[ICSGTEIS 2023] Your paper #1570954852 ('Evaluation of Enrichment in Ontology-Based Knowledge Management System')

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Primary 1

Detailed comments: Please justify your recommendation and suggest improvements in technical content or presentation.

1. I consider this paper to be more of a review paper. Therefore, the author must have a clear understanding of the subject matter and the research that has been conducted because Review paper helps to evaluate the literature but in this paper author only explain about positive impact of social media without explain rectifies the gaps and fill with relevant content.
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Primary 2

Detailed comments: Please justify your recommendation and suggest improvements in technical content or presentation.

This manuscript describes a literature study regarding ontology enrichment, there needs some improvement:

1. In the abstract section, it is not clear the method was used in this literature study.
2. what is the KMS abbreviation in the introduction section, if it is Knowledge Management System, please don't use the abbreviation in the first mentioned terms.
3. in the methodology section, depict the method step that authors used in this research with the process of filtering the paper from searching until the 15 papers that were reviewed. this will make it easy for the reader to understand.
4. there are some typos in the writing.
5. The result from the second research question does not describe the information obtained from literature studies that were taken from 15 articles.
6. in the conclusion section, the author should describe what is the limitation of this study and what the further research from this.

Primary 3

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1. In the Result Data section, it is stated that there were 15 papers assigned to be analyzed in the review. However, in the Findings section, only 7 papers were reviewed.
2. Authors should focus and sharpen the discussion on how enrichment methods work in the papers reviewed. We see that the authors still haven't done that. The discussion is still too shallow.
3. It would be good if at the end a summary of the methods used in the papers reviewed is presented in tabular form, so that you can get a comprehensive picture of the methods. This summary will be useful for researchers who want to use or develop new ontology enrichment methods.

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***Abstract*— Ontology is an organization of knowledge that can represent knowledge in a structured manner. An ontology-based Knowledge Management System is a system that combines elements of knowledge management with the application of ontology as a knowledge base. Meanwhile, knowledge is dynamic and continues to develop all the time, giving rise to new knowledge. Therefore, the ontology must be updated regularly through ontology enrichment to meet adequate knowledge requirements. Ontology enrichment is carried out to ensure that the ontology remains relevant and responsive to developments in its knowledge domain. However, there are no standard stages in implementing enrichment in ontology-based Knowledge Management systems. Therefore, this research conducted a literature review to determine when and how to apply enrichment in ontology development. Data was obtained from related journals in 2018 - 2023. The method used in this research is the Systematic Literature Review method to systematically identify, review, evaluate, and interpret all available research in the area of interest with specific relevant research questions. The research results show that the ontology enrichment procedure generally includes preprocessing stages, relation extraction, and enrichment processes. Ontology enrichment is generally applied during the development of a new ontology as part of the ontology development cycle and on existing ontologies, which are a separate stage from the initial ontology development cycle. Based on these findings, the researcher provides recommendations for researchers who want to use or develop new ontology enrichment methods.**

Keywords—ontology, ontology development, enrichment, knowledge management system, ontology enrichment

I. INTRODUCTION

Ontology is a formal structure used to describe concepts, entities, and relationships between entities in a knowledge domain[1]. Ontologies help in structured modeling, ensure consistency of knowledge, and facilitate knowledge retrieval and understanding. Ontology-based Knowledge Management System is a system combining knowledge management elements with the application of an ontology capable of managing, storing, organizing, and utilizing existing knowledge in a particular domain[2]. Here, ontology acts as a framework for organizing, understanding, and detailing the knowledge stored as a knowledge base in the system[3]. In an ontology-based KMS, the knowledge stored in the system is organized and linked according to an ontology structure that allows users to access, search, and understand existing knowledge easily[4].

Due to the dynamic nature of knowledge, the initially built ontology may be less comprehensive in the KMS because the knowledge domain it represents continues to develop[5]. This change makes ontology enrichment important because if it is not enriched, the ontology will become irrelevant and inaccurate[6]. Ontology enrichment adds new knowledge to an existing ontology, resulting from continuous scientific and technological developments that produce new knowledge that must be integrated into the ontology[7]. With enrichment, the ontology will reflect the latest discoveries in knowledge domain. Changes in rules, terminology, or practices in a domain should be reflected in the ontology. Ontology enrichment can also address ambiguity or incompatibility issues. In ontology, certain entities or concepts have varying definitions or relationships. By clarifying and updating these entities, enrichment can reduce ambiguity and increase consistency. Therefore, ontology enrichment is a vital mechanism to ensure that ontologies remain relevant, accurate, and useful in describing knowledge in the ever-changing KMS domain[5].

From several ontology developments, there are no standard stages in implementing enrichment in ontology-based KMS regarding how enrichment is applied to ontology development. Each study presented various procedural stages and different implementation times. Moreover, research does not place enrichment as part of the KMS ontology development stage. Several studies present proposals for ontology enrichment, including the following limitations: (1) enrichment of only a few ontology components[8]; (2) enrichment based on highly specialized data sources[5], [6], [9]; (3) enrichment is applied to a specific domain[10]; 4) intuitive[11] and non-systematic method[12]. Considering the importance of ontology enrichment in KMS, it is assumed that literature evaluation can provide an overview and obtain knowledge about the stages of ontology enrichment that have been implemented. This study collected data from previous research regarding ontology enrichment in KMS. Next, we will examine when the time is and what stages of the ontology enrichment procedure are applied to enrich knowledge.

