concerns about the feasibility of deploying such systems in operational contexts. Collectively, these gaps highlight the need for a systematic and structured review to clarify the evolution of ontology-driven BI components, assess prevailing design and implementation practices, and evaluate their empirical maturity and technological robustness.

3. Methodology

In this study, the systematic approach was employing to answer the research questions posited. As mentionned by Kitchenham and Charters (Budgen and Brereton, 2006), a systematic review is a structured and methodical process used to identify, evaluate, and interpret all available research relevant to a specific research question, topic or phenomenon. The procedure involves developing a review protocol, conducting a comprehensive and reproducible search, applying predefined inclusion and exclusion criteria, critically appraising the quality of selected studies, and systematically extracting and synthesizing relevant data. The process concludes with transparent reporting, ensuring rigor, reproducibility, and reliability of the findings. These steps illustrated in Figure 1 and described below.

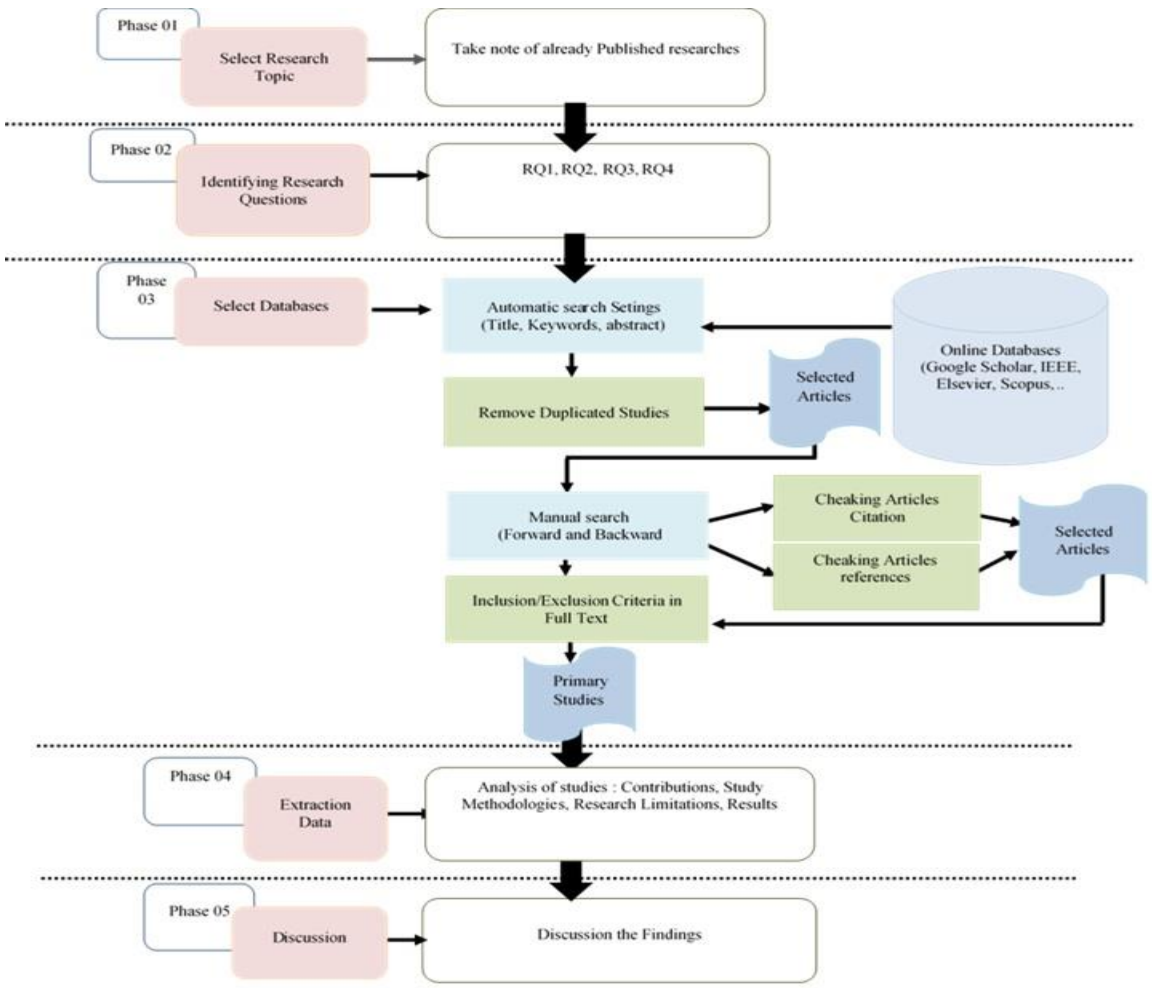

Figure1: Review Protocol

3.1 The Research Question

Based on preliminary scoping and analysis of the literature, three research gaps were identified:

Limited integration of ontology-driven BI components across organizational contexts, methodological fragmentation across prior studies, and insufficient attention to practical applications of the findings. From these gaps, the following research questions were formulated:

RQ1: How has research on ontology-driven BI components evolved over the past decade?

