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ARTIFICIAL INTELLIGENCE-BASED PROCESS AUTOMATION IN E PROCUREMENT: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Electronic Procurement (e-procurement) via a series of complex bids or competitive tendering processes, involving compliance with terms, requirements and conditions and purchasing of goods, services, or works from external suppliers, necessitates a systemic approach streamlining every step and keeping track of itemized technical specifications and procedures. Additionally, this systematic approach involves the electronic processing of data while harnessing the power of Artificial Intelligence (AI) in the form of smart computer algorithms to efficiently solve issues related to the processing of large amounts of procurement data. This paper, which provides a systematic literature review on the use of AI in e-procurement, aims at synthesizing, analyzing, and discussing how AI has been used up till now in different e-procurement processes, like bidding and negotiation, and the extent to which it helped in automating the procedure(s).
Keywords: *E-Procurement, E-Tendering, E-Bidding, Artificial Intelligence, Process Automation*.

1. INTRODUCTION

Organizations around the world consume external resources, like products and services, to exist and strive. These external resources are acquired following the process of procurement. The latter refers to the process of legally purchasing any products and services; transactions can be business-to-business, business-to-customer, or business-to-government [1]. However, procurement entails more than just that.

Procurement operations are run in accordance with specific procedures and are divided in several phases as follows: planning, preparation, bid opening, evaluation, and contract award. The planning phase is the starting point of the procurement process. In this phase, 3 main steps must be taken: identifying the needs, developing the specifications, and developing the plans. Then, bid documents must be prepared and finalized following specific guidelines. When tenderers submit their bid applications, a review process is carried out and each bid is evaluated. Then, a contract is awarded to the bidder whose bid has been determined to the most favorably evaluated one, provided that the bidder is responsible, qualified and with verifiable credentials.

Therefore, and in order to dematerialize the transactions that happen between businesses, e-procurement has been proposed as a viable solution. This latter comes with several benefits such as reducing lead time, eliminating manual tasks, and reducing human error, which leads to the improvement of the speed and efficiency of the entire process. In that regard, AI has been and is still used to solve different problems and is transforming the e-procurement by automating different processes.

The purpose of this research study is to locate and analyze published studies and their results in e-procurement, with a focus on the use of AI in process automation. Inclusion and exclusion criteria have been set to locate the most pertinent works, and research questions have been developed to be focused on process automation. Furthermore, and to the best of our knowledge, there are no published/publicized SLRs on the AI techniques used in procurement.

This paper is structured as follows. Section II presents the background to the study. Section III discusses the adopted methodology. Section IV is about the analysis, in which answers to the research questions are discussed. Last but not least, Section V provides an in-depth discussion of the findings.

2. BACKGROUND

Procurement has a strategic importance in any organization, be it public or private. According to the World Bank, procurement tries to achieve the right balance of 5 parameters which are: right quality, right quantity, right price, right time and place, and right source. The steps of procurements are presented in fig. 1.

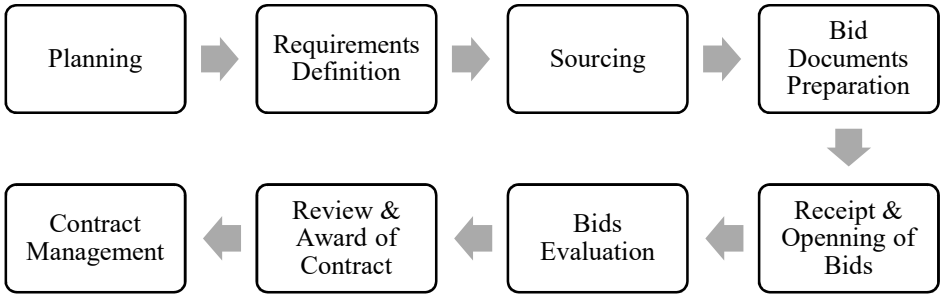

Figure 1: Procurement Steps

In the planning phase, the needs are identified, research is conducted, and the appropriate acquisition method is discussed and agreed upon. This initial phase is crucial as it frames the acquisition approach and strategy to be followed. Then, based on the research results, the requirements are defined, and the core of the procurement process can start. Sourcing and bid documents preparation are carried out. Sourcing is the process of requesting information about the vendors, products quotations, lead time, etc. Bid documents are prepared to provide all the technical and commercial terms. Once bids are received, the opening of bids phase starts. Bids are evaluated and offers are finally made to the selected tenderer(s).

The procurement process benefited greatly from the technological advances that the world has witnessed in the past few decades. The history of e-procurement is presented in Figure 2.

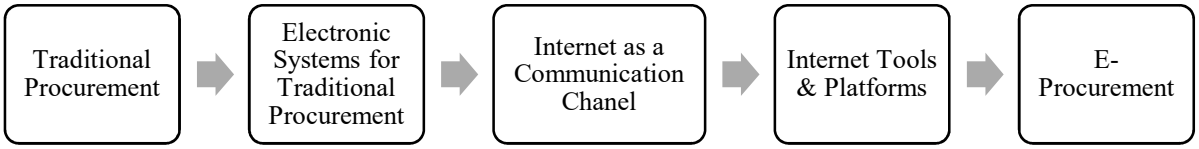

Figure 2: Adapted from the UN Procurement Practitioners' Handbook

Early on, traditional, paper-based procurement was widely used. Later on, electronic systems were gradually introduced to support the process. Then, with the advent of the internet, which was at first used as a communication channel, procurement went through a turning point. Tools and platforms that are internet-based were used in some aspects of the process, before making a steady move from traditional procurement to e-procurement. Additionally, and according to [2], technology has been both the catalyst and enabler for procurement to progress from a transactional, pen-and-paper-driven function of the 1980s to the digital, strategic business partner that we see today. This digital transformation has coincided with tectonic shifts in the technologies and tools that facilitate successful procurement performance. In fact, the rate at which procurement is moving towards being fully digitalized is astonishing, and it is continuing to progress with the advancements of other transformative technologies like AI. Furthermore, according to a survey conducted by [2] in 2018-2019 where 25 large enterprises were interviewed, 88% of enterprises have a procurement digital agenda that they are pursuing. Fig. 3 presents the results of the aforementioned survey.

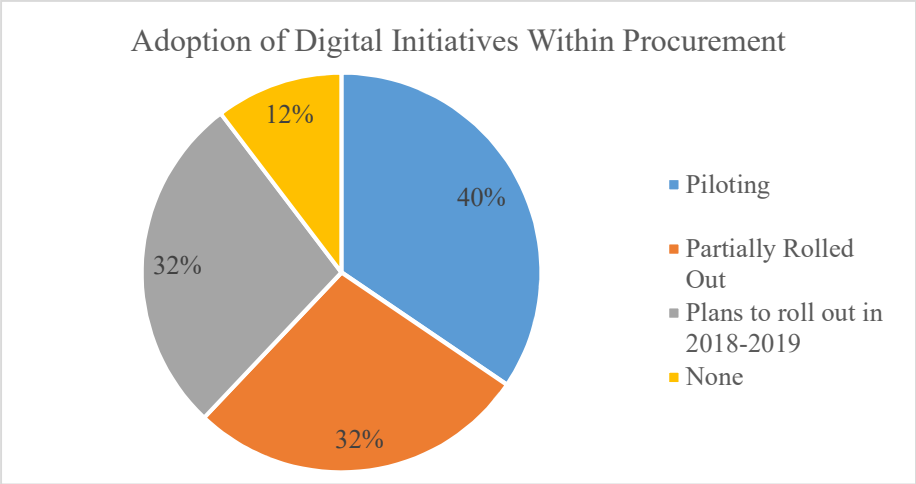

Figure 3: Adoption of Digital Initiatives Within Procurement (from [2])

According to the same source, when asked about the technologies adopted as part of the digital procurement initiative, 72% of the enterprises adopted Blockchain, while only 28% adopted AI.