The data collected are from journals that discuss ontology enrichment in KMS from 2018 to 2023. This data was identified using the Systematic Literature Review (SLR) method. Using the SLR method, reviewing and identifying

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journals systematically in each process following predetermined steps or protocols is possible[13]. Apart from that, the SLR method can avoid subjective identification, and it is hoped that the identification results can add to the literature on using the SLR method in journal identification.

II. METHODOLOGY

This discussion goes through several stages to ensure a comprehensive approach to exploring enrichment's role in ontology development. The SLR approach in this paper follows the guidelines proposed by Kitchenham[13], which are consist of three main stages. The first stage involves planning, which includes identifying review needs and formulating a review protocol. The second stage is the review implementation based on the protocol described in detail in this section. The final stage is reporting, where the results of the review are presented in the form of an analysis.

A. *Planning*

The object of this research is ontology enrichment in KMS. The determination of enrichment as a research object is based on the fact that enrichment is often not the focus of attention for ontology development researchers[4]. They focus more on the formation of ontology as a knowledge base requirement, and there are no standard enrichment procedure stages in ontology-based KMS. On the other hand, the time for implementing ontology enrichment in KMS is different for each ontology development.

Following the research object, it will be investigated how the enrichment ontology is applied in enriching knowledge by formulating research questions. The formulation of research questions is based on five elements[14] known as PICOC (Population, Intervention, Comparison, Outcomes, and Context), described in Table 1.

TABLE 1. PICOC STRUCTURES

Population	Ontology, Ontology-based KMS
Intervention	Enrichment, enrichment procedure, enrichment stages
Comparison	n/a
Outcomes	Ontology Enrichment procedure
Context	Ontology-based KMS

Based on PICOC identification, research questions are created based on the needs of the selected topic. Research Questions that will be discussed in this research are displayed in Table 2.

TABLE 2. RESEARCH QUESTIONS

RQ1	What is the enrichment procedure in ontology-based KMS
RQ2	When is enrichment carried out in ontology ontology-based KMS

The search was conducted to obtain relevant sources in answering Research Questions (RQ1 and RQ2) and other related references. The search process was collected from IEEE Xplore, Scopus, Science Direct, SpringerLink, and Google Scholar. In managing selected literature, we use Mendeley, which is proven practical and effective. The type of literature selected is international articles and proceedings within the last five years (2018-2023). The keywords used in the related literature collection to represent ontology enrichment are “Knowledge Management System” AND “ontology” AND “enrichment” AND(“Ontological Enrichment” OR “Ontology Specialization” OR “Ontology Expansion” OR “Ontology Enhancement” OR “Ontology Enhancement Ontology” OR “Ontology Completeness” OR “Ontology Expansion” OR “Ontology Enlargement”). The search results obtained 135 related papers, shown in Table 3

TABLE 3. PICOC STRUCTURES

Database Journal	Article founds
IEEE Explore	20
Scopus	26
Science Direct	18
Springer Link	20
Copernicus	22
Google Scholar	29
Total	135

B. *Implementation*

At this stage, the selection of the journals obtained is carried out. The search process results will be selected based on inclusion and exclusion criteria, which will decide whether the data found is suitable for use in this evaluation study. Eligible journals are selected if they meet the inclusion criteria and are not eligible if they meet the exclusion criteria. The criteria are presented in Table 4.

TABLE 4. INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria	Exclusion Criteria
- Articles published in the last five years	- References from books, reports, and theses
- Articles that discuss ontology-based knowledge management systems	- Articles that did not go through the peer review process (preprints)
- Discussion of ontology enrichment in KMS	- Articles with incomplete data and research methods
- Articles written in English	- Articles that do not discuss ontology enrichment in KMS
- Articles published through the peer review process	- Duplicate articles

This process left 35 journals. Next, the data found will be evaluated and analyzed based on the following Quality Assessment Questions.

TABLE 5. QUALITY ASSESSMENT QUESTIONS

QA1	Are journal papers published in 2018-2023?
QA2	Does the journal paper discuss ontology enrichment in KMS ?
QA3	Does the journal paper write down the enrichment stages used?
QA4	Does the journal paper state when ontology enrichment was carried out?

Next, Table 6 shows the results of the quality assessment which shows whether the selected data was used or not in this research. This process left 20 journals.

TABLE 6. QUALITY ASSESSMENT RESULT

Index	Number of Journals
Q1	6
Q2	5
Q3	1
Q4	2
Copernicus	2
Scopus non-Q (Conference series)	2
WoS	2
Total	20

III. RESULT AND DISCUSSION

In ontology development, enrichment is the iterative process of adding and improving ontology with additional knowledge, often derived from new sources or insights[15].

In contrast to the conventional view of ontology development as a one-time creation process, enrichment introduces a dynamic dimension into this cycle. Knowledge is dynamic and continues to develop, undergoing continuous expansion, refinement, and transformation. A stage is needed where the ontology must adapt and be responsive to the nature of data and information that continues to develop.

Iqbal et al [16] conducted a review of several development methodology ontologies and found that there is only one ontology that is correct for any domain. Ontology design is a creative process; no two ontologies designed by different people will be the same. The potential applications of the ontology and the designer's understanding and view of the domain will undoubtedly influence the choice of ontology design. We can assess the quality of our ontology only by using it in the applications we design. The best ontology depends on the model, the application of the ontology to be developed, and the ontology researcher's understanding and perception of the domain. In this section, we will discuss what was found in the literature review carried out under the research question.

RQ1. What is the enrichment procedure in ontology development?