RQ2: What approaches, technologies, and tools have been employed to design and implement ontology-driven BI components, and how do they address standardization challenges?

RQ3: In which domains have ontology-driven BI frameworks been applied, and what empirical evidence supports their practical benefits and limitations?

RQ4: To what extent do ontology-driven BI systems achieve scalability, performance, and usability in large-scale or real-time environments?

3.2 Rearch Strategy

The research strategy followed PRISMA 2020 guidelines to ensure transparency and replicability. A comprehensive search was conducted in IEEE, IOS Press, Springer, Elsevier, ACM, Arxiv, Scopus and Google Scholar links. Search strings combined specific keywords across three clusters: ontologies (e.g., ontology, semantic web), business intelligence (e.g., business intelligence, decision support, data warehouse, OLAP, Datamining and ETL), and application terms like framework, integration, implementation) with Boolean operators to refine results. After importing results into a reference manager for duplicate removal, screening proceeded in three stages: title and abstract review, full-text eligibility assessment, and backward/forward citation tracking. . Initially, a total of 254 hits were found.

3.3 Inclusion and Exclusion Criteria

The purpose of this phase is to use a set of selection criteria to assess the relevance of each research for answering the review questions and discard those that do not meet the criteria (Denyer & Tranfield, 2009). In this research, the search was limited to articles published in English. The review covered only studies published between 2011 and 2024. With the application of these criteria, a total of 104 publications were selected out of the 239 initially identified. Afterward, the titles, abstracts, and keywords were reviewed to ensure alignment with the research question. During this process, considerable number of studies were identified that addressed ontology in isolation or business intelligence independently; however, as they did not examine the integration of both domains, they were excluded. A total of 27 publications were selected for further analysis.

The analysis and statistics of the selected papers, organized by publication year and publisher, are shown in Figure 2 and Figure 3.

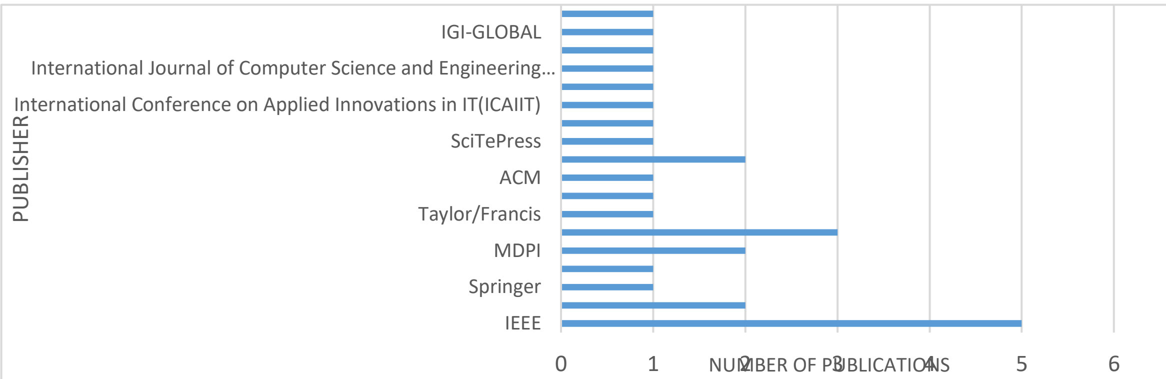

Figure 2: Selected Articles by Publisher

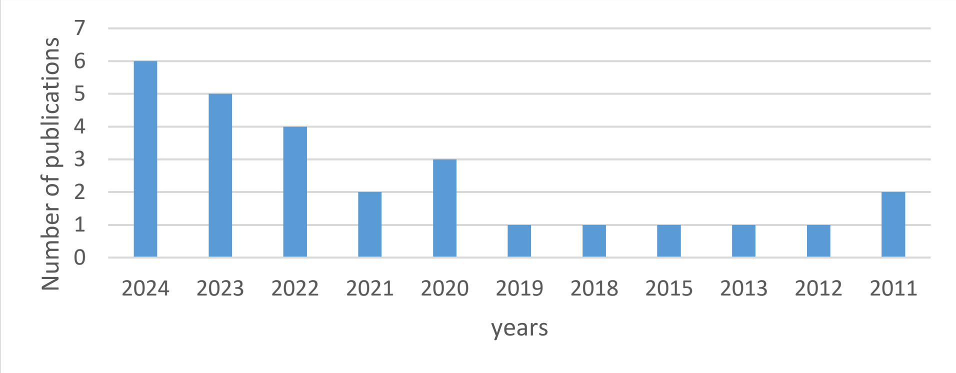

Figure 3: Selected Articles by Year

3.4 Extraction Data

To capture the current landscape of ontology-driven approaches in Business Intelligence (BI), a structured data extraction was performing. Table 1 summarizes key studies by outlining their domains, targeted BI components, ontological functions, methodologies, main contributions, and reported limitations. This synthesis reveals how ontology-based methods have been applied across diverse contexts, highlighting methodological variety, recurring challenges, and areas requiring further empirical validation and scalability testing.