Another survey run in 2020 by the Chartered Institute of Procurement & Supply [3] in collaboration with The University of Melbourne showed that in over 95% of firms targeted, at least one technology is used for their procurement process. In fact, digital technologies affect all aspects, tangible, and intangible, of the procurement process. Because of the number of technologies that can be associated with procurement, experts in the field are now exploring procurement 4.0.

3. METHODOLOGY

Systematic Literature Reviews (SLRs) are known to follow a very meticulous and careful studying of the entire process of searching, categorizing, and selecting research papers.

This SLR follows the methodology defined by [4], that is based on two phases: planning and conducting. Each phase includes several steps that are presented in Fig. 4.

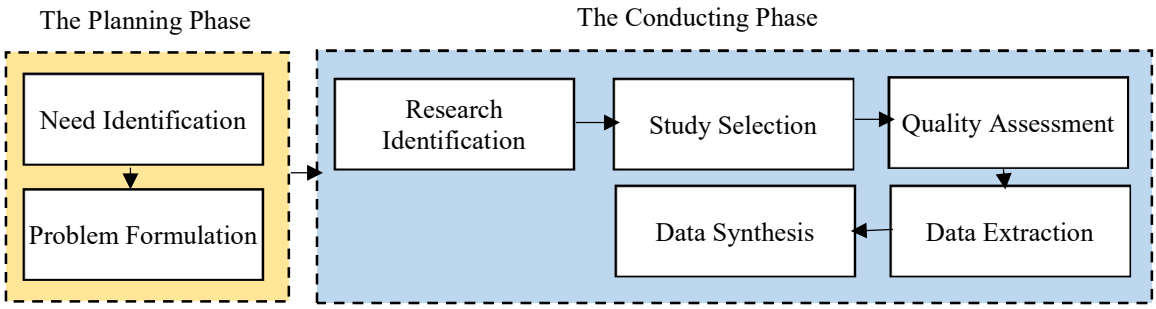

Figure 4: Methodology Followed

As previously mentioned, this research followed the methodology depicted in fig. 3. In the planning phase, the needs for this research and the motivation are explained, and the research problem is formulated. In the second phase, the search strings are identified, inclusion and exclusion criteria are identified, databases are searched, and relevant studies are selected. All selected studies undergo a quality assessment check to verify their reliability and pertinence. Data extraction and synthesis represent the last step in the process.

3.1 Building the Corpus

In this SLR, the search was conducted across 5 databases; some are Computer Science focused, while others are general. The databases are Association for Computing Machinery (ACM), IEEE Xplore, Emerald, SAGE, and Google Scholar. This latter was searched as an extension database to make sure that any relevant paper that is not available in the other 4 databases searched can be spotted and included.

3.1.1 Search String

The following Boolean expression was used to search for relevant articles published between January 1st, 2005, and April 30th, 2021:

(Artificial Intelligence) AND (automation OR semi-automatic) AND (Knowledge Management) AND (E-tendering OR tendering OR e-procurement OR procurement OR bidding) AND (Building OR elaboration)

3.1.2 Inclusion/Exclusion Criteria

Clear inclusion/exclusion criteria were used:

Criterion 1: Only research papers written in English and published in the aforementioned period were considered.

Criterion 2: Questionnaires, surveys, literature reviews, comparative studies, feasibility studies, and secondary studies were not considered as the focus was on research papers that present research outcomes.

The restriction was made because the researchers believe that secondary studies usually do not provide substantial research outcomes, though sometimes discussed in other SLRs. Furthermore, all research papers considered in this SLR are peer reviewed. This is because the peer-review process is, itself, a form of validation and means that the ideas discussed are accepted/acceptable.

Criterion 3: the research papers must discuss some aspect of AI applied to procurement.

The available literature on procurement is huge; therefore, it was decided to limit the selection to papers that discuss AI in e-procurement only, since it is the focus of this research.

3.2 Data Collection

As previously mentioned, this study follows the standard SLR methodology using a set of queries and clear inclusion/exclusion criteria to select relevant articles.

An initial check based on metadata only was carried out, then a check by abstract and by full text following the inclusion and exclusion criteria set (see Table 1). Duplicate papers were removed, and a snowballing process was carried out. 51 papers relevant papers were retained.

The flowchart in fig. 5 presents the methodology followed during the selection process.

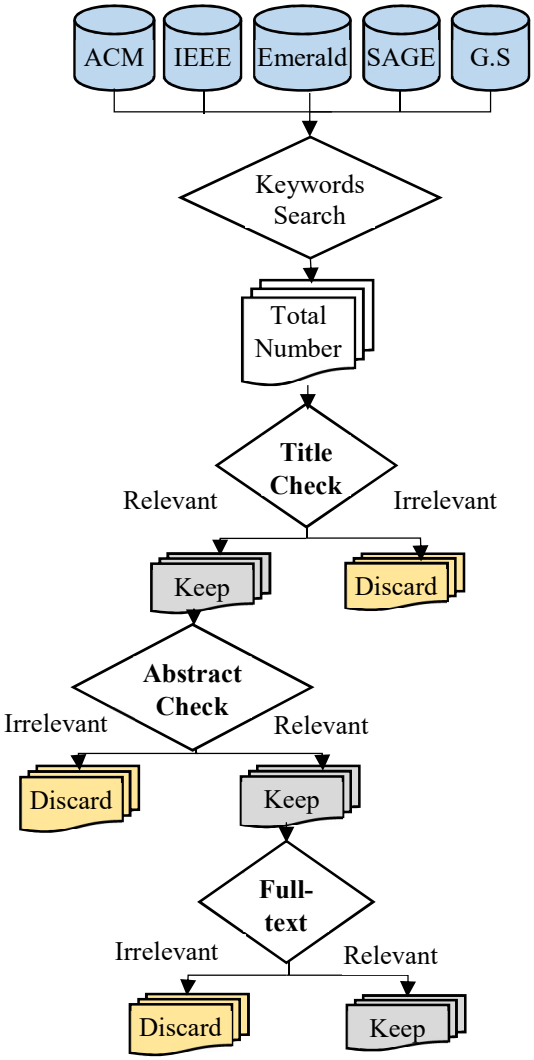

Figure 5: Selection Process

3.2.1 Quality Assessment

For research publications to be considered in this SLR, a quality assessment criterion was defined. 4 questions were defined to assess various aspects of the research paper under consideration. These aspects include rigorousness, significance, validity, and reliability. Each question has a score of 1 or -1. Research papers that accomplished a quality score of at least 3/4 were selected.

The questions used in the quality assessment questionnaire are as follows:

1. Does the paper present a clear statement of the research goal?
2. Are the findings/outcomes of the research discussed?
3. Is there any empirical evidence?

4. Does the study contribute to academia and/or the industry community?

3.3 Research Questions

To instigate and guide this SLR, 5 main research questions have been identified. To address each question, relevant articles were identified from the pool of selected papers, studied, and thoroughly analysed. Table 1 presents the research questions and their rationale.