From the studies conducted, all selected journals have fulfilled quality assessment. Analysis of enrichment procedures in each journal regarding the ontological life cycle (development, integration, and implementation)[17] refers to the system development life cycle. The literature review is shown in Table 7, where EN1 is preprocessing[18]–[21], EN2 is relation extraction[20], [22], EN3 is the enrichment process[5], [10], [18]–[21], [23]–[25] . Some papers use various terms to refer to the enrichment process, so we classify it as another term for enrichment.

TABLE 7. ONTOLOGY ENRICHMENT PROCEDURE

Journal	EN1	EN2	EN3	another term of enrichment
[17]	√	√	√	-
[25]	√	√	√	Ontology Assessment
[26]	√	√	√	-
[18]	√	√	x	Ontology Evaluation
[5]	√	√	√	-
[9]	√	√	√	-
[4]	√	√	x	Golden Standard
[24]	√	√	√	-
[12]	√	√	√	-
[20]	√	√	√	-
[22]	√	√	X	Maintenance
[19]	√	√	√	-
[23]	√	√	√	-
[21]	√	√	√	-
[10]	√	√	√	-
[27]	√	√	x	Validation
[28]	√	√	x	Maintenance
[6]	√	√	x	Ontology Evaluation
[3]	√	√	x	Ontology Evaluation
[29]	√	√	x	Golden Standard

From the studies that have been carried out, it is found that, in general, Ontology Enrichment also adopts an ontology development method, which includes three important stages: the preprocessing stage, relation extraction, and the ontology enrichment process. Several papers use different terms when referring to enrichment with the same intention, namely, to complement the ontology with new knowledge to suit the development of the knowledge domain.

A. *Preprocessing Stage*

The preprocessing stage is the initial stage of the enrichment process. Enrichment needs assessment through analysis to understand whether the ontology responds to its objectives. This assessment can be done using various methods from the ontology evaluation area. A common way to do this is through Competency Questions (CQs)[4][17] [18]. If the ontology cannot answer the competency questions outlined in its development, there will be an indication that it needs enrichment. It is also possible to propose new CQs for ontologies. The frequency with which the need to enrich the ontology is assessed will depend on the individual domain or how frequently the terminology and domain evolve. Next, the existing ontology is prepared to obtain enrichment following the predetermined development needs analysis.

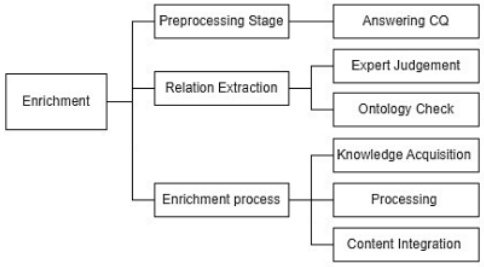

Figure 1. Ontology Enrichment Stages

B. *Relation Extraction Stage*

At the relationship extraction stage, an ontology examination identifies areas where enrichment is needed in the knowledge domain. Ontology researchers can thoroughly inspect the entire ontology content, including all concepts and relationships, to find points that require improvement or enrichment[20][22]. Another alternative is using the 41 pitfalls approach [30] proposed as an ontology diagnostic tool. These pitfalls are designed to overcome common mistakes often occurring during the ontology-building process and can provide clues to places where enrichment activities may be needed. It should be remembered that not all traps are suitable for the enrichment process. They still have to be adapted to each knowledge domain[29], [31]–[33].

C. *Enrichment Stage*

At the enrichment stage, the process of enriching an ontology involves three main steps: Knowledge Acquisition, Processing, and Content Integration into the Ontology.

Knowledge acquisition focuses on accessing information resources necessary for enrichment and may involve a series of iterative steps throughout the process. This stage includes three important things: selecting knowledge sources, techniques, and knowledge extraction processes. In selecting knowledge sources, there are various sources of knowledge, such as domain experts[14] [17] [24] [26], textual sources (such as articles, books, reports)[12] [17] [22] [27], and other KMS (thesaurus, taxonomy, glossary, existing ontology)[4] [8] [22] [27]. All sources considered qualitatively capable of obtaining information on the domain represented by the ontology can be recognized as potential sources of knowledge. The participation of domain experts in a survey

of these sources can be very useful and should be considered. In addition, diagnostic reports carried out at the Preprocessing stage should also be considered because they can provide input for finding sources of knowledge.

Knowledge extraction techniques can include interviews with domain experts, document analysis, field studies, surveys, and literature reviews. These techniques can be manual[19][20] [23], semi-automatic[22], or automatic using linguistic techniques (especially NPL)[19][20][23][27], statistics, and based on machine learning algorithms[12], [18], [23]–[26]. Knowledge sources and techniques must have a strong relationship because the nature of the chosen source will greatly influence the knowledge extraction technique used. After selecting a technique, information is retrieved from the selected knowledge source.

The knowledge extraction process refers to applying knowledge extraction techniques to selected knowledge sources, aiming to extract knowledge that still needs to be covered in the ontology. Extraction can be through interviews with domain experts[14][17][24][26], text analysis (manually, automatically, or semi-automatically)[5], [17], [21] from the domain to get answers. The extraction process is adjusted to the type of knowledge extraction technique and the knowledge source that has been chosen.

RQ2. When is the right time to carry out ontology enrichment??

From the literature review, two approaches are taken in implementing enrichment, shows in Table 8. The first is an approach that adds new knowledge to the built ontology, where enrichment occurs at various points in the ontology development cycle. Some key considerations that need to be considered are the ontology's maturity level, the need for changes and developments in the knowledge domain, and the intended use of the ontology[24], [34]–[36]. Enrichment can be done from the early stages of ontology development when the ontology is still being formed. The ontology development will ensure that the ontology has a more complete and in-depth knowledge base from the start, avoiding possible knowledge gaps.