Table 1: Extraction Data

Citation	Domain / Application	BI Component Targeted	Ontological Function	Methodology	Key Contributions	Reported Limitations
(Vahidnia, Minae and Behzadi, 2024)	Urban decision support (POIs)	Decision Support	Ontology for spatial reasoning	Ontology-based web DSS prototype	Improves semantic accuracy in POI recommendations	Limited to entertainment domain; scalability not tested
(Asogwa, et al. 2024)	Medical processes	Process Modeling / BI	Ontology-based representation of workflows	Intelligent process model with ontology mapping	Supports process reasoning in medical workflows	Lacks large-scale validation; domain-specific
(Antunes, 2024)	General BI systems	Data Warehouse & BI Integration	Semantic Web + Ontology alignment	Conceptual analysis and framework proposal	Highlights integration potential	Lacks empirical validation
(Bracons Cucó, et al, 2024)	Health data (DATOS-CAT)	ETL / Data Integration	Ontology-driven ETL vs traditional	Case study in CDM standardization	Improves data standardization, interoperability	Limited to CDM formats, domain constraint
(Bhattacharjee and Deb Nath, 2024)	Semantic DW	ETL Automation	Ontology-based ETL	Prototype “SETLonDEMAND”	Enables on-demand ETL for semantic DW	Needs performance evaluation

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Citation	Domain / Application	BI Component Targeted	Ontological Function	Methodology	Key Contributions	Reported Limitations
(Aishwarya , et al. 2024)	Biomedical informatics	Datamining	Ontology-based semantic reasoning	Prototype and reasoning algorithms	Enables domain-specific insights	Early-stage; limited datasets
(Robson and Baek, 2023)	Health records	Datamining, ETL , OLAP	Ontology for longitudinal data	Ontology model for EHR mining	Scales data structuring for ML	Complexity in very large-scale adoption
(A.C.B. and Mahesh, 2023)	General BI	OLAP / Datamining	Ontology for ranking/interestingness	Systematic review	Consolidates approaches in ontology-based data interestingness	Review only; lacks new framework
(Nicholson, Giusti and Martos, 2023)	Cancer registry	Datamining	Ontology + AI patterns	Ontology + design constraints in data validation	Improves accuracy in registry validation	Focused on one domain
(Ascencion Arevalo, et al. 2023)	Hydrogen market	OLAP	Ontology for energy domain	Ontology modeling (HOLY)	Supports semantic representation of hydrogen market	Narrow scope; adoption challenges
(Fahad et al. 2022)	Business Intelligence	BI Governance / Collaboration	Collaborative BI Ontology	Ontology design, arXiv report	Defines CBIOnt framework	Lacks empirical deployment
(Antunes, et al. 2022)	Education	OLAP	Ontology-based content organization	Ontology development + gamification	Supports semantic gamified learning	Limited empirical validation
(Ghelani, 2022)	BI queries	OLAP	Ontology-based NL interface	Prototype system	Natural language queries over BI	Preprint; lacks evaluation
(Dhaouadi, et al. 2022)	Data warehousing	Data warehouse	Review of DW → ontology trends	Comparative review	Traces evolution of DW ontology methods	Descriptive, lacks empirical testing
(Asogwa et al. 2022)	Medical intelligence	Data Integration / Knowledge Management	Ontology-based and virtual data integration	Theoretical analysis and conceptual modeling of ontology-driven integration	Provides a conceptual foundation for integrating heterogeneous medical data sources	Empirical implementation or case validation; theoretical focus limits practical applicabili
(Castro et al. 2021)	Big Data Governance	Data Governance	Ontology-based governance model	Ontological framework	Improves governance and compliance	High complexity, not yet validated
(Popova et al. 2021)	Big Data	Multi-level analysis	Multilevel ontologies for processing	Conceptual framework	Supports layered ontology analysis	Lacks case validation
(Quamar et al. 2020)	Conversational BI	OLAP / Data Interaction	Ontology-driven chatbot BI	Prototype conversational BI	Natural BI queries via conversation	Performance and domain scope limits