Table 1: Research Questions

Research Question	
RQ1. What type of solution was provided by researchers?	
RQ2. What parts of the e-procurement process have been automatized?	
RQ3. What are the technologies used by researchers for automation?	
RQ4. What are the AI techniques used in particular?	
RQ5. How and where have semantic technologies been used?	

Each research question is thoroughly analysed and answered in the discussion section.

3.4 Findings

This section presents the findings, starting with the initial search results:

Table 2: Initial Results

Database	ACM	IEEE	Emerald	SAGE	Google Scholar
Number of Publications	4002	1140	1144	553	769

The initial results were quite large because of the popularity of the subject under study. In addition, although there are a set of keywords combined in a Boolean expression used in the search process to help eliminate unrelated articles, many irrelevant articles was still discarded, based on the set exclusion criteria. Table 3 shows the number of papers that were analysed.

Table 3: Distribution of Analyzed Papers

Database	ACM	IEEE	Emerald	SAGE	Google Scholar
Number of Publications	78	52	44	5	91

After a selection by metadata, abstract, and full paper, and after a thorough analysis of all documents while taking the defined inclusion/exclusion criteria into account, the selection results by database are presented in table 4.

Table 4: Selection Results after Analysis

Database	ACM	IEEE	Emerald	SAGE	Google Scholar
Number of Publications	5	6	7	2	16

A snowballing process was carried out in which all the discarded papers were analysed again, and the following are the results of this final step:

Table 5: Selection Results after Snowballing

Database	ACM	IEEE	Emerald	SAGE	Google Scholar
Number of Publications	7	9	7	2	26

3.4.1 Distribution of Research Papers by Year

Figure 6 illustrates the publication trend in terms of the number of papers per year over 15 years, ranging from the year 2005 to 2020.

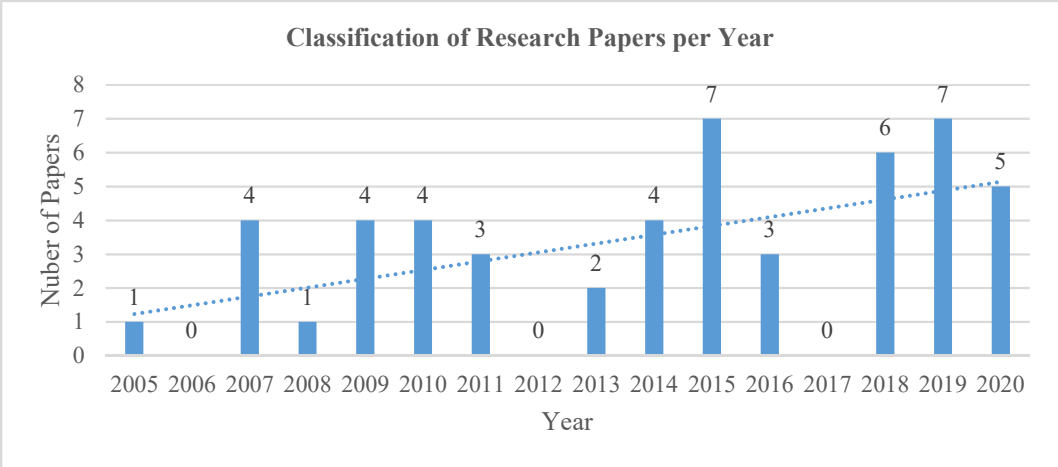

Figure 6: Distribution of Paper by Year

The majority of the selected papers are very recent and have been published between 2013 and 2020, representing 34 out of the 51 papers, i.e., 67% of the papers. The initial impression from the graph is that there is a growing interest in the process automation using AI in procurement.

3.4.2 Classification by Publication Type

Three types of publications were considered: journal papers, conference proceedings, and book chapters. The graph below presents the total number of articles per type of publication.

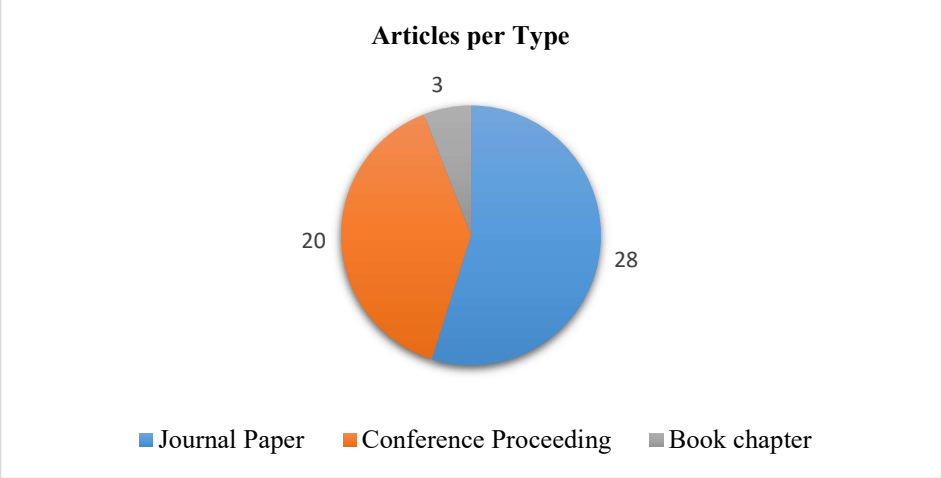

Figure 7: Articles per Type of Publication

Most of the articles selected are journal papers, with 28 out of the 51 selected papers. The remaining papers are conference proceedings (20) and book chapters (3).

3.4.3 Distribution of Articles Across Journals

Table 6 presents the distribution of the selected articles across journals.

Table 6: Distribution of Articles Across Journals

Research Field	Journals
Computer Science	Computers in Industry, Global Journal of Computer Sciences, International Journal of Computer Science
Operations Management	International Journal of Production Research, International Journal of Physical Distribution and Logistics Management, International Journal of Operations and Production Management
Engineering & Construction	Automation in Construction, Engineering Applications of Artificial Intelligence
Knowledge Management	Journal of Knowledge Management, Knowledge-based Systems
Science & Technology	The Scientific World Journal, Journal of Hospitality and Tourism Technology, Journal of Information Technology Teaching Cases
Miscellaneous	Journal of Stock and Forex Trading, Public Security and Public Order Research Journal, Management of Environmental Quality: An International Journal, Benchmarking: An International Journal

The types of journals were analysed, but it was difficult to find a universal classification for all journals. However, the selected articles can be clustered into three possible categories: 1. Methodological, where the main contribution of the article is to provide information on the use of AI in procurement using either qualitative data, quantitative data, or a mixture of both; 2. Investigative, where the goal of the article is to investigate the use of a specific AI technology in procurement processes; 3. Experimental, where the goal of the article is to show the results of an experiment and propose a model, a system, or a framework.

3.4.4 Frequency of countries studied

43% of the selected research papers have focused on a specific country. The most studied countries are: Indonesia, China, and Colombia, with 4 publications each, as shown in table 7.

Table 7: Frequency of Countries Studied

Country	Number of Articles
Indonesia; China; Colombia	4
India; Mexico	2
Hong Kong; Portugal; United Arab Emirates; Serbia; Singapore; Tunisia	1
Latin America & Caribbean Region: Antigua, Bolivia, Ecuador, El Salvador, Nicaragua, Guatemala, Barbuda, Grenada, Haiti, Honduras, Jamaica, Dominican Republic, Costa Rica	1

3.4.5 Main Keywords

The main keywords used in the research papers are presented in fig. 8.