TABLE 8. TYPES OF ONTOLOGY ENRICHMENT

Types of Enrichment	Number of journals	Name of ontology
Part of new ontology development *(Enrichment in the Development of New Ontologies)*	11	- New Ontology [6][25] [24] [23][23][27][3][29] - Pomieri ontology [5] - Lunyu Ontology [9] - Geospatial Ontology[19]
Separate part of the initial development stage *(Enrichment of Existing Ontologies)*	9	- New Ontology[4][20] - OBSM[17] - EGYGOV[26] - EGYTOUR[18] - Kulkul ontology[12] - Phytotherapy[22] - DWIPAII[10] - IWs Ontology[28] - CURIOCITY[29]

The second approach is enrichment carried out on a pre-existing ontology. In this case, the application of ontology enrichment is separate from the development stage, which will be carried out when the ontology has been formed. Enrichment can help address changes in a knowledge domain, update outdated terms, or adapt an ontology to new developments in a related field.

It is important to consider the goals of the ontology and user needs in determining the appropriate time to perform enrichment . Enrichment may be performed less frequently if the ontology is used for more static purposes, such as documentation or reference. However, regular enrichment will be more relevant if the ontology is used in a dynamic or evolving environment, such as a knowledge-based application. There is no standard approach for all. Decisions about when to enrich should be considered carefully based on the context and intended use of the ontology and the flexibility required to accommodate changes in the knowledge domain.

A. *Enrichment in the Development of New Ontologies*

Enrichment in developing a new ontology refers to adding and enriching knowledge that did not previously exist in the domain being represented. Enrichment, in this case, is an important step to ensure the ontology has comprehensive coverage and can represent various aspects and nuances of the domain. In this context, ontology enrichment is not only an additional stage but also a foundation that forms the strength and resilience of the ontology to changes and developments in the domain[9], [24], [25].

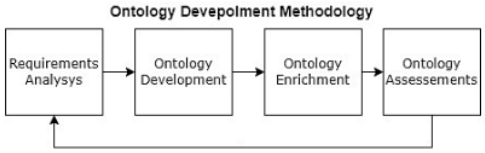

Figure 2. Ontology Development Methodology

Several stages are carried out by the specified ontology development methodology in developing a new ontology. According to the literature review, the ontology development methodology can be described in Figure 2. It consists of several stages: requirements analysis, ontology development, ontology enrichment and assessment/evaluation.

In developing a new ontology, which includes the enrichment of knowledge that does not yet exist, ontology enrichment becomes an integral part of developing a new ontology where additional knowledge is carried out to ensure a more comprehensive and in-depth representation. While enrichment in developing a new ontology provides a richer foundation for representing concepts and relationships in the domain, this stage also challenges developers to ensure that the added knowledge fits the goals of the ontology and user needs. Successful knowledge enrichment depends on a deep understanding of the domain being represented by the ontology, as well as the ability to identify aspects that still need to be strengthened[19]. Ontology enrichment provides a foundation supporting a more robust and relevant ontology architecture, opening the door to better understanding and more informed decision-making.

B. *Enrichment of Existing Ontologies*

Changes that can occur in the knowledge domain have significant consequences that encourage the need to enrich existing ontologies. Knowledge domains are dynamic and constantly evolving environments, with new scientific discoveries, shifts in terminology, concept developments, and expansions of domain scope occurring over time[4] [17],

[21] [22] [29]. Therefore, an ontology that may have worked well initially may lose relevance and precision due to these changes. This ontology enrichment process involves identifying and integrating new knowledge into the ontology that has been formed. Such as by applying newer concepts, rearranging relationships between concepts, or integrating new terminology that emerges. The process ensures that the ontology reflects a deeper understanding of the emerging knowledge domain [22] [28].

However, it needs to be recognized that knowledge domains never stand still, and knowledge continues to develop. Although the initial stages have resulted in a robust ontology, over time, changes in the knowledge domain may affect the relevance and usefulness of the ontology. Ontology enrichment allows the ontology to adapt to these changes by adding new knowledge or expanding the representation of existing concepts.

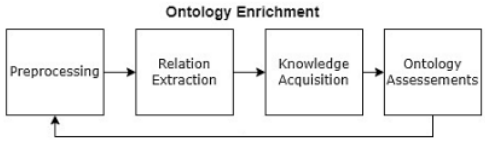

Figure 3. Ontology Enrichment

The ontology enrichment process is not a replacement of an existing ontology but rather additional enrichment systematically integrated into an existing framework[20],[29]. This process helps ensure that the ontology continues to depict a deeper and more accurate understanding of the knowledge domain while maintaining the established structure. In this way, ontology enrichment creates continuity between existing ontologies and changes in the domain environment, allowing the ontology to continue providing relevant value and supporting users in making better decisions.

IV. CONCLUSION

From the literature review carried out, conclusions can be drawn about the ontology enrichment stage consisting of: preprocessing stage, relation extraction and enrichment process. The Preprocessing stage includes testing enrichment requirements for the ontology formed by applying competitive questions. The relationship extraction stage applies and inserts new knowledge information into the ontology, starting with selecting a knowledge source, extraction techniques, and knowledge extraction processes. Meanwhile, the enrichment process

There are two approaches to implementing enrichment in the ontology development cycle: at the stage of developing a new ontology and enrichment in an existing ontology. In the first approach, ontology enrichment is part of the ontology development stage, which makes the resulting ontology stronger and more mature. In the second approach, enrichment is carried out separately from the initial ontology development stage, where the input for the enrichment process is an existing ontology, which is then added to expand towards the phase of perfecting the adequacy of knowledge representation. By applying enrichment at the initial stage and on existing ontologies, ontology development is a continuous iterative process that can overcome change challenges and ensure accurate and up-to-date knowledge representation. One of the characteristics of ontology enrichment is domain independence, so there is no definite time to carry out enrichment because this depends on which domain and the enrichment process will be developed.