Citation	Domain / Application	BI Component Targeted	Ontological Function	Methodology	Key Contributions	Reported Limitations
(Qusyairi et al. 2020)	Sales & Service	DW Design	Ontology + rule-based DW	Case study	Supports DW construction via ontology rules	Small dataset; domain-specific
(Zaman et al. 2020)	Digital Library	ETL process	Ontology in ETL	Case study	Improves data extraction/transfer	Limited to PDFs
(Guo & Liu, 2019)	Decision Support	DSS semantic resolution	Hierarchical Ontology Graph	Prototype	Handles semantic issues in DSS	Early work, limited evaluation
(Rogushina et al. 2018)	Big Data	Metadata Analysis	Ontologies for metadata	Theoretical framework	Ontology in metadata structuring	No case study
(Wongthongtham & Abu-Salih, 2015)	DW & BI	Data Warehouse	Ontology + trust for DW	State-of-art + prototype	Addresses trust in BI	Conceptual, limited adoption
(El Akkaoui et al. 2013)	ETL	Process modeling	Ontology + BPMN	Framework & case	Maintains ETL processes	Complexity in large DW
(Šmíd & Kouba , 2012)	Geospatial	Data Integration	Ontology-driven GIS integration	Prototype	Improves GIS search	Limited scalability
(Rodríguez-Muro and Calvanese, 2011)	OBDA	Data Access	Ontology-based data access	Dependencies framework	Makes OBDA practical	Complexity of constraints
(Mao & Li, 2011)	Spatial DSS	Decision Support	Ontology-driven web DSS	Prototype system	Supports spatial DSS	Narrow focus

3.5 Quality Assessment of Included Studies

To ensure the reliability and methodological soundness of this systematic literature review, each included study has been subjected to a structured quality assessment. This process aimed to evaluate the rigor, transparency, and relevance of the selected works by applying explicit and pre-defined criteria adapted from established SLR guidelines (Kitchenham & Charters, 2007; Denyer & Tranfield, 2009). Each study has been examined in terms of clarity of objectives, methodological coherence, contribution, transparency, limitations, and generalizability. This assessment provided a basis for judging the credibility of the evidence and for interpreting the synthesis results in light of each study's methodological robustness and potential weaknesses. Table 2 presents the results of this evaluation and summarizes the overall quality profile of the included studies.

Table 2: Quality assessment of included studies

Study	Clarity	Methodology	Contribution	Transparency	Limitations	Generaliza-bility
Vahidnia, Minae & Behzadi (2024)	High	High	Medium	Medium	Medium	Low
Asogwa et al. (2024)	High	High	High	Medium	Medium	Medium
Antunes (2024)	High	Medium	High	High	Medium	High

Study	Clarity	Methodology	Contribution	Transparency	Limitations	Generaliza-bility
Bracons Cucó et al. (2024)	High	High	Medium	High	Medium	Medium
Bhattacharjee & Deb Nath (2024)	Medium	High	Medium	High	High	High
Aishwarya et al. (2024)	High	High	High	High	High	High
Robson & Baek (2023)	High	Medium	High	Medium	High	High
A.C.B. & Mahesh (2023)	High	High	High	High	High	High
Nicholson, Giusti & Martos (2023)	High	High	High	High	High	High
Ascencion Arevalo et al. (2023)	Medium	High	Medium	Medium	High	Medium
Fahad, Darmont & Favre (2022)	High	High	High	Medium	High	Medium
Antunes et al. (2022)	Medium	Medium	High	Low	High	Low
Ghelani (2022)	Medium	High	High	Medium	High	Medium
Dhaouadi et al. (2022)	High	Medium	High	High	High	High
Asogwa E.C. et al. (2022)	High	Medium	High	High	High	Medium
Castro et al. (2021)	High	Medium	High	High	High	Low
Popova, Globa & ovogrudska (2021)	High	High	High	High	High	Medium
Quamar et al. (2020)	High	High	High	High	High	Medium
Qusyairi, Sudarma & Dharma (2020)	High	High	Medium	High	High	Low

Study	Clarity	Methodology	Contribution	Transparency	Limitations	Generaliza-bility
Zaman et al. (2020)	High	High	Medium	Medium	High	Medium
Guo & Liu (2019)	High	High	High	Medium	High	Medium
Rogushina, Gladun & Pryima (2018)	Medium	High	Medium	Low	High	High
Wongthongtham & Abu-Salih (2015)	Medium	High	Medium	Low	High	Medium
El Akkaoui et al. (2013)	High	Medium	Medium	Medium	Medium	Low
Šmíd & Kouba (2012)	High	Medium	Medium	Medium	Medium	High
Rodríguez-Muro & Calvanese (2011)	High	High	High	High	Medium	High
Mao & Li (2011)	Medium	Medium	Medium	Low	Medium	Medium

The figure 4 illustrates the overall distribution of quality ratings across the evaluated studies. Most studies scored highly in clarity, methodological rigor, and contribution, reflecting well-defined objectives and robust research designs. Moderate ratings were more frequent in transparency and generalizability, suggesting that although methods and findings were generally well reported, their applicability across different contexts remains limited. Lower scores, though less common, were observed mainly in the discussion of limitations, indicating a tendency to underreport potential biases or constraints. Overall, the figure demonstrates a high level of methodological quality among the included studies, while also revealing areas for improvement in transparency and external validity.