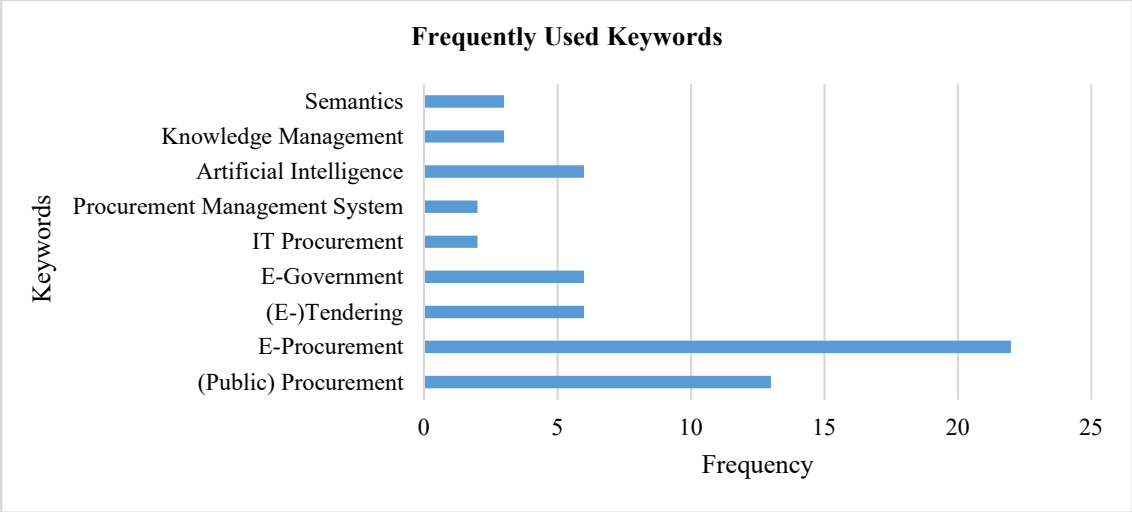

Figure 8: Frequency of Keywords

Figure 8 presents the frequency of keywords mentioned in the abstracts of the selected papers. Procurement, e-procurement, e-government, e-tendering, and AI are the most used keywords. Some keywords that are not related to AI and procurement were present as well such as knowledge management and BIM.

3.5 Synthesis

The analysis is keenly centered on the tools and techniques used for the automation of e-procurement processes. This section presented the criteria used for paper selection, along with the research questions, and the distribution of papers over the years and across journals.

4. Analysis

The present section provides an analysis of the 5 research questions previously defined in section 3.3.

4.1 RQ1. What type of solution was provided by researchers?

Different solutions were proposed by researchers. The following are the solution types provided by researchers in the selected paper.

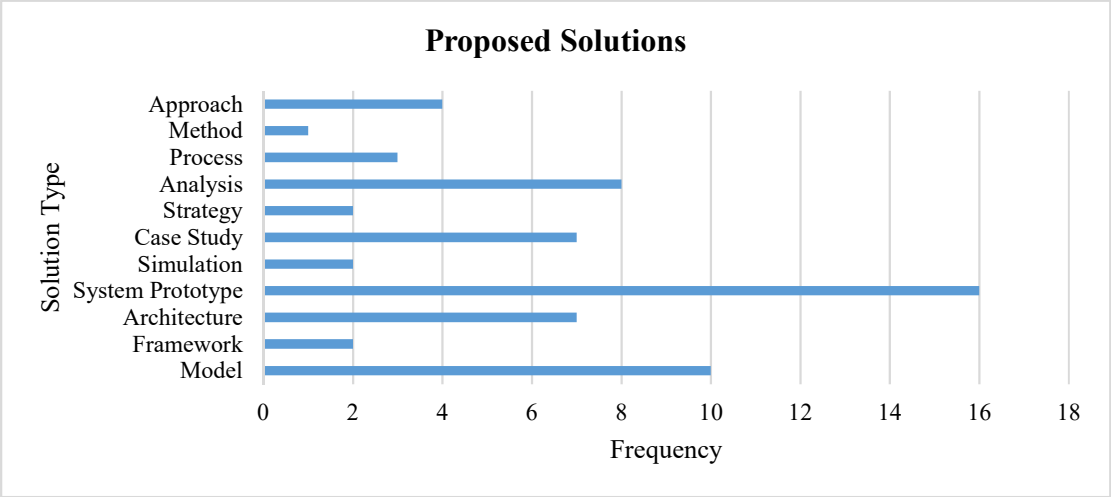

Figure 9: Proposed Solution Types

The frequently provided solution is a system prototype, while the least provided solution is a method. It should be noted that only 7 papers have validated their work using case studies. Methods, strategies, simulations, and frameworks are the least used solutions. Several research studies have, however, used a combination of 2 or more methods. For instance, case studies and system prototypes were a popular combination.

A possible explanation to the low number of research papers that have proposed a strategy, simulation, and framework as a solution would be the chosen keywords for this research. Because we have focused on automation techniques, most papers deal with the technical side of procurement processes rather than the managerial side in which we would have found a lot of strategies and frameworks.

4.2 RQ2. What are the technologies used by researchers for automation?

The following are the main technologies used in the selected research papers.

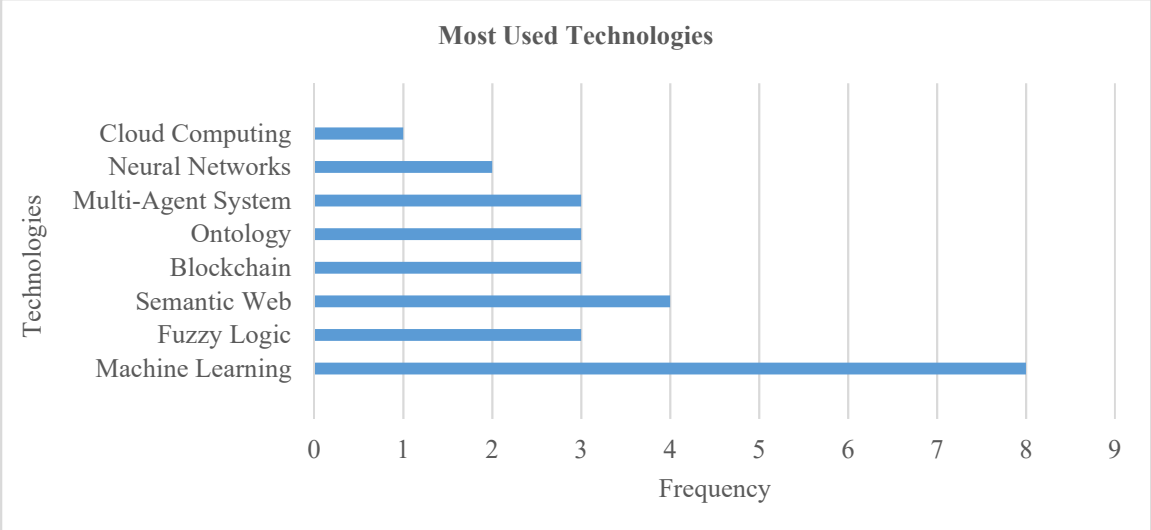

Figure 10: Technologies Used

Different technologies have been used in the selected papers. Some of these technologies are AI-based, while others are not. The most used technologies in the selected papers are machine learning and the semantic web. Other technologies that have been fairly used include ontologies, multi-agent systems,

data mining, machine learning, and Blockchain. The least used technology remains cloud computing.