This research can provide recommendations for researchers who want to use or develop ontology enrichment methods. The limitations of this research are related to the limited number of journals used as references. For further research with sufficient literature, we can continue discussing the measurement of enriched ontology performance evaluation metrics in the quality of knowledge adequacy.

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Evaluation of Enrichment in Ontology-based Knowledge Management System

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***Abstract*— Ontology is an organization of knowledge that can represent knowledge in a structured manner. An ontology-based Knowledge Management System is a system that combines elements of knowledge management with the application of ontology as a knowledge base. Meanwhile, knowledge is dynamic and continues to develop all the time, giving rise to new knowledge. Therefore, the ontology must be updated regularly through ontology enrichment to meet adequate knowledge requirements. Ontology enrichment is carried out to ensure that the ontology remains relevant and responsive to developments in its knowledge domain. However, there are no standard stages in implementing enrichment in ontology-based Knowledge Management systems. Therefore, this research conducted a literature review to determine when and how to apply enrichment in ontology development. Data was obtained from related journals in 2018 - 2023. The method used in this research is the Systematic Literature Review method to systematically identify, review, evaluate, and interpret all available research in the area of interest with specific relevant research questions. The research results show that the ontology enrichment procedure generally includes preprocessing stages, relation extraction, and enrichment processes. Ontology enrichment is generally applied during the development of a new ontology as part of the ontology development cycle and on existing ontologies, which are a separate stage from the initial ontology development cycle. Based on these findings, the researcher provides recommendations for researchers who want to use or develop new ontology enrichment methods.**

Keywords—ontology, ontology development, enrichment, knowledge management system, ontology enrichment

I. INTRODUCTION

Ontology is a formal structure used to describe concepts, entities, and relationships between entities in a knowledge domain[1]. Ontologies help in structured modeling, ensure consistency of knowledge, and facilitate knowledge retrieval and understanding. Ontology-based Knowledge Management System is a system combining knowledge management elements with the application of an ontology capable of managing, storing, organizing, and utilizing existing knowledge in a particular domain[2]. Here, ontology acts as a framework for organizing, understanding, and detailing the knowledge stored as a knowledge base in the system[3]. In an ontology-based KMS, the knowledge stored in the system is organized and linked according to an ontology structure that allows users to access, search, and understand existing knowledge easily[4].

Due to the dynamic nature of knowledge, the initially built ontology may be less comprehensive in the KMS because the knowledge domain it represents continues to develop[5]. This change makes ontology enrichment important because if it is not enriched, the ontology will become irrelevant and inaccurate[6]. Ontology enrichment adds new knowledge to an existing ontology, resulting from continuous scientific and technological developments that produce new knowledge that must be integrated into the ontology[7]. With enrichment, the ontology will reflect the latest discoveries in knowledge domain. Changes in rules, terminology, or practices in a domain should be reflected in the ontology. Ontology enrichment can also address ambiguity or incompatibility issues. In ontology, certain entities or concepts have varying definitions or relationships. By clarifying and updating these entities, enrichment can reduce ambiguity and increase consistency. Therefore, ontology enrichment is a vital mechanism to ensure that ontologies remain relevant, accurate, and useful in describing knowledge in the ever-changing KMS domain[5].

From several ontology developments, there are no standard stages in implementing enrichment in ontology-based KMS regarding how enrichment is applied to ontology development. Each study presented various procedural stages and different implementation times. Moreover, research does not place enrichment as part of the KMS ontology development stage. Several studies present proposals for ontology enrichment, including the following limitations: (1) enrichment of only a few ontology components[8]; (2) enrichment based on highly specialized data sources[5], [6], [9]; (3) enrichment is applied to a specific domain[10]; 4) intuitive[11] and non-systematic method[12]. Considering the importance of ontology enrichment in KMS, it is assumed that literature evaluation can provide an overview and obtain knowledge about the stages of ontology enrichment that have been implemented. This study collected data from previous research regarding ontology enrichment in KMS. Next, we will examine when the time is and what stages of the ontology enrichment procedure are applied to enrich knowledge.

The data collected are from journals that discuss ontology enrichment in KMS from 2018 to 2023. This data was identified using the Systematic Literature Review (SLR) method. Using the SLR method, reviewing and identifying journals systematically in each process following predetermined steps or protocols is possible[13]. Apart from that, the SLR method can avoid subjective identification, and it is hoped that the identification results can add to the literature on using the SLR method in journal identification.

II. METHODOLOGY

This discussion goes through several stages to ensure a comprehensive approach to exploring enrichment's role in ontology development. The SLR approach in this paper follows the guidelines proposed by Kitchenham[13], which are consist of three main stages. The first stage involves planning, which includes identifying review needs and formulating a review protocol. The second stage is the review implementation based on the protocol described in detail in this section. The final stage is reporting, where the results of the review are presented in the form of an analysis.

A. Planning

The object of this research is ontology enrichment in KMS. The determination of enrichment as a research object is based on the fact that enrichment is often not the focus of attention for ontology development researchers[4]. They focus more on the formation of ontology as a knowledge base requirement, and there are no standard enrichment procedure stages in ontology-based KMS. On the other hand, the time for implementing ontology enrichment in KMS is different for each ontology development.