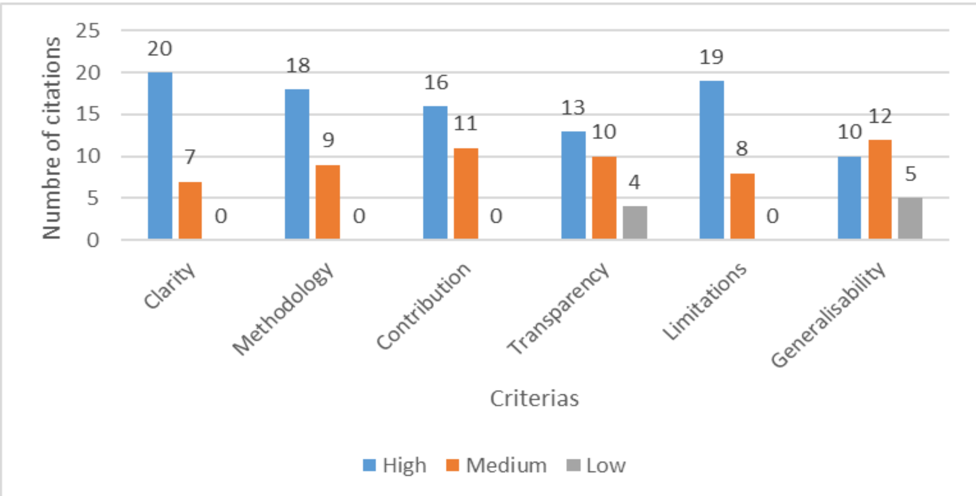

Figure 4: Summary of methodological quality assessment of included studies

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3.6 Comparative Analytical Framework for Ontology-based and Ontology-driven BI Studies

Based on prior conceptualizations of ontology-based and ontology-driven BI, we developed a comparative analytical framework. (Table 3). It presents the structured comparative synthesis of ontology-based and ontology-driven BI approaches. Using a unified analytical framework, the two corpora are contrasted across architectural, functional, analytical, and evolutionary dimensions to support evidence-based examination of their differentiation, development trajectories, and interrelationships.

Table 3: Comparative analytical framework for ontology-based and ontology-driven BI studies

Analytical dimension	Ontology-based BI approaches	Ontology-driven BI approaches
Position of ontology in system architecture	Ontologies function as auxiliary semantic layers added to existing BI architectures. Core components (ETL, data warehouse, OLAP, dashboards) remain conceptually independent.	Ontologies act as central design artifacts structuring the overall BI architecture and informing system organization.
Primary role of ontologies	Support specific tasks such as semantic annotation, schema matching, data integration, and query expansion.	Guide data modeling, business concept formalization, indicator definition, and analytical logic.
Dependency of BI components on ontologies	Low to moderate: BI processes can operate without ontologies, which mainly enhance interoperability and usability.	High: BI components are ontologically grounded; system behavior and analytics depend on ontological models.
BI lifecycle coverage	Typically limited to isolated stages (e.g., data integration, querying, or metadata management).	Spans multiple BI stages, including data acquisition, modeling, analytics, interpretation, and system adaptation.
Type of analytics supported	Predominantly descriptive and exploratory analytics with semantic enrichment.	Knowledge-intensive, adaptive, and semantically driven analytics.
Use of reasoning mechanisms	Limited reasoning (e.g., mapping support, basic inference, consistency checking).	Advanced reasoning (e.g., rule execution, semantic validation, concept-level analytics, explainability support).
Nature of reported contributions	Functional improvements to existing BI systems (e.g., better integration, semantic querying, interoperability).	Architectural and conceptual reconfiguration of BI systems toward intelligent and ontology-centered designs.
Evaluation focus	Task-level validation (query performance, integration accuracy, prototype demonstrations).	System-level validation (architectural coherence, analytical capabilities, decision-support effectiveness).
Evolutionary positioning	Dominant in earlier studies; addresses localized semantic challenges.	More prevalent in recent studies; reflects a shift toward knowledge-centered BI paradigms.
Relationship between approaches	Serves as a foundation for ontology integration within conventional BI systems.	Often builds upon or extends ontology-based mechanisms into core architectural roles, with emerging hybrid configurations.

4. Findings and Discussion

The findings of this systematic literature review are interpreted in direct relation to the research questions and to the broader discourse on intelligent decision-making systems. Beyond describing how ontology-driven BI components have been conceptualized, the synthesis highlights how ontologies are increasingly mobilized as knowledge infrastructures that embed semantic reasoning, contextual interpretation, and governance mechanisms into BI environments. The analysis reveals not only methodological diversity, but also an evolutionary shift from semantic enrichment toward knowledge-centered and decision-oriented architectures, where ontologies mediate between theoretical models of knowledge representation and operational BI systems deployed in real organizational contexts.