In addition, it should be noted that there are a few papers that have not discussed specific technologies. These belong mainly to the category of research papers that have proposed a strategy, framework, analysis, process, or approach. Several papers, on the other hand, have used hybrid methods, i.e., a combination of techniques. This mainly concerns researchers that have proposed a system. These hybrid-method research papers were counted only once.

There are other techniques used for automation such as blockchain and cloud computing. Blockchain technology is mainly used for transactions in the procurement process and has been discussed in a couple of the selected papers. Also, although not many papers have discussed cloud-based automation, it is worth mentioning that it has become a popular e-procurement technology solution. In fact, cloud computing e-procurement contains all the elements of a classic e-procurement system such as the invoice automation, RFQ, and contract management.

4.3 RQ3. What parts of the e-procurement process have been automatized?

In the e-procurement process, researchers have investigated automation techniques, and some have implemented them. The following are a break-down of the different automated procurement parts.

4.3.1 Purchasing

[5] designed a government procurement system for the purchasing department that aims at successfully completing the collection, sorting, and analysis of procurement information. 6 modules were designed, namely the purchase order management, purchasing plan management, commodity management, supplier management, contract management, and user management. In another paper, [6] have also investigated the Chinese government management system in which they spotted some issues in the process of procurement management and for which they proposed a new organizational structure. This latter's goal is to implement a purchasing budget and a purchasing plan management module, a purchasing contract signing and transaction execution management module, and a purchase acceptance management module.

Similarly, [7] modelled an e-procurement system using data mining techniques. The proposed model is designed with the sole purpose of selecting the best supplier. In the same context, [8] modelled a decision-making process for supplier selection in e-procurement. This latter combines different technologies that aim at classifying suppliers based on previously set criteria. The ultimate goal of this study is to reduce the time spent by organizations in the prequalification of suppliers and enlarging the pool from which companies select suitable suppliers. In a later publication, [9] has also investigated the supplier selection issue in e-procurement. This latter provided an integrated approach for mapping the suppliers' using theories of pattern classification. This approach reduced the data requirement of the classifier drastically, and therefore made the decision support model suitable for the problem domain.

[10] presented a Multi-Level E-Procurement system that deploys the procurement process in a hierarchical supplier structure. The system's architecture supports the requirements of e-procurements, allows participants to join/leave dynamically, is flexible, and adaptable.

[11] proposed an architecture for e-procurement internal and external uncertainties applied to supply chain. This latter is said to enhance the system's flexibility to handle all kinds of exceptions, mainly the unexpected ones in an intelligent and autonomous way. Inventory failure, increased demand, and delivery delays have been used to demonstrate the efficiency of the system. The proposed framework contains the following elements: the buyer interface, the service register center, the buyer and supplier, and the actual e-procurement system. The e-procurement system contains 4 modules: the search module, the negotiate module, the contract module, and the monitor module. The system was validated using a case study and a simulation of the inventory failure scenario.

[12] proposed an ontology-based system to improve the procurement process applied to the handicraft domain. The ontology model contains three main processes: the procurement process, in which the purchasing steps of raw materials and tools is underlined, the producing process, in which the different production phases is clarified, and the commercialization process, in which the selling part is highlighted. The proposed system is also divided into three sections: knowledge management, business transactions, and inference. Furthermore, the recommendation procedure is based on two supplier selection levels followed by a negotiation phase. The first level is all about the selection of the

suppliers based on the articles they sell while the negotiation phase is about costs, delivery delays, and so on. Agent technology has also been employed. This system framework has been validated; however, the system was not implemented.

4.3.2 Tender Selection

[13] designed an e-tendering system to ensure that the tender selection process is transparent and effective. The system design followed a 3-step process namely a business analysis, requirements definition, and system design. Furthermore, three actors were taken into account: the procurement committee, tender participants, and online society. This system is said to increase trust and reduce opportunities for fraud.

Moreover, [14] have also designed an e-tendering system that aims at reducing the security issues present in e-procurement systems and encourage transparency and fair procurement process. The system was divided into 4 sections: tender creation and publishing process, bidding process on the tender, evaluation, and negotiation of the bid, and selection of the winning bid.

[15] have also modelled a system for collaboration and communication in e-procurement. The system performs different tasks such as the generation of bid evaluations, contract signature, and monitoring of the contract, and is said to enhance the effectiveness of the tendering process, transparency, and the quality of deliveries.

[16] proposed a new way for the evaluation process and the selection of the best offer. The scholar proposed that each bid be indexed using 4 elements: the name, the importance, the value, and the type. Furthermore, the offers representation should also be represented as an offset. Regarding the evaluation steps, three steps were considered: the company technical level evaluation, direct evaluation, and another stage of the technical evaluation. This method is said to be efficient based on a pilot study that was conducted as part of the research.

Moreover, [17] have also proposed a method for evaluating and selecting the candidate services to get the top-M recommendations. The purpose behind this system is to help the government procurement sector find the most cost-saving and efficient e-procurement scheme.

[18] have also proposed a method for evaluation and bidder selection. The goal of this method is to ensure the objectivity of evaluation and bidder selection by public procurement committees. The model follows three steps: criteria identification and hierarchy construction, criteria evaluation, and evaluation of bidders. The model was tested in a case study from the Serbian Government.

4.3.3 Question/Answer Services

From another perspective, [19] investigated the question answering service in e-procurement in the Republic of Indonesia. The main problem is the fact that there is no system to help the helpdesk answer questions from end-users, and there is no FAQ or automatic question answering system. There is, however, an automatic response system that answers users from a list of suggestions. Therefore, a new model was presented to finding document similarity between user query and the archive of question answer pairs. Several algorithms were used for this purpose, presented in RQ4. The model was implemented and evaluated, and some limitations related to the used algorithms were spotted.

4.3.4 Evaluation and Negotiation

[20] proposed an automatic negotiation system for e-procurement that aims at reducing cost and increasing efficiency. The negotiation follows specific steps, namely: negotiation process design, protocol, model, and strategy. The main technology presented is agent technology. The system was, however, not tested, validated, or implemented.

4.3.5 Documents Management

[21] presented an approach for developing an information model that aims at integrating object models with document management systems with the aim to highlight the needs to bridge this gap through the development of an augmented process model which will enable integrated databases to support collaborative extranets at the procurement tendering stage. The main processes featured are: compilation and finalization of tender documents, follow-up and submission, analysis and selection of successful tenderers, contract award, and post contract activities. This model was fully developed and validated using a real time case study.

4.4 RQ4. What are the AI techniques used in particular?

The following are the AI techniques used by researchers.

Several papers presented system architecture, strategies, or other contributions, but did not mention

the AI techniques used. Those were left out of this section.

4.4.1 Machine Leaning

[22] used data mining techniques to detect anomalies in procurement processes using the open contracting data standard. The model was trained using procurement data from Paraguay. Nonetheless, the transformation the scholars proposed for the data in OCDS format allows the implementation of many algorithms to analyse them, which can be applied to data of all countries that use the standard. Furthermore, the unsupervised learning algorithm, Isolation Forest, is used to obtain a model. The isolation forest is an algorithm for anomaly detection and was proven to increase models' accuracy. The innovation introduced by this specific algorithm lays in its core idea that it should be feasible to "isolate" anomalies based on the specific characteristics that make them unique [23]. Therefore, in this research paper, the isolation forest is used to determine the ranking of data anomaly at different stages of the procurement process.