Following the research object, it will be investigated how the enrichment ontology is applied in enriching knowledge by formulating research questions. The formulation of research questions is based on five elements[14] known as PICOC (Population, Intervention, Comparison, Outcomes, and Context), described in Table 1.

TABLE 1. PICOC STRUCTURES

Population	Ontology, Ontology-based KMS
Intervention	Enrichment, enrichment procedure, enrichment stages
Comparison	n/a
Outcomes	Ontology Enrichment procedure
Context	Ontology-based KMS

Based on PICOC identification, research questions are created based on the needs of the selected topic. Research Questions that will be discussed in this research are displayed in Table 2.

TABLE 2. RESEARCH QUESTIONS

RQ1	What is the enrichment procedure in ontology-based KMS
RQ2	When is enrichment carried out in ontology ontology-based KMS

The search was conducted to obtain relevant sources in answering Research Questions (RQ1 and RQ2) and other related references. The search process was collected from IEEE Xplore, Scopus, Science Direct, SpringerLink, and Google Scholar. In managing selected literature, we use Mendeley, which is proven practical and effective. The type of literature selected is international articles and proceedings within the last five years (2018-2023). The keywords used in the related literature collection to represent ontology enrichment are “Knowledge Management System” AND “ontology” AND “enrichment” AND(“Ontological Enrichment” OR “Ontology Specialization” OR “Ontology Expansion” OR “Ontology Enhancement” OR “Ontology Enhancement Ontology” OR “Ontology Completeness” OR “Ontology Expansion” OR “Ontology Enlargement”). The search results obtained 135 related papers, shown in Table 3

TABLE 3. PICOC STRUCTURES

Database Journal	Article founds
IEEE Explore	20
Scopus	26
Science Direct	18
Springer Link	20
Copernicus	22
Google Scholar	29
Total	135

B. Implementation

At this stage, the selection of the journals obtained is carried out. The search process results will be selected based on inclusion and exclusion criteria, which will decide whether the data found is suitable for use in this evaluation study. Eligible journals are selected if they meet the inclusion criteria and are not eligible if they meet the exclusion criteria. The criteria are presented in Table 4.

TABLE 4. INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria	Exclusion Criteria
- Articles published in the last five years - Articles that discuss ontology-based knowledge management systems - Discussion of ontology enrichment in KMS - Articles written in English - Articles published through the peer review process	- References from books, reports, and theses - Articles that did not go through the peer review process (preprints) - Articles with incomplete data and research methods - Articles that do not discuss ontology enrichment in KMS - Duplicate articles

This process left 35 journals. Next, the data found will be evaluated and analyzed based on the following Quality Assessment Questions.

TABLE 5. QUALITY ASSESSMENT QUESTIONS

QA1	Are journal papers published in 2018-2023?
QA2	Does the journal paper discuss ontology enrichment in KMS ?
QA3	Does the journal paper write down the enrichment stages used?
QA4	Does the journal paper state when ontology enrichment was carried out?

Next, Table 6 shows the results of the quality assessment which shows whether the selected data was used or not in this research. This process left 20 journals.

TABLE 6. QUALITY ASSESSMENT RESULT

Index	Number of Journals
Q1	6
Q2	5
Q3	1

Q4	2
Copernicus	2
Scopus non-Q (Conference series)	2
WoS	2
Total	20

III. Result And Discussion

In ontology development, enrichment is the iterative process of adding and improving ontology with additional knowledge, often derived from new sources or insights[15]. In contrast to the conventional view of ontology development as a one-time creation process, enrichment introduces a dynamic dimension into this cycle. Knowledge is dynamic and continues to develop, undergoing continuous expansion, refinement, and transformation. A stage is needed where the ontology must adapt and be responsive to the nature of data and information that continues to develop.

Iqbal et al [16] conducted a review of several development methodology ontologies and found that there is only one ontology that is correct for any domain. Ontology design is a creative process; no two ontologies designed by different people will be the same. The potential applications of the ontology and the designer's understanding and view of the domain will undoubtedly influence the choice of ontology design. We can assess the quality of our ontology only by using it in the applications we design. The best ontology depends on the model, the application of the ontology to be developed, and the ontology researcher's understanding and perception of the domain. In this section, we will discuss what was found in the literature review carried out under the research question.

RQ1. What is the enrichment procedure in ontology development?

From the studies conducted, all selected journals have fulfilled quality assessment. Analysis of enrichment procedures in each journal regarding the ontological life cycle (development, integration, and implementation)[17] refers to the system development life cycle. The literature review is shown in Table 7, where EN1 is preprocessing[18]–[21], EN2 is relation extraction[20], [22], EN3 is the enrichment process[5], [10], [18]–[21], [23]–[25] . Some papers use various terms to refer to the enrichment process, so we classify it as another term for enrichment.

TABLE 7. ONTOLOGY ENRICHMENT PROCEDURE

Journal	EN1	EN2	EN3	another term of enrichment
[17]	√	√	√	-
[25]	√	√	√	Ontology Assessment
[26]	√	√	√	-
[18]	√	√	x	Ontology Evaluation
[5]	√	√	√	-
[9]	√	√	√	-
[4]	√	√	x	Golden Standard
[24]	√	√	√	-
[12]	√	√	√	-
[20]	√	√	√	-
[22]	√	√	X	Maintenance
[19]	√	√	√	-
[23]	√	√	√	-
[21]	√	√	√	-
[10]	√	√	√	-
[27]	√	√	x	Validation
[28]	√	√	x	Maintenance
[6]	√	√	x	Ontology Evaluation
[3]	√	√	x	Ontology Evaluation
[29]	√	√	x	Golden Standard

From the studies that have been carried out, it is found that, in general, Ontology Enrichment also adopts an ontology development method, which includes three important stages: the preprocessing stage, relation extraction, and the ontology enrichment process. Several papers use different terms when referring to enrichment with the same intention, namely, to complement the ontology with new knowledge to suit the development of the knowledge domain.