4.1 Conceptualization and Evolution of Ontology-driven BI

The reviewed literature evidences a clear conceptual evolution in ontology-driven BI. Early studies (Rodríguez-Muro & Calvanese, 2011; Mao & Li, 2011; El Akkaoui et al., 2013) primarily positioned ontologies as formal semantic models supporting Ontology-driven Data Access and semantic ETL, with the main objective of improving interoperability and query interpretation. These contributions reflect a theoretically grounded phase focused on knowledge representation and semantic consistency, consistent with early Semantic Web and KM perspectives. Subsequent work demonstrates a transition toward knowledge-mediated and decision-oriented BI architectures. Studies such as Bhattacharjee and Deb Nath (2024) and Vahidnia et al. (2024) embed ontologies into automation and spatial decision-support systems, where ontological reasoning supports concrete analytical tasks. More recent contributions (Antunes, 2024; Asogwa et al., 2024) conceptualize ontologies as intelligent layers connecting heterogeneous data to process logic and domain knowledge, enabling systems to move beyond descriptive reporting toward context-aware and semantically guided decision support.

This progression evidences an alignment with the evolving discourse on intelligent decision-making systems, which emphasizes knowledge-centered analytics, reasoning capabilities, and explainability. Importantly, the literature shows that these developments are not purely conceptual: ontology-driven BI is increasingly instantiated in applied systems addressing real decision contexts (e.g., healthcare analytics, urban planning, educational governance). However, despite this maturation, the absence of a unified theoretical definition of ontology-driven BI continues to fragment the field, limiting cumulative theory building and methodological standardization.

4.2 Methodological, Technological, and Tool-based Approaches

Methodologically, the literature is dominated by prototype-based and design-oriented studies (Vahidnia et al., 2024; Robson & Baek, 2023; Quamar et al., 2020), supported by formal modeling and systematic reviews (Asogwa et al., 2022; Dhaouadi et al., 2022). These studies consistently operationalize theoretical constructs from ontology engineering and KM—such as shared conceptualization, semantic alignment, and reasoning—into functional BI components using OWL, RDF, SPARQL, and ontology engineering tools.

Evidence across these studies demonstrates that ontologies are not treated merely as abstract models but are embedded into ETL workflows, analytical engines, and decision-support layers. For example, Bracons Cucó et al. (2024) operationalize semantic standardization in healthcare ETL pipelines, while Aishwarya et al. (2024) implement ontology-based reasoning to support biomedical inference tasks. These implementations illustrate how theoretical perspectives on semantic intelligence are translated into computational mechanisms that support real analytical and decision processes.

A significant methodological trend is the emergence of hybrid intelligent architectures combining ontologies with machine learning and automation techniques (Nicholson et al., 2023; Robson & Baek, 2023). These systems reflect a broader shift in intelligent decision-making research toward integrating symbolic knowledge and data-driven analytics. However, despite these advances, the review reveals a persistent lack of large-scale empirical validation, standardized benchmarks, and longitudinal deployment studies, which constrains the ability to assess the true organizational impact of ontology-driven BI.

4.3 Domains, Integration Frameworks, and Emerging Patterns

The application domains identified in this review provide concrete evidence of how ontology-driven BI bridges theory and practice. Healthcare dominates the literature (Asogwa et al., 2024; Robson & Baek, 2023), where ontologies are operationalized to integrate heterogeneous clinical data, support medical reasoning, and enhance decision relevance. These systems directly instantiate theoretical KM constructs—such as shared vocabularies, conceptual interoperability, and knowledge validation—within real decision-support infrastructures. Beyond healthcare, studies in urban analytics (Vahidnia et al., 2024), education (Antunes et al., 2022), sustainability (Ascencion Arevalo et al., 2023), and corporate governance (Castro et al., 2021) demonstrate the transferability of ontology-driven principles across knowledge-intensive environments. Across these domains, ontologies serve as mediating structures between data repositories, analytical models, and organizational decision frameworks. Architecturally, three dominant integration patterns emerge:

4.3.1 Data warehouse and ETL integration

Ontologies are systematically embedded into ETL and DW processes to operationalize semantic alignment and conceptual consistency (Bracons Cucó et al., 2024; Zaman et al., 2020). These studies provide concrete evidence that theoretical models of shared conceptualization can be implemented as automated semantic pipelines, directly influencing data quality and analytical reliability.

4.3.2 OLAP and data mining analytics

At the analytical layer, ontologies support semantic querying, intelligent aggregation, and inference-based analytics (Aishwarya et al., 2024; Nicholson et al., 2023). These systems illustrate how ontological reasoning enables a transition from data-centric BI toward knowledge-intensive analytics, a defining characteristic of intelligent decision-making systems.