[24] proposed a model for an e-procurement system that is based on data mining techniques. Linear regression was used for predicting suppliers' performance. This latter is, then, utilize to predict the best supplier.

[25] proposed a hybrid method based on fuzzy-based collaborative filtering and Bayesian approach to search for the optimal procurement scheme. "Collaborative filtering is a technique that can filter out items that a user might like on the basis of reactions by similar users. It works by searching a large group of people and finding a smaller set of users with tastes similar to a particular user. It looks at the items they like and combines them to create a ranked list of suggestions." [26]. In this research, a few algorithms were used for that matter. A new trapezoidal fuzzy number similarity algorithm was proposed and used to calculate the similarity between two services and an item-based collaborative filtering was used for recommendations and rankings. The system was implemented and tested, and the limitations were pointed out.

4.4.2 Deep Learning

A few researchers have used deep learning in procurement. Deep learning is a machine learning technique that is based on ANN. This latter is a network of "neurons" that imitate the human brain to carry on operations. From a system architecture perspective, ANN has three main layers: the input layer, the output layer, and the hidden layer(s), as shown in the figure below. The first layer contains the input nodes. The information contained in this later is transferred to the hidden layer, that performs all the computations, and then transfers the results to the output layer [27].

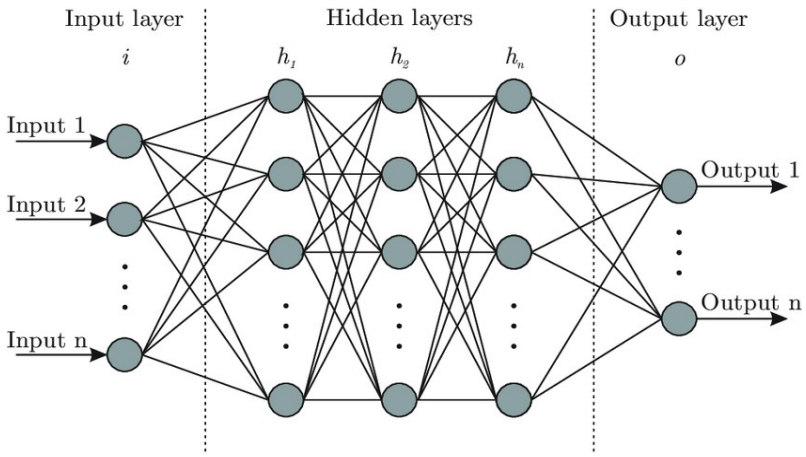

Figure 11: Neural Network Architecture [28]

[29] presented an integrated approach that uses ANN and Analytics Hierarchy Process (AHP) for suppliers' classification. AHP was first proposed by Thomas L. Saaty in the 1970s. It is considered "one of the most popular and widely employed multi-criteria methods. In this technique, the processes of rating alternatives and aggregating to find the most relevant alternatives are integrated. The technique is employed for ranking a set of alternatives or for the selection of the best in a set of alternatives. The

ranking/selection is done with respect to an overall goal, which is broken down into a set of criteria" [30]. In this research project, AHP was used for the prioritization of the different evaluation criteria while ANN was used for mapping the suppliers. It was concluded that the combination of these AHP and ANN results in a decrease of data requirements.

[31] proposed an infrastructure of a knowledge-based system able to capture and keep procurement information related to supply chain procurement using AI technologies and ANN. ANN was used for benchmarking purposes: comparing the different vendors and suggesting the most suitable one.

4.4.3 Agent Technology (AT)

AT has emerged as a promising technology to develop complex and distributed systems. In fact, they have been applied to many areas like healthcare in the last decade [32].

[33] proposed a multi-agent optimization architecture for supply chain procurement. The researchers used two algorithms, namely variable neighbourhood search meta-heuristic (VNS-MH) and distributed market-based heuristic (DMBH), a distributed heuristic based on market interactions for transportation planning. The two latter were tested using a sample that consisted of several pick-up and delivery problems with time windows in stochastic environments, and it was demonstrated that VNS-MH achieved better optimality than DMBH.

[34] proposed an e-procurement system using distributed agents. The system brings in a solution to a recurrent problem in e-procurement systems: sourcing decision under uncertainty. The system proposed a new e-procurement model for multi-level supply chain procurement management system which has many buyers and suppliers who spread all over the world and interacting via the Internet. It is composed of a Main Controller running on a central host and several remote Containers running on remote host. The techniques and algorithms used were, however, not discussed in the research paper.

[35] proposed a multi-agent-based system for e-procurement exception management. AT was used in the system for searching, negotiation, contracting and monitoring. Several agents were used, namely: the interface agent, the contracting agent, the repository agent, the exception management agent, and the evaluation agent. The contracting agent itself contains and searching agent and the negotiating agent. Similarly, the exception management agent contains the monitoring agent, the information agent, and the diagnostic agent. The proposed system was validated using a case study.

4.4.4 Semantic Web Technology

"Semantic Web technologies aim to define and interconnect data in a way similar to that in which traditional web technologies define and interconnect web pages." [36]

[37] proposed a hybrid middleware-oriented architecture that combines the features of SOA and EDA, that uses semantic features for the procurement of products in supply chain. The architecture has four main functionalities: Semantic Web Services discovery, Semantic Web Services orchestration, Process Activity Monitoring, and Semantic Web Services Management. These features provide a comprehensive framework for the development of business integration, collaboration, and monitoring in procurement supply chain.

4.4.5 Fuzzy Logic

Fuzzy logic refers to a human-like method of reasoning, and a generalization of standard logic. Fuzzy logic is an extension of Boolean logic introduced by Lotfi Zadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory [38]. It has mostly been used in process automation, robotics, optimization, control systems engineering, and image processing [39].

[40] proposed an integrated approach for bidder selection in the procurement process. The proposed model is based on two methods, namely the fuzzy extent analysis method that was used to calculate the weights of criteria, and the fuzzy TOPSIS methodology that was used to rank the bidders in the selection process of public procurement. The fuzzy TOPSIS method is an extension of the classical TOPSIS method. Fuzzy TOPSIS, where the weights of criteria and ratings of alternatives are evaluated by linguistic variables represented by fuzzy numbers to deal with the deficiency in the classical TOPSIS, was adopted.

4.4.6 Text Processing

[41] proposed a question answering service for an e-procurement system. Several algorithms were used in the model that was implemented with the purpose of finding document similarity between user queries and the archive of question answer pairs. The Vector Space model algorithms used are the Term Frequency * Inverse Document Frequency (TF*IDF) and Latent Semantic Indexing (LSI).

These were used in a hybrid mode. This latter allows to overcome the limitations of each of the two algorithms if used in a standalone way. The model proposed by the researchers starts with a pre-processing stage in which documents are merged, cleaned, and transformed. Then, Question-Answer pairs are converted to vector space model. The model was implemented and evaluated.