A. Preprocessing Stage

The preprocessing stage is the initial stage of the enrichment process. Enrichment needs assessment through analysis to understand whether the ontology responds to its objectives. This assessment can be done using various methods from the ontology evaluation area. A common way to do this is through Competency Questions (CQs)[4][17] [18]. If the ontology cannot answer the competency questions outlined in its development, there will be an indication that it needs enrichment. It is also possible to propose new CQs for ontologies. The frequency with which the need to enrich the ontology is assessed will depend on the individual domain or how frequently the terminology and domain evolve. Next, the existing ontology is prepared to obtain enrichment following the predetermined development needs analysis.

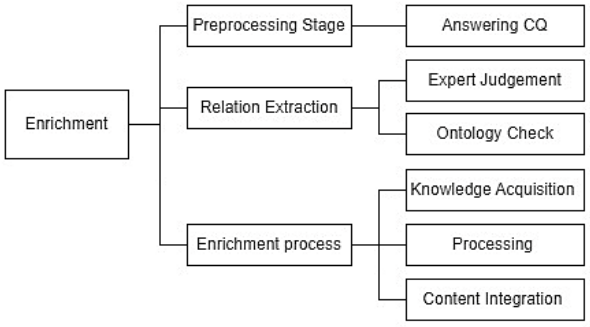

Figure 1. Ontology Enrichment Stages

B. Relation Extraction Stage

At the relationship extraction stage, an ontology examination identifies areas where enrichment is needed in the knowledge domain. Ontology researchers can thoroughly inspect the entire ontology content, including all concepts and relationships, to find points that require improvement or enrichment[20][22]. Another alternative is using the 41 pitfalls approach [30] proposed as an ontology diagnostic tool. These pitfalls are designed to overcome common mistakes often occurring during the ontology-building process and can provide clues to places where enrichment activities may be needed. It should be remembered that not all traps are suitable for the

enrichment process. They still have to be adapted to each knowledge domain[29], [31]–[33].

C. Enrichment Stage

At the enrichment stage, the process of enriching an ontology involves three main steps: Knowledge Acquisition, Processing, and Content Integration into the Ontology.

Knowledge acquisition focuses on accessing information resources necessary for enrichment and may involve a series of iterative steps throughout the process. This stage includes three important things: selecting knowledge sources, techniques, and knowledge extraction processes. In selecting knowledge sources, there are various sources of knowledge, such as domain experts[14] [17] [24] [26], textual sources (such as articles, books, reports)[12] [17] [22] [27], and other KMS (thesaurus, taxonomy, glossary, existing ontology)[4] [8] [22] [27]. All sources considered qualitatively capable of obtaining information on the domain represented by the ontology can be recognized as potential sources of knowledge. The participation of domain experts in a survey of these sources can be very useful and should be considered. In addition, diagnostic reports carried out at the Preprocessing stage should also be considered because they can provide input for finding sources of knowledge.

Knowledge extraction techniques can include interviews with domain experts, document analysis, field studies, surveys, and literature reviews. These techniques can be manual[19][20] [23], semi-automatic[22], or automatic using linguistic techniques (especially NPL)[19][20][23][27], statistics, and based on machine learning algorithms[12], [18], [23]–[26]. Knowledge sources and techniques must have a strong relationship because the nature of the chosen source will greatly influence the knowledge extraction technique used. After selecting a technique, information is retrieved from the selected knowledge source.

The knowledge extraction process refers to applying knowledge extraction techniques to selected knowledge sources, aiming to extract knowledge that still needs to be covered in the ontology. Extraction can be through interviews with domain experts[14][17][24][26], text analysis (manually, automatically, or semi-automatically)[5], [17], [21] from the domain to get answers. The extraction process is adjusted to the type of knowledge extraction technique and the knowledge source that has been chosen.

RQ2. When is the right time to carry out ontology enrichment??

From the literature review, two approaches are taken in implementing enrichment, shows in Table 8. The first is an approach that adds new knowledge to the built ontology, where enrichment occurs at various points in the ontology development cycle. Some key considerations that need to be considered are the ontology's maturity level, the need for changes and developments in the knowledge domain, and the intended use of the ontology[24], [34]–[36]. Enrichment can be done from the early stages of ontology development when the ontology is still being formed. The ontology development will ensure that the ontology has a more complete and in-depth knowledge base from the start, avoiding possible knowledge gaps.

TABLE 8. TYPES OF ONTOLOGY ENRICHMENT

Types of Enrichment	Number of journals	Name of ontology
Part of new ontology development *(Enrichment in the Development of New Ontologies)*	11	- New Ontology [6][25] [24] [23][23][27][3][29] - Pomieri ontology [5] - Lunyu Ontology [9] - Geospatial Ontology[19]
Separate part of the initial development stage *(Enrichment of Existing Ontologies)*	9	- New Ontology[4][20] - OBSM[17] - EGYGOV[26] - EGYTOUR[18] - Kulkul ontology[12] - Phytotherapy[22] - DWIPAII[10] - IWs Ontology[28] - CURIOCITY[29]

The second approach is enrichment carried out on a pre-existing ontology. In this case, the application of ontology enrichment is separate from the development stage, which will be carried out when the ontology has been formed. Enrichment can help address changes in a knowledge domain, update outdated terms, or adapt an ontology to new developments in a related field.