4.3.3 Decision support and governance

Ontologies increasingly structure decision rules, compliance mechanisms, and interpretability layers (Castro et al., 2021; Guo & Liu, 2019), reinforcing their role in explainable and accountable decision environments. Emerging conversational and collaborative BI systems (Quamar et al., 2020; Fahad et al., 2022) further demonstrate how ontologies operationalize human–system interaction and collective sense-making.

Collectively, these patterns evidence a systemic shift toward interactive, explainable, and knowledge-centered BI ecosystems, aligning ontology-driven BI with the core objectives of intelligent decision-making research.

4.4 Impacts, Performance, and Theoretical Implications

Although large-scale quantitative validation remains limited, multiple studies report tangible improvements in semantic accuracy, interoperability, and decision relevance (Vahidnia et al., 2024; Bracons Cucó et al., 2024), alongside enhanced governance and traceability (Castro et al., 2021). These findings provide empirical support for theoretical claims positioning ontologies as enablers of intelligent decision support.

From a theoretical perspective, the synthesis demonstrates that ontologies increasingly function as bridging mechanisms between data, knowledge, and decision logic, operationalizing KM principles within BI architectures. From a practical standpoint, the reviewed systems show how these principles materialize in applied decision contexts, particularly in complex, regulated, and data-intensive environments.

However, the evidence also reveals structural limitations: fragmented engineering practices, weak scalability assessments, and insufficient organizational deployment studies. Addressing these gaps is essential if ontology-driven BI is to move from experimental implementations to a mainstream intelligent decision-making paradigm. Future research must therefore prioritize standardized evaluation protocols, cross-domain frameworks, and industrial-scale validation to consolidate ontology-driven BI as a foundational approach for next-generation decision intelligence.

5. Study Contribution

This study makes a significant contribution to the knowledge management and Business Intelligence (BI) literature by delivering a systematic and integrative synthesis of ontology-driven BI research and by grounding its conclusions in explicit empirical and methodological patterns identified across the reviewed studies. By analyzing and classifying prior work according to core BI components—ETL, data warehousing, OLAP, data mining, and decision support—this review consolidates a fragmented body of research into a coherent analytical framework, clarifying how ontology-driven approaches have been operationalized across the BI lifecycle.

The findings demonstrate, based on the reviewed evidence, that ontologies are not merely used as auxiliary semantic layers, but are frequently positioned as central knowledge structures guiding data integration, schema design, reasoning mechanisms, and analytical processes. Across multiple studies, ontologies were empirically applied to concrete organizational problems, including semantic data integration, decision rule formalization, domain-aware analytics, and context-driven decision support, thereby illustrating how theoretical knowledge-representation models have been translated into implemented architectures, prototypes, and domain-specific BI solutions. This evidence-based mapping explicitly shows how ontology-driven BI research has bridged conceptual foundations from knowledge engineering and semantic web research with real-world BI and decision-support applications.

The study advances theory by reframing ontology-driven BI as a knowledge management paradigm, in which ontologies function as organizing knowledge infrastructures that support semantic interoperability, knowledge formalization, and machine-assisted reasoning across BI processes. At the same time, the review provides empirical insight by identifying dominant methodological trends (e.g., prevalence of framework proposals and prototype implementations), application domains, and validation strategies, while also revealing persistent limitations related to scalability testing, cross-domain transferability, and large-scale organizational evaluation. By systematically evidencing where and how ontology-driven BI has been implemented, and where empirical support remains weak, this review generates actionable research directions. It highlights the need for hybrid architectures, stronger empirical validation, and domain-independent evaluation protocols to move ontology-driven BI from conceptual and experimental stages toward robust, deployable intelligent decision-making systems.

5.1 The Visual Representation of the Findings

To facilitate comprehension, and ensure a clear synthesis of the study's outcomes, a mind map was developed to visually organize and illustrate the key findings. This visualization, presented in Figure 5, to capture the central concepts that emerged from the analysis.

By structuring the results in this manner, the mind map serves not only as a cognitive aid for the reader but also as a tool for highlighting the complexity and coherence of the insights generated that might be less apparent in linear textual formats, thus supporting both analytical clarity and narrative accessibility.