Similarly, [42] investigated how data mining techniques can enhance the visibility of procurement patterns. The researchers proposed the use of text processing algorithms in the Rapid Miner's text mining extension to transform the text data, K-Means clustering algorithm to group the records in terms of frequency, and other clustering algorithms to compare the accuracy of the clustering algorithm. The methodology used in the research is as follows: retrieve the data, process the document by tokenization of non-letters, linguistic tokenization, filtering stop words, filtering tokens, stemming, and generating n-grams. Two approaches were followed and tested.

4.4.7 Non-AI Techniques

Other non-AI technologies were used, like cloud computing and blockchain technology.

4.4.7.1 Cloud Computing

Cloud computing (CC) is an evolution of information technology and a dominant business model for delivering IT resources [43]. From the list of selected publications, only one researcher used CC.

[44] presented a model and an architecture for the evaluation of the costs and benefits connected with CC applied to procurement. In this work, the Total Cost Methodology (TCM) was followed. The TCM is a systematic approach to manage cost throughout the life cycle of any project [45]. In this project, the TCM methodology was agreed upon as it can allow mapping the process upstream of the launch of the program to move to cloud computing. The proposed solution is an e-procurement system that is mainly based on e-sourcing and e-supply chain management. Although CC provides several advantages, the scholar mentioned some challenges that were encountered like cultural changes, privacy, security, and reliability.

4.4.7.2 Blockchain Technology (BT)

BT refers to "a structure that stores transactional records, also known as the block, of the public in several databases, known as the "chain," in a network connected through peer-to-peer nodes" [46]. Blockchain is a way to capture different transactions in the form of blocks that are linked together via a cryptographic hash. A generic architecture is presented in the figure below.

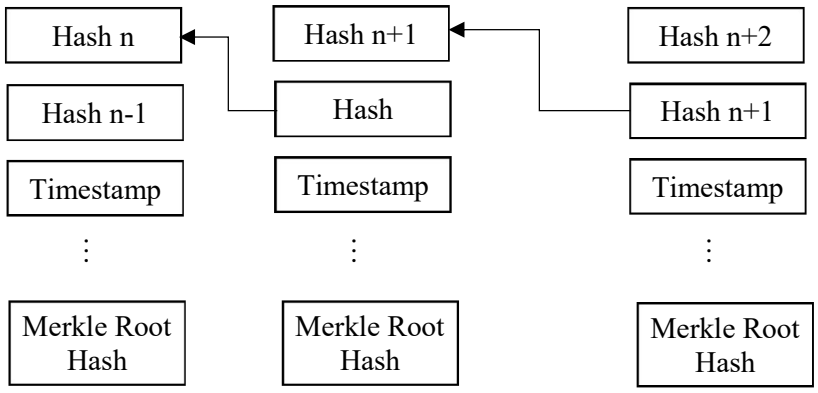

Figure 12: Blockchain Architecture

Every single block in the blockchain has a header and a representation of the transaction. For example, each block of the blockchain contains the hash, that of the previous block, a timestamp, and other block fields. The Merkle root hash block represents the set of transactions in the Merkle tree. This latter is dynamic and varies based on the design of the blockchain implementation.

From the selected papers in this SLR, 3 have used BT.

[47] believes that no complete study has been conducted on sustainable green procurement. The researchers have identified many challenges related to green procurement. Following a thorough analysis using TISM, and to overcome the barriers that were identified, an architecture using Blockchain technology and IoT was developed. TISM refers to the Total Interpretive Structural Modelling method, which is an extension of the Interpretive Structural Modelling (ISM) technique. TISM is interpretive in nature, assists in portraying a complicated system in a simple manner, and was developed to overcome the key drawback of ISM, i.e., poor interpretation of the links [48]. Blockchain was mainly used because of its ability to share information with the different parties involved. A case study was studied, and the architecture was applied to logistics and supply chain.

[49] proposed BT as a solution to the e-tendering system problems that occur. The researchers proposed an e-tendering system design whose main goal is to ensure electronic seals confidentiality by increasing trust, reducing opportunities for fraud, and eliminating third parties.

[50] proposed an e-tendering system based on blockchain. Different algorithms were used for the creation of the tender, placing a bid, evaluation and negotiation of bids, and winner selection and results publishing. Complex cryptographic algorithms like the SHA-256, for instance, were used for security and confidentiality purposes.

4.5 RQ 5. How and where have semantic technologies been used?

From the research papers selected, only 4 have used ontologies in a way. Ontologies define a common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them [51].

[52] presented a review of the different technologies that have been and are still used in e-procurement. The researchers focused on specific technologies, namely the semantic web and linked open data. In the frame of semantic web technologies-based e-procurements, [52] focused on semantic-based vocabularies for e-Commerce and e-Business, ontology-based e-Procurement systems, and semantic-based platforms for e-Procurement systems combining both vocabularies and ontologies. The ontology-based approaches that have been discussed all focus on modelling domain knowledge. For instance, the scholars presented some pertinent works in the field that have used ontologies in supply chain to improve interoperability while others implemented an ontology model for product data and knowledge management. Furthermore, focusing on ontology-based e-procurement systems, the researchers have presented approaches that are focused on modelling domain knowledge under certain logic formalisms to represent data such as the Core Business Ontology (CBO) used to deliver a knowledge-based system. This research paper, however, did not present the specifics of how the semantic technologies were used, but rather presented a holistic view of the techniques, methods, and approaches used/investigates by other researchers.

Furthermore, [53] proposed a system architecture that contributes to the dematerialization of public procurement with the goal of enhancing and modernizing the tendering process and improving the quality of deliveries. Focusing on ontologies alone, Diabagate *et al*. built an ontology that partially relies on the PROC ontology (the Public Procurement Ontology) for the sake of building an e-tendering system. The PPROC ontology itself was developed based on different existing ontologies: Organization Ontology (ORG), the Simple Knowledge Organization System (SKOS), the Good Relations Ontology (GR), the Public Contract Ontology (PCO), and the Friend of a Friend Ontology (FOAF). The system has also several data sources such as the data warehouse of price reference system and the web and social networks.

Additionally, [14] proposed an ontology for the handicraft domain. This latter contains several sub-domains such as ceramic, tapestry, and traditional pastry, to name a few. A generic business ontology model was also developed, with a focus on three main business processes: the procurement, the production, and the commercialization processes. Specific business ontologies have also been developed, each specific to a sub-domain. A profile ontology was also proposed. This latter's goal is to provide personalized assistance to handicraft women from different contexts and diversified fields via the recommendation of several procurement opportunities. The profile ontology has two business actors: the handicraft women and the suppliers. The handicraft women have a buyer profile, a generic profile, and a social profile while the suppliers also a generic profile in addition to a seller profile. These ontologies are to be used in a supply chain procurement recommender system whose goal is to recommend suitable suppliers based on a two

supplier selection levels. This latter is also based on several matching rules that are pre-defined.

Last but not least, [55] investigated a knowledge graph called the TBFY, and for which ontologies were developed. According to [56], "A knowledge graph, also known as a semantic network, represents a network of real-world entities—i.e. objects, events, situations, or concepts—and illustrates the relationship between them. This information is usually stored in a graph database and visualized as a graph structure, prompting the term knowledge "graph."" An ontology networks composed of an ontology for tender data and a reused ontology or euBG for company data. The knowledge graph, that is available online, includes 23M triples that originated from tender data.

5. Discussion

While the research studies used in the present SLR investigated important issues in procurement, none of them actually implemented the solution proposed. The richness of the outcome of these research studies provided insight into how AI is used in e-procurement; however, the actionable part of the studies, though they provided implementable solutions, lacked real-world applications.