It is important to consider the goals of the ontology and user needs in determining the appropriate time to perform enrichment . Enrichment may be performed less frequently if the ontology is used for more static purposes, such as documentation or reference. However, regular enrichment will be more relevant if the ontology is used in a dynamic or evolving environment, such as a knowledge-based application. There is no standard approach for all. Decisions about when to enrich should be considered carefully based on the context and intended use of the ontology and the flexibility required to accommodate changes in the knowledge domain.

A. Enrichment in the Development of New Ontologies

Enrichment in developing a new ontology refers to adding and enriching knowledge that did not previously exist in the domain being represented. Enrichment, in this case, is an important step to ensure the ontology has comprehensive coverage and can represent various aspects and nuances of the domain. In this context, ontology enrichment is not only an additional stage but also a foundation that forms the strength and resilience of the ontology to changes and developments in the domain[9], [24], [25].

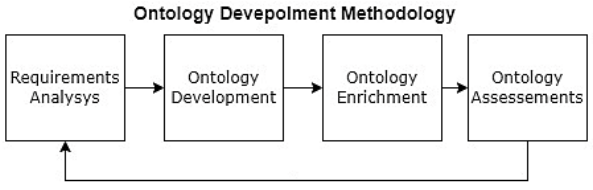

Figure 2. Ontology Development Methodology

Several stages are carried out by the specified ontology development methodology in developing a new ontology.

According to the literature review, the ontology development methodology can be described in Figure 2. It consists of several stages: requirements analysis, ontology development, ontology enrichment and assessment/evaluation.

In developing a new ontology, which includes the enrichment of knowledge that does not yet exist, ontology enrichment becomes an integral part of developing a new ontology where additional knowledge is carried out to ensure a more comprehensive and in-depth representation. While enrichment in developing a new ontology provides a richer foundation for representing concepts and relationships in the domain, this stage also challenges developers to ensure that the added knowledge fits the goals of the ontology and user needs. Successful knowledge enrichment depends on a deep understanding of the domain being represented by the ontology, as well as the ability to identify aspects that still need to be strengthened[19]. Ontology enrichment provides a foundation supporting a more robust and relevant ontology architecture, opening the door to better understanding and more informed decision-making.

B. Enrichment of Existing Ontologies

Changes that can occur in the knowledge domain have significant consequences that encourage the need to enrich existing ontologies. Knowledge domains are dynamic and constantly evolving environments, with new scientific discoveries, shifts in terminology, concept developments, and expansions of domain scope occurring over time[4] [17], [21] [22] [29]. Therefore, an ontology that may have worked well initially may lose relevance and precision due to these changes. This ontology enrichment process involves identifying and integrating new knowledge into the ontology that has been formed. Such as by applying newer concepts, rearranging relationships between concepts, or integrating new terminology that emerges. The process ensures that the ontology reflects a deeper understanding of the emerging knowledge domain [22] [28].

However, it needs to be recognized that knowledge domains never stand still, and knowledge continues to develop. Although the initial stages have resulted in a robust ontology, over time, changes in the knowledge domain may affect the relevance and usefulness of the ontology. Ontology enrichment allows the ontology to adapt to these changes by adding new knowledge or expanding the representation of existing concepts.

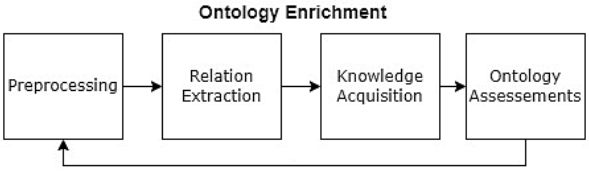

Figure 3. Ontology Enrichment

The ontology enrichment process is not a replacement of an existing ontology but rather additional enrichment systematically integrated into an existing framework[20],[29]. This process helps ensure that the ontology continues to depict a deeper and more accurate understanding of the knowledge domain while maintaining the established structure. In this way, ontology enrichment creates continuity between existing ontologies and changes in the domain environment, allowing the ontology to continue providing relevant value and supporting users in making better decisions.

IV. CONCLUSION

From the literature review carried out, conclusions can be drawn about the ontology enrichment stage consisting of: preprocessing stage, relation extraction and enrichment process. The Preprocessing stage includes testing enrichment requirements for the ontology formed by applying competitive questions. The relationship extraction stage applies and inserts new knowledge information into the ontology, starting with selecting a knowledge source, extraction techniques, and knowledge extraction processes. Meanwhile, the enrichment process

There are two approaches to implementing enrichment in the ontology development cycle: at the stage of developing a new ontology and enrichment in an existing ontology. In the first approach, ontology enrichment is part of the ontology development stage, which makes the resulting ontology stronger and more mature. In the second approach, enrichment is carried out separately from the initial ontology development stage, where the input for the enrichment process is an existing ontology, which is then added to expand towards the phase of perfecting the adequacy of knowledge representation. By applying enrichment at the initial stage and on existing ontologies, ontology development is a continuous iterative process that can overcome change challenges and ensure accurate and up-to-date knowledge representation. One of the characteristics of ontology enrichment is domain independence, so there is no definite time to carry out enrichment because this depends on which domain and the enrichment process will be developed.

This research can provide recommendations for researchers who want to use or develop ontology enrichment methods. The limitations of this research are related to the limited number of journals used as references. For further research with sufficient literature, we can continue discussing the measurement of enriched ontology performance evaluation metrics in the quality of knowledge adequacy.

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