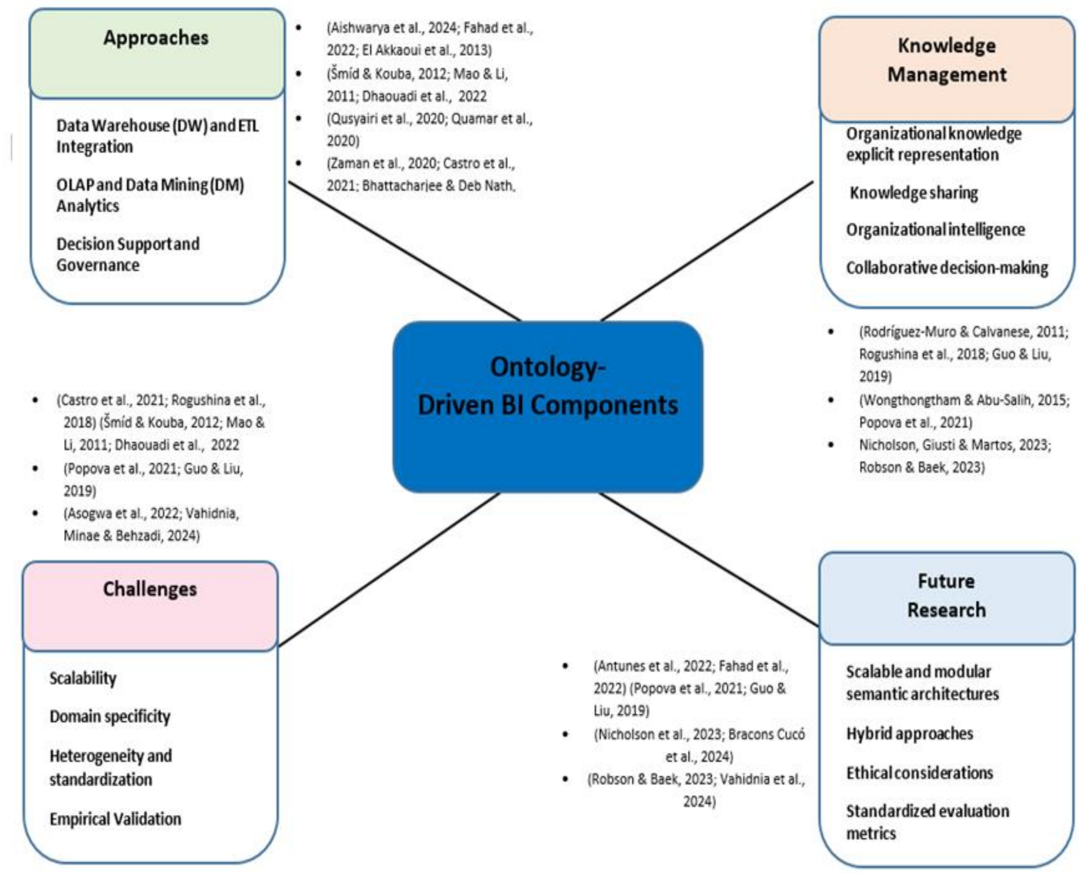

Figure 5: 4 Representation of key findings on BI components (designed by the authors)

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6. Conclusions and Future Research Directions

This systematic literature review synthesized 27 peer-reviewed studies published between 2011 and 2024 to examine the evolution, design, application domains, and performance characteristics of ontology-driven Business Intelligence (BI) components. The findings reveal a clear evolution from early conceptual and ontology-based data integration efforts toward more mature ontology-driven BI architectures that embed ontologies across core BI components to enhance semantic interoperability, reasoning capabilities, and intelligent decision support. From a design perspective, the reviewed studies predominantly adopt layered or service-oriented architectures supported by Semantic Web standards, positioning ontologies as central knowledge structures that mediate between heterogeneous data sources, analytical processes, and decision contexts. The reviewed implementations span diverse domains, including healthcare, industrial systems, smart environments, and public services, providing empirical evidence of the practical relevance of ontology-driven BI in real organizational settings. However, despite consistent benefits in semantic integration, knowledge reuse, and decision support, current approaches remain constrained by scalability challenges, ontology engineering and maintenance complexity, and limited real-time processing capabilities. From a knowledge management perspective, these results demonstrate that ontology-driven BI extends beyond technical data integration to support the formalization, sharing, and operationalization of organizational knowledge. By aligning heterogeneous data under shared conceptual models, ontology-driven BI frameworks contribute to the development of organizational intelligence and knowledge-based decision processes. Future research should therefore focus on developing scalable and performance-aware ontology-driven BI architectures, investigating hybrid models that integrate ontological reasoning with advanced analytics and machine learning, and conducting longitudinal empirical studies to assess organizational value, usability, and adoption dynamics. In parallel, greater attention should be given to governance, ethical, and transparency issues to ensure the responsible deployment of semantically enriched BI systems within knowledge-intensive organizations.

AI Statement: During the preparation of this work, the authors state that AI tools were used solely in order to assist with paraphrasing and proofreading during the writing process. Then the authors reviewed and edited the content as needed to ensure accuracy, originality, and academic integrity.

Ethics Statement: This study is based exclusively on the analysis of previously published literature and did not involve human participants, animals, or the collection of personal or sensitive data. Therefore, ethical approval was not required.

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