Of all the research studies used in this SLR, very few referred to the AI algorithms used in the worked-out solutions, which might be a deliberate act on the part of the researchers for confidentiality purposes. Algorithms that can be used abound, but a specific allusion to the relevant ones might have been very beneficial as it sets a trend for specialists interested in this field to pursue and build on previous works and the accumulated expertise over the years.

Automating processes in procurement is of major importance for several reasons and could have significant impact on the procurement and purchasing function. The size of operations in procurement is, often, huge, and automating operation processes, like processes related to purchasing and invoicing, will reduce all the human errors and eliminate bottlenecks that may occur. There are, in fact, many aspects in which AI can help in procurement, from the start of the process till its end. Avoiding over-engineering, identifying hidden costs, analyzing suppliers' behaviours, and simulating negotiations are a few examples of potential uses of AI in the general procurement process.

It was noticed that the most studied problem within procurement is supplier selection. In fact, AI can be a major asset to the supplier process as a whole as it can be used in several sub-processes; to name but a few, supplier analysis and supplier classification. Several key performance indicators are to be captured like the supplier score, the early and late received quantities, the cancelled amounts/quantities, and the purchase and receipt cycle time.

In a mapping process based on all the selected research studies, the most discussed areas within the (e)-procurement process have been identified as being supply chain, purchasing, tendering, evaluation, supplier selection, negotiation, and decision support systems. For each of the before mentioned areas, we have identified related automation techniques, as seen in figure 13. The most used technique across all areas is machine learning. There might, however, be other techniques that could fit within one or more category that were not included here. This would be due to the studied papers, the keywords used, and the time period selected.

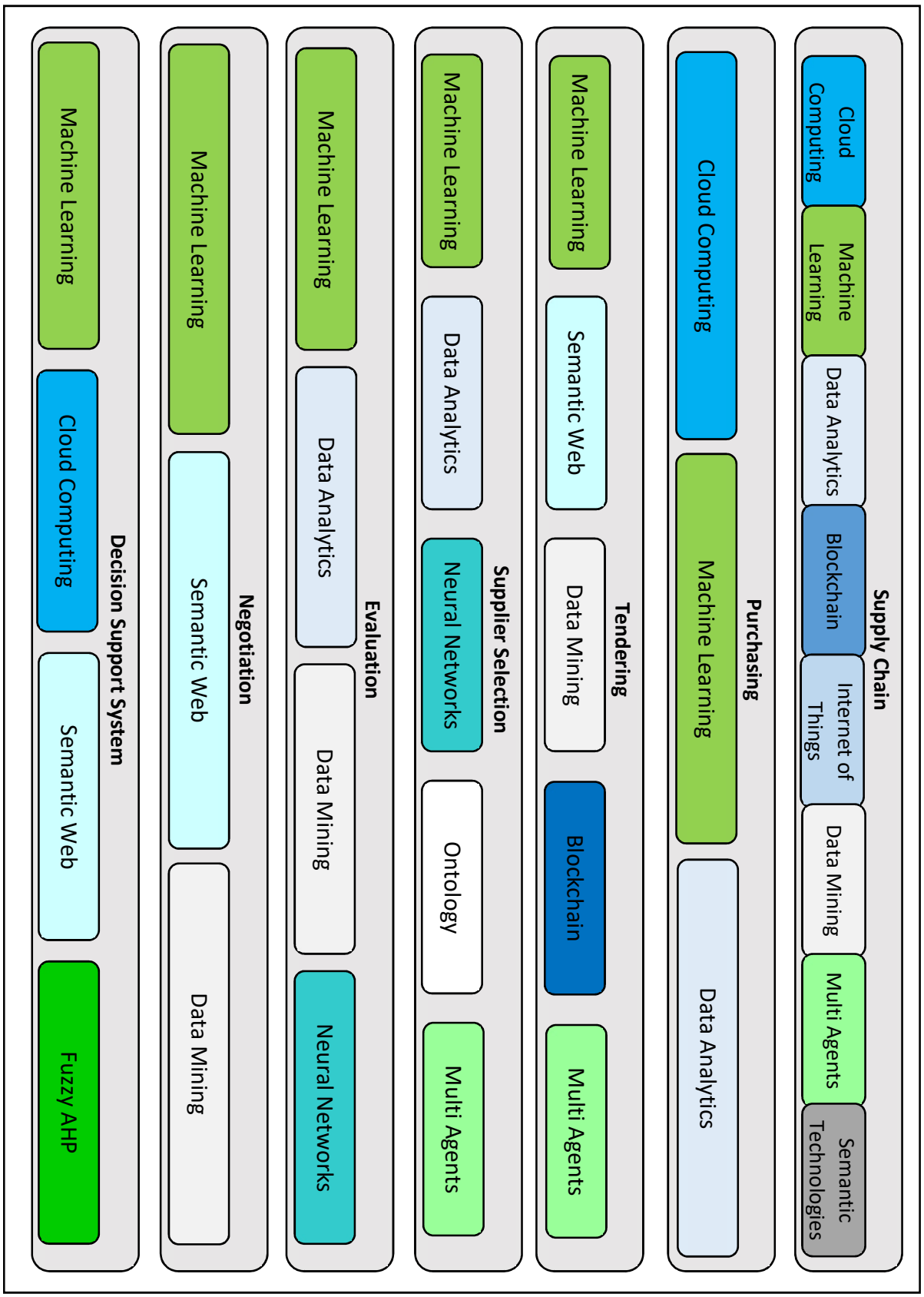

Figure 12: Automation Techniques for Frequently Studied Areas within Procurement

Despite the wealth of literature published on AI in procurement, there are still some areas that are under-investigated such as bids generation, document management, and bids evaluation. Therefore, the absence of reference to the relevant algorithms coupled with the under-investigated areas makes it challenging to pursue research in an area marked by high level of confidentiality and selectivism.

From another perspective, there remains some technical challenges that are worth mentioning. Some of these latter are human issues related to change management and resistance to change, IT security, and disruptive innovation.

6. Limitations

Just like in any SLR, there are some limitations to this study. The main limitation is the search terms used. We tried to make this SLR as focused on artificial intelligence-based procurements as possible. Nonetheless, commonly interchanged terms were included in the search to make sure all relevant articles are included. There might, however, still be some relevant articles that have not matched the search string. Furthermore, the scholarly works considered within the framework of this research have all been published by the April 30th, 2021. There might be new research articles that have not been considered.

7. Conclusion & Future Works

Interest in the use of AI techniques in procurement is gaining popularity, though some aspects are still under-investigated. Indeed, there is growing interest, from a research perspective, in the use of different AI techniques to automatize parts of the procurement process. In all bodies of research, SLRs are valuable in consolidating knowledge.

This paper presented a SLR that shed light on the different solutions proposed, techniques used, and knowledge captured and shared in the various procurement processes. Moreover, a variety of terms associated with, and variants of, procurement are emerging such as green procurement.

The findings of this SLR suggest that, although there is significant interest in the use of AI in procurement, most research papers focused on purchasing and supply chain. There are several other parts of the procurement process that can still be investigated and automated like the bid's generation and evaluation process.

Future Works include the automation of the bid generation sub-process within the general procurement process. Looking at the rate by which deep learning is gaining popularity in different application domains, it will certainly be used more often in procurement processes.

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